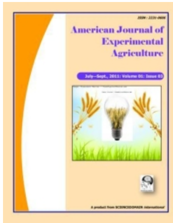

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Wheat Culture Water Needs Diagnosis Carried Out in the Sidi Bel Abbes Semi Arid Valley

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Authors' contributions

This work was carried out in collaboration between all authors. Author BM designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author NLB supervised the work and author SL carried out climatic data, when authors YA and KM managed the analyses of the study and managed the literature searches. Finally the author MA performed the statistical analysis and achieved the whole translation. All authors read and approved the final manuscript.

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ABSTRACT

The Useful Agricultural Area Management Mode in the region of Sidi Bel Abbes reveals prima facie an underutilization of the region's agricultural potential cause of low rainfall level and particularly random distribution often results in a situation of cruel water stress throughout the phenological stages of cereals.
Some daily, monthly and decadal climate parameters, as rainfalls, Potential Evapotranspiration, Maximal Evapotranspiration and temperature and their evolution studies, related to the different stages of development of this culture, helps to identify the phases during which water consumption is really urging. Knowledge of this plant high water demand allows us to target the best moment to palliate those needs to enhance the final productivity of this crop in the plain of Sidi Bel Abbes northwestern Algeria at the Mediterranean Sea. Works during the 2007 - 2011 campaign on "Waha" durum variety

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showed that the wheat water needs are bound to variations in the intensity of the climatic demand. This one, taken over from planting to heading stage reached an amount of 396 mm while durum wheat evoluting in terms of maximum irrigation consumes an equivalent of 351.5 mm average of water. This sentence implies the importance of the water problem facing the cereal, especially those of short cycle in the semi arid areas. Durum wheat consumes an average 74% of its needs, worth of 268.60 mm of water over a period from the third decade of March to the first half of May when the rainfall recorded during the same period with an average of 34.46 mm, covers only 13% of total crops water requirements. The large amount of this deficit clearly accused justifies the very pronounced low grain yields recorded in the region. Hence, the productivity of this crop depends crucially on the choice of a tolerant genotype to semi arid conditions on one hand and the use of supplemental irrigation on the other hand taking into account the requirements of the culture. Wheat crop coefficients determined for the region permit an efficient irrigation application.

Keywords: Wheat culture; water needs; semi-arid; evapotranspiration.

1. INTRODUCTION

Situations of water stress that begin to feel certain previously wet enough regions, has led researchers to focus, more closely, on considering the optimal conditions for water use for maximum yield [1,2].

The soil occupation analysis in the region of Sidi Bel Abbes reveals the dominance of cereals to which a considerable part of the area is reserved annually [3,4]. Hence, according to the Departmental Agricultural Services nearly 200.000 Ha so 50% of the Utile Agricultural Area is allowed to cereals while about 40% of this area is left fallow. Therefore, Wheat crop is subject to variable and poor rainfall patterns resulting in severe water stress and limiting the global produce over a century [5]. Inadequate and erratic rainfall inputs plus the limited water resources of the region are a major constraint severely limiting any program of recovery and improvement of agricultural production [6]. In recent days, gravity system irrigation is predominant implying a significant waste of the resource already affected by the problem of aridity [7]. This situation requires an urgent extensive research program that will gradually lead to a data mastering necessary to conduct appropriate irrigation [8,9].

This paper seeks to show a better understanding of the water cycle part for greater control of relationships linking climate, soil and vegetation in order to establish a referential of crops' water needs according to the major crops needs growing in the region.

2. MATERIALS AND METHODS

The studied variety of winter crop is Waha. It is a winter wheat and has to be planted in autumn, preferably in late September because prolonged exposure to cold temperatures is necessary for head initiation, referred to as vernalization [10].

Land and water scarcity are major constraints to food production required for meeting the quantitative and qualitative shifts of the world's demand in the mid-twenty-first century. Whereas land and water availability are constrained on a global scale, there are important regional and crop-specific differences that need to be understood, quantified and managed [11].

Concerning durum wheat, a lot of water consumption evaluations have been naturally conducted by several authors, but none of these concerns our province, even if it is a good and very ancient cereal region. The term water productivity is defined as the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water [12]. Winter wheat production can be improved and input costs reduced with good knowledge of growth and development. One have to learn and to recognize the various growth stages and the impact of various management inputs [13].

The delineation of water stress and assessing its importance in different stages of considered cereal growth cycle is based on the following sequence of events [5]:

- Calculation of Potential Evapotranspiration (PET) with the region climatic data using the method of TURK.

- Determination of wheat daily water consumption by the method of lysimeter boxes during different phenological stages.

- Evaluation of the impact of climatic factors on water consumption.

- Estimation of crop cultivation coefficient related to phenological stages.

The principle of culture water consumption evaluation is based on the model of water balance. The method involves measuring the inflow and outflow of water in the system soil-plant maintaining the conditions for a sufficient water supply.

For the purposes of such a study, one has referred to an experimental site in the station of Lamtar which was an ancient drained marshland located at an altitude of 560 m and of 35°11 North Latitude and 0°67 West longitude [6]. The study area is characterized by low rainfall rarely exceeding 400 mm per year. The irregular rainfall occurs mainly in the stormy form mainly in autumn and secondary in winter. The insolation is very high and reaches an average of 2683 hours per year. The dry season begins in late April and extends until mid October. The intense evaporation of about 1730 mm per annum is maximal in the dry period. Relative humidity above 70% during seven months in the year from the month of October has a minimum estimated of 55% in summer [7]. The critical period of frosts lasts from December to February and has nearly 20 days of very low temperatures.

Table 1 shows that the thermal regimes are especially contrasted between wet and dry seasons.

The annual volume of rainfall is very low and their seasonal distribution highlights a very strong relation between temperature and rainfall regimes.

Table 1. Climatic data of the plain of Sidi Bel Abbes (Period 2007 to 2011)

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
T° max	30.1	24.72	18.27	15.87	15.25	16.8	20.23	22.53	26.02	31.12	35.2
T° mini	17.23	10.27	7.37	4.95	2.9	3.67	4.2	5.7	10.37	13.5	16.47
T° mean	23.66	17.49	12.82	10.41	9.07	10.23	12.21	14.11	18.19	22.31	25.83
Pluvio (mm)	30.53	25.42	47.73	30.65	39.06	28.95	28.07	11.03	21.12	0.8	0
Days of rain	4	4.5	7.33	6.5	9.75	2.5	4.5	1.75	3.5	0.75	0
Evaporat (mm)	211.5	161.5	103.2	95.25	96.75	94.75	138.7	182.2	231.5	298	336.7
Insolat (hours)	269.7	180.4	203	199.7	202.7	226.5	256.2	305	300.2	359.5	376.5
Humidity (%)	66.5	69	76.25	75	75.25	74.25	68.75	62.5	61.25	51.5	46
Frosts (jour)	0	0.25	3.5	9.75	12.5	10.75	6	1.25	0	0	0
Wind (m/s)	2.1	1.65	2.35	2.30	1.5	1.05	1.25	3.25	2.2	1.8	1.9

The experimental device is based on measuring water consumption by using four Lysimeter boxes installed since February 1997 and completed by a similar in nature soil to that of the guard ring. The boxes contain at their lower level drainage channel a layer of gravel and coarse sand to facilitate drainage percolation. The adopted approach relies on monitoring the daily consumption of durum wheat during its growing season and production. The principle is to provide a daily volume of water measured in advance and collect and measure percolated water while taking into account in calculated consumption possible rainfall contributions.

The volume of consumed water is given by the following relations:
-Case of a non-rainy day:

(Irrigation Water - Water drained)/3.15 = Water consumption (mm).
-Case of a rainy day:

((Rainwater x 3.15) + (Water Irrigation - Water drained))/3.15 = Water consumption (mm).
3.15 factor represents the area of box lysimeters expressed in square meters.

Alongside this operation, the dates and duration of phenological stages were identified to quantify the water requirements for each phase of the cereal development. Table 2 shows the average daily consumption calculated for a period of four years from 2007 to 2011. It is clear that consumption is still low for the months of January and February (stages-germination and seedling emergence) increased rapidly to reach high values for periods of April and May (stages of elongating and heading).

Plantings were manually conducted January 10 at a rate of 120 kg/ha for lysimeter boxes and planter concerning the 1000 m^2 of guard ring. The Culture set up is of WAHA durum wheat variety famous for its adaptation to environmental conditions. Fertilizers background (P and K) were scattered one month before planting to moderate doses of 100 and 80 u/ha, respectively. The nitrate fertilizer were split over two periods, 1/3 at the upstage up and 2/3 at tillering stage, the total intake is about 80 u/ha. The boxes were brought to field capacity by January 8, two days before planting, the duration of 48 hours being the time required for bleeding-off a soil of silt clay nature. The relative humidity at field capacity is 24%. Irrigation is conducted daily and the amount of drained water is collected and measured 24 hours after each irrigation. For a better control of the operation, one maintained the difference between the brought quantity and the volume collected between 10 and 20% of the irrigation dose.

Table 2. Average daily water consumption from 2007 to 2011 in mm/day

Day\Month	January	February	March	April	May	June
1		1.23	1.1	3.99	4.38	4.15
2		1.02	1.84	4.45	5.50	4.24
3		0.88	1.00	4.77	6.10	3.61
4		1.08	1.77	4.27	6,13	2.80
5		1.24	1.56	5.21	5.95	2,74
6		1.20	2.68	3.63	5.15	2.69
7		1.48	1.79	3.59	5.81	2.69
8		0.97	2.05	3.95	5.86	2.31
9		0.93	1.79	4.53	5.25	2.36
10	0.575	0.90	1.93	4.94	5.40	2.16
11	0.72	0.75	2.53	4.57	5.18	
12	0.80	0.80	2.63	5.24	5.42	
13	0.84	0.96	2.51	4.56	5.10	
14	0.72	0.81	1.88	4.45	4.83	
15	0.75	1.04	2.18	4.59	4.30	
16	0.79	1.38	2.69	4.55	4.46	
17	0.81	1.03	2.82	4.30	5.50	
18	0.59	1.10	2.45	5.36	4.83	
19	0.78	1.28	2.51	5.27	4.47	
20	0.69	1.84	2.27	4.87	3.94	
21	0.85	1.47	2.45	5.60	3.49	
22	0.90	1.66	1.26	5.40	3.61	
23	0.79	1.76	2.12	4.98	3.88	
24	1.03	1.57	2.07	5.28	4.51	
25	0.65	1.78	2.40	4.74	4.05	
26	0.64	1.59	3.53	5.06	3.80	
27	0.67	1.30	2.30	5.33	3.98	
28	0.86	0.95	3.31	5.65	4.18	
29	0.79	0.31	2.85	4.21	3.95	
30	1.1		2.27	4.41	3.86	
31	1.07		2.49		3.61	

The PET is estimated using the TURK formula. The data values are determined by decade according to the following equation: PET (mm/10 days) = 0.13 x T x (Rg + 50)/T + 15 With Rg = Rt x (a + b x h/H) and Rg is the Global radiation in cal/cm^2, Ra: Theoretical radiation or extra-terrestrial also in cal/cm^2, h the Real Duration of sunshine (hours) given by heliograph

And H is the real Length of the day (theoretical value) given by the ephemeris, depending on the location latitude. Empirical coefficients a and b were set to 0.18 and 0.68, respectively. The low climatic demand for the months of January and February increased steadily and proportionally to the global radiation reaching high values decadal in June (Table 3).

Table 3. Decadal PET according to TURK relation and from 2007 to 2011

Month	h/H	Ra (cal/cm^2)	Rg (cal/cm^2)	PET mm/10days
	0.649	406.5	252.26	14.55
January	0.641	429.4	264.53	15.14
	0.627	437	265.09	14.64
	0.761	508.8	350.81	20,24
February	0.742	557	376.45	21.58
	0.721	604	400.8	22.87
	0.722	652	429.05	27.12
Mars	0.702	705,5	460.25	28.90
	0.684	759,5	486.92	30,46
	0.817	809,5	592.82	39.33
April	0.797	852	613.52	40.62
	0.781	889,5	630.97	41.71
	0.732	921	624.14	46.5
May	0.719	946,5	632.43	47.07
	0.707	965,5	638.17	47.48
	0.854	978	744.20	61.44
June	0.846	983,5	748.49	61.78
	0.846	983	797.33	65.53

Water consumption of durum wheat is changing, largely based on the evapotranspiration of the mid and varies quantitatively with the phenological stages of the culture. It is quite low but relatively in a steady evolution at the upstage status to the first decade of the tillers formation. It then increases dramatically with the rise of PET to early bolting stage where there is an increased consumption of water. This latter diminished somewhat in intensity with the lowering of PET, regardless of it and reached a maximum at the full heading stage. It fell sharply after full maturity until the grains. (Table 4).

Table 4. Maximum evapotranspiration (MET) of durum wheat related to the PET in the region (from 2007 to 2011)

	Decade	January	February	Mars	April	May	June
	1	0	10.87	17.51	43.33	55.53	29.75
MET	2	7.49	10.99	24.47	47.76	48.02	0
	3	9.37	12.39	27.05	50.66	42.92	0
	1	14.55	20.24	27.12	39.33	46.5	61.44
PET	2	15.14	21.58	28.90	40.62	47.07	61.78
	3	14.64	22.87	30.46	41.71	47.48	65.05

3. RESULTS AND DISCUSSION

Monitoring the evolution of water consumption of durum wheat, compared to the climatic demand of the medium during the growth cycle of the culture reveals that the maximum evapotranspiration MET over potential evapotranspiration PET from early April, corresponding to the wheat bolting phase to the end of the second decade of May date of the wheat heading stage release (Fig. 1).

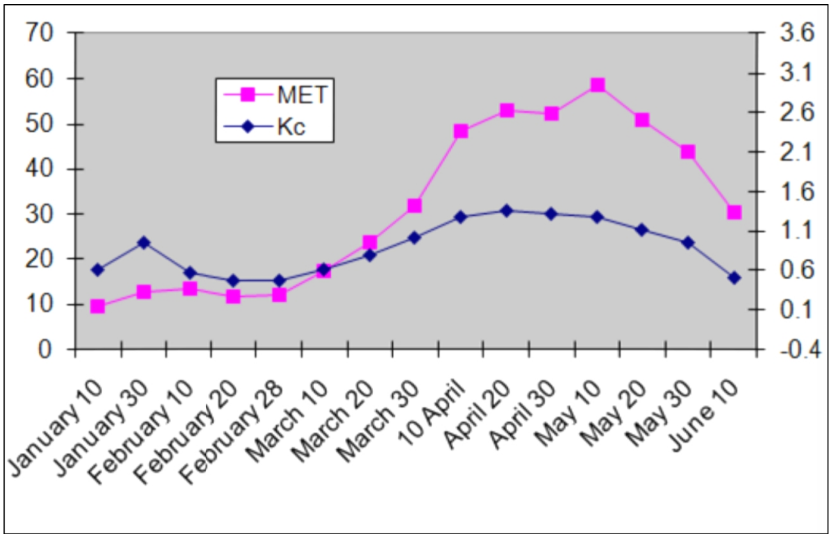

Fig. 1. Durum wheat decadal consumption related to the region's PET

Water consumption, largely due to the variation of the evaporative demand of the environment is also varying with the physiological changes that began during the growth cycle culture course.

This water consumption, measured from the early levee stage to the end of the ears formation, is valued at the 351.52 mm region's rain average. Its distribution by phenological stage showed that wheat consumed 8.45% water at emergence stage, 15.13% at tillering stage, 38.60% at the stage of bolting and 37.82% at the heading stage. Practical results are confined in the following Table 5. Wheat uses the maximum of its water needs during the last two stages of the vegetative cycle which are the wheat growth in height stage and the heading formation stage.

During these two periods running from March 23rd to May 14th, periods where physiological activities of the culture are very intense, wheat consumes nearly 76.42% the 3/4 of its global water needs (Fig. 2).

Table 5. Durum wheat water average consumption by phenological stages (from 2007 to 2011)

Stages	Duration	Consumptions (mm)
Sowing - Lifting	10 January au 28 January	14.47
Lifting	29 January au 23 February	29.72
Tillering	24 February au 22 Mars	53.19
Bolting	23 Mars au 24 April	135.66
Heading	25 April au 20 May	132.95
Maturation	21 May au 10 June	72.09

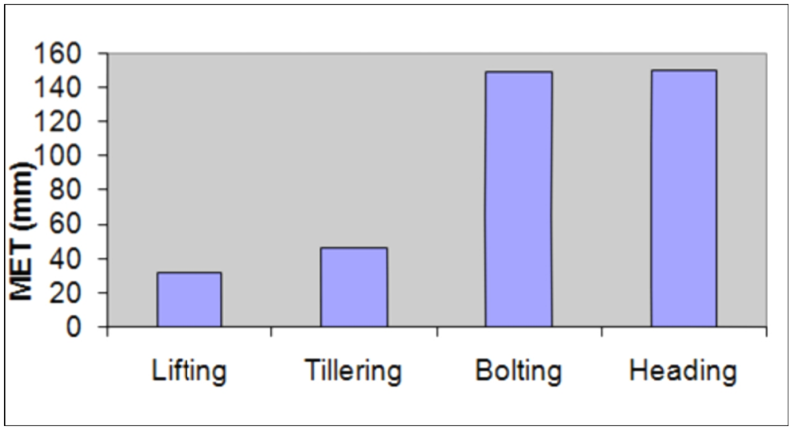

Fig. 2. Durum wheat averaged consumption by phenological stages in mm

Water consumption follows irregularly the gradual increase of average temperatures during the growth cycle of the cereal. No direct proportional link is to state between volume consumed and temperature. These latter changes significantly during the months of March and April, period when the crop, in full tillering and bolting stages, are dramatically increasing their consumption. This latter drops in the second decade of May and declines continuously with the increase of thermal environment intensity. The atmosphere relative humidity seems relatively affect water consumption of durum wheat. The latter is fairly low at the start of the vegetation where the air humidity registers high values close to 75%. It then changes slightly with the gradual decrease of the relative humidity reducing to 68% at tillering stage. It then rises sharply from the month of April (in the entering of the active phase of cereal bolting) until the third decade of May (which corresponds to the end of wheat heading stage) where the humidity is lowered around 60% (see Fig. 3). The impact of low temperatures on water consumption appears to be related to the number of frost days per month. It is feeble in lifting stage where there was a monthly average of not less than 11 days of frost during the months of January and February. It improves in tillering where one register only 6 days of frost in May and increased significantly after the complete disappearance of frostiness during the boot and heading stages.

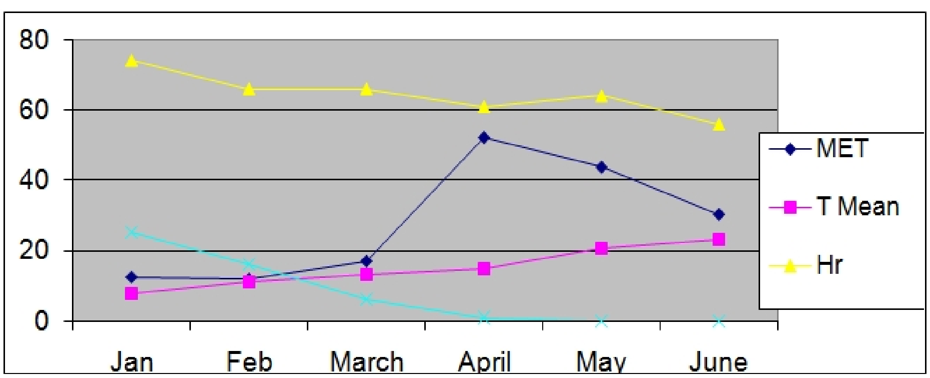

Fig. 3. ETM Evolution related to temperatures, air relative humidity and frostiness

The maximum evapotranspiration evolves significantly during the stages of seedling, lifting and tillering and rarely exceeds 80 mm with an average intake rainfall of 20 mm by phenological stage. It then increases sharply for stage of monting and heading with a sharp decline in contributions rainfall coinciding with high climatic demand and the raising of the average temperature of air (Fig. 4).

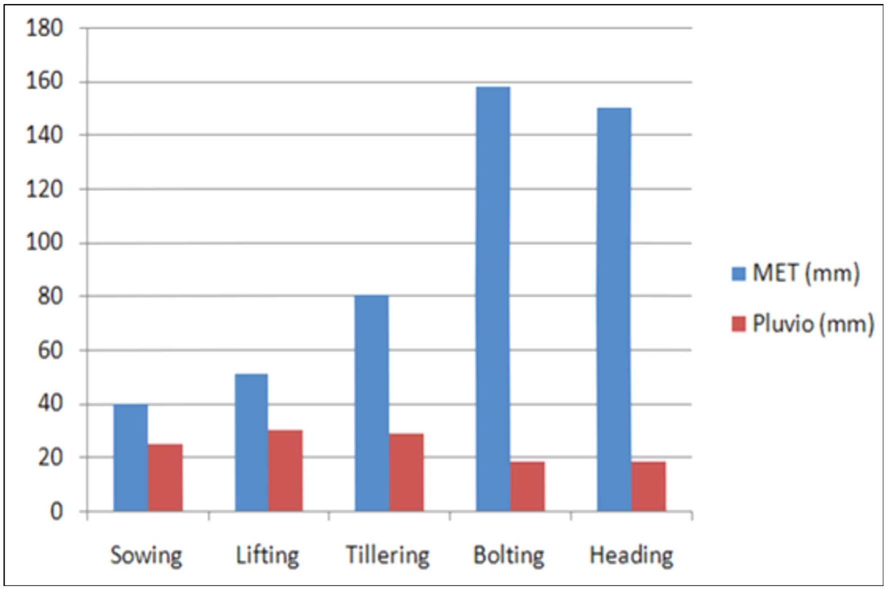

Fig. 4. Durum Wheat consumption related to pluviometric incomings

Determined according to the ETM ration (corresponding to the maximum consumption of wheat) and the ETP (representing the climatic demand calculated on the basis of the TURC formula), the cultural coefficient changes during the growth cycle of the culture and varies in value, according to the cereal different phenological stages.

The obtained results during the monitoring of wheat water consumption showed that the crop coefficient was quite low during the lifting phase (0.56) changing significantly during the formation of tillers (0.67), increased sharply during the bolting (1.05) to reach the peak during the heading phase (1.14) and then decreased gradually at the beginning of grain maturating to the minimum value of 0.48 (Table 6).

Table 6. Evolution of Kc by phenological stage of durum

Stades	Decade 1	Decade 2	Decade 3	Average	Duration
Lifting	0.64	0.54	0.50	0.56	29/ 1- 23/ 2
Tillering	0.54	0.64	0.85	0.67	24/2 - 22/3
Bolting	0.88	1.10	1.17	1.05	23/3 - 24/4
Heading	1.21	1.19	1.02	1.14	25/4 - 20/5
Maturation		0.90	0.48	0.69	21/5 - 10/6

The cultural coefficient of the cereal crop follows relatively changes in climatic demand during the growing period of culture. It increases with the gradual rise of the ETP from lifting stage to tillering one, stabilizes at the same time as the evapotranspiration of heading stage in the beginning of bolting and then decreases with the increase in ETP till grains maturity (Fig. 5).

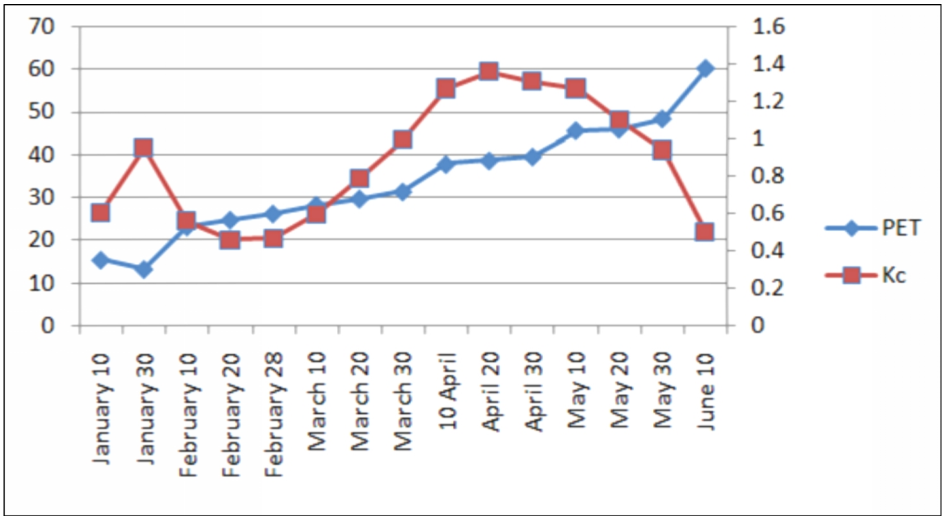

Fig. 5. Kc evolution reported to the region's PET

4. CONCLUSION

The region of Sidi Bel Abbes has a soil potential diversified favorable to an intensive agriculture particularly in the plains and high plains areas of the district.

Therefore, inadequate and erratic rainfalls added to the intensity of evaporation phenomena constitute an insurmountable obstacle to any program of agricultural development.

The use of underground water appears as the only way to overcome the shortcomings of rainfall incoming. Water resources are already severely affected by the problem of aridity, the problem seems to be clearly limited to proper management of water potential of the region.

The need for reasonable irrigation is needed, then that implies knowledge of most exploited crops water requirements in the region.

Works during the 2007 - 2011 campaign on "Waha" durum variety showed that the wheat water needs are bound to variations in the intensity of the climatic demand. This one, taken over from planting to heading stage reached an amount of 396 mm while durum wheat evoluting in terms of maximum irrigation consumes an equivalent of 351.5 mm average of water. This sentence implies the importance of the water problem facing the cereal, especially those of short cycle in the semi arid areas

The monitoring of wheat consumption, quantified by phenological stage, highlighted the water sensitivity phases determining the yields. Durum wheat consumes an average 74% of its needs, worth of 268.60 mm of water over a period from the third decade of March to the first half of May when the rainfall recorded during the same period with an average of 34.46 mm, covers only 13% of total crops water requirements. The large amount of this deficit clearly accused justifies the very pronounced low grain yields recorded in the region. Hence, the productivity of this crop depends crucially on the choice of a tolerant genotype to semi arid conditions on one hand and the use of supplemental irrigation on the other hand taking into account the requirements of the culture.

The main conclusion is that the wheat crop coefficients, which vary according to the phenological stages of wheat, determined in the region permits an efficient irrigation techniques use adapted to this semi arid area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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