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Enhancing Food Security Through Identification of Best Performing Barley Cultivars under Arid Conditions

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ABSTRACT

Background: Plant genetic diversity is the key to the development of new crop varieties for enhanced crop production and improvement of food security. Barley is one of the most dependable cereal crop under saline and drought conditions and used majorly in feed, food and malting industry. The growth and yield of barley is highly influenced by the production environment and genotype.

Methods: The study evaluated the growth and yield performance of fourteen barley genotypes under Kuwait's environmental conditions. The field trials were conducted in Kuwait for two successive seasons 2019-2020 and 2020-2021 in a randomized complete block design with three replicates.

Result: The combined analysis of variance has shown that plant height, number of tillers/m^2, number of days to heading, hundred kernel weight, grain and biomass yield varied significantly between the fourteen different barley varieties. Similarly, all the parameters varied significantly between the years except hundred kernel weight. In addition, an interaction was observed between genotype and year, for all parameters except hundred kernel weight, biomass yield and number of tillers/m^2. Taking into consideration the two growing seasons, the varieties Kuwait 3 and Kuwait 4 presented superior performance over other varieties in terms of grain and biomass yield under Kuwait's harsh environmental conditions.

Key words: Barley, Biomass yield, Correlation, Diversity, Grain yield.

INTRODUCTION

Enhancing crop production in hyper arid desert climate regions like Kuwait is a major challenge due to its harsh environmental conditions marked by several biotic as well as abiotic stresses and scarce natural resources. Barley (*Hordeum vulgare* L.), a main source of food and feed (Harrold, 2010) is one of the most dependable cereal crop under saline and drought conditions (Verstegen, 2014). In Kuwait only 4 to 5% of the total livestock feed requirements are met from the local farming systems, therefore the country mainly depends on imported barley grains, straws and other feeds. In fact, Kuwait had to import 100% of both barley grains and straws for animals (Al-Menaie *et al.*, 2021). In addition to the production environment, genotype affects the expression of growth, yield and other yield traits in barley significantly (Moustafa *et al.*, 2021). In the previous years, several field trials were carried out in Kuwait to screen and select varieties with desired traits for barley breeding programs (Al-Menaie, 2003; Al-Menaie *et al.*, 2014). The wide scale cultivation of genetically homogenous varieties leads to extinction of plant species and therefore emphasizes the need for cultivating more barley varieties that exhibits improved yield and adaptability to arid regions. The present study addressed this gap and evaluated the growth and yield performance of fourteen barley genotypes to select the best cultivars with improved yield under Kuwait's environmental conditions.

MATERIALS AND METHODS

The main objective of the experiment was to identify barley varieties that are well suited for cultivation in arid conditions in Kuwait. The identification of high yielding barley cultivars could benefit the countries characterized by limited water availability and high temperatures. The experimental study was conducted in Kuwait Institute for Scientific Research (KISR) Station for Research and Innovation, Kuwait for two successive seasons 2019-2020 and 2020-2021. The study evaluated the growth and yield performance of fourteen barley genotypes comprising of three mutant barley cultivars [Golden Promise (*ari-e*.GP), *ari-e*.1, *ari-e*.228], the parental lines, Maythorpe, Bonus, Foma, California Marriot and Gustoe and six promising local cultivars namely, Kuwait 1, 2, 3, 4, 5 and 6 under Kuwait's environmental conditions. The field experiment was laid out in a randomized complete block design with three replicates. The seeds of the selected cultivars were sown in six rows, 2.5 m long with 20 cm inter row spacing in plots of area 3 m^2. Phosphorous in the form of single superphosphate (15.5% P_2O_5) at the rate of 60 kg P_2O_5/ha was applied at the land preparation stage.

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Potassium in the form of potassium sulphate (45.5% K_2O) at the rate of 100 kg K_2O/ha was applied in two equal doses during tillering and heading stages. Nitrogen was added as urea (46% N) at the rate of 100 kgN/ha as ten equal doses from seedling establishment stage. Various phenological and yield parameters such as plant height, number of tillers per meter square, hundred kernel weight, grain yield, biomass yield, number of days to heading were determined to identify the high yielding varieties most adaptable to Kuwait. The linear relationship between the variables were determined using Pearson correlation test. All the data obtained were analyzed by analysis of variance (ANOVA) using the statistical program Statistical Package for the Social Sciences (SPSS).

RESULTS AND DISCUSSION

Plant height

The study revealed that plant height differed significantly among the varieties and between the two years of experimental study. It was also observed that an interaction existed between the varieties and year (Table 1). In the first year, plant height attained its highest value in Kuwait 2, whereas California Marriot recorded the maximum value in the second year (Table 1). In addition, previous studies have shown that the plant height is one of the factors that determine the grain yield of crop plants (Alqudah *et al*., 2016). The plant height displayed a significant positive correlation with hundred kernel weight in both years and grain yield only in the second year in the study (Table 2 and 3). The increasing yield with plant height could be attributed to the increased ability of crop light interception with taller plants, thereby enhancing photosynthesis and yield (Jiang *et al*., 2020). The results were in agreement with the results obtained by Minale *et al*., (2011), which reported higher grain yield in plants with higher plant height.

Number of tillers/m^2

The number of tillers significantly differed between the varieties in the study due to the genetic variation in the reproductive development (Karsai *et al*. 1999; Ogrodowicz *et al*. 2017 Borras *et al*. 2009; Alqudah and Schnurbusch 2013). The highest value was reported by Kuwait 4 without any significant difference from Kuwait 5 and Kuwait 6 (Table 1). In addition, the overall mean number of tillers was increased by 11% in the second year which could be attributed to the impact of environmental factors in promoting or repressing lateral shoot development through a network of hormonal and regulatory signals (Shaaf *et al*., 2018). But no interaction was observed between the varieties and the year of the experimental study. The correlation analysis has shown that number of tillers presented a significant positive correlation with biomass yield as well as grain yield (Table 2 and 3) as increased number of tillers could lead to more number of panicles per square meter and thus improve yield (Badshah *et al*., 2014).

Number of days to heading

The heading date differed significantly among the varieties and between the two years of experimental study. In addition, an interaction existed between the varieties and the year of the experimental study. In the first year, Kuwait 5 produced the highest value without significantly differing from Kuwait 2 and Maythorpe. In the second year, Kuwait 4 presented the highest value which was significantly different only from varieties *ari-e.* GP and Maythorpe (Table 1). Previous studies have demonstrated that environmental adaptation and improvement of yield and yield components is highly associated with heading duration. The early heading varieties could overcome the negative effects of high temperature and shortage of rainfall according to Kobata *et al*., 2018. The varieties *ari-e.* GP and Foma exhibited early heading in both seasons of the study. Late heading extends the vegetative phase which in turn increases the biomass accumulation and is associated with higher digestibility (Turner *et al*., 2005; Laidlaw, 2005). In the second year, a significant positive correlation was noted between number of days to heading and biomass yield.

Hundred kernel weight

The hundred kernel weight differed significantly between the varieties, whereas the year factor did not impose any significant effect. In addition, no interaction was observed between the two factors. The overall mean value over two years showed that the highest hundred kernel weight was obtained by Kuwait 3 without any significant difference from varieties Kuwait 1, Kuwait 2, Kuwait 4, Kuwait 5, Kuwait 6, California Marriot and Gustoe (Table 1). Previous studies have reported variation of hundred kernel weight between crop, within varieties of a crop, from field to field and from year to year (Miller and McLelland, 2007). The hundred kernel weight in the study also reported a significant positive correlation with grain yield in agreement to several previous studies (Hadjichristodoulou, 1990).

Grain yield

The grain yield is an important trait of a cereal which is highly influenced by production environment and it varied significantly between the varieties and the year in the study. Besides, an interaction was observed between the two factors (Fig 1). In the first year, the highest grain yield was shown by the variety Kuwait 6 with any significant difference from Kuwait 4, whereas in the second year, Kuwait 2 exhibited the highest value without any significant difference from varieties Kuwait 1, Kuwait 3, Kuwait 4, *ari-e.* GP and California Marriot. The results obtained showed that varieties Kuwait 4 and Kuwait 3, produced higher grain yield over the two individual years of experimental study (Fig 1). The correlation analysis in the study has revealed that biomass yield and hundred kernel weight revealed a significant positive correlation with grain yield under both first and second years (Table 2 and 3). This correlation could be attributed to the translocation of assimilates stored in stem

Table 1. Plant height, number of tillers/m^2, number of days to heading, hundred kernel weight of barley genotypes.

Variety	Plant height			Number of tillers per/m^2			Number of days to heading			Hundred kernel weight (g)		
	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2	Mean
Kuwait 1	90.40^{def}	100.60^{de}	95.50	15.40	19.16	17.28^{abc}	107.00^{abc}	97.60^{bc}	102.30	4.27	5.53	4.90^{ef}
Kuwait 2	111.20^{g}	114.40^{f}	112.80	17.20	17.80	17.50^{ab}	112.00^{cd}	97.00^{abc}	104.50	5.37	4.45	4.91d^{ef}
Kuwait 3	82.80^{cdef}	103.40^{def}	93.10	17.00	20.40	18.70^{abcd}	103.00^{a}	98.40^{bc}	100.70	5.08	5.34	5.21^{f}
Kuwait 4	97.20^{f}	105.00^{ef}	101.10	26.20	27.20	26.70^{e}	102.00^{a}	98.80^{c}	100.40	4.96	4.52	4.74^{cdef}
Kuwait 5	91.60^{ef}	100.40^{de}	96.00	19.60	26.40	23.00^{de}	115.00^{d}	97.80^{bc}	106.40	5.08	5.02	5.05^{f}
Kuwait 6	71.60^{bc}	88.00^{bc}	79.80	29.80	22.00	25.90^{e}	105.00^{ab}	97.00^{abc}	101.00	4.20	4.67	4.44^{bcdef}
ari-e. GP	84.40^{cdef}	91.40^{cd}	87.90	20.20	19.48	19.84^{cd}	103.00^{a}	95.00^{a}	99.00	3.62	3.96	3.79^{bc}
ari-e. 1	78.40^{bcde}	83.20^{bc}	80.80	13.00	14.50	13.75^{a}	107.00^{abc}	98.60^{c}	102.80	3.54	4.43	3.99^{bcde}
ari-e. 228	76.80^{bcd}	79.75^{abc}	78.28	17.40	21.16	19.28^{abcd}	103.00^{a}	98.00^{bc}	100.50	3.80	3.51	3.65^{ab}
Maythorpe	67.60^{b}	75.60^{ab}	71.60	13.80	14.20	14.00^{ab}	110.00^{bcd}	96.20^{ab}	103.10	2.65	2.96	2.81^{a}
Bonus	52.00^{a}	69.28^{a}	60.64	17.20	18.40	17.80^{abcd}	103.00^{a}	98.60^{c}	100.80	3.59	3.95	3.77^{bc}
Foma	78.80^{bcde}	81.80^{bc}	80.30	11.40	17.20	14.30^{abc}	103.00^{a}	97.00^{abc}	100.00	3.81	4.10	3.96^{bcd}
California Marriot	86.00^{cdef}	127.56^{g}	106.78	18.00	21.40	19.70^{cd}	105.00^{ab}	97.40^{bc}	101.20	4.51	5.81	5.16^{f}
Gustoe	85.20^{cdef}	110.00^{ef}	97.60	17.40	21.60	19.50^{bcd}	107.00^{abc}	97.40^{bc}	102.20	5.06	4.76	4.91^{def}
Mean	82.42	95.02	87.12	18.11	20.06	19.08	106.13	97.28	101.70	4.25	4.50	4.37
CD	0.170	0.174	0.161	0.269	0.187	0.208	0.037	0.011	0.019	0.186	0.174	0.165

CD- Coefficient of dispersion.

and leaf reserves before anthesis to the grain (Daniels *et al*., 1982).

Biomass yield

The barley biomass yield is influenced by several factors which includes genotypes, fertilizers, irrigation, environmental factors (Al-Tawaha *et al*., 2003). The biomass yield differed significantly between the genotypes as well as years, whereas an interaction between the two factors was not found (Fig 2). The overall mean value of the biomass yield of the varieties under study was increased by 32% in the second year. The results showed that variety Kuwait 3 consistently produced higher biomass yield over the two individual years of experimental study (Fig 2). The higher biomass yield noted with some varieties could be due to the increased water and fertilizer use efficiency in these varieties when compared to others. In the study, the biomass yield displayed a highly significant positive correlation with grain yield and number of tillers/m^2 in both first and second seasons (Tables 2 and 3). Our results were in agreement with other previous studies that identified biomass yield as a selection criterion in breeding for grain yield owing to it positive correlation with grain yield (Hadjichristodoulou, 1991).

Table 2: Pearson correlation analysis on yield and yield components (Year 1).

	Biomass yield	Grain yield	Number of days to heading	Hundred kernel weight	Number of tillers/m^2	Plant height
Biomass yield	1	0.931**	-0.385	0.514	0.535*	0.320
Grain yield	0.931**	1	-0.309	0.594*	0.711**	0.433
Number of days to heading	-0.385	-0.309	1	0.221	-0.160	0.370
Hundred kernel weight	0.514	0.594*	0.221	1	0.336	0.723**
Number of tillers/m^2	0.535*	0.711*	-0.160	0.336	1	0.113
Plant height	0.320	0.433	0.370	0.723**	0.113	1

*****Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

Table 3: Pearson correlation analysis on yield and yield components (Year 2).

	Biomass yield	Grain yield	Number of days to heading	Hundred kernel weight	Number of tillers/m^2	Plant height
Biomass yield	1	0.641*	0.625*	0.524	0.658*	0.528
Grain yield	0.641*	1	0.079	0.671**	0.312	0.843**
Number of days to heading	0.625*	0.079	1	0.303	0.284	0.017
Hundred kernel weight	0.524	0.671**	0.303	1	0.422	0.759**
Number of tillers/m^2	0.658*	0.312	0.284	0.422	1	0.445
Plant height	0.528	0.843**	0.017	0.759**	0.445	1

*Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

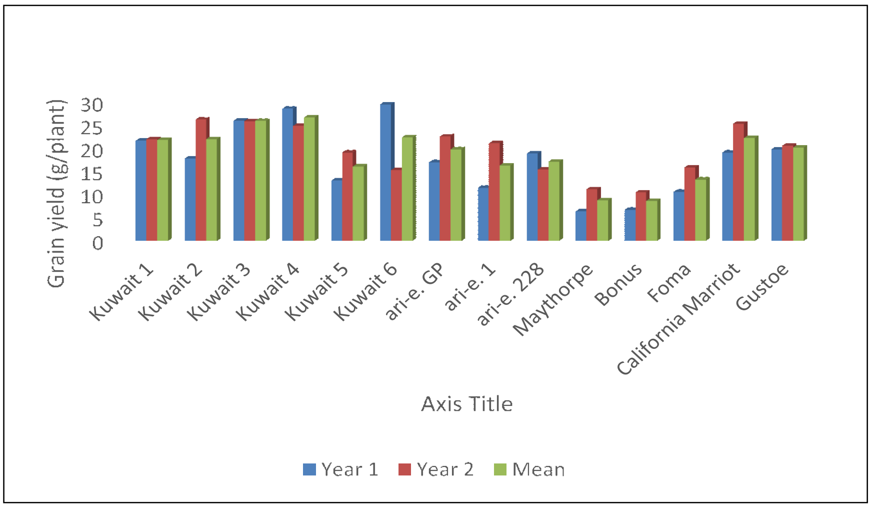

Fig 1: Grain yield over two years in barley genotypes.

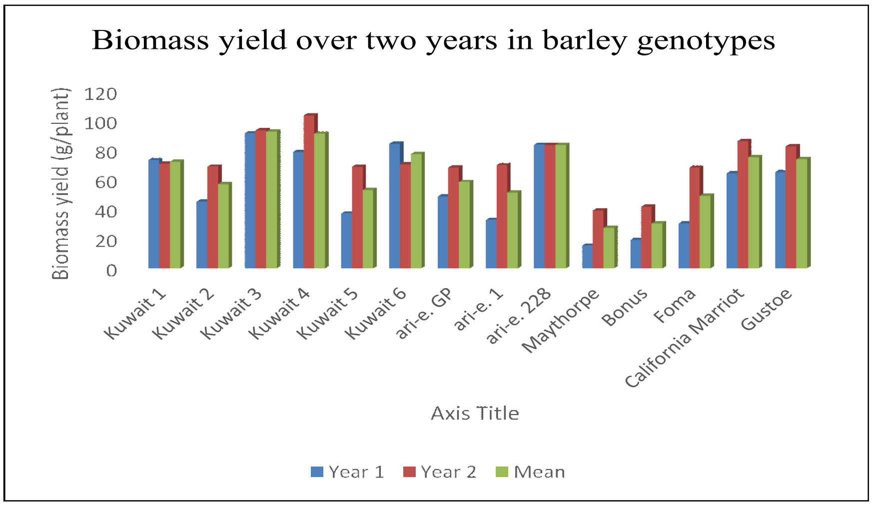

Fig 2: Biomass yield over two years in barley genotypes.

CONCLUSION

The screening of barley varieties under arid condition facilitates identification of cultivars with improved yield, adaptability, resource use efficiency and climate resilience. It contributes greatly to reveal the previously untapped barley genetic diversity and enhance food security in the region. Phenotypic evaluation for yield and several other agronomic traits in barley germplasm presented the diversity among 14 different barley genotypes under Kuwait's environmental conditions. The study conducted over two seasons revealed superior performance of varieties Kuwait 3 and Kuwait 4, in terms of significantly higher biomass yield and grain yield. In addition, the Pearson correlation analysis identified the possibility of utilizing several yield traits as selection indices for improved yield in barley population upon further analysis of phenotypic, genotypic and environmental correlation coefficients. The genotypic characterization data along with the phenotypic data of these locally adapted genotypes could provide information on beneficial alleles to be incorporated in barley breeding purposes for improved varieties in response to climate change and population growth.

Conflict of interest: None.

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