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IMPACT OF CLIMATIC VARIABILITY ON DURUM WHEAT (*Triticum durum* L.) YIELDS IN NORTH WESTERN OF ALGERIA

Meterfi Baroudi [1], Wael El Zerey[2]*, Salaheddine Bachir Bouiadjra [3]

[1,2,3] Department of environment sciences, Djillali Liabes University - Sidi Bel Abbes, Algeria
*Corresponding author: wael.elzerey@gmail.com

Abstract

In semi arid region of the South West of the Mediterranean basin, low rainfall, and thermal fluctuations cause water stress situations affecting at different levels, with varying intensities, the development of durum wheat yields. This work aims to study the major climatic factors that determine water environment of durum wheat in its reproductive period and assess their trend related to yields of the grain. Comparing diagrams of Bagnoul and Gaussen, established for two periods (1913-1937 and 1977-2014), highlighted an increase in the duration of the dry season due to rising temperatures, especially summer and a decrease in volume of the seasonal rainfall involving therefore water stress during the reproductive phase of cereal. The analysis of water regime in the past three decades, for the months of March, April and May, through the application of the approach of UNESCO-FAO, highlighted a very large variability in intensity of water stress during grain development period during the last years and also the tendency of the spring season months to be more drought. This reflects the complexity of the selection for yield components in this region.

Key words: Climatic variability; Durum wheat; Yields; Drought; Sidi Bel Abbes.

Introduction

The work of the IPCC (Intergovernmental Panel on Climate Change) have shown ,that agriculture is one of the most economic sectors affected by climate change, particularly in the developing countries (Agoumi, 2003). This observation becomes important in the South West of the Mediterranean basin where the agricultural system is based largely on cereals (Benseddik and Benabdelli, 2000; Mekhlouf et al., 2006). Agriculture appears to be one of the most vulnerable sectors to climate change because of its sensitivity to direct effects of changes in climate such as temperature, rainfall and carbon dioxide (CO_2) and indirect effects through water or soil. Indeed, climate is one of the main determinants of agriculture productivity, and climate change could have important consequences for food security and economy (Closset et al., 2015).Water is considered the main limiting factor for agricultural production in arid and semiarid areas (Al Hamdan et al., 2014). Crops are very sensitive to climate change and its impact is reduction in yield. Rise in temperature has a negative effect on wheat. The production is also reduced due to changes in the climate particularly due to longer drought and erratic rain (Bhandari, 2013a; 2013b).The historical climate data of Algeria shows the persistence of drought with negative impacts on water needs and soil, particularly for agricultural, and forest ecosystems (National report, 2014; El Zerey, 2014).The practice of extensive agriculture, as a substitute to overcoming the low yields of cereals, especially in western Algeria, is linked to water conditions in the region. In Algeria, water availability is the prime factor limiting wheat yields, and is expected to worsen in the near future due to climate change (Rezzoug et al., 2008; Rezzoug and Gabrielle, 2009; Alexandrov and Hoogenboom, 2001). Rainfall is one of the most important factors for the growth of cereals. Inadequate water results poor growth and reduced yield (Bhandari, 2014).This relation between wheat yields and rainfall led to the need to study more rainfall variability as a limiting factor causing irregular production in relation to water stress (Benseddik and Benabdelli , 2000).The constraint water, although long highlighted, remains unclear when we reason with respect to sustainable agriculture. It therefore deserves to be evaluated on the scale that best adjusts to climate change since improved yields are conditioned to this trend towards greater aridity in this part of the southern shore of the Mediterranean (Slama et al., 2005). The real challenge under climate change conditions is to use adaptation strategies, which are improved agricultural management practices, to reduce the damage of climate change on the yield (Rezzoug et al., 2008; Rezzoug and Gabrielle, 2009).

According to Dahal et al (2015). If the farmers have not access to appropriate seeds, the increase in yield could be difficult also to cope with the climatic change, a prudent management related to wheat farming is needed for the benefit of the farmers

Materials and methods

Study area

The study is based on a representative region of western Algeria, for its central geographic position. The region of Sidi Bel Abbes is located to the North West of Algeria about 80 Km of Oran. At an altitude of 486 m, it extends over an area of 9150 Km^2. The region is characterized by a Mediterranean climate and belongs to the semi-arid bioclimatic stage.

Agro climatological approaches

The particularity of the Mediterranean region, especially in the case of Algeria, is the fact that the grains of wheat are often subject to intermittent drought at any time of their cycle (Bamouh, 2000).The calculation of aridity index has always been a subject of climatology research. Of all the indicators formulated, the most known, according to Guyot (1999), remains that of Bagnouls and Gaussen. Better representing the water deficit, an approach that defines the drought of the year according to the relationship: mean monthly rainfall less than or equal to the average temperatures of the months considered, $P < 2T$ (Bagnouls and Gaussen, 1953). To set the level of aridity (Nouvelot and Descroix, 1996), UNESCO-FAO suggested using the ratio between the average rainfall (P) and potential evapotranspiration (PET), where potential evapotranspiration (PET) is important for the estimation of water requirement of crops. The index of bioclimatic aridity determined from the equation $R = P / PET$ is used as a quantitative criterion of differentiation of dry areas (Skouri, 1993). Its application for the months of March, April and May allows knowing the water balance of each month and its variability over the past 100 years.

Data collection and analysis

Climatic data were collected, from the ancient Seltzer climate data (1913-1937) (Seltzer, 1946) and the climate data of the period (1977 - 2014), registered by the meteorological station of Sidi Bel Abbes (ONM, 2014). ET0 calculator software was used for data analysis, The reference evapotranspiration is assessed meteorological data by means of the ***FAO Penman-Monteith equation***. This method has been selected by FAO as the reference because it closely approximates grass ETo at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters (FAO. 2008), and SPSS software was used for statistical analysis.

Results and discussion

The temperatures

The superposition of temperature curves plotted for two periods (1913-1937 and 1977-2014) shows a variation in their evolution over the last century. If the minimum ranged from an increase of 0.9 °C and a decrease of 0.7 °C, maximum alternated in cold and wet season, between a lowering of 0.2 and an increase of 1.38 °C but have, however, an increase of around 2 °C from early summer to late autumn (Figure 1). The daily temperature variations caused, do not exceed 1°C in the wet season but exceed 2 °C in summer and autumn season. The comparison shows that the decadal average temperatures have increased, disturbingly so, in the last 30 years. The average increase is 1.78 °C for March, 1.90 °C and 2.68 °C in April to May. The results observed in this area are consistent assumptions that climate change should be reflected in the Maghreb by higher temperatures between 0.6 and 1.2 °C by 2020 (Quirion et al., 2005).

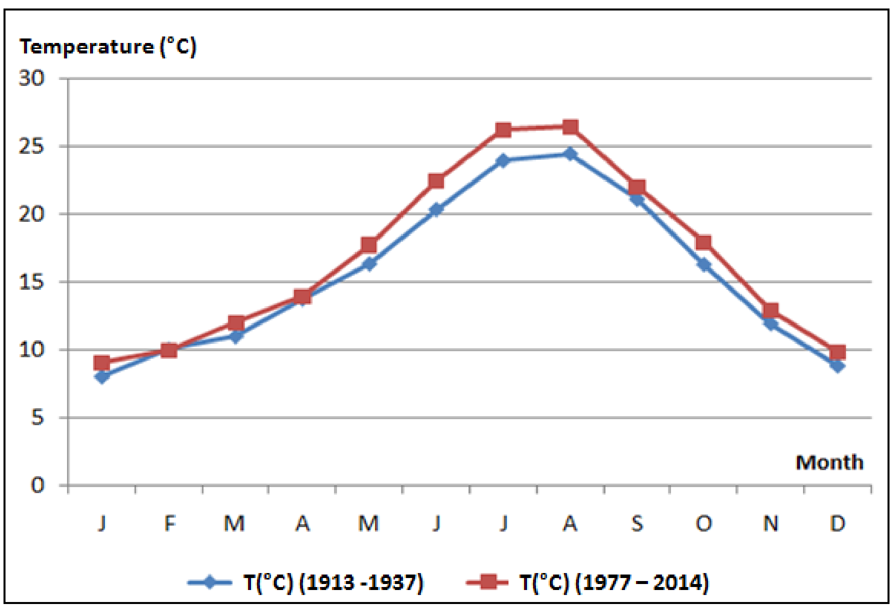

Figure 1. Average temperatures of the two periods (1913-1937; 1977-2014)

Rainfall

The comparison, by value, of the average annual rainfall of the beginning and end of the century highlights a decrease of 18.62 %. This deficit is particularly important from an agronomic perspective, since the spring rainfall volume decreases on average 24 %, while the autumn rains and winter recorded a decline of around 17 % of the corresponding initial volume (Figure 2).

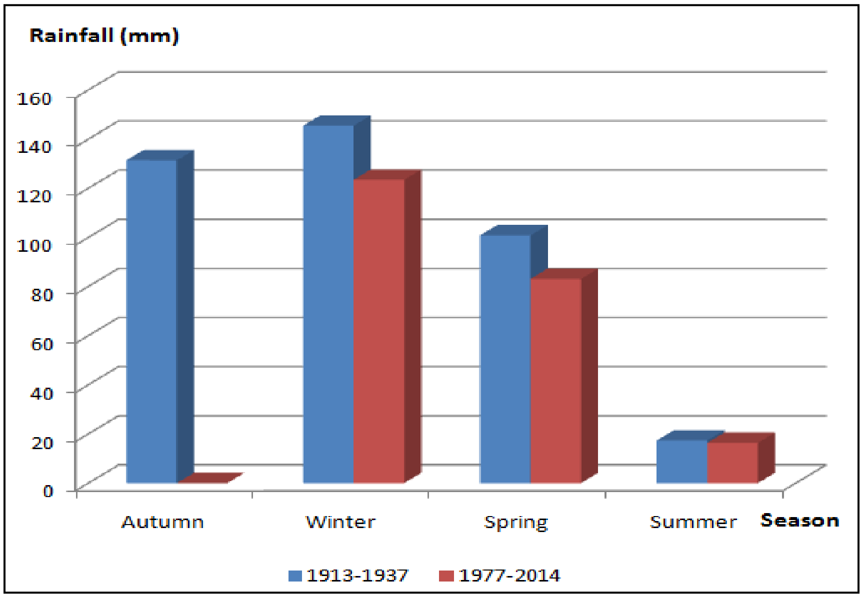

Figure 2. Rainfall repartition by season, for the period (1913-1937 and 1977-2014)

Bioclimatic analysis

The rainfall quotient calculated, according to the approach of Emberger (Emberger, 1942), allows to evaluate the changing climate situation where durum wheat cultivation in the region.

Dry season

The dry period is the climate parameter that best represents the changing water conditions in which cereal crops. The established diagram for two periods of the last century (1913-1937; 1977-2014), measures the change in value of precipitation and temperature and to deduce the impact of variability on the development of wheat. According to the obtained results the dry season increased by an average of 30 days from the beginning to the end of the century (Figure 3, Figure 4) .

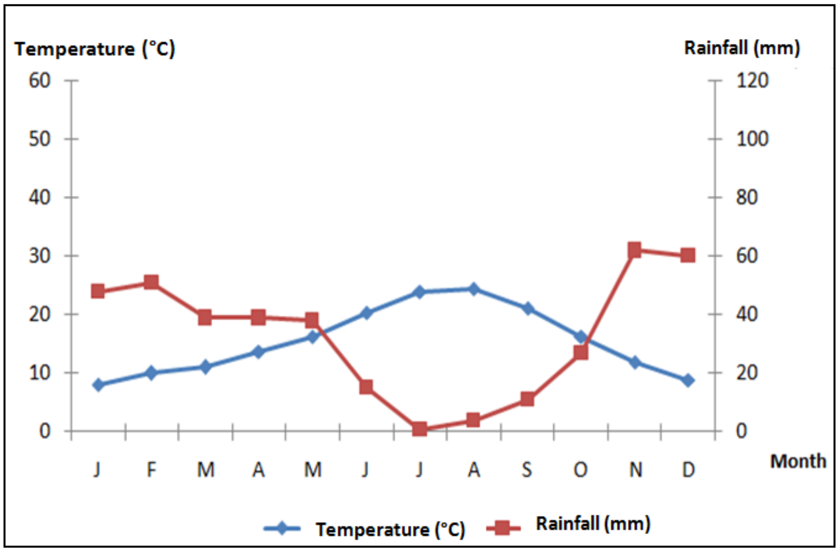

Figure 3. Dry season for the period (1913-1937)

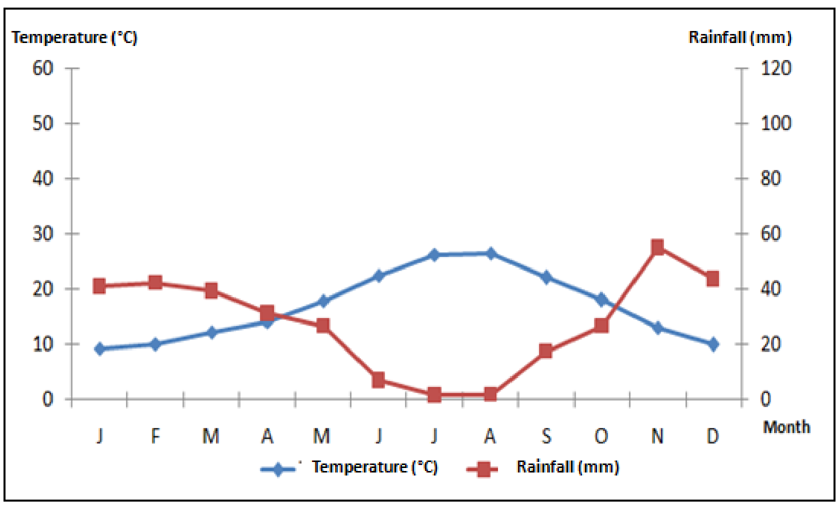

Figure 4. Dry season for the period (1977- 2014)

It begins on May for the period (1913 – 1937), while it begins in April for the period (1977 – 2014) , these results show that the effect of drought has spread elongating , amplifying, therefore, the returns problem of long cycle wheat at the beginning of this century. Very irregular in duration over the past three decades (Figure 5), it can fluctuate from 133 to 296 days as it can develop drought phases of one to two months during the winter season.

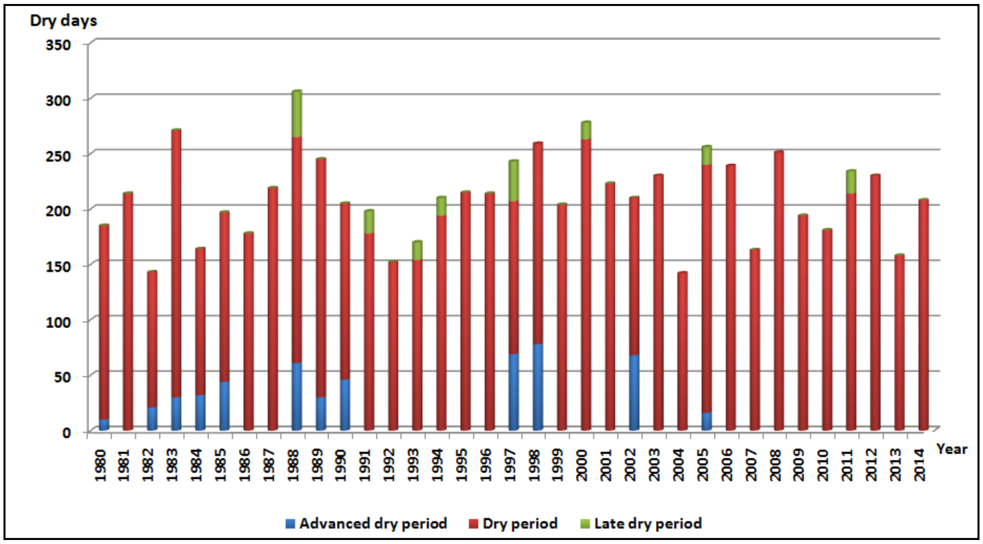

Figure 5. Importance of dry period from 1980 to 2014

An evolutionary analysis of this phenomenon highlights inter-annual variation and intra annual periods of drought which affect cereal crops in the region. It would be interesting to assess the drought in terms of water availability for the months of March, April and May, corresponding to the three stages of the development of cereals production.

The analysis of the water regime, per month, in its dynamics over the last 3 decades has highlighted the effective increase in the aridity gradient from March to May .This observation allows to deduce that, in large part, water stress is increasing in intensity with the progress of the 3 phases of durum wheat production. The change in the arid months in the direction of global climate change will lead to the change of stress at different phenological stages (Meterfi and Moueddene, 2002).

Aridity and relative yields of durum wheat

Ranging from 350 to 1200 Kg/ ha, yields do not exceed the threshold of 1000 Kg/ ha, that indicates the dominance of the depressive effect of water stress in the region. The superposition of durum wheat yields with different levels of aridity identified during the months of March, April and May highlights the relationship established between changes in water deficit with fluctuations in yields (Figure 6).

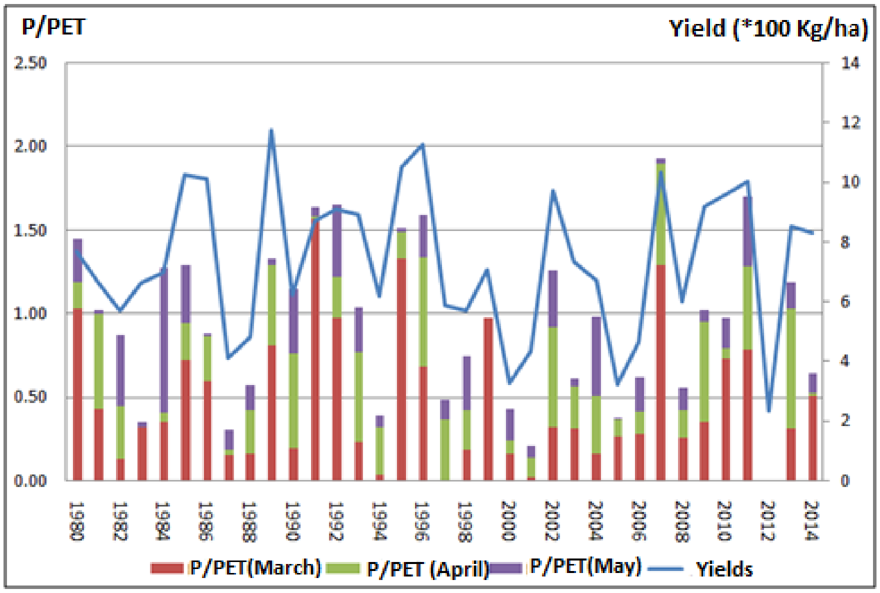

Figure 6. Cumulated effects of aridity level per month on wheat yields (1980 – 2014)

Cereals in the plain of Sidi Bel Abbes

Durum wheat, occupied during the campaign 1995-1996, 21% of cereals area. The occupied surface increased by 6.77 % until early 2000 then declined gradually over the past decade and achieve during the 2009-2010 campaign, a very representative area in terms of its importance, about 9 % of cereals area. Yields are generally quite low and declined during the last fifteen years to reach alarming values close to 1000 Kg/ ha (Figure 7, Figure 8).

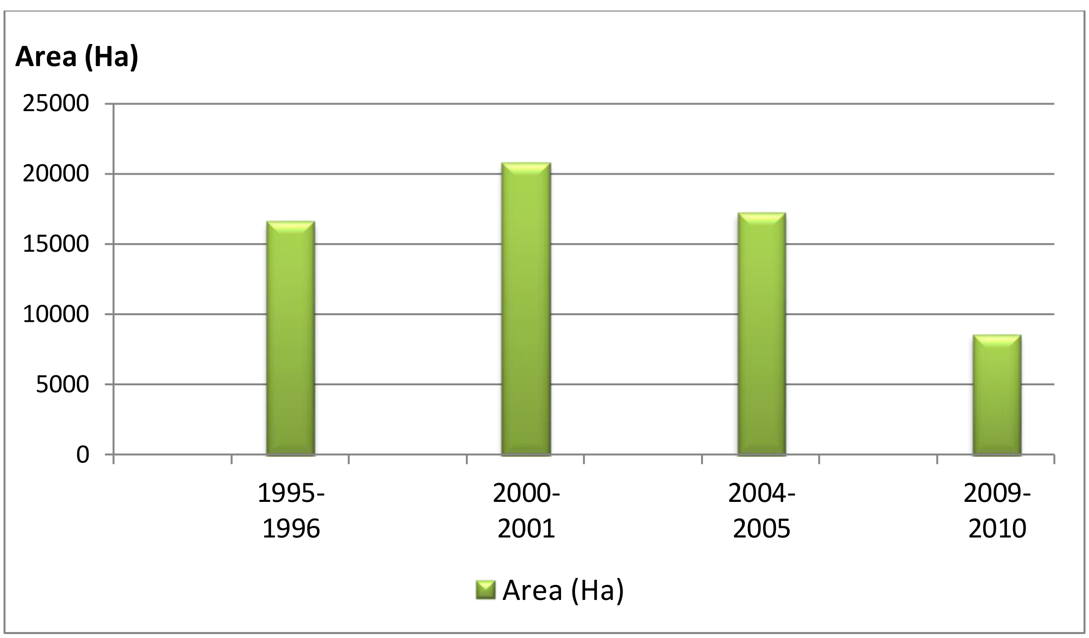

Figure 7. Cereals area in the plain of Sidi Bel Abbes

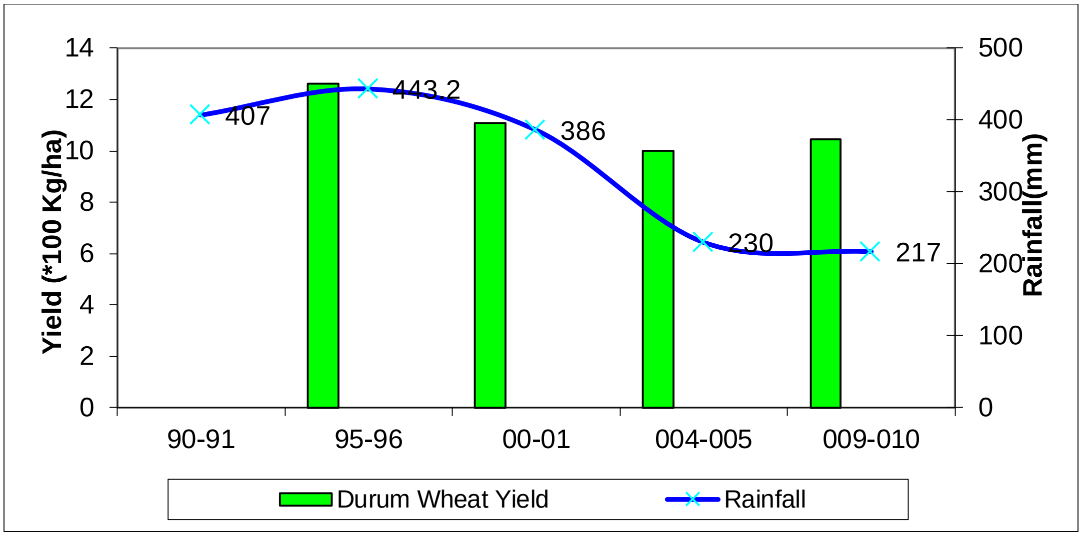

Figure 8. Relation between Durum wheat yield and rainfall (1990 – 2010)

Statistical analysis

The yields are closely linked to gradients of aridity which is subject the month of March, the determined correlation between yields and the aridity index of the month is significant, it is of the order of 0.64 for a P- value equal to 0.0002, as they are also conditioned by the different levels of aridity affecting the month of April, the correlation is 0.49 for a P-value of 0.0075. Water availability during the tillering phase would be critical in the development of yields in the region. The principal components analysis on the correlation matrix of the data table whose columns are composed of variables yields and indices of aridity of three months (March, April and May) determines two distinct groups of years their performance and the value of the index of aridity months: The first includes the years to underperform or equal to 700 Kg/ ha (except 2003) where the indices of aridity months are low to very low for the month of March and variables for the month of April.

• The second brings together years outperform 7, the aridity index of March is average (0.28) to very high (1.49) and the April ranging from very low (0.00) and high (0.61)

• In view of very close values of yields and other factors that may occasionally interfered in the development of yields, the proper interpretation can only be global. In the region, yields above 7.5 quintals / ha are recorded, mostly when the moisture conditions are March as the P / PET ratio is greater than 0.54 (1980, 1985, 1986.1996, 1989, 1991.1992, 1995, 1996.2007) than those of April where we identified two of the 28 cases studied. (1993.2002). The change in the aridity of May does not seem to affect yields, water at this final stage of development is involved in grain growth (Figure 9).

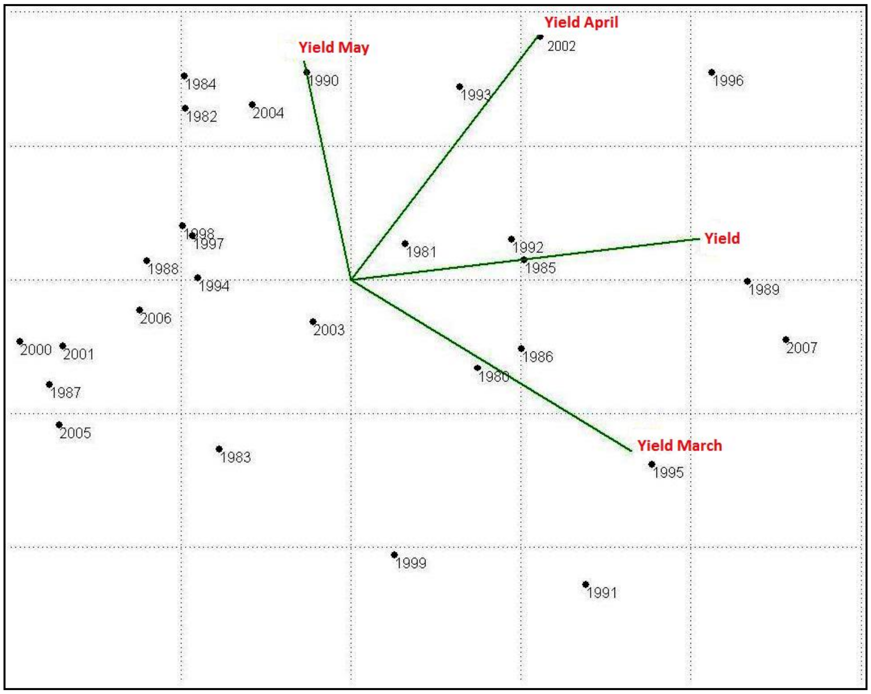

Figure 9. Principal Components Analysis (PCA)

Low and irregular yields of wheat in the plain region of Sidi Bel Abbes are due to deficiencies in rainfall and their randomness. Cereals in this semi-arid region are indeed often subjected to intermittent droughts during their reproductive period. The analysis of water regime during this period, according to the «UNESCO- FAO " evaluation system, shows indeed that it , over a period from 1980 to 2007,has undergone stress intensity and variable frequency during its development. But the regressive changes in yields observed are rather due to the irrational exploitation of cereal areas which severely affected the soil quality. Degradation of agricultural soil potential in the region of Sidi Bel Abbes and the ability to propose solutions can be evaluated by monitoring the physical and biological properties of soils under different crop management techniques. This degradation, which results a decline in cereal production and wheat in particular, is due to poorly adapted production systems. The changes are less marked in the predominantly sandy soils. Direct seeding does not affect the porosity of the surface layer and that it grows best in loamy or clay soils but seems to remain without effects on soils with sandy texture. Direct seeding is a solution against soil degradation by increasing the stability of

surface aggregates and improving the most visible structural stability in silt soils than in clay soil texture but is not precise enough in sandy soils.
Besides the benefits of economic and working time, the technique of direct seeding is an agricultural approach that best ensures the restoration of the natural fertility of the soil and developing its structural stability.

Conclusion

According to the obtained results, it is possible to note the following: Temperatures rised and rainfall reduced over time. The problem is, first, in terms of water gaps in the region. Indeed, the work done on the water requirements of durum wheat in the region of Sidi Bel Abbes showed that wheat consumption: 15.10 % of its water needs, tillering, 38.60 % to 37.82 % bolting and its heading. Consumption is an average of 268.60 mm of water from the upstream to heading while the average rainfall recorded during these two phases is only 34.46 mm, a relative deficit of 87 % water. Improving yields inevitably relies on solutions to mitigate or avoid the effects of water stress on durum and this is the main objective of agricultural research in Algeria as in all regions of the southern of the Mediterranean. Different selection strategies to produce varieties adapted to this environment have been adopted. This, the most applied to identify the most stress-tolerant varieties, by shortening the cycle. The genotypes fast growing and early maturing efficiently use available water which allows them to produce enough biomass and effectively ensure the transfer of assimilates and grain filling time to avoid completely or partially dry periods in late spring. A detailed analysis of the drought highlights the uncertain nature, duration and intensity of stress affecting at different levels, reproductive phase of cereal between March and May. This demonstrates the complexity of the selection for yield components in such situations. The contribution of new genotypes in this environment is more difficult to highlight because of the instability of performance grains. Genetics would certainly be the desired tool for this purpose. It allowed a 50% gain for grain yield under regular climatic conditions. The agro-meteorological approach adopted in this work will be integrated as a preliminary stage in the search for suitable varieties. It is proposed as a base of physiological approaches that target genetic improvement of adaptation characters. Finally, among the alternatives for improving grain yields, in arid and semi-arid regions where water resources are scarce, are the development and selection of varieties.

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