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Agronomic Traits and Yield Performance Variation in Hulled and Naked Barley (*Hordeum vulgare* L.) Varieties for Adaptation in East Algeria

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ABSTRACT

Background: Hulled barley has been extensively cultivated in Algeria. While naked barley was neglected in terms of research and genetic improvement. But it is now receiving renewed interest due to the potential health and agronomic benefits. Therefore, the aim of this research was to evaluate the agronomic performance of naked and hulled barley landraces collected from main production areas in the East of Algeria.

Methods: The field experiments were conducted under rain-fed conditions, in 2018 and 2019 cropping seasons, in semi-arid zone of eastern Algeria. Both populations of plants were characterized agronomically, taking into account for nine quantitative traits.

Result: Hulled barley cultivars outperformed the naked barley and from the results of Principal Component Analysis, it was found that the most important variables for the classification of barley cultivars are high grain yield, high straw yield and high biological yield. Hulled barley varieties showed the best yield performance, contrary to naked barley, which showed the poorer yield performance.

Key words: Agronomic traits, Grain yield, Hulled barley, Naked barley, Spikes, Tillers.

INTRODUCTION

After wheat, rice and maize, barley (*Hordeum vulgare* L.) is the fourth major cereal crop in the world (Miroshnichenko *et al.,* 2018). It is classified into naked and hulled barley. Compared with hulled barley, naked barley has caryopses with easily separable husks after threshing (Dickin *et al.,* 2010). Hulled barley is currently widely grown as animal feed in different places in the world, comprising North Africa (Algeria and Tunisia) (Harwood, 2019). Decreased yield relative to that of naked barley is the major factor limiting its production as an alternative to hulled barley, however, it is important source of human food due to the abundance of dietary factors mainly β-glucans (Tanaka *et al.,* 2009). Barley has a wide ecological range. It can be cultivated in a wider range of growing conditions in terms of climate, moisture, tillage, fertility and crop rotation, however, it is not well adapted to wet and acidic soil condition (Munns *et al.,* 2016). In Algeria, barley is cultivated mainly under the semi-arid zone which characterized by a great variability of the frequency of rain events and temperatures (Bouzerzour and Dekhili, 1995). Furthermore, few studies exist on the local resources of barley in Algeria. Studies concerned generally the local approved varieties and hence the diversity within the local material is not known (Rahal-Bouziane *et al.,* 2015).

Few studies have compared naked and hulled barley genotypes for agronomic traits (Griffey *et al.,* 2010). According to Gallagher *et al.* (1976), the determination of agronomic traits is a first step to explaining the differences in yield between varieties and helps to understand the influence of environmental factors, especially for the biological yield appeared to be the most important source affecting grain yield variation in semi-arid regions and consequently may be considered as effective critter for selecting towards grain yield improvement (Fellahi *et al.,* 2013). This makes the integration of these parameters of great interest in estimating the variation of agronomic traits and yield performance of barley varieties. Therefore, the main objective of this study were to evaluate the agronomic performance of naked and hulled barley landraces collected from main production areas in the East of Algeria, this is by analyzing and comparing grain yield and its components to improve our knowledge and thus identify the most relevant characteristics to choose the most effective and adapted varieties.

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MATERIALS AND METHODS

The field experiment was conducted under rain-fed conditions during two consecutive years (2018 and 2019) at the Research Farm, Institute of Agriculture and Veterinary Sciences, Souk Ahras University in Algeria (36°13′N, 8°11′E and 887 m above sea level). The study area has a mean

Table 1: Names and origin of the barley varieties used in the study.

	Naked barley	Hulled barley					
Varieties	Chair Ennabi	Rihane	Barberousse	Dingo	Saïda	Tichedrett	El fouara
Origin	Arabie Saoudite	Syria	France	Italy	Algeria	Algeria	Algeria

annual rainfall and temperature ranging from 693-784.3 mm and16.4-16.2°C, respectively (Algeria State Meteorological Service, 2019), fertile loam soil, with pH value = 7.97. The description of barley cultivars used in the study is presented in (Table 1). The experiment was laid out in a randomized complete block design (RCBD) with four (4) replications. All varieties were evaluated for nine (09) agronomic traits; the number of grass tillers (NTG) is determined by direct counting of the number of grass tillers of all plants/ varieties, from the 5-leaf stage. The number of fertile tillers (NTF) (except the main shoot) of all plants/varieties, maturity stage. At the end of field experiments, plants were harvested at maturity and the following traits were recorded: grain yield (GY) (Qx/ha), biological yield (BY) (Qx/ha) and straw yield (SY) (Qx/ha). Thousand-kernel weight (TKW) (g) was determined as the weight of a sample of 250 grains after harvest.

The observations recorded in kilograms per square meter (m^2) were converted to quintal per hectare. The measures also focused on the number of plants per square meter (P.M2), the number of spikes per square meter (NS) and the average number of grains/spike (NGS). Statistical analyses were carried out with R version 3.6.1 for Windows (R Core Team, 2019) with significance level α = 0.05, by using the appropriate packages. Differences among barley genotypes were tested by Kruskal-Wallis test (rank-based nonparametric test) followed by the Dunn test for pairwise multiple comparisons. The Spearman test of correlation, Principal Component Analysis (PCA) and Hierarchical clustering approach was also applied.

RESULTS AND DISCUSSION

The comparative analysis of seven (07) barley varieties studied under the same conditions was illustrated in (Fig 1-9). Varieties showed no significant agronomic difference for thousand-kernel weight, grain yield, fertile tillers, number of plants/m^2, number of spike/m^2 and Biological yield. Our findings are in compliance with those of Choo *et al.* (2001).

As indicated in Fig1, Hulled barley varieties have the higher grain yield, particularly, Saïda genotype which gave the highest value (60.20±15.01 Qx/ha), whereas, minimum of this trait was observed for the Naked barley variety with 34.83±12.68 Qx/ha. This result are in line with those of Choo *et al.* (2001) which reported that naked barley yield on average are 10% to 30% less than those of hulled barley. Concerning the number of grass and fertile tillers (Fig 2 and 3), Dingo variety had more number of grass tillers (3.26±1.62) than other varieties. The lowest number was

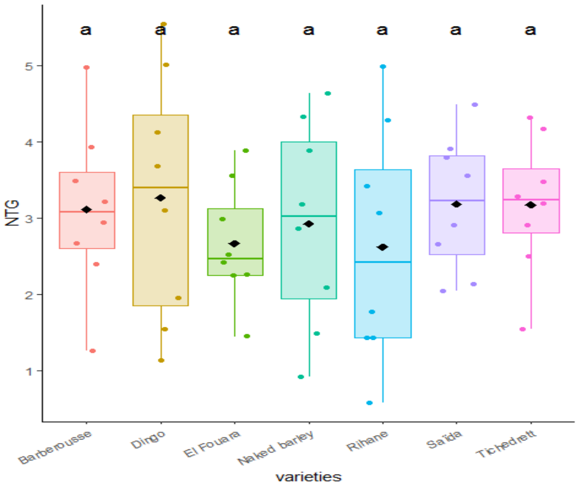

Fig 2: Variation of the number of grass tillers among the different barley varieties.

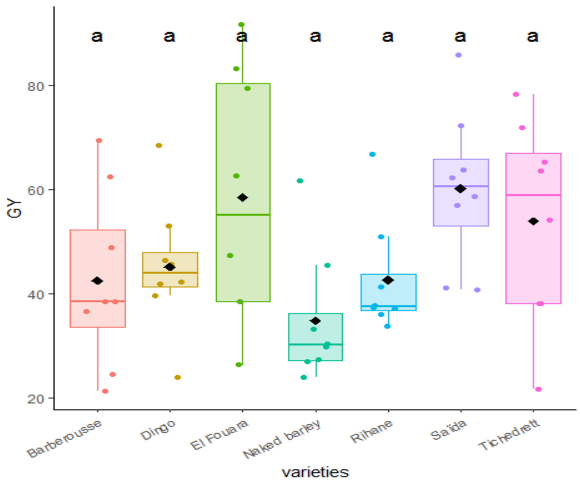

Fig 1: Variation of grain yield (Qx/ha) among the different barley varieties.

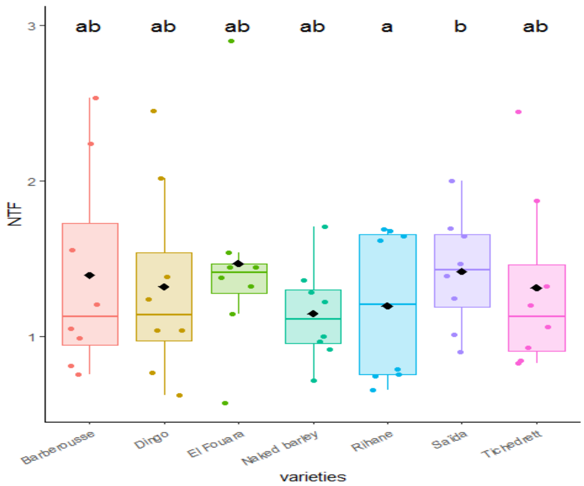

Fig 3: Variation of the number of the fertile tiller among the different barley varieties.

obtained from Rihane variety (2.62±1.55), while, El fouara variety had the highest number of fertile tillers (1.46±0.65) but Naked barley genotype gave the lowest value (1.14±0.30). According to Jeżowski (2008) the tillering can be used to identify genotypes producing under drought stress.

Barley varieties differed significantly in number of plants/ m² (Fig 4). The Highest number was recorded in Tichedrett variety (200.62± 22.97plants/ m²) and the minimum was observed in naked barley (187±33.06 plants/ m²) which is also in congruence with earlier reports by Thomason *et al.* (2009). Rymuza *et al.* (2012) illustrated that thousand kernel weight as the variable most closely related to grain yield and was often used in selecting high yielding wheat cultivars. Among the varieties, Saïda had the highest Thousand-kernel weight (53.77±12.07g), while Naked barley had the lowest weight (37.56±10.53g) (Fig 5). The last results are in conformation with the findings of Zeng (2015). Some previous works reported that the naked (hulless) trait in barley has been associated with low seed weight (Choo *et al.*, 2001).

The results of investigation shown in figure 6 confirm that the highest number of grains/spike was noted by Dingo variety (hulled barley) (52.10±6.64). This is similar to the findings of Thomason *et al.* (2009), which found that a greater number of grains/spike was observed for hulled barley at all seeding rates when compared to naked barley. With respect to the number of spike / m², it is El fouara variety who recorded the highest value (283.89± 106.49 spike/m²) (Fig 7). Rasmusson and Cannell (1970) demonstrated that spike number was consistently associated with yield.

This study also revealed that Barley varieties differed significantly in the straw yield. Saida had the most level of this trait (79.38±25.57 Qx/ha). In contrast, the lowest straw yield was belong to Dingo and Barberouss varieties (58.02±18.07 and 59.39±20.55Qx/ha, respectively) (Fig 8). As shown in Fig 9, Saïda variety produced the highest

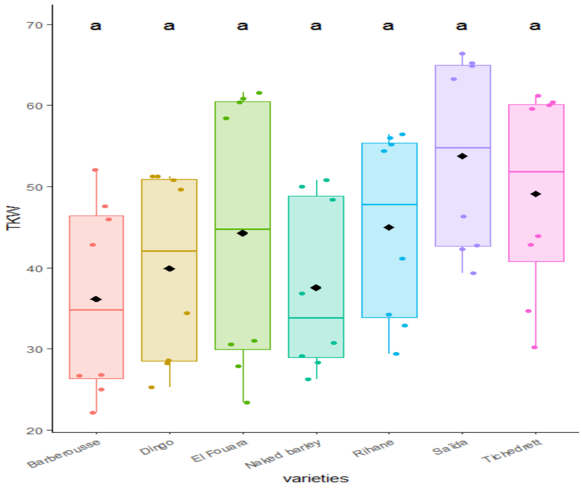

Fig 5: Variation of thousand-kernel weight among the different barley varieties.

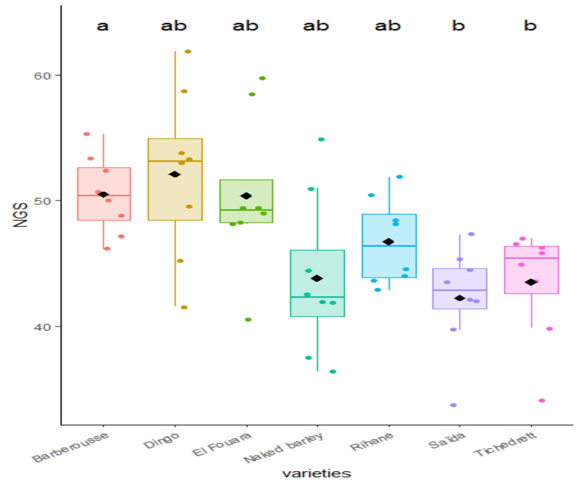

Fig 6: Variation of the number of grains / spike among the different barley varieties.

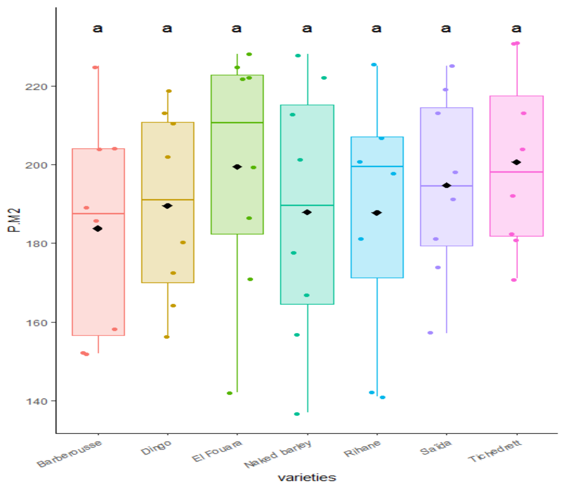

Fig 4: Variation of the number of plants/ m² among the different barley varieties.

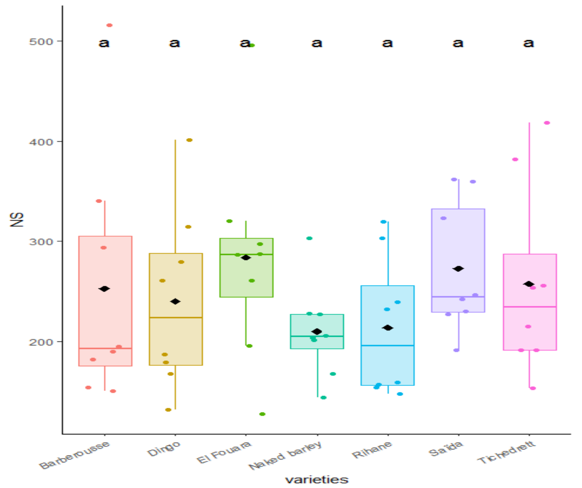

Fig 7: Variation of number of spike per m² among the different barley varieties.

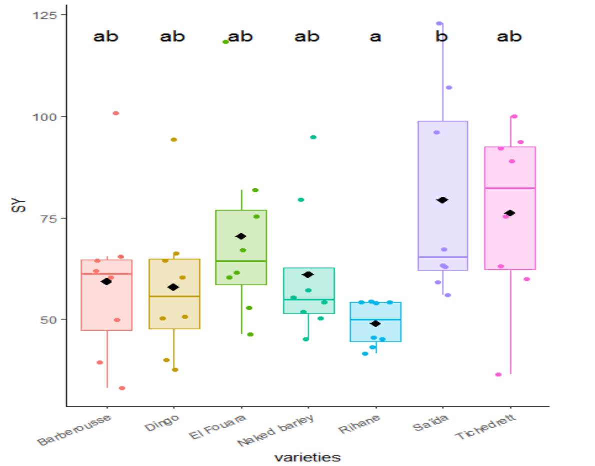

Fig 8: Variation of straw yield among the different barley varieties.

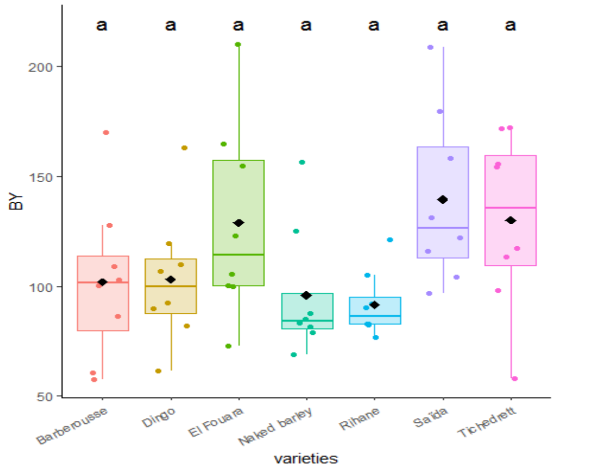

Fig 9: Variation of biological yield among the different barley varieties.

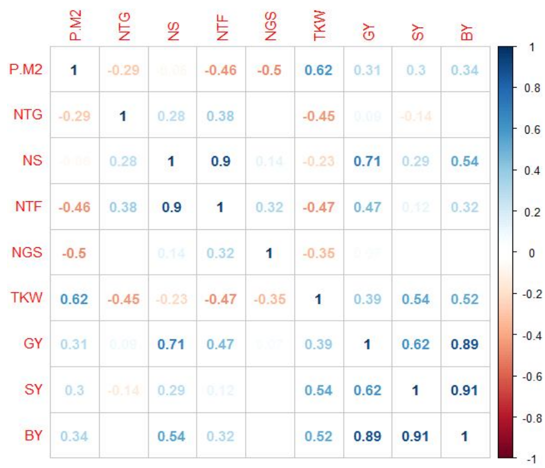

Fig 10: Inter-variable correlation matrix (Spearman correlation) between agronomical traits of seven (7) barley genotypes (*Hordeum vulgare* L.)

P.M2=plants/ m², NTG= number of grass tillers, NTF=number of fertile tillers, NGS =number of grains / spike, TKW=Thousand-kernel weight (g), GY=grain yield (Qx/ha), BY=Biological yield (Qx/ha), SY= straw yield (Qx/ha), NS= number of spike / m²

Biological yield (139.58± 39.21 Qx/ha).Whilst, this trait was the lowest in Rihane (91.66± 14.73 Qx/ha). Jamshidi and Javanmard (2018) reported that the biological yield and grain yield had the highest rate of variation. This variation may be explained by the effect of the genetic potential of the studied varieties (Chaudhury *et al.,* 1994). In addition, Shahinnia *et al.* (2005) reported that biological yield explained 96.8% of the total yield variation of barley.

In the current study, we have also taken into consideration the matrix of correlation (Fig10) which showed a positive relationship between grain yield and biological yield, number of spikes/m² and straw yield (r = 0.89, r = 0.71, r =0.62, respectively). This is consistent with many other studies such as (Fellahi *et al.,* 2013 and Larsen *et al.,* 2012). Furthermore, Ranjan (2016) and Saha (2019) reported that grain yield is the final product of the action and interaction of a number of components such as thousand grains weight, grains per spike and number of tillers. In addition, biological yield had a positive correlation with straw yield (r = 0.91), grain yield (r = 0.89) and Thousand-kernel weight (r = 0.52). The results are in line with Mohammad *et al.* (2005). On the other hand, the correlation study showed a slight positive correlation between the number of grains/spike and thousand kernel weight (r = 0.36). The same result was found by Fellahi *et al.* (2013). Also, our matrix showed a positive association between straw yield and thousand kernel weight (r = 0.54).

A principal component analysis was performed from nine (09) variables (Fig 11). We notice that the first two axes develop 76.7% of the total information. Therefore, these two axes had better summarized the information provided by all the initial variables. The first principal component alone explains 41.2%; it is strongly correlated with six of the original variables: number of plants/m², Thousand-kernel weight (TKW), grain yield (GY), straw yield (SY) and biological yield (BY). This axis correlates most strongly with biological yield (r=0.94). It could state thereby, that this principal component

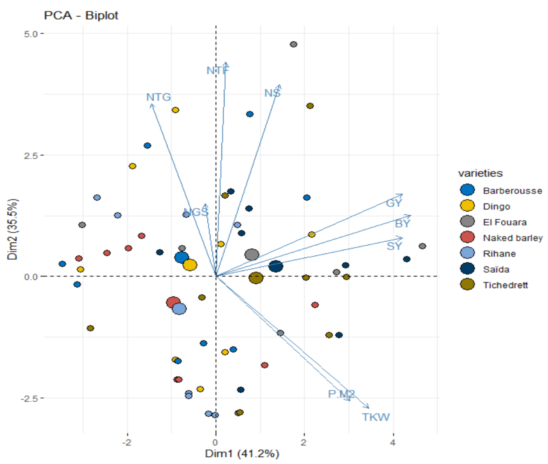

Fig 11: principal component analyses (PCA) based on the correlation matrix of nine (9) traits data from seven (7) barley genotypes tested.

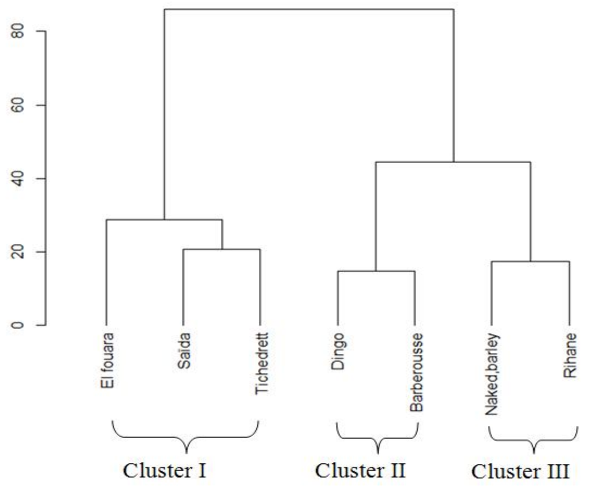

Fig 12: Hierarchical clustering based on agronomical traits considered in our study.

is primarily a measure of grain yield; otherwise, NTG, NS and NTF are positively correlated with the second principal component. The principal component analysis showed that thousand-kernel weight, straw yield, biological yield and grain yield elements had higher loading compared to the rest of the elements. Therefore these elements are important for accounting variability of multiple elements.

The results of the hierarchical cluster are presented in (Fig 12). The grouping according to the degree of similarity between the different barley varieties based on the principal component analysis which led us to group them according to the chosen parameters. The number of plants/ m^2, the grain yield, Biological yield, Thousand-kernel weight and biological yield are the most discriminating characters. Also, the hierarchical classification is consistent with the conclusion that emerges from the CPA analysis and reveals three distinct groups of varieties: cluster I consist of the genotypes El fouara, Saïda and Tichedrett; cluster II is represented by Dingo and Barbarous varieties and cluster III includes Naked barley and Rihane varieties. The first includes hulled barley (El fouara, Saïda and Tichedrett) with High yields; they have the highest values of grain yield, thousand-kernel weight and Biological yield. It becomes clear this group showed better performance in environments than other varieties. Reguieg *et al.* (2013) reported that Saida and Tichedrett varieties are well adapted for the semi-arid areas in Algeria. Effectively, farmers of the region prefer Saida (Fufa *et al.* 2010). In a previous study, Mekonnon (2014) reported that local varieties showed better yield components. Nevertheless, Yield is not the only criterion for adoption (Jalleta, 2004). The second group contains Dingo and Barberouss, two cultivars newly released in Algeria which were characterized by grain yield relatively lower than other varieties. Varieties introduced are said to have a high yield capacity under better conditions (Zeven, 1998).

The naked barley variety included in third group was poor yielding as well as poor biological yield and lower straw yield. Previous reports have demonstrated that the reduced yields of naked barley could be a result of a negative pleiotropic effect of the nud gene (Barabashi *et al.,* 2012).

CONCLUSION

The results of our study show that naked barley gave lower yields compared with hulled barley. The differences in the yield of hulled barley varieties El fouara, Saïda, Tichedrett) compared to naked barley variety (Chair Ennabi) grown in the same environmental conditions can be explained by the genetic constitution. Naked barley is an important crop in Algeria, but the production area is shrinking fast. It can also, give a higher yield than hulled barley under favorable conditions. Therefore, it is necessary to carry out this study in wider and different areas.

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