International Journal of Water Resources and Arid Environments 7(2): 153-159, 2018
ISSN 2079-7079

Effects of Drought on the Production of Winter Wheat in Semi-arid Zones

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Abstract: Winter wheat, as other rainfed crops, suffered from the random effects of drought. According to its occurrence during the crop cycle, drought may be decisive on the final production's quantity and quality. this paper aims, to estimate the reductions in wheat yields caused by drought through soil-plant-atmosphere interactions as well as analyzing of water deficit impact on yield of wheat for each of the main wheat phonological stages. To study the effects of drought three dates of wheat sowing were selected. The simulation was conducted in ten consecutive agricultural years (1999-2008) and for three stations, namely ORAN, SIDI BEL-ABBES and TIARET characterizing the semi-arid climate in western Algeria. CROPWAT software which incorporates the distribution of rainfall over the growing season and the deficit of water relative to potential needs was used. The methods of calculating water needs of crops are mainly based on methods presented in the FAO bulletins of irrigation and drainage. The analysis of obtained results in semi-arid Mediterranean, particularly in the north-western Algeria, show that the total seasonal rainfall is insufficient to cover the water requirements of rainfed crops, especially winter cereals. On the other hand, the rainfall distribution over time favors during the development cycle, the occurrence of periods of water stress or long that may affect the final yield. However, planting date provides suitably chosen, to some extent a more interesting biological itinerary, which subtracts the plant in such a climate hazard and dampens the reducing effects of drought.

Key words: Winter Wheat · Rainfed Crop · Drought · CROPWAT software

INTRODUCTION

The cultivation of winter wheat is mainly rainfed, particularly on the south shore of the Mediterranean. It is subject to variable rainfall patterns and often low which result in periods of drought control. This water often stressful environment imposes a limit to the expression of genetic abilities cultivars and partly explains the stagnation of performance that has not improved significantly in over a century. Indeed, as an example for the wilaya of Saida, the average annual return for the period 1871-1875 is similar to that of 1991-1995, is 6 to 8 quintals per hectare [1], the same similarity was observed for 2001-2005.

Periods of recurring droughts recorded in recent years in Algeria [2] and the weak performance of crop's yield that resulted confirm the random nature of precipitation [3] and incentives to better identify the water stress. The water stress is poorly defined when we reason at the level of phenomenological changes that occur in the body (show leaves, tillering, flowering. ..) or even cell for physiological traits (water content, sweat. ..) [4]. Daily rainfall appears to be best suited to characterize and identify the influence of this parameter on the phases of growth and development of wheat and thus better manage performance [5]. In order to study the influence of planting date on the different phenological stages of wheat we chose three planting dates and achieve a simulation of the behavior of culture with free FAO software CROPWAT.

CROPWAT is a software program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. This program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. All calculation

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procedures used in CROPWAT are based on the two FAO publications of the Irrigation and Drainage Series, namely, N°56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" [6] and N°33 titled "Yield response to water" [7].

MATERIALS AND METHODS

In this study, we used the CROPWAT software which incorporates the distribution of rainfall over the growing season and the deficit of water relative to potential needs.

The analysis is based on three experimental sites representative of grain semi arid regions of Algeria:

Oran: located in north west Algeria (Greenwich longitude 0° 37' W, latitude 35° 45' N) and characterized by a dry Mediterranean climate.

Sidi Bel Abbes: located in west of Algeria (Greenwich longitude 0° 38' W, latitude 35° 15' N) and characterized by a semi-arid climate.

Tiaret: located in south west Algeria (Greenwich longitude 1° 19' E, latitude 35° 19' N) and characterized by a sub Saharan climate.

The meteorological parameters used are:

Temperature: Maximum, minimum and average temperatures data in degrees Celsius were used.

Humidity: Relative moisture expressed in percentage or vapor pressure in kPa.

Daily Sunshine: Percentage ratio of sunshine / day length or sunshine hours.

Wind Speed: The averages daily course of wind measured 24 hours in km/day or m/s.

We adopted a simplified notation of phenological phases of wheat as follows:
Phase A: Tillering.
Phase B: Stem Extension.
Phase C: Heading.
Phase D: Ripening.

This is consistent with the rating Feekes' and Zadoks' scales [8]. It should be noted that Among the scales quantifying the development of cereal crops currently used Feekes and Zadoks scales are most common (Figure 2).

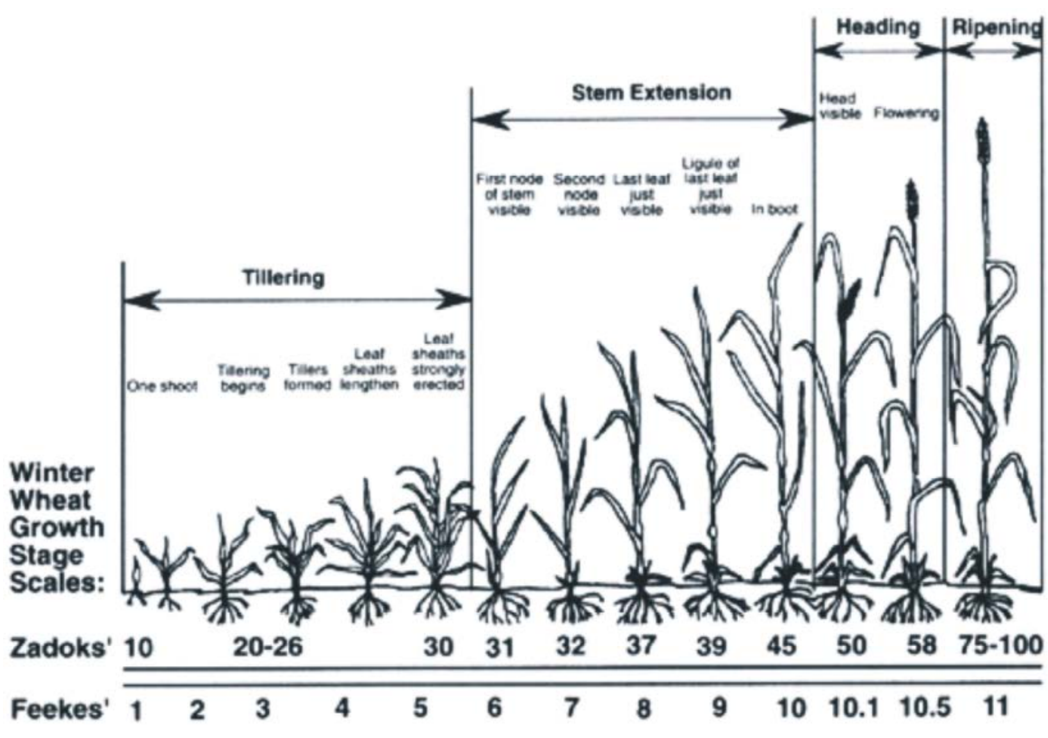

Fig. 1: Growth stages of wheat according to the Zadoks and Feekes scales [8].

RESULTS AND DISCUSSION

In general, the amount of rain, collected during the agricultural year, covers consumption needs of water at up to 55%. The water deficit that results may also involve one or more phases, the sensitivity will be decisive in the final production. For winter wheat, the first phases of the growing season are somewhat protected from the vagaries of the weather by the choice of planting date and the fact that they coincide with the rainy season. It is not the same for the other phases, which in turn suffer the effects of drought more or less severe. In particular, a lack of water phase C will result in reduced yields ranging from 4% to 31% in favorable cases.

Oran's Station (Dry Mediterranean Climate)**:** For the three planting dates selected (05/12, 15/12 and 25/12), phases A and B that include the period from sowing to flowering, have no visible negative impact on performance (Table 1).

However, the last planting date (25/12) showed that Phase B shows a yield reduction of 3.4% in 2008, accumulating a low total rainfall of 186 mm. There is also in phase C for the year 2000 a minimum yield reduction regardless of the date of planting; this is due to sufficient rainfall. On the other hand, the maximum yield reduction at the same phase averaged 36.1% for 2004 due to poor distribution of rainfall over time. A water deficit occurs in late stage (Phase D) does not induce a high variability in yields. However, late planting exposes the plant to a high water deficit in ripening step in reducing the yield of nearly 40%.

In summary, in order to limit the risk of yield loss due to water stress, it is recommended early planting, or failing to make a supplemental irrigation during times of fertilization and fruiting (Table 2).

Sidi Bel Abbes's Station (Semi-arid Climate): The rains occur usually in winter and enjoy the early development stages and ensure a smooth start of the crop. Thus the phases A and B do not suffer from water stress, did not significantly affect the level of production, with the exception of 2007 when the wheat crop has received only a small amount of water (141 mm of 323 mm needed) and unevenly distributed in time so that only 12 mm of rain are actually used by the plant during Phase B, hence the relative contribution of this phase to a lower yield (Table 3).

Inputs of rainwater (43 mm) in beginning of the stage C were insufficient to replenish the soil up to the reserve easily usable (84 mm) or even below the survival reserve (around 56 mm). This deficit has reduced the yield of 37%. Moreover, still in phase C, there is a minimal reduction in yield in 2000 and 2006 due to good rainfall annually, 408 mm and 477 mm respectively, which have limited the risk of occurrence of dry spells.

Table 1: Percentage of yield reduction by phase for Oran.

Planting date: 05/12					
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	29,9	39,3	24,2
2000	0	0	9,6	34,3	17,6
2001	0	0	20,3	37,1	25,5
2002	0	0	19,3	29,7	19
2003	0	0	30,7	37,9	37,1
2004	0	0,1	34,1	39,5	35,4
2005	0	0	25,7	39	24,8
2006	0	0	22,5	39,3	24,3
2007	0	0	37,5	39,9	33
2008	0	0	37,6	37,7	37,6
Planting date: 15/12					
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	15	34,3	27,5
2000	0	0	5,4	30,3	16,8
2001	0	0	15,1	36,8	20,7
2002	0	0	14,6	22	14,2
2003	0	0	27	34,4	28
2004	0	0	32,5	39	36,3
2005	0	0	19,8	34,3	22,8
2006	0	0	14,5	34,6	22,3
2007	0	0	27,1	37,7	30,4
2008	0	0	24,4	35	29,1

Table 1: Continued

Planting date: 25/12					
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	29,5	39,2	30,1
2000	0	0	14,2	37	22
2001	0	0	27	39,6	29,6
2002	0	0	19,1	36,5	27,7
2003	0	0	36,9	39,7	32,6
2004	0	0,8	39,7	39,7	37,3
2005	0	0	37,1	37,6	30,3
2006	0	0	29,2	39,9	29,7
2007	0	0	35,9	39,3	35,2
2008	0	6,4	34,1	39,9	34,7

Table 2: Total rainfall during the growing season and yield reduction by year and planting date for Oran.

	05/12		15/12		25/12		
Planting date Year	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)	Yield Reduction per season (%)	Annual rainfall (mm)
1999	275.8	22.5	221.9	26.2	207.5	31.1	272.4
2000	309.3	15.8	321.7	17.6	312.1	22.0	457.3
2001	300.0	20.7	279.7	25.5	274.2	29.6	351.0
2002	295.8	16.2	267.8	19.0	262.3	21.7	340.3
2003	155.5	28.8	164.8	31.1	164.9	32.6	306.5
2004	162.2	33.3	138.0	35.4	133.8	37.3	227.9
2005	313.6	22.8	293.5	26.8	247.3	30.3	402.0
2006	312.5	22.3	312.4	26.3	298.0	29.7	368.6
2007	174.6	30.4	157.5	33.0	148.4	35.2	279.4
2008	182.2	28.1	148.8	31.6	133.5	34.7	186.1

Table 3: Percentage of yield reduction by phase for Sidi Bel Abbes.

Planting date: 05/12					
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	29,5	34,8	27
2000	0	0	16,9	34,8	19,8
2001	0	0	25,7	37	29,3
2002	0	0	17,5	36,4	27,6
2003	0	0	19,5	37,5	29,4
2004	0	0,8	32,8	37,6	36,7
2005	0	0	30,2	39,4	37,6
2006	0	0	16,4	24,2	14,2
2007	0	4,4	39,9	39,1	39,9
2008	0	2,3	37,2	39,5	34,9
Planting date: 15/12					
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	29,5	34,8	27
2000	0	0	16,9	34,8	19,8
2001	0	0	25,7	37	29,3
2002	0	0	17,5	36,4	27,6
2003	0	0	19,5	37,5	29,4
2004	0	0,8	32,8	37,6	36,7
2005	0	0	30,2	39,4	37,6
2006	0	0	16,4	24,2	14,2
2007	0	4,4	39,9	39,1	39,9
2008	0	2,3	37,2	39,5	34,9

Table 3: Continued

			Planting date: 25/12		
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	19,7	27,7	27,6
2000	0	0	17	29,3	19
2001	0	0	4,4	24,4	13
2002	0	0	17,2	20,1	14
2003	0	0	18	24,5	27,2
2004	0	0	33	39,2	35,7
2005	0	0,2	14,7	36,8	29,2
2006	0	0	6,6	20,4	9,4
2007	0	0	1	24,9	11
2008	0	0	17,1	22,6	15,7

Table 4: Total rainfall during the growing season and yield reduction by year and planting date for Sidi Bel Abbes.

	05/12		15/12		25/12		
Planting date Year	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)
1999	205.0	19.2	196.0	28.2	187.7	27	285.8
2000	299.5	13.1	285.9	16.7	268.4	19.8	408.3
2001	285.0	19.4	281.2	24.8	226.3	29.3	306.1
2002	245.9	15.1	240.9	18.3	285.4	21.6	281.6
2003	287.7	16.6	282.9	20.2	280.8	28.4	335.6
2004	175.4	28.0	175.4	31.3	173.8	33.7	301.9
2005	224.2	23.3	208.7	27.8	193.2	31.6	285.4
2006	411.0	9.5	415.4	13.0	415.9	16.2	477.3
2007	132.3	34.0	153.7	36.7	116.2	38.9	322.7
2008	155.2	30.7	144.3	33.9	133.2	36.9	186.5

Table 5: Percentage of yield reduction by phase for Tiaret.

			Planting date:05/12		
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	14,7	26,3	19,2
2000	0	0	14,9	19,3	15,8
2001	0	0	6,6	15,1	7,3
2002	0	0	9,7	15,8	10,7
2003	0	0	14,9	17,8	14,2
2004	0	0.1	29,3	34,4	32,8
2005	0	0	10,3	36,2	19,5
2006	0	0.8	0,5	17,6	4,2
2007	0	0	0,5	15,7	5,1
2008	0	0	17,6	10,3	10,7

			Planting date 15/12		
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	19,7	27,7	27,6
2000	0	0	17	26,3	19
2001	0	0	4,4	24,4	13
2002	0	0	17,2	20,1	14
2003	0	0	18	24,5	27,2
2004	0	0	33	39,2	35,7
2005	0	0,2	14,7	36,8	26,2
2006	0	0	6,6	20,4	9,4
2007	0	0	1	24,9	11
2008	0	0.7	17,1	22,6	15,7

Table 5: Continued

			Planting date: 25/12		
Year	Phase A	Phase B	Phase C	Phase D	Agricultural season
1999	0	0	14,7	19,1	14,9
2000	0	0	15,4	15,5	15,8
2001	0	0	2	9,9	4
2002	0	0	9,1	10,3	9,7
2003	0	0	17,7	17,9	15
2004	0	0	25	36,5	29,9
2005	0	0	4,7	29,8	14,8
2006	0	0	0	0	0
2007	0	0.2	7,8	0	1
2008	0	0	12,1	5,8	9,5

Table 6: Total rainfall during the growing season and yield reduction by year and planting date for Tiaret

	05/12		15/12		25/12		
Planting date Year	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)	Yield Reduction per season (%)	Total Rainfall (mm)
1999	199.7	14.9	198.3	18.2	194.4	21.6	293.1
2000	251.3	12.8	252.3	15.8	248.6	19.0	326.8
2001	261.0	4.0	258.8	7.3	258.4	13.0	382.0
2002	251.1	8.7	249.9	10.7	245.3	14.0	303.0
2003	207.5	12.0	198.8	16.2	188.8	21.2	267.6
2004	114.7	28.9	108.9	32.8	107.3	35.7	334.3
2005	217.2	14.8	218.5	19.5	218.4	28.2	292.0
2006	372.1	0	378.7	4.2	384.1	9.4	458.0
2007	351.4	1.0	314.6	5.1	277.4	11.0	523.0
2008	226.7	9.5	225.5	10.7	222.1	15.7	253.0

Any water deficit occurring at the end of the cycle (phase D) is not limiting production if the soil moisture reserves are not exhausted. Nevertheless, high values of yield reduction due to a lack of water in D phase can be observed for irrigated crops more vulnerable to water stress than rainfed crops whose root growth is a form of adaptation to local variations of soil moisture. However, this resistance to a rainfed drought is only effective to the extent that a large proportion of rainfall occurs during its growth cycle. Table 4 below lists the contributions of rain during the growing season for agriculture each year according to the three planting dates selected and indicates that early planting is strongly recommended, but a supplemental irrigation is still needed in phase B from the agricultural year promises to be deficient.

Tiaret's Station (Sub Saharan Climate): Regardless of planting date, a maximum reduction of yield due to water stress for the two phases C and D (Figure 1), was observed in 2004. Both phases have received respectively 26 and 9 mm. Indeed, the proportion of rainfall (115 mm) fell during the growing season has been far from sufficient to cover the needs estimated at 459 mm (Table 5). The year 2006 for its part, had a relatively high rainfall (458 mm) and evenly distributed throughout the growing season, especially if it starts earlier. A late planting could cause a water deficit late in the cycle and hence reduce the yield of about 10 to 20%. Good rainfall is not always sufficient in itself to reduce the risk of occurrence of dry spells of varying length that may occur during the agricultural year. This is the case of 2007 particularly wet (523 mm), but much of the rain fell outside the growing season and the rest evenly divided over it (Table 6). Thus drought occurring late in the cycle has reduced the yield of about 13 to 25% (late planting).

CONCLUSION

It is clear from the analysis of results obtained in semi-arid Mediterranean, particularly in the North-western Algeria, that the total seasonal rainfall is insufficient to cover the water requirements of rainfed crops, especially winter cereals. On the other hand, the rainfall distribution over time favors during the development cycle, the occurrence of more or less periods of water stress that may affect the final yield. However, suitably chosen planting date provides, to some extent a favorable biological development, which subtracts the plant in such a climate hazard and dampens the effects of reducing drought.

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