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RESPONSE OF SUGAR BEET TO SOIL WATER DEFICIT

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ABSTRACT

An investigation was carried out at Rimski Šančevi, experiment field of Institute of Field and Vegetable Crops, Novi Sad in the period 2001-2006, aiming to determine the response of sugar beet to soil water deficit, using crop response factor (ky). The values of ky were derived from the linear relationship between relative seasonal evapotranspiration deficits (1-ETa/ETm) and relative yield loss (1-Ya/Ym). Values of crop response factor in the growing period (ky 0.45) indicated that sugar beet is moderately sensitive to soil water stress in the climatic conditions of the Vojvodina Province.

Key words: sugar beet, soil water deficit, crop response factor (ky).

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) takes an important place among the field crops grown in the Vojvodina Province, northern part of Serbia, considering its economic importance as the raw material for the production of sugar. To fulfil the demands and capacity of all sugar beet refineries, a certain amount of sugar beet must be produced. Required sugar beet acreage is difficult to plan because yield vary in dependence of weather conditions, soil properties and applied production technology. In the variable climatic conditions of the Vojvodina Province, in which summers are semi-arid to semi-humid (Bošnjak, 2001) high and stable yield of sugar beet can be obtained only by irrigation (Pejić et al., 2006).

Sugar beet is adapted to a wide range of climatic conditions. It is tolerant to moderate soil water stress (Hills et al., 1986). In the conditions of the Vojvodina Province drought is a regular phenomenon, occurring each year, causing large or small decrease in sugar beet yield (Bošnjak et al., 2005).

When sugar beet plants lose water from their leaves faster than their roots can absorb it from the soil, internal water deficit develops, growth is slowed, and the plants may wilt. Even with plenty of water, sugar beet may wilt slightly during the afternoon on hot, dry days. Such wilting does not indicate a need for irrigation. However, if the plants wilt early in the day, or if recovery is slow in the late afternoon as temperatures and light intensity decline, irrigation is needed.

In arid and semiarid areas, irrigation may supply all or most of the water that crops need. In more humid production areas, irrigation is used primarily to supplement infrequent or irregular precipitation during short-term droughts. Taking into consideration that irrigation in Vojvodina has a supplementary character, sugar beet irrigation scheduling gains additional importance.

The soil moisture technical minimum for this crop is 70% of the field water capacity (FWC), i.e., irrigation should be performed when about two thirds of available water in the soil layer to 0.6 m is spent (Dragović, 2000; Mahmoodi et al., 2008).

If irrigation schedule is not harmonized with crop requirements and water-physical soil properties, effect of irrigation may be negligible, or missing (Pejić et al., 2006).

The crop response factor (ky) which is the amount of yield (Y) lost per unit of evapotranspiration (ET) loss, expresses the response of the crop to water deficit. A larger ky value indicates larger yield losses due to water deficit. The accuracy of ky depends on

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having a sufficient range and number of values for Y and ET, and assumes that the relationships between Y and ET are linear over this range.

Comparison of ky among different crops shows that for given water deficit sugar beet is better able to produce a yield than many other crops (Doorenbos and Kassam, 1979; Bazza and Tayaa, 1999). Part of the reason for this is that the formation of economic yield in sugar beet is simply dependent on vegetative growth and not on sensitive reproductive or tuber forming stages.

Therefore, a seasonal ky, valid for the total growing period, is adequate for yield predictions of sugar beet, since the beet root is a vegetative storage organ without a differentiated response to water stress at various growth stages (Hoffmann et al., 2009; Shrestha et al., 2009).

Doorenbos and Kassam (1979) have estimated the average ky values for sugar beet at 0.6-1.0. Vaux and Pruitt (1983) suggest 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 in terms of evapotranspiration, Petcu et al., 2009), growing season length, irrigation methods and programs (Uçan and Gençočlan, 2004) and inadequacies of production technology.

The objective of this study was to determine the effect of water stress on growth and production of sugar beet, in order to obtain more information that could improve the crop management of sugar beet in the Vojvodina Province.

MATERIAL AND METHODS

The experiments were conducted at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops in Novi Sad (N 45°19`, E 19°50`) on the calcareous chernozem soil on the loess terrace, in the period 2001-2006. The experiment was established in a system of randomized blocks and adapted to technical specifications of the sprinkler irrigation. The experiment included model with irrigation (T_I) – at 70% of field water capacity (FWC) and a non-irrigated, control model (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. Potential evapotranspiration (ETm) of sugar beet (cv. Drena) during growing season was calculated using the procedure of water balance, and bioclimatic method using hydrophytothermic index (K), the value of which had been estimated at 0.18 for sugar beet in the climate of Vojvodina (Dragović, 2000). After determining the ETm value, the actual evapotranspiration (ETa) was calculated on the basis of precipitation data and pre-vegetation soil water reserve. These values were then used to calculate the soil water deficit during the sugar beet growing season.

Precipitation (P) and temperature (T) data were obtained from Rimski Šančevi Meteorological Station.

$$ETm = \sum_{i=1}^{n} (K \; x \; Ti)$$

ETm – monthly maximum (potential) evapotranspiration for sugar beet (mm);
K – hydrophytothermic index for sugar beet;
Ti – sum of mean daily air temperatures in a given month (°C).

The effect of water stress during growing season on sugar beet yield was determined using the method given by Doorenbos and Kassam (1979):

$$\left(1-\frac{Y_a}{Y_m}\right) = ky\left(1-\frac{ET_a}{ET_m}\right)$$

where:

Ya is the actual harvested yield (t ha^{-1});
Ym – the maximum harvested yield (under irrigation, non limiting conditions, t ha^{-1});
ky – the crop response factor;
ETa – the actual evapotranspiration (mm);
ETm – the maximum evapotranspiration (mm) corresponding to Ym,(1-ETa/ETm) – the relative evapotranspiration deficit and (1-Ya/Ym) the relative yield decrease.

The experimental sugar beet plots received conventional growing technology adjusted to the conditions of irrigation. Sugar beet was harvested at technological maturity and root yield (Y) was calculated in t ha^{-1}. Statistical processing of data was done by the analysis of variance, testing the obtained results by the LSD test. The relationship between relative yield decrease and relative crop evapotranspiration for sugar beet through the total growing season was evaluated using regression analysis.

RESULTS AND DISCUSSION

In the Vojvodina Province, sugar beet is considered to be an irrigation-requiring crop, because it rarely meets its water requirement from precipitation received during the growing season. The situation is especially critical in the summer months of July and August (Bošnjak, 2001). Dragović et al. (1998) stated for the Vojvodina Province that the sugar beet water requirements were 555 mm for the growing season or 60 mm in April, 90 mm in May, 110 mm in June, 120 mm in July, 125 mm in August, and 50 mm in September.

In the study period, evapotranspiration rate in irrigation conditions (ETm) ranged from 534 to 696 mm, and in rainfed conditions (ETa) in the interval from 274 to 534 mm (Table 1). The linear relationship between evapotranspiration and yield of sugar beet was statistically significant (at the 0.05 probability level for the 6 years), with r = 0.860 (Figure 1). Stewart and Hagan (1973), Uçan and Gençočlan, (2004) also reported that there was a significant relationship between evapotranspiration and yield of sugar beet, and that this relationship was linear.

In the course of this study, the growing seasons of 2001, 2002, 2003, 2004, 2005 and 2006 had the precipitation amounts of 570, 177, 228, 442, 530 and 420 mm, respectively (Figure 2).

A comparison of monthly precipitation amounts and monthly sugar beet water requirements indicated a water deficit and the need for irrigation. In the study period water added by irrigation was in range from 60 mm in rainy 2005 to 355 mm in 2003 with limited precipitation and higher than average seasonal temperatures (Table 1).

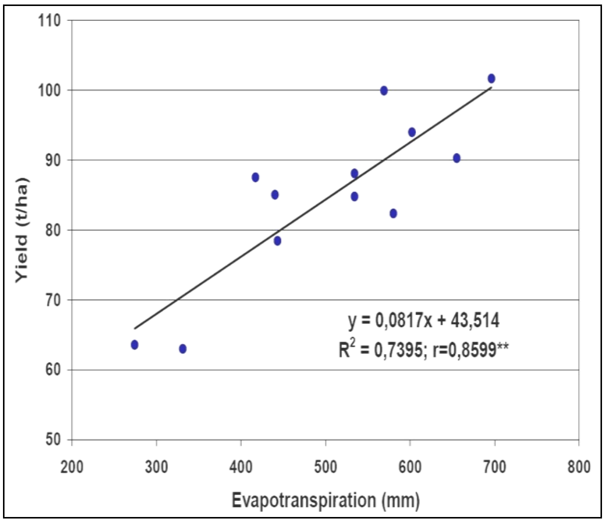

Figure 1. Relationship between crop evapotranspiration and yield of sugar beet

In the study period, on average, the yield of sugar beet was significantly higher in irrigated than in rainfed conditions (Table 1). The average yield increases of sugar beet due to irrigation practice was on average 15.78 t ha^{-1}, ranging from 38.10 t ha^{-1} in years with limited precipitation (2003) to 3.30 t ha^{-1} in rainy years (2005). Our results confirm that irrigation in Vojvodina is supplementary in character and that precipitation can affect the soil water regime and irrigation schedule of sugar beet.

In the variable climate of Vojvodina, where precipitation cannot be predicted for long term, a negative effect of irrigation may occur if it is done before a heavy rain, because in that case the soil may become over moist, and the excess water may percolate into deep soil layers taking the nutrients with it. This was the case in the rainy years of 2001 and 2005.

Similar results of irrigation influence on sugar beet yields in rainy years (10-12%) were reported by Dragović et al. (1998). Maksimović and Dragović (2002) reported that in years with limited precipitation, the effect of irrigation on sugar beet yield was higher than 45%, but in rainy years that effect was lower than 20%. Pejić et al. (2006) also pointed out that in rainy years, in Vojvodina, effect of irrigation on sugar beet yield may be negligible, or missing. Takac et al. (2008) emphasized the supplementary character of irrigation for conditions of Slovakia, and higher water productivity of sugar beet in rainfed than in irrigated conditions. They also reported that sometimes precipitation combined with irrigation does not contribute to higher water productivity. Similar results were obtained in soybean production by Bennett and Albrecht (1984). They stressed that excessive water, caused by unexpected precipitation following irrigation, resulted in low oil content, reduced N fixation and stomata closure.

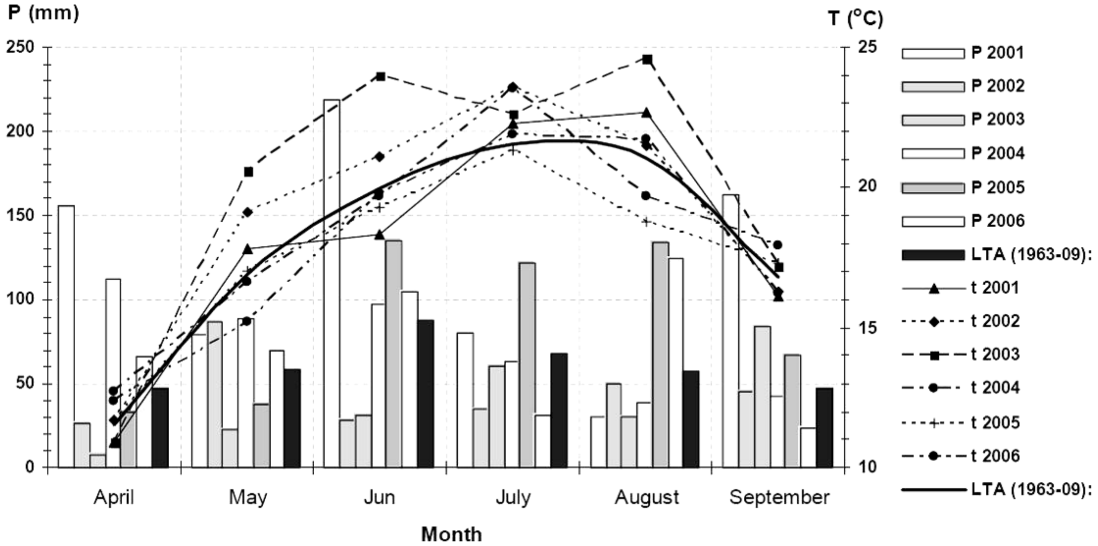

Figure 2. Mean monthly air temperatures (T °C), monthly precipitation sums (P mm) (Rimski Šančevi, 2001-2006) and long-term averages (Rimski Šančevi LTA, 1963-2009) in the sugar beet growing season

Table 1. Maximum (ETm) and actual (ETa) evapotranspiration (mm), irrigation water applied (I mm) maximum (Ym) and actual (Ya) yield (t ha^{-1}) and crop response factor (ky) of sugar beet

Year	ETm	ETa	1-ETa/ETm	I	Ym	Ya	1- Ya/Ym	ky
2001	580	443	0.236	150	82.36	78.44	0.048	0.20
2002	655	331	0.495	350	90.27	63.00	0.302	0.61
2003	696	274	0.606	355	101.67	63.57	0.374	0.62
2004	569	417	0.267	105	99.95	87.54	0.124	0.46
2005	534	534	none	60	88.09	84.79	0.038	none
2006	602	440	0.269	180	94.00	85.05	0.095	0.35
01/06	606	406	0.374	200	92.84 **a**	77.06 **b**	0.163	0.45

Numbers followed by different letters in the same row are significantly different by the LSD test at P≤ 0.05

The ky of 0.45 obtained in our study (Table 1) for whole sugar beet growing season was lower than data of 0.6-1.0 reported by Doorenbos and Kassam (1979), 0.8-0.9 by Kassam and Smith (2001) and 0.73 by Uçan and Gençočlan (2004) for Kahramanmaras region in Turkey. The results indicate that sugar beet is moderate sensitive to soil water stress in the climatic conditions of the Vojvodina Province. The variation of ky from 0 to 0.61 observed during the study period (Table 1) is the consequence of weather conditions, mostly amount and distribution of precipitation. Crop yield response factor (ky) indicates a statistically significant linear relationship (at the 0.05 probability level for the 6 years) between the decrease in relative water consumption and the decrease in relative yield (r = 0.962, Figure 3). Relative evapotranspiration decrease by 37.4% resulted in yield reduction of 16.3% (Table 1). Obtained yield response factor of sugar beet (ky 0.45) could be used for the planning, design and operation of irrigation projects, allowing quantifications of water supply and water use in terms of crop yield and total production for the project area.

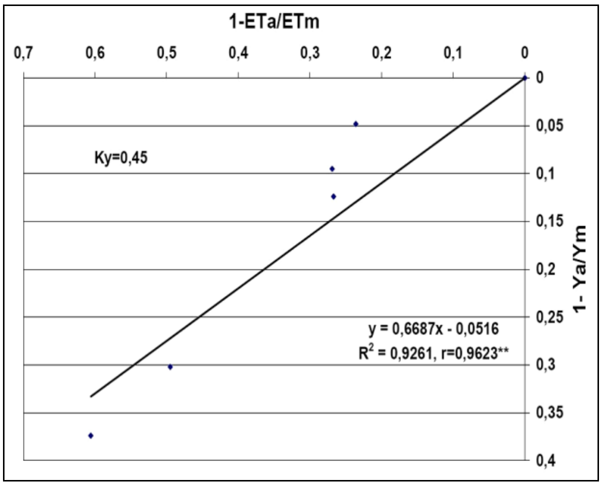

Figure 3. Relationship between relative yield decrease and relative crop evapotranspiration for sugar beet growing season

CONCLUSIONS

Based on the analysis of sugar beet response to soil water deficit in the growing season, using crop response factor (ky), we can conclude that sugar beet is moderately sensitive to soil water stress in the climatic conditions of the Vojvodina Province. The determined value of ky (0.45) could be used as a good platform for sugar beet growers in the region, in terms of improvement of the cropping technology, optimum utilization of irrigation water and for the planning, design and operation of irrigation projects in the region.

REFERENCES

Bazza, M, Tayaa, M., 1999. *Contribution to improve sugar beet deficit irrigation.* In: Cirda C., Moutonnet, P., Hera, C., Nielsen, D.R. (eds.) Contribution to improve sugar beet deficit irigation, Dodreht, Kluwer Academic Publishers, The Netherlands: 148-161.

Bennett, J.M, Albrecht, S.L., 1984. *Drought and flooding effects in N_2 fixation, water relations and diffusive resistance of soybean.* Agrn. J., 76: 735-740.

Bošnjak, Dj., 2001. *The problems of drought in the Vojvodina Province and drought control measures.* A Periodical of Scietific Research on Field and Vegetable Crops, 35: 391-402.

Bošnjak, Dj., Pejić, B., Maksimović, L., 2005. *Irrigation a condition for high and stable corn production in the Vojvodina Province.* Contemporary Agriculture, 3-4: 82-87.

Doorenbos, J., Kassam, A.H., 1979. *Yield responsible to water.* FAO, Irrigation and Dreinage Paper, No. 33, Rome, 193.

Dragović, S., Kovačev, L., Karagić, Dj., Maksimović, L., 1998. *Water requirements and irrigation effect on different NS sugar beet hybrids.* Proc. of the 2nd Balcan Symposium on Field Crops, 2: 229-235.

Dragović, S., 2000. *Irrigation.* Edit. Research Institute of field and Vegetable Crops, Novi Sad, Serbia, 179.

Hills, F.J., Johnson. S.S., Goodwin, B. A., 1986. *The sugarbeet industry in California.* Univ. California Agric. Exp. Stn. Bull.: 1916.

Hoffmann, C.M., Huijbregts, T., Swaaj Van, N., Jansen, R., 2009. *Impact of different environments in Europe on yield and quality of sugar beet genotypes.* Europ. J. Agron., 30: 17-26.

Kassam, A., Smith, M., 2001. *FAO methodologies on crop water use and crop water productivity.* In: Expert Meeting on Crop Water Productivity, paper No. CWP-M07, Rome, Italy.

Mahmoodi, R., Maralian, H., Aghabarati, A., 2008. *Effects of limited irrigation on root yield and quality of sugar beet* (*Beta vulgaris* L.). African Journal of Biotechnology, 7 (24): 4475-4478.

Maksimović, L., Dragović, S., 2002. *Effect of sugar beet irrigation in different environmental growing conditions.* A Periodical of Scietific Research on Field and Vegetable Crops, 36: 43-56.

Pejić, B., Maksimović, L., Milić, S., 2006. *Effect of different rates of nitrogen fertilizers on yield and quality of sugar beet in irrigation.* Annals of Scientific Work, 1: 126-133.

Petcu, E., Schitea, M., Cirstea, V.E., 2009. *The effect of water stress on cuticular transpiration and its association with alfalfa yield.* Romanian Agricultural Research, 26: 53-56.

Shrestha, N., Geerts, S., Raes, D., Horemans, S., Soentjens, S., Maupas, F., Clouet, P., 2009. *Yield response of sugar beet to water stress under Western European conditions.* Agric. Water Manage, doi: 10.1016/j.agwat.2009.10.005 (Article in press).

Stewart, J.I, Hagan, R.M., 1973. *Function to predict effect of crop water deficit.* J. Irrig. Drain.Div., ASCE, 99, IR4: 421-439.

Takac, J., Nejedlik, P., Siska, B., 2008. *COST734 workshop.* Adagio, Cecilia, Italy.

Uçan, K., Gençočlan, C., 2004. *The effect of water deficit on yield components of sugar beet*. Turk. J. Agric. For., 28: 163-172.

Vaux, H.J, Pruitt, W.O., 1983. *Crop - water production functions.* In: Hillel, D. (eds.), Advances in Irrigation. New York, Academic Press, USA, 61-93.