Bulgarian Journal of Agricultural Science, 28 (No 3) 2022, 443–450

Characterization of modern durum wheat genotypes (*Triticum durum* Desf.) for some morphological, physiological and biochemical parameters under the effect of water treatment (rainfall and irrigation) in semi-arid environments

Bourahla, A.[1,3*] and H. Chennafi[2,3]

[1]*Mohammed El Bachir El Ibrahimi Bordj Bou Arreridj University, Department of Agronomic Sciences, Faculty of Natural and Life Sciences and Earth and Universe Sciences, 34000 Sétif, Algeria*
[2]*University Ferhat Abbas Sétif, Department of Agronomic Sciences, Faculty of Natural and Life Sciences, 19000, Sétif, Algeria*
[3]*Laboratory of valorisation of natural biological ressources (VRBN), (LVRBN)*
[*]*Corresponding author:* amelbourahla@univ-bba.dz

Abstract

Bourahla, A. & Chennafi, H. (2022). Characterization of modern durum wheat genotypes (*Triticum durum* Desf.) for some morphological, physiological and biochemical parameters under the effect of water treatment (rainfall and irrigation) in semi-arid environments. *Bulg. J. Agric. Sci., 28 (3)*, 443–450

In the semi-arid regions of the Algerian highlands, demand for irrigation water has increased due to population growth, and climate change. Irrigation and the selection of durum wheat genotypes play an essential role in the payer economy and require comparative and identification studies of new durum wheat varieties. To understand the current situation, we compared two new durum wheat genotypes with old ones on morphological, biochemical, physiological parameters, and yield components; in addition, we examined the response of the genotypes to the components of water use efficiency. In a pilot farm in a semi-arid environment in the Algerian highlands, we compared two new durum wheat genotypes with two pregnancies on different morphological, biochemical, physiological parameters and Statgraphics centurion 18 and JMP Pro 13 test yield components for two-water treatment based on cropwat software, the results obtained.

The results show that the new genotypes have similar and sometimes better traits than the old ones. Boutaleb (BT), new genotype it showed better reactions on all the parameters studied, it decreased leaf area for a resistance reaction, higher biomass in rainfall as an index of sensitivity to water stress, better yield to present a production trait, as well as Boutaleb (BT) and the variety with the highest water value for both treatments. The new varieties Boutaleb (BT) and Oued el bared (OEB) reveal the existence of a great variability for most of the parameters measured, there are still other parameters to be studied for the well classified in the future.

Keywords: durum wheat; water efficiency; cropwat; semi-arid

Introduction

Cereals farming remain the centrepiece of the development strategy of the agricultural sector in Algeria and must be clearly considered a priority for food independence (Grignac, 1981). The variation in grain yields of durum wheat (*Triticum durum* Desf.) from semi-arid areas of altitude derives largely from the effects of abiotic stresses of a water and thermal nature (Bouzerzour & Monneveux, 1993). In addition, the surfaces devoted to this culture, have not changed for a long time

(Mouellef, 2010). Faced with this situation, various improvement strategies can be applied. Among them, it is necessary to know well its characters to be able to use its potentialities. For this, the study and characterization of genetic resources to create new varieties with good quality, high yield, adapted to climatic variations and resistant to diseases (Amallah et al., 2016) is paramount. Choosing the genotype that best adapts to rainfall conditions results in the best grain and straw yield. It is in this aspect that the objective of this demonstration is based to arrive at a suitable choice between the four genotypes Waha (W), Oued el bared (OEB), Boutaleb (BT) and Bousselam (BS).

Material and Methods

Four durum wheat varieties were planted during the 2018/2019 agricultural campaign, the site is at an altitude of 862m, at latitude 35°58'74'N and longitude 40°44'5'E, the agricultural campaign recorded an average temperature in January of 5°C, and 29.7°C in July. Maximum temperature in July 38.2°C, and a minimum of 1.2°C during the month of January, the cumulative rainfall is 355.1 mm.

The variety collection was provided by the Technical Institute for Field Crops (ITGC) in Setif. The plant material used concerns the two new genotypes Oued El Bared (OEB), and Boutaleb (BT) are varieties authorised for production and marketing by the Official Journal of the Republic of Algeria N°59 on 09 October 2016 (Article2), OEB is adapted to the area of high plateaux, full interior of Eastern Algeria, tolerant to cold and early, whereas BT is an intermediate variety, tolerant to cold, Waha (W) straw genotype and shorter cycle time, and the fourth genotype is Bousselem (BS) early and medium-sized.

These varieties were sown in a very heavy soil, clay texture, alkaline pH, low organic matter content (Laboratoir Fertial, 2018), in elementary plots of 1m^2, contains 6 lines, with two treatments (T1: a rain crop pipe without irrigation, and a T2: a water-restricted pipe throughout the cycle), with three replicates. Irrigation doses were determined by the climwat for cropwat software. The soil worked with the plough has socs, the preparation of the seedbed is carried out manually, a background fertilizer has been deposited, and it is the phosphactyl at 35 g/m^2. Sowing was carried out at a density of 300 grains per m^2. Weeding was applied manually and continuously from time to time as soon as weeds developed.

Yield components, biochemical, physiological, morphological parameters, and water use efficiency were measured for yield components, all on an average of 10 spikes collected from each elemental plot, treatments and for each genotype. The resulting data were processed by Statgraphics centurion 18 and JMP Pro 13.

Results and Discussions

A. Performance Components

- ***Plant height (h)*:** The phenotypic variability of the plant height, gives a very highly significant difference for treatments and highly significant for genotypes, and the student t gives two homogeneous groups, long group A in BT and BS and a short group B in W and OEB, (Table 1). These results show that the new BT variety shows a high resistance to the lack of water because the latter in rainfall has a value of 87.4 cm higher than that of W and OEB in rainfed and not far from old BS which is known among the varieties of high straw. (Figure1).
- ***Number of ears per m² (NE):*** The statistical study of the component number of ears per square metre reveals a highly significant deference to the two factors studied, two homogeneous groups are identified, A which groups OEB and BT, in addition BT shares group B with BS and W (Table 01), based on this distribution of homogeneous groups, the existence of intra-specific variability can be noted. OEB and BT the new varieties have taken the highest values compared to enceint (W and BS), the maximum value is 273 epi/m^2 observed in OEB. (Figure 1).
- ***Weight of ears (WE):*** A very highly significant variance for both factors, and not significant for their interactions, three homogeneous groups present, Group A for BT, Group B for BS, and EPO shares Group C with W. (Table 1). Once again BT takes the first place in terms of lifetime weight of cobs record-

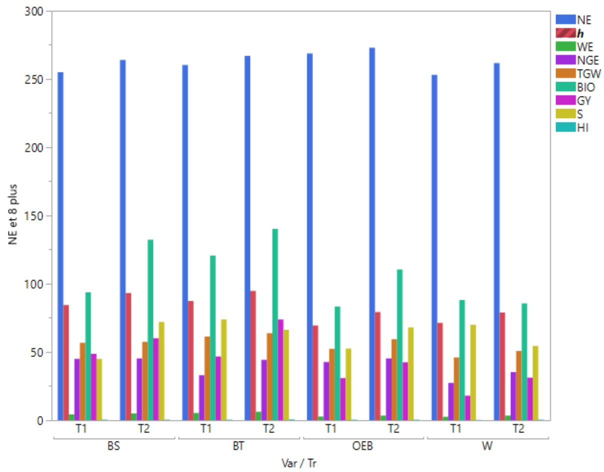

Fig. 1. Performance components of the four genotypes and their treatments

ed, Figure 1, at the treatment led by irrigating, the genotype BT records a weight difference of 2.85g compared to the W classified last.

- ***Number of grains per ear (NGE):*** The ANOVA effect tests show a very highly significant difference for treatments, genotypes, the student t gives three homogeneous groups or OEB occurs in both groups A and B. (Table 1). The graphical presentation (Figure 1) shows the highest average number of grains per ear in BS and OEB which is 45.3 grains per ear at the irrigated treatment, followed by BT and W.
- ***Thousand grain weight (TGW):*** Weight of thousand grains varies from 63.9 g/m², a value observed in BT by irrigating followed by OEB to 59.5 g/m² for the same treatment (Figure 1). The analysis of variance is very highly significant for treatments and genotypes, and significant for interaction (treatments x genotypes), Three homogeneous groups according to the student t are identified, BT and W is alone in first and third group, and BS and OEB share Group B together (Table 1).
- ***Biomass (q/ha):*** Analysis of biomass variance shows a highly significant difference for genotypes and treatments, three homogeneous groups are found, A for BT and BS, B for BS and OEB, C for OEB and W (Table 1). Figure 1 shows a difference of 8 q/ha between the large and small value for the treatment conducted by irrigating the two genotypes BT and BS, but they recorded the same weight in rainfall (121 q/ha), W records the lowest weight in irrigating and OEB in rainfall.
- ***Grain yield (GY) (q/ha):*** Statistical analysis reveals a very highly significant deference of the two factors, and not significant for their interactions, two homogeneous groups are removed by the student t, 1st high group in BT and BS, 2nd group B for OEB and W (Table 1). The new BT genotype has the best yield for treatments 73.3 q/ha irrigating and 48.7 q/ha rainfall (Figure 1).
- ***Straw (q/ha):*** The analysis of the variance of the straw yield component showed a non-significant difference for all sources, with a single homogeneous group given by the student t which groups all genotypes starting with BT, W, OEB and BS (Table 1). For Figure 1, the straw yield for BT in rainfall is the highest 73.9 q/ha, whereas BS yields 72.2 q/ha at the irrigated treatment followed by OEB.
- ***Harvest Index (HI):*** The best harvest index recorded for our experimental trial is that of BT (0.53 in irrigating), followed by BS (0.52 in rainfall) (Figure 1), the analysis of variance shows a very highly significant difference for genotypes, significant for processing and interaction (GxT), student t-tests identify three homogeneous groups, group A which groups the BS and BT genotypes, BT shares group B with OEB, and finally group C or OEB shares group B with W. (Table 1).

Yield components are among the characterization parameters for durum wheat genotypes, the ability to produce an acceptable biomass at maturity is a desirable feature in semi-arid areas given climate variability (Bouzerzour et al., 1988). Stress that high biomass is the main cause of high yields in our case it is recorded in BT and BS irrigating. The NE per square metre is the most closely related performance component (Bouzerzour & Monneveux, 1993). According to Bouzerzour & Monneveux (1993), NE/m^2 varies more by year and place than by variety for the same year. The results obtained for this parameter are similar to those of Couvreur (1981), Nachit (1986) and Hamada (2002), which show that NGE plays a very important role in yield variability and depends on the fertility of spikelets. Grignac (1981) indicates that TGW decreases when epi fertility increases.

This weight is highly dependent on climatic conditions and nitrogen nutrition during maturation and is confirmed

Table 1. Mean square of analysis of variance for yield components of the four genotypes and treatments during the 2018/2019 crop year

Source	Ddl	H	NE	WE	NGE	TGW	BIO	GY	S	HI
Treatments	1	423.36***	308.16**	3.49***	187.04***	88.16***	2576.53**	1506.38***	142.64^{NS}	0.022*
Genotyps	3	1395.57***	636.33**	33.56***	716.45***	617.93***	6534.49**	4831.83***	460.36^{NS}	0.152***
GxT	1	5.71 ^{NS}	20.83^{NS}	0.003^{NS}	112.45*	35.14**	1345.36^{NS}	254.81^{NS}	1766.89^{NS}	0.053*
Groups		A (BT, BS), B (W,OEB)	A (OEB, BT), B(BT, BS, W)	A (BT), B (BS), C (OEB, W)	A (BS,OEB), B (OEB, BT), C (W)	A (BT), B (BS, OEB), C (W)	A (BT, BS), B (BS, OEB), C (OEB, W)	A(BT,BS), B (OEB, W)	A(BT, W, OEB, BS)	A (BS, BT), B (BT, OEB), C (OEB, W)

H: Plant height, NE: Number of ears, WE: Weight of ears, NGE: Number of grains per ear, TGW: Weight of 1000 grains, BIO: Biomass, GY Grain yield (q/ha), S: Weight of straw (q/ha), HI: Harvest index ***, **, *, ns: very highly significant, highly significant, significant and non-significant respectively: Waha, OEB: Oued el bared, BT: Boutaleb, BS: Bousselem.

by our trial. The yield is determined by its components such as TGW, NGE, BIO; whereas the tolerance is determined by phenological, physiological characteristics such as the precocity to the epilation, the height of the vegetation, chlorophyll content of leaves and relative water content (Ghennai et al., 2017). GY is conditioned by the genetic potential of the variety, but also by agro-climatic conditions and crop management.

It is the purpose of any plant breeding work (El-Hakimi, 1995). According to Monneveux (1991) the choice of the genetic aptitude of the yield as a selection criterion is justified where the environmental conditions allow the expression of this aptitude. However, under conditions of significant environmental constraints, GY cannot be selected as a selection criterion. However, several studies have shown that the improvement of a complex character, such as GY, which is little inheritable, can be approached indirectly through the characteristics that are strongly related to it and less influenced by the environment (Sharma & Smith, 1986; Monneveux, 1991; Ceccarelli & Grando, 1991).

All this will lead us to classify the new best BT genotype for all the performance components studied under the current climate change conditions.

B. Biochemical and morphological parameters

- ***Sugar content (SC in µg/g MF):*** Analysis of the variance of soluble sugar content indicates that genotypes are highly significant and highly significant for genotype interaction, treatment, student t indicates two groups A and B or genotype W occurs in the second group alone (Table 2). The high accumulations of soluble sugars for both treatments are observed in BS and BT by irrigating them (1.86 µg/g MF, 1.81 µg/g MF respectively), and in OEB and W by rainfall (2.83 µg/g MF, and 1.99 µg/g MF respectively) (Figure 2).
- ***Leaf area (LA):*** A very highly significant difference for genotypes and interactions (GxT), three homogeneous groups are released, A large area occupied by W, and BT, group B for BS, and C occupied by OEB (Table 2). The leaf area varies between the four genotypes studied (Figure 2), where a large SF was noted for the three genotypes (BT, BS and OEB) (8.56 cm², 5.76 cm² and 3.79 cm²), to the rainfed treatment, while W, on the other hand, has the largest LA at the treatment conducted by irrigating (8.60 cm²) (Figure 2).

Table 2. Mean square of the analysis of variance for biochemical and morphological parameters of the four genotypes and treatments during the 2018/2019 crop year

Source	Ddl	SC, µg/g de FM	LA, cm²
Treatment	3	0.0368^{NS}	3.936*
Genotyps	1	3.539***	75.923***
GxT	3	2.727**	17.358***
Groups		A (OEB, BS, BT), B (W)	A (W, BT), B (BS), C (OEB)

SC: sugar content (µg/g of fresh material), LA: leaf area (cm²). ***, **, *, ns: highly significant, highly significant, significant and non-significant respectively. W: Waha, OEB: Oued el bared, BT: Boutaleb, BS: Bousselem.

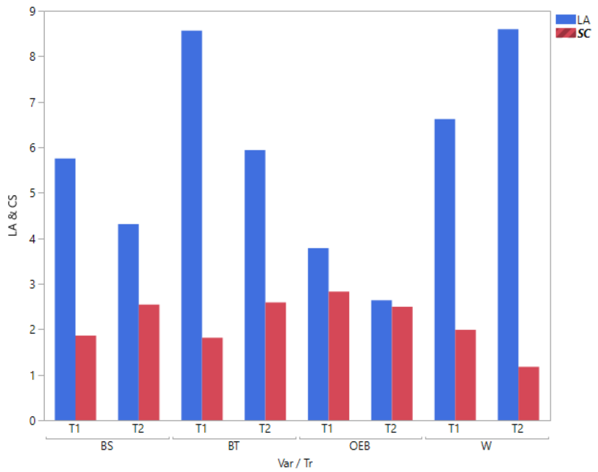

Fig. 2. Biochemical and morphological parameters of the four genotypes and treatments

Under stress, there is a high accumulation of soluble sugars in the new OEB variety. The accumulation of soluble sugars is a method adopted by plants in case of stress, in order to resist the constraints of the environment (Mouellef, 2010). Khelil (2017), in our case OEB presents itself. For LA our results coincide with the work of Baldy (1973) , which shows that under rainfed conditions, relatively large leaf genotypes still have higher grain yield, confirming our new BT variety for rainfed treatment.

For irrigating treatment, the BT genotype has the same characteristics asserted by Gate (1995), which shows that in situations of limited water supply this parameter can be used as a selection index to obtain a high yield, because small leaf area genotypes are more tolerant of water deficit compared to large leaf area varieties.

C. Physiological parameters

- ***Relative water content (RWR%):*** The relative water content of the leaf was determined by the method described by Barrs (1968). Using this method, the leaves are cut at the base of the leaf blade and weighed immediately to obtain their fresh weight (FW). These sheets are then placed in test tubes filled with distilled water and placed in the dark in a cool place, after 24 hours the sheets are removed, passed through a blotting paper to absorb the water from the surface, weighed again to obtain the weight of full turgescence (FT). The samples are then heated to 80°C for 48 hours and weighed to obtain their dry weight (DW). The relative moisture content is calculated by the following formula (Clark and Mac-Caig formula, 1982): RWR (%) = [(FW-DW) / (FT- DW)]. 100. The analysis of variance shows a very highly significant difference for all sources of variation, with the student t showing three groups. (Table 3). W in the rainfed took the first level with a percentage double compared to the second BT in irrigating, a difference of 20.71% for the last level which is occupied by OEB in irrigating (Figure 3).

- ***Cellular integrity (IC%):*** The analysis of variance is very highly significant for genotypes and interaction (GxT) and not significant for treatments, t de student identify two groups, group A for genotype BS and group B for genotypes OEB, W and BT (Table 3). The highest average cell damage value is noted in BS by irrigating, the lowest is expressed by BT for the same treatment. Of the 4 genotypes studied, W conducted in rain appears to be the least affected under the effect of water stress with the lowest cell damage value at 38.2% while the most important average value of this variable is present by BS at 72.8% (Figure 3). These values represent the percentage of cells damaged under stress. They are relatively high and variable from one genotype to another.

- Dosage of chlorophyll pigments
    - ***Chlorophylls a:*** The analysis of variance indicates a very highly significant effect for all sources of variation, with two homogeneous groups drawn by the student t (Table 3). Resulted that the treatments lead in rainfall for the four genotypes is ranked first by high values compared to irrigated treatments, OEB in irrigated shows low value 6.43 SPAD, W distinguish in order by higher levels of 61,4 SPAD in the rain, followed by the BT genotype which is marked by 21.2 SPAD (Figure 3).
    - ***Chlorophylls b:*** The variance analysis shows a highly significant difference for treatments and not significant for genotypes and interactions, the student t group all genotypes under the same group (Table 3). Figure 3 shows that chlorophyll b values are high for rainfed and low for irrigating, except for the new OEB genotype or found the opposite.
    - ***Chlorophylls (a+b):*** Analysis of the variance of chlorophyll content (a+b) indicates a highly significant difference for the interaction source (TxG), significant for genotypes and not significant for treatments, two homogeneous groups or the OEB and BS genotypes occur in both

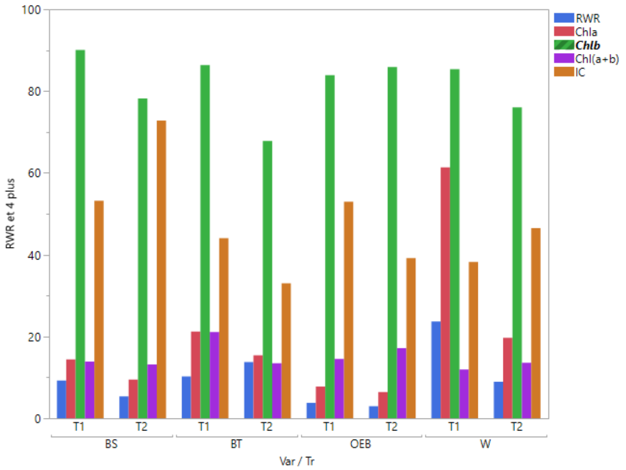

Fig. 3. Physiological parameters of the four genotypes and treatments

Table 3. Mean square of the analysis of variance for Physiological Parameters of the four genotypes and treatments during the 2018/2019 crop year

Source	Ddl	RWR%	Ic%	Chl a	Chl b	Chl (a+b)
Treatment	3	94.28***	3.76 NS	1081.79***	531.948**	5.99 NS
Genotyps	1	568.45***	2097.17***	3930.15***	231.28NS	77.89*
G X T	3	273.89***	1142.79***	1613.23***	329.44NS	96.48**
Groups		A (W, BT), B (BT, BS) C (BS, OEB)	A (BS), B (OEB, W, BT)	A (W), B (VBT, BS, OEB)	A (OEB, BS, W, BT)	A (BT,OEB, BS), B (OEB, BS, W)

RWR%: percentage of water content. IC%: percentage of cell integrity, Chl a: Determination of chlorophyll pigments a, Chl b: Determination of chlorophyll pigments b, Chl (a+b): Determination of total chlorophyll pigments. ***, **, *, ns: Very highly significant, highly significant, significant and non-significant respectively. W: Waha, OEB: Oued el bared, BT: Boutaleb, BS: Bousselem.

(Table 3). The BT genotype marks the highest rainfall value (21.1 SPAD), and OEB marks the highest rainfall value (17.2 SPAD) (Figure 3).

Lack of water is a key factor for plant growth, particularly in arid and semi-arid regions. It induces a decrease in relative water content in stressed plants (Albouchi et al., 2000). Clarck & Mac-Caig (1982) draw attention to the use of RWR as an indicator of the water state of the stressed plant. The RWR of durum wheat leaves decreases proportionally with the reduction in soil water (Bajji et al., 2001). Scofield (1988), note that this decrease is more rapid in susceptible varieties than in resistant varieties. On the other hand, Zeghida et al. (2004) was found to have elevated RWR under stress conditions. On the other hand, Mberkani (2012), show that genotypes that maintain high RWR in the presence of water stress are tolerant genotypes. W in rainfall appears less sensitive to cell damage than BS, OEB and BT. Maintaining the integrity of cell membranes under water stress is one of the universally recognized traits in explaining plane tolerance to drought. According to Cornaire et al. (1995) and Lefebvre et al. (2009) among the mechanisms that can intervene in the maintenance of cell turgescence is protoplasmic resistance, which depends on the ability of the cells to resist mechanical damage and denaturation of proteins at the membrane or cytoplasmic level. Reynolds et al. (1994) found a strong correlation between the percentage of cellular damage caused by thermal shock and the reduced productivity of the genotypes tested. This suggests that selection based on low cell damage significantly improves grain yield. Therefore, selection for this feature favours the BT genotype by irrigating and W in rainfall. The increase in chlorophyll content noted in the BS, BT and W rain genotypes would likely be the result of reduced leaf cell size as a result of water stress leading to higher concentration. This assumption is reinforced by the reduction of leaf RWR and LA in these populations. Total chlorophyll is a good indicator of the water stress tolerance threshold as reported for which the higher this parameter the more tolerant the varieties are to water deficit. These results lead us to conclude that the BS, BT and W varieties would adapt better to drought than the OEB genotype (Bougdad & Benkaddour, 2015).

D. Genotyping response to water use efficiency components

- ***Water Use Efficiency for grain yield (WUEGY):*** The analysis of the variance shows a very highly significant difference for all the sources of variation, the student t shows two homogeneous groups or OEB in both groups (Table 4). The water-use efficiency for grain yield (WUEGY) is different from one genotype to another, for both treatments distinguishes that BT is close to BS and OEB is close to genotype W, as well as the amount of water used to produce one kg per mm of water is 15,6 kg.h^{-1}.mm^{-1} for W, is 42 kg.h^{-1}.mm^{-1} for BS irrigate it (Figure 4).
- ***Water use efficiency for biomass (WUEBIO):*** A very highly significant difference for the sources of genotype variation and treatment, and not significant for their interaction, a single homogeneous group (A) is derived from the student t (Table 4). The efficiency of water use to produce aerial biomass varies from genotype to genotype and from treatment to treatment, Figure 4 records a biomass of 104 kg.h^{-1}.mm^{-1} per BT in rainfall compared to the OEB gen-

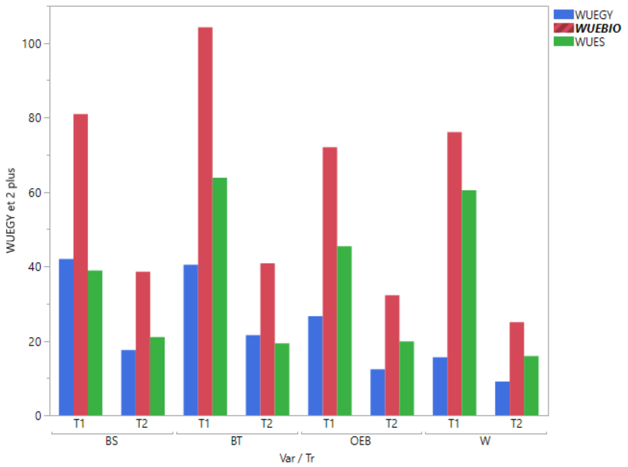

Fig. 4. Components of water use efficiency of the four genotypes and treatments

Table 4. Mean square of the analysis of variance for the water use efficiency components of the four genotypes and treatments during the 2018/2019 crop year

Source	Ddl	WUEYG	WUEBIO	WUES
Treatment	3	1541.28***	14490.4***	6580.61***
Genotyps	1	1411.60***	1816.03***	495.99^{NS}
GxT	3	259.85***	509.75^{NS}	825.06*
Groups		A (BT, BS, OEB), B (OEB, W)	A (BT, BS, OEB, W)	A (BT,W, OEB, BS)

WUEYG: Water Use Efficiency for grain yield. WUEBIO: Water use efficiency for biomass. WUES: Water use efficiency for straw. ***, **, *, ns: Very highly significant, highly significant, significant and non-significant respectively. W: Waha, OEB: Oued el bared, BT: Boutaleb, BS: Bousselem.

otype which appears less efficient for water to produce aboveground biomass.

- ***Water use efficiency for straw (WUES):*** The efficiency of using water to produce straw (WUES) is highly significant for treatments, not significant for genotypes, the student t gives a single homogeneous group. (Table 4). BT is distinguished by the best value of water use efficiency with 63.8 kg.h^{-1}.mm^{-1} in rainfall and 21 kg.h^{-1}.mm^{-1} for genotype BS in irrigating (Figure 4).

Water use efficiency, defined as the production of biomass per unit of water consumed, is an important drought

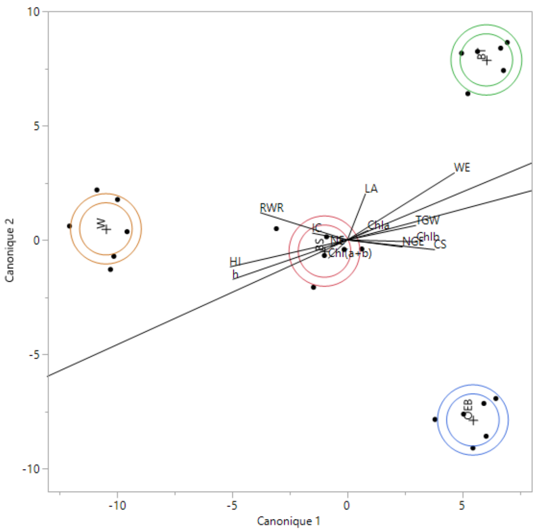

Fig. 5. Canonical graph of the linear discriminant analysis of the parameters studied for the four genotypes of the 2018/2019 crop year

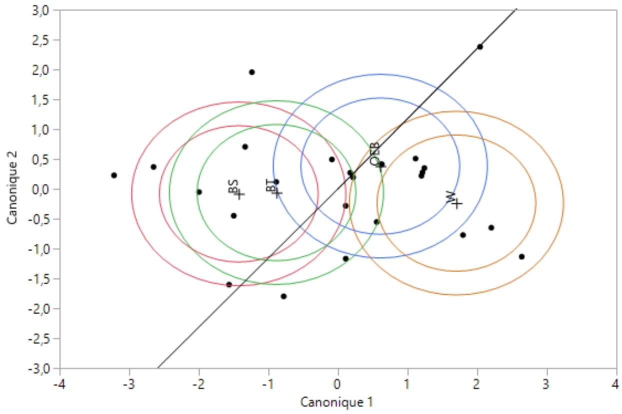

Fig. 6. Canonical graph of the linear discriminant analysis of water use efficiency for the four genotypes of the 2018/2019 crop year

tolerance trait (Richards et al. (2002). The new genotype BT is the most valuable in water under the effect of the two treatments study (rain and irrigate). Distinguished by a WUEYG of 40.4 kg.h^{-1}.mm^{-1} in rainfall and 21.5 kg.h^{-1}.mm^{-1} in irrigating, followed by BS, OEB and W.

E. Linear discriminant analysis of the parameters studied

According to Figure 5, the results of the performance parameters studied for the W and OEB and BS genotypes differ from the BT and OEB genotypes, they have similar characteristics.

Regarding the water use efficiency of YG, BIO and S, Figure 6 shows that BT and BS is different from OEB and W, BT and BS are similar.

Conclusions

Study of yield components, biochemical and morphological parameters, the physiological parameters and water-use efficiency of the new BT and OEB varieties with the old W and BS reveals a high degree of variability for most of the measured parameters. Our study reveals the new BT varieties that have been shouting at the highlands, full interior Algerian, and authorized for production and marketing by the Official Journal of the Algerian Republic N°59 on 09 October 2016 (Article 2), to show a similarity to that of BS and OEB to shows a similarity to W for most of the measured parameters. But what concerns the morphological parameters BT it to watch features peculiar to it. The most important, is the best reaction of the latter to the morphological characteristics or it has decreased the leaf area for a resistance reaction, higher biomass in rainfall as an index of sensitivity to the water stress, better yield to show a production character. These findings suggest that it is important for the public decision-maker to facilitate the choice of variety as appropriate.

Acknowledgements

The authors thank the LAABACHI pilot farm for their assistance during the experiment.

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Received: **February, 21, 2021**, *Accepted*: **May, 21, 2021**, *Published*: **June 2022.**