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Effect of planting date on seed yield and quality of barley grown under semi-arid Mediterranean conditions

Nezar H. Samarah* and Taha A. Al-Issa

Department of Crop Production, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan.
**e-mail: nsamarah@just.edu.jo.*

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Abstract

Planting date may affect barley grown in semi-arid regions, where high temperature and drought stress are common during late crop development and maturation. The objective of this research was to study the effect of planting date on seedling emergence, yield and yield components, seed germination and vigor of two barley cultivars. Field emergence, yield and yield components and seed quality were measured for plants grown at two planting dates. Seed quality was estimated by the standard germination test, the germination rate index, the electrical conductivity of seed leachate, and the germination after accelerated aging (AA) test. Field emergence was higher for early planting date than that of late planting date for both cultivars. Number of spikes m^{-2}, 100-grain weight and grain yield were higher in early planting date than those of late planting date. Planting date had no effect on seed quality except for the germination after AA test, due to seed dormancy. In conclusion, the improvement in grain yield of the early-planted barley might be due to the increase in field emergence and consequently the number of plants and spikes per unit area and/or the drought-stress avoidance of the early-planted barley. Planting date had no effect on seed quality except for the expression of seed dormancy in accelerated aging test. Further work is needed to identify more suitable accelerated aging conditions that do not induce seed dormancy to evaluate seed vigor in barley or to develop a treatment to overcome seed dormancy after the test.

Key words: Planting date, drought avoidance, seed germination, seed vigor.

Introduction

Barley is one of the most widely grown cereal crop in Jordan and other West Asian countries. The barley-based farming system exists in wide areas along the dry margins (200-300 mm annual rainfall) of cultivation in Syria, Jordan and Iraq [17]. In the year 1999, the area planted with barley in Jordan was 6.1 thousand hectares, which produced 6.1 thousand tons, while in the year 2003 the planted area increased to reach 66.6 thousand hectares producing about 68 thousand tons of barley [22]. Lack of soil moisture was identified as the major factor limiting crop growth and production under rainfed conditions [20].

Planting date usually has a large effect on seed yield of barley in West Asia and North Africa. Experiments showed that early planting resulted in higher barley grain yield by producing early ground cover to make better use of precipitation [14, 15, 19]. In arid environments, farmers always plant their barley crops before the first rainfall of the season, which allows for seed germination [30]. On the contrary, farmers in semiarid environments normally plant their barley after the first rain [30].

Planting date ensures a proper stand establishment and is one of the most important factors affecting crop yield under dryland conditions in Jordan [16]. Farmers, practicing dryland agriculture in Jordan and other countries of the Near East Region, learned by trial and error that seeding small grains before sufficient rain received is very risky [28]. With light early showers, seeds may germinate in the absence of sufficient moisture and dry out. However, to delay seeding until enough moisture is stored in the soil profile to ensure germination and seedling growth leads to yield reduction [9, 16].

Selection of the planting date is one of the most important management decisions for wheat production [13]. Early planting increases the total length of time that the wheat is in the field and exposed to the environment. It is associated with increased incidences of several diseases [5]. Thus, early planting increases the probability of unfavorable consequences relative to grain yield. Planting date may also influence the quality of the produced seeds.

Dryland soybean producers who face potential yield losses due to drought stress can benefit from information on yield-enhancing production practices such as tillage system, planting date and cultivar selection [26]. Planting date is another production component that can be manipulated to counter the adverse effects of drought stress. This is accomplished through early plantings so that a soil moisture deficit is avoided during the critical stages of plant growth [6, 12, 21].

A series of seeding date experiments at locations differing in annual rainfall were conducted to determine the proper seeding dates for wheat production in Jordan [23-25]. Results of these experiments, over several growing seasons and across locations, indicated that seeding before the onset of rain resulted in higher yields.

Al-Issa [1] found that the optimum time span for planting wheat in rainfed areas of Northern Jordan is the week of November 14 to November 19. According to Al-Issa [1], planting wheat in the rainfed areas of Northern Jordan at any time before Nov. 14 or after Nov. 19 lead to timeliness penalties. For example, he found that planting wheat one month earlier than the optimum time lead to the loss of

292 kg ha^{-1}, while planting one month later than the optimum time lead to the loss of 359 kg ha^{-1}.

During the last decade, Jordan has been experiencing severe drought stress. The time of the onset of rainfall delayed and the rainfall season ended earlier, resulting in late severe-drought stress condition. Since barley is mainly grown in the marginal semi-arid region of Jordan (250-300 mm annual rainfall), the optimum planting date for barley needs to be re-evaluated under the changing environmental conditions in Jordan. The relationship of planting with field emergence and establishment of barley under such condition needs to be studied. In addition, no information is available in the literature about the effect of planting date on the germination and vigor of the produced seeds in semi-arid conditions in Jordan. The objective of this research was to study the effect of planting date on seedling emergence, yield and yield components, seed germination and vigor of two barley cultivars.

Materials and Methods

Field trial was carried out at a field site of Jordan University of Science and Technology (JUST) campus in Northern Jordan, Irbid (32°34'N latitude, 36°01'E longitude and 520 m altitude), during the growing season of 2002-2003. The JUST location is characterized by semi-arid conditions of mild rainy winters and hot dry summers. The long-term average annual precipitation was 218 mm for the period 1990-2000. The experimental site had a fine-loamy, mixed, thermic, calcic paleargid soil.

The experiment was devised as a split-plot in a randomized complete block design with four replications. Prior to planting, field was fertilized with diammonium phosphate (DAP) at the rate of 10 kg ha^{-1}. Two barley cultivars (ACSAD176 and Rum) were assigned to main plots and two planting dates (November 28, 2002 and January 9, 2003) were assigned to split- plots. Each plot was 4.5 m long and 80 cm wide. There were 4 rows in each plot 20 cm apart with 50 seeds planted in each row (total of 200 seeds plot^{-1}).

Maximum temperatures were below 16°C in December, January, February and March (Table 1). Minimum temperatures were below 6°C in all months except for May. The mean maximum and minimum relative humidity were high from December to March, then decreased during April and May. Annual rainfall received during the growing season was 366 mm, which was above the long-term average for the region.

Seedling emergence percentage was measured at 30 days after planting. Number of spikes m^{-2}, 100-grain weight and grain yield (kg ha^{-1}) were measured at the harvest maturity for both cultivars and planting dates.

Seed quality analysis: Standard germination and seed vigor, as estimated by the germination rate index, electrical conductivity of seed leachate and the germination after accelerated aging test were evaluated for the harvested seeds from plants grown at two planting dates. Standard germination test was conducted according to the AOSA [2]. Four replicates of 30 seeds were planted between folded germination papers in 17 cm x 11cm x 7 cm plastic boxes covered with sealed lids and prechilled at 5°C during the first five days of germination to overcome seed dormancy. Number of normal and abnormal seedlings and dormant and dead seeds were recorded and expressed as a percentage.

The electrical conductivity (EC) test was conducted as described in the Seed Vigor Testing Handbook [3]. Four samples of 25 seeds were weighed, placed in a 125-ml Erlenmeyer flask containing 75-ml of deionized water and held at 25°C for 24 h. Electrical conductivity of seed leachates was measured with a conductivity meter and reported as µS cm^{-1} g^{-1}.

The accelerated aging (AA) test was conducted according to the AOSA [3] procedures. Seeds were placed on a wire-screen tray suspended over 50 ml of distilled water in 11 cm x 10 cm x 3.5 cm plastic container. Seeds in plastic containers were incubated under 100% RH and 45°C for 48 h. Following aging, four replicates of 30 seeds were immediately planted to prevent seed desiccation prior to testing. Seeds were then incubated at 20°C for 14 days as described in the AOSA [2]. Percent germination was determined based on the number of normal seedlings.

Data for all variables were subjected to analysis of variance (ANOVA). Mean values were separated by Fisher's protected least significant difference test (LSD) at $p \leq 0.05$.

Results and Discussion

Field emergence: Field emergence was higher for early planting date than that of late planting date for both cultivars (Table 2). The reduction in seedling emergence in late-planted barley might be due to the lower amount of rainfall. The average rainfall during January (the late planting date) was less than that during November-December (the early planting date) (Table 1). The combination of low rainfall with poor soil characteristics (high silt content, strong surface crust, low organic matter and weak aggregate stability) might be responsible for poor establishment in barley [18].

There was no significant difference between cultivars in mean field emergence averaged over planting dates. However, Rum cultivar showed higher field emergence than ACSAD176 for the early planting date, while both cultivars showed similar field emergence in the late planting date.

Yield and yield components: Yield and yield components were improved by early planting date as compared with late planting date for both cultivars (Table 3). Number of spikes per m^2, 100-grain weight and grain yield were higher in early planting date than those of late planting date. The improvement in final grain yield of the early-planted barley might be due to the increase in field emergence and consequently the number of plants and spikes per unit area and/or the drought-stress avoidance of the early-planted barley. Mean yields of several barley genotypes were very low in Jordanian villages which suffered from late drought stress [18]. The reduction in the grain yield of barley was

Table 1. Maximum and minimum temperature, maximum and minimum relative humidity, and rainfall during the growing season 2002- 2003.

Month	Temperature, °C		Relative humidity, %		Rainfall, mm
	Maximum	Minimum	Maximum	Minimum	
December	14.8	5.7	82.5	61.3	111
January	15.9	5.9	78.2	58.6	32
February	12.5	4.7	80.3	64.2	141
March	14.8	5.3	84.3	64.6	71
April	22.9	4.6	73.3	49.3	10
May	31.9	13.9	56.9	33.9	1
Total					366

positively correlated with the intensity of the drought stress, which negatively affected harvest index, plant height and kernel weight [18].

These results are in consistence with the findings of Chen *et al.* [7], who found that winter wheat had the greatest yield at early planting dates and that yield decreased with delayed planting dates. Decrease of winter wheat yield with delayed planting dates was also reported in Canada and the Upper Midwest of the USA [8, 10]. In a study about the effect of planting date on seed yield of safflower cultivars grown in Turkey, Samanci and Ozkaynak [27] found that seed yield decreased with delay in planting date in all safflower genotypes.

The variation between planting dates affected grain yield and yield components of barley more than the variation between genotypes. For the early planting date, Rum cultivar gave a little more number of spikes m^{-2} than ACSAD176, which gave little more number of spikes in the late planting date. For the 100-grain weight, 'ACSAD176' gave more 100-grain weight than 'Rum' cultivar for both planting dates. ACSAD176 cultivar also gave higher grain yield (kg ha^{-1}) for both planting dates than Rum cultivar. These results were consistent with the results of Benmahammed *et al.* [4], who showed that the seasonal variation affected the expression of the grain yield of barley grown in the semi-arid environmental conditions much more than the genotype variation.

Seed germination and vigor: Effect of planting date on seed germination and vigor was shown in Tables 4 and 5, respectively. The results showed that the germination of the harvested seeds from plants in early planting date was not significantly different from those of the late planting date for both cultivars. Seeds from both planting dates and cultivars had standard germination higher than 88%. Abnormal seedlings, dormant and dead seeds represented a low percentage and were not significantly different between different planting dates or cultivars. For the germination rate index (GRI) of the harvested seeds, there was no significant difference between the two planting dates, but cultivar ACSAD176 had higher mean GRI than Rum. Electrical conductivity of seed leachate was not significantly different between either planting dates or cultivars. Subjecting barley seeds to accelerated aging test to evaluate seed vigor induced a secondary dormancy, which was expressed differently between planting dates and cultivars. Seeds from early planting date had higher percentage of dormant seeds in AA-test than seeds from late planting date. The cultivar Rum had higher percentage of dormant seeds in AA-test than ACSAD176. The result of germination after AA-test was low, due to the occurrence of seed dormancy during the test.

Many researchers have reported that seed viability and vigor of other species were reduced when seeds were developed and matured under unfavorable environmental conditions such as high temperature, high precipitation, and high relative humidity in the subtropical hot conditions [11, 29]. However, little information is available about seed quality in the semi-arid hot conditions. In the present study, barley grown at different planting dates and matured under semiarid hot conditions did not vary in seed quality except for the germination after AA test, where the seeds varied in seed dormancy during the test.

Conclusions

The improvement in grain yield of the early-planted barley might be due to the increase in field emergence and consequently the number of plants and spikes per unit area and/or the drought-stress avoidance of the early-planted barley. Planting date had no effect on seed quality except for the expression of seed dormancy in accelerated aging test. Further work is needed to identify more suitable accelerated aging conditions that do not induce seed dormancy to evaluate seed vigor in barley or to develop a treatment to overcome seed dormancy after the test.

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Table 2. Field seedling emergence of two barley cultivars grown at two planting dates.

Planting date	Cultivar		Mean
	Rum	ACSAD176	
	%		
Nov 28, 2002	100	89	94 a
Jan 9, 2003	82	83	82 b
Mean	91 a	86 a	

Means not sharing same letters are different at the 5% LSD level.

Table 3. Yield and yield components of two barley cultivars grown at two planting dates.

Planting date	Cultivar		Mean
	Rum	ACSAD176	
	Spike No. m^{-2}		
Nov 28, 2002	60	52	56 a
Jan 9, 2003	14	18	16 b
Mean	37 a	35 a	
	100-grain Weight (g)		
Nov 28, 2002	3.36	3.48	3.42 a
Jan 9, 2003	3.07	3.15	3.11 b
Mean	3.22 a	3.32 a	
	Grain yield (kg ha^{-1})		
Nov 28, 2002	974	1070	1022 a
Jan 9, 2003	186	325	256 b
Mean	580 a	698 a	

Means not sharing same letters are differentt at the 5% LSD level.

Table 4. Percentage of normal, abnormal seedlings, dormant and dead seeds in standard germination test for two barley cultivars grown at two planting dates.

Planting date	Cultivar	Normal	Abnormal	Dormant	Dead
		%			
Nov 28, 2002	Rum	88	1	4	7
	ACSAD176	94	0	4	2
Jan 9, 2003	Rum	90	0	5	5
	ACSAD176	92	0	3	5
Mean					
Nov 28, 2002		91 a	1 a	4 a	5 a
Jan 9, 2003		91 a	0 a	4 a	5 a
Rum		89 a	1 a	5 a	6 a
ACSAD176		93 a	0 a	3 a	3 a

Means not sharing same letters are different at the 5% LSD level.

Table 5. Germination rate index, electrical conductivity of seed leachate, and germination after accelerated aging test for two barley cultivars grown at two planting dates.

Planting date	Cultivar	GRI	EC	AA Test			
				Normal	Abn	Dorm	Dead
			µS cm^{-1} g^{-1}	%			
Nov 28, 2002	Rum	5.03	185	13	0	78	9
	ACSAD176	5.90	169	23	0	68	9
Jan 9, 2003	Rum	5.68	197	28	0	66	6
	ACSAD176	6.15	213	33	0	56	11
Mean							
Nov 28, 2002		5.46 a	177 a	18 a	0 a	73 a	9 a
Jan 9, 2003		5.91 a	205 a	30 a	0 a	61 b	9 a
Rum		5.35 b	191 a	20 a	0 a	72 a	8 a
ACSAD176		6.03 a	191 a	28 a	0 a	62 b	10 a

Means not sharing same letters are different at the 5% LSD level.