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Effect of planting dates on the yield of three cultivars of bread wheat (*Triticum aestivum* L.)

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Abstract

In order to evaluate the performance of 3 promising cultivars under the identified optimal planting dates, a field experiment was carried out in the winter season of 2020–2021 in the fields of the Agricultural Research Department at Abu Ghraib. The purpose of the experiment was to examine the effects of 6 planting dates (25/10/20, 10/11/20, 25/11/20, 11/12/20, 25/12/20, 10/1/21) on the yield and its components of 3 approved wheat cultivars (Bohooth 10, Bohooth 22 and Bohooth 158). A Split Plot Design with 3 replications was used. Planting date D3 (25/11/20) outperformed the other dates in most of the studied traits, with the highest weight of 1000 grains (39.14 g) and the highest grain yield (6.42 t ha^{-1}). While, cultivar Bohooth 22 outperformed the other cultivars in most of the studied traits, with the highest mean plant height (89.61 cm), number of spikes per m^2 (281.9), weight of 1000 grains (33.73 g) and grain yield (5.02 t ha^{-1}). There were no significant differences between cultivars in the number of grains per spike trait. Cultivar Bohooth 22 at planting date 25/11/20 outperformed the other combinations between cultivars and planting dates, with a grain yield of 8.03 t ha^{-1}.

Keywords

Planting date; spikelets number; grain weight; number of grains per spike; total grain yield

Introduction

Wheat (*T. aestivum* L.) is considered a strategically important crop in countries worldwide including Iraq due to being a staple food for most populations. It serves as a primary source of energy for humans due to its high content of essential nutrients necessary to provide the body with calories (1). Wheat production suffers from insufficient local output for human consumption, making it necessary to search for high-yielding cultivars by understanding the yield components of each cultivar and the possibility of obtaining high-yielding cultivars (2-5). Cultivars vary genetically and interact with environmental conditions such as light periods, temperatures and moisture, which significantly affect yield and its components (6, 7). Therefore, it has become essential for crop producers to pay attention to planting dates, ensuring suitable environmental conditions and sufficient grain filling duration (8, 9).

Many cultivars of bread wheat have been registered and adopted in recent years, characterized by high productivity and suitability for Iraq's

environmental conditions, including the cultivars studied in this research. Cultivars vary in their genetic makeup and consequently interact with environmental factors, resulting in variation in yield and its components. Most studies have indicated variation among cultivars in response to planting dates. A recent study showed that wheat cultivars differed in yield and its components (3). The cultivar "Al-Fath" outperformed in most studied traits such as grain yield per ha, weight of 1000 grains and average grain number per spike compared to the cultivar "Abu Ghraib," which gave lower values for these traits. As shown in a study, using 7 cultivars of bread wheat and 4 planting dates, the cultivar "IPA" outperformed in most of the studied traits regarding yield and its components (10). Concerning planting dates, the 15th of November was found to be the optimal date. Similarly, it was found in a study on 12 cultivars of wheat (Abu Ghraib 3, Buhooth, Al-Rashid, Al-Fath, Al-Latifia, Al-Furat, Bohooth 22, Tamuz2, IPA 95, IPA 99, Al-Baraka 10 and Bohooth 158) that the cultivars were varied in yield and its components (11).

The appropriate planting date is considered essential to provide suitable environmental conditions to meet the requirements of all plant growth stages until harvest preparation, considering that there is variation in the response of some cultivars to these conditions (8, 12). Some Bohoothers at the Nasiriyah station also noted that the planting date of 21st of November is the best for its superiority in all yield components (13). Additionally, found in South Asia that suitable planting dates are important for achieving higher yields and as a result of climate changes in recent years (14), because of the problem of climate change in recent years this study aimed to determine the genetic suitability of some adopted cultivars in Iraq and their compatibility with Iraq's environmental conditions, selecting the best among them and knew their impact on yield and its components as well as selecting the optimal planting date.

Materials and Methods

The experiment was conducted during the winter season of 2020-2021 at the Agricultural Research Station in Abu Ghraib – Iraq, about 10 km west of Baghdad, within 44°E longitude and 33°N latitude, in a soil with loamy clay texture, affiliated with the Ministry of Agriculture. Three approved cultivars of bread wheat were used in the experiment, namely (Bohooth 10, Bohooth 22 and Bohooth 158), denoted respectively as (V1, V2, V3) and 6 planting dates for wheat were (25/10/20, 10/11/20, 25/11/20, 10/12/20, 25/12/20, 10/1/21), denoted as (D1, D2, D3, D4, D5, D6) respectively. The Split Plot Design was employed with 3 replications. The experimental unit area was 6 m^2 with dimensions of (2×3) meters and a distance of 20 cm between rows, with 10 rows per experimental unit, each row being 3 meters long, and a seeding rate of 120 kg ha^{-1} (15). Additionally, 100 kg of phosphate fertilizer was added per ha in a single application at planting and 120 kg of urea was applied in 2 splits, the first after weed control and the second at tillering (16). Crop management operations including irrigation, addition of fertilizers, weed control and harvesting were carried out according to the recommendations. The crop was harvested on May 20, 2021. The following traits were studied after physiological maturity of the crop: 1- Plant height (cm). 2- Number of spikes perm^2. 3- Grain number per spike. 4- Weight of 1000 grains (g). 5- Number of spikelets per spike. 6- Spike length (cm). 7- Grain yield (t ha^{-1}). 8- Biological yield (t ha^{-1}).

The data were statistically analyzed using the Genstat software according to the Split Plot Design and mean comparison was conducted using the Least Significant Difference (LSD) test at a significance level of 0.05.

Results and Discussion

Plant height (cm)

The results in Table 1 and Fig. 1 indicate significant differences between planting dates in their effect on plant height (cm). Planting date D1 gave the highest plant height at 91.22 cm, surpassing planting date D6, with the lowest value of 71.67 cm, additionally; planting dates (D2, D3) outperformed planting date D6, with no significant differences between them. These results are consistent with another study (17), which noted genotypic differences in plant height based on planting dates.

Table 1. Effect of planting dates and cultivars on plant height (cm).

Planting dates/day	Wheat cultivars			Mean
	V1	V2	V3	
D1	89.00	91.33	93.33	91.22
D2	87.33	91.67	93.0	90.67
D3	90.33	96.00	87.0	91.11
D4	83.33	94.67	87.33	88.44
D5	83.33	94.67	87.33	88.44
D6	67.00	75.00	73.00	71.67
LSD		5.529		LSD
Means	83.67	89.61	86.94	3.192
LSD 5 %		2.257		

Furthermore, the results indicate significant differences between cultivars V3, V2 and cultivar V1 in plant height (cm). Cultivar V2 recorded the highest at 89.61 cm, surpassing cultivar V1, which gave the lowest mean at 83.67 cm, while there were no significant differences between cultivars V3 and V2. This may be attributed to the genetic variation and its interaction with the environment (18). Moreover, the interaction between cultivar Bohooth 22 and planting date (D3) denoted as (V2 D3) resulted in the highest mean for the trait at 96.00 cm, while the combination (V1 D6) gave the lowest mean for the trait at 67 cm. This could be attributed to the interaction of Bohooth 22 with environmental conditions, which positively influenced the trait. These results are consistent with another study, which found significant interaction of planting dates and cultivars (7).

Fig. 1. Plant height.

Number of spikes (per m2)Top of Form

The results show that planting dates had a significant effect on this trait (Table 2), where the number of spikes per m^2 reached its highest mean at planting date D2, with 319.8 spikes perm^2, while planting date D6 gave the lowest mean at 215.3 spikes per m^2. There were no significant differences between planting dates D2 and D3. Possibly due to the decreased temperature at planting date D6 (10/1/21), a decrease in the number of spikes per $m^2$and tillers for all wheat cultivars were observed

Table 2. Effect of planting dates on the number of spikes (per m^2) in bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	236.3	312.0	300.0	282.8
D2	286.0	299.7	373.7	319.8
D3	289.3	354.0	299.0	314.1
D4	233.7	228.0	216.7	226.1
D5	223.0	248.7	226.3	232.7
D6	180.7	249.0	216.3	215.3
LSD		78.93		LSD
Means	241.5	281.9	272.0	45.57
LSD 5 %		32.22		

Cultivar variation in spike number per m^2 was statistically significant, with V2 achieving the highest mean of 281.9 spikes per m^2 and V1 the lowest at 241.5. This disparity suggests potential differences in the cultivars' efficiency of transporting photosynthates and other resources from source organs (leaves) to developing grains (sink), likely influenced by underlying genetic factors. This result is consistent with another study, which observed variation between cultivars in spike number per m^2(18).

The optimal planting date for maximizing spike density varied depending on the cultivar. While the V3 D2 combination (cultivar V3 planted on date D2) achieved the highest average value, V1 D6 combination (cultivar V1 planted on date D6) resulted in significantly lowest value. These findings emphasize the importance of considering both cultivar selection and planting timing for optimizing grain production.

Number of grains per spike

Choosing the optimal planting date is crucial for maximizing grain number per spike. Our results showed significant effects of planting date on grain number per spike (Table 3). Planting date D3 yielded the highest mean (66.3 grains/spike), while D6 produced the lowest value (49.0 grains/spike). This variation can be attributed to the longer vegetative growth period associated with D3, allowing for greater assimilate (photosynthate) accumulation and subsequent transfer from source organs (leaves) to sink organs (grains) (17).

Table 3. Effect of planting dates on the number of grains per spike in bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	59.7	47.1	57.1	54.6
D2	57.7	61.8	60.3	59.9
D3	64.7	72.6	61.6	66.3
D4	66.4	64.8	64.6	65.3
D5	54.6	58.9	55.7	56.4
D6	48.7	43.6	45.7	49.0
LSD		15.01		LSD
Means	58.6	58.1	59.0	8.66
LSD 5 %		N.S		

Although no statistically significant differences in grain number per spike were observed among cultivars alone, the analysis revealed a significant interaction effect between planting dates and cultivars. The V2 D3 combination (cultivar V2 planted on date D3) exhibited the highest mean value (72.6 grains per spike), whereas the V2 D6

combination (cultivar V2 on date D6) produced the lowest mean (43.6 grains per spike). These findings emphasize the complexity of determining optimal planting dates, as cultivar specific responses to different timing may be crucial for maximizing grain production.

1000 grain weight (g)

Table 4 reveals statistically significant variations in 1000 grain weight (g) across planting dates. Planting date D3 exhibited the highest mean value (39.14 g), significantly surpassing all other dates, with D6 recording the lowest mean (23.49 g). Interestingly, no significant differences were observed between D1 and D2 (37.40 and 35.44 g respectively) and between D4 and D5 (30.23 and 30.33 g respectively). This phenomenon potentially aligns with the extended grain filling period facilitated by earlier plantings and coincides with previous reports associating favorable environmental conditions during this stage with enhanced grain development in wheat cultivars (19, 20).

Table 4. Effect of planting dates on the 1000 grain weight (g) of bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	38.07	39.07	35.07	37.40
D2	33.07	36.03	37.23	35.44
D3	39.53	39.93	37.97	39.14
D4	29.67	31.57	29.47	30.23
D5	33.07	31.00	26.93	30.33
D6	23.90	24.80	21.77	23.49
LSD		4.487		LSD
Means	32.88	33.73	31.41	2.591
LSD 5 %		1.832		

Statistical analysis revealed significant cultivar effects on 1000 grain weight (g). Cultivar V2 (Bohooth 22) exhibited the highest mean (33.73 g), statistically outperforming all other cultivars. Conversely, cultivar V3 (Bohooth 158) recorded the lowest mean value (31.41 g). Moreover, no significant differences were observed between V1 and V2. This trait serves as an indicator of a cultivar's capacity to effectively translocate photosynthetic assimilates towards the developing grains (sink), ultimately leading to increased seed weight. These findings resonate with the observations of another study (17), which documented considerable cultivar specific variations in this trait, further underscoring the genetic basis of grain weight determination.

Statistical analysis revealed a significant interaction effect between planting dates and cultivars on 1000 grain weight (g). The V2 D3 combination (cultivar V2 planted on date D3) exhibited the highest mean value (39.93 g), significantly exceeding all other combinations. In contrast, the V3 D6 combination (cultivar V3 planted on date D6) recorded the lowest mean value (21.77 g). This complex pattern can be attributed to the interplay between photoperiod duration and cultivar specific photosynthetic resource utilization efficiency. The extended photoperiod associated with the earlier planting date (V2 D3) likely facilitated longer grain filling and enhanced resource allocation in cultivar V2, leading to the superior performance. Conversely, the shorter photoperiod during grain filling for cultivar V3 under the later planting date (V3 D6) might have limited its photosynthetic activity and subsequent resource transfer to developing grains, resulting in the lowest mean value. These findings resonate with few other studies of (8, 21), emphasizing the importance of considering both environmental factors and cultivar characteristics for optimizing grain weight.

Number of spikelets per spike

Statistical analysis revealed a significant effect of planting date on the number of spikelets per spike. Planting date D3 (November 25th) resulted in the highest mean value (23.11 spikelets per spike), significantly exceeding all other dates. Conversely, planting date D1 (October 25th) led to the lowest mean value (20.89 spikelets per spike). In addition, no significant differences were observed among planting dates D2, D4, D5 and D6. Early maturity in cultivars planted on D1 might have shortened the spikelet initiation period, leading to reduced spikelet numbers, as supported by findings from (22).(Table. 5.)

Table 5. Effect of planting dates on the number of spikelets per spike in bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	21.33	20.67	20.67	20.89
D2	21.33	22.00	22.67	22.00
D3	22.00	24.00	23.33	23.11
D4	22.00	23.33	22.67	22.67
D5	23.33	23.33	21.33	22.67
D6	22.67	21.33	22.67	22.22
LSD		1.996		LSD
Means	22.11	22.24	22.422	1.152
LSD 5 %		N.S		

Although no overall differences were observed among cultivars in terms of average spikelet number per spike, with regards to the interaction between planting dates and cultivars, the V2 D3 treatment demonstrated a statistically significant superiority in this trait rate, achieving a value of 24.00 compared to 21.33 for V2 D6. This differential outcome may be attributable to the inherent genetic potential of the Bohooth 20 cultivar for continued growth under favorable environmental conditions, as exemplified by D3. However, Bohooth 20 cultivar displayed a negative response to the delayed planting date (D6, 10/1/21). This finding corroborates with the existing Bohooth that underscores the primacy of optimal planting dates for optimizing growth characteristics and yield (7).

Spike length (cm)

Statistical analysis of Table 6 reveals significant differences in the trait of spike length (cm) across planting dates

for bread wheat cultivars. Planting date D3 achieved the highest mean spike length (13.60 cm), exhibiting a statistically significant advantage over the date D6 which yielded the lowest mean (12.61 cm). The planting dates (D1, D2, D3, D4 and D5) did not differ significantly in spike length trait, yielding 13.19, 13.26, 13.60, 13.30 and 13.53 cm respectively.

Table 6. Effect of planting dates on spike length (cm) of bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	12.43	13.50	13.63	13.19
D2	12.43	13.43	13.90	13.26
D3	12.73	14.87	13.20	13.60
D4	13.43	13.70	12.77	13.30
D5	12.63	14.33	13.63	13.53
D6	11.77	13.37	12.70	12.61
LSD		0.854		LSD
Means	12.57	13.87	13.31	0.493
LSD 5 %		0.349		

Statistical analysis of Table 6 highlights significant differences in the trait of spike length between cultivars. Bohooth 22 demonstrably attained the highest mean spike length (13.87 cm), showcasing a statistically significant superiority compared to both other cultivars, particularly Bohooth 10 which yielded the lowest mean (12.57 cm).

Statistical analysis of Table 6 further revealed the presence of significant interactions between planting dates and cultivars in spike length. The V2 D3 treatment obviously attained the highest mean value (14.87 cm), while the V1 D6 combination yielded the lowest mean value (11.77 cm).

Total grain yield (t ha-1)

Statistical analysis of Table 7 data revealed that planting date D3 (25/11/20) achieved the highest mean grain yield (6.42 t ha^{-1}), demonstrating its superiority among all evaluated dates. Conversely, D6 exhibited the lowest mean yield (2.54 t ha^{-1}). Notably, no statistically significant differences were identified between the mean yields of D3 and D4.

Table 7. Effect of planting dates on total grain yield (t ha^{-1}) of bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	2.47	3.30	3.70	3.16
D2	4.30	5.13	4.03	4.49
D3	5.44	8.03	5.80	6.42
D4	5.20	6.83	5.67	5.90
D5	3.57	4.47	3.97	4.00
D6	2.93	2.37	2.33	2.54
LSD		1.220		LSD
Means	3.98	5.02	4.25	0.704
LSD 5 %		0.498		

Statistical analysis of grain yield data revealed significant differences between cultivars. V2 achieved the highest mean yield (5.02 t ha^{-1}), demonstrating its superiority. Conversely, V1 exhibited the lowest mean yield (3.98 t ha^{-1}). Whereas, no statistically significant differences were identified between the mean yields of V1 and V3 (cultivars Bohooth 10 and Bohooth 158).

Furthermore, the interaction between planting dates and cultivars significantly influenced grain yield. The combination of V2 D3 achieved the highest average value) 8.03t ha^{-1}(,while V3 D6 yielded the least value 2.33 t ha^{-1}. This highlights how genetically superior cultivars, when paired with their optimal planting dates and environmental conditions, excel in terms of key yield components like grains per spike, 1000 grain weight and spike density. This aligns with findings from other studies (10, 17, 23) which emphasized the interplay of genetic makeup and environmental factors in determining varietal yield performance.

Biological yield (t ha-1)

Statistical analysis of biological yield data underscores its significant dependence on the duration between planting and harvest, during which wheat encounters varying photoperiods and temperatures influenced by the selected planting date (15, 22). Table 8 demonstrates the clear advantage of D1, achieving the highest mean biological yield (17.99 t ha^{-1}) with no statistically significant difference from D2 and D3. Conversely, D6 exhibits the lowest mean yield (8.21 t ha^{-1}). There were no significant differences between cultivars in biological yield (Fig. 2).

Table 8. Effect of planting dates on Biological yield (t ha^{-1}) of bread wheat cultivars.

Planting dates/day	Cultivars			Mean
	V1	V2	V3	
D1	15.37	21.80	16.80	17.99
D2	13.23	16.50	14.40	14.71
D3	15.37	13.60	15.20	14.72
D4	18.20	10.50	8.20	12.30
D5	9.07	8.67	8.03	8.59
D6	7.47	7.80	9.37	8.21
LSD		3.122		LSD
Means	13.12	13.14	12.00	1.802
LSD 5 %		N. S		

The interaction between planting dates and cultivars had a significant effect on biological yield, as the combination V2 D1 yielded the highest average (21.80 t ha^{-1}), while the combination V1 D6 yielded the lowest average value of 7.47 t ha^{-1}. The increase in biological yield can be attributed to the duration of vegetative growth traits and their suitability for environmental conditions, which stresses cultivars in the process of converting the products of photosynthesis from the source to the sink. This result is consistent with a study, which emphasized an increase in crop biological yield with an increase in the crop's growth duration (21).

Fig. 2. Biological yield.

Conclusion

Planting date and cultivar selection both significantly influenced the yield and yield components of three bread wheat cultivars in the 2020-2021 winter season. November 25th (D3) proved the optimal planting date for most traits, while cultivar Bohooth 22 consistently outperformed the others. Notably, the combination of Bohooth 22 and D3 yielded the highest overall grain yield (8.03 tons ha-1). Therefore, for similar environmental conditions, planting these cultivars on November 25th is recommended for maximized yield potential. Additionally, Bohooth 22 appears particularly promising due to its consistent high performance across different planting dates.

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Authors' contributions

All the authors were involved in carrying out the experiments by participating in all the works including agriculture, taking measurements and statistical analysis.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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