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Impact of sowing dates on the growth and straw yield of some bread wheat cultivars and their relationship with accumulated heat units

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Abstract. An experiment was conducted at Research Station, State Board for Seeds Testing and Certification, Baghdad, Iraq during 2015/2016 season to determine the effect of four sowing dates (20^{th} October, 10^{th} November, 30^{th} November and 20^{th} December) on growth and straw yield of three wheat cultivars (Bohooth-22, Bohooth-158, and Rasheed) and their relationship with accumulated heat units. Flag leaf area and biological yield decreased with late sowing dates. Highest values of flag leaf area (62.17 cm^2), number of tillers m^{-2} (375.8), biological yield (15.12 t ha^{-1}) and straw yield (14.47 t ha^{-1}) were obtained on 20^{th} October. Cultivars responded differently to the four sowing dates. Highest values of phenology (DAS) (177.3 days) and growing degree days (GDD) (2607.2 ^0C) were obtained at maturity stage with sowing date 20^{th} October. Highest value for phenothermal index (PTI) was obtained during the period from sowing to seedling growth stage with sowing date 20^{th} October (23.6). Bohooth-22 gave highest values regarding DAS and GDD during the first period (from sowing to seedling growth stage), while Rasheed gave highest values during the rest periods. Highest and lowest values of PTI were recorded with Bohooth-158 (14.8 and 11.8) during the period from sowing to seedling growth, respectively.

Keywords: wheat, sowing dates, accumulated heat units, straw yield, biological yield.

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1 INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most important among all cereals used as a food grain in the world. It ranks first in the world cereal production and is a staple food of about one third of the world's population (Iqtidar et al., 2010) and cultivated worldwide primarily/mainly as a food commodity. Wheat is widely adapted and grown in most regions across the globe; from almost 60° N in Northern Europe (Norway) to 40° S in South America (Chile) (El-Nakhlawy et al., 2015). Wheat is a source of protein and rank's second after rice as a source of calories in the diets of consumers in developing countries (Braun et al., 2010). Wheat contributes about 60% of daily protein requirement and more calories to world diet than any other food crop (Hussain et al., 2002). Man is dependent on wheat crop for food and for feed for his domestic animals because wheat straw is very important for livestock feed.

Wheat is considered one of the top dominant crops in the world as well as in Iraq, where wheat was sown on an area of 2109455 hectares during 2013-2014. The total production of wheat was 5055111 tons with an average yield of 2396.4 kg ha^{-1} (FAO, 2014). So, the total production of the wheat in Iraq is still far below the consumption and annual demand. The most factors that lead to the increase of wheat yield is breeding and producing new cultivars with high yield, planting in optimum time and using all other ways such as fertilization, irrigation, pests control and etc. that increase the yield.

Planting 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 the vegetative and reproductive stages. The differences in sowing dates play an important role in the variation of wheat yield per unit area. Seeding earlier increases chances of disease and insect problems. Seeding later reduces chance of survival, generally delays maturity, increases disease chances and reduces yield potential (El-Gizawy, 2009). Early or late sowing increases the risk of yield losses (Madani et al., 2010).

Favorable planting date range of different cultivars varies with regions, depending on growth conditions of a specific tract that could be evaluated by sowing them at different dates (Zia – ul – Hassan et al., 2014).

The highest values of some vegetative traits, yield attributes and grain yields as well as increment in biological and economical yield occurred when wheat sown earlier (Qasim et al., 2008). Too early sowing produces weak plants with poor root system as the temperature is above optimum, while late planting results in poor tillering and generally slows crop growth because of low temperature (Tahir et al., 2009). Late planting affects the growth, yield and quality of wheat, because early sowing produces higher yields than late sowing due to longer duration. Temperatures below or above normal alter plant functions and productivity (Lak et al., 2013). Nour et al. (2011) showed that the recommended sowing date (25th November) produced the highest number of spikes/m2, number of kernels/spike, 1000- kernel weight, biological yield and grain yield compared with late sowing date (25th December). Early or late sowing increases the risk of yield losses (Mostafa et al., 2010). Similarly plant height (Hasina et al., 2012), number of tillers/m^2 (RakeshKumar Sharma, 2003), straw and biological yields (Nohe et al., 2009) were increased with early sowing (early November) over late sowing (December).

Due to global warming, temperature increases are probable to decrease wheat production in developing countries (where almost 66% of all wheat is produced) by 20-30% (Rosegrant and Agcaoili, 2010). According to the estimates a rise in temperature of 1°C in the wheat growing season could reduce the wheat yields by about 3-10% (You et al.,

2009). Global production of wheat is predicted to decrease by 6% for each °C of further increase in temperature and become more variable over space and time (Asseng et al., 2014). It is reported that continual heat stress affects approximately 7 million hectare of wheat in developing countries, while terminal stress is a problem in 40% of the temperate environments, which cover 36 million hectare. Continual heat stress is defined a mean daily temperature of over 17.50C in the coolest months of the season, and over 50 counties (importing more than 20 m. tons of wheat per year) experience this type of stress throughout the entire wheat cycle (Reynolds, et al., 2001; Sial, et al., 2001).
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. Maximum temperatures 35+3^{0}C in March and April are known to force maturity. The lower temperatures slow the growth while the high temperatures speed up the maturity of the crop (Sial, et al., 2005). The effect of sowing dates and temperature on phenology, growth and straw yield of wheat can be studied under field conditions through the accumulated heat units system.
The genotypic response of wheat to planting dates varies for yield contributing characters due to different genetic potential.
So, the aim of this study was to determine the impact of accumulated temperatures on the growth and straw yield of three bread wheat cultivars under four different sowing dates.

2 MATERIALS AND METHODS

An experiment was conducted at Research Station, State Board for Seeds Testing and Certification, Baghdad, Iraq, located at latitude of 33^o.32´N and longitude of 44^o.23´E. during the winter season 2015-2016. Split plot design in the arrangement of Randomized Complete Block Design (RCBD) with three replicates was used. Sowing dates (20th October, 10th November, 30th November and 20th December) occupied the main plots, whereas the cultivars (Bohooth-22, Bohooth-158 and Rasheed) were in sub–plots.
The net of sub plot area was 6 m^2 (nine rows, three meters long, 20 cm apart and 5 cm depth). Recommended land preparations to facilitate uniform distribution of seeds, fertilizers, and irrigation water were performed. Wheat grains (120 kg ha^{-1}) were sown manually with single row hand drilling. The soil was irrigated after the sowing immediately. Before sowing, soil was analyzed for its mechanical and chemical properties as shown in Table 1. 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 (Zadoks et al., 1974), whereas 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 occurrences of different phonological stages viz., beginning of (seedling growth, stem elongation, heading, anthesis and maturity) were recorded when 50% of the plants in each replication reached the respective stages. The daily meteorological data regarding temperatures for the five mentioned stages during the study period were collected from Abu-Ghuraib Meteorological station, Ministry of Agriculture. The obtained data were statistically analyzed through analysis of variance (ANOVA) 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 (Steel et al., 1997).

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Table 1. Mechanical and chemical analysis of upper 30 cm of soil.

Mechanical analysis		Chemical analysis	
Clay %	47.6	Available N (ppm)	70.0
Silt %	40.0	Available P (ppm)	5.38
Sand %	12.4	Available K (ppm)	372.0
Soil texture	C. loam	pH	7.0
		Ec ($dS.m^{-1}$)	3.6

2.1 Studied characters

1. Phenology (days after sowing): During the stages: Seedling growth stage, stem elongation, heading, anthesis and maturity.
2. Flag leaf area (cm^2):
3. Number of tillers m^{-2}: Total number of tillers per one meter row length was counted and converted to one meter square.
4. Biological yield ($t\ ha^{-1}$):
5. Straw yield ($t\ ha^{-1}$):
6. Growing degree days (GDD): Was calculated from sowing till the beginning of the stages: Seedling growth, stem elongation, heading, anthesis and maturity, according to the formulae of Rajput (1980):

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

Where:
T_{max} = maximum temperature
T_{min} = minum temperature
T_{base} = base temperature (0^oc)

7. Phenothermal index (PTI): Was calculated according the formulae of Rajput (1980):

$$PTI = GDD \div \text{Growth days}$$

3 RESULTS AND DISCUSSION

3.1 Flag leaf area (cm^2)

Results in Table 1 showed a significant effect for sowing dates on flag leaf area during the experimental season. Results showed that the highest flag leaf area (62.17 cm^2) was obtained when wheat was sown in October 20. While, seeding wheat on December 20 gave the lowest flag leaf area (44.86 cm^2). Flag leaf area for plants sown on November 10 and November 30 were 57.21 and 51.02 cm^2, respectively. It evident from these results that flag leaf area was decreased by 8.67%, 21.85% and 38.59% with delaying sowing date from November 10, November 30 and December, respectively. These results may be due to the effect of environmental conditions. These results are in harmony with those obtained by Hamam and Abdel-Sabour Khaled (2009) and Abdel-Hady and Hoda El-Naggar (2010) who found that flag leaf area was significantly influenced and decreased by 13.29% with delaying sowing date from November (favorable) to December (heat stress).

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Results in Table 1 indicated that the differences in flag leaf area among wheat cultivars were significant. In general, results indicated clearly that Bohooth-158 tended to produce the highest flag leaf area (58.35 cm^2) followed by the cultivars Rasheed and Bohooth-22 which gave plants with flag leaf area of 54.12 and 48.98 cm^2, respectively. These results might be attributed to the differences in the genetic makeup of the cultivars.

3.2 Number of tillers m^{-2}

It is evident from the results in Table 1 that the number of tillers m^{-2} was significantly affected by sowing dates. Generally, results showed that the highest number of tillers m^{-2} (375.8) was obtained when wheat was sown on 20^{th} October, while the lowest number of tillers m^{-2} (260.9) was obtained when wheat was sown on 30^{th} November. Seeding wheat on 10^{th} November and 20^{th} December gave 314.2 and 282.2 number of tillers m^{-2}, respectively. These results may be due to the effect of environmental conditions. Similar results were reported by RakesKumar Sharma (2003) who found that delay in sowing from 15 November to end of December decreased this trait.

The results shown in Table 1 clearly indicated that the differences in number of tillers/m^2 due to wheat cultivars were insignificant. Bohooth-22 which gave the highest number of tillers m^{-2} (322.6) followed by Bohooth-158 (312.2) than Rasheed (290.1). These results are in agreement with those obtained by Bhandari et al. (2000), Menshawy (2007) and Tawfelis (2006), who found that genotypes appeared a different effect on this trait.

3.3 Biological yield

The results in Table 1 clearly indicated that sowing date had a significant effect on biological yield per unit area. Sowing wheat early on 20^{th} November was promising and gave highest biological yield (15.12 t ha^{-1}), whereas sowing wheat on 20^{th} December gave the lowest biological yield (9.39 t ha^{-1}). Sowing on 10^{th} November and 30^{th} November gave a biological yield of 14.12 and 9.86 t ha^{-1}, respectively. However the differences between the two later sowing dates (30^{th} November and 20^{th} December) were not significant, as well as between the two earlier sowing dates (20^{th} October and 10^{th} November). It is clear from these results that sowing wheat on 20^{th} October out yielded sowing on 10^{th} November, 30^{th} November and 20^{th} December by 7.08%, 53.35% and 61.02%%, respectively. These results could be explained by the highest flag leaf area (Table 1). These results are in harmony with those obtained by Nasim et al. (2006), Haj et al. (2007) and Shahzad (2007). They reported that sowing wheat in November gave higher biological yield per unit area than sowing in December. On the other hand, Nohe et al. (2009) found that sowing wheat at 15^{th} December produced the highest biological yield ha^{-1}.

Results in Table 1 clearly indicated that cultivars had insignificant effect on biological yield per unit area. Rasheed clearly had the highest biological yield (12.81 t ha^{-1}) followed by Bohooth-22 (12.60 t ha^{-1}). Whereas, the lowest biological yield (10.95 t ha^{-1}) was produced from Bohooth-158. These results are in harmony with those obtained by Mowafy (2002) and Njuguna et al. (2010) who found that the cultivars differed in their biological yield. Haroun et al. (2012) indicated that Gemmiza 9 cultivar produced the highest biological yield (17.81 t ha^{-1}) compared with Sakha 93 and Giza 168 cultivars which produced the lowest biological yield (15.74 and 15.79 t ha^{-1}), respectively.

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3.4 Straw yield

The results in Table 1 indicated that straw yield significantly affected by changing in sowing dates. The highest straw yield (14.47 t ha^{-1}) was produced from the first sowing date (20th October) followed by the second sowing date (10th November) which gave (11.58 t ha^{-1}), while the lowest yield (23737.23 t ha^{-1}) was obtained from the third sowing date (30th November). It is clear from these results that early sowing in 20th October increased straw yield by 24.96% and 100.14% as compared with sowing in 10th November and 30th November, respectively. These results may be due to the increment in the number of tillers/m^2 (Table 1) in the early sowing date (20th October) as compared with the later sowing sowing dates. These results are in harmony with those obtained by Nohe et al. (2009) and Mostafa et al. (2010) who reported that delay in sowing decreased this trait.
On the contrary, results in Table 1 clearly indicated that effect of cultivars was insignificant on straw yield. Mean straw yield comparison indicated that highest yield belonged to Rasheed (11.00 t ha^{-1}), while the lowest yield belonged to Bohooth-158 (9.11 t ha^{-1}). Rasheed out yielded Bohooth-22 and Bohooth-158 by 6.38% and 20.75%, respectively.

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

Treatments	Flag leaf area (cm^2)	Number of tillers m^{-2}	Biological yield (t ha^{-1})	Straw yield (t ha^{-1})
Sowing dates				
20th Oct.	62.17	375.8	15.12	14.47
10th Nov.	57.21	314.2	14.12	11.58
30th Nov.	51.02	260.9	9.86	7.23
20th Dec.	44.86	282.2	9.39	7.32
L.S.D 5%	7.979	51.42	2.626	1.948
Cultivars				
Bohooth-22	48.98	322.6	12.60	10.34
Bohooth-158	58.35	312.2	10.95	9.11
Rasheed	54.12	290.1	12.81	11.00
L.S.D 5%	3.760	NS	NS	NS

3.5 Changes in phenology (days after sowing)

Results presented in Table 2 showed a significant effect for planting dates on this trait. The days after sowing increased as sowing dates delayed for tillering stage, while this trait decreased with delayed sowing dates. The values for this trait increased from sowing date 20th October to 10th November, and then followed with a decrease for other sowing dates. This reduction with late sowing dates during booting and Anthesis stages is attributed to the increment in temperatures during these stages which in turn caused a decrease in this trait. The highest value was attained on 20th October at maturity stage (177.3 days), whereas the lowest number was attained on the same sowing date at emergence stage (5.6 days). Haider et al. (2003) studied the effect of sowing dates on phenology of four bread wheat cultivars, and indicated that the late sown plants had significantly shorted phonological stages than early sown plants in all cultivars. Ghosh and Patra (2004) 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.

Table 2 indicates that 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 emergence stage (8.6 days), while Rasheed needed the largest number of days after sowing at maturity stage (153.4 days). This difference among the cultivars is due to their different genetic makeup. These results are in accordance with those obtained by Rahman et al. (2009).

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

Treatments	Seedling growth stage	Stem elongation stage	Heading stage	Anthesis stage	Maturity stage
Sowing dates					
20th Oct.	5.6	44.3	101.2	123.9	177.3
10th Nov.	6.7	59.0	115.3	130.1	160.7
30th Nov.	11.7	52.8	112.2	124.6	140.9
20th Dec.	12.7	58.7	102.0	115.3	122.4
L.S.D 5%	0.9220	0.6376	0.2937	1.0233	0.6566
Cultivars					
Bohooth-22	9.5	53.7	105.9	123.5	150.1
Bohooth-158	8.6	50.8	99.0	111.8	147.5
Rasheed	9.3	56.7	118.2	135.0	153.4
L.S.D 5%	0.3383	0.3816	0.4784	0.3677	0.4446

3.6 Changes in growing degree days (GDD)

It is obvious from data in Table 3that GDD requirement to attain the different phonological stages significantly decreased and increased during the four sowing dates at the five growing stages (emergence, stem elongation, heading, anthesis and maturity).

In general, highest GDD requirement was recorded at maturity stage on 20th October (2607.2 ^{0}C), while the lowest GDD requirement was at emergence stage on 10th November (105.1 ^{0}C). Late sown plants showed reduced GDD requirement for attaining anthesis and maturity stages, i.e. there was a reduction in GDD from October 20 till December 20 for these stages. Regarding stem elongation stages, there was a reduction in the GDD from October 20 till November 30 then followed by an increase till December 20. These results are in agreement with those obtained by Khichar and Niwas (2005) 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.).

It is clear from data in Table 3 that 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 at all stages, except at emergence stage where Bohooth-22 consumed more GDD, followed by Rasheed and Bohooth-158.

The lowest GDD was attained by Bohooth-158 at emergence stage (110.4 ^{0}C), whereas the highest GDD was attained by Rasheed at maturity stage (2234.8 ^{0}C). 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 (2000) who reported that wheat cultivars differed in their GDD consumption.

3.7 Phenothermal index (PTI)

Phenothermal index from Sowing till emergence, stem elongation till heading, heading till Anthesis and anthesis till maturity 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 first period (Sowing till emergence stage). The values of this trait decreased from 20th October till 30th November, and then followed with an increase till 20th December for the period from emergence till stem elongation stage. PTI decreased from October 20 till November 10, then followed with an increase till the sowing date December 20 for the periods; from stem elongation till heading stage, from heading till anthesis stage and from anthesis till maturity stage

It is clear from the findings showed in Table 4 that the three cultivars differed significantly during the five periods. Bohooth-158 gave the highest PTI during the period from sowing till emergence stage, while Rasheed gave the highest values for the other four periods followed by Bohooth-22. Bohooth-158 gave the highest values for this trait during the period from Sowing till emergence stage (14.8), whereas the lowest value was obtained with the same cultivar during the period from emergence till stem elongation stage (11.8).

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

Treatments	Seedling growth stage	Stem elongation stage	Heading stage	Anthesis stage	Maturity stage
Sowing dates					
20th Oct.	131.3	775.4	1326.6	1608.7	2607.2
10th Nov.	105.1	639.5	1323.6	1591.5	2244.9
30th Nov.	131.3	500.0	1362.0	1561.6	1974.5
20th Dec.	105.3	579.6	1325.6	1534.6	1812.6
L.S.D 5%	9.10	17.19	6.47	16.24	16.56
Cultivars					
Bohooth-22	123.7	626.3	1310.3	1567.5	2151.5
Bohooth-158	110.4	583.3	1210.9	1393.8	2093.2
Rasheed	120.8	661.3	1482.0	1761.0	2234.8
L.S.D 5%	4.32	13.33	6.92	5.60	12.21

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

Treatments	From sowing till seedling growth stage	From seedling growth till Stem elongation stage	From stem elongation till heading stage	From heading till anthesis stage	From Anthesis till maturity stage

Sowing dates					
20th Oct.	23.6	17.5	13.2	13.0	14.7
10th Nov.	15.8	10.8	11.5	12.2	13.9
30th Nov.	11.3	9.5	12.1	12.5	14.0
20th Dec.	8.3	9.9	13.0	13.3	14.8
L.S.D 5%	0.31	0.46	0.04	0.03	0.052
Cultivars					
Bohooth-22	14.7	12.0	12.4	12.7	14.34
Bohooth-158	14.8	11.8	12.3	12.5	14.19
Rasheed	14.7	12.0	12.6	13.1	14.57
L.S.D 5%	0.08	NS	0.02	0.01	0.041

4 CONCLUSION

The highest values of biological and straw yield were achieved when cultivar Rasheed was sown earlier (20th October).

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