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The Effect of Deficit Irrigation on Potato Evapotranspiration and Tuber Yield under Cool Season and Semiarid Climatic Conditions

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Abstract: Field experiments were conducted to study the effects of water deficits on potato (*Solanum tuberosum* L.) evapotranspiration, tuber yield and water-use efficiency. The experiments were carried out under cool season semiarid climatic conditions in Erzurum province located in the east of Turkey in the spring seasons of 2003 and 2004. The experiment included six water deficits: 0% (well-irrigation), 20, 40, 60, 80 and 100% (non-irrigation). Results indicate that deficit irrigation influenced evapotranspiration, tuber yield and water-use efficiency. Potato evapotranspiration decreased as water deficit increased. Seasonal evapotranspiration was 445.2 mm in well-irrigated treatment and 195.2 mm non-irrigated treatment. Potato yield and water-use efficiency were also found decrease as water deficit increased. Potato yield of well-irrigated treatment was 26.43 t ha^{-1} while 8.28 t ha^{-1} in non-irrigated treatment. A linear relationship was found between evapotranspiration and tuber yield. Water use efficiency was 59.56 kg/ha/mm for well-irrigated treatment and 42.13 kg/ha/mm for non-irrigated treatment. The seasonal yield response factor (k_y) for potato was also found as 1.12.

Key words: Deficit irrigation, evapotranspiration, potato, yield response factor

INTRODUCTION

According to recent FAO statistics, Turkey has 200 000 ha potato growing area and the produce 24.0 t ha^{-1} average yield. On the other hand, the growing area of the potato of the world is 19 132 110 ha and average yield is 17.19 t ha^{-1} (FAOSTAT, 2004).

Gradual increase in the need for fresh water makes it necessary to use the water efficiently. In this case, irrigation scheduling that aim to obtain the maximum income from per unit water is required. Deficit irrigation is a strategy which allows a crop to sustain some degree of water deficit in order to reduce irrigation costs and potentially increase revenues (Shock and Feibert, 2000). The potential benefits of the deficit irrigation derived from 3 factors: increased irrigation efficiency, and reduced irrigation costs and water opportunity costs (English and Raja, 1996). Yield reduction in deficit irrigation is minimized through the cost of the water saving or yield increase from new command areas out of water savings from deficit irrigation (English, 1990).

The water stress in plant has an important effect on water consumption and yield. Depending on the decrease in the water that can be used in soil, physiological formations in plant damage, the growth slow down and yield decreases (Korukçu and Kanber, 1981; Köksal *et al*., 2001).

Potato needs frequent irrigation for its good growth and yield. The yield is greatly influenced by timing, amount and frequency of irrigation applied (Kashyap and Panda, 2003; Kang *et al*., 2004; Onder *et al*., 2005). Soil moisture is probably the most important factor determining potato yield and quality (Motes and Cartwright, 1994). Irrigation increases potato tuber quantity (Yuan *et al*., 2003). It is very sensitive against water stress all growing season, in particular at the duration of tuber formation (Hess *et al*., 1997; Thornton, 2002; Shock, 2004). There is a decrease in tuber yield, tuber quality, income and marketing degree on the conditions of deficit irrigation (Shock *et al*., 1998; Shock, 2004). Even the decrease for the level of 10% in the optimum water treatment in the growing period could have caused a decrease in the yield of potato (King and Stark, 1997). Hassan *et al*. (2002) reported that, potato was more sensitive to water stress at the stolonization and tuberization stages than bulking and tuber enlargement stages. In the tuber enlargement stage, water deficit could be applied with a slight decrease in yield.

The objectives of this study are: (1) to examine the effects of different water deficits on potato evapotranspiration, yield and water-use efficiency in the semiarid and cool climate conditions (2) to determine the seasonal yield response factor that would contribute to

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irrigation scheduling in deficit irrigation treatment for similar regions.

MATERIALS AND METHODS

The study was conducted at the Agricultural Research Station of Atatürk University located in Erzurum-Turkey (39°55' N and 41°16'E, 1835 m a.s.l.) during the spring seasons of 2003 and 2004. Plots consisted of raised beds, 5.0 m long and 3.0 m wide. A 3.0 m space was left between the plots in order to prevent water interactions among the treatments. cv. Granola tubers were used as material with the amount of 2500 kg ha^{-1}. Tubers were planted on May 13 in 2003 and on May 25 in 2004. The planting distances were 70×35 cm between and within rows. All treatments received at the same amount of P_2O_5 (100 kg ha^{-1}), K_2O (50 kg ha^{-1}) and N (150 kg ha^{-1}) fertilizer during soil preparation before sowing. Then 150 kg ha^{-1} N applied on all plots in hilling stage. The crop was weeded manually with a hoe and repeated as required. No pesticide was applied. Potato crops were harvested on October 15 in 2003 and on October 5 in 2004, respectively.

Some physical and chemical properties of experimental field soil for 0-30, 30-60 and 60-90 cm depth are given in Table 1. These were determined according to the methods used by Klute (1986) and Page *et al.* (1982).

During the growth period, the average seasonal temperature, total seasonal precipitation and relative humidity were 14.12°C, 156.7 mm and 62.23% in 2003 and 13.88°C, 59.50 mm and 60.72% in 2004, respectively. Total precipitations were measured from the standard pluviometer replenishment in experiment field while seasonal average temperature and relative humidity values were taken from Rural Services Erzurum Research Institute meteorology station. Good quality underground water with electrical conductivity 0.27 dS m^{-1}, sodium adsorption ratio 0.41 and pH 7.8 was applied by surface irrigation method.

Irrigation water levels were selected to be 100% of usable soil water in well-irrigated treatment (control) (T_1) and 80, 60, 40, 20 and 0% of usable soil water in deficit irrigation treatments (T_2, T_3, T_4, T_5 and T_6 (non-irrigation), respectively). Irrigations were done when the available moisture in soil was decreased to the level of 30% of the control treatment. Effective root depth was taken as 60 cm (Kanber, 1999; FAO, 2002). Irrigation water was measured when it was applied for all plots.

Evapotranspiration of each treatment was calculated according to the water balance method (Doorenbos and Kassam, 1988; Hassan *et al.*, 2002).

$$ET = I + P - D_w - R_f \pm \Delta S$$

Table 1: Some physical and chemical properties of experiment area soils

	Soil depth (cm)		
Properties	0-30	30-60	60-90
Texture	Loam	Loam	Loam
Field capacity (Pv)*	29.58	29.66	30.03
Wilting point (Pv)*	16.65	15.93	16.85
Bulk density (gcm^{-3})	1.51	1.47	1.42
pH**	7.15	7.27	7.34
Electrical conductivity (dS m^{-1})	568	605	527
Carbonates (%)	1.97	2.14	2.25
Organic matter (%)	1.24	1.03	0.95

*:% water of volume, **: in paste

where ET is evapotranspiration, I is irrigation water applied during the growth period, P is effective rainfall during the growing period plus capillary rise, D_w is amount of drainage water, R_f is amount of runoff and ΔS is change in the soil moisture content determined by gravimetric sampling. Soil moisture content at effective root depth was measured gravimetrically prior to irrigations, on 10, 20 and 30 or 31 of each month, and at harvest. Rainfall during the growing period was accepted effective rainfall. There was no observed runoff during the experiment. Drainage water below effective root zone, according to the soil water content measurements, was considered as negligible.

The relationship between relative evapotranspiration reduction and relative yield reduction was determined using the method given by Doorenbos and Kassam (1979).

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

or

$$Y_d = k_y \, ET_d$$

where, Y_a; actual harvested yield, Y_m; maximum harvested yield, k_y; yield response factor, ET_a; actual evapotranspiration, ET_m; maximum evapotranspiration, Y_d; relative yield reduction, ET_d; relative evapotranspiration reduction.

Water-use efficiency (kg/ha/mm) was calculated according to the ratio of tuber yield (kg ha^{-1}) to evapotranspiration (mm) (Hassan *et al.*, 2002).

Experimental plots were arranged in a complete randomized block design with three replications. Statistical analyses were made with MINITAB statistical package (release 11.12, 1996; Minitab Inc.). General Linear Model ANOVA was used. Significant means were compared with Duncan multiple range test method by using MSTAT-C package software (MSTAT-C 1988).

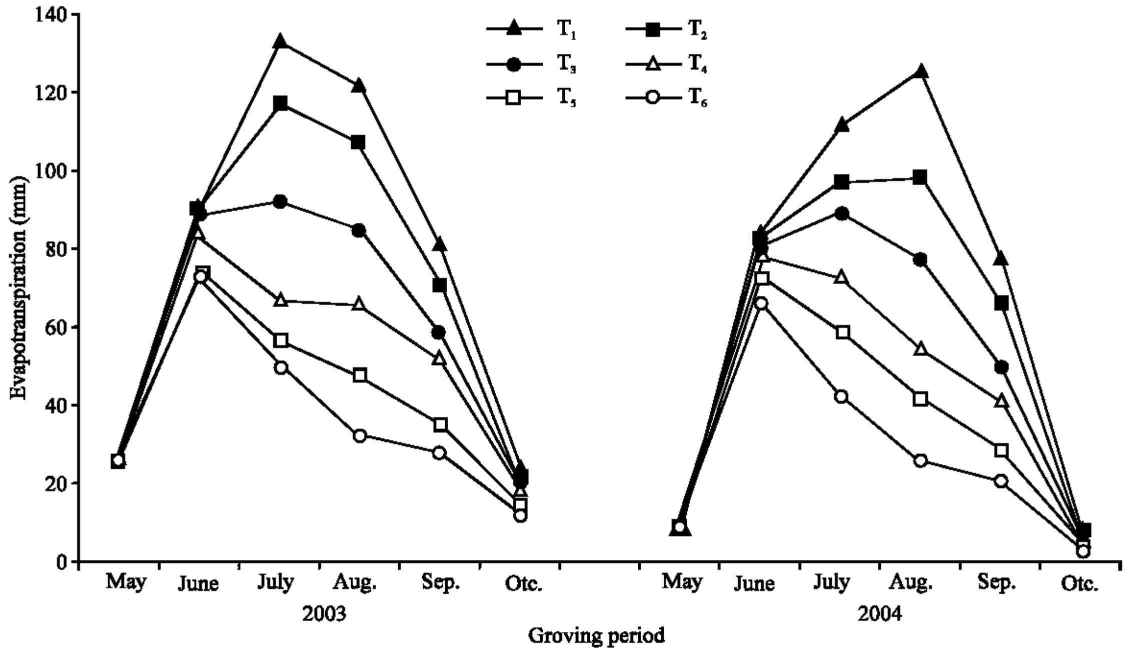

Fig. 1: Changes in evapotranspiration according to treatments in 2003 and 2004

RESULTS AND DISCUSSION

Evapotranspiration was decreased in accordance with water deficit applications in every two years (Fig. 1). While seasonal evapotranspiration was 475.2 mm in well-irrigated T_1 and 222.6 mm non-irrigated T_6 in the year of 2003, these values were 415.1 mm for T_1 and 167.7 mm for T_6 in the year of 2004. Crop water requirements are a function of climatic conditions (Panigrahi *et al.*, 2001; Onder *et al.*, 2005). 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.

In view of water deficit, it was determined that there was a decrease in evapotranspiration at the level of 53.16% in 2003 and 59.60% in 2004 for T_6 compared with T_1. These values for T_2 were determined as 8.90% in 2003 and 12.94% in 2004. Shock *et al.* (2002) implied that different values of evapotranspiration in years can be caused from planting date, local precipitation, field and many other conditions.

Deficit irrigation treatments significantly decreased ($p<0.01$) tuber yield and effect of water deficit on tuber yield was similar both 2003 and 2004 (Fig. 2). While total tuber weight was 26.94 t ha^{-1} in T_1, tuber yield declined in 9.81 t ha^{-1} with decrease of 63.59% in the T_6 in 2003. In the year 2004, the tuber yield was determined as 25.91 t ha^{-1} in the T_1, it was also determined as 6.74 t ha^{-1} with the decrease of 73.99% in the T_6. On the conditions of minimum water deficit (T_2), the decreasing ratio of tuber yield was 14.85% in 2003 and 13.08% in 2004 compared with T_1. Because potato is very sensitive against water stress, the decrease in yield, even on the condition of minimal water deficit can be seen easily (Hess *et al.*, 1997; King and Stark, 1997; Motes and Cartwright, 1994; Shock *et al.*, 2002; Thornton, 2002; Shock, 2004).

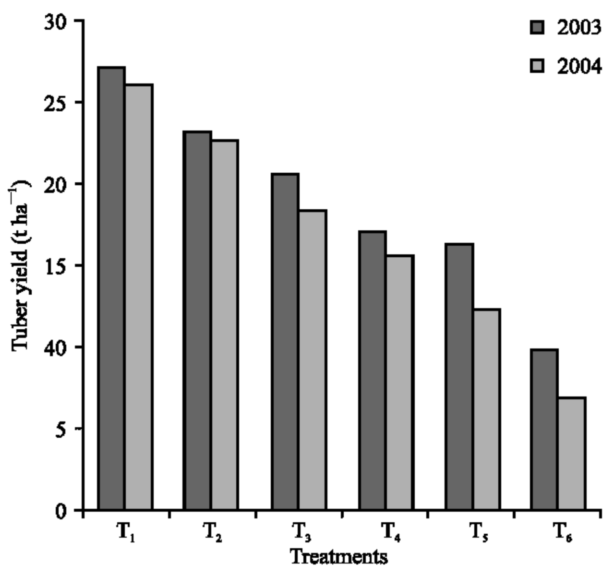

Fig. 2.: Changes in tuber yield according to treatments ($LSD_{0.01}$= 240.60 t ha^{-1})

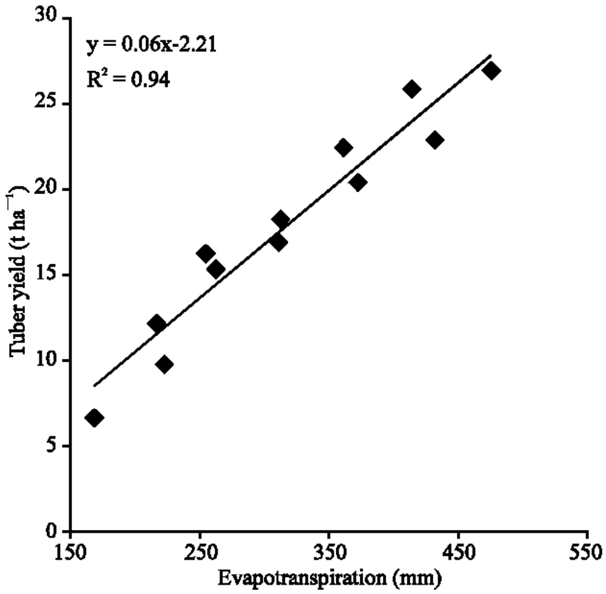

Fig. 3: Relationship between seasonal evapotranspiration and tuber yield

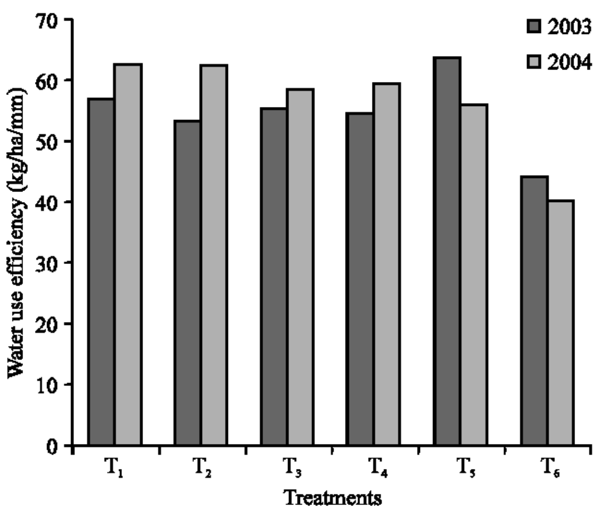

Fig. 4: Water use efficiency according to treatments

There was a linear relationship between seasonal evapotranspiration and tuber yield of potato (Fig. 3). Thus, the changes in evapotranspiration directly reflect to the yield.

Water use efficiency changed between 63.38 kg/ha/mm for T_5 and 44.07 kg/ha/mm for T_6 in the year of 2003 and between 62.42 kg/ha/mm for T_1 and 40.19 kg/ha/mm for T_6, also in 2004 (Fig. 4). Except for T_6, the water use efficiencies for all treatments were found close to the value determined in T_1.

Figure 5 shows the relationship between relative evapotranspiration decrease (Et_d) and relative yield

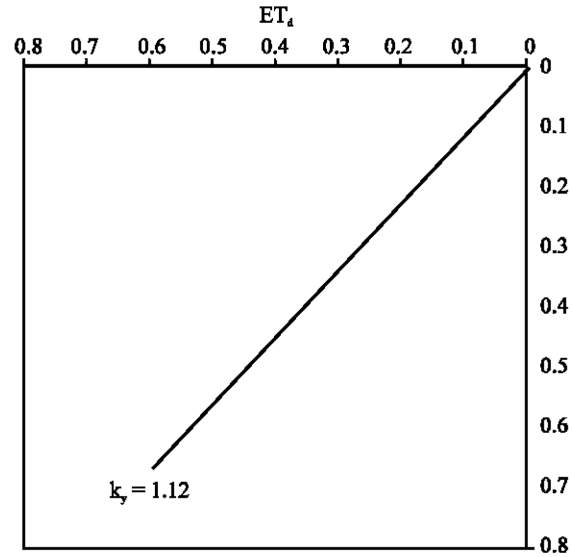

Fig. 5: Relationship between relative evapotranspiration decrease and relative yield decrease

decrease (Y_d). By using this graphic, the yield response factor (k_y) was determined as 1.12. It was reported as 1.10 in FAO (2002) document.

CONCLUSIONS

Water stress has reduced the evapotranspiration and tuber yield of potato. But, it may be said that water can be saved in the view of the tuber yields for per unit water used in irrigation. Therefore, by irrigation more much lands, it will have supplied the maximized of total income with the water to be saved.

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