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STUDY ON THE DIVERSITY OF GENOTYPIC VARIETIES OF DURUM WHEAT (*Triticum durum* Desf.) IN THE SUB-HUMID REGION OF EL HARROUCH, ALGERIA

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Abstract

The study on the yield parameters and the morpho-biometric characterization of twenty genotypic varieties of durum wheat (*Triticum durum* Desf.) was carried out in the sub-humid region of El Harrouch of Algeria. A descriptive sheet according to the recommendations of UPOV (2014-2017) and the calculation of the Shannon and Weaver diversity index was prepared with 27 qualitative characters and one quantitative character relating to the different parts of the ear. The yield parameters, such as number of plants/m^2, herbaceous tillers, ear tillers, number of ears/m^2, number of grains/ear, weight of 1000 grains, grains yield, harvest index, areal biomass, economic yield and straw yield showed a great diversity among these varieties. The Shannon and Weaver index (H') revealed a great diversity of all the studied genotypes (H'=0.52). The high polymorphic characters were the shape of the shoulder of the lower glume (H'=1), the curvature of the beak of the lower glume (H'=0.9), the length of the rachis of the ear (H'=0.87), the disposition barbs (H'=0.86), the length of the hairs of the grain brush (H'=0.84), the hairiness of the first article of the rachis of the ear (H'=0.84) and the length of the first article of the ear (H'=0.81). Based on study result, the varieties suitable to this agro-ecological conditions could be chosen for this region. It is concluded that the creation of descriptive sheets, the knowledge of production and adaptation parameters could be considered as precursors of high yield for economic needs and mastery of production techniques in improvement programs.

Key words: *Triticum durum* Desf.; Genotypic varieties; Phenotypic diversity; Morpho-biometric characterization.

INTRODUCTION

Durum wheat (*Triticum durum* Desf.) is one of the most consumed cereals in the world and the most cultivated in the Mediterranean region and semi-arid areas (Pataco *et al*. 2015, Ahmed *et al*. 2019, Fiorilli *et al*. 2022). The Mediterranean region is one of the main hotspots caused by variability and extremes in temperature, precipitation and climate change (Diffenbaugh and Giorgi 2012, Schilling *et al*. 2020, Chourghal and Hartani 2020). The Maghreb countries are the biggest consumers of wheat in the world, especially Algeria with nearly 216 kg/inhabitant/year (Derbal 2015). According to the FAO (2022), wheat consumption in Algeria was 11.37 million tonnes between July 2020 and June 2021. Algeria imported on average more than 12 million tonnes of cereals per year during the last five years, when the annual production was about 4.92 million tons, including 3.3 million tons of wheat. In 2021, the drought episodes that hit North Africa affected cereal production. In Algeria, total cereal production in 2021 is estimated at 3.5 million tonnes, which is below the five-year average and about 38% less than the previous year (FAO 2022).The variation in cereal production in Algeria is strongly linked to abiotic climatic conditions, such as frost and the poor distribution of rains in time and space (Djermoun 2009), which causes drought and high terminal temperatures and at the dominance of the use of local varieties which are well adapted to the most difficult conditions, but which have a low yield potential. Varietal selection has been practiced until recent years on the basis of improvement programs that have allowed us to select thousands of varieties. This selection was made to meet the great agro-ecological diversity on the one hand and the specific needs of farmers on the other; thus, providing farmers with high-performance varieties adapted to the conditions of the environment. The aim of any genetic improvement program is to produce varieties with high and stable yield. Grain yield is a genetically complex trait and its improvement requires selection of productivity and adaptive traits to abiotic and biotic environments (Oulmi *et al*. 2014, Fellahi *et al*. 2017, 2018, 2020, Salmi *et al*. 2021). Indeed, the new genotypes obtained are more often selected according to their performance without taking into account the adaptive characters (Laala 2010). In this optical the objective of this study is integrated, which will focus on the evaluation of the production and adaptation characters of twenty genotypes of new durum wheat varieties (*Triticum durum* Desf.) on the basis of phenotypic morpho-physiological characters according to the international standards of the Union for the Protection of Plant Varieties (UPOV 2014-2017) in sub-humid conditions in the region of El Harrouch in the wilaya of Skikda (North-eastern of Algeria).

MATERIAL AND METHODS

The plant material of 20 genotypes of durum wheat (*Triticum turgidum* ssp. *durum* L.) were obtained from the AXIUM Agro Multi Investment and Services SPA (Ain Smara, Constantine) (from G1 to G7) and Technical Institute of Field Crops (TIFC) of El Khroub (Constantine) (from G8 to G20) (Table 1).

Table 1. Origin of studied genotypes of durum wheat.

Genotypes	Name	Pedigree	Origin
G1	Ovidio	Svevo/Claudio	Italy
G2	Emilio Lepido	Orobel//Acrcobaleno/Svevo	Italy
G3	Ancomarzio	Stotka//Altar84/Ald	Italy
G4	Mimmo	Simeto/ Medora	Italy
G5	Simeto	Capeiti8/Valnova	Italy
G6	Ciccio	Appulo/Valnova//Valforte/Patrizio	Italy
G7	Core	Platani/Gianni	Italy
G8	Bousselam	Can 2109//jo/aa/3/s15/cr	Algeria
G9	Sigus	Ter1/3/stj3//bcr/lks4	CIMMYT (Mexico)
G10	MouletEddar	Unavailable	Algeria
G11	Numidia	Unavailable	Algeria
G12	Bouhamenna	Unavailable	Algeria
G13	Cirta	Hedba3/GdoVZ 619	Algeria
G14	Beni Mestina	Lahn/cham12003	Algeria
G15	Oued El Bared	Gta dur/Ofanto	Algeria
G16	Waha	Plc/Ruff//Gta/Rtte	ICARDA (Syria)
G17	Ammar6	Lgt3/Bicre//cham1//orlgt3/4/Bicre/3/Ch1//Gav/Starke	ICARDA (Syria)
G18	Ettayeb	Mexicali75× Ofanto	Algeria
G19	Wahbi	Bidi 17/Waha//Bidi 17	Algeria
G20	Gta /durum69	Gta ‘s’/ dur 69//Egret’s’/3/Win	CIMMYT (Mexico)

Description of the study site: The test was carried out during the season of 2021/2022 at the pilot farm Daoudi Larbi of El Harrouch located in the wilaya of Skikda (North East of Algeria) (Fig. 1 and 2) at 36°39’08” N and 6°49’12” E, above 142 m sea level. According to the Köppen-Geiger classification, the climate of El Harrouch province is mediterranean type Csa. The average temperature at El Harrouch is 17.4°C. It falls on average 704 mm of rain per year. The driest month is July with only 5 mm. With an average of 126 mm, January recorded the highest precipitation.

With an average temperature of 26.0°C, the month of August is the warmest of the year. With an average temperature of 10.0°C, the month of January is the coldest of the year (DSAS 2020). The soil is very heavy in clay texture (52% clay, 32% silt and 16% sand) with very high fertility, unsalty, and an alkaline pH (8.1) (PFDL 2020).

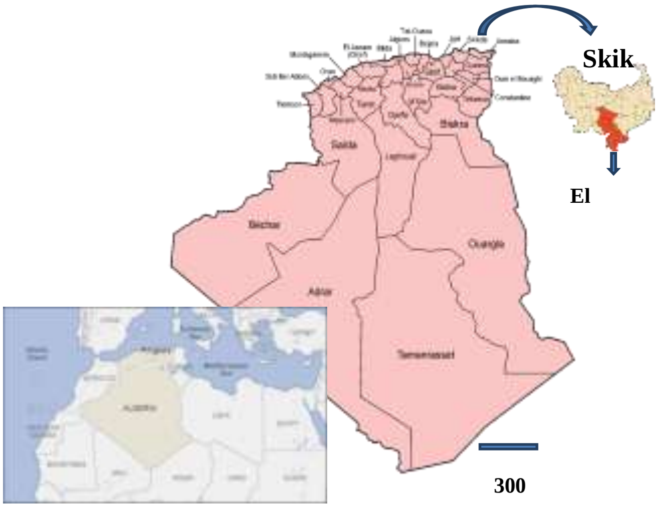

Fig. 1. Location Map of study site, El Harrouch (Wilaya de Skikda).

Fig. 2. Plot used in the Larbi Daoudi pilot farm (Via Google earth).

Study methods: In the field, a trial of 20 genotypes was installed according to an experimental device of completely randomized blocks with three replications; each elementary plot is 1m x 1m and consists of 5 rows spaced 20 cm apart with a spacing of 50 cm between each genotype. Sowing is carried out manually on November 25, 2021 with a sowing density of 350seeds/m^2.

Morpho-biometric characterization and descriptive sheets: The morphological characterization of the genotypes was carried out according to the International Union for the Protection of New Varieties of Plants (UPOV 2014-2017), using 27 qualitative characters and one quantitative character (Table 2). Among these characters studied, we have 2 characters concerning the plant (length and section of the straw) and 26 characters relate mainly to the ear, lower glumes and the grain, each of which has different states. 12 samples/plant/genotypes were measured at maturity.

Growth and adaptation of studied genotypes

Number of plants/m^2: It is obtained by direct counting of all plants lifted/genotype/repetition. We then deduce the average of the plants raised/m^2.

Number of herbaceous tillers/plants: It is determined by direct counting of the number of herbaceous tillers of 12 plants/genotype, from the 4-leaf stage until the end of tillering. We then deduce the average herbaceous tillers/plant.

Number of ears/plant tillering: It is determined by direct counting of the number of ears formed of herbaceous tillers of 12 plants/genotype, from the 4-leaf stage until the end of tillering. The average of the ear tillers/plant is then deduced.

Efficiency of transformation of herbaceous tillers into ear tillers (%)

Number of ears/m^2: It is obtained by direct counting of all the ears formed/genotype/repetition. We then deduce the average of ears/m^2.

Number of grains/ears: It is obtained by direct counting of a sample of 10 ears/genotype.
1000 grain weight (TGW): It is obtained by direct weighing on a precision balance (Metter-P.C 400), of 1000 grains/genotype. It is expressed in grams.
Grain yield (GY): The grain yield is estimated by the calculation according to the components of the yield by the following formula (expressed in g/m^2 then in q/ha):

$$GY = \text{Number of ears/m}^2 \times \text{Number of grains/ear} \times \text{1000 grain weight}/100$$

Aerial biomass (ABIO): The aerial biomass is determined from the harvesting of a sample of vegetation from a row segment 1 linear meter long. The weight of the sample is reconverted into q/ha and represents the parcel value of this variable
Straw yield (SY): The straw yield was estimated by the difference, between the aerial biomass and the grain yield, derived from the moen bundle of vegetation of a 1 m long row segment per elementary plot. Expressed in q/ha. It is calculated by the formula:

$$SY = ABIO – GY$$

Where, ABIO= Aerial biomass (q/ha) and GY= Grain yield (q/ha).
Economic yield (E_{eco} Y): The economic yield is calculated as the sum of the grain yield plus 30% of the straw yield. Expressed in q/ha. It is calculated by the formula of Annicchiarico *et al.* (2005):

$$E_{eco}Y = GY + 0.3\,SY$$

Where, GY= Grain yield and SY= Straw yield

Harvest index (HI): The harvest index (%) is determined using the plot values of grain yield and aboveground biomass estimated from the vegetation sample harvested from a 1 m long row segment. Expressed in %. It is calculated by the following formula:

$$HI\ (\%) = GY / ABIO$$

Where, GY=Grain yield (q/ha) and ABIO= Aerial biomass (q/ha).

Table 2. Phenotypic classes and nature of characters of studied Durum wheat.

N	Characters	Observation and notation	Nature
1	Plant: Length (stem, ear and awns)	Very short: <60 cm (1), Short: 60-75 cm (3), Medium: 75.1-90 cm (5), Long: 90.1-115 cm (7), Very long: >115 cm (9)	Qualitative
2	Straw: Pith in cross section (half way between base of ear and stem node below)	Thin (1), Medium (3), Thick (5)	Qualitative
3	Ear: Presence or absence des awns	Presence (1), Absence (2)	Qualitative
4	Ear : Distribution of awns	Awnless (1), Tip owned (2), Half owned (3), Fully owned (4)	Qualitative
5	Ear : Disposition of awns	Not divergent (1), Weakly divergent (3), Half divergent (5), Divergent (7), Very divergent (9)	Qualitative
6	Ear : Pigmentation of awns	None or very weak (1), Weak (3), Medium (5), Strong (7), Very strong (9)	Qualitative
7	Ear : Colour of awns	White (1), Light brown (2), Medium purple (3), Dark purple (4)	Qualitative
8	Ear: Length of awns	Very short: <50 mm (1), Short: 50-80 mm (3), Medium: 80.1-100 mm (5), Long: 110.1-120 mm (7), Very long: >120 mm (9)	Qualitative
9	Ear: Length of awns at tip relative to length of ear	Shorter (1), Equal (2), Longer (3)	Qualitative
10	Ear : Density	Very lax: D<20 (1), Lax: 20<D<23 (2), Medium: 23<D<26 (3), Dense: 26<D<29 (4), Very dense: D>29 (5) D = 10 x N / L D: Density, N: Number of spikelets, L: Spine length (mm)	Qualitative
11	Ear : Colour (at maturity)	White (1), Slightly coloured (2), Strongly coloured (3)	Qualitative
12	Ear : Shape in profile view	Tapering (1), Parallel-sided (2), Semi clavate (3), Clavate (4), Fusiform	Qualitative

		(5)	
13	Ear : Length of ear (excluding awns)	Very short: <50 mm (1), Short: 50-60 mm (3), Medium: 60.1-80 mm (5), Long: 80.1-110 mm (7), Very long: >110 mm (9)	Quantitative
14	Ear: Length of first article	Very short (1), Short (3), Medium (5), Long (7), Very long (9)	Qualitative
15	Ear: hairiness of margin of first rachis segment	Absent or very weak (1), Weak (3), Medium (5), Strong (7), Very strong (9)	Qualitative
16	Ear: neck glaucescence	None or very weak (1), Weak (3), Medium (5), Strongly coloured (7), Very strong (9)	Qualitative
17	Ear: glaucescence	None or very weak (1), Weak (3), Medium (5), Strongly coloured (7), Very strong (9)	Qualitative
18	Ear : Length of rachis	Very short (1), Short (3), Medium (5), Long (7), Very long (9)	Qualitative
19	Lower glume: shape	Ovoid (1), Medium oblong (2), Narrow oblong (3)	Qualitative
20	Lower glume: colour	Yellowish white (1), Pale red (3), Red (5), Brown (7), Black (9)	
21	Lower glume: shape of shoulder	Sloping (1), Rounded (2), Straight (3), Elevated (4), Elevated with a 2nd beak (5)	Qualitative
22	Lower glume: width of shoulder	Very narrow (1), Narrow (3), Medium (5), Broad (7)	Qualitative
23	Lower glume: length of beak	Very short: <1mm (1), Short: 1-2mm (3), Medium: 2-5mm (5), Long: 5-10mm (7), Very long: >10mm (9)	Qualitative
24	Lower glume: Curvature of beak	Absent (1), Weak (3), Moderate (5), Strong (7)	Qualitative
25	Lower glume: Hairiness of external surface	Absent (1), Present (9)	Qualitative
26	Grain: Length of brush hair in dorsal view	Short (1), Medium (3), Long (5)	Qualitative
27	Grain: Shape	Slightly elongated (1), Moderately elongated (2), Strongly elongated (3)	Qualitative
28	Grain: Colour	Whitish yellow (1), Yellow orange (2), Slightly brown (3)	Qualitative

Shannon and weaver relative diversity index

The Shannon and Weaver relative diversity index (Shannon and Weaver 1949) as described by Jain *et al*. (1975) was calculated with the aim of determining the phenotypic diversity of the durum wheat collection studied, to reveal the degree of polymorphism of the 26 traits analysed. It is worth noting that each character state is defined as a distinct phenotypic class. The Shannon and Weaver index was calculated using the following formula:

$$\mathbf{H} = -\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{p_{i^*Ln}p_i}$$

Where, **H** = Shannon and Weaver diversity index; **Pi** = Frequency of each phenotypic class i of a given trait; **n** = Number of phenotypic classes of each trait.

The index (H) is converted to the relative index of phenotypic diversity (H') by dividing it by its maximum value H_{max} (Ln (n)) in order to obtain values between 0 and 1.

$$\mathbf{H'} = -\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{p_{i^*Ln}p_{i/\,Ln(n)}}$$

The relative index of diversity (H') reaches its minimum value which is equal to zero for monomorphic characters. Moreover, the value of this index increases with the degree of polymorphism and reaches a maximum value (1) when all the phenotypic classes present equal frequencies.

Sanitary state of plants

Visual notation of the various diseases (foliar, stem and ear) and physiological accidents.

Statistical analysis

It was done by Excel stat 2020.

RESULTS AND DISCUSSION

The results of descriptive sheets for each genotype were reported in Table 3 and morpho-biometric characters are grouped together in Table 4.

Plant height: According to the results obtained, the height of the plants studied varies between 45.37cm to 63.64cm in the varieties "Oued El Bared and Simeto", respectively. We note the presence of an average phenotypic variability which classifies the genotypes according to the characteristics of varietal identification of the UPOV in two groups: very short with a rate of 90% in the varieties "Ovidio, Emilio Lepido, Mimmo, Ciccio, Core, Bousselam, Sigus, Mouleteddar, Numidia, Bouhamenna, Cirta, Beni Mestina, Oued el Bared, Waha, Ammar6, El tayeb, Wahbi and Gta/durum69", and short with a percentage of 10% in the two varieties "Ancomarzio and Semito". Ludlow and Muchow (1990) and Annicchiarico *et al*. (2005) show that stem length is considered a key trait in adaptation to terminal drought stress. Selectors have long assumed that the most drought-tolerant cereal varieties are tall-strawed varieties, because there is a positive relationship between plant height and drought tolerance can be explained by the ability of high-straw genotypes to fill the grain in case of terminal water deficit by the quantity of assimilate stored in the stem and the ability to remobilize these reserves towards the grains (Annicchiarico *et al*. 2005, Bahlouli *et al*. 2005). Siddique *et al*. (1989) point out that the negative correlation between water use efficiency and plant height is due to the fact that dwarf varieties make better use of soil moisture. In addition, the height of the stubble is associated with a root system capable of going deep, suggesting the adoption of tall varieties in the environment with low rainfall and in soils where there is residual moisture that can be exploited at depth.

Straw section: The majority of the genotypes studied "Ovidio, Emelio Lepido, Ancomarzio, Core, Bousselam, Sigus, Mouleteddar, Cirta, Beni Mestina, Oued EL Bared and Waha" have a moderately thick stem with a rate of 55%, while 40% of the genotypes have a thin stem "Mimmo, Simeto, Numidia, Bouhamema, Ammar6, El Tayeb, Wahbi and Gta/durum 69" and the genotype "Ciccio" having a thick stem (5%). According to these results, it can be concluded that the majority of genotypes studied show good resistance to lodging except the "Mimmo, Simeto, Numidia, Bouhamema, Ammar 6, El Tayeb, Wahbi and Gta/durum 69" genotype which have a thick stem and may show sensitivity to lodging, because according to Maamouri *et al*. (1988) stem rigidity may be the source of lodging resistance.

Production and distribution of awns: All genotypes were found to produce awns and this character is often considered in case of water deficit. Indeed, the presence of awns, by their upright habit and their position in the immediate neighborhood of the seed, increases the possibility of using water and the development of dry matter during the grain formation phase, especially after the senescence of flag leaves (Gate *et al*. 1990). The distribution of awns of the genotypes studied is 100% over the entire length of the ears (fully owned). According to Gate *et al*. (1990), the beards on the ear contribute to the translocation of assimilates stored at the level of the seed, which makes photosynthesis more efficient.

Disposition of awns: All the genotypes studied present awns with different dimensions and notations, which classify them according to the UPOV criteria into four main groups: We note that the genotypes "Ovidio, Emilio Lepido, Mimmo, Ciccio, Core, Bousselam, Sigus , Mouleteddar, Numidia, Bouhamenna, Cirta and Beni Mestina" have divergent beards with a rate of 60%; the varieties "Numidia, Ammar 6, Wahbi and Gta/durum 69" have weakly divergent awns with a percentage of 20%; the "Cirta, Waha and Boussellam" genotypes show non-divergent beards with a rate of 15%; while the "Oued El Bared" genotype shows the presence of very divergent beards (5%). According to Teresa *et al.* (2009), bearded genotypes are sought especially in areas where the climate is dry and hot, while beardless genotypes are predominant in temperate and humid regions.

Anthocyanin pigmentation of awns: All genotypes show none or very weak (100%) awns pigmentation. According to Coulomb *et al.* (2004) anthocyanin pigmentations are indicators of senescence (red colour of the leaves in winter before they fall), but also of stress: a plant can, when attacked, increase its production of foliar anthocyanins (mildew, deficiencies, etc.).

Awns colour: Almost all of the genotypes (90%) have white awns, while the "Simeto" variety has a meduim purple colour and the "Beni Mestina" variety has a dark purple colour. According to Bammoun (1997) for the colour of glumes and awns, their role is not well known, but it seems that it very probably intervenes in the reflectance and therefore in the use of radiation.

Awns length: The length of the beards varies between 5.11cm in the "Simeto" variety and 7.76cm in the "Oued El Bared" variety, and according to the UPOV criteria all the genotypes are considered as varieties with short beards (100%). Bouzerzour (2004) shows that the presence of long beards in certain situations is linked to tolerance to water stress, because the beards continue to ensure photosynthesis well after the senescence of the flag leaf, and its presence contributes for more than 7% increase in the yields under water stress.

Length of the awns at the tip relative to length of ear: The length of the awns at the tip relative to length of ears varies between 11.35cm in the "Simeto" variety and 14.60cm in the "Oued El Bared" variety. These results show the existence of phenotypic variability which arranges the genotypes into three classes: shorter for 15 varieties with a percentage of 75% (Ovidio, Emilio Lepido, Ancomarzio, Ciccio, Core, Sigus, Mouleteddar, Numidia, Bouhamenna, Beni Mestina, Waha, Ammar 6, Bousselam, Wahbi and Gta/durum 69), equal for the three varieties "Mimmo, Simeto and Bousselam" with a rate of 15% and longer for the two varieties "Cirta and Oued El Bared".

Density of ears: The density or compactness of the ears in the varieties studied varies between the value of 26.2 for the variety "Mimmo" and the value of 35.8 for the variety "Ammar 6". These results show a bit important diversity, which divides the genotypes into two groups: very dense density with a rate of 60%, in the following genotypes: "Ancomarzio, Simeto, Ciccio, Core, Bousselam, Sigus, MouletEddar, Bouhamenna, Oued El Bared, Waha, Ammar 6 and Gta/durum 69", and dense density with a rate of 40% in the following varieties: "Ovidio, Emilio Lepido, Mimmo, Numidia, Cirta, Beni Mestina, El tayeb and Wahbi" This character is linked to the importance of the spacing between the spikelets and the length of the articles. According to the results obtained, all the genotypes studied show a genetic source of adaptation to frost given their very compact and compact density of the ears. It is generally admitted that a good yield is based on a good compactness of the ear (Boudour 2006).

Colour of ears: Among the 20 varieties studied, there are 14 varieties with a rate of 70% (Ovidio, Emilio Lepido, Ancomarzio, Mimmo, Simeto, Ciccio, Bousselam, Beni Mestina, Waha, Amma 6, El Tayeb, Wahbi and Gta/durum 69) present slightly coloured ears, and five varieties (25%) have white ears (Sigus, Mouleteddar, Numidia, Bouhamenna and Oued El Bared.), while the "Cirta" variety has a strongly coloured ear. According to Teresa *et al.* (2009) cultivars from the regions with high light density have a tendency to develop colouration on extremity of the tips of the ears.

Shape of ears: According to the results obtained, we note that 12 genotypes present ears with a Tapering shape (60%) which are "Ovidio, Emilio Lepido, Mimmo, Cirta, Beni Mestina, Waha, El Tayeb, Wahbi and Gta/durum 69", and six varieties (30%) have fusiform ears "Ciccio, Core, Bousselam, Bouhamenna and Ammar6", and two varieties with a half-club shape "Ancomarzio and Ammar 6".

Length of ear (excluding awns): According to UPOV criteria, the length of the ears of all the genotypes is average, varies between 5.95 cm in the "Semito" variety and 7.65 cm in the "Wahbi" variety. According to Blum (1985) and Monneveux and This (1997) the ear plays an important role in photosynthesis and transpiration, and is considered a determining factor in tolerance to water stress. Djekoun *et al*. (2002) have also shown that the significant length of the ear is a predictive parameter of a harvest index and high yield potential.

Length of first article: The length of the 1st article presents a significant diversity which classifies the genotypes in three classes: medium in 10 varieties with a rate of 50% (Ciccio, Bousselam, Mouleteddar, Numidia, Oued El Bared, Waha, Ammar 6, El Tayeb, Wahbi and Gta/durum 69), long in seven varieties with a rate of 35% (Mimmo, Semito, Core, Sigus, Bouhamenna, Cirta and Beni Mestina), and very long in the following three varieties: "Ovidio, Emilio Lepido and Ancomarzio" with a percentage of 15%.

Hairiness of the margin of first rachis segment: The presence of hairiness at the lateral edges of the first segment of the rachis presents a phenotypic diversity of four classes: weak in five varieties with a rate of 25% (Mimmo, Semito, Core, Numidia and Bouhamenna), medium in a single variety of "Ancomarzio", strong in 12 varieties with a percentage of 60% (Ovidio, Emilio Lepido, Ciccio, Bousselam, Sigus, Mouleteddar, Cirta, Beni Mestina, Ammar 6, El Tayeb, Wahbi and Gta/durum 69), and very strong in two genotypes of “Oued El Bared and Waha”. According to Boudour (2006), the strong hairiness of the rachis is a criterion of adaptation to water deficit. So, we can conclude that the genotypes having a strong and very strong hairiness of the rachis are considered as varieties resistant to water stress.

Neck glaucescence: The glaucescence of the neck of the ear shows significant variability between the varieties studied which classifies them into three groups: weak in three varieties with a percentage of 15% for "Ovidio, Emilio Lepido and Bousselam", medium in 15 varieties with a rate 75% for "Ancomarzio, Mimmo, Ciccio, Core, Bousselam, Sigus, Mouleteddar, Numidia, Bouhamenna, Beni Mestina, Oued El Bared, Waha, Ammar 6, El Tayeb, Wahbi and Gta/durum 69", and strongly coloured in the varieties "Simeto and Cirta".

Glaucescence of ear: The glaucescence of the ear presents a specific diversity which classifies the genotypes into three groups: weak in half of the varieties (50%) for "Ovidio, Ancomarzio, Core, Bousselam, Mouleteddar, Numidia, Waha, El Tayeb, Wahbi and Gta/durum 69", medium in nine varieties for "Ancomarzio, Mimmo, Ciccio, Sigus, Bouhamenna, Cirta, Beni Mestina, Oued El Bared and Ammar 6", and strongly coloured in the "Semito" variety. According to the results obtained, we can consider that the variety "Semito" is more resistant to water stress because of its high glaucescence compared to other genotypes. Ludlow and Muchow (1990) show that glaucescence is a caracter which reduces the rate of water loss (cuticular transpiration) under water deficit conditions and which strongly influences yield and delays leaf senescence. Hakimi (1992) also considers that glaucescence is a morphological parameter of adaptation to water deficit.

Length of rachis: The length of the rachis varies between 5.23 cm for the "Semito" variety and 6.75 cm for the "Emilio Lepido" genotype. These results show the presence of a strong phenotypic diversity which classifies the genotypes into four classes: Short with 5% in the "Simeto" genotype, medium with 55% in 11 genotypes (Sigus, Ancomarzio, MouletEddar, Bousselam, Ciccio, Oued El Bared, Ovidio, Ammar6, Core, Cirta and Bouhamenna), long with 10% in "Ettayeb and Waha" and very long with a rate of 30% in the genotypes "Emilio Lepido, Beni Mestina, Gta/durum 69, Wahbi, Numidia and Mimmo".

Shape of the lower glume: The glume of the ear has a mefium oblong shape for 80% in 16 varieties which are: "Ovidio, Emilio Lepido, Ancomarzio, Mimmo, Semito, MouletEddar, Bouhamenna, Cirta, Beni Mestina, Oued El Bared, Ammar6, El Tayeb, Wahbi and Gta/durum69", a narrow oblong shape with 15% in three genotypes: "Core, Bousselam and Sigus" and an ovoid shape in "Ciccio".

Colour of the lower glume: All genotypes studied show a yellowish-white lower glume colour. According to Blum (1985), when the flag leaf becomes senescent, the last chlorophyll organs (glumes and awns) play a predominant role in grain formation.

Shape of the shoulder of the lower glume: The shape of the shoulder of the glume is very variable with the presence of four classes distributed as follows: Sloping with 35% in 7 varieties (Ovidio, Mimmo, Semito, Ciccio, Sigus and Oued El Bared), elevated with 35% in 7 varieties (Emilio Lepido, MouletEddar, Waha, Ammar 6, El Tayeb, Wahbi and Gta/durum 69), rounded with 5% in the "Bouhamenna" variety and straight with 25% in five varieties (Ancomarzio, Bousselam, Numidia, Cirta and Beni Messina). Sloping (1), Rounded (2), Straight (3), Elevated (4), Elevated with a 2^{nd} beak (5).

Width of the shoulder of the lower glume: The width of the shoulder of the lower glume shows significant diversity with the presence of 3 phenotypic classes: very narrow with 45% in nine varieties "Ovidio, Sigus, Mouleteddar, Beni Mestina, Oued El Bared, Ammar 6, Ettayeb, Wahbi and Gta/durum 69", narrow with 45% in nine varieties “Emilio Lepido, Ancomarzio, Mimmo, Simeto, Ciccio, Core, Bouhamenna, Cirta and Waha” and broad with 10% in "Bousselam and Numidia".

Length of the beak of the lower glume: The length of the beak of the lower glume is long in the following 12 genotypes (60%): "Ancomarzio, Mimmo, Core, Bousselam, Sigus, Moulateddar, Numidia, Oued El Bared, Ammar6, El Tayeb, Wahbi and Gta/durum 69" and medium for the following 8 genotypes (40%): "Ovidio, Emilio Lepido, Semito, Ciccio, Bouhamenna, Cirta, Beni Mestina er Waha".

Curvature of the beak of the lower glume: The curvature of the beak of the lower glume shows a significant diversity which classifies the genotypes into four groups: group without curvature in 11 genotypes with a rate of 55% "Emilio Lepido, Ancomarzio, Mimmo, Semito, Ciccio, Bousselam, Sigus, Bouhamenna and Waha", group of weak curvature in five varieties with a rate of 25% "Ovidio, Moulet Eddar, Numidia, Cirta and Gta /durum 69", group of moderate curvature with a rate of 15% in "Core, Ammar 6 and Ettayeb" and group with strong curvature in the "Wahbi" genotype.

Hairiness of the external surface of the lower glume: For the hairiness of external surface of the lower glume, we note that 60% of the genotypes do not have external hairiness, such as "Ancomarzio, Mimmo, Simeto, Ciccio, Core, Sigus, Mouleteddar, Numida and Cirta", while the rest of the varieties (40%) have hairiness "Ovidio, Emilio Lepido, Bousselam, Bouhamenna, Beni Mestina, Oued El Bared, Waha, Ammar 6, Ettayeb, Wahbi and Gta/durum 69". Knowing that the hairiness of the glumes is a dominant single-gene trait (Mcintosh 1988) the dominance of glabrous glumes thus suggests the presence of a disadvantageous selection linked to this gene. The role of glume hairiness in wheat adaptation is not well understood, but some authors have reported its association with resistance against insects and pests (Negassa 1986, Warham 1988) while others consider this parameter as a criterion of adaptation to water deficit (Boudour 2006).

Length of brush hair in the dorsal view of the grain: The length of grain hairs shows a significant diversity which divides the genotypes into three classes: class of short hairs with a rate of 20% in the varieties "Simeto, Ciccio, Core and Sigus", class of medium hairs with a rate of 50% in 10 varieties

"Mimmo, Bousselam, MouletEddar, Numidia, Cirta, Beni Mestina, Waha, El Tayeb, Wahbi and Gta/durum 69" and class of long hairs with a rate of 30% in the varieties "Ovidio, Emilio Lepido, Ancomarzio, Bouhamenna, Oued El Bared and Ammar 6".

Shape of grain: Regarding the shape of the grain, the varieties studied show significant variability with the presence of three classes: moderately elongated class in 13 genotypes with 65% (Emilio Lepido, Ancomarzio, Mimmo, Ciccio, Bousselam, Sigus, Mouleteddar, Numidia, Cirta, Waha, Ammar 6, El Tayeb and Wahbi), strongly elongated class in five varieties with 25% (Ovidio, Bousselam, Bouhamenna, Beni Mestina and Oued El Bared) and a slightly elongated class in two varieties with 10% "Simeto and Core".

Colour of grain: The colour of the grain shows a significant diversity with the presence of three groups: group of yellow orange colour in 12 genotypes (60%) "Ovidio, Emilio Lepido, Ancomarzion, Mimmo, Ciccio, Bousselam, Sigus, Mouleteddar, Numidia, Bouhamenna, Beni Mestina and Ammar6", slightly brown colour group in five varieties (25%) "Semito, Cirta, Waha, El Tayeb and Wahbi" and whitish yellow colour group in three genotypes (15%): "Core, Oued El Bared and Gta/durum 69". It seems that the yellow colour of wheat is an indicator of a high protein level.

Table 3. Descriptive sheets of the qualitative and quantitative parameters of studied durum wheat genotypes.

N	Caractère	Ovidio	Emilio Lepido	Ancomarzio	Mimmo	Simeto	Ciccio	Core	Bousselam	Sigus	MouletEddar	Numidia	Bouhamenna	Cirta	Beni Mestina	Oued El Bared	Waha	Ammar6	Ettayeb	Wahbi	Gta /durum 69
1	Plant: Length (stem, ear and awns)	1	1	3	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Straw: Pith in cross section	3	3	3	1	1	5	3	3	3	3	1	1	3	3	3	3	1	1	1	1
3	Ear : Distribution of awns	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
4	Ear : Disposition of awns	7	7	7	7	7	7	7	7	7	7	3	7	1	7	9	1	3	1	3	3
5	Ear : Pigmentation of awns	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	Ear: Presence or absence des awns	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	Ear : Colour of awns	1	1	1	1	4	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1
8	Ear: Length of awns	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
9	Ear: Length of awns at tip relative to length of ear	1	1	1	2	2	1	1	2	1	1	1	1	3	1	3	1	1	1	1	1
10	Ear : Density	4	4	5	4	5	5	5	5	5	5	4	5	4	4	5	5	5	4	4	5
11	Ear : Colour	2	2	2	2	2	2	2	2	1	1	1	1	3	2	1	2	2	2	2	2
12	Ear : Shape in profile view	1	1	3	1	1	5	5	5	1	1	5	5	1	1	3	1	5	1	1	1
13	Ear : Length of ear (excluding awns)	5	5	5	5	3	5	5	5	5	5	3	3	5	5	5	5	5	5	5	5
14	Ear: Length of first article	9	9	9	7	7	5	7	5	7	5	5	7	7	7	5	5	5	5	5	5
15	Ear: neck glaucescence	3	3	5	5	7	5	5	3	5	5	5	5	7	5	5	5	5	5	5	5

16	Ear: glaucescence	3	3	5	5	7	5	3	3	5	3	3	5	5	5	5	3	5	3	3	3
17	Ear: hairiness of margin of first rachis segment	7	7	5	3	3	7	3	7	7	7	3	3	7	7	9	9	7	7	7	7
18	Ear : Lenght of rachis	5	9	5	9	3	5	5	5	5	5	9	5	5	9	5	7	5	7	9	9
19	Lower glume: shape	2	2	2	2	2	1	3	3	3	2	2	2	2	2	2	2	2	2	2	2
20	Lower glume: colour	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	Lower glume: shape of shoulder	1	4	3	1	1	1	1	3	1	4	3	2	3	3	1	4	4	4	4	4
22	Lower glume: width of shoulder	1	3	3	3	3	3	3	5	1	1	5	3	3	1	1	3	1	1	1	1
23	Lower glume: length of beak	5	5	7	7	5	5	7	7	7	7	7	5	5	5	7	5	7	7	7	7
24	Lower glume: Curvature of beak	3	1	1	1	1	1	5	1	1	3	3	1	3	1	1	1	5	5	7	3
25	Lower glume: Hairiness of external surface	9	9	1	1	1	1	1	9	1	1	1	9	1	9	9	9	9	9	9	9
26	Grain: Length of brush hair in dorsal view	5	5	5	3	1	1	1	3	1	3	3	5	3	3	5	3	5	3	3	3
27	Grain : Shape	3	2	2	2	1	2	1	2	2	2	2	3	2	3	3	2	2	2	2	3
28	Grain : Colour	2	2	2	2	3	2	1	2	2	2	2	2	3	2	1	3	2	3	3	1

Production and adaptation of characters

Number of plants/m^2 land: The number of plants emerged per square meter land varies from 216.67±2.52 to 350±4.58 in the varieties "Numidia and Ciccio", respectively. While the varieties "Ancomarzio, Mouleteddar, Beni Mestina, Waha, Sigus, Cirta, Ovidio, Ammar6 and Oued El Bared" represent significant values between 250±13.75 to 339±7.81 plants/m^2 (Table 4). The seeding density of our study was found around 350 grains/m^2, the losses can be justified by the quality of the seed used, the depth of sowing, the date of sowing, the biotic stresses and the nature of the soil (Bouzerzour and Refoufi 1992).

Herbaceous tillers/plants: The "Wahbi, Ovidio and Emilio Lepido" genotypes cover the ground well producing more herbaceous tillers with 2.93±0.42, 2.73±0.42 and 2.70±0.52 herbaceous tillers/plant, respectively, compared to “Numidia, Core and Simeto” which record 1.87±0.31, 1.83±0.06 and 1.63±0.93 herbaceous tillers/plant, respectively (Table 4). The number of tillers/plants is a component that indirectly explains the dry matter yield. This parameter is largely influenced by temperature and the level of nutrient supply, and by varietal characteristics and cultivation techniques (Meynard 1980).

Ear tillers/plant: The highest ear tillering potential is measured in the "Bousselam" variety with 1.77±0.29 ear tillers/plant and the lowest is measured in the "Mimmo, Core, Numidia and Cirta" varieties with 1.10 ear tillers/plant (Table 4). The result obtained agrees with those obtained by Blum (1985) and Oudjani (2009) which shows that there is no relationship between the herbaceous tillering capacity and the number of rising ears per unit area.

Efficiency of the transformation of herbaceous tillers into ear tillers (%): The "Simeto" genotype shows a higher-than-average rate of transformation from herbaceous tillers to spike tillers with 93.86% followed by the following varieties: "Bousselam" with 79.37%, "Beni Mestina" with 78.4%, "Ciccio" with 73.57%. The other genotypes range between 69.55 to 43.82% for the genotypes "El Tayeb, Ancomarzio, MouletEddar, Gta/durum69, Ovidio, Bouhamenna, Core, Numidia, Waha, Emilio Lepido, Ammar 6, Sigus, Mimmo, Cirta, Wahbi and Oued El Bared" (Table 4). The number of ears/plants is dependent on the herbaceous tillering capacity. This tillering ability allows the plant to adjust to a variable environment to ensure a minimum of production, the regularity of production of fertile tillers therefore depends on a high grain yield **(**Hadjichristodoulou 1985).

Table 4. Number of plats/m^2, herbaceous tillering/plant, ears tillering/plant and efficiency of transformation.

Genotypes	Number of plants/m^2	Number of herbaceous tillers/plants	Number of ears tillering/plant	Efficiency of transformation of herbaceous tillers into ear tillers (%)
Ovidio	252.33±2.52	2.73±0.42	1.67±0.31	61.17
Emilio Lepido	240.67±8.50	2.70±0.52	1.53±0.23	56.67
Ancomarzio	339±7.81	2.27±0.31	1.57±0.47	69.16
Mimmo	230±4	2.10±0.1	1.10±0.1	52.38
Simeto	230.33±7.64	1.63±0.93	1.53±0.23	93.86
Ciccio	216.67±2.52	2.27±0.31	1.67±0.12	73.57
Core	250±13.75	1.83±0.06	1.10±0.1	60.11
Bousselam	200±13.23	2.23±0.59	1.77±0.29	79.37
Sigus	286.67±16.07	2.40±0.35	1.30±0.17	54.16
MouletEddar	333.33±20.82	2.03±0.40	1.33±0.15	65.52
Numidia	350±4.58	1.87±0.31	1.10±0.1	58.82
Bouhamenna	222.33±8.74	2.67±0.31	1.63±0.25	61.05
Cirta	264.00±13.53	2.23±0.06	1.10±0.17	49.33
Beni Mestina	330±15	2.13±0.06	1.67±0.25	78.4
Oued El Bared	223.67±3.21	2.67±0.46	1.17±0.29	43.82
Waha	317.67±6.81	2.33±0.42	1.33±0.23	57.08
Ammar6	251.33±15.04	2.67±0.12	1.50±0.17	56.18
Ettayeb	222.33±3.06	2.20±0.1	1.53±0.23	69.55
Wahbi	242.67±10.69	2.93±0.42	1.40±0.35	47.78
Gta /durum69	222.33±4.62	2.63±0.59	1.63±0.45	61.98

Number of ears/m^2: The "Ovidio" genotype represents the highest number of ears/m^2 with 423.33 ±15.95 ears/m^2, followed by significant averages of the following varieties: "Waha, Beni Mestina, Oued El bared, Ammar6, Ancomarzio, Sigus, Gta/ durum69, Simeto, Bouhamenna, Ciccio, Bousselam, Emilo Lepido and El Tayeb" which range from 422.67±12.50 to 341±3 ears/m^2. While the least low values are found in the genotypes of: "Mimmo, Wahbi, Core, Numidia, MouletEddar and Cirta" with averages of 289±14 to 237±12.29 ears/m^2 (Table 5). The number of ears/m^2 represents the number of tillers having given an ear (Souilah *et al*. 2014, Hazmoune and Benlaribi 2004).

Number of grains/ears: For the number of grains/ears, the "Gta/durum69" genotype is at the top of the ranking with 38.8±7.05 grains/ears, followed in second position by "Emilio Lepido" with 37.1±6.85, after we find: "Wahbi, Sigus, Beni Mestina, Mimmo, Ciccio and Core" with values of 35±4.40, 34.4±6.42, 33.1±3.81, 32.16±6.732.4±5.13 and 31.9±1.38 grains/ear, respectively. While the average values range between 30.3±5.89 and 25.86±4.88 grains/ear, in the following genotypes: "Ancomarzio, Ovidio, Numidia, Waha, Oued El Bared, Bouhammena, Ammar6, MouletEddar and Ettayeb". While low averages are noted in the varieties: "Cirta, Semito and Bousselam" with 27.7±4.45, 26.2±2.86 and 25.3±3.13 grains/ear, respectively (Table 5). These results agree with those of Souilah (2009) who shows that the number of grains/ear varies from 23 to 58 and also depends on the fertility of the ear of each genotype. Annicchiarico and Pecetti (1993) found that the number of grains/ears influences the capacity of the well under water deficit conditions and considered a good indicator of drought tolerance.

Grain weight (GW): The genotypes that record high thousand grains weight (TGW) values are "Simeto and Core" with 60.7g and 50.5g, respectively. While the other values range between 49.35g and 40.6g, while the variety of "Ammar6" is represented the lowest value with 36.85g (Table 5). The values obtained are higher than those obtained by Oudjani (2009) on 25 genotypes of durum wheat which shows that the TGW varies from 49.72 to 39.8g. A high TGW will imply a high specific weight of the genotypes, which will favor a high yield when the conditions are optimal (Benmounah and Brinis 2018).

Grain yield (GY): The grain yield is the product of three components: the number of ears/m^2, the number of grains/ear and the TGW. It is noticed that, a compensation between these three parameters according to genotype and culture conditions. The highest grain yield is recorded by the genotype "Gta/durum69" with 68.50±3.56 qx/ha, after it comes "Ovidio" with 62.13±2.34 qx/ha. While the lowest yield is recorded by the "Cirta" genotype with 30.63±1.59 quintals/ha (Table 5). These results obtained do not agree with those of Oudjani (2009), which show a yield varying between 38.82 and 16.06 q/ha. Grain yield is a polygenic, complex and low heritable trait, the improvement of this trait can be approached indirectly through the traits that are strongly linked to it and less influenced by the environment (Fellahi *et al*. 2018, 2020).

Table 5. Yield parameters of studied genotypes of durum wheat.

Genotypes	Number of ears/m^2	Number of grains/ears	1000 grain weight (g)	Grain yield (q/ha)	Biomassaerial (q/ha)	Strawyield (q/ha)	Economicyield (q/ha)	Harvest index (q/ha)
Ovidio	423.33±15.95	30.2±5.031	48.6	62.13±2.34	184.624±1.7	122.94±1.77	98.88±2.01	33.65
Emilio Lepido	351±4	37.1±6.85	43.94	57.22±0.65	162.307±21.14	105.88±20.49	88.74±6.80	35.62
Ancomarzio	375±25	30.3±5.89	48.19	54.76±3.65	161.526±37.34	106.77±33.69	86.78±13.75	34.81
Mimmo	289±14	32.7±6.16	40.6	38.37±1.86	137.248±25.28	98.88±24.3	74.23±18.86	28.42
Simeto	364±6	26.2±2.86	60.7	57.89±0.95	176.883±19.78	118.99±18.83	93.58±6.6	32.96
Ciccio	361.67±7.64	32.4±5.13	47.2	55.31±1.16	194.209±14.48	138.9±14.82	96.97±4.21	28.59
Core	271.67±19.56	31.9±1.38	50.5	43.76±3.15	143.484±11.60	99.72±14.64	73.68±1.52	30.75
Bousselam	352.67±7.57	25.3±3.13	49.35	44.03±0.94	149.614±9	105.58±8.24	75.7±3.27	29.48
Sigus	372.67±24.54	34.4±6.42	45.25	58.01±3.82	190.122±50.07	132.11±46.69	97.64±17.45	31.69
MouletEddar	245.67±17.47	28.9±6.95	45.23	32.12±2.22	103.767±11.35	81.72±9.66	56.62±4.76	28.3
Numidia	259.33±12.22	30.1±5.34	44.35	34.62±1.63	128.869±16.46	94.25±15.35	62.89±5.8	27.08
Bouhamenna	362.67±11.68	29.2±4.80	45.75	48.45±1.56	178.224±40.89	129.78±40.33	87.38±12.71	24.57
Cirta	237±12.29	27.7±4.45	46.65	30.63±1.59	101.185±0.56	70.56±1.5	51.79±1.17	30.27
Beni Mestina	385.33±12.50	33.1±3.81	42.52	54.23±1.76	171.737±33.11	117.51±31.36	89.48±11.16	32.25
Oued El Bared	378.33±27.32	29.5±3.75	43.9	49.00±3.54	159.286±17.26	110.29±13.81	82.08±7.62	30.84
Waha	422.67±12.50	29.5±4.01	41.1	51.25±1.52	171.876±14.42	120.63±15.09	87.43±4.02	35.69
Ammar6	378.33±10.21	28±5.72	36.85	39.04±1.40	139.056±3.29	100.02±2.4	69.04±1.67	28.27
Ettayeb	341±3	28.6±4.88	45.5	44.37±0.39	145.182±24.64	100.81±24.83	74.61±7.26	31.18
Wahbi	282.67±12.50	35±4.40	43.9	43.43±1.92	135.892±4.32	92.46±3	61.92±14.49	31.96
Gta /durum69	366.67±19.03	38.8±7.05	48.15	68.50±3.56	182.861±17.76	114.36±15.9	102.8±7.11	37.62

Aerial biomass (ABIO): The "Ciccio, Sigus and Ovidio" genotypes recorded the best aerial biomass values with 194.209, 190.122 and 184.624q/ha, respectively. While "MouletEddar and Cirta" had the lowest values with 103.767 and 101.185q/ha, respectively (Table 5). According to Meberkani (2012), the ability to make a high aerial biomass is a characteristic of adaptation to variable environments. Belkherchouche *et al.* (2015) suggests that to maximize the assimilates to the grain, selection should take into account ear size, glume lifetime, awn length and density, yield per m² and per ear, 1000 grain weight, specific weight and length of the last internode and the neck of the ear. The selection of such traits contributes to accumulating in the identified genotypes the yield potential and adaptation to dry Mediterranean conditions.

Straw yield (SY): The highest straw yield is recorded by the "Ciccio" genotype with 138.9±14.82 q/ha, followed by "Sigus and Bouhamema" with 132.11±46.69 and 129.78±40.33 q/ha, while the other genotypes show values averages between 122.94±1.77 and 92.46±3 q/ha, whereas the "Mouleteddar and Cirta" varieties are ranked last with 81.72±9.66 and 70.56±1.5 q/ha, respectively (Table 5). Morphological characters, such as straw yield and plant height have been identified as morphological markers of drought tolerance (Salmi *et al*. 2021). Morphological markers are effective ways to study wheat genetic diversity (Al Khanjari *et al*. 2008, Kirouani *et al*. 2019).

Economic yield (E_{eco} Y): The "Gta/durum69, Ovidio, Sigus and Ciccio" genotypes recorded a better economic yield with 102.8, 98.88, 97.64 and 96.97q/ha, respectively, while the low economic yield values are recorded in "MouletEddar" with 56.62 q/ha and "Cirta" with 51.79 q/ha (Table 5). These results show the expression of a good vegetative development and a good grain filling knowing that the economic yield is calculated as the sum of the grain yield plus 30% of the straw yield. The strong correlation between grain yield and economic yield and the number of ears per square meter makes it possible to propose the biomass and the number of ears to be used as a rapid and early selection criterion for screening (Oulmi *et al*. 2018).

Harvest index (HI): Regarding the harvest index, the "Gta/durum 69, Waha, Emilio Lepido and Ancomarzio" genotypes have the best values with 37.62, 35.69, 35.62 and 34.81%, respectively, while the "Numidia and Bouhamenna" genotypes represent the lowest values with 2l7.08 and 24.57%, respectively (Table 5). The harvest index is the report of grain on straw. The factors that act on this parameter are the height of the plant, drought and early heat (Oudjani 2009). The improvement of the harvest index follows the reduction of the height of the plant because this criterea is important for adaptation to the constraints of the environment. A high height induces the production of a significant biomass, which is desirable, but this to the detriment of grain yield, following a low harvest index. Conversely, a significant reduction in the height of the plant certainly improves the number of ears, and the yield, but this is done to the detriment of the length of the root system and the production of straw (Subira *et al*. 2016, Rabti 2021).

Shannon-Weaver diversity index (H) and relative index (H') of different characters

The relative diversity index (H'mean) of all the genotypes studied is around 0.52 (Table 6), reflecting the great morphological diversity of the ears in this study. This diversity is equal to that obtained by Belhadj *et al*. (2015) on indigenous populations of southern Tunisia with an index of 0.51 and that of Al Khanjari *et al*. (2008), within an indigenous population of durum wheat from Oman with an index of 0.52.

Table 6. Relative index of diversity and variation in the frequency of the classes of the different characters of studied genotypes.

Character	H	H'	Classe	Frequency	%
Plant : Length	0.26	0.26	Very short	18	90
			Short	2	10
Straw: Pith in cross section	0.85	0.69	Thin	8	40
			Medium	11	55
			Thick	1	5
Ear: Presence or absence of awn	0	0	Presence	20	100
Ear : Distribution of awns	0	0	Fullyowned	20	100
Ear : Disposition of awns	1.06	0.86	Very divergent	1	5
			Divergent	12	60
			Weakly divergent	4	20
			Not divergent	3	15
Ear : Pigmentation of awns	0	0	White	20	100
Ear : Colour of awns	0.39	0.32	White	18	90
			Medium purple	1	5
			Darkpurple	1	5
Ear :Length of awns	0	0	Short	20	100
Ear: Length of awns at tip relative to length of ear	0.73	0.59	Shorter	15	75
			Equal	3	15
			Longer	2	10

Ear : Density	0.67	0.55	Dense	12	60
			Very dense	8	40
Ear :colour	0.75	0.61	Slightly coloured	14	70
			White	5	25
			Strongly coloured	1	5
Ear: Shape in profile view	0.9	0.73	Tapering	12	60
			Semi clavate	2	10
			Fusiform	6	30
Ear: Length of ear (excluding awns)	0	0	Medium	20	100
Ear: Length of first article	0.99	0.81	Medium	10	50
			Long	7	35
			Very long	3	15
Ear: Neck glaucescence	1.03	0.84	Weak	3	15
			Medium	15	75
			Strongly coloured	2	10
Ear: glaucescence	0.73	0.59	Weak	10	50
			Medium	9	45
			Strongly coloured	1	5
Ear: hairiness of margin of first rachis segment	0.86	0.69	Weak	5	25
			Medium	1	5
			Strong	12	60
			Very strong	2	10
Ear : Length of rachis	1.07	0.87	Short	1	5
			Medium	11	55
			Long	2	10
			Very long	6	30
Lowerglume :shape	0.61	0.5	Ovoid	1	5
			Medium oblong	16	80
			Narrow oblong	3	15
Lowerglume :colour	0	0	Yellowish white	20	100
Lower glume: shape of shoulder	1.23	1	Sloping	7	35
			Rounded	1	5
			Straight	5	25
			Elevated	7	35
Lower glume: width of shoulder	0.95	0.77	Very narrow	9	45
			Narrow	9	45
			Broad	2	10
Lower glume: length of beak	0.67	0.55	Medium	8	40
			Long	12	60
Lower glume: Curvature of beak	1.11	0.9	Absent	11	55
			Weak	5	25
			Moderate	3	15
			Strong	1	5
Lower glume: Hairiness of external surface	0.67	0.55	Absent	8	40
			Present	12	60
Grain: Length of brush hair in dorsal view	1.03	0.84	Short	4	20
			Medium	10	50
			Long	6	30
Grain : Shape	0.86	0.7	Slightlyelongated	2	10
			Moderateelongated	13	65
			Stronglyelongated	5	25
Grain :Colour	0.94	0.76	Whitishyellow	3	15
			Yellow orange	12	60
			Slightlybrown	5	25
H'Moyen	/	**0.52**	/	/	/

The high diversity of the studied collection is mainly due to the presence of several polymorphic characters. In particular, the shape of the shoulder of the lower glume (H'=1), the curvature of the beak of the lower glume (H'=0.9), the length of the rachis of the ear (H'=0.87), the disposition barbs (H'=0.86), the length of the hairs of the grain brush (H'=0.84), the hairiness of the first article of the rachis of the ear (H'=0.84) and the length of the first article of the ear (H'=0.81), were the most diversified characters (Table 6).

These results obtained do not agree with the work carried out by Belhadj *et al*. (2015) who concluded that the shape of the truncation of the lower glume (H'=0.58) and the curvature of the beak of the lower glume (H'=0.53) are the moderately polymorphic characters. These same authors show that the hairiness of the first article of the rachis of the ear (H'=0.19) is the weakest character of polymorphism. While, the character of the length of the hairs of the grain brush (H'=0.80) is the only character which has an important and almost equal diversity with our obtained result.

In addition, other traits studied were mainly represented by a class of significant phenotypic diversity that varies from a value of H'=0.77 to H'=0.50 (Table 6). For the characters related to the ears, the genotypes studied show a dominance for: the tapered shape (H'=0.73), the low glaucescence (H'=0.69), the slightly coloured colour (H'=0.61), the short length of the ears without awns (H'=0.59), the average glaucescence of the neck of the ear (H'=0.69) and the very dense compactness or density of the ears (H'=0.55). The dominant characters linked to the lower glumes are: the very narrow and narrow width of the shoulder (H'=0.77), the presence of hairiness on the external surface (H'=0.55), the long length of the beak (H'= 0.55), the presence of hairiness on the external surface (H'=0.55) and the moderately oblong shape (H'=0.50) (Table 6). The work on wheat from southern Tunisia carried out by Belhadj *et al*. (2015) and on Ethiopian wheat by Bechere *et al*. (1996) show that the character of the compactness of the ears is the least polymorphic with a diversity of H'=0.33 and 0.24, respectively. In addition, Othmani *et al*. (2015) and Zarkti *et al*. (2012) reported that the pyramidal shape of the ears is the most abundant in Tunisian and Moroccan collection of durum wheat. In studying the diversity of Ethiopian durum wheat populations, Tesemma *et al*. (1991) observed a monomorphism of glumes of zero hairiness, while Al Khanjari *et al*. (2008) noticed a higher frequency of glumes hairy in the durum wheat collection from Oman.

Concerning the characters related to the grains, the requested genotypes showed a dominance for the moderately elongated shape, a medium dominance for strongly elongated and a weak dominance for slightly elongated with H'=0.70. The colour of the grains of the varieties studied has a strong dominance of the yellow orange colour, medium dominance of the slightly brown colour and a weak dominance of the whitish-yellow colour with H'=0.76 (Table 6). These results agree with the work carried out by Belhadj *et al*. (2015) and Bechere *et al*. (1996) who concluded that grain shape is the most polymorphic character with H'= 0.98 in southern Tunisian wheats and H'= 0.96 in Ethiopian durum wheats, respectively. Al Khanjari *et al*. (2008) found reddish-brown grains to be the most expected in the Oman collection, while Bechere *et al*. (1996) noted the presence of all phenotypic classes in a collection of Ethiopian durum wheat, from yellow colour to purple colour. The predominance of these colours could depend on the subsequent use of these wheats. This has also been explained by Demissie and Bjornstad (1996) and Whan *et al.* (2014) who noticed the existence of a close association between the colour of wheat and barley grains and human consumption.

Concerning the monomorphism characters of our series studied, they are found in: the presence, distribution, pigmentation and length of awns, the length of the ears without awns, and the colour of the lower glume with an index H'=0 (Table 6). This difference in results can be explained by the expression of hereditary characteristics according to the nature of the genes and the study environment.

The development of descriptive sheets and the study of the yield characters of twenty durum wheat varieties studied show the presence of great intra-specific variability due to the agro-climatic conditions of the environment. The criteria that allow us to choose new, more efficient genotypes are numerous, and possess parameters of tolerance and adaptation to environmental constraints. The morpho-physiological characters studied also allow us to classify these genotypes into 3 classes: class of varieties resistant to water deficit (Ovidio, Emilio Lepido, Bousselam, Oued El Bared, Waha, Wahbi and Gta/durum 69), class of non-resistant varieties to water deficit (Mimmo, Core, Cirta and Ettayeb) and class of intermediate varieties (Ancomarzio, Simeto, Ciccio, Sigus, MouletEddar, Numidia, Bouhamenna, Beni Mestina and Ammar 6). Finally, the establishment of descriptive sheets, knowledge of the diversity index and production and adaptation parameters are essential mechanisms that constitute the starting point of any program for the creation of new variability. They remain a powerful factor for improving yield, preserving genetic resources against erosion and enriching them through crossbreeding.

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