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The Water use Efficiency for Different Varieties of Wheat and the Effect of Supplemental Irrigation in the Semi-Arid Regions of Tunisia

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Abstract – **This work was recorded during the year 2008/2009 within thepublic farm ofagricultural machinery training center in Siliana-Tunisia (AMTCS) that belongs to the irrigated district of Lakhmess covering an area of 1275 ha. Cereals are the most practicedcrops representing 49% of the total cultivated area within the irrigated district. Themain objective of the study is to determine the water use efficiency for different wheat cultivars and to analyze the impacts of supplemental irrigation on cultivars yields.Five cultivars of durum wheat (Karim, Khiar, Razeg, Nasr, Oumrabii) andfour cultivars of soft wheat (Birsa, Vaga, Utique, Hidra) were cultivated in the public farm and one cultivar of durum wheat (Khiar) was cultivated within a private farmbelonging to the same region. The area was divided into 9 strips (100 m x 20 m). These different varieties were conducted under rain fed and in supplemental irrigation conditions. An amount of 100 mm of irrigation water was provided in the plot of the AMTCS as follows: 50 mm in seedling stage (December16th, 2008), 50 mm in the fulltillering stage (March10th, 2009). In the plot of the private farm, 150 mm of irrigation water was distributed as following: 50 mm in the seeding stage (10 December 2008), 50 mm in full tillering stage (10 March 2009), 50 mm in grain filling stage (May 2nd, 2009). The sprinkler irrigation was used with a spacing of 12m x 12 m and the plots were irrigated by a hydrant irrigation existing in each plot.The flowwas 5 l/s supplied from Lakhmess dam with a salinity of 0.5 g/l. The sprinkler rainfall was 8.5 mm/h with a uniformity coefficient of 92 %.The model CropWat was used to determine the water requirements of wheat. Grain yield was determined by multiplying the density of cobs by the number of grain per cobs and the Mile grains weight (g). The water use efficiency is the ratio of the grain yields and the amount of water consumed. Under rainfed conditions: The average of water use efficiency was 0.38, 0.36 kg/m^{3}respectivlyfor durum and soft wheat. Under irrigated conditions, the best efficiencies of durum wheat were obtained by Khiar, Razeg and Nasrwith an average of 1 kg/m^3.For soft wheat the varieties Vaga and Utique had the best efficiencies of 1.14 Kg/m^3.In the private farm, the water use efficiency of the variety Khiar used was only 0.95 Kg/m^3. The effect of supplemental irrigation was remarkable. In fact, it improved theyields for all varieties of durum and soft wheat respectively by 397% and 347 %.**

Keywords – **Durum Wheat, Soft Wheat, Water Use Efficiency, Supplemental Irrigation, Yields.**

I. INTRODUCTION

Tunisia is considered among the least endowed with water resources in the Mediterranean basin.The potential mobilized water is about 4.8 million m^3, representing a low quota of500 m^3/hab/year [7]. This ratio will be only 360m^3/hab/year in 2030 when the population will be around 13 million [7]. The average annual rainfall is estimated at 36 billionm^{3}characterizedby large variability depending on the year; but this average is to be stable over long periods [8]. They are generally insufficient for rainfed agriculture because of the arid climate and erratic rainfall. That's the reason why irrigation is necessary in farming. The agricultural sector consumes about 80% of the mobilized water volumeand the total irrigated area is about 400 000 ha, which represents 7to8% of the total agricultural area. Faceto demographic change, the fragility of the agricultural sector and the limited water resources, it is clear that the Mediterranean countries located in thesouth of the basin would have to raise a specific challenge aiming to increase agricultural production particularly of strategic crops: cereals aiming not onlyto ensure food security but also toensure water security and take into consideration the sustainability of natural ecosystems [1]. Cereal production is marked by ayearly fluctuation depending on the climate.The level of self-sufficiency ranges between 16% for a low production year and 60% for one year of high production with an average import rate of 55% [10]. The average yield of durum and soft wheat were respectively of 14 qt/ha and 17.5 qt/ha; averages which are very low when compared to France: 50.3 qt/ha for durum wheat and 72.5 qt/ha for soft wheat.
In North Africa and West Asia, the main factors affecting cereal yields are water and nitrogen [9].This has been demonstrated in Tunisia [12]-[6]. In Tunisia, cereal yields are subject to an important fluctuationin relation with the yearly rainfall in addition to seasonal water deficits that could prevail even during a rainy year [11].

Improving the water use efficiency can be obtained by including crop breeding in order to increase the ratio transpiration/biomass; sweating through proper soil reparation, efficient fertilization and also thanks to the reduction of water losses due to runoff, drainage or deep percolation and evaporation [2]-[3].

In Siliana, where our trials have been conducted, the cereal area was about 168 000 of ha, which represents54%

of arable land, divided into 160 000 ha in rainfall and 8000ha in the irrigated area. The percentage of farmers who practice cereals in their farms was 72%. This region contributed to the gross national product with 14% namely in the field of cereals. Thewater deficit in the region was about 888 mm/year.It has become an economicissueof a high interest which is diverting the irrigation techniques. It has become important to know the main ways which optimize the water used in irrigation. The irrigation schedule should be realized when ensuring the competitiveness of production costs.The problem of drought, scarcity and erratic rainfall, and the worries to mitigate water deficit led to a very important concept in the world of irrigation called supplementary irrigation [4].Several studies have shown the interest of this irrigation technique to limit the water deficit and improve yields [5]. The supplemental irrigation of cereal will ensure at least minimum guaranteed production, regardless of weather conditions. The present work is to study the effectiveness of supplemental irrigation for fivevarieties of durum wheat (Karim, Khiar, Razeg, Nasr and Oumrabii) and four soft wheat varieties (Birsa, Vaga, Utique and Hidra).

II. Materials and Methods

Experiments were conducted in the agricultural training center's exploitation of Siliana (northwestern Tunisia); at 400m above sea level.Its geographical coordinates are: Latitude:North 39G97° and 40G69°, Longitude: 7G81° and 7G89°, the climate is semi-arid with an annual rain fall average of 380mm/year and the potential evapotranspiration is of 1560 mm/year. The soil is deep with a clay loam texture. Given the field capacity and the permanent wilting point, the available soil moisture was about 130mm. Measured parameters were summarized in table 1.

Table 1: Parameters measured in experimental plots

Layers (cm)	0-20	20-40	40-60	60- 100
Clay (%)	60	65	60	40
Loam (%)	30	30	25	33
Sand (%)	10	5	15	27
Bulkdensity	1.3	1.45	1.5	1.5
Field capacity (%)	24.5	24	22.5	25
Wilting point (%)	15	14	14	15
Hydraulic soil conductivity (mm/h)	14			
Available soil moisture (mm/m)	130			
Ph	7.42			
Water electrical conductivity (dS/m)	0.75			
Piezometric level of the ground water (m)	17.5			

A. Climatic conditions

The study area is characterized by a Mediterranean climate, arid to semi-arid; with rainy winters and hot dry summers.Autumn and spring are generally temperate. Therainfall average in this area was about 380mm for a period of 23years (1974 to 1997), and about 666 mm in 2008/2009 campaign (Table 2). The total rainfall for the year 2008/2009 was 414mm recorded between December and May. It was characterized by its monthly and decadal variations.The wettest decade was noticedduring the third decade of January with 133 mm, followed by the third decadeof April with 93 mm. During the month of December, there were only 14 mm during the first decade (Table3). The highest temperature during the year 2008/2009 was observed in May with 27°C, while it was minimal during January with 4°C.The potential evapotranspiration was determined by the CropWat model. The total of potential evapotranspiration for 2008/2009was about 1560 mm.

Table 2: Climatic parameters inSilianaduring the year 2008/2009

Month	S	O	N	D	J	F	M	A	M	J	J	A	Total
Monthly average rainfall (1974-1997)	43	39	41	32	35	42	46	38	33	11	6	14	380
Monthly rainfall	72	56	4	14	177	30	27	129	37	0	47	73	666
Max T (°C)	31	25	20	15	14	14	18	19	27	33	38	36	
Min T (°C)	17	14	7	5	5	4	5	8	12	15	19	20	17
Average T (°C)	24	19	14	10	10	9	11	13	19	24	29	28	24
Evapotranspiration (mm)	177	99	107	64	52	69	86	57	144	240	251	214	1560

Table 3: Decade Rainfall in Siliana during the year 2008/2009

Month	December			January			February			March			April			May			Total (mm)
Decade	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	-
Rainfall (mm)	14	0	0	16	133	28	4	19	9	14	0	13	24	93	10	2	35	0	414

B. Experimental protocol

Five varieties of durum wheat (Karim, Khiar, Razeg, Oumrabii, Nasr) and four varieties of soft wheat were used in a public plot belonging to the **(AMTCS) on** an area of 2 ha. The variety Khiar was used in the private farm within an area of 1.5 ha. The sowing was done mechanically with a dose ranging from 160 to 180 kg/ha. These plotswere conducted under a supplemental irrigation and rainfall conditions. The public plot has received two irrigations of 50 mm during the period of sowing and full tillering; while the private farm has received three doses of 50mm/irrigation during the periods of seeding, full

tillering and grains filling. A quantity of 600 kg of ammonium nitrate was applied in both plots with a centrifugal fertilizer spreader, andatreatment against weeds was achieved with a projected spray jet.

III. Results and Discussion

A. Water content

The gravimetric method was used by taking ten samples within a soil profile of 1 m at a rate of one sample every each 10 cm. Within the private farm, measured humiditywas always ranging between moisture at wilting point and that at the field capacity. Whereas in the public farm, measured humidityduring the month of May was lower than humidity at the wilting point.

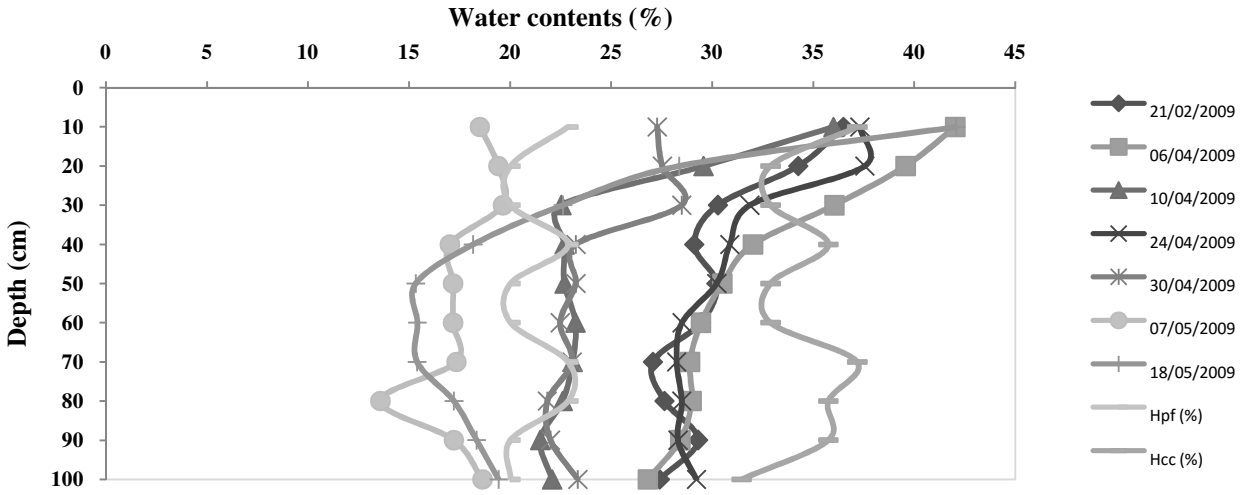

Fig.1. Variation of water content within the public plot of (AMTCS)

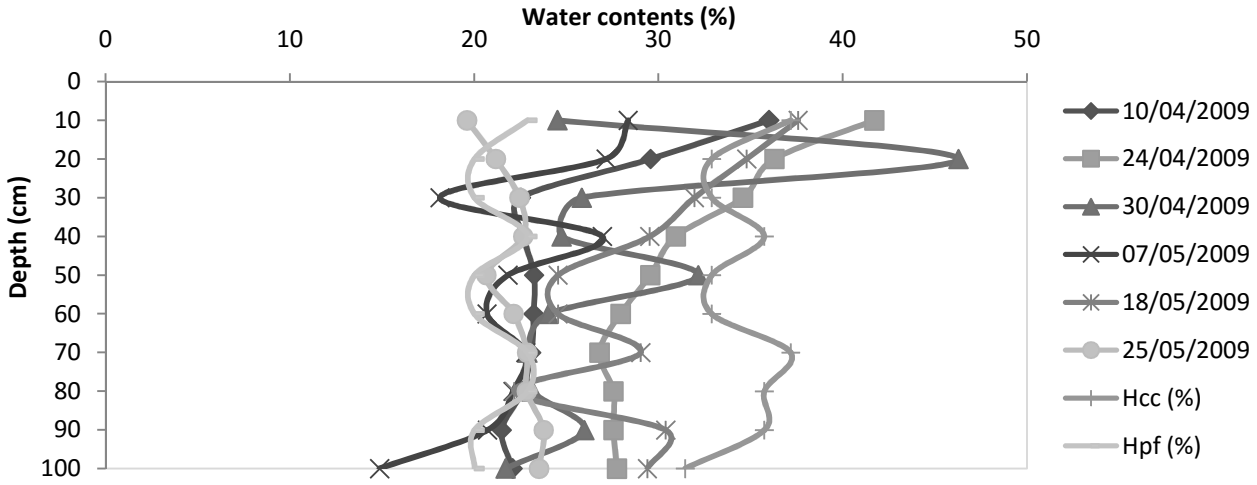

Fig.2. Variation of water content within the private plot

B. Agronomic parameters

The parameters measured were:the height of the stem, the density of cobs, the number of grains per cob, the one thousand's grainsweight, and the grain's yield. Oum Rabia variety was distinguished by its height with an average of 110 cm, followed by Razeg variety with an average height of 90 cm, Khiar and Nasr had a height of 85 cm, while Karim had a shorter height with an average of 80 cm.For the soft wheat variety, Birsa has an average height of 95 cm followed by Utique and Hidra as havingaheight of 90 cm. Vaga variety was the shortest, with 75 cm of height.The average density was 276 spikes/m^2 in case of durum wheat; while for soft wheat the average density was 315.The average number of grains per cob was 38 for durum wheat and 36 for soft wheat. The average weight of one thousand grains was 51g for durumwheatand 46g for soft wheat. The variety Hidra occupied the lowest weight with 38g (Table 4).

Under the irrigated conditions, the average yield of the durum wheat within the public farm was 50 qt/ha. The Nasr was the best variety with 54 qt/ha, followed by Khiar variety with 52 qt/ha. In private farm, this yield was about 54 qt / ha. The average yield ofsoft wheat under irrigated regime was about 54qt/ha and the most noted was the

varietyVaga with 59qt/ha. While the average under rainfallconditions for both durum and soft wheat was 13 qt/ha (Fig.3), which shows the effectiveness of supplemental irrigation. Despite the addition of 50 mm of irrigation rate in the private farm during the grain filling stage as compared to the public farm, the difference in grains yield of Khiar variety in both farms is not significant.This can be explained by the observation at the end of May of poured phenomenon in the private farm, which was not observed in the public farm.

Table 4: Number of grains per ear for durum wheat and soft wheat in the state farm

	Durumwheat					soft wheat			
Variety	Karim	Khiar	Razeg	Nasr	Oum rabia	Birsa	Vaga	Utique	Hidra
Density of cobs	269	245	279	300	290	320	336	325	300
Number of grains percob	36	44	37	34	40	33	35	38	40
One thousand grains weight	55	47	55	50	47	51	50	47	38

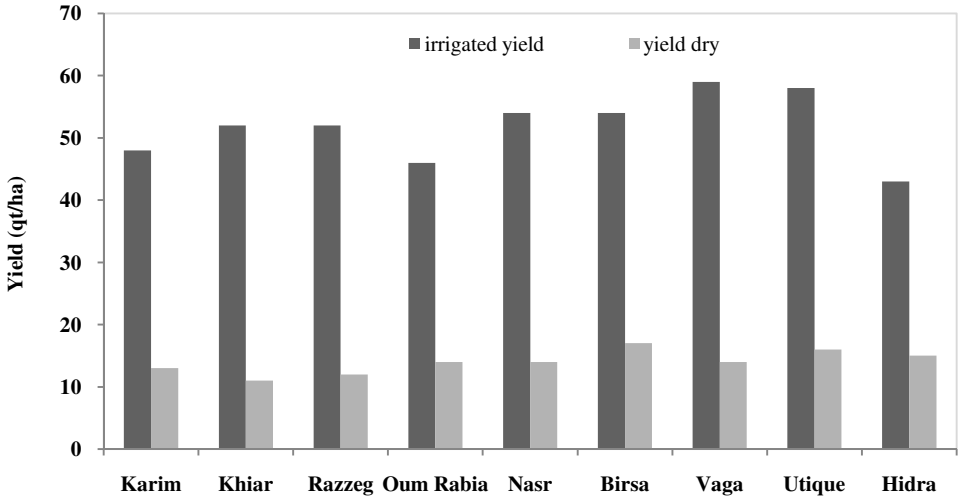

Fig.3. Yields in both irrigated and dry

C. Water use efficiency

- *Under rainfall regime*

Therainfall measured in the study plots during the growth cycle (December to May) ofwheat was 414 mm.The water use efficiency of the durum wheat was 0.31 kg/m^3 and the best efficiencieswere obtained by the Oumrabiivariety and Nasr with 0.34 kg/m^3, while for the soft wheat this average was 0.37 kg/m^3.TheBirsavariety had the best efficiency of 0.41 Kg/m^3 (Table5).

Table 5: Rainfall yield and water use efficiency within the public farm

	Durum wheat				Soft wheat				
Variety	Karim	Khiar	Razeg	Nasr	Oum-rabii	Birsa	Vaga	Utique	Hidra
Rainfall Yield (kg/ha)	1300	1100	1200	1400	1400	1700	1400	1600	1500
Water use efficiency(Kg/m^3)	0.31	0.26	0.29	0.34	0.34	0.41	0.34	0.38	0.36

- *Under irrigation regime*

The intake of 100 mm of irrigation water within the public farm and 150 mm within the private farm has allowed tothe following results: Varieties of durum wheat: Khiar, Razeg, Nasr had the best efficiencies of 1 Kg/m^3, followed by Karim variety (0.93 kg/m^3).The lowest efficiency was that obtained with the variety Oumrabii (0.89 Kg/m^3).The best varieties of soft wheat were Vaga, Utique(1.14 Kg/m^3); Hidra variety had the lowest efficiency with 0.84 Kg/m^3. Within theprivate farm, the Khiar variety had an efficiency of 0.95 Kg/m^3 (Table6).The results show the importance of supplemental irrigation in improving water use efficiency with comparison to rainfed regime.

Table 6: Water use efficiency of durum and soft wheat within the public farm

	Durum wheat					**Soft wheat**			
Variety	Karim	Khiar	Razeg	Nasr	Oum rabii	Birsa	Vaga	Utique	Hidra
Yield (Kg/ha)	4800	5200	5200	5400	4600	5400	5900	5800	4300
Water use efficiency (Kg/m^3)	0.93	1	1	1	0.89	1	1.14	1.14	0.84

IV. CONCLUSION

Field trials were conducted within the irrigated district of LAKHMESS located in Siliana and covering a surface of 1275ha completely arranged.In this irrigated district, sprinkler irrigation is the mostpracticed system.The average of rainfall is around 380 mm. Results shown that under rainfed conditions, grain yields ranged from 11 to 14 qt/ha for durum wheatand from 14 to 17 qt/ha for soft wheat.Under irrigated conditions, these yields varied from 48 to 54 qt/ha and 43 to 59 qt/ha respectively for durum and soft wheat. The average of water use efficiencies were 0.31 kg/m^3 and 0.37 kg/m^3 respectively for durum and soft wheat practiced under rainfed regime. Whereas, under irrigated conditions efficiencies were of 0.96 kg/m^3 for durum wheat and 1kg/m^3 for soft wheat. The best efficiencies for durum wheat varieties were obtained with Karim, Khiar and Nasr (1 kg/m^3). For the soft wheat, the best efficiency was recorded with Utiqueand Vaga varieties (1.14 kg/m^3) that have received an applied irrigation water amount of 100 mm divided into seedling and tillering full.

Within the private farm, the efficiency of Khiar variety was 0.95 kg/m^3; the irrigation water amount was of 150 mm applied during seedling stage, full tillering and grain filling.

Supplemental irrigation has significantly improved grain yield compared to treatment without irrigation.In fact, the increase in yields within the public farm is 397 % for durum wheat, 347 % for soft wheatand 490 % for the Khiar variety. It also improved the water use efficiency (300% and 277%) respectively for durum and soft wheat.

The results of this study show that:

- The varieties of durum wheat (Karim, Khiar, Nasr) and soft wheat (Vaga, Utique) valorize well waterand can be popularized among farmers in the region.
- The supplemental irrigation improves and stabilizes the grain yield in arid sowing, where water is a limiting factor.

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