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Effect of sowing dates on the growth and yield of different wheat cultivars and their relationship with accumulated heat units

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ABSTRACT

An experiment was conducted in 2015/2016 at Research Station, State Board for Seeds Testing and Certification, Baghdad, Iraq to investigate the effect of four sowing dates (20th October, 10th November, 30th November and 20th December) according to the thermal time on developmental traits, yield and its components of three bread wheat cultivars (Bohooth-22, Bohooth-158 and Rasheed). Data on different growth and yield contributing traits were recorded and statistically analyzed. Cultivars responded differently to the four sowing dates. Highest grain yield was achieved on 30th November (2.629 t ha^{-1}). Bohooth-22 gave the highest grain yield (2.262 t ha^{-1}). Effect of sowing dates and cultivars was significant on phenology (days after sowing), growing degree days (GDD) and phenothermal index (PTI). Highest values of phenology (DAS) (130.09 days) and growing degree days (GDD) (1608.7 ^{0}C) was obtained at anthesis stage with sowing date 10th November and 20th October, respectively. The highest value for phenothermal index was obtained during the period from sowing to tillering with sowing date 20th October (20.1). Rasheed gave highest values regarding DAS and GDD at all growing stages. Highest values of PTI were recorded for Bohooth-158 and Rasheed during periods from sowing to tillering and booting to anthesis stage, respectively. Part of PhD dissertation for the first author.

KEY WORDS

wheat, sowing dates, growing degree days, Phenothermal index, grain yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important cereal grain and staple food for millions of people worldwide and third most widely grown crop with unique protein characteristics [1]. The nutritional value of wheat is extremely important and it supplies more calories, protein, dietary fiber, B-group vitamins and minerals to the diet of world's population than any other cereal crop [2]. In Iraq, there is a gap between wheat consumption and production, and this gap is continuously increasing due to steady increases in the country population with limited cultivated area. Thus, using suitable sowing dates, promising cultivars and seeds treatments are very important to increase the productivity of wheat. The final yield of wheat is an outcome of the interaction of genetic, environmental conditions (temperature and light) and agronomic factors. Sowing date is one of the most important agronomic factors involved in producing high yielding small grain cereal crops, which affects the timing and duration of vegetative and reproductive stages [3].

An optimum sowing date positively impacts the grain yield and baking quality of wheat, causing better adjustment to the physiology, phenology and environmental conditions [4]. In addition, the optimum sowing date also affects the water, temperature and solar radiation available for the crop [5]. It is possible to increase wheat grain yield by 10% to 80% with management of the sowing dates, cultivars and environmental conditions [6].

The favorable temperature for wheat crop is usually 15-25 ^{0}C, however, its growth continues at lower temperature down to 3 to 4 ^{0}C or at higher temperature up to 30-32 ^{0}C [7].

High temperatures during anthesis and wheat grains maturity, initiated a significant decrease in the carbohydrate accumulation in developing grains as compared to plants sown under optimum conditions [8]. Pre anthesis and post anthesis high temperatures may have huge effects on wheat growth, and this stress reduces the photosynthetic efficiency of crop [9].

You et al. [10] observed significant reduction in yield due to rise in temperature and it was concluded that with 1.8°C rise in temperature caused 3-10% reduction in wheat yields.

Sowing wheat on optimum time according to environmental conditions is the best way to increase growth, yield and quality traits of grains. Jalota et al. [11] concluded that wheat sown in early November gave the highest grain yield. Seleiman et al. [12] showed that sowing wheat grains on 15th November gave the highest values for all growth, yield and its components as well as grain quality characters in comparison with other sowing dates. Low temperature in the growing season may reduce germination and retard vegetative growth by inducing metabolic unbalances and can delay or prevent reproductive devolvement [13]. Abdel-Nour, Nadya and Hayam [14] found that all studied characters (days to heading and maturity, plant height, number of spikes m-², number of kernels spike^{-1}, 1000-kernel weight, biological yield and grain yield) were significantly highest in the optimum date compared to the late and early dates of planting. Temperatures more than optimum accelerates developmental processes in wheat and further reduction in yield may occur due to increasing photorespiration in C3 species [15]. The genotypic response of wheat to planting dates varies for yield contributing characters due to different genetic potential.

So, the objective of this study is to determine the effect of four sowing dates on the growth and yield of three bread wheat cultivars and their relationship with accumulated heat units.

MATERIALS AND METHODS

The study was conducted at Research Station, State Board for Seeds Testing and Certification, Baghdad, Iraq, located at latitude of 33º.32´N and longitude of 44º.23´E. during 2015-2016. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement, placing sowing dates in main plots and cultivars in sub–plots with three replications. The treatments were four sowing dates (20th October, 10th November, 30th November and 20th December) and three bread wheat cultivars (Bohooth-22, Bohooth-158 and Rasheed).

The net of sub plot area was 6 m^2 (nine rows, three meters long, 20 cm apart and 5 cm depth). Seed bed was prepared by ploughing the field three times with cultivator followed by planking. Wheat grains (120 kg ha^{-1}) were sown manually with single row hand drilling. Before sowing, soil was analyzed for its physico-chemical properties which was clay loam in texture with 70.0 available nitrogen, 5.38 ppm available phosphorus, 372.0 ppm available potassium, 3.6% dSm-1 Ec and 7.0 pH. The nitrogen fertilizer in the form of urea (46%) was applied as per treatment in four splits, one at the time of sowing, second at growth stage ZGS:13, third at ZGS:32 and forth at ZGS:40 according to Zadoks scale [16], while, phosphorus was added at the time of planting in a form of tri super phosphate (P_2O_5 46%) . All plots received uniform cultural practices.

The dates of occurrence of different phonological stages (beginning of tillering, stem elongation, booting, and Anthesis) were recorded when 50% of the plants in each replication reached the respective stages. Climatic data regarding temperature for the four mentioned stages during the study period were collected from Abu-Ghuraib Meteorological station, Ministry of Agriculture. The recorded data were analyzed statistically by using statistical software package Genstat version (12). The least significant differences (L.S.D) at the level of 0.05 probability was employed to compare the differences among the treatment means [17]. The studied traits are:

1. Changes in phenology (days after sowing): Days were recorded at the beginning of the stages: tillering, stem elongation, booting and anthesis.
2. Plant height (cm): Ten plants from each plot was taken at maturity and averaged.
3. 1000-grain weight (g): 1000 grain were counted after harvest from each plot and then weighted by using a digital balance with two digits at moisture of 12%.
4. No. of grains spike^{-1}: Were counted from ten randomly selected spikes in each replicate at harvest.
5. Grain yield (t ha^{-1}): At maturity, one square meter was harvested manually from each plot. Spikes were threshed manually and grains were separated and weighed. Then the grain yield was converted into tons per hectare.
6. Growing degree days (GDD): was calculated at the beginning of the stages: tillering, stem elongation, booting, and anthesis according to the formulae of Rajput [18]:

$$\text{Growing Degree Days } (\mathbf{GDD}) = \frac{T_{max} + T_{min}}{2} - T_{base} \quad (0^oC)$$

Where:

T_{max} = maximum temperature
T_{min} = minum temperature
T_{base} = base temperature (0^{o}c)

7. Phenothermal index (PTI): Was calculated according the formulae of Rajput [18]:

PTI = GDD ÷ Growth days

RESULTS AND DISCUSSION

3.1 Plant height (cm):

Crop height is mainly controlled by the genetic makeup of a cultivar and it can also influenced by environmental conditions. Data presented in Table 1 showed that plant height differed significantly by sowing dates. Sowing on 20th October produced the tallest plants (108.86) as compared with those sown on 10th November, 30th November and 20th December which gave 100.09, 79.98 and 79.61 cm, respectively. It is obvious from these results that the plants sown earlier in October gave the tallest plants, while plants sown late gave the shortest plants. These findings might be attributed to the suitable temperatures beside other environmental conditions that encouraged growth and early development of plants sown in October rather than those sown in November or December. These results are in harmony with those obtained by RakeshKumar Sharma [19] who recommended that sowing earlier seemed to be more favorable for producing tallest plants in comparison with other later sowing dates.

Results also indicated that wheat cultivars were significantly differed in their plant height. Rasheed gave the tallest plants (103.46 cm) followed by Bohooth-22 and Bohooth-158 which gave plants with height of 86.59 and 86.36 cm, respectively. The differences between Bohooth-22 and Bohooth-158 were not significant. The differences in plant height among cultivars might be due to the differences in their genetic makeup. These results are in agreement with those obtained by Javid Iqbal et al. [20].

3.2 No. of grains spike^{-1}:

Results in Table 1 indicated that sowing dates had a significant effect on number of grains spike^{-1}. Sowing wheat 30th November attained the highest number of grains spike^{-1} (60.9), compared with those obtained when wheat was sown at 20th October, 10th November and 20th December which produced 16.4, 52.8 and 50.6, respectively. The increase in this trait with sowing wheat on 30th November may be due to the available weather condition during plant life that helped rapid growth and formation of good canopy able to make good photosynthesis. These results are on line with those obtained by RakeshKumar Sharma [19] and Nohe et al. [21]. They found that sowing dates significantly affected the number of grains spike^{-1} which increased when wheat was sown on optimum date compared with early or late sowing dates.

Regarding the cultivars, results in Table 1 showed that no significant differences were found between the tested cultivars. Generally, the highest cultivar in number of grains spike^{-1} was Bohooth-22 followed by Rasheed and Bohooth-158 which produced 49.2, 46.5 and 39.9, respectively. These results are not in agreement with those obtained by Abd Allah et al. [22] and Reiad et al. [23] who found great response since specific one surpassed others significantly in this character.

3.3 1000-grain weight (g):

Results in Table 1 showed that there were significant differences in 1000-grain weight regarding sowing dates. The highest 1000-grain weight was recorded with plants sown on 10th November (39.55 g), while the lowest value was with plants sown on 20th December (31.94 g). The means of 20th October and 30th November were 32.72 and 35.16 g, respectively. It is obvious from the results that 1000-grain weight decreased as the sowing date delayed from 10th November till 20th December. The highest value for 1000-grain weight on 10th November might be due to the suitable and longer environmental conditions for vegetative growth, which resulted in the active photosynthesis and maximum translocation of the assimilates to the grains and thus had heaviest grains. These results are in agreement with those obtained by Menshawy [24] who reported that under late sowing, a reduction in 1000-grain weight could be attributed to the reduction in grain filling period.

Results clearly showed that no significant variations found among the tested cultivars. Meanwhile, Rasheed had the heaviest 1000-grain weight (36.27 g), followed by Bohooth-158 (35.34 g) then Bohooth-22 (32.92 g). These results are on line with those obtained by Sadek Iman [25] who declared that the reason behind the variation in 1000-grain weight for wheat cultivars might be due to their different genetic constitutions as well as their response to the prevailing environmental conditions.

Table 1: Effect of sowing dates and cultivars on plant height (cm), no of grains spike^{-1}, 1000-grain weight (g) and grain yield (t h^{-1}).

Treatments	Plant height (cm)	No. of grains spike^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})
Sowing dates				
20th Oct.	108.86	16.4	32.72	0.646
10th Nov.	100.09	52.8	39.55	2.539
30th Nov.	79.98	60.9	35.16	2.629
20th Dec.	79.61	50.6	31.94	2.064
L.S.D 5%	2.15	6.81	4.56	0.81
Cultivars				
Bohooth-22	86.59	49.2	32.92	2.262
Bohooth-158	86.36	39.9	35.34	1.836
Rasheed	103.46	46.5	36.27	1.811
L.S.D 5%	1.67	NS	NS	NS

3.4 Grain yield (t ha^{-1}):

Grain yield is an important trait in evaluating the adaptability of a crop to environmental variations. Data in Table 1 showed that grain yield was significantly influenced by sowing dates. The highest value for this trait (2.629 t ha^{-1}) was obtained when wheat was sown on 30th November, and the lowest value was obtained at sowing date on 20th October (0.646 t ha^{-1}). The value of grain yield when wheat was sown on 10th November and 20th December was 2.539 and 2.064 t ha^{-1}, respectively. Delaying sowing to 20th December decreased grain yield about 27.37% compared with the sowing on 30th November, while the reduction in grain yield when wheat sown on 20th October was 306.97% compared with wheat sown on 30th November. The sowing on 10th and 30th November was more beneficial than the late sowings as far as in arid regions the growing season for the winter crops is short, therefore, the growth period is complicated by high temperature at the end of the growing season. Furthermore, analysis of data revealed that sowing at optimum time favored the maximum partitioning of photosynthesis when compared to the late sowing and gave maximum grain yield. While, the decrease in grain yield when wheat sown early (20th October) is attributed to the low temperatures during anthesis stage, which affected the viability of pollen grains and consequently reduced the pollination by these unviable pollen grains. Similar results have also been reported by [26] and [27]. The reduction in wheat grain yield under heat stress could be caused by accelerated senescence, increased respiration, reduced photosynthesis and accelerated phasic development. On the contrary, Nohe et al. [21] showed that sowing wheat on 15th December gave the highest grain yield per unit area.

The effect of cultivars on grain yield was insignificant as shown on Table 1. The cultivar Bohooth-22 gave the highest yield (2.262 t ha^{-1}) followed by Bohooth-158 (1.836 t ha^{-1}) and Rasheed (1.811 t ha^{-1}). Bohooth-22 ranked 1st, Bohooth-158 ranked 2nd and Rasheed ranked 3rd. This variation among the three cultivars could be attributed to their different adaptation to wide differences in climatic conditions, and this difference could be due to their different genetic constitution. Similar results obtained by Mahgoub Hayam and Sayed [28] who showed that there was no significant differences between the two tested wheat cultivars (Giza 167 and Sids 1) in grain yield per unit area.

3.5 Changes in phenology (days after sowing):

Data in Table 2 showed that days to attain different phonological stages differed significantly from sowing day to others. The days after sowing increased as sowing dates delayed at tillering stage, while for other stages the number of days after sowing increased from 20th October till 10th November, then the numbers decreased from 10th November till the fourth sowing date (20th December), and this reduction is attributed to the increment in daily temperatures during these stages (stem elongation, booting and anthesis) which in turn caused a decrease in this trait. The highest number of days after sowing attained on 10th November at anthesis stage (130.09 days), whereas the lowest number was attained on 20th October at tillering stage (30.3 days). Haider et al. [29] studied the effect of sowing dates on phenology of four bread wheat cultivars, and indicated that the late sown plants had significantly shortest phonological stages than early sown plants in all cultivars. Ghosh and Patra [30] studied the effect of sowing dates (20th November, 4th December, 18th December and 1st January) on four wheat cultivars and concluded that the delay in sowing from 20th Nov. to 1st Jan. shortened the life cycle by 26.7 days. Regarding the cultivars, it is obvious from the results in Table 2 that the cultivars differed significantly in this trait. Highest number of days after sowing was attained when the cultivar Rasheed was sown, while the lowest number was with the cultivar Bohooth-158 for all growing stages. Bohooth-158 needed lowest number of days after sowing at tillering stage (32.9 days), while Rasheed needed the largest number of days after sowing at the anthesis stage (135.0 days). These differences among the cultivars are due to their different genetic makeup. These results are in agreement with those obtained by Rahman et al. [31].

3.6 Changes in growing degree days (GDD):

Perusal of data in Table 3 showed that GDD requirement to attain the different phonological stages significantly decreased and increased during the four sowing dates at the four growing stages (tillering, stem

elongation, booting and anthesis). In general, the lowest GDD requirement was observed at tillering stage on 30th November (354.1 ^{0}C) and the highest GDD requirement was observed at Anthesis stage on 20th October (1608.7 ^{0}C). Late sown plants showed reduced GDD requirement for attaining booting and anthesis stages, i.e. there was a reduction in GDD from 30th Nov. to 20th Dec. for these stages. Regarding tillering and stem elongation stages, there was a reduction in the GDD from 20th Oct. till 30th Nov. then followed by an increase till 20th December. These results are in harmony with those obtained by Khichar and Niwas [32] who studied the effect of two sowing dates (20th Nov. and 20th Dec.) on GDD and found that wheat plants sown early (20th Nov.) needed more GDD than those sown late (20th Dec.). As shown in Table 3 cultivars differed significantly in their GDD requirement. Cultivar Rasheed consumed more GDD than other cultivars, while Bohooth-158 consumed less GDD, followed by Bohooth-22. The lowest GDD was attained by Bohooth-158 (414.6 ^{0}C) at tillering stage, whereas the highest GDD was attained by Rasheed (1761.0 ^{0}C) at Anthesis stage. The differences in the genetic constitution among the cultivars are behind their GDD requirement differences. These results are on line with those showed by Paul and Sarker [33] who reported that wheat cultivars differed in their GDD consumption.

Table 2: Phenology (days after sowing) of three wheat cultivars as influenced by four sowing days.

Treatments	Tillering stage	Stem elongation stage	Booting stage	Anthesis stage
Sowing dates				
20th Oct.	30.3	44.3	84.2	123.9
10th Nov.	31.4	59.0	110.1	130.09
30th Nov.	37.8	52.8	106.0	124.6
20th Dec.	41.8	58.7	96.6	115.3
L.S.D 5%	1.751	0.638	0.496	1.023
Cultivars				
Bohooth-22	35.6	53.7	98.0	123.5
Bohooth-158	32.9	50.8	91.6	111.8
Rasheed	37.5	56.7	108.1	135.0
L.S.D 5%	1.435	0.382	0.353	0.368

Table 3: Growing degree days (GDD) of three wheat cultivars as influenced by four sowing days at different phonological stages.

Treatments	Tillering stage	Stem elongation stage	Booting stage	Anthesis stage
Sowing dates				
20th Oct.	610.2	775.4	1143.9	1608.7
10th Nov.	404.1	639.5	1237.2	1591.5
30th Nov.	354.1	500.0	1247.8	1561.6
20th Dec.	387.7	579.6	1235.7	1534.6
L.S.D 5%	18.00	17.19	10.93	16.24
Cultivars				
Bohooth-22	440.2	626.3	1204.1	1567.5
Bohooth-158	414.6	583.3	1104.9	1393.8
Rasheed	462.4	661.3	1339.5	1761.0
L.S.D 5%	15.28	13.33	5.88	5.60

3.7 Phenothermal index (PTI):

Phenothermal index from Sowing to tillering, tillering to stem elongation, stem elongation to booting, booting to anthesis of four sowing dates showed significant differences (Table 4). The values of phenothermal index decreased from early sowing (20th Oct.) till late sowing (20th Dec.) for Sowing to tillering stage, while the values of this trait decreased from 20th October till 30th November, then followed with an increase till 20th December for tillering to stem elongation stage. PTI decreased from 20th October till 10th November, then followed with an increase till the sowing date 20th December. Regarding the cultivars, it is clear from the findings showed in Table 4 that the three cultivars differed significantly during the four periods. Cultivar Bohooth-158 gave the highest PTI during period from sowing to tillering stage followed by Bohooth-22. Rasheed gave the highest values during periods from tillering to stem elongation, stem elongation to booting stage and booting to anthesis stage. Bohooth-158 and Rasheed gave the highest values for this trait during the period from Sowing to tillering stage (13.1) and from booting to anthesis stage (13.1), while the lowest value was obtained with cultivar Bohooth-158 during the period from tillering to stem elongation stage (11.8).

Table 4: Phenothermal index (PTI) of three wheat cultivars as influenced by four sowing days at different periods.

Treatments	From sowing to tillering stage	From tillering to stem elongation stage	From stem elongation to booting stage	From booting to anthesis stage
Sowing dates				
20th Oct.	20.1	17.5	13.7	13.0
10th Nov.	12.9	10.8	11.2	12.2
30th Nov.	9.4	9.5	11.8	12.5
20th Dec.	9.3	9.9	12.8	13.3

L.S.D 5%	0.12	0.46	0.06	0.03
Cultivars				
Bohooth-22	12.9	12.0	12.4	12.7
Bohooth-158	13.1	11.8	12.2	12.5
Rasheed	12.8	12.0	12.4	13.1
L.S.D 5%	0.07	0.34	0.02	0.01

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