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Impact of environmental conditions on the yield variability of durum wheat (*Triticum durum. Desf*) and its associated characters at Algerian semi-arid areas

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Abstract

The environmental stresses are most common in Algeria. Drought, cold and hot weather are often present. These production constraints are abiotic, they are combined together more aggravating the loss in crop yields, especially durum. Indeed, a study was conducted under different agro-ecological conditions in the 2010/11 year. The approach adopted has been characterized by integration across experiment and pedoclimatic zoned. To do this, tests were conducted at the three zones and followed up from the installation the plant to harvest. The observations concern the effects of environmental constraints on yield and traits associated; with measurements, it is focused on morpho-phenological characteristics of the vegetation, soil moisture and physicochemical properties of the soil. A substantial variation in yield were observed between zones can be explained by the significance soil tillage, crop rotation the characteristics of each zone. Results confirm particularly that correlations between yield and associated characters exist and that various genotypes respond differently with the environments. Improved genotypes and precocious ensure the best yield. The early stage of heading is a trait often sought in Mediterranean areas, since it allows them to avoid the terminal water deficit or deficiency. The study confirmed the existence of significant correlations entered yield and it is components of and that genotypes responded differently depending on the environment to which they are subjected.

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Introduction

The climatic changes recorded these last years have sustained changes to the composition and geographic distribution of ecosystems. This situation is due to the northward movement of arid zones all the way to the confines between the Sahara and the high cereal plains.

Due to its rainy nature, so highly dependent of the climatic conditions, the cereal culture is characterized by an extensive behavior aggravated by the use of inappropriate cultural techniques. Hence, the management of climatic risks, which are the reason for the weakness of the agricultural products, proves to be now more necessary than ever. The ability of a cultivar to be reasonably efficient in an environment with a variable recorded rainfall or semi-arid climate is an important character for the stability of production, since the frequency of drought stress, cold or heat is very important.

The practice of rainfed culture even if it corresponds to recorded rainfall higher than 400 mm/year, it still represents only 4.8 millions of hectares of which the half part, or in other words 2 millions of hectares are not worked on because of lack of rain and especially due to the latter's poor distribution in space and time. (Hammiche, 1993, Smadhi *et al.*, 2002). Hence, despite the importance of wheat in the food diet, and although the production of cereals (all kinds included) only covers on average 30% of the country's needs (Mouhouche et Khiati, 1999) cereal farming (cultivation) has experienced very little improvement, amounting to 6.21% (ITGC, 1997). The productions undergo major fluctuations, partly due to low recorded rainfall, 70% of cereal farming areas are located in areas where the accumulation is less than 400 mm (Jouve *et al.*, 2000).

Among cereals, durum wheat occupies a prominent place in the diet of Algerian populations. Cultivation has always been the object of research of adapted genotypes able to withstand the conditions of the semi-arid environment. The success of this cultivation is linked to the influence of climatic risks such as drought, cold and high temperature at the end of the cycle. In fact, interannual and seasonal variability of rainfall is considered the major cause of fluctuating yields which remain very weak and highly variable (3 to13 cwt / ha). This low level of production is not due to only climatic conditions, but also to effects of the soil (nature of soil) and to the kind of hardware used. The objective is to quantify the effect of these limitations that are due to various environmental factors on the performance of durum wheat (*Triticum durum*. Desf). This is to propose alternative solutions to allow the increase of yields through the use of well-adapted genotypes.

Material and methods

Vegetal materials

To conduct this study, we examined the behavior, in different environments, of six varieties of durum wheat, namely: Oued Zenati BD 1/94 (local varieties), and Vitron, Oum Rabie 9, Chen's' and Waha (improved varieties). On each environment, data is collected from the soil characteristics of the chosen sites obtained through the monitoring of the soil moisture, phenological characteristics and the components of yields.

Experimental sites

The region of Sidi Bel-Abbes extends over an area of 9150 km² and occupies a privileged position in the Oran tell. Due to its strategic location, it is a hub for West of the country.

The experiment was conducted in three different zones, namely zone 1, zone 2 and the zone 3. These zones are supposed to be favorable for cereal cultivation, particularly durum wheat (Benabdelli, 1993), in which the conditions print their natural vocation to spaces; thus, each space is characterized by a type of land occupation and terrain acting on water that makes it a determining factor in crop production.

Experimental plan

The experimental plan consists of complete random blocks with three replicates. The elementary area is

6m². Observations are made within each parcel, set to be the observation unit, where all measures are performed.

Data Analysis

The analysis of data related to the monitoring of parcels was performed on the basis of the STAT-FITC software.

Results and discussion

Results

Analysis of the performance variability can be carried by following up the behavior in a variety of different situations (climate, soil, technical itineraries), in the same group of genotypes and examining the relationship between yield and the genotypic component.

The climate

The climate of the Sidi bel abbes region is qualified from semi-arid with hot dry season and another fresh, climate has undergone (as all of northern Algerian) significant changes: reduced rainfall, environmental degradation and deterioration of soil fertility. precipitation that determine the mobilization of surface water used for agricultural production oscillate between 200 and 400mm / year, according to the oro-geographical conditions of spaces of the region. the average volume of annual precipitation is the order of 1.6 billion cubic meter, often poorly distributed in space and time, often translating in water deficit important coinciding with the critical development phases of winter cereals to origin of obtaining low levels of performance.

The very erratic rains generally occur in the cold season with a maximum of 70% of the annual total brought over the fall and winter seasons. the dry period, long enough, lasts an average of five and a half months, it starts from the end of April and continue until the middle of October. this situation of water in sufficiency in the region is aggravated by a quite high insulation to which is added an intense evaporation severely disrupting the normal development of crops carried out in sec.

The combined effect of temperature and rainfall affects the environment and determines the type of climate in the region. The use of the rainfall quotient of EMBERGER whose application is specific to Mediterranean regions allows classifies the region in the floor of the semi-arid bioclimatic lower at cool winter.

The precipitations

We reported on Table 1, the average rainfall recorded in the region. There is a global deficit compared to the average of seltzer -120.4mm. This deficit is even more marked if we consider the installation period for the settlement and tillering which corespond to December (-25.9 mm) and January (-43.8 mm) and the dry matter maximum elaboration period corresponding to the months of February (-46.0 mm) and March (-15.8 mm).

Table 1. Precipitation average recorded at Sidi Bel-Abbès during the growing season of durum wheat.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
Precipitation recorded (mm)	30.9	116.2	34.1	4.2	6.0	23.2	55.4	22.5	*204.6*
Average (Seltzer) (mm)	27.0	62.0	60.0	48.0	51.0	39.0	39.0	38.0	*325.0*
Difference (mm)	+3.9	+54.2	-25.9	-43.8	-46.0	-15.8	+17.4	-15.5	*-120.4*

The temperatures

On temperature readings (Table 2.), we find that the maximum and minimum average temperatures are close to average temperatures recorded during the same period seltzer. However, we note that the number of days of frostis important in the months of January and February (average of 15 days for January and 18 days for February). these periods offrost is coincided with the phases of the settlement system and tillering.

Table 2. Temperature average recorded at Sidi Bel-Abbès during the growing season of durum wheat.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
Average Max. recorded	28.6	17.2	15.3	16.5	18.7	19.6	21.1	25.3	
Average (Seltzer) (°C)	25.0	19.0	15.0	14.0	15.0	18.0	20.0	23.0	
Average Min. recorded	14.8	7.7	4.2	2.7	2.5	6.2	7.6	11.8	
Average.(Seltzer) (°C)	10.0	6.0	3.0	2.5	3.0	4.0	7.0	9.0	
Number of days of frost	0	0	2	15	18	18	1	0	*53*

The floor

The soils of the zone 1 are heavy, to high retention capacity, they are characterized by a vertical cracking. those of zone 2 are characterized by asilty-sandy texture, by against the soils of the zone 3 are a dominant silt and there fore has a sensitivity to compaction and the crusting accentuated. The soils are rich in assimilated phosphorus and plays an important role in the growth and develop pement of Wheat (fertilization, fruit set, maturation and stockpiling). It is often a factor earliness result in the increase of fertilized spikelets and thousand kernel weight (better utilization of water and mineral element). a deficiency of this element increases the risk of scalding and can improve the cold resisitance. In terms of pH, all soils are alkaline and not saline.

Monitoring of the soil moisture

The results obtained in the three areas (Fig. 1, 2 and 3), have shown that a water deficit at ground level was installed during the run-heading phase. stage where the plant shows an increased need for water to know 3 to 7 mm / day and it becomes very sensitive to lack of water : it's the floral specialization phase during which is realized the pollen meiosis and elongation the last between-node.

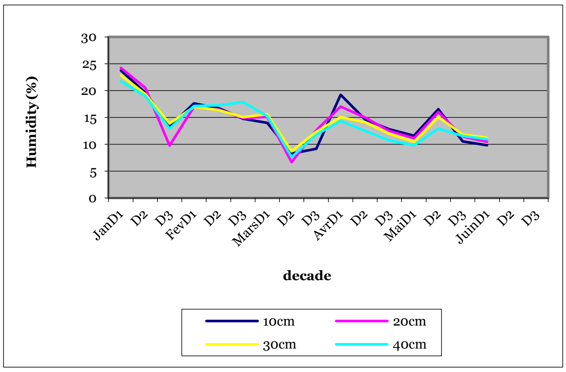

Fig. 1. Moisture variation in area 1.

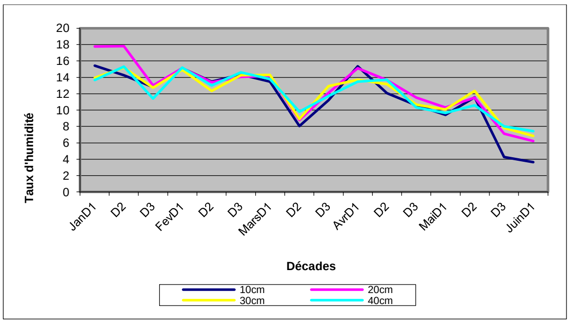

Fig. 2. Moisture variation in area 2.

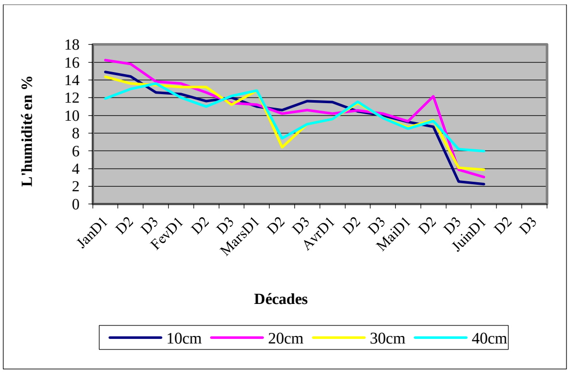

Fig. 3. Moisture variation in area 3.

The determinism of this phase is essentially climatic order. This dryness was also recorded during the milky stage of grain, stage of intense cell multiplication.

In such a deficit may change the potential number of each component through its effect on the rate of formation of the organs or the term of differentiation. On the other hand the lack of water also changes the final number of each component because it is one of the climatic factors that increase the disappearance of differentiated organs.

The decrease in soil water potential under drought conditions causes a significant loss of turgor in the plant. The increase in production depends on the tolerance mechanisms which provide cellular hydration and decrease parte of water maintaining a favorable water status in leaf development. Maintaining a high water potential is related to the ability to extract water from the soil and the ability to reduce water loss by transpiration.

This drying at ground level was found at all sites and across all study areas. However, differences in yield are recorded from one site to another, which can be attributed to the nature of the soil and more particularly to retention capacity and depth. Nevertheless, He concluded that:

- That ground work is important because it increases the retention capacity by breaking the plow pan
- The rotation could also make a difference on soil moisture, as it promotes better rate of organic matter
- Also the agro-pedoclimatic characteristics of each area determines its own potentialities.

Monitoring of plots

Analysis of relative variance on grain yield and its components

The analysis of variance performed the existence reveals variety effects and highly significant area in the three zones, for all characters studied except the number of grains per spike (Table 3.) component which varies depending on varieties and planting dates.

Table 3. Physicochemical characteristic soil for the three selected areas.

	Area 1	Area 2	Area 3
Granulometry			
- Coarse sand (2 – 0.2 mm) %	4.53	14.03	34.13
- Fine sand (0.2 - 0.05 mm) %	24.72	29.45	4.41
- Coarse silt (0.05 - 0.02 mm) %	14.25	13.52	17.96
- Fine silt (0.02 - 0.002 mm) %	18.50	22.00	29.00
- Clay (< 0.002 mm) %	38.00	21.00	14.50
Texture	Clay	Silty -Sandblaster	Silty
- Organic carbon (%)	1.52	1.76	1.34
- Total nitrogen (%)	0.154	0.145	0.136
- Report C/N	9.98	12.13	10.88
- Phosphorus (ppm)	10.50	94.0	31.50
- $CaCO_3$ Total	3.22	35.26	10.64
- $CaCO_3$ active	00	23.00	08.00
- PH (H_2O)	8.04	8.09	8.10
- Cation exchange complex	-	-	-
- Organic matter	2.62	3.03	2.31
- Electrical conductivity (umhos/cm)	0.110	0.135	0.100

Yields vary a lot from year to year and from one area to another, reflecting the variation in rainfall and other environmental factors (Acevedo, 1990). Thus the highest yields were recorded in Zone 1 (mean = 29.36 cwt / ha). Average yields are clearly lower in Zone 3. These are the improved varieties that reach the highest average yields; the weakest yields meanwhile is the fact of the variety O / Zenati (15.48 cwt / ha). (Fig. 4.).

The correlations

The study of total correlations between grain yield and the various characters associated with it verifies the results. Thus, in the majority of cases studied, the production was negatively associated with the duration of the phase of lifting - heading and positively to the numbers of tillers - ears per unit area, to the plant height and thousand grain weight. However, grain production appears, on average, more closely associated with tillering - ears per unit area and height. These characters, in semi - arid areas, would be more relevant for the selection of genotypes better adapted to drought. A relatively high straw and a lifetime of the last relatively long sheet confer to the plant in case of a severe water deficit, a better ability to drought tolerance.

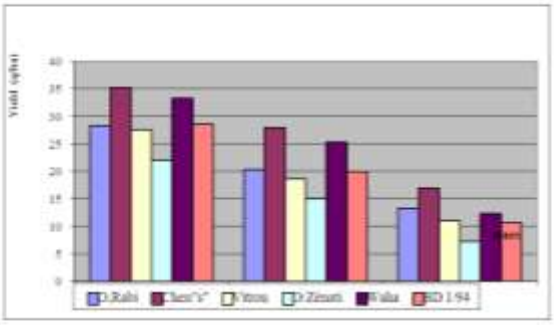

Fig. 4. Yield variation with the area.

This behavior is explained by higher potentials of carbohydrate reserves in addition, the correlation matrix established on the interaction of genotypes x areas shows that the return is linked to the number of plants per linear meter, to the number of ears per linear meter and to the earliness at the maturity; variables that also contribute positively to the realization of the number of grains / ear (r=0.506, 0.553 and 0.228 respectively. The level of the averages observed, inside existing variability, indicates the earliness at heading and the height of plant positively contribute to TKW (r = 0.628, 0.355 and 0.444 respectively) (Table 4).

Table 4. ANOVA of genotypic effects and area of the measured characteristics (P<0.05).

	Tiller/m	*DHE (days)*	*Ears/m*	*PHT (cm)*	*DMA (dayss)*	*Grain/ear*	*Yield (q/ha)*	*TKW(g)*
- BD 1/94	61.64	99.67	53.67	56.11	152.44	25.78	20.29	38.67
- O/Zénati	57.44	107.67	47.89	81.89	177.00	21.56	15.48	45.44
- Waha	54.78	87.00	48.78	61.67	167.33	26.44	24.48	38.00
- Chen's'	59.89	91.22	47.00	60.22	161.00	28.00	27.66	38.78
- O. Rabie	54.78	95.33	51.11	64.67	158.56	27.33	21.21	36.00
- Vitron	59.56	90.67	55.78	60.00	155.89	27.22	19.37	38.00
- Zone 1	61.78	94.33	57.89	70.00	171.89	26.61	29.36	39.72
- Zone 2	57.17	98.50	50.17	64.11	164.50	27.17	21.34	44.33
- Zone 3	55.00	92.94	44.06	58.17	149.72	24.39	13.56	33.39
- Average test	*57.98*		*50.70*	*64.09*	*162.04*		*21.42*	*39.15*
- S.D	*3.77*	*95.26*	*6.54*	*9.72*	*15.04*	*26.06*	*3.11*	*4.30*
- CV (%)	*6.5*	*4.99*	*12.9*	*15.2*	*9.3*	*4.94*	*14.5*	*11.0*
-Genotypic effect .	*S*	*5.2*	*S*	*S*	*S*	*19.0*	*S*	*S*
- Area effect		*S*				*NS*		
-Interaction	*S*	*S*	*S*	*S*	*S*	*NS*	*S*	*S*
(genotype x area)	*NS*	*S*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*

Yield : grain yield ; Tiller/m : number of tillers per linear meter N.ears/m : number of ears per linear meter ; N.Gr/ear: number of grains per ears ; TKW : thousand kernel weight ; DHE : number of days of plant emergence at exit 50% of ears per variety per basic plot ; DMA : number of days of plant emergence on the date that the envelopes of the ears lose their green color ; PHT : Plant Height including the beard; C.V: coefficient of variation.

S: effect significant; NS: not significant.The principal component analysis

The results obtained in in the context of this test resulted in a multivariate analysis. The principal component analysis (PCA) is a technic which allows to highlight the association relationship and opposition of different variables and individuals. It allows us to visualize the positioning of the varieties according to their behavior in different environments across the yield and its components.

Study variables

the diagonalization results show that the percentage of the information given by each axis is: Axis 1 = 40.5% , Axis 2 = 31.1% , Axis 3 = 9.9% and Axis 4 = 7.9%. The first two principal axis so explain 71.6% of the information. The interpretation of the correlations is made through the graphical representation; a vector connecting the center of the circle to different points representing the variables (Fig. 5.).

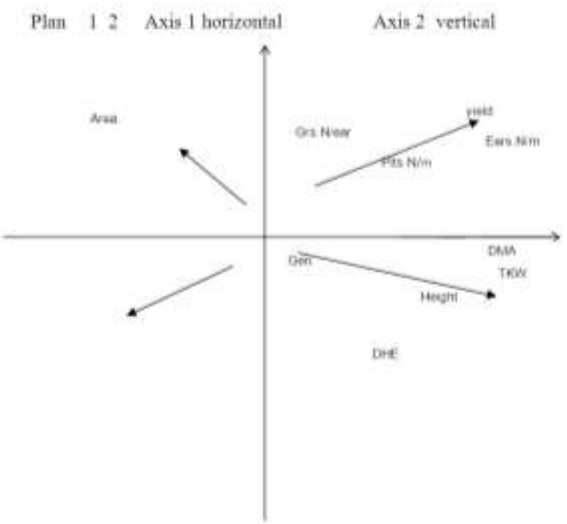

Fig. 5. Multivariate analysis performed on the measured variables.

The study of the representation of the main components shows that among the variables studied; four are well represented (r> 0.7) and are correlated positively with respect to the axis 1 and 2; except for component (PHT) which correlates negatively with respect to the axis 2. These are the variables that depend much more the variety than of the environment. They are the Group 1 compound, the number of grains / ear (Grs / er), plant height (PHT), the number of plants to the lifting / linear meter (PLTS / m) and grain yield (yield).

The earliness at heading (DHE), maturity (DMA) and the thousand kernel weight (TKW), are represented averagely (0.4 <r <0.7), variables that depend on the environment in which the plant is put into site (soil tillage, fertilization ... etc.). They are correlated positively with respect to the axis 1 and negatively with respect to the axis 2. The number of ears / linear meter is poorly represented (r = 0.33); and constitute the group 2.

Individuals study

To see the quality of the representation of individuals, we add the square cosine of axis 1 and 2, according to the results obtained, we find that on the eighteen individuals studied, nine of them are well represented (sum of cosine square> 0.60), three are averagely represented (0.4 <cos <0.6) and six are poorly represented (Table. 5.).

Table 5. Correlations between pairs of characters measured on genotypes studied.

	Zone	genotype	tillers/m	DHE	Ears/m	PHT	DMA	Yield	Gr/ears	
Zone	1.000									
Genotype	0.000	1.000								
Tillers/m	-0.507	0.313	1.000							
DHE	-0.060	0.382	0.221	1.000						
Ears/m	-0.635	0.261	0.471	0.115	1.000					
PHT	-0.363	-0.041	0.311	0.499	0.354	1.000				
DMA	-0.488	-0.188	0.202	0.143	0.279	0.553	1.000			
Yield	-0.180	-0.111	0.280	-0.049	0.295	0.212	0.177	1.000		
Gr/ears	-0.801	-0.109	0.506	-0.162	0.553	0.129	0.288	0.340	1.000	
TKW	-.0360	0.071	0.357	0.628	0.193	0.444	0.355	0.227	0.250	1000

Table 6. Individuals representation.

Representation	Zone 1	Zone 2	Zone3
Cosine > 0.6	Oued Zenati, Vitron	Oued Zenati	Waha, Chen's', Om Rabie 9, Oued Zenati, Vitron, BD 1/94
0.4 <Cosine < 0.6	Waha, Chen's',	Vitron	
Cosine < 0.4	Om Rabie 9, BD 1/94	Waha, Chen's' Om Rabie 9, BD 1/94	

Discussion

In addition to its role in photosynthesis, in the transport and accumulation of nutrients and temperature regulation, water plays an important role in the growth and development of cultivated plants (Riou, 1993). From a climate perspective, the important water deficit more particularly register red during the period elongation - heading and frosts the months of January and February (18 days in January and 18 days for February, which coincided with the stand setup phases and tillering) are helped to explain the yield sobtained. The analysis of the development of grain yield shows that the best yields are obtained in zone 1 where the soil is heavy and deep, with high capacity of retention and moisture equivalent, having allowed a tolerance to deficit has experienced by the region during the experimentation. This deficit is even marked if we consider the period of settlement and installation of tillering (- 25.9 mm - 43.8 mm), compared with the average Seltzer, respectively for the months of December and January), and the maximum development period of dry matter corresponds to the months of February and March, with respectively - 46.0 mm and -15.8 mm (always in relation to the average Seltzer. This period coincides with the run phase and heading, critical phases of development of winter cereals by recording low levels of yields (Baldy, 1992).

This constraints the most important factor limiting the production of cereals. It is the first abiotic stress leading to differences not only between average yields and potential, but also between the different agricultural seasons (Sorrels *et al.*, 2000). It is often combined with other stresses such as winter temperatures, high temperatures during the grain filling period and nutritional stress (Ceccarelli et Grando, 1990). It also affects the growth of roots and aerial parts, leaf development and reproductive organs (Debaeke *et al.*, 1996). This is the stage where the plant shows an increased need for water, on the order of 3 to 7 mm / day (Mekliche, 1976) and she becomes very sensitive to lack: it is the floral specialization phase during which is carried out the pollen meiosis and elongation between-node. The determinism of this phase is essentially climatic (Graciela, 1990). The drying was also recorded during the milky stage of grain (- 15.5 mm during the month of May), stage of the intense cell multiplication. Such a deficit resulting a reduce the genotype production and may change the potential number of each component by its effect on the speed of formation of organs or on differentiation duration (Graciela, 1990). Furthermore, the lack of water changes the final number of each component because it is the climatic factor that increases the abortion of differentiated organs.

Once installed, the water deficit affects different processes, amending the growth of vegetative and reproductive organs, the development and the final crop yield. The number of fertile spikelet is reduced when the drought occurs during spikelet's differentiation phase resulting in a reduction in the number of grains per spike (Bouzerzour *et al.*, 2002). This is the case of local genotype Oued Zenati. According to the results obtained, it also appears that the improved genotypes, Chen's' and Vitron, are best expressed. One hypothesis is could be advanced to explain the regression of tillers in the earliness of genotypes improved from the local genotype Oued Zenati in which the end of the bolting and heading occurs during a period of frosts: Celle- it could lead to abortion of flower drafts and therefore greatly reduce the number of grains per spike (21.56 grains per ear on average).

Genotypic effects and areas highly significant can be rated on the number of tillers, and the number of ears per linear meter, and the thousand kernel weight. The cereal yield is the product of three factors namely: the number of ears / m^2, number of grains / spike and thousand grain weight. Between these components there is a mutual compensation effect: the reduction of one of them may result in increasing the other two (Sombrero *et al.*, 1992). The number of ears presents significant differences between genotypes and the environment in which they were set up. This finding coincides with Hucl and Baker (1989) which emphasize that environmental conditions determine the number of ears. The thousand kernel weight, component directly dependent on water supply conditions during the filling phase and the grain formation, is dependent translocations and temperature conditions after the water landing (Baldy, 1992). The number of ears varies according more on years of experimental sites and as a function of the genotypes for the same year (Bouzerzour et Monneveux, 1992), while the number of grains per spike varies according to genotypes and planting dates (Benmahammed et Bouzerzour, 1991). It is an essential component of yields, its role is particularly important in cases of early and marked water deficit (Benabdellah et Bensalem, 1992). At the plant cover, a report tillering / ears more balanced and an average height of the plants would enable the genotype to adapt its water consumption to real needs in grain production, resulting in improved efficiency of the use of water. The yields of gains would then be associated with the number of grains per spike. Furthe rmore, a short stage of lifting – heading would enable the genotype to escape late droughts occurring frequently in the region and in similar areas during the phase post - anthesis.

The Precocity is often a character sought in Mediterranean areas, in sofar as it allows the dodge of terminal water deficit (Benseddik et Benabdelli, 2000). This characteris a very important parameter because it defines the timing against environmental constraints cycle (Slama *et al.*, 2005) and provides greater efficiency of water use. Thus, for a high biomass production, genotypes fast growing and early maturing value a best available water and are there foreless exposed to environmental stresses compared to late genotypes (Acevedo et Ceccarelli, 1990). As genotype shad a high speed growth have the ability to better use sources by the end of the development cycle when they become limiting (Slama *et al.*, 2005).

Conclusion

The cultivation of durum wheat in the region of Sidi Bel-Abbes is relatively accentuated in the northern part which a climatic and soil particularities that differentiate it from other production areas. Climatic variables that cause the greatest variations in yields are rainfall and temperatures. The rainfall has a non-uniform distribution: irregular distribution is noticed during the agricultural companion, important frosts that penalize the fruiting plants and excessive heat during the heading stage – maturity resulting in poor grain fill.

Directed real environment, this study has highlighted a number of relationships between firstly grain yield of durum wheat and its components and also between environmental constraints. Some of the results are obtained on general in scope; others are related to the conditions of the years of study. And improved varieties present a better adaptation to early drought conditions in the region (This "tolerance" to drought can be explained by their ability to extract available water in the deeper layers of the soil (important rooting) and maintain a high evapotranspiration rates during the dry period.

The earliness in heading also constitutes a desirable feature. This biological mechanism could be quantified dodge because early genotypes can complete their cycle thus avoiding the terminal drought.

Based on the analysis of varietal characteristics, a series of works were under taken, whose main objectives were:

- Quantifying the effects of climate stress caused by the distribution of rainfall and temperature on the yields of durum wheat.
- Propose morpho-phenological characteristics that allow get high yields under these climatic conditions.
- Define areas of adaptation and strengthening of durum system.
- Some of the factors and conditions the environment specifically affecting on the development of yields. We will retain:
- The effects of the physicochemical nature of the soil on yield and its components.
- Negative effects of frost on the rate of spike let sterility.

- The effects of water stress that experienced by the region during the months of January and February

So the analysis of the components grain yield development, shows that the best yields are obtained in heavy and deep soils with high retention capacity and clay texture; equivalent moisture that allowed a tolerance to water deficit experienced by the region in the run-earring phase.

From a climate perspective, the important water deficit particularly registered during the period elongation-heading, and severe frosts of the month of January to February contributed to explaining the yields obtained. Once installed the water shortage affects different processes, modifying the growth of vegetative and reproductive organs, the development and the final crop yield. The number of fertile spike lets is reduced when drought occurs during spike lets differentiation phase resulting in a number of grains / spike low (case of the local variety Oued Zenati).

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