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# EFFECT OF IRRIGATION AND NITROGEN RATES ON YIELD AND WATER PRODUCTIVITY OF SUGAR BEET

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*SUMMARY: Experiments were conducted at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops, on a calcareous chernozem soil on the loess terrace, from 2004 to 2006. The experiments included a variant of irrigation (T1) and a nonirrigated control (T0) and four variants of nitrogen fertilization, N1 90, N2 120, N3 150 and N4 180 kg ha-1. Coefficients of irrigation water use efficiency (I/WUE, t ha-1/mm) and evapotranspiration water use eficiency (ETm/WUE and ETa/WUE, t ha-1/mm) were used to assess the effect of applied irrigation schedule on the yield of sugar beet root and water productivity both in irrigation and rainfed condition under different variants of nitrogen fertilization. As there were no statistically significant differences in sugar beet root yield either among the variants with high nitrogen doses or among the values of I/WUE, ETm/ WUE and ETa/WUE, the variant of nitrogen fertilization with 120 kg ha-1 is adequate for both irrigation and rainfed conditions. Higher values of ETa/WUE in relation to ETm/ WUE indicated that water consumption by sugar beet was more productive under rainfed than under conditions of irrigation. Low values of I/WUE in some years and higher values of ETa/WUE than ETm/WUE in the period of study indicate that irrigation in the climate of Vojvodina is supplementary in character.*

*Key words: sugar beet, irrigation, nitrogen rates, yield,water productivity*

## INTRODUCTION

Sugar beet takes an important place among the field crops grown in the Vojvodina Province, not considering its acreage, but considering its economic importance as the

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raw material for the production of sugar. To meet the needs of all operative sugarbeet refineries, a certain amount of sugar beet must be produced. A required sugar beet acreage is difficult to plan because yields vary in dependence of weather conditions, soil properties and applied cultural practices. In the variable climatic conditions of the Vojvodina Province, in which summers are semi-arid to semi-humid high and stable yields of sugar beet roots can be obtained only in irrigation (Pejić et al., 2006).

Besides climatic factors, a decisive role in determining sugar beet yield performance and quality is played by fertilization practice. Among the nutritive elements required by sugar beet, nitrogen is most important. Nitrogen deficit in sugar beet nutrition leads to reduction of root yield which in turn considerably reduces total sugar production per unit area. On the other hand, excessive and untimely fertilizer application increases the root yield slightly while reducing sugar content in the root and the production of white sugar (Marinković et al., 1997).

Taking in 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 are spent (Dragović, 1976, Mahmoodi et al., 2008). If irrigation schedule is not harmonized with crop requirements and water-physical soil properties, effect of irrigation may be negligible (Pejić et al., 2006).

Percentage of yield increase of sugar beet roots need not always be a reliable indicator of irrigation efficiency. Calculation of irrigation water use eficiency (I/WUE) and evapotranspiration water use eficiency coefficients (ETm/WUE and ETa/WUE) may give a more realistic assessment of the effect of irrigation, i.e., the effect of the irrigation schedule applied. If calculated values of I/WUE, ETm/WUE and ETa/WUE are below those previously established for that region, a failure must have occurred in the technology of crop, primarily in the application of inadequate irrigation schedule.

The objective of the research was to determine the most optimal dose of nitrogen fertilizer for sugar beets grown under irrigation and rainfed conditions, and also, based on the calculated values of I/WUE, ETm/WUE and ETa/WUE coefficients, to analyse the effectiveness of the applied irrigation schedules, i.e., the productivity of water applied in irrigation and rainfed conditions, and so obtain more information that could improve the production 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, on the calcareous chernozem soil on the loess terrace, from 2004 to 2006. The experimental setup was the random block system adapted to the conditions of sprinkler irrigation. The experiment included a variant with irrigation ($T_1$ - 70% of the field water capacity - FWC) and a nonirrigated control variant ($T_0$). Irrigation schedule was determined by monitoring the dynamics of soil moisture.

The study included four variants of nitrogen fertilization:

- $N_1$ - 90 kg N $ha^{-1}$ (applied before primary tillage);
- $N_2$ - 120 kg N $ha^{-1}$ (90 + 30 kg N $ha^{-1}$ before primary tillage + preplanting);
- $N_3$ - 150 kg N $ha^{-1}$ (90 + 30 + 30 kg N $ha^{-1}$ before primary tillage + preplanting + top dressing);

- $N_4$ - 180 kg N $ha^{-1}$ (90 + 30 + 30 + 30 kg N $ha^{-1}$ before primary tillage + preplanting + top dressing).

All variants of nitrogen fertilization had received 90 kg $ha^{-1}$ of both $P_2O_5$ and $K_2O$ before the primary tillage. The nitrogen applied before planting and for top dressing was added in the form of KAN that contained 27 % of active ingredient. Consumption of water for sugar beet potential evapotranspiraciju (ETm) during growing season was calculated using the procedure of hydrophytothermic bioclimatic indexes (Dragović, 2000). After calculating ETm, actual evapotranspiration (ETa) was calculated on the basis of rainfall data and water reserve accumulated in the soil before the beginning of the growing season. Rainfall (P) and temperature (T) data were taken from Rimski Šančevi Meteorological Station. The coefficient of irrigation water use eficiency (I/WUE, t $ha^{-1}$/mm) was calculated on the basis of the differences in sugar beet root yields obtained in variants $T_1$ and $T_0$ in relation to irrigation water applied (Wirr) (Bos, 1985):

I/WUE = Yirr – Ydry/Wirr

- Yirr = yield in irrigation conditions (t $ha^{-1}$/mm)
- Ydry = yield in nonirrigated - rainfed conditions (t $ha^{-1}$/mm)
- Wirr = irrigation water applied (mm)

Evapotranspiration water use eficiency coefficients (ET/WUE, t $ha^{-1}$/mm) were calculated on the basis of yields obtained in variants $T_1$ and $T_0$ and evapotranspiration rates in varaints $T_1$ (ETm) and $T_0$ (ETa), (Bos, 1985):

ET/WUE = Y/ET

- Y = yield (t $ha^{-1}$/mm)
- ETm = evapotranspiration rate under conditions of irrigation (mm)
- ETa = evapotranspiration rate under nonirrigated - rainfed conditions (mm)

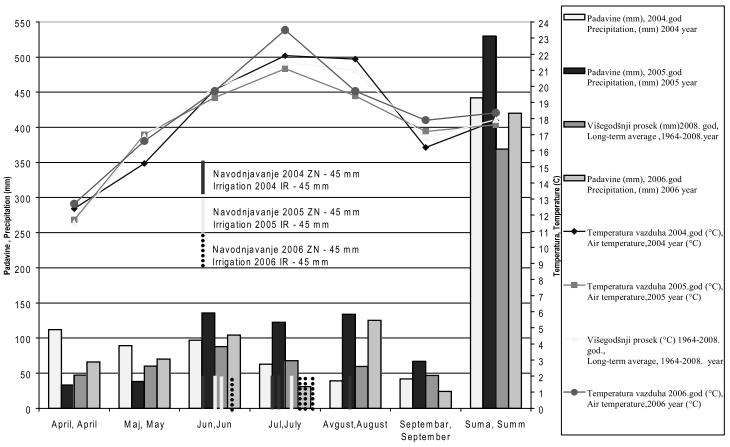
The experimental sugar beet plots received conventional cultivarion practices adjusted to the conditions of irrigation. Sugar beet was harvested at technological maturity and root yield (Y) was calculated in t $ha^{-1}$. Statistical processing of data was done by the analysis of variance, testing the obtained results by the LSD test.

## 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 rainfall received during the growing season. The situation is especially critical in the summer months of June, July and August. Dragović (1976) 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 602 mm, and in rainfed conditions (ETa) in the interval from 417 to 534 mm (Table 2).

In the course of this study, the growing season of 2004, 2005 and 2006 had the rainfalls of 442, 530 and 420 mm (Graph 1). A comparison of monthly precipitation amounts and monthly sugar beet water requirements indicated a deficit in readily available water and the need for irrigation. In the 2004 growing season, four irrigations were performed in July and August, each with the irrigation water of 45 mm. In 2005, although the amount of rainfall matched the level of sugar beet water requirement, three irrigation had to be performed in June and July, each with 45 mm of water, because the rainfall distribution was in disagreement with the dynamics of sugar beet requirements

for water. In 2006, four irrigations were performed in June and July, each with 45 mm of water (Graph 1).




Graph 1. Mean monthly air temperatures (T °C), monthly precipitation sums (P mm), irrigation schedules and irrigation water applied (mm) in the sugar beet growing season (Rimski Šančevi, 2004-2006)

*Grafikon 1. Srednja mesečna temperatura vazduha (T°C), mesečna suma padavina (P mm) u vegetacionom periodu šećerne repe, vreme zalivanja, norma navodnjavanja (mm) (Rimski Šančevi, 2004-2006)*

In the study period, on average, there were no statistically significant differences in sugar beet root yield between the irrigated and rainfed variants. The irrigation increased the yield by 9.4% or 8.01 t ha$^{-1}$ (Table 1).

The effect of fertilization on the yield of sugar beet roots varied considerably in dependence of nitrogen doses and irrigation. In all three study years, highest sugar beet root yields were achieved in fertilization variants with high nitrogen doses (Table 1).

Table 1. Yield of sugar beet root (t ha$^{-1}$)
*Tabela 1. Prinos korena šećerne repe (t ha$^{-1}$)*

| Year *Godina* | $T_1$ $T_0$ | Fertilization - *Djubrenje* (kg N ha$^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| | | 90 ($N_1$) | 120 ($N_2$) | 150 ($N_3$) | 180 ($N_4$) | Average *Prosek* |
| 2004 | $T_1$ | **91.95** | **99.95** | **113.35** | **105.26** | **102.63** |
| | $T_0$ | 85.80 | 87.54 | 95.16 | 96.99 | 91.37 |
| 2005 | $T_1$ | **78.49** | **88.09** | **94.58** | **91.57** | **88.18** |
| | $T_0$ | 77.07 | 84.79 | 86.38 | 90.25 | 84.62 |
| 2006 | $T_1$ | **67.20** | **94.00** | **97.70** | **93.27** | **88.04** |
| | $T_0$ | 56.07 | 85.05 | 90.32 | 83.95 | 78.85 |
| Average - *Prosek* | | 76.10b | 89.90a | 96.25a | 93.55a | Average - *Prosek* $T_1$ 92.95 ns - $T_0$ 84.94 ns |

Values with no common superscript are significantly different (P≤ 0.05)
*Vrednosti koje nemaju isto slovo u superskriptu su statistički značajno različite (P≤ 0.05)*

Statistically significant differences in root yield were obtained between the fertilization variants with high nitrogen doses as compared with the fertilization variant with 90 kg N ha$^{-1}$ (Table 1). As no statistically significant differences in sugar beet root yield were established between variants with 120, 150 and 180 kg N ha$^{-1}$, it was concluded that the fertilization variant with 120 kg N ha$^{-1}$ was acceptable for both irrigation and rainfed

conditions, taking in consideration that favorable conditions for mineralization in soil can provide additional amounts of nitrogen (Marinković et al., 1997). Studying nitrogen fertilization of sugar beet suitable for conditions of Poland, Podlaska and Artysza (1995) found that the amount of 120 kg N $ha^{-1}$ is most acceptable from the aspects of yield performance and sugar content in roots.

On average for all fertilization variants, the value of the coefficient I/WUE for the investigated period was 0.048 t $ha^{-1}$/mm, the actual values ranging in the interval from 0.033 t $ha^{-1}$/mm in the fertilization variant with 180 kg N $ha^{-1}$ to 0.068 t $ha^{-1}$/mm in the fertilization variant with 150 kg N $ha^{-1}$ (Table 2).

Table 2. Amounts of water used for potential (ETm) and actual (ETa) evapotranspiration, irrigation water applied, and water use efficiency coeficients of sugar beet (WUE) depending on different rates of nitrogen fertilizer

*Tabela 2. Utrošak vode na potencijalnu (ETm) i stvarnu (ETa) evapotranspiraciju, norna navodnjavanja, koeficijenti iskorišćenosti vode šećerne repe (WUE) u uslovima različite doze djubrenja azotom*

| Year *Godina* | ETm ETa (mm) | Irr. wat. app. *Norma nav.* (mm) | WUE (t $ha^{-1}$/mm) | Fertilization - *Djubrenje* (kg N $ha^{-1}$) | | | | Average *Prosek* |
|---|---|---|---|---|---|---|---|---|
| | | | | 90 ($N_1$) | 120 ($N_2$) | 150 ($N_3$) | 180 ($N_4$) | |
| 2004 | | 180 | I/WUE | 0.054 | 0.080 | 0.101 | 0.046 | ***0.070*** |
| | 569 | | ETm/WUE | 0.162 | 0.176 | 0.199 | 0.185 | *0.180* |
| | 417 | | ETa/WUE | 0.206 | 0.210 | 0.228 | 0.232 | *0.219* |
| 2005 | | 135 | I/WUE | 0.011 | 0.024 | 0.061 | 0.001 | ***0.024*** |
| | 534 | | ETm/WUE | 0.147 | 0.165 | 0.177 | 0.171 | *0.126* |
| | 534 | | ETa/WUE | 0.144 | 0.159 | 0.161 | 0.169 | *0.158* |
| 2006 | | 180 | I/WUE | 0.062 | 0.050 | 0.041 | 0.052 | ***0.051*** |
| | 602 | | ETm/WUE | 0.112 | 0.156 | 0.162 | 0.155 | *0.146* |
| | 440 | | ETa/WUE | 0.127 | 0.193 | 0.205 | 0.191 | *0.179* |
| Average *Prosek* | | 165 | I/WUE | **0.042b** | **0.051ab** | **0.068a** | **0.033b** | **0.048** |
| | 568 | | ETm/WUE | **0.140b** | **0.166ab** | **0.179a** | **0.170a** | **0.164** |
| | 464 | | ETa/WUE | **0.159b** | **0.187a** | **0.198a** | **0.197a** | **0.185** |

Values with no common superscript are significantly different (P≤ 0.05)

*Vrednosti koje nemaju isto slovo u superskriptu su statistički značajno različite (P≤ 0.05*

Various authors provided different values of this coefficient, but noting that they depended on the method of irrigation, soil and climatic conditions, time of sowing, cultivars, plant density, control of disease and weeds (Bos, 1985). Draycott (2006) reported the average value of I/WUE for sugar beet of 0.050 t $ha^{-1}$. Kenan and Cafer (2004) gave the value of 0.047 t $ha^{-1}$ for the conditions of Turkey, Kavazza (1976) the value of 0.055 t $ha^{-1}$ for the conditions of Italy. Based on the comparison of the I/WUE values obtained in the study period with those from the literature, it can be concluded with certainty that a cost-efficient irrigation schedule was designed which took into account the water requirement of sugar beet plants and water-physical soil properties.

The average value of the coefficient ETm/WUE for all fertilization variants was 0.164 t $ha^{-1}$/mm, the actual values ranging in the interval from 0.140 t $ha^{-1}$/mm in the variant with 90 kg N $ha^{-1}$ to 0.179 t $ha^{-1}$ / mm in the variant with 120 kg N $ha^{-1}$ (Table 2). The

average value of the coefficient ETa/WUE for all fertilization variants was 0.185 t $ha^{-1}$/mm, with the actual values ranging from 0.159 t $ha^{-1}$/mm in the fertilization variant with 90 kg N $ha^{-1}$ to 0.198 t $ha^{-1}$ / mm in the fertilization variant with 150 kg N $ha^{-1}$ (Table 2).

The higher productivity of applied water at $T_0$ (ETa/WUE 0.185 t $ha^{-1}$/mm) in relation to the values established in the $T_1$ variant (ETm/WUE 0.164 t $ha^{-1}$/mm) indicated the supplementary character of irrigation in the Vojvodina Province. In the variable climate of Vojvodina, where precipitation cannot be predicted for long term, negative effect of irrigation may occur if it is done before a heavy rain, because in that case the soil may become overwatered, and the excess water may percolate into deep soil layers taking the nutrients with it. This was the case in the rainy year of 2005. Takac et al. (2008) also emphasized the supplementary character of irrigation for conditions of Slovakia, and higher values ETa/WUE (0.115 t $ha^{-1}$/mm) of sugar beet than ETm/WUE (0.098 t $ha^{-1}$/mm).

## CONCLUSION

Based on the analysis of sugar beet yield achieved under conditions of irrigation and with different doses of nitrogen fertilizer, it can be concluded that the irrigation did not significantly affect yield performance, although the root yield in irrigation was higher than that in dry farming by 9.4% or 8.01 t $ha^{-1}$.

As there were no statistically significant differences in sugar beet root yield either among the variants with high nitrogen doses or among the values of I/WUE, ETm/WUE and ETa/WUE, a conclusion was drawn that the variant of nitrogen fertilization with 120 kg $ha^{-1}$ is adequate for both irrigation and rainfed conditions.

The higher values of ETa/WUE in relation to ETm/WUE indicated that sugar beet water use was more productive under rainfed conditions than under irrigation conditions.

The low values of I/WUE observed in some years and the higher values of ETa/WUE than ETm/WUE in the study period indicated that irrigation in the Vojvodina Province is supplementary in character.

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## UTICAJ NAVODNJAVANJA I DJUBRENJA AZOTOM NA PRINOS I PRODUKTIVNOST UTROŠENE VODE ŠEĆERNE REPE

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### Izvod

Eksperimentalna istraživanja su obavljena na oglednom polju Instituta za ratarstvo i povrtarstvo na Rimskim Šančevima, na zemljištu tipa karbonatni černozem lesne terase u periodu od 2004-2006. godine. U ogledu su bile zastupljene varijanta sa navodnjavanjem ($T_1$) i kontrolna, nenavodnjavana varijanta ($T_0$) i četiri varijante djubrenja azotom $N_1$ 90, $N_2$ 120, $N_3$ 150 i $N_4$ 180 kg ha$^{-1}$. Koeficijenti iskorišćenosti vode dodate navodnjavanjem (I/WUE, t ha$^{-1}$/mm) i vode utrošene na evapotranspiraciju (ETm/WUE and Eta/WUE, t ha$^{-1}$/mm) su korišćeni za ocenu efekta realizovanog zalivnog režima na prinos korena šećerne repe, odnosno za ocenu produktivnosti utrošene vode kako u navodnjavanju tako i u uslovima prirodne obezbedjenosti biljaka vodom, na raličitim varijantama djubrenja azotom. Navodnjavanje nije signifikantno uticalo na visinu prinosa korena šećerne repe ali je prinos u uslovima navodnjavanja bio veći za 9,4%, odnosno 8,01 t ha$^{-1}$. Kako nisu utvrdjene statistički značajne razlike u postignutim prinosima korena šećerne repe i koeficijenata I/WUE, ETm/WUE, ETa/WUE izmedju varijanti sa visokim dozama djubrenja azotom, upućuje na zaključak da je varijanta djubrenja azotom 120 kg ha$^{-1}$ prihvatljiva kako za uslove navodnjavanja tako i za uslove prirodne obezbedjenosti biljaka vodom. Veće vrednosti ETa/WUE u odnosu na ETm/WUE ukazuju na produktivniju potrošnju vode u uslovima prirodne obezbedjenosti biljaka vodom u odnosu na proizvodnju šećerne repe u uslovima navodnjavanja. Niske vrednosti I/WUE u pojedinim godinama kao i veće vrednosti ETa/WUE u odnosu na ETm/WUE u periodu istraživanja ukazuju na dopunski karakter navodnjavanja u klimatskim uslovima Vojvodine.

**Ključne reči:** šećerna repa, navodnjavanje, doze azota, prinos, produktivnost utrošene vode.

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