ASSESSMENT OF ON-FARM VEGETABLE CROP RESPONSE TO DRIP-IRRIGATION SCHEDULING WITH SALINE WATER IN THE SOUTHERN TUNISIA

EVALUATION A LA PARCELLE DE LA REPONSE DU MARAICHAGE AU PILOTAGE D'IRRIGATION A L'EAU SALEE DANS LE SUD TUNISIEN

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ABSTRACT

The effects of irrigation regimes with saline water on vegetable yields, soil salinity and water productivity were investigated over two years in southern Tunisia. Crops were drip irrigated with well waters (6 dS/m). Full (FI100) and deficit (DI70) irrigation based on soil water balance (SWB) were compared to farmer practices (FM). For both experiments, the highest ECe values were observed under FM compared to FI100 treatment. DI70 treatment resulted also in low ECe values. FI100 provides the highest yield (potato: 24.4-27.5 t/ha, carrot: 28.4-30.3 t/ha, green beans: 19-21.3 t/ha and pepper: 10.9-12.5 t/ha) compared to FM which caused yield reduction as results of soil salinity increase. The higher water use under FM ranging from 12.5 to 22.5% for all crops induced low irrigation water productivity (IWP), while the highest values were obtained under DI70 treatment. For economic and water-saving purposes, the FI100 scheduling is suggested for irrigated vegetable crops. DI70 could be a promising strategy under water scarcity conditions.

RÉSUMÉ

L'effet des régimes d'irrigation à l'eau sale sur les rendements du maraîchage, la salinisation du sol et la productivité du l'eau a été étudié sur deux ans dans le sud Tunisien. Les cultures ont été irriguées au goutte à goutte à partir d'un puits de surface (6 dS/m). Les traitements d'irrigation totale (FI100) et déficitaire (DI70) ont été comparés avec la méthode agriculteur (FM). Pour les deux expériences, Les valeurs élevées de la ECe sont observées avec le traitement FM par rapport à ceux de FI100 et DI70. Les rendements les plus élevés sont obtenus avec le traitement FI100 (pomme de terre: 24.4-27.5 t/ha, carotte: 28.4-30.3 t/ha, fève: 19-21.3 t/ha et piment: 10.9-12.5 t/ha) en comparaison avec FM qui a réduit le rendement due à l'augmentation de la salinité du sol. Le traitement FM a conduit à une utilisation de 12.5 à 22.5% plus d'eau d'irrigation ce qui a engendré une réduction de la productivité de l'eau d'irrigation (IWP); tandis que les valeurs les plus élevées sont obtenues avec le traitement DI70. Pour des raisons d'économie de l'eau et de rentabilité, Le traitement FI100 constitue une stratégie adéquate pour l'irrigation des cultures maraichères. La stratégie DI70 pourrait être une alternative pour la conduite du maraîchage en conditions de pénurie d'eau.

Keywords: Irrigation scheduling ;saline water ; yield; vegetable, water productivity

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1. Introduction

Limited supply of good quality water is a major constraint to crop production in the Mediterranean region of Tunisia. Thus, there is an increasing pressure to use highly saline water to intensify agriculture. Local practices give to vegetables, since their high economic values, an important place in the irrigated lands. Most of these lands were located around shallow wells having a salinity more than 3 dS/m. To improve farmer's practices and the efficient use of saline water,a good irrigation management is required. Many studies have reported substantial increases in crop yields as a result of suitable irrigation management, including studies in saline conditions (Batra 1990; Ayars et al. 1991; Minhas 1996; Bustan et al. 2004; Sermet et al. 2005; Ali et al. 2007; Nagaz et al. 2013). Unanimously, it has been demonstrated that optimal irrigation scheduling requires accurate estimates of crop evapotranspiration (ETc) (Doorenbos and Pruitt 1977). In the absence of sufficient rainfall events, irrigated farms in arid lands are exposed to salt accumulation in the soils. Thus, irrigation management should take into consideration the effect of irrigation on both crop yield and environment, particularly the risk of soil degradation.
Vegetable crops are grown in arid regions of Tunisia during autumn to spring periods which coincide with the rainy season. The optimal irrigation management strategy is to maximize yield by supplying the irrigation requirement of the crop. However, under local practices, irrigation is usually scheduled according to farmers' experience, despite the water scarcity, and supply often exceeds crop requirements. The present work aims at determining irrigation water requirements of vegetable crops and to assess yield response to different irrigation regimes using saline waters in order to identify the best irrigation strategy that allow water saving with reduced effect on soil salinity and crop productivity under the arid Mediterranean conditions of southern Tunisia.

2. Materials and methods

Field experiment was conducted during two years (2012-2014) in farm situated in Southern Tunisia (33°27' N, 10°31' E; altitude 55 m). The climate is typical of arid areas with average rainfall of 151 mm/year. 107 mm of rainfall was received only in the second season and most of which fell during November, December and February. The soil of the study site is sandy soil with 80.6% sand, 12.6% silt and 6.8% clay. The field capacity and permanent wilting point are, respectively, 11.5, 6.7%. The bulk density of soil was 1.57 g/cm3. The total soil available water for an assumed root extracting depth of 1.00 m was 74 mm. Potato, carrot and green beans were planted, respectively, on 9 September, 14 and 27 October in rows spacing 70 cm and plants were sown each 40 cm, in a randomized complete block design with four replicates and three treatments. Plants of pepper were transplanted on 1 May. The plots were drip irrigated with well waters having an ECi of 6 dS/m. Each dripper had a 4 l/h flow rate.Three irrigation treatments were considered : the FI100 method consisted in replacement of 100% ETc considered as full irrigation, and deficit irrigation regime supplying 70% (DI70). Farmer method (FM) based on local practices, where fixed amounts of water are supplied to the crop with fixed intervals from planting to harvest.
Before planation, Organic manure, potassium (K_2O) and phosphate (P_2O_5) were supplied as basal doses. Nitrogen was divided and delivered with the irrigation water for all treatments during early vegetative growth. The amounts were applied according to fertilizer levels used by farmer's for vegetable production in the region.
Daily climatic data includes Tmax,Tmin and wind speed collected from the meteorological station, located at Médenine were used to calculate reference evapotranspiration using Penman-Monteith method (Allen et al., 1998). The crop coefficient (Kc) was computed following dual crop coefficient approach that provides separate calculation of soil evaporation and crop transpiration. At harvest, yields were determined for each treatment. All plants within each plot are harvested by hand to determine yield (t/ha) and yield components.
To evaluate the impact of irrigation on soil salinization, soil samples are taken before planting and after harvest and then analyzed for ECe. The irrigation water productivity (IWP) was calculated as follow: WP (kg/m^3) = Yield (kg/ha) / irrigation water (m^3/ha) from planting to harvest. The net income was calculated for each irrigation treatment by subtracting total production costs from the gross income. Gross return was calculated by multiplying the total amount of yield by its market price.

3. Results and discussion

3.1. Soil salinity

The results show that during 2012-2013, an increase in ECe values is observed under all treatments compared to initial soil salinity due to the absence of rainfall. In 2013-2014, a decrease in ECe values measured at harvest is observed under all treatments compared to initial soil salinity. The decrease of ECe values is attributed to the leaching of salts by rains (107 mm) received during growing periods of potato, carrot and green beans and rains (35 mm) during maturity stage of pepper. Figure 1 shows a decrease in ECe values for FI100 treatment. While, the FM method resulted in high ECe values. Thus, with FM strategy, irrigation with high frequency and fixed amounts seems to concentrate salts in the root zone. A relative low ECe values were observed under DI70 treatment. Low values of ECe at harvest under the prevalent climatic conditions were also due to the natural leaching of soluble salts by rainfall that occurred during fall and/or winter periods in the second year.

3.2. Crop yield

For all crops, yields observed under FI100 treatment were significantly higher compared to DI70 and FM treatments (Figure 2). In addition, FM method resulted in yield losses ranging from 11 to 36% than DI70 treatment in spite of, the farmer used 12 to 22% more irrigation water than FI100. These higher amounts of water supplied by farmer were inefficient since he doesn't take into account the soil characteristics and crop water requirements.

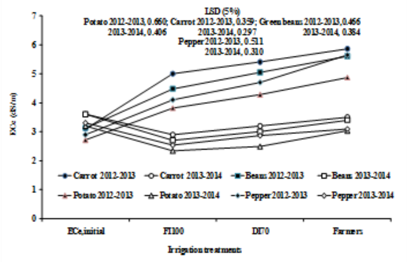

Figure 1. Soil salinity (ECe, dS/m) under different treatments

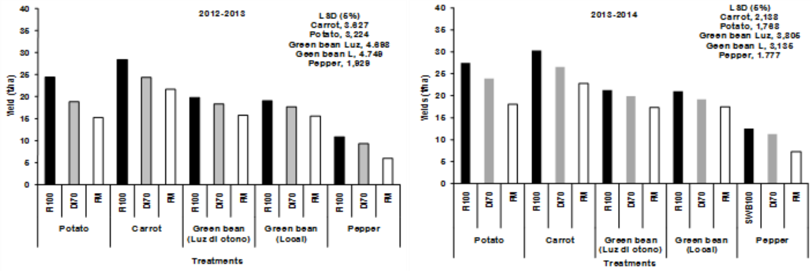

Figure 2. Yields of potato, carrot, green beans and pepper under different treatments.

The highest yield registered in the second could be attributed to low soil salinity and the higher rainfall amounts (107 mm). The use of SWB strategy for managing irrigation water resulted in better yields than farmers local practices. The higher soil salinity levels associated with farmer's method induced substantial yield reduction of crops. The SWB scheduling technique could be recommended for farmers to optimize irrigation for vegetable crops in the case where farmers have their own water sources. In southern Tunisia, most of farmers use shallow well waters therefore accurate scheduling is manageable. Smith (1985) reported that optimal irrigation scheduling is only possible when water supply can be managed independently by farmer.

3.3. Water supply and productivity

The FI100 treatment allows to save 12 to 22% of water according to crops compared to FM. Moreover, DI70 saved 30% and 42 to 52% relative to FI and FM treatments (Figure 3).
For all experiments, the IWP values obtained with FI100 treatment were significantly different from those obtained with DI70 and FM treatments (Figure 4). Highest IWP are obtained in 2013-2014 with 13.7, 11.7, 13.5 and 2.6 kg/m3 for DI70 and 11.1, 9.3, 10.3 and 2.1 kg/m3 for FI100 treatment, respectively, for potato, carrot, green beans and pepper. Lowest IWP values were obtained with FM treatment during both seasons. This can be attributed to yield reduction and higher irrigation water use.

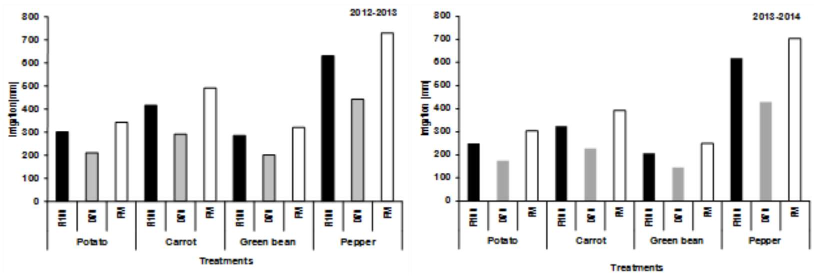

Figure 3. Irrigation Water supply under different irrigation treatment

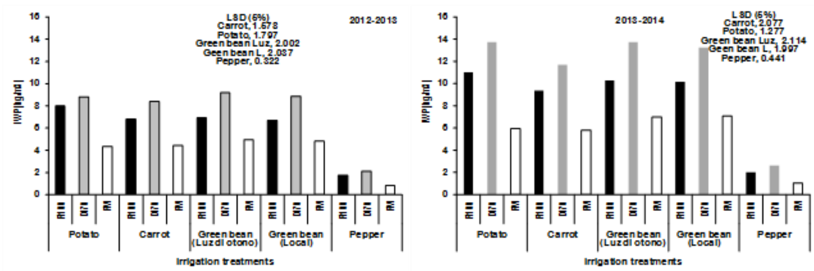

Figure 4. Irrigation water productivity (IWP, kg/m3) under different irrigation treatments.

3.4. Economic evaluation

Economic analysis (Table 1) shows that the highest net return was observed with FI100 treatment followed by DI70 deficit treatment. Whereas farmer method presented the lowest net return across two years. In fact, FI100 treatment was the most profitable due to the highest yields produced through the adoption of this strategy compared to other treatments.

Under non-limiting water conditions FI100 seems to be the most suitable strategy in terms of economic return. However, deficit irrigation technique (DI70) can be an appropriate solution for the sustainability of farmers production systems.

Table 1. Production costs and net return of vegetable production under different irrigation treatments (US$ ha^{-1})

Treatment	Cost of production($)	Gross return($)	Net income($)
	FI100		
Potato	3634	9411	5777
Green bean	4292	6510	2217
Carrot	2987	7309	4322
Pepper	5604	27625	22020
	DI70		
Potato	3576	7867	4290
Green bean	4242	6006	1764
Carrot	2912	6326	3414
Pepper	5485	24312	18827
	FM		
Potato	3667	6062	2394
Green bean	4337	5366	1028
Carrot	3036	5555	2519
Pepper	5665	15676	10010

4. Conclusions

The results of field experiments conducted over two years demonstrated that deficit irrigation (DI70) reduced vegetable yields that caused net profit decrease. However, this strategy allowed to improve IWP with 30% water saving and small impact on soil salinization compared to full irrigation strategy (FI100). SWB scheduling technique (FI100) provides the highest yield and net income with more water saving compared to FM, which caused yield reduction as results of soil salinity increase. Therefore, the implementation of demonstration pilot on farm field assisted farmers to evaluate their local irrigation practices and selected the most useful irrigation strategy through their continuous interaction during the experimental period.

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