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# PRODUCTIVITY OF THE POTATO CROP UNDER IRRIGATION WITH LOW QUALITY WATERS

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**SUMMARY** - Opportunities to enhance agricultural productivity in arid Tunisia have been the domain of active investigation during the last years. Many field experiments were carried out on the potential of using limited amounts of saline water from wells to grow profitably crops. This paper concerns the performance of the potato crop gown in commercial farms under relatively stressful conditions. The FAO-Water Balance calculation method was applied for irrigation scheduling over three contrasting seasons. Results obtained from full and deficit irrigation treatments show that under optimum irrigation, marketable yields varied from about 40 t/ha to 20 t/ha , and water productivity from 11.7 to 9.1 Kg/m$^3$, respectively for the spring and autumn periods of the year. We propose here a simple linear relationships between yield (Y, t/ha) and total water application (Q, mm) to be used for quick appraisals of attainable yields of the potato crop when waters of about 3-3.5 dS/m are used. Within a range of 150 to 350 mm total water supply after planting the models are [Y= 0.1Q+5] for the spring-summer season and [Y=0.1Q-5] for the autumn-winter season. These models could be valuable tools for estimating yield gaps and potential for water savings concerning the potato crop grown under arid environments.

**Key words:** irrigation scheduling, potato yield, water productivity, salinity.

## INTRODUCTION

Potato is considered relatively susceptible to salinity (Maas and Hoffman, 1977) and normally is not suited for stressful conditions. However its cultivation has been gaining popularity during the last decade in arid areas as a cash crop because temperature and radiation conditions allow for cropping over the spring, fall, and winter seasons.

In the Southern part of Tunisia where mean annual rainfall is less than 200 mm, potato is cultivated primarily on shallow wells in private farms where water is limiting not land. Irrigation is typically applied on a routine basis without scheduling. Surveys carried out recently in the governorate of Medenine show that potato yield vary usually between 10 and 20 t/ha. Inadequate management of irrigation has been identified as an important limiting factor (Nagaz and Ben Mechlia, 2003, Nagaz et al. 2004). In farms where cultivation is practised under drip irrigation water savings by drip seem to be forfeited with inappropriate scheduling.

Yield is greatly influenced by timing, amount and frequency of irrigation applied, therefore, precise knowledge of the amount of water required by the crop and the proper timing for supply is essential. Scheduling based on crop water requirements and soil characteristics allows for applying irrigation water when needed during the growing season. However, its application is only possible when water supply and irrigation amounts can be managed independently by farmers (Smith, 1985). In areas where potato is irrigated with well waters, accurate scheduling is manageable. This is precisely the case of our area, therefore chances to achieve tangible productivity improvements are high.

Field trials were implemented with the objective to evaluate the applicability of representative irrigation scheduling methods for drip systems. Basically, the investigation had to quantify yield, water use efficiency and soil salinity when the soil water balance method is used instead of the prevailing common approach. With the expectation to enable growers to incorporate more appropriate irrigation scheduling methods in their usual production practices, all field work was conducted with farmers participation.

## MATERIALS AND METHODS

Irrigation-scheduling experiments were carried out during the years 2000 to 2004 in commercial farms situated in the south-eastern part of Tunisia near the “Institut des Régions Arides, IRA-Mdenine”. The potato cultivar "Spunta" was used following standard cultural practices as reported by Nagaz et al. (2004) over three distinct growing periods: spring, autumn and winter seasons.

For the irrigation-scheduling experiment, the soil water balance (SWB) methodology was adopted. A spreadsheet program estimates the day when the soil readily available water (RAW) would be depleted and estimates the amount of irrigation water needed to replenish the soil profile to field capacity. The target depletion threshold was set to 35 % of total available water in the root zone (TAW).

The program calculates the soil water depletion with potato root depths estimated on daily basis. The soil depth of the effective root zone is increased with the program from a minimum depth of 0.15 m at planting to a maximum of 0.60 m in direct proportion to the increase in the potato crop coefficient. Once the maximum root depth is reached, it is held constant.

The soil is of a sandy type with low organic matter content. The total soil available water, calculated between field capacity and wilting point for an assumed potato root extracting depth of 0.60 m, is 75 mm.

The crop evapotranspiration (ETc) was estimated for daily time step by using reference evapotranspiration (ET0) combined with a potato crop coefficient (Kc), following the FAO-56 method given in Allen et al. (1998). Weather data used in this experiment (Tmax, Tmin and u2) were collected daily from a nearby meteorological station located at IRA-Medenine.

The development of quantitative relationships between yield and water supply was an integrated part of this study. To produce experimental data, the layout included four distinct water treatments with decreasing amounts in relation to maximum crop evapotranspiration (ETc). Full irrigation is the treatment that received 100 % of accumulated ETc. Deficit treatments were irrigated at the same frequency as the control, but with quantities equal to 80, 60 and 40 % of accumulated ETc .

The producer method consisted in the supply of fixed amounts of water of about 17 mm to the crop every 5 days from planting till harvest. This method corresponds to irrigation practices traditionally implemented by local farmers using drip irrigation.

A randomised block design with four replications was used as trial layout. Water, obtained from a well with a conductivity of 3.25 dS/m, was applied by means of polyethylene dripper lines with an emission rate of 4 l $h^{-1}$. For each block, it passed through a water meter, gate valve, before passing through laterals placed in every potato row. A control mini-valve in the lateral permits use or non-use of the dripper line.

Before planting, the soil was set to field capacity over a depth of 0.6 m i.e. all treatments received a start amount of 75 mm. Our investigation was concerned with the effect of different water management tactics corresponding to decreasing irrigation water supplies on yield, water saving and soil salinization.

Potato yields were estimated from samples of ten plants per row within each plot. Soil samples were collected after harvest and analyzed for ECe.

## RESULTS

The SWB scheduling techniques based on limited weather information and standard data provided in FAO guidelines was effective for managing irrigation under ordinary farming conditions. Maximum yields obtained under this scheduling technique (Yo) were respectively 39.7, 30.4 and 22.7 t/ha for spring, autumn and winter crops.

### Yield water supply relationships

Reduction of irrigation amounts resulted in proportional reduction of yield (Figure 1). Because all treatments were uniformly at field capacity at the beginning of the cropping seasons, the impact of irrigation reduction varied slightly from one season to the other, depending on the contribution of soil reserves to the overall water supply to plants. Intuitively one can assume that the least irrigated treatment would rely more on soil water initial store, provided that sufficient roots were developed over the wetted profile. The little amounts of rainfall waters although relatively limited can also affect the plant water status and therefore mitigate to different extents the effect of irrigation restrictive regimes.

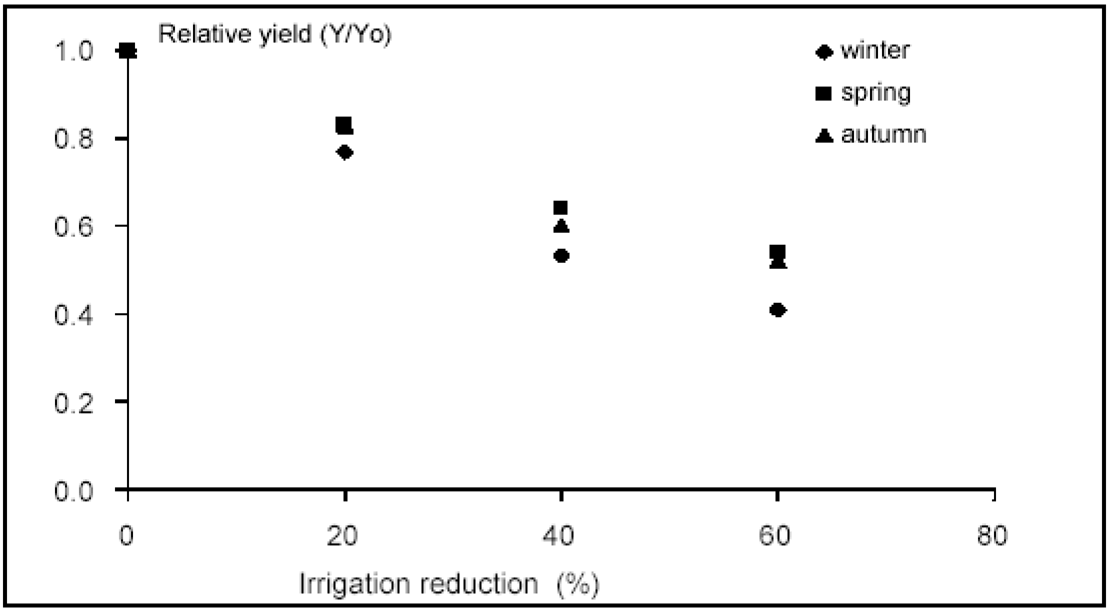


Fig. 1. Relative yield decrease of the potato crop in relation to reduction of irrigation, for different production seasons in Southern Tunisia.

Figure 2 represents yields obtained under situations of full and deficit irrigation regimes with saline waters. Two simple linear relationships are identified for the spring and for the autumn-winter seasons. The proposed quantitative models are:

$$Y = 0.1\ Q + 5, \text{ for spring productions} \quad (1)$$

$$Y = 0.1\ Q - 5, \text{ for the autumn-winter season} \quad (2)$$

with Y the yield of fresh potato tuber in t/ha, and Q the total water supply during the growing season, including the little amounts of rainfall. As empirical relationships, these equations correspond to situations where applied water is comprised between 150-350 mm limits, water salinity about 3 dS/m and rainfall input representing less than 20 % of the total supply. It is worthy to notice that these results were obtained on sandy soils not significantly affected by salinity (ECe less than 4 dS/m).

The obtained models have different intercepts because of differences between growing conditions in spring and Autumn seasons. Temperature and radiation regimes affect the partitioning of dry matter between tuber and vegetative pert. High temperatures and low radiation are known to be favorable to vegetative development (Autumn), whereas cool conditions associated with important radiation loads (spring) are suitable for more tuber production. Our results show that the ratio between dry matter of tubers and total dry matter biomass is 10-13% higher for spring productions than for the other two seasons.

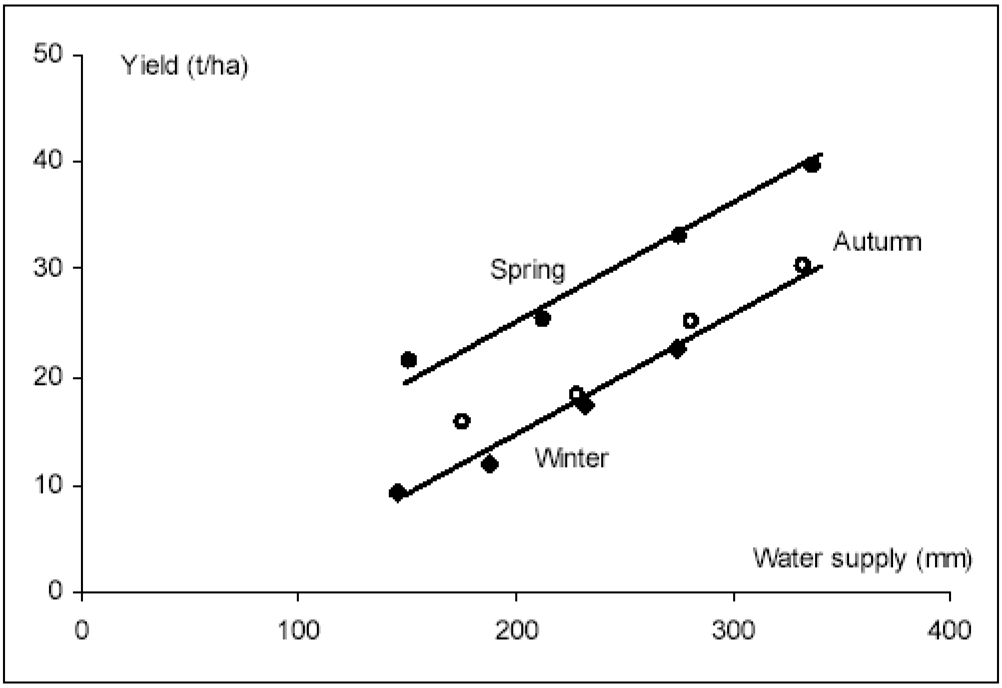


Fig. 2. Potato yields obtained with irrigation waters having an ECi of 3.25 dS/m over three contrasting growing seasons in Medenine, southern Tunisia. The soil is sandy with ECe lower than 4 dS/m and rainfall represented about 6 to 20% of the total supply. Prior to planting, all treatments received 75 mm to put the top 60 cm soil layer at field capacity.

Marginal gains in fresh tuber yield associated with increased water supply seem to be similar for the various cropping periods. The slope of the idealized linear relationships indicates an overall water productivity of 100 kg $ha^{-1}mm^{-1}$. This value fall within ranges commonly reported in the literature (Bowen 2003).

## Water use efficiency and potential for water saving

Amounts of irrigation water and total water supply for the two growing seasons are presented in Table 1. With the producer method more water was used than the SWB. Surplus was about 63 mm.

The water use efficiency (WUE) expressed as the ratio of potato yield to water supply from planting to harvest varied typically from 11 to 9 Kg/$m^3$ (Table 1). These values are comparable to those obtained in other field studies (Bowen, 2003; Fabeiro et al., 2001; Ferreira et al., 1999). Maximum values were observed during the spring season (11.7 Kg/$m^3$) under full irrigation with the SWB method. Since water used to prepare the field for planting (75 mm) is not included in the calculation of total water supply, caution should be used in analyzing productivity under deficit irrigation. It would be normal that with differential water reduction levels variable amounts of the soil readily available waters are used.

Actually water use efficiency (WUE) was significantly affected by deficit irrigation treatments. The highest values occurred in the 100 % and 80 % treatments. It was also observed that significant reduction in marketable tuber size (tuber weight) were associated with the 60 % and 40 % regimes.

The lower yields and WUE values obtained by the producer are attributable to the fact that water was applied regardless of plant changing ETc. Irrigation occurrences relates to days after planting rather than to crop growth stages progress and to ETo values.

The relatively high yields and water use efficiency values noted under full irrigation in both seasons indicate the high potential of the potato crop to valorize irrigation waters of limited quality, provided that good management is applied.

Table 1. Water supply from planting to harvest and water use efficiency (WUE) measured under SWB scheduling and grower's practices.

| | SWB method | Grower method |
|---|---|---|
| **Spring** | | |
| Irrigation (I, mm)* | 311 | 374 |
| Precipitation (P, mm) | 26 | 26 |
| Total water received (I+P) | 337 | 400 |
| W.U.E (Kg/m$^3$) | 11.7 | 7.1 |
| **Autumn** | | |
| Irrigation (I, mm)* | 261 | 323 |
| Precipitation (P, mm) | 72 | 72 |
| Total water received (I+P) | 333 | 395 |
| W.U.E (Kg/m$^3$) | 9.1 | 4.9 |

* a pre-planting irrigation of 75 mm has not been included here

**Soil Salinity**

The electrical conductivity (ECe) values measured before planting were, respectively, 1.35 and 3.45 dS/m (0-60 cm depth of soil) for spring and autumn seasons. Under the different irrigation scheduling methods, ECe in both seasons remained lower than ECi of the irrigation water. Low ECe levels were observed after rainfall events. The leaching by rain occurred mainly during September, October and December in autumn season (72 mm), and in April and May in spring season (29.7 mm). Under the prevailing conditions leaching seemed to be sufficient to control the build-up of soluble salts in the profile of this well-drained soil. Singh and Bhumbla (1968) observed that the extent of salt accumulation depended on soil texture and reported that in soils containing less than 10 % clay the ECe values remained lower than ECi.

Differences between treatments within a given season were also observed. With SWB full irrigation, the average ECe value was equal to 1.0 dS/m, beneath the emitter in autumn and to 0.75 dS/m in spring season. The zone of highest ECe was moved out to 20 cm from the emitter. With the producer method values of 1.9 and 1.7 dS/m were recorded below the emitter, respectively, in the spring and autumn seasons.

**CONCLUSION**

The potential of irrigation scheduling to improve yield and to save water has been demonstrated in this work. Results, obtained under actual farming conditions, support the practicality and usefulness of using the Soil Water Balance (SWB) scheduling method as simplified by FAO to optimise irrigation in arid regions.

Using well waters having an ECi of 3.25 dS/m, it was possible to produce potato at about 20 to 40 t/ha, depending on the period of the year. Scheduling can ensure a water productivity of 10 Kg/m$^3$ of water, in spite of the stressful environmental conditions.

The proposed quantitative linear relationship between yield and water applied from planting to harvest could be used as a tool for selecting the appropriate irrigation tactic to respond to irrigation water shortages after planting.

$Y = 0.1\ Q + 5$, for spring productions

$Y = 0.1\ Q - 5$, for the autumn-winter season

These model can be also used to investigate the causal factors for potato productivity variations and yield gaps in areas similar to Southern Tunisia.

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