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# TUBER YIELD AND EVAPOTRANSPIRATION OF POTATO DEPENDING ON SOIL MATRIC POTENTIAL

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## Abstract

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This study has been carried out through field trials with irrigation in the river valley of Southern Morava, near Nis, at the alluvium soil type, in the period 2008-2009. The experimental field consisted of three treatments with irrigation (soil matric potential of 20, 30 and 40 kPa), as well as unirrigated control. Irrigation schedule was determined by tensiometers based on the observed soil matric potential values. The highest potato tuber yield (48.30 t $ha^{-1}$) was observed at the variant where soil matric potential of 30 kPa was kept. Potato tuber yield was the highest when water consumption for evapotranspiration amounted from 491.3 to 498.6 mm, while at higher or lower values of water consumption for ET tuber yield dropped. Water use efficiency of potato during the studied period ranged from 81.23 to 98.21 kg $ha^{-1}$ $mm^{-1}$. The data concerning tuber yield, evapotranspiration and WUE of potato point to the fact that, in order to reach high potato tuber yield and quality, one ought to keep soil matric potential at levels around 30 kPa for the conditions of south Serbia.

*Key words*: potato, evapotranspiration, soil matric potential, water use efficiency

## Introduction

The total world potato production amounts about 330 million tons on 18.3 million ha (FAOSTAT, 2010), or 18 t $ha^{-1}$ as average. In Serbia, it is grown on 80 000 to 90 000 ha, reaching the average tuber yield of 10 t $ha^{-1}$ (Stat. Year. Serb. 2008). Genetic potential for potato tuber yield can be up to 100 t $ha^{-1}$. Water deficiency in soil leads to a decrease of potato tuber yield and quality, caused by the drop of photosynthetic activity per leaf square unit (Van Loon, 1981). Climatic conditions of south Serbia in the last few years were characterized by long drought periods without precipitation, and extremely high temperature during vegetation period. Optimal soil moisture for growing agricultural crops can only be reached in the conditions of irrigation. Insight in values of potential evapotranspiration (PET), or water demands by plants is a necessary precondition for realizing an efficient water regime. Excessive irrigation leads to deep percolation of nutrients, higher potential for appearing plant diseases and pests, deterioration of soil structure and water losses, causing increased production costs. Potato PET depends on climatic conditions, soil moisture and potato cultivar. Potato evapotranspiration established by many researches amounted from 283-700 mm (Doorenbos and Kassam, 1979; Tanner, 1981; Wright and Stark, 1990; Pereira et al., 1995; Kiziloglu et al., 2006). Evapotranspiration and irrigation of potato in Serbia were studied only in the conditions of Vojvodina Province (Bošnjak and Pejić 1994; Bošnjak and Pejić, 1995; Bošnjak et al., 1996; Bošnjak, 2006; Milić et al., 2009).

Irrigation schedule is important in order to avoid negative irrigation effects. Numerous reports confirmed efficiency of potato irrigation based on measuring soil matric potential (Phene and Sanders, 1976; Eldredge et al., 1992; Hegney and Hoffman, 1997; Pereira and Villa Nova, 2002; etc).

Water use efficiency (WUE) is defined by tuber yield divided by water consumed for evapotranspiration (ET) of potato (Doorenbos and Pruitt, 1977). Having in mind the obtained results concerning potato irrigation, this investigation has been aimed to determine soil matric potential, potato PET, tuber yield, and WUE in the conditions of south Serbia.

## Material and Methods

Field trials with irrigation of potato have been set in the river valley of Southern Morava, near Nis, at the alluvium soil type, in the period 2008-2009. Local coordinates of the loca-

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tion were the following: latitude 43º19 ‘, longitude 21°54’, altitude 194 m. The trial was set in random complete block design, and drip irrigation was applied. Elementary plot was 10.50 $m^2$ of area, and plots were separated by 2.5 m of each other. Determining irrigation term was done by tensiometers. Soil matric potential (SMP) was measured at 8:30, daily. The experimental field consisted of three treatments with irrigation (SMP of 20, 30 and 40 kPa), as well as unirrigated control.

Potato planting (distance 70 cm between rows and 30 cm in the row) was done in the first half of April in both investigation years, with the cultivar Kennebec, original category, where tuber size was from 35-55 mm. After soil chemical analyses soil was fertilized before cultivation, as well as during vegetation by water-soluble fertilizers through irrigation systems. The total amount of nutrients deposited to soil was N -200 kg $ha^{-1}$, $P_2O_5$ - 120 kg $ha^{-1}$, $K_2O$ - 300 kg $ha^{-1}$, CaO - 100 kg $ha^{-1}$ and MgO - 60 kg $ha^{-1}$. During vegetation, the all-modern agro technique measures were applied, and tuber harvest was carried out in the third decade of August in both years of the study.

Calculation of water consumption for evapotranspiration in the conditions of irrigation was done for each month and for vegetation period in whole, by balancing water from precipitation during vegetation period, soil supplies, irrigation, and potentially percolated or flown out water after heavy rains (Aksic et al., 2011).

The data of potato tuber yield were processed by analysis of variance, and significance of differences in tuber yield was determined by comparing them with LSD values for $P<0.05$ and $P<0.01$. The effect of soil matric potential and evapotranspiration on potato tuber yield was analyzed by regression analysis.

**Mechanical and water-physical properties of soil in the experimental field**

The obtained values of texture analysis (Table 1) were expected, because fractional relations confirm that this is a loamy alluvial soil.

Immediately before the study began, water-physical properties of soil in the experimental field were determined (Table 2).

**Meteorological conditions of the studied years**

Air temperature was observed at meteorological station Nis and a rain gauge at the experimental field (Table 3) measured precipitation. Vegetation 2008 was wormer by 1.8°C

**Table 1**
**Mechanical properties of soil**

| Depth, cm | Total sand, % | Powder, % | Clay, % |
|---|---|---|---|
| | > 0.02 mm | 0.02-0.002 mm | < 0.002 mm |
| 0-20 | 42.1 | 40.5 | 17.4 |
| 20-40 | 40.3 | 37.8 | 21.9 |
| 40-60 | 38.7 | 36.3 | 25.0 |
| 60-80 | 36.7 | 35.9 | 27.4 |
| 80-100 | 35.1 | 32.3 | 32.6 |

**Table 2**
**Water-physical properties of soil**

| Depth, cm | FWC, weight % | Specific weight, g $cm^{-3}$ | Bulk density, (g $cm^{-3}$ | Total porosity, vol.% | Capacity for water, vol. % | Capacity for air, vol. %,) |
|---|---|---|---|---|---|---|
| 0-20 | 27.32 | 2.65 | 1.35 | 49.05 | 36.88 | 12.17 |
| 20-40 | 25.94 | 2.58 | 1.34 | 48.06 | 34.76 | 13.3 |
| 40-60 | 24.44 | 2.56 | 1.34 | 47.65 | 32.75 | 14.9 |

**Table 3**
**Mean monthly temperatures (ºC) and monthly amount of precipitation (mm)**

| Year | Month | | | | | |
|---|---|---|---|---|---|---|
| | IV | V | VI | VII | VIII | IV-VIII |
| Mean monthly temperatures | | | | | | |
| 2008 | 13.1 | 17.9 | 22.3 | 22.6 | 23.5 | 19.9 |
| 2009 | 14.3 | 18.3 | 20.5 | 22.8 | 23.0 | 19.8 |
| 1961-1990 | 11.9 | 16.6 | 19,5 | 21.3 | 21.1 | 18.1 |
| Amount of precipitation | | | | | | |
| 2008 | 65.5 | 38.7 | 32.5 | 61.2 | 24.8 | 222.7 |
| 2009 | 28.4 | 27.0 | 91.5 | 46.0 | 38.3 | 231.2 |
| 1961-1990 | 51.3 | 66.7 | 69.7 | 43.6 | 43.3 | 274.6 |

than the average, and the greatest difference from the mean value was observed in June, which was wormer by 2.8°C than the many-year mean. Precipitation regime in this period was basically characterized by a great dispersion of precipitation, and existence of longer or shorter dry periods in May, June, early July, and August, which had a negative effect on the observed potato tuber yield in the conditions without irrigation.

Precipitation deficiency in April 2009 was flagrantly expressed in the first part of the month, causing a decrease of water supplies in soil. High temperatures and precipitation deficiency in May had a bad effect on plants growth and development. June 2009 was characterized by a relatively warm weather with high amount of precipitation, especially near the end of month. The first half of the July was droughty, which had a negative effect to potato crops, being then in full flowering stage. August was deficient with precipitation having a bad influence to tuber growth.

## Results

Concerning the all irrigated variants, tuber yield was high-significantly higher about the unirrigated control. The highest potato tuber yield (48.30 t $ha^{-1}$) was observed at the variant with soil matric potential of 30 kPa (Table 4). Statistically high-significantly, important differences in tuber yield were observed between the treatment with SMP of 30 kPa and the treatments with SMP of 20 and 40 kPa. However, at the treatment with SMP of 20 kPa, tuber yield was significantly higher regarding the treatment with SMP of 40 kPa.

Tuber yield dependency on soil matric potential was described as $y=-2440.0+3747.2x-68.3x^2$ based on regression analysis (Figure 1), together with high, positive correlation (r=0.93**). The highest potato tuber yield was observed at the treatment with SMP of 30 kPa, while lower (SMP of 40 kPa) or higher (SMP of 20 kPa) soil humidity led to a decrease of tuber yield.

Regression analysis defined tuber yield dependency on water consumption for ET as follows: $y=22543.9-37.8x+0.2x^2$ (Figure 2). Correlation between these two parameters was high and positive (r=0.93**). The highest potato tuber yield was found when water consumption for evapotranspiration was from 491.3 to 498.6 mm, while at higher or lower water consumption for ET tuber yield decreased.

Water use efficiency during the studied period was between 81.23 and 98.21 kg $ha^{-1}$ $mm^{-1}$ (Table 5). The best ratio between water consumption for ET and potato tuber yield (96.97-98.21 kg $ha^{-1}$ $mm^{-1}$) was observed at the treatment with SMP of 30 kPa.

**Table 4**
**Tuber yield of potato (t $ha^{-1}$)**

| Year (B) | Soil matric potential (A) | | | | Average (B) |
|---|---|---|---|---|---|
| | 20 kPa ($A_1$) | 30 kPa ($A_2$) | 40 kPa ($A_3$) | Control ($A_4$) | |
| 2008 ($B_1$) | 44.71 | 47.64 | 36.49 | 24.52 | 38.34 |
| 2009 ($B_2$) | 45.48 | 48.97 | 39.13 | 26.78 | 40.09 |
| Average (A) | 45.09 | 48.30 | 37.81 | 25.65 | 39.21 |
| LSD | | A | B | AB | |
| 0.05 | | 1.95 | 1.39 | 2.76 | |
| 0.01 | | 2.15 | 1.54 | 3.05 | |

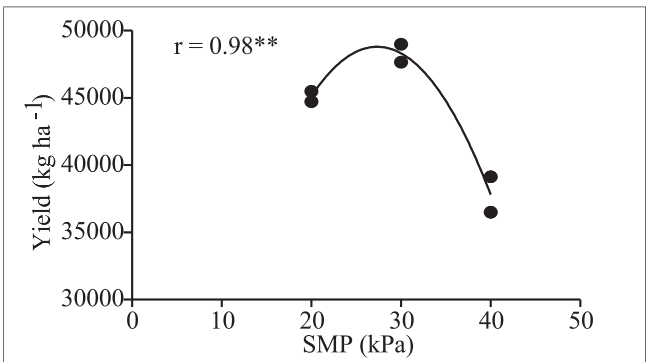


**Fig. 1. Effect of SMP on potato tuber yield**

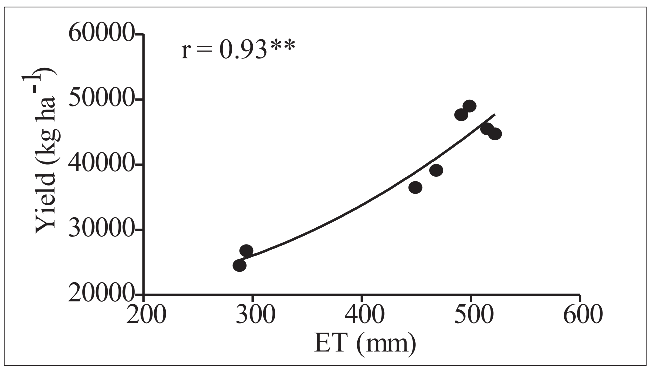


**Fig. 2. Effect of ET on potato tuber yield**

**Table 5**
**Evapotranspiration and WUE of potato**

| Year | SMP, kPa | Soil water supplies, mm | P, mm | I, mm | ET, mm | Yield, kg $ha^{-1}$ | WUE, kg $ha^{-1}$ $mm^{-1}$ |
|---|---|---|---|---|---|---|---|
| 2008 | 20 | 21.8 | 222.7 | 278 | 522.1 | 44710 | 85.63 |
| | 30 | 32.6 | 222.7 | 236 | 491.3 | 47640 | 96.97 |
| | 40 | 51.5 | 222.7 | 175 | 449.2 | 36490 | 81.23 |
| | Control | 65.4 | 222.7 | - | 288.1 | 24520 | 85.11 |
| 2009 | 20 | 27.8 | 231.2 | 256 | 515.0 | 45480 | 88.31 |
| | 30 | 48.4 | 231.2 | 219 | 498.6 | 48970 | 98.21 |
| | 40 | 53.1 | 231.2 | 184 | 468.3 | 39130 | 83.56 |
| | Control | 63.2 | 231.2 | - | 294.4 | 26780 | 90.96 |

## Discussion

During the two-year investigation of potato irrigation the highest tuber yield was reached with SMP of 30 kPa, which was in accordance with the results of Shock et al. (2002) and Shae et al. (1999). When potato tuber yield is concerned the optimal soil humidity before irrigation (SMP of 30 kPa) observed in our study are in opposition with the following reports: Epstein and Grant (1973) – SMP of 25 kPa; Eldredge et al. (1992, 1996) – SMP from 50 to 60 kPa; Hegney and Hoffman (1997) – SMP of 20 kPa; Pereira and Villa Nova (2002) – SMP of 15 kPa; and Kang et al. (2004) – SMP of 25 kPa. Decreased potato tuber yield caused by increased soil humidity (SMP of 20 kPa) is in accordance with the results of Wang et al. (2006), Pereira and Shock (2006) and others. Вољnjak (2006), in the conditions of Vojvodina Province (Serbia), also found that higher soil humidity (80% FWC) decreased potato tuber yield. Differences in optimal values of SMP for the irrigation start are primarily caused by irrigation method, soil type and studied environment.

The established value of evapotranspiration in our experimental field ranged from 294.4 mm at the variant without irrigation to 522.1 mm at the irrigated variant with SMP of 20 kPa. According to many researches, water demands of potato vary over a great range, depending above all on studied environment. For high tuber yield vegetation demands of potato for water ranged from 500 to 700 mm, depending on climatic conditions (Doorenbos and Kassam, 1979). During a three-year investigation, potato evapotranspiration in Wisconsin (USA) was between 293 and 405 mm (Tanner, 1981). Wright and Stark (1990) stated water consumption of potato for evapotranspiration from 640 to 700 mm in irrigated areas of Oregon and Washington (USA). Pereira et al. (1995) found potato evapotranspiration of 283 mm. Kiziloglu et al. (2006) stated that in the conditions of Erzurum (Turkey) potato evapotranspiration ranged from 167 mm without irrigation to 610 mm in the conditions of irrigation. According to Erdem et al. (2006) in Trakia Region (Turkey), potato evapotranspiration was between 464 and 683 mm.

The highest and stable tuber yield in the two-year period of study was reached when water consumption for evapotranspiration was between 491.3 and 498.6 mm, so that value could be considered as potential evapotranspiration (PET) of potato, i.e. its water demands in the conditions of south Serbia. The measured value of potato PET in our study is greater about the value of potential evapotranspiration (460-480 mm) established by Bošnjak and Pejić (1994) for the conditions of Vojvodina Province (north Serbia).

In the conditions of irrigation, the highest average value of potato WUE of 97.59 kg $ha^{-1}$ $mm^{-1}$ was observed at the variant with SMP of 30 kPa. WUE values of potato obtained by this study (from 81.23 to 98.21 kg $ha^{-1}$ $mm^{-1}$) were similar to the values reported by Wright and Stark (1990) and Beheral and Panda (2009).

Our values of potato WUE are not in accordance with the values stated by Wang et al. (2006) from 50.4 to 77.1 kg $ha^{-1}$ $mm^{-1}$ in season 2001 and 103.2-131.6 kg $h^{-1}a$ $mm^{-1}$ in season 2002 in the conditions of North China Plain. Values of WUE in our study were higher than the ones determined by Kiziloglu et al. (2006), which were from 40.2 to 63.4 kg $ha^{-1}$ $mm^{-1}$, as well as the ones of Rashidi and Gholami (2008) who stated WUE ranging from 19.2 to 52.5 kg $ha^{-1}$ $mm^{-1}$.

## Conclusion

High and stable potato tuber yield was reached when water consumption for evapotranspiration was between 491.3 and 498.6 mm, so that value could be considered as potential evapotranspiration (PET) of potato in the conditions of south Serbia. The highest water use efficiency of potato, which was from 96.97 to 98.21 kg $ha^{-1}$ $mm^{-1}$, was observed at the variant with SMP of 30 kPa.

Results of tuber yield, evapotranspiration and WUE of potato revealed the fact that, in order to reach high potato tuber yields and quality, one ought to keep soil matric potential at levels around 30 kPa for the conditions of south Serbia.

## References


**Aksic, M., S. Gudzic, N. Deletic, N Gudzic and S. Stojkovic,** 2011. Tomato fruit yield and evapotranspiration in the conditions of south Serbia. *Bulg. J. Agric. Sci.*, **17:** 150-157.

**Beheral, S. K. and R. K. Panda,** 2009. Judicious management of irrigation water and chemical fertilizer for potato crop in subhumid subtropical region. Assam *University Journal of Science & Technology: Physical Sciences and Technology*, **4** (II): 22-28.

**Bošnjak, Đ.**, 2006. Efekt navodnjavanja i predzalivne vlažnosti zemljišta na prinos i kvalitet krompira. Eco-conference, Proceedings – Safe Food, Book I: 143-150.

**Bošnjak, Đ. and B. Pejić,** 1994. Effect of irrigation and pre-irrigation moisture on yield and evapotranspiration of potato. Zbornik radova – Poljoprivredni fakultet u Novom Sadu. *Institut za ratarstvo i povrtarstvo*, **22**: 181-189.

**Bošnjak, Đ. and B. Pejić,** 1995. Zalivni režim krompira u klimatskim uslovima Vojvodine. *Savremena poljoprivreda*, **43**: 119-125.

**Bošnjak, Đ., Pejić, B. and S. Dragović,** 1996. Potato yield depending on evapotranspiration in the Vojvodina Province. *Acta Hort.*, **462:** 297–301.

**Doorenbos, J. and W.O. Pruitt,** 1977. Crop water requirements, irrigation and drainage. Paper 24. Food and Agricultural Organization of the United Nations, Rome, Italy.

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

**Eldredge, E. P., C. C. Shock and T. D. Stieber,** 1992. Plot sprinklers for irrigation research. *Agronomy Journal,* **84**: 1081-1984.

**Eldredge, E. P., Z. A. Holmes, A. R. Mosley, Shock, C. C. and T. D. Stieber,** 1996. Effects of transitory water stress on potato tuber stem-end reducing sugar and fry color. *Am. Potato J.*, **73**: 517-530.

**Epstein, E. and W. J. Grant,** 1973. Water stress relations of the potato plant under field conditions. *Agron. J.,* **65**: 400-404.

**Erdem, T., Y. Erdem, Orta, H. and H. Okursoy,** 2006. Water-yield relationships of potato under different irrigation methods and regimens. *Sci. Agric*. (Piracicaba, Braz.), **63:** 226-231.

**FAOSTAT,** 2010. http://faostat.fao.org/

**Hassan, F. A.**, 1985. Drip irrigation and crop production in arid regions. ASAE Publication 10-85, Drip/Trickle Irrigation In Action. Proc. Third Int. Drip Irrig. Cong., **1**:150-155.

**Hegney, M. A. and H. P. Hoffman,** 1997. Potato irrigation – development of irrigation scheduling guidelines. Final Report, Horticultural Research and Development Corporation Project NP 6. *Agriculture Western Australia,* 114 pp.

**Kang, Y., Wang, F. X., Liu H. J. and B. Z. Yuan,** 2004. Potato evapotranspiration and yield under different drip irrigation regimes. *Journal Irrigation Science*, **23** (3): 133-143.

**Kiziloglu, F. M., Sahin, U., Tune, T. and S. Diler,** 2006. The effect of deficit irrigation on potato evapotranspiration and tuber yield under cool season and semiarid climatic conditions. *J. Agron.*, **5:** 284–288

**Milić, S., Bošnjak, Đ., Maksimović, L., Jovica, V., Ninkov, J. and T. Z. Škorić,** 2009. Dynamics of potato vine yield formation and biological yield as affected by pre-irrigation soil moisture. A periodical of scientific research on field and vegetable crops. Institute of Field and Vegetable Crops, Novi Sad, Serbia. **46**: 23-32

**Pereira, A.B. and C.C. Shock,** 2006. Development of irrigation best management practices for potato from a research perspective in the United States. Sakia. Org e-publish. 1: 1-20.

**Pereira, A. B. and N. A. Villa Nova,** 2002. Physiological parameters and potato yield submitted to three irrigation levels. *Eng. Agric.* (Jaboticabal, Brazil), **22**:127-134.

**Pereira, A. B., Pedras, J. F., Villa Nova, N. A. and D. M. Cury,** 1995. Water consumption and crop coefficient of potato (*Solanum tuberosum* L.) during the winter season in municipality of Botucatu-SP. *Rev. Bras. Agrometeorol.*, **3**: 59-62.

**Phene, C. J. and D. C. Sanders,** 1976. High frequency trickle irrigation and row spacing effects on yield and quality of potatoes. *Agronomy Journal*, **68** (4): 602-607.

**Rashidi, M. and M. Gholami,** 2008. Review of crop water productivity values for tomato, potato, Melon, watermelon and cantaloupe in Iran. *Int. J. Agric. Biol.,* **10:** 432–436

**Sammis, T. W.,** 1980. Comparison of sprinkler, trickle, subsurface and furrow irrigation methods for row crops. *Agronomy Journal,* **72** (5): 701-704.

**Shae, J. B., Steele, D. D. and B. L. Gregory,** 1999. Irrigation scheduling methods for potatoes in the Northern Great Plains. *American Society of Agricultural Engineers,* **42** (2): 351-360.

**Shock, C. C., Eldredge, E. P. and D. Saunders,** 2002. Drip irrigation management factors for Umatilla Russet potato production. In Malheur Experiment Station Annual Report 2001, *Special Report 1038*, Oregon State University, pp. 157-169.

**Statistical Office of the Republic of Serbia,** 2008. Statistical Yearbook of Serbia 2007. Belgrade.

**Steyn, J. M., Du Plessis, H. F., Fourie, P. and T. Ross,** 2000. Irrigation scheduling of drip irrigated potatoes. Micro-irrigation technology for developing agriculture. 6th International Micro-irrigation Congress. South Africa. October 22-27, 2000.

**Tanner, C. B.,** 1981. Transpiration efficiency of potato. *Agron. J.*, **73**: 59-64.

**Van Loon, C. D.**, 1981. The Effect of water stress on potato growth, development, and yield. *Am. Potato J.*, **58**: 51-69.

**Wang, F. X., Kang, Y., Liu, S. P. and X. Y. Hou, 2006.** Effects of soil matric potential on potato growth under drip irrigation in the North China Plain. *Agricultural Water Management,* **79:** 248-264.

**Wright, J. L. and J. C. Stark,** 1990. Potato. In: Irrigation of agricultural crops- Agronomy Monograph No 30. ASA-CSSA-SSSA, Madison, WI 53711, pp. 859-888.


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