Seeding rates influence on 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 2016/2017 season to determine the effect of six seeding rates (80, 100, 120, 140, 160 and 180 kg ha$^{-1}$) on the growth and yield of three wheat cultivars (Booooth 22, Booooth 158, and Rasheed) and their relationship with accumulated heat units. Data on different growth and yield contributing traits were recorded and statistically analyzed. Plant height increased with increasing seeding rate and highest value recorded when plants sown at 180 kg ha$^{-1}$ (104.57 cm). Highest values of number of tillers, biological yield and straw yield were recorded at 140 kg ha$^{-1}$ seeding rate. Stem diameter decreased with increasing seeding rate and maximum value noted at seeding rate 80 kg ha$^{-1}$ (4.14 cm). Highest mean of phenology (DAS) (152.7 day), growing degree days (GDD) (2029.45°C) and phenothermal index (PTI) (13.29°C day$^{-1}$) was recorded at seeding rate 80 and 100 kg ha$^{-1}$ during physiological maturity. Planting at seeding rate of 140 kg ha$^{-1}$ gave the highest value of heat use efficiency (HUE) for biological yield (6.133). Cultivars differed significantly in their response to different seeding rates. Rasheed cultivar gave the highest mean regarding plant height (112.92 cm), number of tillers m$^{-2}$ (418.3), stem diameter (4.04 cm), biological yield (13.559 t ha$^{-1}$) and straw yield (7.557 t ha$^{-1}$).

KEY WORDS
wheat, seeding rates, biological yield, straw yield, Phenothermal index

INTRODUCTION

Wheat (Triticum aestivum L.) that belongs to the family of (Poaceae), is an important and extensively used cereal in human diets worldwide. It ranks first in the world cereal production and is a staple food of about one third of the world’s population [1]. Man is dependent on wheat crop for food and for feed for his domestic animals because wheat straw is very important for livestock feed.

With the existing semi-dwarf high yielding varieties, there is enormous potential of obtaining higher crop productivity by adopting production technology such as appropriate seed rates, sowing date, N and P rates [2]. Seeding rate is important for wheat plants, since it directly influences the number of spikes per unit area. As a consequence, an increase in other yield components such as the number of grains per spike and individual grain weight will occur [3]. Appropriate seeding rate is considered an important management factor for increasing wheat yield. It has a particular importance in wheat production because it is under the control of farmers in many cropping systems[4].

The appropriate seeding rate varies significantly from region to region due to the difference of climatic factors, type of soil, sowing date, and genotypes [5]. Using higher seeding rates may increase the overall input
costs, but lowering the seeding rate may increase the risks for reducing yield [6]. High seeding rates increase the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield [7]. Using low seeding rate will reduce wheat yield due to less number of plants per unit area [8]. Higher seeding rates compensate for reduced tillers formation and promote more main stem spikes which can be favorable, particularity for genotypes that tend to produce less number of tillers [9].

Ali et al. [10] studied the effect of four levels of seeding rates (125, 150, 175 and 200 kg ha\(^{-1}\)) and concluded that straw yield increased with the increase in seeding rate. The highest values were obtained with seeding rate 200 kg ha\(^{-1}\) (4.35, 4.52 and 4.58 t ha\(^{-1}\)) for the first, second and third season, respectively, while the lowest values were obtained with seeding rate 125 kg ha\(^{-1}\) (4.11, 4.17 and 4.36 t ha\(^{-1}\)) for the three consecutive seasons, respectively. Gafaar [11] showed that the highest mean of biological yield in wheat crop was attained when seeding rate increased up to 400 gains m\(^{-2}\).

Currently, the seeding rate used for the wheat ranges from 250 to 400 viable grains m\(^{-2}\). This is based on the cultivar cycle, as well as its dual ability as a forage and grain crop [12]. Seleiman et al. [13] studied the effect of four seeding rates (250, 300, 350 and 400 grains m\(^{-2}\)) and found that increasing seeding rate up to 350 or 400 grains m\(^{-2}\) gave the highest number of spikes, number of grains spike\(^{-1}\), biomass and straw yield but a reduction in seed filling rate occurred. Moreover, many workers showed that wheat cultivars differ in yield and yield components [14].

Regarding cultivar differences, a number of previous studies clearly revealed that selecting cultivars which are related to the specified density and use by growers may be a practicable option for the increasing the yield of wheat [7], Sothe present study was therefore conducted to investigate the effect of six seeding rates on growth and straw yield of three wheat cultivars and their relationship with accumulated heat units.

**MATERIALS AND METHODS**

An experiment was conducted at Research Station, State Board for Seeds Testing and Certification, Baghdad, Iraq, located at latitude of 33\(^\circ\).32' N and longitude of 44\(^\circ\).23' E. during 2016-2017. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement, placing seeding rates in main plots and cultivars in sub-plots with three replications. The experiment included six seeding rates (80, 100, 120, 140, 160 and 180 kg ha\(^{-1}\)) and three bread wheat cultivars: Bohooth 22, Bohooth 158 and Rash. The area of each experimental plot was 6 m\(^2\) and consisted of nine rows of three meters length and spaced 20 cm apart. The research fields were prepared with standard production practices, such as land preparation, and fertilizer and herbicide applications. Wheat grains were sown manually with single row hand drilling.

The soil analysis of experimental areas showed that soil was clay loam in texture with 71.0 available nitrogen, 5.88 ppm available phosphorus, 377.0 ppm available potassium, 3.0% dSm\(^{-1}\) Ec and 7.3 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 [15], while, phosphorus was added at the time of planting in a form of tri super phosphate (P\(_2\)O\(_5\) 46%). All plots received uniform cultural practices.

The dates of days after sowing (DAS), Growing degree days and phenothermal index (PTI) of different phonological stages viz., beginning of (emergence, tillering, stem elongation, booting, heading, anthesis and physiological maturity) 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. Data were recorded and statistically analyzed by using statistical software package Genstat version (12). The differences among the treatment means were compared using least significant difference (LSD) test at the level of 0.05 probabilities [16].

**Studied characters:**
1. Plant height (cm).
2. No. of tillers m\(^{-2}\): It was counted from m\(^2\) area at harvest.
3. Stem diameter (cm).
4. Biological yield (t ha\(^{-1}\)): Wheat bundles of each sub plot were threshed and average biological yield was recorded in kg plot\(^{-1}\) and then converted into t ha\(^{-1}\) at harvest.
5. Straw yield (t ha\(^{-1}\)): It was calculated according to the following formulae:

   **Straw yield:**
   \[(t \text{ ha}^{-1}) = \text{Biological weight} - \text{Grain yield}\]

   6. Changes in phenology (days after sowing): Days were recorded at the beginning of the seven stages mentioned before.
7. Growing degree days (GDD): was calculated according to the formulae of Rajput [17]:
Growing Degree Days (GDD) = \frac{T_{max} + T_{min}}{2} - T_{base} (°C)

Where:
- $T_{max}$ = maximum temperature
- $T_{min}$ = minimum temperature
- $T_{base}$ = base temperature (°C)

8. Phenothermal index (PTI): Was calculated according to the formulae of Rajput [17]:

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

9. Heat use efficiency (HUE): calculated for biological as follows:

$$HUE = \frac{\text{Yield}}{GDD}$$

Haider et al. [18]

RESULTS AND DISCUSSION

3.1 Plant height (cm):

Results presented in Table (1) showed a significant effect of seeding rates on plant height, cultivars and their interaction. The height of plants increased with increasing seeding rate, and plants sown at seeding rate 180 kg ha$^{-1}$ gave the tallest plants (104.57 cm), while 180 kg ha$^{-1}$ seeding rate plants gave the shortest plants (96.44 cm). Higher seed rate caused to changing plant height because of the lower light penetrating in to plants canopy bed and more inter specific competition to more absorption light. Similar results were shown by Kabir et al. [19] and Soomro et al. [20] who noticed taller plants by increasing seeding rates and they encouraged the use of optimum seeding rate to get plants with desirable height.

Cultivar Rasheed gave the tallest plants (112.92 cm) followed by Bohooth 22 (96.86 cm), while the shortest plants were recorded by Bohooth 158 (94.36 cm). The differences between Bohooth 22 and Bohooth 158 were not significant. The variation in plant height among cultivars might be attributed to their different genetic makeup.

Regarding the interaction, the highest value was obtained when Rasheed was sown at seeding rate of 180 kg ha$^{-1}$ (119.65 cm), whereas the lowest value was recorded with Bohooth 158 at seeding rate of 80 kg ha$^{-1}$ (93.64 cm).

Table 1: Effect of seeding rates and cultivars on plant height (cm).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Seeding rates (kg ha$^{-1}$)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Bohooth 22</td>
<td>93.75</td>
<td>96.31</td>
</tr>
<tr>
<td>Bohooth 158</td>
<td>93.64</td>
<td>93.71</td>
</tr>
<tr>
<td>Rasheed</td>
<td>101.92</td>
<td>103.94</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>6.705</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>96.44</td>
<td>97.99</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>4.015</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Number of tillers m$^{-2}$:

The economic yield of most cereals is determined by the number of tillers m$^{-2}$. In this study the effect of seeding rates, cultivars and their interaction were significant (Table 2). The highest number of tillers were recorded at seeding rate of 140 kg ha$^{-1}$ but beyond 140 kg ha$^{-1}$ resulted in downward trend of tillers. Higher and statistically at number of tillers m$^{-2}$ (463.6) was obtained at seeding rate of 140 kg ha$^{-1}$, while lowest number of the trait was recorded at seeding rate of 180 kg ha$^{-1}$. The decrease in the number of tillers beyond the seeding rate of 140 kg ha$^{-1}$ might be due to the high competition among the plants for available resources.

These findings are in conformity to the results reported by Malik et al. [21], Seleiman et al. [13] and Ali et al. [10] who produced maximum tillers up to a certain level of seeding rate and then the number of tillers decreased.

Rasheed cultivar gave the highest number of tillers m$^{-2}$ (418.3) followed by Bohooth 158 (395.0) and Bohooth 22 (367.4). Whereas Bohooth 22 gave the lowest mean for this trait (367.7).

The highest number of tillers m-2 was reported when plants of the cultivar Rasheed sown at seeding rate of 140 kg ha$^{-1}$ (490.7), while the lowest number for the same character were obtained with plants of cultivar Bohooth 22 when sown at seeding rate of 180 kg ha$^{-1}$ (306.0).

3.3 Stem diameter (cm):

It is evident from the results shown in Table (3) that the stem diameter was significantly affected by seeding rates. The stem diameter of plants decreased with increasing seeding rate from 80 kg ha$^{-1}$ till 180 kg ha$^{-1}$. Generally, results showed that the highest diameter was recorded with plants at seeding rate of 80 kg ha$^{-1}$ (4.14 cm), while the lowest value for this trait was noticed with plants at seeding rate of 180 kg ha$^{-1}$ (3.78 cm). This
decrease in stem diameter with increasing seeding rate might be due to the limited available resources for the plants at a given area and the lower light penetrating in to plants canopy bed, so the high competition among plants affected their growth and consequently their stem diameter at higher seeding rates.

Cultivars responded differently to seeding rates regarding stem diameter. The highest mean for stem diameter was shown with Rasheed cultivar plants (4.04 cm), while the lowest value for the same character was recorded with plants of Bohooth 158 (3.86). The differences among Rasheed and the two other cultivars were significant, whereas the difference between Bohooth 22 and Bohooth 158 was not significant.

As shown in Table 3 the studied interaction (seeding rates × cultivars) was not significant.

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

Seeding rates showed significant differences among treatments for biological yield (Table 4). The biological yield increased with increasing seeding rate from 80 kg ha\(^{-1}\) till 140 kg ha\(^{-1}\), then followed with a decrease beyond the seeding rate of 140 kg ha\(^{-1}\). Maximum biological yield (13.586 t ha\(^{-1}\)) was recorded with seeding rate of 140 kg ha\(^{-1}\), while the minimum biological yield (11.866 t ha\(^{-1}\)) was obtained with seeding rate of 80 kg ha\(^{-1}\). The reason behind the highest biological yield obtained at seeding rates from 80 kg ha\(^{-1}\) to 140 kg ha\(^{-1}\) could be due to the production of more number of plants per unit area. Results confirming these findings were demonstrated by Seleiman [13] and Laghari et al. [4] who obtained significant increase in biological yield by using different seeding rates.

Results in Table 4 clearly indicated that cultivars had a significant effect on biological yield per unit area. Rasheed had the highest biological yield (13.559 t ha\(^{-1}\)) followed by Bohooth 22 (13.155 t ha\(^{-1}\)), while the lowest biological yield (12.135 t ha\(^{-1}\)) was produced with Bohooth 158. These results might be attributed to the prevailed differences in the genetic makeup of cultivars.

Results presented in Table 4 indicated that the studied interaction i.e. seeding rates and cultivars had a significant effect on biological yield. Generally, the highest biological yield was given by planting Rasheed at seeding rate of 140 kg ha\(^{-1}\) (14.054 t ha\(^{-1}\)), whereas the lowest biological yield was produced by planting Bohooth 158 at seeding rate of 180 kg ha\(^{-1}\) (10.397 t ha).

3.5 Straw yield (t ha\(^{-1}\)):

Results in Table (5) show that the effect of seeding rate on straw yield was significant. The straw yield increased with increasing seeding rate till 140 kg ha\(^{-1}\), and then followed by a decrease till 180 kg ha\(^{-1}\). The highest straw yield (7.362 t ha\(^{-1}\)) was produced from plants sown at seeding rate of 140 kg ha\(^{-1}\), while the lowest straw yield (6.181 t ha\(^{-1}\)) was obtained from 80 kg ha seeding rate. The increase in straw yield with increased seed rate might be attributed to the increment in plant height (Table 1) and number of tillers m\(^{-2}\) (Table 2). These results are in harmony with Mennan and Zandstra [22] and Ali et al. [10].

It is obvious from Table 5 that the effect of cultivars on straw yield was significant. Mean straw yield comparisons indicated that the highest straw yield was belonged to Rasheed (7.557 t ha\(^{-1}\)), whereas the lowest straw yield was obtained from Bohooth 158 (5.793 t ha\(^{-1}\)).

Regarding the interaction, Bohooth 22 gave the highest straw yield at seeding rate of 140 kg ha\(^{-1}\) (8.314 t ha\(^{-1}\)), while Bohooth 158 produced the lowest value for this trait at 80 kg ha\(^{-1}\) seeding rate (5.092 t ha\(^{-1}\)).
Table 4: Effect of seeding rates and cultivars on biological yield (t ha\(^{-1}\)).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Seeding rates (kg ha(^{-1}))</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.8526</td>
<td></td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.4590</td>
<td></td>
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</tbody>
</table>

Table 5: Effect of seeding rates and cultivars on straw yield (t ha\(^{-1}\)).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Seeding rates (kg ha(^{-1}))</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Bohooth 158</td>
<td>5.092</td>
<td>6.392</td>
</tr>
<tr>
<td>Rasheed</td>
<td>7.366</td>
<td>7.333</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.7940</td>
<td></td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.4696</td>
<td></td>
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</tbody>
</table>

3.6 Changes in phenology (days after sowing):

It is obvious from Figure 1 that the days after sowing (DAS) for all growth stage was significantly affected by seeding rates except at stem elongation stage. The DAS decreased at all growing stages with increasing seeding rates, i.e. each increment in seeding density decreased in days to each growing stage. The highest DAS was observed when plants sown at seeding rate of 80 kg ha\(^{-1}\) at physiological maturity stage (152.7 day), while the lowest DAS was documented during emergence stage at seeding rate of 180 kg ha\(^{-1}\) (9.2 days). Like the other studies, the reduction in DAS due to seeding rate was negatively linear and significant at all growing stages. Though significant difference was observed between the highest seed rate and others, the difference was not more than two days at all growth stages. The seeding rate of 180 kg ha\(^{-1}\) exhibited early maturity which might be due to the increase in plant population that increased intra-plant competition for nutrients and light which plants stay no longer for heading and maturity. This may have also contributed to the reduction in grain filling period, because heading and maturity at higher seeding rate hastened than lower seeding rate. These findings were confirmed by Khalil et al. [23] who showed that higher seeding rates significantly reduced days to heading in bread wheat. Laghari et al. [4] also found significant improvement in bringing early maturity of crops by adopting suitable planting rate in wheat.

Cultivars also differed significantly in their response to different seeding rate at all growth stages (Figure 2). The cultivar Rasheed needed more DAS to reach each growing stage, followed by Bohooth 22, while Bohooth 158 needed less DAS to reach the same growth stages. The highest DAS was recorded with Rasheed at maturity stage (153.9 day), whereas the lowest DAS was noticed with Bohooth 158 at emergence stage (9.7 day). This could be attributed to the genetic variation of the cultivars in their phenology.

3.7 Changes in growing degree days (GDD):

Growing degree days (GDD) was affected significantly by using different seeding rates at all growth stage (Figure 3). The GDD decreased with increasing seeding rates at all stages. The lowest mean values were recorded at emergence stage, while highest values were documented at maturity stage. Plants at seeding rate of 180 kg ha\(^{-1}\) consumed less heat units (121.28 °C) at emergence stage, whereas plants sown at 80 kg ha\(^{-1}\) seeding rate consumed more heat units (2029.45 °C). The difference in GDD at different seeding rates might be due to the difference in DAS for all stage at different seeding rates. The increase in DAS led to more heat unit consumption, and vice versa. It is clear from the results in Figure 1 that the difference in GDD at different seeding rates is due to the difference in the DAS to reach each growth stage.

Growing degree days also affected significantly with using different cultivars at all stages (Figure 4). Rasheed consumed more heat units at all stage except at emergence where Bohooth 22 consumed more heat units at this stage only. The highest GDD was recorded with Rasheed at physiological maturity (2063.97 °C), whereas the lowest GDD was noted with Bohooth 158 at emergence stage (125.23 °C).
Fig. 1: Phenology (days after sowing) as affected by seeding rates

Fig. 2: Phenology (days after sowing) as affected by cultivars
3.8 Phenothermal index (PTI):

The effect of seeding rate on PTI was significant at most stages except for tillering and stem elongation stages as shown in Figure 5. There was a decrease in PTI values with increasing seeding rates at stem elongation, booting, heading, anthesis and physiological maturity. At emergence stage, there was an increase in the value of PTI with increasing seeding rate from 80 kg ha$^{-1}$ till 120 kg ha$^{-1}$. During tillering stage the value of PTI increased with increasing seeding rate from 80 kg ha$^{-1}$ till 120 kg ha$^{-1}$, beyond which there was a decrease till 180 kg ha$^{-1}$ seeding rate. The highest value was noticed at seeding rates of 80, 100 and 120 kg ha$^{-1}$ during maturity stage (13.29 $^\circ$C day$^{-1}$), while the lowest value for the same trait was recorded at seeding rate of 180 kg ha$^{-1}$ during stem elongation stage (9.21 $^\circ$C day$^{-1}$).

The difference among cultivars was significant for this trait at all growth stages (Figure 6). The highest PTI value was noted with Rasheed at physiological maturity stage (13.41 $^\circ$C day$^{-1}$), while the lowest value was documented with Bohooth 158 cultivar during stem elongation stage (9.20 $^\circ$C day$^{-1}$).
3.9 Heat use efficiency (HUE):

The effect of seeding rate on heat use efficiency for biological yield was significant as shown in Figure 7. HUE increased with increasing seeding rates from 80 kg ha$^{-1}$ till 140 kg ha$^{-1}$, and then there was a decrease in HUE value till the seeding rate of 180 kg ha$^{-1}$. The highest value for this trait was obtained at seeding rate of 140 kg ha$^{-1}$ (6.749 t ha$^{-1}$), while the lowest value for the same character was noted at seed rate of 80 kg ha$^{-1}$ (5.901 t ha$^{-1}$).

Regarding the cultivars, the differences among cultivars were significant in this trait (Figure 8). Rasheed cultivar gave the highest HUE value (6.569), followed by Bohooth 22 (6.499), while Bohooth 158 gave the lowest HUE (6.154).
Fig. 7: Heat use efficiency (HUE) as influenced by seeding rates

Conclusion:
From the results it might be concluded that the seeding rates had no effect on the amount of heat units consumed by plants. The little differences in GDD at different seeding rates might be due the differences in the DAS needed at each seeding rate during each growth stage.

REFERENCES


