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Evaluation of barley lines for morphological characteristics using line tester

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ABSTRACT

Barley (*Hordeum vulgare* L.) is an important cereal crop grown around the world for a variety of applications in the food, feed, and beverage industries. Creating high-yielding barley cultivars with good agronomic features is critical for fulfilling the increasing demands of a growing global population. This study used a line × tester mating approach to assess the combining ability and genetic potential of various barley lines for specific morphological traits. The goal of this study was to find parents with superior traits and superior F1 hybrids with high SCA that could be used for breeding. The cross was created with four barley lines and three testers (4×3). The results for different parameters were measured. The parameters include days to heading, plant height, spike length, grains per spike, 1000 grains weight, and grain yield per plant. The data that was collected showed promising differences between genotypes for all traits. General combing ability (GCA) and Specific combining ability (SCA) effects were estimated. The lines and hybrids having high GCA and SCA values for different traits were evaluated. This research showed important insights into the genetic bases of morphological traits of barley. It also showed the importance of line-tester analysis for the identification of high-breeding varieties.

KEYWORDS

Barley; Line-tester; Morphology; Yield; Genotype; Tracheophyta

ARTICLE HISTORY

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Introduction

Hordeum vulgare L. commonly known as barley is a versatile crop that is used globally for the production of malt, a key ingredient in the brewing industry. Moreover, it is used as a food source for humans and animals. Barley is a useful crop due to its large number of nutrition and the ability to adjust to different environments [1]. Barley's nutritional value such as its richness in fibers, proteins, vitamins, minerals, and antioxidants plays an important role in human health [2]. The nutrients that are mentioned play significant roles and provide many advantages like maintaining blood glucose levels, controlling cholesterol levels, and improving the digestive system. In Egypt, barley is the main grain crop grown on freshly recycled land as well as the Northwest Coast and the northern Sinai districts. Agriculture needs to produce barley varieties with higher yield potential. Cultivating early maturing barley varieties before cotton is planted is another way to increase grain production [3]. This will increase domestic barley production and lessen the gap between barley production and consumption.

It is critical to produce superior barley cultivars with increased yield, improved quality features, and increased tolerance to biotic and abiotic stressors, given the growing world population and the pressing need for sustainable food production [4,5]. Increasing the efficiency of grain crop productivity is of the utmost importance. A complete understanding of genetic mechanisms, such as combining ability, is essential for the production of improved genotypes with increased yield potential before beginning a crop improvement program. A detailed evaluation of genetic data and a thorough understanding of combining ability, which informs parental selection, greatly raises the possibility of finding promising F1 hybrids. Combining Ability Analysis is a powerful tool that is used by plant breeders to identify the perfect parents and hybrid combinations to obtain better crops. Firstly, Plant Breeders identify a parent that has strong General Combining ability so that it produces good offspring continuously. They also look for high SCA to produce better offspring together. For this purpose, plant breeders use many techniques. The best performing and advantageous technique that is used is Line×Tester analysis. [6].

The Line×Tester technique is useful for estimating GCA [7]. Line×Tester analysis identifies combinations of best parents that produce hybrids having high yield and better characteristics than parents [8]. By using the Line×Tester technique, the researchers can obtain barley lines that have high value for hybridization.

The main purpose of this study was to obtain functioning parents and testers and their F2 population by studying their GCA and SCA [9]. This study aimed to measure the genetic factors that affect the production of valuable traits. The main aim was to select genotypes having better GCA and SCA to transfer to the next breeding program [10]. The purpose of this study was also to identify gene action and magnitude that causes phenotypic variance between lines and the next upcoming generation.

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Materials and Methods

This experiment was performed in the field allotted to the Faculty of Agriculture at the University of The Punjab Lahore that was located at (31.5035° N latitude, 74.3217° E longitude, and 217 meters altitude). The soil at the experimental site was characterized as loam with a balanced mixture of sand, silt, and clay, providing good drainage and nutrient-holding capacity. The soil pH was slightly alkaline, ranging from 7.5 to 8.0, indicating suitable conditions for barley growth. Organic matter content and other nutrient levels were within optimal ranges for crop development. The Genetic material was composed of Baladi 16, Mariout, Sahara 93, and Rihane 03 (females)and the testers Tadmor, Barke, WI2291 (males). These lines and testers were selected because they are locally adapted and contain a wide genetic base. The F1 hybrid was developed by using lines×testers 1224×3 design. The lines and testers were crossed to produce 12 F1 hybrids. In the first growing season lines and testers were grown. At the anthesis stage, the crosses were made between lines and testers, and seeds from each cross were harvested to obtain F1 hybrids. In the next growing season, lines, testers, and hybrids were grown separately and comparison was made between them having different parameters like plant height, days to heading, spike length, grains per spike, 1000 grains weight, and grain yield/plant. The plant height was measured by a Stadiometer from the base of the stem to the top of the plant. The spike length was measured by measuring tape. 1000 grains weight was also measured by taking 1000 grains and calculating by weight balance. The total grain yield of every plant was also calculated. After calculating all the parameters, Statistix 8.0 software was utilized to check the significance of parents and hybrids for each parameter. The GCA and specific combining ability were also calculated by manually formulating an Excel sheet.

Results and Discussion

This experiment was performed to find out the GCA and SCA effects for various parameters in Line ×Tester analysis having a total of seven parents. Four parents were used as lines and three parents were used as testers.

Analysis of variance

After analyzing different traits of barley breeding showed fascinating design and significant results for the betterment of the crop. An important parameter, days to heading which governs flowering time and maturity showed significant results for genotypes, parents, and hybrids (Table 1). This showed a notable genetic effect on this parameter that allowed plant breeders to choose a particular heading time depending on the conditions of the environment. In the same way, plant height and spike length which are important parameters for yield and lodging resistance showed significant results for all parameters. It shows greater genetic differences among all parameters that allow plant breeders to alter plant structure for better yield and performance [11]. The trait 1000 grains weight which is an important trait for yield, showed significance for genotype. It shows that an essential difference is present between different barley varieties in the weight of grains. Anyhow, the combination of parents and crosses did not change this trait. This research can be used to control the weight of grains that involves the effect of many genes and their interaction or different factors of environment that play eco-friendly role. The parameter grain yield per plant which is the main parameter to measure the total production showed significant variation among genotypes, parental lines, and crosses. This shows that the grain yield is affected both by genetics and the environment. Plant breeders can give importance to selecting genotypes that are commending and also combinations of different parents. They must give attention to agronomic practices to increase the yield [12].

Table 1. Mean square values of all parameters of 7 parents and 12 F2 populations were evaluated by line×tester analysis (4×3) of Barley during the year 2023-24 at FAS.

Source of Variation (SOV)	Days to Heading	Plant Height	Spike Length	Grain per Spike	1000 Grains Weight	Grain Yield/Plant
Rep (Replications)	0.47	0.51	0.013	0.47	0.22	0.13
Gen (Genotypes)	22.45×	40.32*	0.73*	14.63	8.68*	4.94*
Parents	31.71*	47.84*	0.80*	14.86	9.51	5.25*
Crosses	19.34*	39.71*	0.75*	15.52	8.80	5.12*
P×C	1.17	1.93	0.14	3.48	2.42	1.10
L (Lines)	47.58	103.55	2.07	40.25	25.79	15.73
T (Testers)	33.25	60.17	0.97	22.75	9.30	4.30
L×T	0.58	0.97	0.01	0.75	0.15	0.10
Error	5.29	8.19	0.20	5.29	2.58	0.72

General combining ability (GCA)

L2 and L4 have positive GCA effects, suggesting they would contribute to earlier heading in hybrids. L3 has the most negative GCA, likely contributing to the later heading (Table 2). Similar to DH, L2 and L4 show positive GCA (taller plants), while L3 contributes to shorter plants. L4 has the highest positive GCA for longer spikes, while L3 contributes to shorter spikes. Line 4 (L4) showed the highest General Combining Ability Value in positive. Similarly, L3 showed the highest negative value of GCA. Line 4 having the highest positive General Combining Ability produces the highest grain weight and Line 3 reduces it. Line L4 showed high value for various traits which shows that this line is important to increase the yield of grains. Line L3 showed the results in negative continuously which shows it will be discarded. The study of General Combining Ability has given information on many

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Barley lines that can be used to produce improved hybrids [13]. General Combining Ability is measured by taking the average performance of parents among different crosses. GCA acts as a vital component to measure the breeding value. This study showed that LINE 2 had very high GCA for the parameter days to heading. This showed that the LINE 2 can be used as a parent to grow Barley varieties that will have early days to heading property. This property of early days to heading is important for areas having short growing seasons. It can be grown in areas where there is excessive heat to prevent heat stress. It allows crops to mature before stress. Also, adding these varieties to the breeding program will produce hybrids that will show resistance to environmental factors show better responses, and increase yield [14].

Likewise, the L4 lines exhibited high GCA plant height values, another key trait affecting barley productivity. Optimum plant height is critical to balancing yield potential with lodging resistance(the plant's ability to withstand strong winds and rain without collapsing). The high GCA values of L4 indicate its potential to facilitate breeding efforts aimed at optimizing plant height, ultimately increasing yields and reducing crop losses due to lodging. In contrast, L1 and L3 lines showed negative GCA values on several traits. This shows that these lines perform poorly on average in various cross combinations, indicating lower overall breeding value. While these lines may possess specific desirable traits, their negative GCA values raise concerns about their potential to continue providing advantageous traits to future generations [15]. Therefore, it would be prudent to exclude L1 and L3 from further breeding efforts and focus resources on more promising lines such as L2 and L4. The results of GCA analyses have significant implications for barley breeding programs. Breeders can increase the likelihood of creating superior varieties by preferentially using lines with high GCA values as parents in crosses. This approach increases the effectiveness and efficiency of breeding activities while also saving considerable time and money [16]. However, it is important to realize that GCA is only a small part of a complex breeding process. Although a strain's performance in a particular cross may vary due to the influence of SCA, a high GCA rating is indicative of the strain's overall potential. Deviations from predicted mean performance based on GCA are caused by unique interactions between certain parent combinations, which are reflected in SCA. Therefore, comprehensive breeding strategies should consider both GCA and SCA to maximize genetic gain and develop varieties with desired trait combinations [17]. Furthermore, the efficacy of the selected strains in various settings must be confirmed through comprehensive field studies [18]. Although GCA provides useful information about the average performance of a line, many environmental factors (such as soil type, rainfall patterns, and temperature changes) may affect the actual performance of the line. Field trials allow breeders to assess the stability and adaptability of promising lines in the field, which helps ensure that the varieties they select will perform well in a variety of agricultural environments. Finally, this GCA analysis provides a useful tool for wheat breeders by showing the potential of lines L2 and L4 to create superior varieties with desired early heading and plant height traits. However, this analysis must be considered within the broader context of an integrated breeding strategy, which includes SCA assessment, field trials, and other relevant factors. By leveraging this multifaceted approach, barley breeders can accelerate the development of high-yielding, climate-resilient, and economically viable barley varieties to meet growing global food demand [19].

Table 2. General combining ability effects among lines and testers for various traits were evaluated in lines 4×3 and tester mating design of Barley during the year 2023-24.

Parental Genotypes	Days to Heading (DH)	Plant Height (PH)	Spike Length (SL)	Grain per Spike (Tp)	1000Grains Weight	Grain Yield/ Plant (GYLD)
Lines						
L1	-0.58	-1.11	-0.19	-0.75	-0.67	-0.65
L2	1.08	0.78	0.06	0.58	0.64	0.29
L3	-2.92	-3.88	-0.50	-2.42	-1.96	-1.35
L4	2.42	4.20	0.63	2.58	1.98	1.71
Testers						
T1	0.42	0.97	0.14	0.67	0.33	0.26
T2	1.42	1.59	0.19	0.92	0.67	0.43
T3	-1.83	-2.56	-0.33	-1.58	-1.00	-0.68

Specific combining ability (SCA)

The current study explored the potential of several barley hybrids (line x tester) by evaluating their specific binding ability (SBA). SCA is an important genetic metric that measures the extent to which a specific hybrid performs differently compared to the expected average of its parent strains [20]. High positive SCA values are a sign of ideal hybrid vigor, or hybrid vigor, indicating that a hybrid is superior to its parents on a given attribute. Hybrid combinations with strong positive SCA values for many important agronomic traits make excellent choices. Table 3 shows that hybrids L1×T1, L3×T3, and L4×T3 consistently showed excellent plant height, indicating their potential to produce lodging-resistant, high-yielding wheat varieties. L1×T2 showed a significantly higher 1000 kernel weight, a key yield component. The discovery highlights the potential to increase grain yields and improve the overall economic value of barley production. The increased number of grains per panicle in L1T3 and L3T2 directly contributes to

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increased yield. These hybrids could revolutionize barley productivity in regions where grain production is subject to major constraints [21]. L2×T3 and L4×T2 demonstrated early heading, which is a beneficial trait in situations where the growing season is short or terminal high temperature or drought stress is high. These stress factors can be avoided through early heading varieties, ensuring reliable yields even under difficult circumstances. The number of grains per panicle increased significantly in L2×T1, which is a strong signal of high yield potential. Such hybridization could play a key role in creating barley varieties to meet the world's growing food needs. On the other hand, many crosses, including L2×T2, L3×T1, and L4×T1, showed negative SCA values on a variety of traits. This indicates that these hybrids do not perform as well as their parent lines. Therefore, we decided that these crosses were not suitable for additional breeding attempts, thus saving time and money [22]. For barley breeders, the results of the SCA analysis provide insightful information. By identifying potential hybrids and weeding out failed varieties, research accelerates the breeding process and contributes to the production of high-yielding, climate-resilient, and commercially viable barley varieties [23]. But it's important to realize that SCA is only one component of the whole. High SCA scores show a hybrid's potential, but many environmental conditions (such as soil type, rainfall patterns, and temperature changes) can affect how a hybrid performs in the field. Extensive field testing is therefore crucial to verify the functionality of these interesting hybrids in real-world environments. Additionally, it is important to consider Generic Combination Capabilities (GCC) alongside SCA. GCA represents the average performance of a parent across various cross combinations and provides insight into its overall breeding value. Integrated breeding strategies should consider both SCA and GCA to maximize genetic gain and develop superior barley varieties [24].

Table 2. SCA of hybrids all parameters

F2 Population	Days to Heading (DH)	Plant Height (PH)	Spike Length (SL)	Grain per Spike (Tp)	1000Grains Weight	Grain Yield/ Plant (GYLD)
L1×T1	0.58	0.45	0.02	0.00	0.02	0.01
L1×T2	-0.42	0.03	-0.03	-0.25	0.04	0.01
L1×T3	-0.17	-0.48	0.02	0.25	-0.06	-0.01
L2×T1	-0.08	0.49	0.09	0.67	0.31	0.28
L2×T2	-0.08	-0.42	-0.06	-0.58	-0.24	-0.13
L2×T3	0.17	-0.07	-0.04	-0.08	-0.07	-0.15
L3×T1	-0.08	-0.25	-0.04	-0.33	-0.09	-0.06
L3×T2	-0.08	-0.17	0.01	0.42	-0.04	0.00
L3×T3	0.17	0.42	0.03	-0.08	0.13	0.06
L4×T1	-0.42	-0.69	-0.07	-0.33	-0.23	-0.22
L4×T2	0.58	0.56	0.08	0.42	0.23	0.12
L4×T3	-0.17	0.14	-0.01	-0.08	0.00	0.11

One limitation of this study is that the evaluation was conducted under a specific set of environmental conditions, which may affect the generalizability of the results to other regions. Additionally, the study focused solely on morphological characteristics without incorporating molecular or physiological traits, which could provide a more comprehensive understanding of the genetic potential. Future research should include multi-environment trials and integrate molecular markers to validate the findings and enhance breeding strategies.

Conclusions

In conclusion, analysis of barley traits revealed complex interactions between genetics and environment. Days to heading, plant height, and panicle length are significantly affected by genetics, providing opportunities for intensive breeding to enhance these traits for specific environmental and agronomic goals. Although direct genetic selection may not have much impact on thousand-grain weight, parental combinations, and environmental influences can still lead to improvements. The large variation in grain yield per plant due to genetic and environmental factors highlights the possibility of significantly increasing yields by combining targeted breeding with efficient agricultural techniques. These results provide a useful roadmap for upcoming barley breeding programs aimed at developing cold-tolerant, high-yielding varieties to address global food security concerns. The findings suggest that the identified barley lines with superior morphological traits should be considered for breeding programs aimed at enhancing yield and adaptability.

Disclosure Statement

No potential conflict of interest was reported by the author.

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