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Decadal Evaluation of Durum Wheat Water Requirements to Improve Rainfed Agriculture under Semi-Arid conditions

Chennafi Houria[1a]*

[a]Faculty of Lif and Natural Sciences, Agronomy Department, University Ferhat Abbas Sétif, 19000 (Algeria)

Abstract

The estimating water requirement of durum wheat is a technical tool which seats a practical water management. The water needs of durum wheat grown on the High Plains of Sétif raised sharply by the first decade of march. In fact, it reached 46 mm from the mid of the tillering to the mid of jointing (march - april) and raised to 103 mm during the booting –heading growth phase. For a crop cycle lasting from the mid-november to the third decade of may, the crop water requirements were estimated to 672 mm. The periods with the high water demand coincide with limited offer. These results suggested applying limited water quantities to reduce water deficit effect on the crop. This contributes to stabilize wheat production through soil conservation and durable management of the scarce water resources in semi-arid area.

Key words: decadal water requirements – limited irrigation - durum wheat – durable management-

1. Introduction

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: *h_chenafi@yahoo.fr*

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Durum wheat is largely grown in the semi-arid area of Algeria. However, precipitations are insufficient and variable, limiting yield potential. Low and instability yields are mainly due to Climatic constraints and to inappropriate farming techniques. Indeed, water deficit of variable intensity and events, causes yield reduction. It is the principal factor limiting cereals production under semi-arid conditions [1, 2, 3]. Durum wheat is considered as drought tolerant species. However, under harsh conditions of the High Plateaus, this crop is very sensitive to abiotic stress [4]. To reduce water deficit effects on crop production, the characterization of natural environment potentialities is important to choose crop management by adopting appropriated agricultural techniques and tolerant varieties with short vegetative cycle, to avoid terminal abiotic stress and to minimize yield reduction [5, 6]. However, in arid and semi-arid areas the water management in rainfed agriculture requires the practice of deficit irrigation. It is an alternative to increase grain yield, in fact it remains as the most efficient technique and its effects are obvious and immediate, principally when available water is well managed [7, 8, 9].

The High Plateaus of Sétif, Eastern Algéria, are located in the semi-arid bioclimatic stage. In this area, durum wheat is conducted in rainfed conditions characterized by great climate deficit variation, two marked seasons: cold winter and, hot and dry summer. The 70% of rainfall are recorded in winter, in spring terminal stresses become severe, caused by sharp rise of the temperature and less rainfall events. Soil is calcareous, calcium carbonate tenor is appreciable exceeding 35%, low level of organic matter, soil depth and refill capacity during winter rainfall are lows [9]. Therefore, water valorisation is a determining factor of the production under semi-arid climate. Indeed, water is necessary to reduce the effects of the climatic constraints, for increasing and in stabilizing yield [10]. The water is scarce, however, the management of the available water needs to be optimized. Thus, crop water requirements require to be managed through small amounts water applied by limited irrigation. The crop water requirement is defined as the height of water necessary to satisfy the crop evapotranspiration [11]. It evaluated starting from the climatic request and the crop coefficient [12]. The crop water requirements are function of the vegetative stage, the environmental conditions and the cultivation methods applied [11]. The present study raises an approach of assessing crop water of durum wheat (*Triticum durum* Desf.) conducted in the High Plateaus of Sétif (Eastern Algérie).

2. Materials and methods

The climate deficit study and the crop evapotranspiration determination (Etc) were estimated over 23 years of the period 1981/2003. These parameters were calculated by using climatic daily data unregistered by Weather National Office (WNO) of Sétif, situated at the latitude 36°11'N, Longitude 5°25' E and altitude 1033 m above sea level.

According to [13], the deficit climate is calculated using the model:

$$D_c = R - ET_P \qquad (1)$$

Dc= deficit climate (mm), R= Rain, ETp= Potential evapotranspiration (mm)

The crop evapotranspiration (ETc) is the crop water demand (mm), determined by the Turc equation mentioned by [14]):

$$ETc = ETp \ X \ kc \qquad (2)$$

ETc= crop evapotranspiration (mm), kc= Crop coefficient

The decadal potential evapotranspiration (ETp) is calculated with the values of temperatures (T°C), solar radiation (RG), relative humidity (HR%) and relative solar (h/H). The Turc method gave satisfactory results in Mediterranean climate [14, 15]. The application of Turc formula depends on the relative humidity. In this case, where the humidity is above 50%, the ETp is deducted by:

$$ET_P = 0,13 \left(t / t + 15 \right) (RG+50) \qquad (3)$$

In cases where the humidity is below 50%, the variant formula is:

$$ET_P = 0,13 \left(t / t + 15 \right) (RG+50) \left[1 + (50 - HR)/70\right] \qquad (4)$$

t= Air mean temperature (°C), HR= Relative humidity air (%); h/H= relative solar, 0.13= decadal coefficient. RG= Total radiation calculated by:

$$RG \ (cal \ cm^{-2} \ day^{-1}) = Rg_0 \ (0,29 \cos \lambda + 0,52 \ h/H) \qquad (5)$$

The irrigation water amount to apply to crop is defined by the agricultural deficit. It calculated according to the approach methods used by [14, 16]:

$$D_a = kc \ x \ ET_P - R - \Delta_S \qquad (6)$$

Da= agricultural deficit (mm), R= Rain, $\Delta_{S=}$ Available soil water (negligible after long dry period).

The data were analyzed using the Microsoft EXEL 2003.

3. Results and Discussion

3.1. Mean climate deficit evaluation

Analysis of decadal climate balance reveals great variability inter-crop-seasons (Figure 1). The mean climate deficit year of 23 studies crop years is of 1278.0 mm. The year 1983 is the most deficient, with an average value of 1946.0 mm. The crop year 2002/2003 was relatively the wettest with a mean climate deficit of 558.0 mm (Figure 1 A). These results corroborated those of Mendes et *al.*, [17] who reported similar values, with a mean deficit year of 1235.0 mm, for cumulative precipitations of 391.0 mm and 1626.0 mm of potential evapotranspiration. Against, Bonneau et Souchier [13] mentioned value of climate balance of 700.0 mm, while Al-Jihad [18] founded an average of 917.0 mm. The large variability, in arid and semi-arid climate Mediterranean zone is characterized by a high rainfall variability associated with frequent dry periods that remain independent to the cumulative total year (Guyot; Ceballos et *al.*,) [19, 20]. The crop season 1996/1997, with an average of 754.0 mm was the driest and that of the 2002/203 was relatively wetter with 60.0 mm (Figure 1B). For the crop vegetative cycle which extends from the third decade of october to that of may, the mean climate balance of the 23 studies crop seasons was 433.0 mm (figure 1B, table 1).

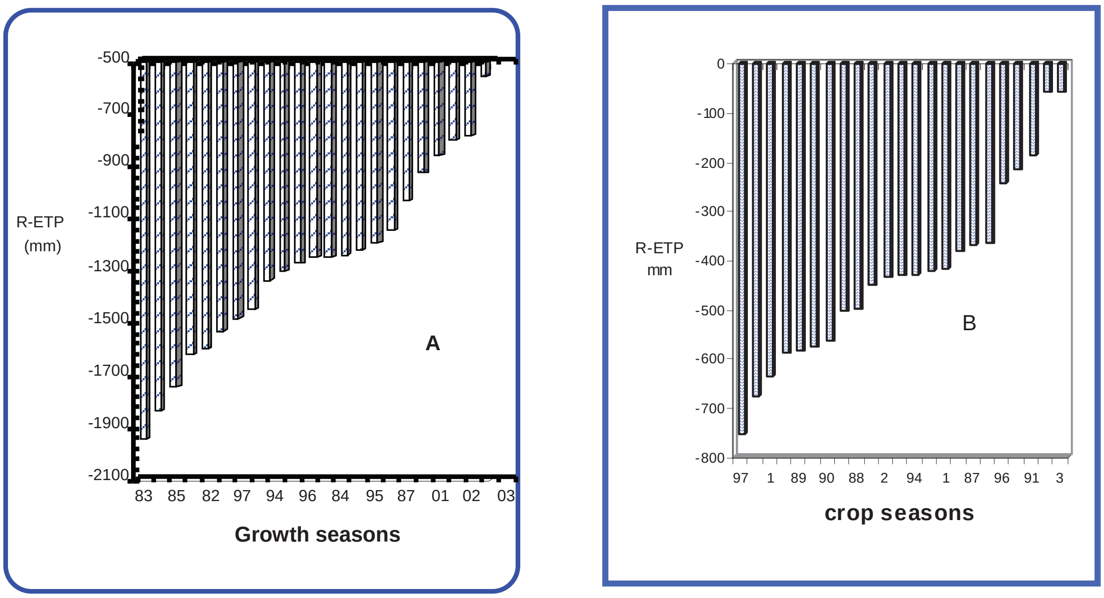

Fig.1. Variation of the year climate balance (September– august, A) and of wheat crop vegetative cycle (October–may, B) of the 23 studies crop seasons

3.2. Water requirement of durum wheat crop

In the High Plateaus, water requirements of durum wheat rise from the first decade of march. Only for the months of march and april, actual evapotranspiration corresponding to the quantity of water needed for growing wheat, reached 276.0 mm (table 1). Deficiency value of actual evapotranspiration (ETc) represents the actual evaporate amount water by the plant, it depends on the level of potential evapotranspiration, the soil moisture and stomatal regulation (Tuzet et Perrier) [21]. In this study, the used values of crop coefficient (Kc) are for initial phase 0.5, stage 2-3 nods 1.2, phase swelling-heading + 15 days 1.5 and 0,5 for the grain filling period (Doorenbos et Pruitt; Hamadi et Charfi) [10, 22]. The maximum value of Kc is reached at the heading stage.

The highest requirement water is observed since the first decade of may. At the 3rd decade of may, the cumulative requirement water is 666 mm. From the first decade of april to the 3 third of may, the value is of 450 mm (table 1). Eliard [23] reported 450 mm and he considered that the critical period is 15 days before and 10 days after heading. Chennafi [24] mentioned 608 mm of water requirements of durum wheat under the High Plateaus conditions of Sétif; Baldy [25] reported 450 to 600 mm. The results revealed that durum wheat is required on water. The mean decadal at the tillering and at the two nodes stages is 55 mm (april). The Consumption amounts rises to 103 mm in heading-flowering stage (Table 1). Clement et Galand [16] indicated for cereals, that water consumption after heading is half the amount needed during the full cycle.

These results suggested that effects on yield are variable to the degree and to the duration of water deficiency and to the adjustment capacity of the stresses plant [25]. It inducted a water deficit on soil which reduced wheat potential productivity. High Plateaus climate conditions are very limited on water. In addition, the evaporation air is very high, and therefore reduces the water use efficiency (Jouve) [26]. According to Chennafi et *al.*, [27] water use efficiency of durum wheat varied from 3.2 to 14 kg ha^{-1} mm^{-1} depending on weather conditions, variety and especially the vegetative stage of water supply. Pereira et *al.*, [28] emphasized that requirements water concept is the basis for the applying water management of irrigation. The assessment of water requirement manages better the supply of the amounts limited water to improve the potential production of cereal in semi-arid zone.

Table 1. Mean decadal values of rainfall (R) of potential evapotranspiration (ETp) , crop evapotranspiration ('ETc) and of climate deficit (R-ETc), in (mm) during the crop wheat cycle for the period 1981-2003 (Sétif, Algeria)

Months	Decades	Rain(mm)	ETP/dec	kc	R-ETP	ETc	R-ETc
O	d1	15	46	0,5	-31	23	-8
O	d2	10	40	0,5	-29	20	-9
O	d3	11	35	0,5	-12	18	-7
N	d1	14	28	0,5	-14	14	0
N	d2	9	23	0,5	-14	11	-2
N	d3	12	20	0,5	-17	10	2
D	d1	16	15	0,5	1	8	9
D	d2	13	15	0,5	-2	8	5
D	d3	17	13	0,5	4	6	11
J	d1	15	12	0,7	3	8	6
J	d2	12	15	0,7	-3	11	1
J	d3	11	14	0,7	-3	10	1
F	d1	14	16	0,7	-1	11	3
F	d2	13	20	0,7	-7	14	-1
F	d3	6	27	0,7	-20	19	-12
M	d1	11	26	1,2	-15	31	-20
M	d2	12	31	1,2	-19	37	-25
M	d3	10	36	1,2	-26	43	-34
A	d1	11	43	1,2	-32	51	-40
A	d2	9	46	1,2	-37	56	-47
A	d3	15	49	1,2	-33	58	-43
M	d1	14	59	1,5	-45	88	-74
M	d2	14	63	1,5	-49	94	-80
M	d3	17	68	1,5	-51	103	-85
Cycle	Oct- May	302	760		-454	752	-450
Cycle	Trd Nov- May	243	588		-353	666	-423

3. 3. Irrigation water requirements

The approach of decadal water deficit indicates that only winter period extending from the first of december to the second of february decades recharged the soil profile on moisture (Figure 4). The rest of the plant cycle is subjected to water deficit more or less intense. At the beginning of march, the soil water of surface horizons accessible to the roots decreases.

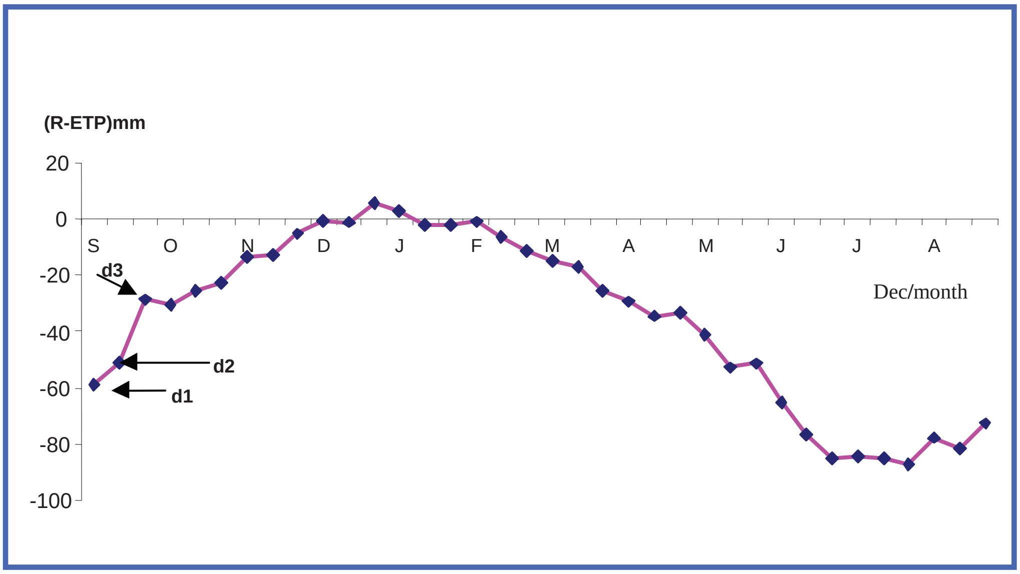

Fig. 4. Mean decadal (d) water deficit. Period 1981-2003 (Sétif, Algeria)

The decadal agricultural water deficit (Da) represents the irrigation water requirement (IWR) of crop (Ollier et Poirée) [14]. Pereira et *al.*, [28] defined the IWR as the net water high to apply to crop to satisfy its specific needs. Early sowing is favored, it allows to crops to avoid drought of late season, characteristic of semi-arid environments. Planting period in the High Plateaus region of Sétif is marked by negligible soil stock water. Indeed, this period is preceded by a long dry period with negative climate balance. From the third decade of november to that of may, cumulative irrigation demand is estimated to 423.0 mm (Table 3). These results supported the suggestions of Kang et *al.*, [29] who describe that limited irrigation means that the soil water deficit is controlled at certain stages of crop growth, a practice that became more important in area where water resources is limited.

The research methodology was identified by experiments during several growth seasons wheat [9]. The crop water requirement positioned with the climate deficit, combined to the controlled soil water balance, determined the irrigation water requirement. These parameters were quantified to manage the limited water irrigation. Therefore, when water is available, the practical of regulated deficit irrigation increased wheat yields in rainfed semi-arid conditions [30, 9]. In the other hand, when water is scarce at a crop stage, deficit irrigation was practiced at critical crop growth periods by applying small amounts water [27, 9].

Conclusion

In the High Plateau of Sétif, water deficit is observed at sow period and from the end of winter. The mean of water demand of durum wheat varied from 31mm to 103 mm per decade for the periods of march to the end of may. This area is confronted to a severe water deficit at the beginning of march, from which water demand becomes important. Wheat evapotranspiration is of 666 mm for a vegetative crop cycle between third november to may decades. The irrigation water requirements are estimated as 450 mm on mean crop season. Unfavorable cropping seasons are characterized by rainfall inferior to 262 mm and which represents 50% of crop water requirement, it accounts 50% of studies crop seasons. These results suggested the urgency water management with good water resources governance. The applying of limited amounts water during critical stages will contribute to increasing yields, minimizing the risk of the climate constraint, and will ensure a sustainable development of agricultural production in this area. With conjunctive use of an appropriated cultural practices and deficit irrigation improve crop production under rainfed semi-arid conditions.

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