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EFFECT OF WATER STRESS ON YIELD AND EVAPOTRANSPIRATION OF SUNWLOWER

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SUMMARY

An experiment was conducted at Rimski Šančevi Experiment Field of Institute of Field and Vegetable Crops in Novi Sad during 2000 - 2005. The soil in the experimental plot was calcareous chernozem on loess terrace. Using the yield response factor (ky), the study investigated how sunflower yield and evapotranspiration were affected by deficit of available soil water during the growing season. The experiment consisted of an irrigated treatment (T_1), in which irrigation was used when soil moisture levels dropped to 60-65% of FC (field capacity), and a nonirrigated control treatment (T_0). The sunflower hybrid used in the study was NS-H-111.

On average, no significant differences in yield level were observed between T_1 (3.79 t ha^{-1}) and T_0 (3.75 t ha^{-1}) treatments. Seasonal evapotranspiration (ETm) obtained in T_1 treatment was in the 402-479 mm range. The yield response factor (ky) was obtained as 0.20 for total growing season and 0.27, 0.31 and 0.48 for vegetative, flowering and yield formation period, respectively. Period from flowering to maturity was the most sensitive towards water deficiency.

Key words: **sunflower (*Helianthus annuus* L.), yield response factor (ky), yield, evapotranspiration**

INTRODUCTION

Sunflower is the most important oil crop in Serbia as well as in some other parts of the world. In the Vojvodina Province, in the north of Serbia, sunflower is grown more than any other oil crop, and the acreage planted to the crop averages about 170,000 ha a year. The average yield between 2000 and 2005 was 1.98 t ha^{-1}, ranging from 1.52 to 2.46 t ha^{-1} (Statistical Yearbook of Serbia, 2005), and the yield level depended primarily on the amount and distribution of precipitation.

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Sunflower is commonly regarded as a plant that is tolerant to drought and that uses water efficiently. Nevertheless, the crop consumes a large amount of total water due to the fact that it produces high yields and a large vegetative bulk and it has a long growing period coinciding with the warm months of spring and summer (Bošnjak and Marinković, 1992; Škorić, 1992). Sunflower is capable of enduring drought but its yield will be lower in that case, because the plants are forced to take up less available forms of water from the soil. Sunflower is the most susceptible to soil water deficiency at flowering, fertilization and grain fill, whereas at the start and end of the growing period the sensitivity is not so evident (Jana *et al.,* 1982; Unger, 1986; Stone *et al.,* 1996; Erdem and Delibas, 2002). The driest months in Vojvodina are July and August, when only 15-20% of the sunflower's potential evapotranspiration (ETP) minimum of 100 mm are provided (Milić, 2008). Using *Hergreaves's* model, Bošnjak (1993, 1993a) and Dragović (1995) determined that the months of July and August in the province are semi-arid to arid and not suitable for crop production if only natural water supplies are relied upon. In Vojvodina, the critical stages of sunflower growth and development in terms of water supply coincide with the period of drought, so the yield is highly correlated with the amount and distribution of precipitation during that period.

Given that irrigation in Vojvodina is supplementary in character, the irrigation regime is an issue of major importance for sunflowers. The technical soil moisture minimum in this crop is 60-65% of the FC (field capacity), in other words, irrigation should be implemented when two thirds of total available water are expended from the soil layer 0-60 cm (Bošnjak, 1993). Under variable climatic conditions in which precipitation cannot be predicted in the long run, irrigation may have negative effects if followed by a period of abundant rain. In such a case, the soil may become waterlogged and a microclimate may develop within the crop stand that will be characterized by reduced air temperatures and increased relative humidity, which may create a favorable environment for attack by pathogens. In such years, irrigation effects do not come to expression and yields are often higher in non-irrigated areas (Szabo and Pepo, 2005).

Irrigated sunflower acreage is small in Vojvodina, because relatively high yields can be obtained under non-irrigated conditions. Still, if the natural deficit of available soil water that occurs during sunflower growing in dry years in the province is eliminated by the use of irrigation systems, high and stable yields of over 4 t ha^{-1} can be obtained (Bošnjak and Marinković, 1992; Bošnjak, 1993; Dragović *et al.,* 1996; Maksimović, 2005).

The sunflower water requirement (ETm) in Vojvodina is 450-470 mm (Bošnjak and Marinković, 1992; Bošnjak, 1993; Dragović *et al.,* 1996). The likelihood that such rainfall level will occur naturally during the growing season is only 4-5%, which means that the genetic potential for yield of otherwise very high-yielding sunflower hybrids will not be fully realized, since the amount of precipitation determines the potential yield level. Agriculture in Vojvodina indubitably lacks water as one of the cornerstones of crop production (Vučić, 1973).

The yield response to water deficit of different crops is of major importance in production planning. Water deficit in crops and resulting water stress on plants affect crop evapotranspiration (ET) and crop yield. When water supply does not meet crop water requirements, actual evapotranspiration (ETa) will fall below maximum evapotranspiration (ETm). Under such conditions, water stress will develop in plants, which adversely affects crop growth and ultimately crop yield. However, for a full evaluation of the effect of limited water supply on yield and production, consideration must be given to the effect of the limited water supply during individual growth stages of the crops. The response of yield to water supply is quantified through the yield response factor (ky) which relates relative yield decrease to relative ET deficit (Doorenbos and Kassam, 1979).

Doorenbos and Kassam (1979) have estimated the average ky value for sunflower at 0.95. Vaux and Pruitt (1983) claimed that it is highly important to know not only the ky values from the literature but also those determined for a particular crop species under a specific set of climatic and soil conditions. This is because ky may be affected by other factors besides soil water deficiency, namely by soil properties, climate (environmental requirements associated with evapotranspiration), growing season length and inadequacies of cultivation technology.

The objective of this study was to determine, based on a long-term experiment, how available soil water deficit affects sunflower yield and evapotranspiration during entire growing season and at during specific growth stages. The yield response factor (ky) was used in the study. The broader aim was to assess the potentials of sunflower growing under irrigation in the Vojvodina Province.

MATERIALS AND METHODS

The experimental part of the study was conducted during 2000 - 2005, at Rimski Šančevi Experiment Field of Institute of Field and Vegetable Crops in Novi Sad (45° 19' N, 19° 50' E, 84 m above sea level).

The trial was established in a random block design adapted to technical specifications of the sprinkler irrigation system. The trial consisted of an irrigated treatment (T_1) with preirrigation soil moisture of 60-65% of the field capacity (FC) and a nonirrigated control. (T_0). Irrigation was scheduled by monitoring soil moisture levels at 10 cm intervals down to 60 cm depth. This was done gravimetrically every ten days, or at shorter intervals when needed.

The maximum evapotranspiration (ETm) by month and the entire growing season was calculated bioclimatically (1) using the hydrophytothermic index (K), the value of which had been estimated at 0.16 for sunflower in the climate of the Vojvodina Province (Bošnjak, 1993). ETm values for the month of September were calculated only for the first ten-day period of the month, because that is when sunflower harvest typically takes place. After calculating ETm, actual evapotranspiration (ETa) was determined based on precipitation and water reserves that had accumulated in the soil down to 0.6 m depth before the growing season. These values were then used to calculate the available soil water deficit during the sunflower growing season.

$$ETm = \sum_{i=1}^{n} (K \times Ti) \qquad (1)$$

- ETm - monthly maximum evapotranspiration for sunflower (mm)
- K - hydrophytothermic index for sunflower (0.16)
- Ti - sum of mean daily temperatures in a given month (^{o}C)

The effect of water stress during the entire growing season and individual growth stages on sunflower yield was investigated using Doorenbos and Kassam's model (1979) (2) as follows:

$$\left(1 - \frac{Ya}{Ym}\right) = ky \times \left(1 - \frac{ETa}{ETm}\right) \qquad (2)$$

where: Ya is the actual harvested yield (t ha^{-1}), Ym the maximum harvested yield (t ha^{-1}), ky the yield response factor, ETa the actual evapotranspiration (mm), ETm the maximum evapotranspiration (mm) corresponding to Ym, (1-Ya/Ym) the relative yield decrease and (1-ETa/ETm) the relative ET deficit.

Precipitation (P) and air temperature data (T), (Figure 1) were taken from Rimski Šančevi weather station, which is located on the premises of the Institute's experiment field at Rimski Šančevi. Irrigation scheduling and amounts of irrigation water applied are shown in Figure 1. Stages of sunflower growth and development (Table 1) were determined by field observation.

Table 1: Stages of growth and development of the sunflower hybrid NS-H-111

Emergence budding	Budding flowering-pollination	Flowering-pollination maturity
1 May-15 June	15 June-10 July	10 July-10 September

The hybrid NS-H-111 was used in the experiment. There were four replicates and the experimental unit was 35 m^2 in size. In the fall, prior to primary tillage, fertilization was performed at 400 kg ha^{-1} NPK, or 60 kg ha^{-1} of active substance. Planting was done in the first half of April. Before budding, 53 kg N ha^{-1} were top dressed. Harvesting was conducted manually at technological maturity and seed yield (Y) was expressed as t ha^{-1} at 14% moisture. Seed oil content was determined by NMR. Up-to-date technology of sunflower growing was used and all the cultural practices were performed at optimal dates.

Data were statistically processed by ANOVA and the results were checked using the LSD test. The regression values and significance of correlation coefficients were determined. All the analyses were conducted using the statistical software STATISTICA 8.0, Series 608c (StatSoft Inc. USA).

RESULTS AND DISSCUSION

Soil and weather

The soil at the experiment site was a highly calcareous loam (Table 2). The contents of sand, silt and clay in the soil were recorded as 31, 46 and 23%, respectively. Field capacity (FC), wilting point (WP) and bulk density in the soil layer to 0.6 m depth were 33.8 vol.%, 14.2 vol.% and 1.29 g cm^{-3}, respectively. The soil available water was 117.6 mm. The contents of N, P_2O_5 and K_2O were 62.6, 892.8 and 1078.2 kg ha^{-1}, respectively. The soil had an organic matter content of 2.33% (Table 3). The reaction of the soil solution was slightly alkaline (8.15). The total porosity was 51.8%, with air porosity of 18.0% (Table 2). The soil structure was crumbly to dusty. Structural stability to 0.6 m was good, with 50-71% of soil aggregates larger than 0.25 mm being persistent in water (Pejić *et al.*, 2005). Concerning the chemical, physical and water properties, this soil is quite suitable for any crop and any irrigation system (Živković *et al.*, 1972).

Table 2: Physical and water characteristics of the soil at the experiment site

Depth (cm)	Textural status (%)			Bulk density (g cm^{-3})	Total porosity (vol%)	Air porosity (vol%)	Field capacity (vol%)	Wilting point (vol%)	Total available soil water (mm)
	Sand	Silt	Clay						
0-30	34	48	18	1.27	54.9	21.9	33.0	13.8	57.6
30-60	29	44	27	1.31	48.8	14.1	34.7	14.7	60.0
0-60	31	46	23	1.29	51.8	18.0	33.8	14.2	117.6

Table 3: Chemical characteristics of the soil at the experiment site

Depth (cm)	pH	$CaCO_3$ (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Organic matter (%)
0-30	8.05	1.95	70.1	931.5	1113.8	2.63
30-60	8.25	3.79	55.1	854.1	1042.5	2.03
0-60	8.15	2.87	62.6	892.8	1078.2	2.33

The period under study (2000 - 2005) had varying annual weather conditions from. This was especially true for the amount and distribution of precipitation, which varied from one year to the next. The growing seasons of 2000, 2002 and 2003 had very low rainfall, 108 mm, 132 mm and 162 mm, respectively (Figure 1), therefore, they can be regarded as extremely dry and unfavorable for sunflower production under rainfed conditions. High air temperatures and small amounts and uneven distribution of rainfall led to a larger number of irrigations and irrigation norms which amounted to 180 mm, 100 mm and 165 mm in 2000, 2002 and 2003, respectively (Figure 1).

The other three years had 501 mm (2001), 295 mm (2004) and 429 mm (2005) of rain during the sunflower growing season. However, despite its abundance, the rainfall was unfavorably distributed (Figure 1), so additional water had to be supplied by irrigation at 100 mm, 105 mm and 120 mm (Figure 1). The climatic pat-

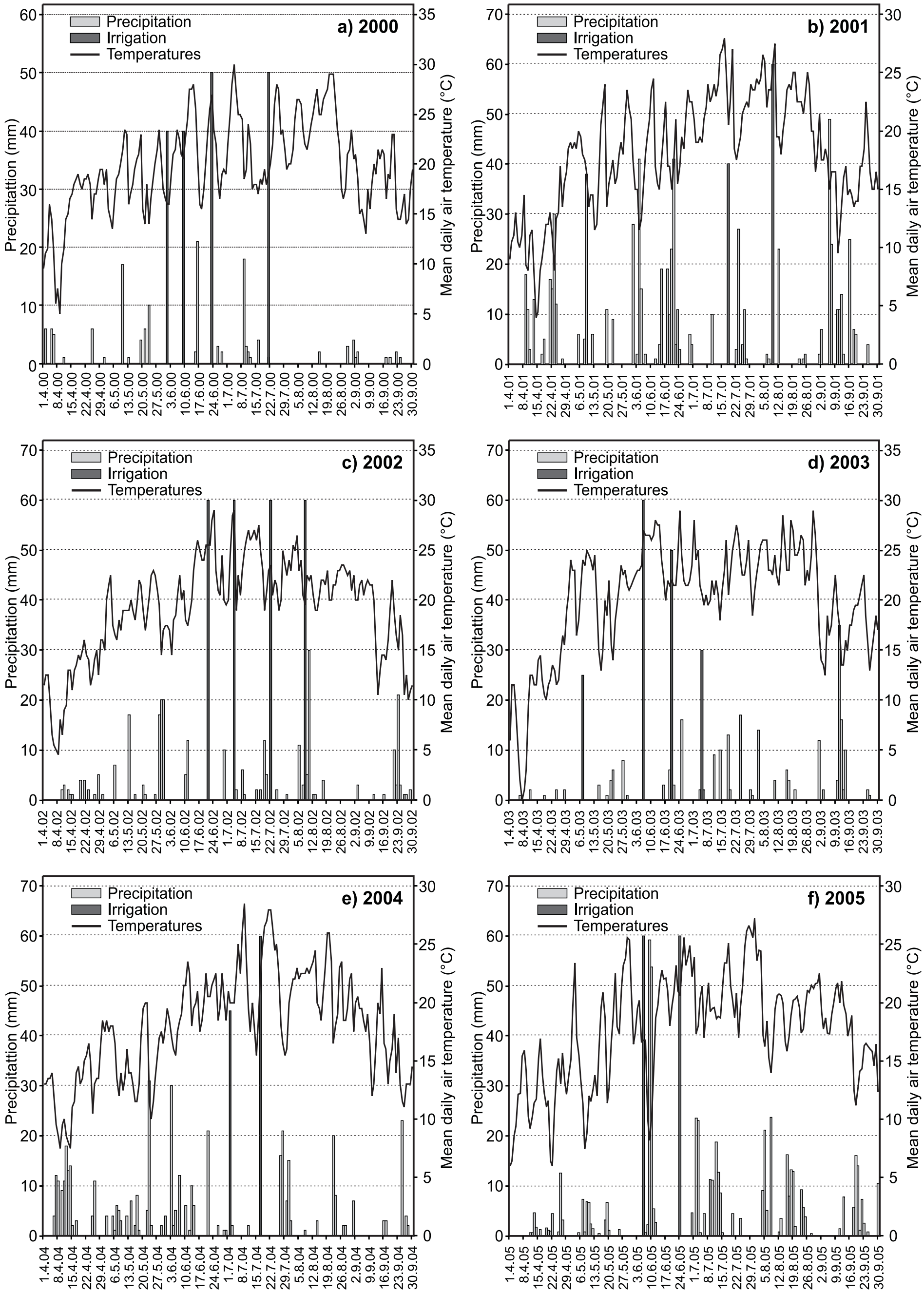

Figure 1: Mean daily air temperatures, daily precipitations, irrigation schedule and irrigation norms applied during sunflower growing seasons (Rimski Šančevi, 2000 - 2005)

tern in the Vojvodina Province is variable and long-term predictions of rainfall are not possible. Consequently, the irrigations in these three years were followed by abundant rains, so the soil became waterlogged and a microclimate developed within the canopy that was favorable to the occurrence of pathogens. Under such conditions, the irrigation had no positive effect on sunflower yields, which were lower than expected (Table 6).

Water stress, yield and evapotranspiration

The values of the yield response factor (ky) were in the 0.07-0.29 range (Table 4), which were far below the value of 0.95 as reported in the literature (Doorenbos and Kassam,1979) and supported the case for growing sunflowers without irrigation in the Vojvodina Province (Maksimović, 2005; Dragović *et al.,* 2005). According to Erdem and Delibas (2003), the sunflower is less susceptible to stress caused by a lack of moisture in the soil (ky 0.78-0.85) than claimed by Doorenbos and Kassam (1979). The same authors therefore concluded that irrigation in the semi-arid conditions of Turkey can be supplementary in character, provided optimal soil moisture levels are secured for the period from flowering to pollination, which is the most sensitive stage of sunflower growth and development.

Table 4: Maximum (ETm, mm) and actual evapotranspiration (ETa, mm), yields in irrigated (Ym, t ha^{-1}) and rainfed conditions (Ya, t ha^{-1}) relative evapotranspiration deficit (1-ETa/ETm), relative yield decrease (1-Ya/Ym) and yield response factor (ky) of sunflower in the conditions of the Vojvodina Province

Year	ETm	ETa	1-ETa/ETm	Ym	Ya	1-Ya/Ym	ky
2000	452	168	0.62	5.46	4.46	0.18	0.29
2001	425	372	0.12	3.11	3.02	0.03	0.25
2002	446	192	0.57	5.06	4.50	0.11	0.19
2003	479	222	0.54	3.32	3.17	0.04	0.07
2004	413	339	0.18	4.02	4.41	0	0
2005	402	402	0	1.76	2.94	0	0
Average	436	282	0.41	3.79	3.75	0.09	0.20

Negative water stress effects on sunflower depend on the stage of growth and development at which the stress occurs as well as on how long it lasts. Stanojević and Dragović (1988) observed significant reductions in flower number when soil water deficit was present at budding. Drought at flowering stage results in poor pollination and reduced number of florets in the central portion of the head, which leads to a decline in total seed weight per head and 1000-seed weight, bringing about major yield losses. A water deficit at seed fill will reduce seed oil content. Plaut (1995) indicates that water deficiency will have a greater negative effect if there is an extreme drought during a particular period of growth and development than if moderate drought is present throughout the growing season. According to Bošnjak (1993), the two most critical periods for sunflowers growing in Vojvodina are flowering and seed fill.

In this study, the values of ky factor by growth stages (Table 5) show that sunflower is the most sensitive to water deficit in the period from flowering to maturity (ky 0,48). A water deficit occurring during this period (54%) will reduce the yield by 26%. A water deficit occurring during the stage from budding to flowering (67%) will reduce the yield by 21% (ky 0.31). The least susceptible stage is that between emergence and budding (ky 0.27). Soil water deficit present during this stage (33%) will reduce the yield by 9%. Stegman and Lemert (1981), Stone *et al.* (1996), Erdem and Delibas, (2003) obtained similar results and reported that sunflower is the most susceptible to soil water deficiency at flowering, fertilization and grain fill. Erdem and Delibas, (2003) reported ky values as 0.43 for vegetative period, 0.67 for flowering and 0.40 for yield formation. However, Unger (1982), Erdem and Delibas (2003) pointed out that adequate water for good initial plant growth was important for making plants capable of responding to later irrigations. Irrigation before or at budding stage generally provided good plant growth.

Table 5: Relative evapotranspiration deficit (1-ETa/ETm), relative yield decreases (1-Ya/Ym) and yield response factor (ky) of sunflower in different parts of the growing season

Growth stage	1-ETa/ETm	1-Ya/Ym	ky
Emergence- budding	0.33	0.09	0.27
Budding-flowering	0.67	0.21	0.31
Yield formation-ripening	0.54	0.26	0.48

Irrigation effect on sunflower yield in Vojvodina depends mostly on the amount and distribution of rainfall. The results of this study (Table 6) showed that irrigation, on average, had no significant effect in terms of yield increase. In rainy years such as 2001, 2004 and 2005, irrigation effect was missing as a result of variable climatic conditions and the influence of the distribution of rainfall on soil water regime and severity of pathogen attacks. Pospišil *et al.* (2006) have also reported that large amounts of rainfall during the sunflower season in Croatia promoted disease attacks and were the main reason behind yield losses. Bošnjak and Marinković (1992) indicated that sprinkler irrigation as the dominant method of irrigation in the region may create favorable conditions for the spread of diseases, which can result in significant yield losses. New sunflower hybrids resistant or tolerant to diseases can be used to increase the area of this crop under irrigation. This would help eliminate the water deficit occurring during the sunflower growing season and make it possible to achieve high yields that would justify the high inputs associated with irrigation systems. Vučić (1976) suggested that sunflower irrigation in Vojvodina must also be considered from the point of view of the irrigation method. The above considerations seem to indicate that localized irrigation (most notably drip irrigation) would go a long way towards providing a solution to the problems discussed above. These recommendations pertain primarily to sunflower seed production on light soils with a low available water capacity. Vučić (1976) has also pointed out that irrigation is less important for soils that have good water-physical properties and can accumulate large amounts of water from pre-growing season precipitation.

This is especially important for sunflower irrigation in the late stages of plant development because of diseases and the effects they have on yield level.

Table 6: Sunflower yield (t ha^{-1})

Year	Irrigated (T_1)	Rainfed (T_0)	Average
2000	5.46	4.46	4.96a
2001	3.11	3.02	3.06c
2002	5.06	4.50	4.78a
2003	3.32	3.17	3.24c
2004	4.02	4.41	4.22b
2005	1.76	2.94	2.35d
Average	3.79 ns	3.75 ns	

Numbers followed by the same letters in the same column are statistically nonsignificant according to the LSD test at P≤0.05

In the dry years (2000, 2002 and 2003), water deficit in the 0.6 m layer was extremely high, 62%, 57% and 54% of the sunflower ETm and yet the yield was reduced by only 18%, 11%, and 4%, respectively. This disagreement is attributed to the fact that the sunflower has a well-developed root system that has a great capacity for water absorption and it penetrates the soil down to depths of two meters and beyond and thus has access to available water reserves present in the deep soil layers. Bošnjak (1993), Dragović *et al.* (2005) indicated that the sunflower is an efficient user of soil water reserves accumulated prior to growing season. The plant is capable of satisfying around 50% of its total water requirement by withdrawing 200 mm of water from the deep soil layers. Connor *et al.* (1985) noted that if the soil has good hydrophysical properties, the sunflower roots will be capable of taking up enough water during seed formation and seed fill, which is especially important in the case when irrigation is only supplementary. Djurović *et al.* (2008) also pointed to the fact that the sunflower is more resistant to soil water deficit than other crops in Serbia. If there is a deficiency of available soil water during the growth of sunflower, soybean, maize and sugar beet, the yields will be reduced by by 17.8%, 29%, 30% and 39%, respectively.

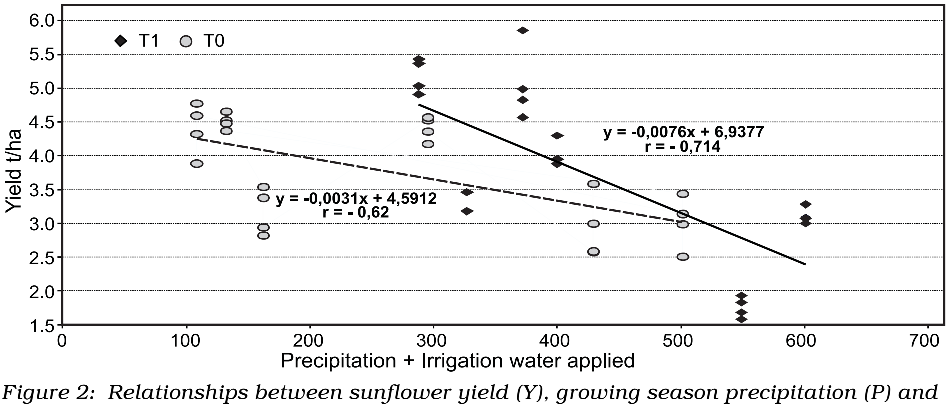

Figure 2: Relationships between sunflower yield (Y), growing season precipitation (P) and irrigation water applied (IWA)

The negative correlation between growing season precipitation and sunflower yields (r=-0.62, Figure 2) indicates that it is possible to grow sunflowers under rainfed conditions in the variable climate of Vojvodina. Also, the negative correlation between yield and total amount of water (precipitation + irrigation water applied) during the growing season (r=-0.71, Figure 2) suggests caution in the implementation of irrigation schedule for sunflowers.

In the present study, water consumption by evapotranspiration (ETm) was in the 402-479 mm range (Table 4), which met sunflower water requirements for the Vojvodina Province (450-470 mm) as determined previously by Bošnjak and Marinković (1992), Bošnjak (1993), and Dragović *et al.* (1996). Of the total amount of water used for sunflower evapotranspiration (ETm), 32% were spent from emergence to budding, 20% from budding to flowering, and 48% during flowering, pollination, seed formation, seed fill, and ripening (Table 7). Daily water consumption by ETm was in the 3.0-3.5 mm interval. The lowest values of this parameter were recorded at the start of the growing season, from emergence to budding, while the highest were observed between budding and flowering, during the period of intensive growth and yield formation.

Table 7: Maximum evapotranspiration - ETm (mm), water used by sunflower in different growth stages (%) and daily evapotranspiration (mm day^{-1})

Growing season	ETm	%	mm day^{-1}
Emergence- budding	139	32	3.0
Budding-flowering	87	20	3.5
Yield formation-ripening	210	48	3.4

Oil content

The oil content in sunflower seed depends on weather conditions, disease attacks during the season, and the hybrid's characteristics. According to Škorić *et al.* (1994), oil synthesis ceases in sunflower seed whenever the plant is exposed to any kind of stress. Škorić (1992) indicated that oil content in sunflower seed depends on mean daily air temperature, water supply at seed fill and the duration of the seed filling stage. Harris *et al.* (1978) noted that the oil content of sunflower seed decreased with increasing air temperature, whereas Unger and Thompson (1982) came to the opposite conclusion based on their findings. The average oil content values in this study (Figure 3) indicated that there were no significant differences between the irrigated treatment and the nonirrigated control.

Oil yield (kg ha^{-1}) is a reliable indicator of sunflower hybrid productivity. Given that there were no significant differences in seed yield between the irrigated treatment and the nonirrigated control, no significant differences were found between the oil yields in the two treatments either (Figure 3). The highest oil yield (2571 kg ha^{-1}) was recorded in the irrigated treatment in 2000 and the lowest (824 t ha^{-1}) in the irrigated treatment in the rainy year of 2005. Beside soil water deficits, waterlogging that occurred in the rainy years of 2004 and 2005 (Figure 1) also affected the oil content in sunflower seed (Figure 3). Mercau *et al.* (2001), Maksimović (2005) also observed that another factor affecting sunflower oil yield in addition to hybrid characteristics was the occurrence of diseases in years with abundant precipitation. Water deficiency at seed formation and seed fill had the greatest effect on sunflower seed level (Table 5), *i.e.*, on oil yield per unit area. Alessi *et al.* (1977), Stanojević and Dragović (1988), and Bošnjak (1993) also indicated that it is water deficit at these two stages of plant development that defines the oil content in sunflower seed.

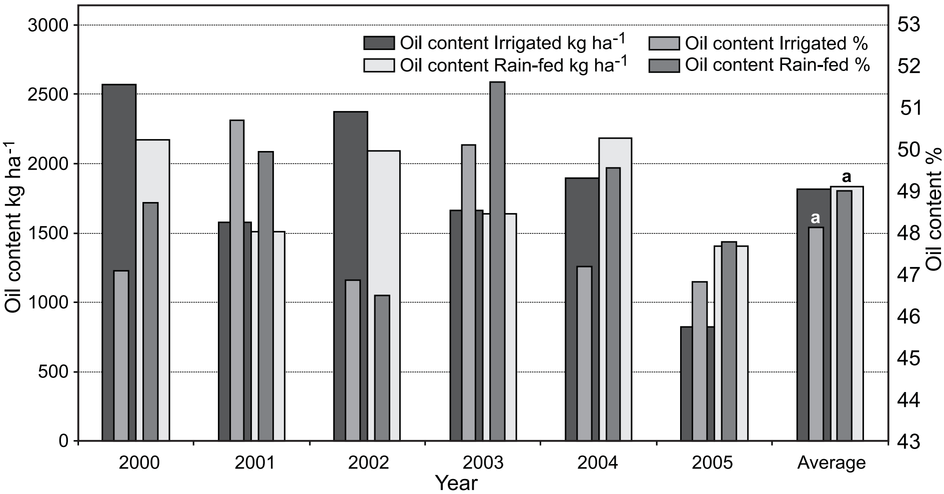

Figure 3: Oil content in sunflower seed in conditions with and without irrigation

CONCLUSION

The long-term study of the effect of available soil water deficit on sunflower yield and evaportanspiration showed that there were no significant differences, on average, in seed and oil yield levels between the irrigated treatment and the nonirrigated control.

The yield response to water deficit of different crops is of major importance in production planning. In this study, the yield response factor (ky) of sunflower was determined at 0.20 for the total growing period. Consequently, in the Vojvodina Province, sunflower does not have priority in irrigation planning.

Similary, the yield response to water deficit in individual growth stages is of major importance for irrigation scheduling. The yield response factor (ky) was obtained as 0.27, 0.31 and 0.48 for vegetative, flowering and yield formation periods, respectively. Of the total amount of water used for sunflower evapotranspiration (ETm), 48% were spent during flowering, pollination, seed formation, seed fill, and ripening. As a result, irrigation scheduling of sunflower must be programmed to provide optimal soil moisture levels during the periods of flowering and yield formation. As irrigation has a supplementary charater in the province, irrigation should be performed to the start of flowering. Otherwise, there is a danger of soil becoming waterlogged if a heavy rain occurs after irrigation. Also, such practice may lead to the development of excessive plant bulk. Such conditions may promote the development of diseases, leading to a reduction in yield level and seed quality due to decreased seed oil content.

Seasonal evapotranspiration (ETm) obtained in T_1 treatment was in the 402-479 mm range, which met sunflower water requirements for the Vojvodina Province (450-470 mm) as previously determined.

REFERENCES

Alessi, J., Power, J.F., Zimmerman, D.C., 1977. Sunflower yield and water use as influenced by planting date, population and row spacing. Agronomy Journal 69: 465-469.

Bošnjak, Dj., Marinković, R., 1992. Sunflower requirement for water in the chernozem zone of Yugoslavia. Proc. 13th Int. Sunflower Conference, Piza, Italy, Vol. 1: 57-63.

Bošnjak, Dj., 1993. Potencijalna evapotranspiracija suncokreta u klimatskim uslovima Vojvodine. Savremena poljoprivreda 40: 51-53.

Bošnjak, Dj., 1993a. Stanje, posledice i predvidjanje suše u Vojvodini. Zbornik radova Instituta za ratarstvo i povrtarstvo 21: 85-89.

Connor, D.J., Jones, T.R., Palta, J.A., 1985. Response of sunflower to strategies of irrigation. Field Crop Res. 12: 281-293.

Cox, W.J., Jolliff, G.D., 1986. Growth and yield of sunflower and soybean under soil water deficits. Agronomy Journal 78(2): 226-230.

Doorenbos, J., Kassam, A.H., 1979. Yield responsible to water. FAO Irrigation and Drainage Paper, Rome, Italy 33: pp. 193.

Djurović, N., Stričević, R., Rudić, Ž., 2008. Statistical analysis of the correlation of standardized precipitation index (spi) and yield reduction of some crops. Soil and Plant 57(2): 89-101.

Dragović, S., Maksimović, L., Karagić, Dj., 1996. Effect of sprinkler and furrow irrigation on sunflower seed yield and quality. Proc. of 14th Int. Sunflower Conference, Bejing, China, 1: 389-394.

Dragović, S., Maksimović, L., Radojević, V., Cicmil, M., Radojević, V., 2005. Uticaj navodnjavanja na povećanje prinosa suncokreta u agroekološkim uslovima Vojvodine. Zemljište i biljka 54(2): 115-124.

Erdem, T., Delibas, L., Orta, A.H., 2002. Water use characteristics of sunflower (*Helianthus annuus* L.) under deficit irrigation. Pakistan Journal of Biological Sciences, 7: 766-769.

Erdem, T., Delibas, L., 2003. Yield response of sunflower to water stress under Tekirdag Conditions. Helia 26: 149-158.

Harris, H.C., Mcwilliam, J.R., Mason, W.K., 1978. Influence of temperature on oil content and composition of sunflower seed. Aus. J. Agric. Res. 29: 1203-1212.

Jana, P.K., Misra, B., Kar, P.K., 1982. Effect of irrigation at different physiological stages of growth on yield attributes, yield, consumptive use and water use efficiency of sunflower. Indian. Agric. 26: 39-42.

Jones, O.R., 1984. Yield, water-use efficiency, oil concentration and quality of dryland sunflower grown in the southern High Plains. Agron. J. 76: 229-235.

Maksimović, L., 2005. Adaptability to variable weather conditions and irrigation response in NS sunflower hybrids. Helia 28: 113-124.

Mercau, J.L., Sadras, V.O., Satorre, E.H., Messina, C., Balbi, C., Uribelarrea, M., Hall, A.J., 2001. On-farm assessment of regional and seasonal variation in sunflower yield in Argentina. Agricultural Systems 67(2): 83-103.

Milić, S., 2008. Dinamika formiranja prinosa i kvaliet krtola krompira u zavisnosti od predzalivne vlažnosti. Magistarska teza, Univerzitet u Novom Sadu, Poljoprivredni Fakultet.

Pejić, B., Šeremešić, S., Belić, M., Milošev, D., Kurjački, I., 2005. Uticaj plodoreda i navodnjavanja na strukturno stanje černozema. Letopis naučnih radova Poljoprivrednog fakulteta u Novom Sadu, 1: 85-92.

Plaut, Z., 1995. Sensitivity of crop plants to water stress at specific developmental stages: re-evaluation of experimental findings. Israel Journal of Plant Sciences 43: 99-111.
Pospišil, M., Pospišil, A., Antunović, M., 2006. Prinos sjemena i ulja istraživanih hibrida suncokreta u ovisnosti o vremenskim prilikama. Poljoprivreda 12(2): 11-16.
Škorić, D., 1992. Achievements and future directions of sunflower breeding. Field Crops Research 30: 231-270.
Škorić, D., Marinković, R., Mihaljčević, M., Rakić, B., Sotin, M., Pap, J., Martinović, R., Jovanović, B., Krstić, Dj., Rožić, R., 1994. Sunflower production in Vojvodina in 1992-1993 and a recommenddation for the 1994 assortment. A Periodical of Scientific Research on Field and Vegetable Crops, 22: 321-339.
Stanojević, D, Dragović, S., 1988. Water balance in vertisol at different stages of sunflower development. Proc. 12th Int. Sunflower Conference, Novi Sad, Yugoslavia 1: 451.
Statistical Yearbook, 2005. On-line statistical database of the Republic of Serbia, http://webrzs.stat.gov.rs/.
Stegman, E.C. and Lemert, G.W., 1981. Sunflower yield *vs.* water deficit in major growth periods. Trans ASAE 24: 1533-1538.
Stone, I.R., Schlegel, A.J., Gwin, R.E., Khan, A.H., 1996. Response of corn, grain sorghum and sunflower to irrigation in the High Plains of Kansas. Agric. Water Manag. 30: 251-259.
Szabo, A., Pepo, P., 2005. Effect of agrotechnical and meteorological factors on yield formation in sunflower production. Cereal Research Communications 33(1): 49-52.
Unger, P.W., Thomson T.E., 1982. Planting date effects on sunflower head and seed development. Agron. J. 74: 389-395.
Unger, P.W., 1982. Time and frequency of irrigation on sunflower production and water use. Soil Sci. Soc. Am. J. 46: 1072-1076.
Unger, P.W., 1986. Growth and development of irrigated sunflower in the Texas High Plains. Agron. J. 78: 507-515.
Vučić, N., 1973. Vodni bilans kao osnova za zalivni režim. Vodoprivreda, 26: 425-427.
Vučić, N., 1976. Navodnjavanje poljoprivrednih kultura. Poljoprivredni fakultet Novi Sad.
Vaux, H.J., Pruitt, W.O., 1983. Crop-water production functions. *In*: Hillel, D., (Ed.) Advances in Irrigation. Academic Press, New York, USA 2: 61-93.
Živković, B., Nejgebauer, V., Tanasijević, Dj., Miljković, N., Stojković, L., Drezgić, P., 1972. Soils of Vojvodina, Institute for agricultural research, Novi Sad Serbia.

EFECTO DEL ESTRÉS HÍDRICO SOBRE EL RINDE Y EVAPOTRANSPIRACIÓN DE GIRASOL

RESUMEN

Se condujo un experimento en Novi Sad, durante 2000 - 2005. El suelo utilizado fue un chernozem calcáreo. Se estudio cómo el rendimiento de girasol y la evapotranspiración se vieron afectados por déficit de agua fácilmente disponibles durante el crecimiento. El experimento consistió en un tratamiento de regadío (T_1), la irrigación se realizó cuando los niveles de humedad del suelo cayó a 60-65% de CC (capacidad de campo) y un control sin riego (T_0). El híbrido girasol usado fue NS-H-111. En promedio, no hubo diferencias significativas en rendimiento entre la T_1 (3.79 t ha^{-1}) y T_0 (3,75 t ha^{-1}). La evapotraspiración estacional obtenida en T_1 estuvo en el rango de 402-479 mm (ETm). El factor de respuesta rendimiento (Ky) fue 0,20 para todo el ciclo de crecimiento y 0,27, 0,31 y 0,48 para los períodos vegetativos, floración y rendimiento, respectivamente. El período desde floración a madurez fue el más sensible a la carencia de agua.

EFFET DU STRESS HYDRIQUE SUR LE RENDEMENT ET L'ÉVAPOTRANSPIRATION DU TOURNESOL

RÉSUMÉ

Une expérimentation en champ a été menée à Rimski Šančevi, de l'Institute of Field and Vegetable Crops à Novi Sad, entre 2000 et 2005. Le sol était un tchernozion calcaire sur terrasse de lœss.

Utilisant le rendement (KY) comme facteur de mesure, l'étude a tenté de quantifier les effets du déficit en eau de la fraction facilement disponible dans le sol sur le rendement et l'évapotranspiration pendant la durée du cycle

L'expérience comportait un traitement irrigué (T_1), pour lequel l'irrigation a été déclenchée lorsque le taux d'humidité du sol baissait à 60-65% de la capacité au champ et un traitement non irrigué de contrôle (T_0). L'hybride de tournesol utilisé dans l'étude était NS-H-111.

En moyenne, aucune différence significative n'a été observée pour le rendement entre les traitements T_1 (3.79 t ha^{-1}) et T_0 (3.75 t ha^{-1}).

L'évapotranspiration saisonnière (ETm) mesurée pour le traitement T_1 était dans l'intervalle 402 - 479 mm. Le facteur de réponse rendement (KY) était de 0.20 pour le cycle complet et respectivement de 0.27, 0.31 et 0.48 pour la période végétative, la floraison et l'élaboration du rendement. Le stade entre floraison et maturité était le plus sensible à l'insuffisance de l'eau.