A comparative study of some growth and quality characteristics of Libyan Hulless and Covered Barley varieties

Radia Omar Salem[1], Seham Mohamed Alzeweek[2], Abraheem Abdullah Abraheem[3]
[1,2] Department of Crop Science, Faculty of Agriculture, University of Tripoli, Tripoli, Libya.
[3] The Agricultural and Animal Research Center Tripoli, Libya
radiasalem2007@yahoo.com

دراسة مقارنة لبعض خصائص النمو والجودة لأصناف الشعير الليبي العاري والمغطى

راضية عمر سالم[1]، سهام محمد الزويك[2]، إبراهيم عبد الله إبراهيم[3]
[1،2] قسم المحاصيل، كلية الزراعة، جامعة طرابلس، طرابلس، ليبيا
[3] مركز البحوث الزراعية والحيوانية طرابلس، ليبيا
radiasalem2007@yahoo.com

المستخلص:

يعتبر الشعير من محاصيل الحبوب الرئيسية ذات الاستخدامات النهائية الواسعة، وقد حظي باهتمام متزايد من قبل علماء الزراعة والأغذية بسبب تركيبته الكيميائية الخاصة وفوائده الصحية. وكان الهدف من هذه الدراسة مقارنة التركيب الكيميائي وخصائص النمو المبكر لسلالات تربية الشعير العاري الجديدة مع بعض أصناف الشعير المغطى المحلية. اظهرت نتائج الدراسة أن سلالات تربية الشعير العاري قدمت متوسطات أعلى للإنبات ومؤشرات النمو عند مقارنتها بالأصناف المغطاة. وتباين التركيب الكيميائي ($P < 0.05$) بين جميع الأنماط الوراثية للشعير. احتوت حبوب الشعير العاري على كمية أكبر بكثير من البروتين الخام (17.6٪) والنشا (59.9٪) مقارنة بالشعير المغطى. في حين كانت الألياف الخام الكلية (5.7٪)، والرماد الخام (1.7٪)، ومحتوى الرطوبة (10.9٪) أعلى بشكل ملحوظ في أصناف الشعير المغطى. تساهم هذه الدراسة في فهم التركيب الكيميائي لبعض أصناف الشعير الليبي وتشير إلى بعض الخصائص التي يمكن استخدامها كمعايير لانتخاب الأصناف في برامج التربية.

الكلمات المفتاحية: *الشعير المغطى، الشعير العاري، الصنف، جودة الحبوب.*

Abstract:

Barley is a major cereal crop with a broad range of end uses, and has been receiving more attention from both agricultural and food scientists because of its special chemical composition and health benefits. The objective of this study was to compare the new naked barley breeding line’s chemical composition and early growth traits with some domestic covered barley varieties. The results of study shows that hull-less barley breeding lines presented higher averages of germination and growth indices when compared to the covered varieties. The chemical composition varied ($P < 0.05$) among all the barley genotypes. hulless barley grain contained significantly more crude protein (17.6%) and Starch (59.9%) in comparison with covered barley. in turn, total crude fibre (5.7%), crude ash (1.7%), and moisture contents (10.9%) were significantly higher in hulled barley varieties. This study contributes to understanding the chemical composition of some Libyan barley varieties and indicates some characteristics that can be used as criteria for selecting varieties in breeding programs.

Keywords: *hulled barley, Hulless barley, variety, grain quality.*

Introduction:

Barley (*Hordeum vulgare* L.) is one of the oldest domesticated cereal crops in the world. Its cultivation began 10,000 years ago in the "Fertile Crescent" (Elouadi et al., 2023). Barley ranked the fourth most cultivated area and production quantity in the world after maize (*Zea mays*), wheat (*Triticum spp.),* and rice (*Oryza sativa*) (Lukina et al., 2022). The annual world harvest of barley in 2024 was approximately 142,441 Mt obtained from nearly 46.72 Mha (USDA, 2024). According to Sharidi et al. (2020), barley occupies more than 80% of the country's cereal cultivated area, making it the first crop in Libya. As the annual barley harvest in 2021 amounted to more than 70 thousand tons from about 136.46 thousand hectares (Yearbook of Agricultural Statistics, 2022).

Barley grain is used mainly for animal feed (about 70% of the total barley production), and 20–25% of barley grain is used to make beer, whisky, and other alcoholic beverages. A small amount of barley has been consumed as human food (5–10%) (Kumar et al., 2021; Genievskaya et al., 2023). However, throughout its history, it has remained a major food source in several regions, such as some areas of North Africa and the Middle East, Northern and Eastern Europe, and Asia (Tamm et al., 2015; Badea and Wijekoon, 2021). In recent years, there has been renewed interest in barley throughout the world from both agricultural and food scientists due to its unique chemical composition and health benefits, such as β-glucan, tocols, and resistant starch. Barley β-glucan lowers blood cholesterol and increases insulin sensitivity, which can reduce the risk of chronic heart disease. Resistance starch has the ability to lower blood sugar and improve intestinal function, whereas tocols have the impact of decreasing serum cholesterol (Geng et al., 2022). Barley has been shown to have antitumor properties through regulating the immune system and limiting cancer cell proliferation and dissemination. Furthermore, barley possesses antioxidant and anti-inflammatory characteristics, which may contribute to its anticancer potential (Raj et al., 2023). In Libya, local barley meals are not only a food but also a public cultural expression. A large variety of dishes are made from barley products, including bread, bazin, zummeta, dshesha, harisa, and couscous. Although the consumption rate of these traditional foods is decreasing among the younger generations, it is still higher in rural areas than in cities. However, in some social occasions, such as wedding and funeral gatherings, barley food is preferred, especially Bazin (Zentani, 2005).

The main component of barley grain is carbohydrates. Carbohydrates make up 78-84 % of the grain. Starch is the most abundant carbohydrate in barley grain (52-72 %), followed by β-glucan (4-6 %), pentosans (4-8 %), and cellulose (1.5-5 %). In addition to carbohydrates, barley grain also contains protein (10-17%), free lipids (2-3%), minerals (1.5-2.5%), vitamins, antioxidants, and total dietary fiber ranges from 11-34% containing soluble dietary fiber within 3-20%. dietary fibers, depending on genotype and environmental conditions during cultivation (Das and Kaur, 2016; Yuliya et al., 2023).

Cultivated barley can be classified as a spring or winter variety depending on whether they need a cold exposure, ranging from two to several weeks before making the transition to the reproductive phase of growth (Das and Kaur, 2016); two-rowed or six-rowed depending on spike morphology. The development of a six-rowed spike is controlled by a single allele, vrs1 (formerly v for vulgare), that is recessive to the dominant allele responsible for the two-rowed spike (Vrs1). In two-rowed barley, only the middle spikelet is fertile, while in six-rowed barley, the lateral spikelets are also fertile (Bleidere and Grunte, 2007); covered or naked/hulless (which refers to the presence or absence of an outer husk on the grain) (Badea and Wijekoon, 2021). Hull-less (naked) barley is caused by a naturally occurring mutation in a gene (Nud) on chromosome 7H of barley, which blocks the synthesis of the lipid that permits adhesion of the husk (hull) to the outer grain tissues (Meints et al., 2021; Lukina et al., 2022). Depending on the grain's composition, barley can also be classified as normal, waxy, or high amylose starch, high lysine, high β-glucan, or proantho-cyanidin-free. Compared to hulled barley, the free-threshing character of hulless barley proportionally increases contents of protein and the limiting amino acids lysine and thereonine, respectively, and as well levels of β-glucan but lowers contents of insoluble dietary fibre components (Siebenhandl-Ehn et al., 2011).

The main advantage of the hulless barley for application in the food industry is its use without the need to remove the husk after the harvest. Hulled varieties must be pearled before human consumption to remove the unpalatable hull. This involves a mechanical abrasion process to remove the hull, which also removes part or all of the bran and germ, resulting in the grain being ineligible for whole grain status and losing valuable minerals and micronutrients that are located in the bran layer. In addition, the absence of hulls means that the grain has more nutrients and higher energy per unit weight, and therefore it requires less space for storage and transport. Poor threshability (ease of hull removal) can occasionally cause pearling in naked barley. Threshability is an important trait to select for in naked barley because end-use quality can decline if the percentage of grains with undetached hulls is over 5% for food and 15% for feed (Tišma et al., 2018; Meints et al., 2021).

There is nothing that has been reported in the open literature about the differences between Libyan-covered barley cultivars and hullless barley lines. The objective of this study was to compare the new naked barley breeding line's chemical composition and early growth traits with some domestic covered barley varieties.

Material and methods:

Ten genotypes of hull-less and hulled barley (Hordeum vulgare L.), obtained from the National Gene Bank for Plant Resources (NGPR), Tripoli, Libya, were used for the comparative study of grain quality and some growth traits. The experiment was carried out in the Seed Testing and Technology laboratory, Department of Crop Science, Faculty of Agriculture, and University of Tripoli, during the 2019–2020 growing season on four varieties of six-rowed hulled barley (Maknossa, Barjouj, Adlimi, and Beecher) and six advanced breeding lines (11, 19, 73, 82, 87, and 103) of hull-less barley.

Seeds were surface sterilised with sodium hypochlorite (20%) for 5 minutes. Residual sodium hypochlorite was removed by thorough washing three times with sterilised distilled water. Ten seeds from each genotype were placed in two layers of Whatman No. 1 filter paper in Petri dishes measuring 90mm. After placing the seeds in Petri dishes, a measured volume of 10 ml of distilled water was poured into the Petri dishes, and the Petri dishes were kept under laboratory conditions at 25±2 °C for 10 days.

The experiment was arranged according to a completely randomised design (CRD) with three replications. The number of seeds germinated was counted daily from the 4th day of the experiment, and the seeds were considered germinated with the emergence of the radicle. Three parameters of germination, which include final germination percentage (GP), germination rate index (GI), and seedling vigour index (SVI), were determined according to the International Seed Testing Association (ISTA) protocols (ISTA, 2024).

Germination percentage = (Number of germinated seeds/total number of seeds) * 100

Germination index = Day (Number of seeds germinated/days to first count) +... + (Number of seeds germinated/days to final count)

Seedling vigour index = ((Root length + Shoot length) * GP)/100

The primary root, shoot, and coleoptile lengths (RL, SL, and CL) were measured for all seedlings on each Petri dish with a scaled ruler (in cm). Then, the coleoptile fresh weight (CFW) was recorded in grammes using a sensitive balance. Biochemical analysis to determine grain quality characteristics was performed at the Food and Drug Control Centre, Tripoli, Libya.

All collected data were subjected to statistical analysis of variance (ANOVA) using GENSTAT statistical software, 17th edition (Gen Stat, 2012). The significance of differences among means was compared using the least significant difference (LSD) test at the 5% level of probability.

Result and dissection

The results of the analysis of variance ($p < 0.01$) show that there is considerable variation among the barley genotypes found for all traits (Table 1). Among all test barley varieties, the advanced breeding line 19 of hull-less barley exhibited the highest values for germination percentage (80%), germination rate index (17.8), and seedling vigour index (1528.4), while the lowest ones were detected for the genotype Barjouj (1.7%, 4.0, and 2.59), respectively. Likewise, advanced breeding lines 19 showed maximum values for root length (8.8), shoot length (10.1 cm), and coleoptile length (18.9 cm), followed by genotype Adlimi (4.9, 9.1, and 14 cm), respectively. Whereas, the lowest values of this trait were in the genotype Barjouj (0.6, 0.8, and 1.4 cm). A similar trend was observed in the case of the fresh coleoptile weight at the end of the germination test, except for advanced breeding lines 82 (4.23 g) and 11 (3.87 g), which were the best, followed by line 103 (3.43 g). It was also observed that the minimum fresh weight of coleoptile (0.04 g) for the genotype Barjouj. The low germination percentage and poor plant establishment of covered barley varieties may be due to the long seed storage period. According to the report, final germination percentage, germination index percentage, energy of germination percentage and emergence rate percentage, speed of germination, seedling length, seedling dry weight, and seedling vigour index were decreased as storage periods were increased (Gebeyaw, 2020; Gebeyehu, 2020). Naked barley varieties typically exhibit lower germination percentages than their covered counterparts; this is largely due to its low field germination caused by the protrusion of the radicle beyond the grain. It affects the embryo’s resistance to the mechanical impact of threshing equipment, results in injuries, and leads to a decrease in field germination of its seeds. However, establishment of 85% can be obtained by reducing combine drum speed at harvest (Dickin, et al., 2012; Lukina et al., 2022). Moreover, Indore et al., (2023) emphasize that some hulless varieties may perform better in storage conditions, the hulled barley varieties showed more deterioration in microstructure than the hulless varieties of barley, where a direct correlation between microstructural changes and alterations in nutritional content was found.

Table 1. Mean Comparison of germination and growth indices of covered and naked barley genotypes.

Varity or line	GP	GI	SVI	RL cm	SL cm	Cl cm	CFW g
11	73.3	16.3	390.4	1.8	3.5	5.3	3.87
19	80.0	17.8	1528.4	8.8	10.1	18.9	2.27
73	53.3	13.2	653.9	4.9	7.3	12.3	3.17
82	66.7	16.0	719.8	4.5	6.3	10.7	4.23
87	70.0	16.3	389.9	2.3	3.3	5.6	3.30
103	80.0	11.5	812.0	4.0	6.1	10.2	3.43
Maknossa	3.0	7.2	6.23	0.6	1.5	2.1	0.05
Barjouj	1.7	4.0	2.59	0.6	0.8	1.4	0.04
Adlimi	6.0	17.7	84.2	4.9	9.1	14.0	0.09
Beecher	7.7	17.5	114.6	5.5	8.8	14.3	0.09
LSD at 0.05%	7.7	3.7	247.5	1.4	1.7	2.8	0.23

Table 2 presents the chemical composition of the grain of ten hulless and hulled barley varieties. The analysis of protein contents (%) in the grain revealed that the highest amount of protein (17.6%) was established for the advanced breeding lines 73 (hullless barley), whereas the lowest quantity of protein was determined for the covered variety Beecher (9.5%) ($P < 0.05$). On the other hand, the results indicated that the naked barley genotype was higher in protein content compared with the covered barley genotype. Our results are in agreement with those of (Bleidere and Grunte, 2007; Šterna et al., 2017), who reported that naked barley grains had a higher protein content, the sum of essential amino acids, and, particularly lysine, was not far behind the content recommended by FAO/WHO. Protein content in barley grain also depends strongly on the variety, environmental conditions, and growth conditions, particularly with the rate and timing of nitrogen fertilization. Which was evidenced in studies by Bleidere et al., (2013); Abdel-Aal and Choo, (2014); and Elouadi et al., (2023).

Table 2. Chemical composition (%, w/w dry basis) of covered and hull-less barley varieties grain.

Varity or line	% protein	% starch	% fiber	% ash	% moisture
11	15.7	54.5	3.4	1.3	9.7
19	15.5	56.2	2.9	1.3	9.7
73	17.6	52.3	3.9	1.4	9.5
82	11.4	59.9	1.9	1.0	9.9
87	13.1	59.8	1.8	1.1	10.0
103	13.5	58.5	1.9	1.6	9.8
Maknossa	11.6	49.4	5.7	1.7	10.8
Barjouj	10.9	50.9	5.4	1.2	10.6
Adlimi	11.5	50.2	5.5	1.6	10.6
Beecher	9.5	49.7	5.7	1.1	10.9
LSD at 0.05%	0.3	0.2	0.1	0.1	0.2

Starch is the main available carbohydrate in barley and related cereals and contributes significantly to the energy intake. Other available carbohydrate components in barley are sugars (glucose, fructose, sucrose, and maltose), but they are present in barley at low concentrations (<2g hg^{-1}) (Abdel-Aal and Choo, 2014). The two components of starch in common barley type are amylopectin and amylose, the ratio of amylose to amylopectin has a substantial impact on its physicochemical properties. Depending on the ratio of amylose and amylopectin, there are two varieties of barley cultivators: waxy starch and non-waxy starch (Raj et al., 2023). The results regarding crude starch in the grain showed a significant difference among hulless and hulled Barley varieties ($p < 0.05$). The mean value of starch content for hulless barley (52.3-59.9%) was significantly higher than for hulled barley varieties (49.4-50.9%) (Table 2). The crude starch content in the advanced breeding line 82 delivered the maximum value (59.9%), followed by line 87 (59.8%), and 103 (58.5%), while the hulled barley variety Beecher has the lowest content (49.4%). Starch content in barley was found to vary by genetic differences, environment, and growing conditions (Abdel-Aal and Choo, 2014). According to Tamm et al., (2015), starch content was more influenced by genotype. As reported by Bleidere and Grunte, (2007, the starch content for the waxy barley variety 'Candle' was considerably higher than for hulless barley and covered barley with normal endosperm.

Dietary fibre content is an essential measurement for the assessment of potential health benefits associated with barley consumption. It is also an important trait in determining the feeding value of barley. Barley is a good source of dietary fibre, which is found throughout the kernel (Abdel-Aal and Choo, 2014). Crude fibre contents of hulled varieties were significantly higher ($P < 0.05$) than the hull-less varieties (Table 2). The content of total dietary fibre in the hulless barley lines ranged from 1.8 (line 87) to 3.9% (line 73) compared to hulled varieties, which recorded a maximum of 5.7% (Maknossa and Beecher), followed by Adlimi (5.5%) and Barjouj (5.4%). The results obtained in this research show that hulless barley varieties have slightly lower fibre contents than the hulled ones. Similar findings on fibre contents between hulled and hulless barleys were reported by Bleidere and Grunte, (2007); Šterna et al., (2017); Baidoo et al., (2019).

The ash content has an important role in determining the amount of essential minerals or inorganic compounds; phosphorus and potassium have been found to be major minerals present in barley, while iron and zinc are the major trace minerals (Rani et al., 2020). The results regarding crude ash content showed significant differences ($p < 0.05$) among the tested genotypes (table 2). The highest ash content was analysed in Maknossa (1.7%) followed by Adlimi (1.6%) and line 103 (1.6%), whereas the minimum value was recorded in line 82 to be 1%. Similarly, Bleidere and Grunte (2007) reported that hulled barley has a significantly higher crude ash than hulless barley. According to results of Abdel-Aal and Choo (2014), the ash content of barley varied between 1.8 and 2.3 g hg^{-1}, with year, location, and year×location interactions having substantial influence on ash content. The total ash content of the whole barley grain could vary with barley type and agronomic management. Fertilization and drought stress were also found to have an impact on the minerals in barley grain.

Moisture content is an essential component playing a major role in determining the shelf-life of cereals and the variation in moisture content among different barley varieties could be due to their genotypic variations (Rani et al., 2020). The moisture content ranged from 9.7% to 10.9% among barley genotypes. The data in Table 2 indicated that the moisture content was significantly higher in the Beecher (10.9%) and Maknossa (10.8%) varieties than in other genotypes ($p < 0.05$). However, there was no significant difference between the hulless barley varieties, with the exception of line 73, which had the lowest value of 9.5%. These differences might be due to a variety of factors, including storage conditions, geological change, and water holding capacity (Quddos, et al., 2021). Our moisture results are in line with the results of (Attya and Mohammed, 2021), who found that the covered barley genotypes were higher in moisture content compared with naked barley genotypes, the moisture content ranged 11.11-11.75% for covered barley genotypes, while ranged10.38 - 10.86 % for naked barley genotypes during both seasons.

Conclusion and recommendations:

Overall, the present study revealed significant genotype-dependent variations in quality parameters such as starch content, protein content, crude fibre, crude ash, and moisture contents in barley grain genotypes. The hull-less breeding lines of barley accumulated the highest amount of crude protein and starch; in turn, total crude fibre, crude ash, and moisture contents were significantly higher in hulled barley varieties. Future research should focus on conducting field experiments to compare the influence of genetic and environmental factors on the agro-morphological and quality parameters of hulled and hulless barley varieties, with appropriate variety selection and processing. Furthermore, investigate the impact of post-harvest processing methods on the nutritional composition and bioactive compounds of covered and naked barley.

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