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# EFFECT OF DIFFERENT IRRIGATION REGIMENS ON WATER-YIELD RELATIONSHIPS OF POTATO

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*SUMMARY: Yield response to irrigation of different crops is of major importance in production planning. The study aim of the experiment was to determine the effect of different irrigation regimens on water-yield relationships of potato. The study was carried out at the experimental field of the Institute of Field and Vegetable Crops in Novi Sad in the period 2002-2003. The trial included three irrigation variants (pre-irrigation soil moisture of 60, 70 and 80% of field water capacity – FWC, or irrigation was performed when 70%, 50% and 30% of available soil water, respectively, was consumed), and the non-irrigated, control variant. The trial was established in a system of random blocks and adapted to technical specifications of the sprinkling irrigation. Water used on evapotranspiration of potato was determined by balancing the amounts of water taken up from the soil layer of 2 m depth, from natural rainfall and irrigation. To assess the effectiveness of irrigation IWUE and ETWUE coefficients were used. Effects of irrigation on potato yield were positive and highly significant. The highest yield of potato was obtained on the irrigation variant of 70% of FWC (43158 kg ha$^{-1}$). The amounts of water used on evapotranspiration under irrigation ($ET_m$) and non-irrigation conditions ($ET_a$) ranged from 451.4 to 501.4 mm, and 373.4 to 381.2 mm, respectively. The values of IWUE and ETWUE varied from 71.4-112.5 kg ha$^{-1}$ mm$^{-1}$ and 67.0 do 91.9 kg ha$^{-1}$ mm$^{-1}$ respectively. As the highest values of yield, IWUE and ETWUE coefficients of potato were obtained on the irrigation variant of 70% of FWC that level of soil moisture represents the time when to start with irrigation if potato is grown in a soil with medium soil texture, under climatic conditions of the Vojvodina region.*

***Key words:*** *potato, irrigation, water-yield relationships*

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## INTRODUCTION

Production of potato (*Solanum tuberosum* L.) takes a very important place in world agriculture, with a production potential of about 368 million t harvested and 19.3 million ha planted area with an average yield of 19.1 t $ha^{-1}$ (FAO, 2012). In Vojvodina the northern part of Serbia potato is grown at about 18.000 ha with an average yield of 15.3 t $ha^{-1}$ (Statistical Yearbook of the Republic of Serbia, 2012). The yield in the region is three times lower than this achieved in the leading potato-growing countries (Germany 45 t $ha^{-1}$, France 45 t $ha^{-1}$, Belgium 44 t $ha^{-1}$, Swiss 43 t $ha^{-1}$, FAO, 2012). The low yields are the consequence of inadequate management practices, insufficient amount and unfavorable arrangement of precipitation in the growing season and inappropriate irrigation scheduling applied.

Irrigation scheduling is one of the most important tools for developing best management practices for irrigated areas (Vučić, 1976, Yuan et al., 2003, Onder et al., 2005, Halim et al., 2006, Kiziloglu et al., 2006, Milić 2010). If shortage of readily available water in the soil is eliminated by irrigation it is possible to achieve high and stable yields of potatoes, at the level of 40-50 t $ha^{-1}$ or higher. Bošnjak and Pejić 1997, Milić et al., 2010 found out that the lower limit of optimum soil moisture for potatoes is 70% of field water capacity (FWC) when this crop is grown in a soil with medium texture. Thonthon and Siecka 1980, Costa et al., 1997, claimed that the lower limit of optimum soil moisture for potatoes is reached when 50% of available water is consumed.

A preliminary step to a more intensive exploitation of the available agroecological conditions or to the development of irrigation schedules for any crop implies a study of crop requirements for water, that is, the evapotranspiration (ET) for any particular crop. To fully utilize the genetic yield potentials of potato, to achieve high and stable yields, it is necessary to gain knowledge of the crop's capabilities under conditions of dry farming and irrigation. Wright and Stark (1990), Bošnjak and Pejić (1997) stressed the influence of local conditions on seasonal water use of potato.

Dwindling water resources and increasing food requirements require greater efficiency in water use, both in rainfed and in irrigated agriculture (Smith et al., 2002). The irrigation water use efficiency (IWUE) provides a more realistic assessment of the irrigation effectiveness, but the evapotranspiration water use efficiency (ETWUE) establishes whether the growing period is favorable for plant production or not.

The objective of this study were (1) to examine the effects of different pre-irrigation soil moisture on potato yield, water used on seasonal evapotranspiration, evapotranspiration and irrigation water use efficiency (2) to determine the best pre-irrigation soil moisture that would contribute to potato irrigation scheduling, particularly to assist in developing strategies for improved production technology of potato in the Vojvodina and similar regions.

## MATERIALS AND METHODS

The field trial was conducted at Rimski Šančevi experiment field of the Institute of Field and Vegetable Crops in Novi Sad, Serbia (19° 51' E, 45° 20' N, 84 m above sea level), on the calcareous chernozem soil of the loss terrace. Sprinkling irrigation was applied. The trial was conducted in two years (2002/2003). There were three irrigation variants, with pre-irrigation soil moisture of 60% FWC, 70% FWC and 80%

FWC or irrigation was performed when 70%, 50% and 30% of available soil water, respectively, was consumed. To establish the irrigation schedule, soil moisture dynamics was monitored in 10 – 20 cm layers to the depth of 60 cm. Soil samples were taken at 7 day intervals or at shorter intervals when necessary. Moisture was determined by the thermogravimertic method, in the dryer at 105 – 110 °C. Evapotranspiration was calculated by the water balance method (Doorenbos and Kassam, 1986):

$$ET = P + I - D \pm \Delta W$$

where P is the precipitation (mm), I is the irrigation water applied (mm), D is the deep percolation (mm), and $\Delta W$ is the change in water storage of the soil profile to 2 m depth (mm).

Evapotranspiration water use efficiency (ETWUE, kg $ha^{-1}$ $mm^{-1}$) for each treatment was calculated as tuber yield divided by seasonal evapotranspiration (ET) (Hassan et al., 2002). Irrigation water use efficiency (IWUE, kg $ha^{-1}$ $mm^{-1}$) was determined as (Zhang et al., 1999):

$$IWUE = Y_i - Y_d / I$$

$Y_i$ is the tuber yield of irrigated treatments (kg $ha^{-1}$), $Y_d$ is the tuber yield of non-irrigated treatment (kg $ha^{-1}$), $ET_m$ is the evapotranspiration of irrigated treatments (mm), ETa is the evapotranspiration of non-irrigated treatment (mm), and I is the amount of irrigation water applied (mm).

The experimental potato plots (20 $m^2$) received conventional growing technology adjusted to the conditions of irrigation. Potato was harvested at technological maturity and yield (Y) was calculated by kg $ha^{-1}$. Data on effects of different pre-irrigation soil moisture on potato yield was done by the analysis of variance (ANOVA) and testing the obtained results by the Fisher's LSD test ($P< 0.05$, $P< 0.01$ levels between the means).

## RESULTS AND DISCUSSION

Effects of irrigation on potato yield were positive and highly significant (Table 1). On average, the yields were increased by 89 to 164 %. In a dry 2003 year, on the irrigation variant of 70% of FWC, increase in yield of potato was 185%. Results are in agreement with those of Borza et al. (2010) who found out that irrigation increased the yield of potato in average of 137.2%, but in years with severe drought an increase in yield was 210%. Bošnjak and Pejić 1997 also reported that in extremely dry years irrigation could increase the yield of potato more than two times.

The potato yield of 43158 kg $ha^{-1}$ obtained on the irrigation variant of 70% of FWC (50% of available water) was statistically higher than those obtained on 80% of FWC, 36926 kg $ha^{-1}$ (30% of available water) and 60% of FWC, 30887 kg $ha^{-1}$ (70% of available water), (Table 1). van Loon (1981) and Dorenboos and Kassam (1986), Kiziloglu et al. (2006), Erdem et al. (2006) also reported that to optimize yields of potato, the total available soil water should not be depleted by more than 30–50%. Wilson et al. (2001), Kang et al. (2004) found that good yields of potatoes can only be achieved at high values of soil moisture, at -25 and -35 kPa.

Table 1 Potato yield (Y), precipitation (P), amount of irrigation water applied (I), evapotranspiration on irrigated treatments ($ET_m$), evapotranspiration of non-irrigated treatment ($ET_a$), irrigation (IWUE) and evapotranspiration (ETWUE) water use efficiency at different irrigation treatment

| Year | Variant | Yield | P | I | $ET_m/ET_a$ | IWUE | ETWUE |
|---|---|---|---|---|---|---|---|
| 2002 | 80 % FWC | 36808 | 212.7 | 240 | 484.2 | 83.5 | 76 |
| | 70 % FWC | 40860 | 212.7 | 225 | 471.8 | 107.1 | 86.6 |
| | 60 % FWC | 32468 | 212.7 | 180 | 469.7 | 87.3 | 69.1 |
| | Ø | 16759 | 212.7 | 0 | 381.2 | - | - |
| 2003 | 80 % FWC | 37043 | 156.1 | 270 | 501.4 | 78.1 | 73.9 |
| | 70 % FWC | 45456 | 156.1 | 250 | 467.3 | 118 | 97.3 |
| | 60 % FWC | 29306 | 156.1 | 240 | 451.5 | 55.6 | 64.9 |
| | Ø | 15966 | 156.1 | 0 | 373.4 | - | - |
| 2002/2003 | 80 % FWC | 36926 | 184.4 | 255 | 492.8 | 80.8 | 75 |
| | 70 % FWC | 43158 | 184.4 | 237.5 | 469.6 | 112.5 | 91.9 |
| | 60 % FWC | 30887 | 184.4 | 210 | 460.6 | 71.4 | 67 |
| | Ø | 16362 | 184.4 | 0 | 377.3 | - | - |

| LSD | A | B | AB |
|---|---|---|---|
| 0.05 | 3.149 | 2.226 | 4.453 |
| 0.01 | 4.287 | 3.031 | 6.062 |

In the study period, evapotranspiration rate in irrigation variants ($ET_m$) ranged from 451.5 to 501.4 mm, and in rainfed conditions (ETa) in the range from 373.4 to 381.2 mm (Table 1). As the highest yields of potato were obtained in the irrigation variant of 70% of FWC (50% of available water) that pre-irrigation soil moisture should be recommended to schedule irrigation when potato is grown in the soil with medium soil texture. The water used on evapotranspiration in that irrigation variant of 470 mm, on the average, (Table 1) may be considered as the water requirement of potato grown under climatic conditions of the Vojvodina region. According to FAO (2002) data, due to climatic conditions, evapotranspiration changed from 500 to 700 mm for potato to get high yield at 120-150 days vegetation period. Obtained results are in accordance with those of Kiziloglu et al. (2006) that seasonal evapotranspiration of potato was 475.2 mm under semiarid conditions in the east Turkey. Erdem et al. (2006) reported that seasonal evapotranspiration of potato, drip irrigated, at the level of 50% of the available water, varied from 473 mm to 524 mm under semiarid conditions of Trakya region in Turkey. Onder et al., (2005) stressed that crop water requirements are a function of climatic factors, methods of irrigation and the length of the growing period.

The best methods to describe the effectiveness that irrigation has in agriculture production are coefficients of irrigation (IWUE) and evapotranspiration (ETWUE) water use efficiency. Many researchers have evaluated water use efficiency in

different ways (Viets, 1962; Begg and Turner, 1976; Howell, 2001). Consequently, care should be taken when comparing WUE values. The highest values of IWUE (112.5 kg ha$^{-1}$ mm$^{-1}$) and ETWUE (91.9 kg ha$^{-1}$ mm$^{-1}$), on average, were obtained in the irrigation variant of 70% of FWC (50% of available water). The results are in line with those reported earlier by Kang et al. (2004), Onder et al. (2005), and Erdem et al. (2006). Kang et al. (2004) reported that the highest IWUE values were achieved with a soil matric potential threshold of -25 kPa (114.8 kg ha$^{-1}$ mm$^{-1}$). Onder et al. (2005) found out IWUE values of 102.5 kg ha$^{-1}$ mm$^{-1}$ and 99.1 kg ha$^{-1}$ mm$^{-1}$ for surface drip and subsurface drip irrigation methods respectively. Erdem et al. (2006) reported that the highest WUE values were generally obtained from application of irrigation when 30% of the available water was consumed. Drip irrigation method yielded higher values of IWUE (137.1 kg ha$^{-1}$ mm$^{-1}$) and WUE (91.0 kg ha$^{-1}$ mm$^{-1}$), since drip irrigation consumed less water than furrow irrigation.

## CONCLUSION

Irrigation significantly influenced the tuber yield of potato. The highest yield was obtained on the irrigation variant of 70% of FWC (50% of available water). That soil moisture could be used as the optimum when this crop is grown in a soil with medium texture. The water used on evapotranspiration, in that irrigation variant, of 470 mm may be considered as the water requirement of potato grown under climatic conditions of the Vojvodina region. High values of yield, IWUE and ETWUE coefficients, which were similar with those obtained under different climatic and soil conditions, confirmed that performed irrigation schedule was correct, i.e., fitted to biological characteristics of potato plants as well as to physical soil properties.

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## REFERENCES

BEGG, J.E., TURNER, N.C.: Crop water deficit. Advances in Agronomy, 28:161-217, 1976.

BORZA, I., DOMUȚA, C., ȘANDOR, M., DOMUȚA, C., BREJEA, R., VUȘCAN, A., JURCA, A.: Research regarding the irrigation influence on water use efficiency in potato in the crisurilor plain conditions. Research Journal of Agricultural Science, 42 (1):14-21, 2010.

BOŠNJAK, DJ., PEJIĆ, B.: Potato water requirement in the chernozem zone of Yugoslavia. Proc. 2nd International Symposium on Irrigation of Horticulture Crops. Acta Horticlturae, 499:211-215, 1997.

COSTA, L.D., DELLE, V.G., GIANQUINTOI, G., GIOVANRDI R, PERESSOTTI, A.: Yield, water use efficiency and nitrogen uptake in potato: influence of drought stress, Potato Research, 40:19-34, 1997.

DOORENBOS, J., KASSAM, A.H.: Yield response to water. FAO Irrigation and Drainage Paper No. 33, FAO Rome Italy, 1986.

ERDEM, T., ERDEM, Y., ORTA, H., OKURSOY, H.: Water-yield relationships of potato under different irrigation methods and regimens. Scientia Agricola, 63(3):226-231, 2006.

FAO. Crop water management. Potato, AGLW, Water Management Group, FAO Rome, 2002.

FAO, FAOSTAT 2012.

HASSAN, A.A., SARKAR, A.A., ALI, M.H., KARIM, N.N.: Effect of deficit irrigation at different growth stages on the yield of potato. Pakistan Journal of Biological Science, 5:128-134, 2002.
HOWELL, T.A.: Enhancing water use efficiency in irrigated agriculture. Agronomy journal, 93:281-289, 2001.
KANG, Y., WANG, F.X., LIU, H.J., YUAN, B.Z.: Potato evapotranspiration and yield under different drip irrigation regimes. Irrigation Science, 23:133-143, 2004.
KIZILOGLU, F.M., SAHIN, U., TUNC, T., DILER, S.: The effect of deficit irrigation on potato evapotranspiration and tuber under cool season and semiarid climatic conditions. Journal of Agronomy, 5(2):284-288, 2006.
MILIĆ, S., BOŠNJAK, DJ., MAKSIMOVIĆ, L., PEJIĆ, B., SEKULIĆ, P., NINKOV, J., ZEREMSKI-ŠKOROĆ, T.: Potato yield and yield structure depending on irrigation. Field and Vegetable Crops Research, 47(1):251-265, 2010.
ONDER, S., CALISKAN, M.E., ONDER, D., CALISKAN, S.: Different irrigation methods and water stress effects on potato yield and yield components. Agriculture water management, 73:73-86, 2005.
SMITH, M., KIVUMBI, D., HENG, L.K.: Use of the FAO CROPWAT model in deficit irrigation studies. In: Deficit irrigation practices, FAO, 17-27, 2002.
THORTON, R.E., SIECZKA, J.B.: Commercial potato production in North America. American Potato Journal, 57:1-36, 1980.
VIETS, F.G.: Fertilizers and the efficient use of water. Advances in Agronomy, 14:223-264, 1962.
VUČIĆ, N.: Irrigation scheduling. In: Irrigation of Agricultural Crops, Faculty of Agriculture, Novi Sad, Serbia, 187-220, 1976.
VAN LOON, C.D.: The effect of water stress on potato growth, development and yield. American Potato Journal, 58:51-69, 1981.
YUAN, B.Z., NISHIYAMA, S., KANG, Y.: Effects of different irrigation regimes on the growth and yield of drip irrigated potato. Agriculture Water Management, 63:153–167, 2003.
WILSON, C.R., PEMBERTON, B.M., RANSOM, L.M.: The effect of irrigation strategies during tuber initiation on marketable yield and development of common scab disease of potato in Russet Baurbank in Tasmania. Potato Research, 44:243–251, 2001.
WRIGHT, L.J., STARK, C.J.: Potato. In: Irrigation of Agricultural Crops – Agronomy Monograph (B.A. Stewart, and D.R. Nielsen, eds.), 30, ASA-CSSA-SSSA, Madison, Wisconsin, USA, 859-886, 1990.
ZHANG, H., WANG, X., YOU, M., LIU, C.: Water-yield relations and water use efficiency of winter wheat in the North China plain. Irrigation Science, 19:37-45, 1999.