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Research Article

EFFECTS OF PARTIAL ROOT-ZONE DRYING IRRIGATION IN COMPARISON WITH DEFICIT AND FULL IRRIGATION ON POTATO (*Solanum Tuberosum* L.) GROWTH, YIELD AND WATER USE EFFICIENCY UNDER SEMI-ARID CLIMATE CONDITIONS IN TUNISIA

Ben Ammar Haroun[1,2,3*], Kanzari Sabri[2], Ben Nouna Béchir[2]

[1] Technical Centre of Potato and Artichoke, Mannouba, Tunisia
[2] National Institute of Rural Engineering, Waters and Forestry, University of Carthage, Rural Engineering Laboratory, Ariana, Tunisia
[3] National Agronomic Institute of Tunisia, University of Carthage, Tunis, Tunisia.

**Corresponding Author:*
E-mail: harounbenammar@gmail.com

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ABSTRACT. A series of severe drought years that have afflicted Tunisia since 2016 has resulted in a critical water shortage, particularly in surface water resources. This, in turn, has led to a decrease in agricultural production, including the potato crop. To address this challenging situation, the adoption of water-saving irrigation techniques has become imperative in the Tunisian context, rather than merely an option. To evaluate the impact of the Partial Root-zone (PRD) irrigation technique on potato growth, yield, and irrigation water use efficiency (IWUE), a two-year experiment was conducted at the Technical Centre of Potato and Artichoke in the lower valley of the Medjerda. The experiment encompassed three treatments: Full Irrigation (FI), which received 100% of the ETc (crop evapotranspiration); Deficit Irrigation (DI75), receiving 75% of the ETc; and the PRD treatment, which was supplied with only 50% of the ETc. The results revealed that, given the specific soil and climatic conditions of the experimental site, the PRD technique, even with only 50% of the required water, did not significantly hinder potato growth and yield when compared to the FI and DI75 treatments. On the other hand, the PRD technique allowed significant increase of the IWUE and tuber dry matter than the FI treatment with 43.2% and 7.6% respectively.

Keywords: *PRD, Potato crop, IWUE, Irrigation management, water saving*

INTRODUCTION

Potato (*Solanum Tuberosum* L.) is the world's number one non-grain commodity and is a staple food in the global diet [1]. Worldwide production of potato crop is estimated to be around 367 million tonnes annually. In Tunisia, the potato is considered as a strategic crop for the country since 1984 [2]. Annual potato production in Tunisia is about 410 thousand tones coming from the cultivation of nearly 23000 ha [3]. With such values, potato contributes with 12% of the total legume production in Tunisia and occupies 15.5% of the total legume surface [3]. However, despite the importance of this crop for the Tunisian agriculture, its production stability has known many difficulties during the last years due to different reasons. One of the most important reasons is the lack of water resources, either surface or underground water, which is due to a series of drought years hitting the country since 2016 particularly [4]. This sever and continuous drought years led to the lowest levels of surface water resources in the country especially in the years 2017, 2018, 2021 and 2022 and forced authorities to take sever measurements since 2017. These measurements consisted mainly in prioritizing fruit trees irrigation and restrict or even delete horticultural cultivation [4]. Such restrictions led to a decrease in potato production areas and subsequently to a fluctuating production and high prices of the product for the consumer.

Those decisions are not enough to stabilize production and conserve the surface and underground water resources. Other approaches need to be implemented at the farm level such as adopting water saving irrigation strategies that allow the improvement of water use efficiency at farm level [5]. These irrigation strategies are the deficit irrigation and the partial root zone drying irrigation [6].

Deficit Irrigation (DI), defined as irrigating under the crop is full-water requirements is an important tool to reach the goal of less water use and to cope with scarce water supplies [7]. DI has been widely used in many dry regions of the world as a valuable and sustainable production strategy [8].

Partial Root Zone-Drying (PRD), is an evolution form of the DI technique [9]. The principle of the PRD technique consist in irrigating a part of the root system (approximately the half of it) while letting the other part subjected to drying soil and in the next irrigation event the irrigated and dried-out sides are alternated [10,11]. The physiological basis behind this technique consist in promoting the production of a root to shoot chemical signal (the Abscisic Acid ABA) from the roots in the drying soil part inducing a reduction of the stomatal conductance, transpiration and shoot growth. While the roots in the wetted soil part keep supplying shoots with water and thus maintain a high water status of the shoot and avoid severe water deficit [11,12]

The DI and PRD techniques have been widely tested around the world on several crops and under various climates and soils conditions [6,13]. Both techniques showed a high ability to save water and to increase the yield per unit of water applied in comparison with the full irrigation treatments[10,12,13]. In comparison between both techniques, Sadras [15] reported that PRD resulted in better irrigation water use efficiency (IWUE) than the DI but without being statistically distinguishable. Adu et al., [16] in their meta-analysis stated that PRD and DI led to similar yields when receiving same amounts of water while other authors stated that PRD yielded better than DI when receiving the same amount of water [10,14].

Our study aims to explore the impacts of the PRD technique with only 50% of water requirements on potato crop is growth, yield, tuber quality and irrigation water use efficiency under the semi-arid climate of the lower valley of the Medjerda. This particular zone is a big basin of potato production in the country. We hypothesized that, under this specific soil and climate conditions, the application of 50% of water requirements to the potato crop using the PRD technique would lead to same yield and to a better tuber quality and IWUE than using 100% or 75% of the water requirements of the crop using the conventional drip irrigation.

MATERIALS AND METHODS

Experimental site and pedo-climatic conditions

The field experiment was carried out in 2021 and 2022 at the experimental station of the Technical Centre of Potato and Artichokes (CTPTA) localized at 17 km to the west of the capital Tunis (36°49’24”N, 9°58’04”E and 32 m Alt). The site is located in the lower valley of the Medjerda river and belongs to the superior semi-arid climate with irregular rainfall of about 450 mm annually [15].

Weather conditions for the experimental years were daily measured with an automatic weather station (METOS® Compact, Pessl Instruments GmbH, Australia). The measured climatic data are minimum and maximum temperature, minimum and maximum relative humidity, wind speed (at 2 m height) and rainfall.

Table 1 gives the main soil properties of the two experimental fields of 2021 and 2022. The physical and chemical properties of the two experimental fields are very similar. According to the soil texture triangle used by the United States Department of Agriculture [16] both soils are clay loam. Both fields are strongly alkaline, have moderate level of organic matter and total nitrogen very high levels of exchangeable potassium (K2O) and extractable phosphorus [17]. Both fields have also very high levels of mineral nitrogen NO3- [17].

Table 1. *Physical, chemical and hydraulic soil properties of the experimental fields in 2021 and 2022*

<table>
<tr><th colspan="7">Physical properties (0-40 cm)</th></tr>
<tr><td></td><td colspan="2">% Clay</td><td colspan="2">% Loam</td><td colspan="2">% Sand</td></tr>
<tr><td>2021</td><td colspan="2">32.06</td><td colspan="2">40.25</td><td colspan="2">27.69</td></tr>
<tr><td>2022</td><td colspan="2">32.87</td><td colspan="2">38.02</td><td colspan="2">29.11</td></tr>
<tr><th colspan="7">Chemical properties (0-40 cm)</th></tr>
<tr><td></td><td>pH</td><td>%OM</td><td>N organic (g/Kg)</td><td>K2O (mg/kg)</td><td>P2O5 (mg/kg)</td><td>$N\text{-}NO_3^-$ (Kg/Ha)</td></tr>
<tr><td>2021</td><td>8.72</td><td>1.96</td><td>1.5</td><td>905</td><td>68</td><td>72</td></tr>
<tr><td>2022</td><td>8.53</td><td>2.19</td><td>1.29</td><td>733</td><td>64</td><td>100</td></tr>
<tr><th colspan="7">Hydraulic properties (0-60 cm)</th></tr>
<tr><td></td><td>H_{FC} (%)</td><td>H_{WP} (%)</td><td>TAW (mm)</td><td>Bulk density (g/cm^3)</td><td colspan="2">Humidity at planting (%)</td></tr>
<tr><td>2021</td><td rowspan="2">37.46</td><td rowspan="2">21.61</td><td rowspan="2">95.06</td><td rowspan="2">1.24</td><td colspan="2">26.97</td></tr>
<tr><td>2022</td><td colspan="2">29.47</td></tr>
</table>

Plantation, Irrigation treatments and experimental design

Pre-sprouted potato seeds (Soalnum tuberosum L. cv. Spunta), class E, calibrated 35-45 mm were planted on 02 March and 20 February in 2021 and 2022 respectively. For both experimental years, three irrigation treatments were set up in a complete randomized block design with three replicates (Figure 1). Treatments were: 1- Full Irrigation (FI) receiving 100% of the crop evapotranspiration (ETc),2- deficit irrigation (DI) with 75% of the ETc, and 3- partial root-zone drying (PRD) with only 50% of the ETc. DI and PRD treatments started two weeks after tuber initiation onset i.e. 55 day after planting (DAP). From planting to the end of the tuber initiation onset irrigation was equal to 100% of the ETc for the three treatments.

Each experimental plot had 6 rows of potato with an inter-row of 0.86 m and 9 m length giving a total plot surface of 46.4 m2 and a total experimental area of 418 m2. Experimental plots were separated with a bare soil zone of 2 m width. Besides, the first and the last line of each plot were considered as borderlines and never used in measurements. The second and fifth lines of each plot were used to assess biomass accumulation along the crop cycle. The third and fourth lines served for non-destructive measurements along the crop cycle and were used to assess the final yield in each treatment/ replication (Fig. 1).

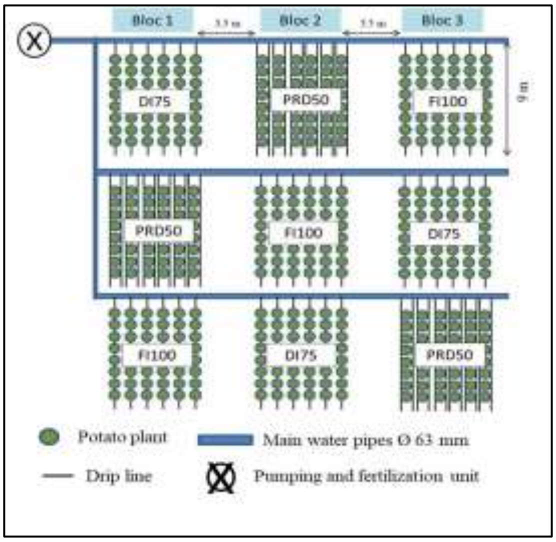

Fig. 1. *Schematic layout of the experimental design for the two experimental years*

Irrigation management

The measured climatic data (see pg. 2.1) were used to daily compute the water requirements for the FI treatment using the MABIA software [18]. The MABIA software allows daily calculation of soil water balance, potential and actual evapotranspiration and yield loss based on the dual crop coefficient (Kc) method presented in the FAO irrigation and drainage paper 56 [19].

Daily water consumption (DWC) was calculated using the following equation [20]:

$$DWC = P + I + CR - R - D - \Delta S$$

Where P is the precipitations, I the depth of irrigation applied, CR the capillary rise into the root zone, R is the surface runoff, D the downward flow below the root zone and ΔS the change in water storage in the soil profile exploited by crop roots (0-60 cm). All terms expressed in mm. Total rainfall and irrigations depths applied per treatment for each experimental year are given in table 2.

Measured parameters

Percentage ground cover

Percentage ground cover (PGC) is defined as the proportion of ground covered by green foliage and given in percentage [21]. Measurements of GC were made with a light metal frame of 0.8/1 m dimensions and split into 80 equal sections of 0.1/0.1 m. The frame once placed over the crop is observed from above and then sections more than half filled with green leaves are counted [22]. The proportion of the ground cover is than calculated by dividing the number of counted sections by the total number of sections.

Table 2. *Rainfall (mm) and irrigation water depth (mm.ha-1) recorded for each irrigation treatment (FI, DI 75 and PRD50) and cropping season.*

Cropping season	**2021**			**2022**		
Treatment	FI	DI75	PRD50	FI	DI75	PRD50
Total Rainfall (mm)		38			117	
Rainfall during protocol period (mm)		16			25	
Total irrigation applied (mm)	313.5	262.3	198.8	272	215.25	158.5
Irrigation applied during protocol period (mm)	204.5	153.4	102.3	227	170.3	113.5

Biomass accumulation

Above ground, Tuber and total dry matter accumulation throughout the crop cycle were measured fortnightly starting 55 day after plantation (DAP) until 100 DAP. For this, three adjacent plants were sampled from the second or the fifth line of each plot. Leaves, stems and tubers were then separated and fresh weighted. Dry weight was obtained after oven drying sub-samples of each organ in an air-forced oven under 75°C until constant weight.

Final yield and yield components

Final yield was assessed by harvesting the two central lines of each plot. The final harvest occurred 2 weeks after total leaf maturity. After collecting the tubers, they were separated into 4 classes which are: C1: under 45 mm, C2: 45-55 mm, C3: 55-65 mm and C4: more than 65mm. The class 1 tubers are considered as small and non-marketable. The tubers of classes 2 and 3 are medium size and easily marketable and the class 4 represent the biggest size and most wanted in French fries industry. In addition to the tuber classes, the final number of marketable tubers (classes 2 to 4) and non-marketable tubers (C1) by square meter was calculated. Dry Matter (DM) content was measured in tuber class C4 to assess the impact of the irrigation treatments on tuber quality for French fries.

Irrigation Water Use Efficiency

Irrigation Water Use Efficiency (IWUE) of the fresh tuber yield at harvest (kg.ha-1) was calculated using the following equation [23].

$$\text{IWUEY (Kg/m3)} = \text{Yield (Kg.ha-1)} / \text{Irrigation amount (m3.ha-1)}$$

Statistical analysis

All measured parameters were subjected to analysis of variance (ANOVA) using the general linear model procedure (PROC GLM) implemented in the Statistical Analysis

System (SAS) software version 9.1 [24]. Treatments means separation was performed using the Least Significant Difference (LSD) test at P=0.05 level.

RESULTS

Climatic conditions

Climatic conditions (Fig. 2) between the two experimental years were very different. The experimental year 2021 was much hotter and drier than 2022. In fact, in 2021 many days with maximum temperatures above 25°C were registered especially at the tuber bulking phase (almost for 20 days in a row from 70 to 90 DAP in 2021). Temperatures higher than 25°C during tuber bulking are known to decrease the linear tuber growth rate and biomass production [25]. Rainfall was scarcer in 2021 than in 2022. Total rainfall was 38 and 117 mm during the whole crop cycle in 2021 and 2022 respectively. Registered rainfall during the treatment period was 16 and 25 mm in 2021 and 2022 respectively. Reference evapotranspiration (ET0) had similar trend in both years and total ET0 registered was 435 and 432 mm for 2021 and 2022 respectively.

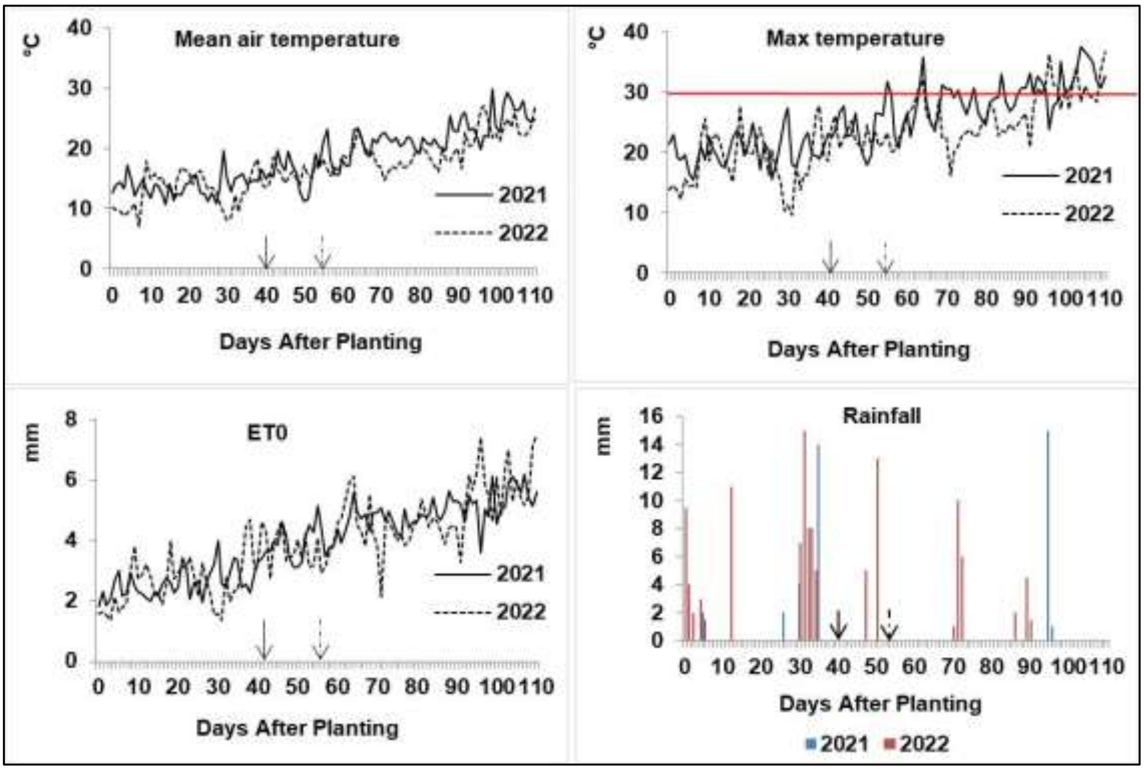

Fig. 2. *Climatic conditions during the two experimental years (2021 and 2022). The full arrow indicates the date of tuber initiation which was around 40 DAP for both years. The dotted arrow indicates the date of the treatment start at 55 DAP for both years.*

Crop growth

Percentage Ground Cover (PGC)

PGC evolution (Fig. 3) showed no significant difference between the three irrigation regimes along the whole crop cycle in each experimental year and in the average of both years. PGC evolution was likely the same for FI, DI75 and PRD50 until 76 DAP. After this date, the PGC showed different behaviour in the two experimental years. In fact, in 2021, which was a hotter year specially during the period 70-90 DAP (see pg. 3.1), the FI treatment kept the highest values of PGC than DI75 and PRD50. At 92 DAP in 2021 PGC values were 52%, 41% and 36% for FI, DI75 and PRD50 respectively. In 2022, which was a cooler year, DI75 kept the highest values of PGC in comparison with FI and PRD. At 92 DAP in 2018 PGC values were 52%, 62% and 43% for FI, DI75 and PRD50 respectively.

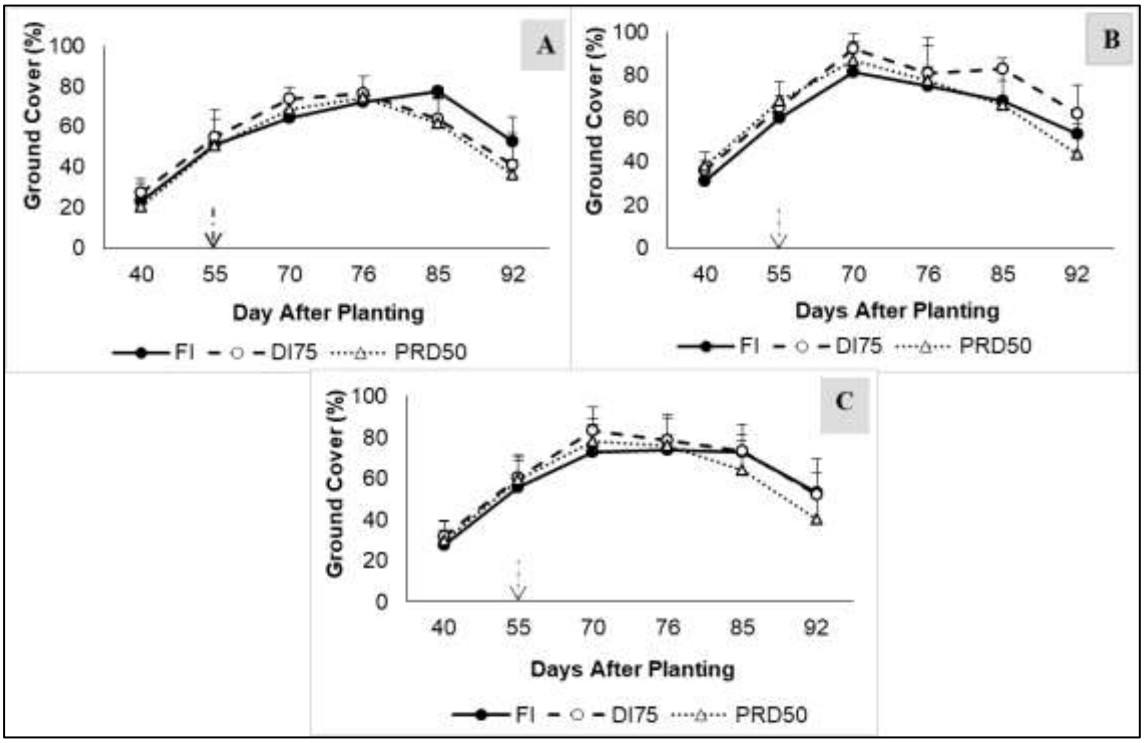

Fig.3. *Impact of irrigation treatments on potato ground cover in 2021 (A), 2022 (B) and both years (C).Vertical bars indicate the standard deviation (n=3). The dotted arrow indicates the date of the treatments start at 55 DAP for both years*

Biomass accumulation

The above ground, tubers and total biomass accumulation (Fig. 4) did not show any significant difference between the three irrigation treatments for each experimental year and in average of both years.

For the above ground dry matter, the FI treatment showed the highest values in 2021 and 2022 at 70 DAP whereas DI75 and PRD50 showed their highest values later at 85 DAP (average of two experimental years). Highest values of above ground dry matter were 1.85, 1,716 and 1.52 T/ha for FI, DI75 and PRD respectively as an average of both years.

As for the tubers dry matter accumulation, the increase of this parameter across the time was almost linear for all three parameters with domination of the FI treatment above DI75 and PRD50. Maximum values of tuber dry matter were registered at 100

DAP and they were 5.3; 4.8 and 4.6 in 2021 and 9.6; 8.7 and 9.0 in 2022 for FI, DI75 and PRD50 respectively.

Total dry matter followed the evolution scheme of tubers dry matter but with lesser speed in biomass accumulation between 85 and 100 DAP which was mainly due to the decrease in the above ground dry matter. Maximum total dry matter (2 years average) was 8.6; 8.0 and 7.7 t/ha for FI, DI75 and PRD50 respectively.

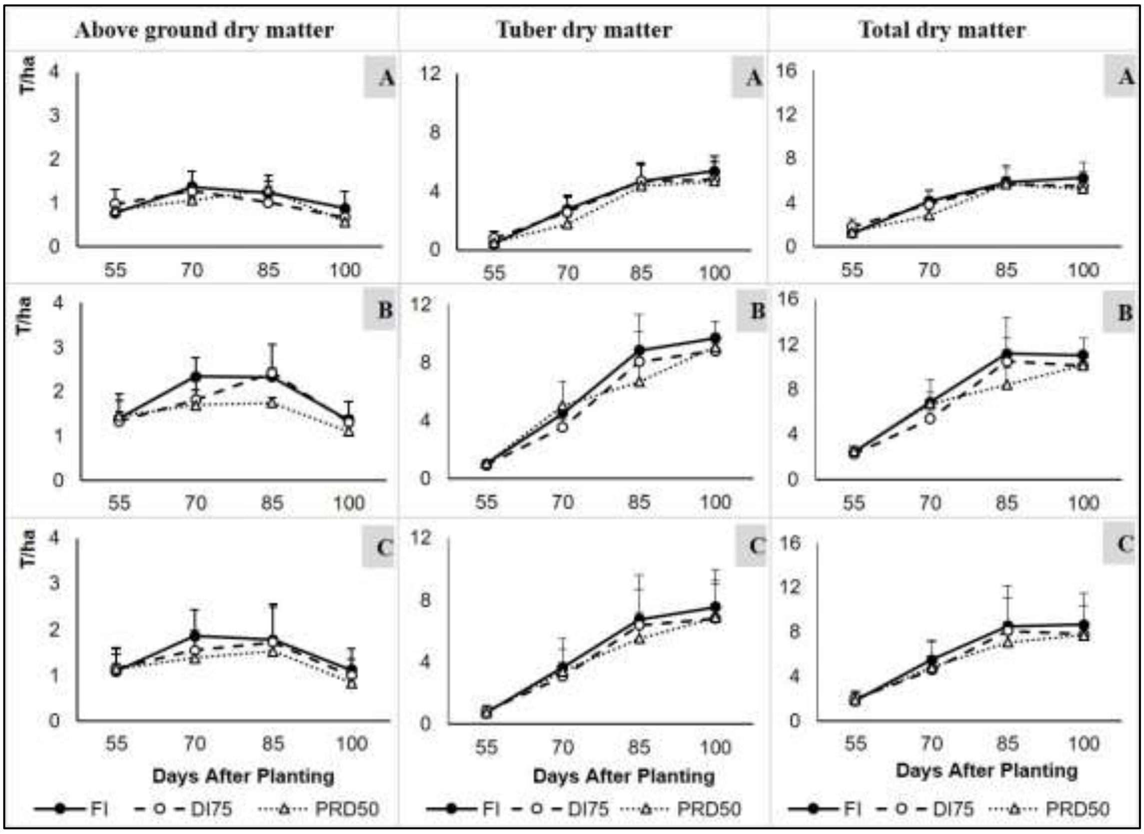

Fig. 4. *Impact of the different irrigation techniques on above ground dry matter (left column of figures), tubers dry matter (central column of figures) and total dry matter (right column of figures) evolution in 2021 (A), 2022 (B) and both years (C). Vertical bars indicate the standard deviation (n=3)*

Final Yield and Yield components

Yield per tuber size, total and marketable yield, marketable yield components (i.e. tubers number per m^2 and average tuber weight) and tuber dry matter are given in tables 3 and 4.

Total yield and marketable yield (tables 3 and 4) did not show any significant difference between the three irrigation treatments. However, FI and DI75 treatments had similar yields while PRD50 had the lowest yields in both experimental years. In 2021, DI75 had the highest yield with 18.9 T/ha followed by FI and PRD50 with 17.9 and 15.4 T/ha respectively. In 2022, total yield was 35.3; 34.6 and 30.1 T/ha for FI, DI75 and PRD50 respectively. The Marketable yield (Tuber size >45 mm) followed closely the same trend of the total yield.

Table 3. *Impact of the irrigation techniques on the final yield per tuber class and total yield*

	Final yield per tuber class (T/ha)				**Total Yield (T/ha)**
	C1	**C2**	**C3**	**C4**	
	<45 mm	**45-45 mm**	**55-65 mm**	**> 65 mm**	
2021					
FI	1.6±0.5	5.4±1.0	8.6±2.4	2.1±0.4	17.9±3.7
DI75	1.8±0.7	7.2±1.6	7.2±2.4	2.6±1.0	18.9±3.4
PRD50	1.4±0.4	5.1±2.0	7.3±1.0	1.4±0.7	15.4±3.8
Significance [a]	ns	ns	ns	ns	ns
2022					
FI	2.4±0.5	8.3±1.1b	16.5±3.0	7.9±3.9a	35.3±1.3
DI75	2.1±0.5	8.7±0.6ab	17.7±3.0	5.9±1.7ab	34.6±4.6
PRD50	3.0±0.8	10.3±1.0a	12.4±1.1	4.2±2.8b	30.1±2.1
Significance [a]	ns	*	ns	*	ns
Average of 2021 and 2022					
FI	2.0±0.6	6.9±1.8	12.6±4.9	5.0±4.0	26.6±9.4
DI75	2.0±0.6	8.0±1.4	12.5±6.0	4.2±2.1	26.8±9.0
PRD50	2.2±1.0	7.7±3.1	9.9±2.8	2.8±2.4	22.8±8.2
Significance [a]	ns	ns	ns	ns	ns

[a] F-test for treatments : significant at 5% level (*), 1‰ level (**) or not significant (ns). Means with different letter in the columns are significantly different.

The yield by class of tuber size was significantly affected by irrigation treatments in 2022 where PRD50 negatively affected the tuber size. In fact, in 2022, the PRD50 treatment had significant lower yield in tubers with size > 65 mm than the FI treatment. The same trend was observed also in 2021 where PRD50 resulted in the lowest yield of the biggest tubers than FI and DI75 but without being significantly different.

The number of marketable tubers per square meter (table 2) was not significantly different between the three treatments for both experimental years. However, the mean weight of marketable tubers was highly significant ($P<0.001$) between the three treatments in 2022 where FI resulted in the highest weight of one marketable tuber with 187.9 gr followed by DI75 and PRD50 with 177.8 and 164.3 gr. In the average of both experimental years, the FI treatment had significant ($P<0.05$) higher tuber weight than the PRD50 treatment.

As for the tubers quality, the PRD treatment had a positive effect on this latter parameter when it significantly ameliorated the dry matter (DM) percentage of tubers in comparison with FI and DI75. In fact, in the average of both experimental years, the DM percentage of harvested tubers was 18.8% for FI and DI75 and 20,3% for PRD50.

Table 4. *Impact of the irrigation techniques on marketable yield, marketable yield components and tuber dry matter*

	Marketable Yield (T/ha)[a]	**Number of marketable tubers / m^2**	**Average weight of one marketable tuber (gr)**	**Tubers Dry matter (%)**
2021				
FI	16.2±3.1	9.7±2.1	172.6±9.4	18.7±1.4
DI75	17.1±3.9	12.5±4.3	145.9±19.2	18.6±1.0
PRD50	13.9±3.6	9.6±3.2	151.0±9.2	21.0±0.4
Significance [b]	ns	ns	ns	ns
2022				
FI	32.8±1.3	22.5±2.2	187.9±a	18.9±0.3
DI75	32.4±5.0	22.0±1.1	177.8±b	19.0±1.0
PRD50	27.1±2.0	21.2±1.5	164.3±c	19.5±0.5
Significance [b]	ns	ns	**	ns
FI	24.5±8.9	16.1±7.0	180.2±a	18.8±1.0b
DI75	24.8±9.0	17.3±5.8	161.9±ab	18.8±1.0b
PRD50	20.5±7.4	15.4±6.5	157.7±b	20.3±0.9a
Significance [b]	ns	ns	*	*

[a] The marketable yield is the sum of the 3 tuber classes C2, C3 and C4 shown in table 3.

[b] F-test for treatments : significant at 5% level (*), 1‰ level (**) or not significant (ns). Means with different letter in the columns are significantly different.

Irrigation Water Use Efficiency (IWUE)

IWUE for total yield ($IWUE_{TotY}$) was significantly ($P<0.05$) influenced by the irrigation regime (Fig. 5). The PRD50 treatment showed the highest values of $IWUE_{TotY}$ in both experimental years followed by DI75 and FI treatment.

In 2021, $IWUE_{TotY}$ was highest in PRD50 followed by DI75 and FI but without being statistically significant between the three treatments. Whereas in 2022, $IWUE_{TotY}$ obtained in the PRD50 treatment was significantly ($P<0.05$) higher than in FI. However, DI and FI were not significantly different. $IWUE_{TotY}$ obtained in 2022 was 12,99±0.48; 16.10±2.16 and 19.04±1.33 for FI, DI75 and PRD50 respectively.

As an average for both experimental years (Fig. 5c), PRD50 and DI75 were significantly higher than FI treatment. $IWUE_{TotY}$ was 9.36±3.89; 11.67±4.93 and 13.41±6.09 for FI, DI75 and PRD50.

IWUE for marketable yield ($IWUE_{MY}$) was in general lower than the $IWUE_{TotY}$ and followed the same trend in statistical analysis and in the order of higher treatments.

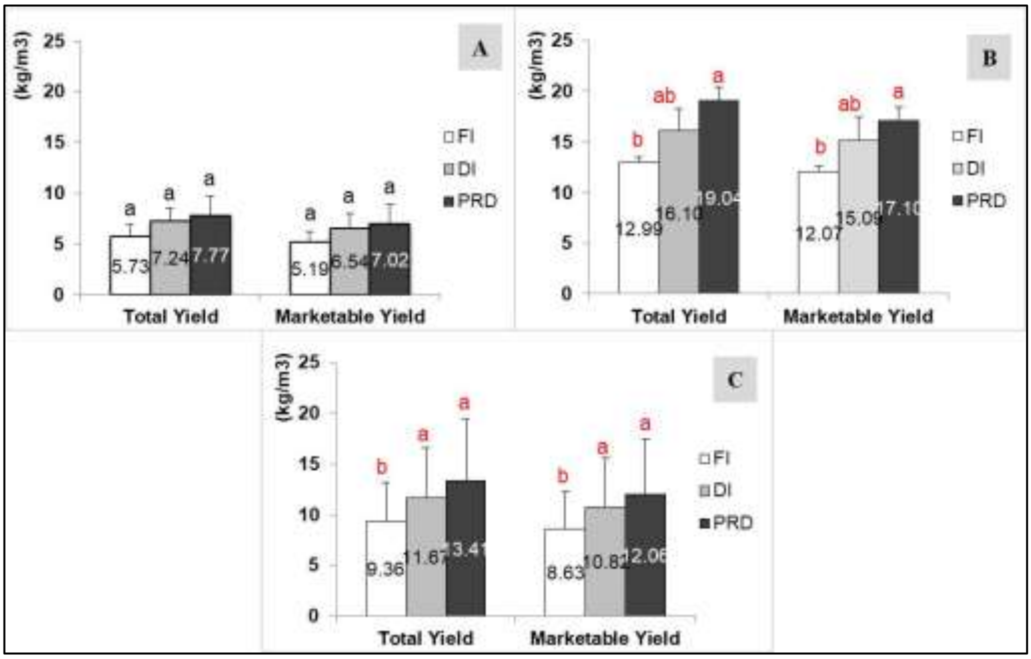

Fig. 5. *Irrigation Water Use Efficiency for total yield and for marketable yield in 2021 (A) 2022 (B) and in both years (C). Vertical bars indicate the standard deviation (n=3). The small letters indicate the treatments grouping*

DISCUSSION

Canopy development, measured as percentage of GC or as Leaf Area Index (LAI), is a very important parameter in determining final yield as it is linearly correlated to light interception and hence to DM accumulation [21,26]. Impacts of deficit irrigation technique or drought simulated conditions on canopy cover reduction were shown in many researches [22,27]. Our results showed that the PRD technique, and with 50% less water, slightly affected the PGC evolution of the potato crop but without significant differences in comparison with the FI and the DI75 treatments. Many research results showed that vegetative growth of the potato crop, didn’t significantly reduce under PRD technique conducted with mild water stress (i.e. 80% to 65% of FI) [28]. While with severe water stress (i.e. 60 to 50% of FI) most of the research results we have found in literature indicated a significant decrease in potato canopy growth under PRD50 [29,30]. Our findings could be supported with other research results led on other crop species like Maize and cotton [31] and tomato [32] where PRD technique and with sever water stress (50% less water) didn’t significantly reduce the canopy growth.

The above ground, tubers and total biomass accumulation evolution closely followed the GC evolution. In fact, DI75 and PRD50 led to slight but non-significant reduction of above ground, tuber and total DM accumulation in comparison with the FI treatment. This is highly explained by the close correlation mentioned above between the canopy development and the DM accumulation [26]. Our results are supported with the findings of Jovanovic et al.[33] who showed no significant decrease in DM accumulation of leaves, stems and tubers when using PRD technique with a severe water stress (57% of the FI). However, other researchers mentioned a significant decrease, when using PRD technique with 50% of the ETc, of above ground DM, Tuber DM and total DM [29,34].

Average marketable yield obtained in this study was about 23 t/ha for all treatment combined. This yield is higher than the Tunisian national yield obtained during the 6 years period from 2015 to 2020 which is about 19 t/ha in average [35].

Total yield and marketable yield obtained in this work were slightly decreased with the PRD50 technique than the DI75 and FI but without being significantly different among the three treatments. Our results are supported by the findings of Yactayo et al. [23] who showed that PRD technique used early or late in the season (6 or 8 weeks after planting) and with 50% water less than the FI treatment led to non-significant differences in final and marketable yield. . Also Xie et al. [36] showed that PRD technique with 50% water less than the FI, throughout the whole crop cycle, and thought conducted in two different semi-arid regions of china, led to similar yields than the FI treatment. Yet, other researches showed contradictory results than found in our work. Badr et al. [34] and Zin El-Abedin et al. [37], conducting field experiments under the hot arid climate of Egypt and Saudi Arabia respectively, showed significant yield reduction when using PRD technique with 50% less water than the FI treatment.

These contradictory findings are attributed to many factors, which are mainly the climate and the soil impact on potato response to water deficit. In fact, soil properties have an important role in determining potato yield as reported in Ahmadi et al. [28] who found that loamy sand soils led to significant higher potato yield than in coarse sand. These is also strongly supported by the findings of Adu et al. [13] in their meta-analysis where they concluded that successful DI or PRD is more probable on more finely soils than in coarse soils. Climate is also an important factor in determining potato yield and mainly by its air temperature. In fact, hot air temperatures, going from 15 to 27°C and higher, could severely impair tuber growth rate [25]. Differences between results found in literature could be ascribed to other factors than soil and climate such as cultivar response to water deficit [38], the wetting-drying cycle length [30] and to the time of water stress application [23].

Number of marketable tubers per square meter was not significantly different between the three treatments. This could be assigned to the fact that water restriction started after tuber initiation onset as mentioned by [22]. On the other hand, the average tuber weight linearly decreased with the water reduction and was significantly different between the treatments. Our results corroborate with other research results showing that the yield reduction was correlated to the reduction in average tuber yield and not to the reduction in tuber numbers [22,34,37].

Tuber dry matter (DM) is an essential quality trait for processing potato into chips and French fries. According to Kirkman [39], potatoes with DM content less than 19.5% are not accepted by industrials of French fries. Our results showed that PRD technique allowed a significant increase in tubers DM in comparison with the FI and the DI75 treatments and allowed a DM higher than 19.5%.

Water Use Efficiency (WUE) is defined as the ratio between the crop yield achieved and the water irrigation amount used [23]. Our results showed that PRD technique, with 50% of ETc, significantly increased IWUE with 43% and 15% than FI and DI75 respectively. This increase was significant between PRD50 and DI75 on one hand and FI in the other hand. Our findings are sustained with many other research results that showed significant impact of PRD technique on the IWUE. Indeed, Badr et al. [34] showed that PRD technique, with either 50% or 75% of the ETc, significantly increased IWUE than the FI treatment. On the other hand, other researchers reported a non-significant increase in IWUE with PRD (50% ETc) than FI [40] and even a decrease in this parameter when using PRD technique with 50% or 60% of the ETc [30,37].

CONCLUSION

To cope with water scarcity that Tunisia is witnessing, new strategies of water use should be taken at different levels in the irrigated agriculture of the country.

At farm level, water saving irrigation techniques should be adopted as soon as possible by the farmers so they can use water more economically and keep their productions more stable. From this necessity, our work comes to investigate the impact of the Partial Root-zone Drying (PRD) irrigation technique on potato crop development and yield under the semi-arid climate of Tunisia. For this purpose, a two years experiment was set-up in the experimental station of the Technical Centre of Potato and Artichoke at the lower valley of Medjerda. 3 irrigation treatments were tested which are the Full Irrigation (FI) treatment with 100% of the ETc, the Deficit Irrigation (DI75) at 75% of the ETc and the PRD50 at 50% of the ETc. Our results showed that under the specific soil and climate properties of the experimental site, the PRD technique and with only 50% of water requirement didn’t significantly impair the potato growth and yield in comparison with FI and DI75. On the other hand, the PRD technique resulted in the highest Irrigation Water Use Efficiency (IWUE) and Dry Matter (DM) content of tubers, and it was statistically significant than the FI treatment.

Hence, it can be concluded that, the use of PRD with 50% of ETc from tuber initiation stage to harvest, has a advantages compared to full irrigation and deficit irrigation in terms of improving the irrigation water use efficiency, while keeping the same tuber yield as that of the FI treatment.

Our results are very important for the Tunisian context. In fact, the site where this work was done represents a big basin of potato production belonging to the lower valley of Medjerda. In this specific zone, potato area is decreasing because of water interruption in the public irrigated perimeters in this zone. Hence, using our results it would be possible to maintain the surfaces of potato production in this zone while using half the water requirements of the crop and without significantly decreasing the yields by applying the PRD technique. It is also important to study the impact of the PRD technique on potato growth in other production zones of the country where the climate is hotter and the soils are sandier.

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