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# Effect of Sowing Dates and Seeding Rates on Grain Yield and Yield Components of Triticale (×*Triticosecale* Wittmack) under Basrah Governorate Conditions

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## Abstract

A field experiment was carried out during the winter season of 2023–2024 at the Agricultural Research Station of the College of Agriculture, University of Basra. The aim was to meticulously detect the influence of sowing date (20 October, 5 November, and 20 November) on different seeding rates (140, 160, and 180 kg ha$^{-1}$) in growth characteristics and yield. The experiment followed a randomized complete block design with a split-plot arrangement and three replications. The sowing dates were assigned to the main plots and the seeding rates to the sub-plots. Results revealed that sowing date and seeding rate significantly affected all major yield components and overall productivity. Early sowing on 20 October (treatment D1) consistently outperformed later dates, producing the greatest spike length (9.98 cm), spike number (618.28 spikes m$^{-2}$), grains per spike (52.85), thousand-grain weight (40.21 g), grain yield (4.94 t ha$^{-1}$), and biological yield (16.27 t ha$^{-1}$). Delaying planting to 20 November (treatment D3) reduced these traits because of higher temperatures, shorter photoperiod, and a shortened grain-filling period. Seeding rate also had marked effects. The medium rate of 160 kg ha$^{-1}$ (treatment S2) achieved the highest grain yield (4.54 t ha$^{-1}$) and biological yield (15.97 t ha$^{-1}$) by maintaining an optimal balance between plant density and resource use, while the lowest rate of 140 kg ha$^{-1}$ (treatment S1) improved spike length, grains per spike, and thousand-grain weight but lowered total spike density. Significant interactions between sowing date and seeding rate (D by S) showed that combining early sowing (D1) with the medium seeding rate (S2) produced the highest grain yield (4.92 t ha$^{-1}$) and biological yield (16.57 t ha$^{-1}$). Overall, sowing on 20 October with a seeding rate of 160 kg ha$^{-1}$ provided the most favorable conditions for balanced vegetative and reproductive growth, leading to maximum productivity of triticale under the arid climate of Basra, Iraq.

***Keywords: Triticale; sowing dates; seeding rates; grain yield; biological yield; Basrah Governorate.***

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# I. Introduction:

Triticale (× *Triticosecale* Wittmack) is an interspecific hybrid derived from wheat (*Triticum* spp.) and rye (*Secale* spp.), developed as a forage crop well suited for cultivation on low-productivity soils. Certain triticale genotypes exhibit a remarkable tolerance to stress conditions such as poor soil fertility, salinity, and drought, making this crop highly suitable for dual-purpose use—both as green forage and grain—in regions traditionally reliant on wheat and barley cultivation (Ehtaiwesh, 2022).

The sowing date is one of the most critical factors influencing the productivity of cereal crops and is more easily adjustable than other crop-management components such as cultivar choice or fertilization rates. It is directly associated with temperature and solar radiation, which vary according to climatic conditions and the growing season, thereby affecting all physiological and biological processes in the crop and ultimately determining growth and yield (Muratov & Epifantsev, 2023). Delaying sowing beyond the optimum date generally reduces potential yield, primarily because the vegetative canopy cannot fully exploit autumn sunlight.

Researchers have demonstrated that differences in the growth characteristics of triticale cultivars can lead to substantial variation in yield and its components. Rashid and Alwahid (2023) in Iraq and El-Absy (2024) in Egypt reported that cultivar-specific growth patterns play a decisive role in determining productivity. In another study, Noaema et al. (2020) examined the effect of sowing dates on several triticale cultivars under the conditions of Al-Muthanna Governorate in southern Iraq, testing three planting dates (1 November, 15 November, and 1 December). The results showed that the earliest date (1 November) was superior for most traits, recording the highest mean spike length of 13.12 cm, the greatest spike density of 684 spikes $m^{-2}$, the highest grain number of 62.06 grains $spike^{-1}$, the highest biological yield of 2.58 kg $m^{-2}$, and the greatest grain yield of 12.575 t $ha^{-1}$. The second date (15 November) excelled in 1000-grain weight, achieving a maximum mean of 45.91 g. Conversely, the latest date (1 December) produced the lowest grain yield (7.608 t $ha^{-1}$) and the fewest grains per spike (54.67 grains $spike^{-1}$). These findings confirm that early sowing promotes increased spike length and grain number per spike.

Aziz and Qadir (2022) demonstrated that seeding rate (200 R1, 300 R2, and 400 R3 seeds $m^{-2}$) has a pronounced effect on yield traits in triticale. The highest seeding rate (R3: 400 seeds $m^{-2}$) produced the greatest mean plant height (104.44 cm), the highest spike density (505.3 spikes $m^{-2}$), and the highest grain yield (5.83 t $ha^{-1}$), indicating that increased plant density enhanced vegetative biomass and overall productivity of triticale. Conversely, the lowest seeding rate (R1: 200 seeds $m^{-2}$) excelled in certain yield components, recording the highest mean grains per spike (38.30 grains) and the greatest 1000-grain weight (43.90 g), but it showed the lowest values for spike density (452.4 spikes $m^{-2}$) and grain yield (4.98 t $ha^{-1}$).

Among the most effective and easily applied field practices for increasing crop production is the cultivation of diverse genetic lines at varying seeding rates while assessing cultivar responses to local conditions. Appropriate seeding rates can enhance yield, and improving growth characteristics along with the physiological parameters of crop development is crucial for analyzing factors that influence yield and its components. These parameters also enable the evaluation of plant growth stages and dry matter production and accumulation (Baygi et al., 2017).

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Several researchers have reported that differences in growth traits among triticale cultivars lead to variations in yield and its components (Rashid & Alwahid, 2023; El-Absy, 2024). Variability in seeding rates alters plant density per unit area, thereby affecting growth traits, yield, and yield components. Abbas and Omer (2022) and Abdullah & Khalaf (2023) demonstrated that seeding-rate differences significantly influence growth and productivity traits, while Al-Hamidawi and Noaema (2024) noted that growth characteristics and productivity of rye types also vary with seeding rate. Studies further indicate that the relationship between spike number per unit area and grain yield is most evident under low plant densities, especially in small fields that permit extensive tillering; in dense plant communities, however, intense competition for light may negatively affect the association between yield components (Batool et al., 2022).

Given the limited research on triticale production compared to wheat, most agronomic recommendations for triticale cultivars have traditionally been derived from wheat studies. To address this gap, the present study aimed to evaluate the effects of sowing dates and different seeding rates on the yield and its components of four triticale cultivars under the climatic conditions of Basra, Iraq, and to identify the optimal planting date and density for maximizing production.

## II. : Materials and Methods

A field experiment was conducted during the 2023–2024 growing season at the Agricultural Research Station of the College of Agriculture, University of Basrah (30°34′11″ N, 47°45′05″ E). According to the Amberg climatic classification, the region is characterized as arid, with a total annual rainfall of only 98.65 mm during the 2023/2024 season. Air temperatures ranged from a minimum of 8.96 °C in January to a maximum of 36.94 °C in October.

**Table (1): Meteorological data of the experimental site of growing season in 2023–2024.**

| | October | November | December | January | February | March | April |
|---|---|---|---|---|---|---|---|
| Max. temperature (°C) | 36.94 | 23.87 | 21.07 | 22.02 | 21.28 | 25.59 | 34.11 |
| Min. temperature (°C) | 21.14 | 9.62 | 10.30 | 8.96 | 9.30 | 12.05 | 19.26 |
| Accumulated temperature | 745.25 | 352.33 | 331.23 | 325.31 | 298.41 | 428.27 | 650.53 |
| Total solar radiation (MJ $m^{-2}$ $day^{-1}$) | 12.37 | 9.76 | 11.68 | 10.81 | 12.40 | 15.00 | 17.33 |
| Precipitation (mm) | 0.30 | 1.30 | 18.45 | 7.70 | 26.10 | 37.9 | 6.90 |
| Max. relative humidity (%) | 45.94 | 86.84 | 88.03 | 81.82 | 86.99 | 81.58 | 58.24 |
| Min. relative humidity (%) | 12.24 | 27.14 | 35.06 | 26.75 | 30.03 | 23.99 | 13.07 |

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A randomized complete block design (RCBD) with a split-factorial arrangement and three replications was employed. The main plots included three sowing dates—20 October, 5 December, and 20 December—designated as D1, D2, and D3, respectively. In the sub-plots, the second factor, seeding rate, was randomly assigned with three levels: 140, 160, and 180 kg ha$^{-1}$, designated as S1, S2, and S3, respectively.

Soil samples were randomly collected at a 30 cm depth from various locations within the experimental field. The fundamental physical and chemical properties of these samples are presented in Table 2.

**Table 2. Chemical and physical properties of the experimental soil before sowing.**

| Properties | Value | Unit |
|---|---|---|
| EC | 7.82 | ds m$^{-1}$ |
| PH | 7.62 | - |
| OM | 2.05 | g kg$^{-1}$ |
| N | 38.50 | mg kg$^{-1}$ |
| P | 12.25 | mg kg$^{-1}$ |
| K | 139.50 | mg kg$^{-1}$ |
| Sand | 287.30 | g kg$^{-1}$ |
| Silt | 596.70 | g kg$^{-1}$ |
| Clay | 116.00 | g kg$^{-1}$ |
| Soil texture | Loamy silt | - |

Seeds were sown in six parallel rows spaced 20 cm apart, with each sub-plot measuring 2 × 1.5 m². Nitrogen fertilizer was applied as urea (46 % N) at a total rate of 120 kg ha$^{-1}$ in two equal splits: the first at seedling emergence and the second 60 days after planting. Phosphorus was applied as triple superphosphate (46 % $P_2O_5$) at 80 kg ha$^{-1}$. Irrigation and weeding were carried out as required throughout the growing season. Harvesting took place when 50–75 % of the plants reached full maturity.

**Traits studied:**

1. Spike length (cm): The mean of ten randomly selected spikes, measured from the base to the terminal tip (excluding awns) at physiological maturity.
2. Spike Number (spikes m$^{-2}$): Determined using a 1 m² quadrat.
3. Number of Grains per Spike (grains spike$^{-1}$): The mean grain number of twenty randomly selected spikes.
4. Thousand-Grain Weight (g): Calculated by weighing 250 grains and multiplying by four.
5. Biological yield (t ha$^{-1}$): Determined from the total above-ground biomass harvested from a 1 m² area.
6. Grain yield (t ha$^{-1}$): Weighed after threshing and cleaning the harvested grain.

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Data were statistically analyzed using the GenStat 12.1 statistical software (table 3), and means were compared using the least significant difference (LSD) test at p ≤ 0.05.

**Table (3): Mean squares for the studied parameters of triticale.**

| S.O.V | df | SL (cm) | SN (spike $m^{-2}$) | GN (grains $spike^{-1}$) | TGW (gm) | GY (t. $ha^{-1}$) | BY (t. $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| **Replicate** | 2 | 107.623 | 15021.7 | 1166.353 | 410.9034 | 0.32103 | 72.1726 |
| **Sowing Dates (D)** | 2 | 1.20085 ** | 334801.8 ** | 116.339 ** | 297.674 ** | 13.25828 ** | 38.2847 * |
| **Error** | 4 | 0.00979 | 642.7 | 0.001 | 0.0087 | 0.00913 | 5.0292 |
| **Seeding Rate (S)** | 2 | 2.75673 ** | 18988.4 ** | 223.578 ** | 129.4876 ** | 0.35521 ** | 23.0162 ** |
| **D × S** | 4 | 0.11542 ** | 895.2 ** | 12.395 N.S | 21.0504 ** | 0.12988 * | 2.1217 ** |
| **Error** | 12 | 0.01292 | 101.50 | 6.633 | 0.8871 | 0.04011 | 0.2589 |

*Significant at $p \leq 0.05$; ** Significant at $p \leq 0.01$; (ns) non-significant

Legend: SL, spike length; SN, spike number $m^{-2}$; GN, grain number per spike; TGW, thousand- grain weight; GY, grain yield; BY, biology yield.

## III. Results and Discussion

### 1. Spike Length (cm):

The results in Table 4 show that spike length was significantly affected by sowing date. The earliest sowing date (D1) produced the greatest mean spike length (9.98 cm), whereas the latest date (D3) resulted in a markedly shorter mean of 9.62 cm. This difference can be attributed to the more favorable environmental conditions associated with early planting, which provided moderate temperatures and an appropriate photoperiod during the critical floral development stages. These conditions promoted internode elongation along the spike axis, leading to longer spikes capable of carrying more grains. Similar findings were reported by Altai et al. (2024) for rye and by Mohammed and Mohammed (2022) for triticale, where early or optimum sowing enhanced spike length and grain set compared with delayed planting, which shortened the grain-filling period and exposed plants to heat stress.

Table 4 also indicates a significant effect of seeding rate on spike length. The lowest seeding rate (S1) recorded the highest mean spike length (10.10 cm), whereas spike length decreased progressively with increasing seeding rate,

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reaching 9.60 cm at the highest rate (S3). Reduced plant density lessens competition for resources such as water, light, and nutrients, allowing for greater vegetative growth and spike elongation. In contrast, higher seeding rates increase crowding and shading, limiting spike extension and resulting in shorter spikes. These observations are consistent with the findings of Sadullaevich and Meylikovich (2023), who reported that moderate seeding densities enhance spike length and grain number, whereas excessive density suppresses spike growth due to intensified competition.

Furthermore, the sowing date × seeding rate interaction (D × S) was significant. The combination of early sowing (D1) with the lowest seeding rate (S1) achieved the greatest mean spike length (10.28 cm), whereas the latest sowing date combined with the intermediate seeding rate (D3 × S2) recorded the shortest mean spike length (9.41 cm).

**Table (4): The effect of Sowing dates and seeding rates on spike length (cm) of triticale**

| D×S | **Seeding Rates** | | | Mean |
|---|---|---|---|---|
| **Sowing Dates** | **S1** | **S2** | **S3** | |
| **D1** | 10.28 | 9.82 | 9.83 | 9.98 |
| **D2** | 10.09 | 9.69 | 9.44 | 9.74 |
| **D3** | 9.92 | 9.41 | 9.53 | 9.62 |
| Mean | 10.10 | 9.64 | 9.60 | |
| LSD $_{p \leq 0.05}$ | S | D | D×S | |
| | 0.05 | 0.06 | 0.09 | |

**2. Spike Number (spikes m⁻²):**

The results in Table 5 indicate that sowing date had a significant effect on spike number. The earliest planting date (D1) produced the highest mean of 626.70 spikes $m^{-2}$, whereas the latest date (D3) recorded only 474.40 spikes $m^{-2}$—a relative reduction of 24.3 % compared with D1. This decline is attributed to the more favorable environmental conditions provided by early sowing, including moderate temperatures and an appropriate photoperiod (Table 1), which enhance photosynthetic efficiency and carbohydrate accumulation, thereby increasing the number of tillers that subsequently develop into productive spikes. In contrast, delayed sowing exposed plants to lower temperatures and shorter day lengths during the stem-elongation stage, limiting lateral tillering and resulting in fewer spikes. These findings agree with the reports of Aziz and Qadir (2022) and Ehtaiwes and Emsahel (2023) for triticale, who confirmed that early planting offers optimal conditions for increased tiller and spike formation, while late planting leads to significant reductions because of thermal and photoperiod stress.

Table 5 also shows a significant effect of seeding rate on spike number. The highest seeding rate (S3: 180 kg $ha^{-1}$) achieved the greatest mean spike density of 546.74 spikes $m^{-2}$, followed closely by the medium rate S2 (160 kg $ha^{-1}$) with 558.86 spikes $m^{-2}$, whereas the lowest rate (S1: 140 kg $ha^{-1}$) recorded the smallest mean of 514.43 spikes $m^{-2}$. The superiority of the higher seeding rate is due to greater plant density, which provided more plants per unit area and thus more effective tillers that developed into productive spikes. Conversely, the lower plant density of S1 allowed more space for individual plant growth but reduced the total number of plants and tillers per unit area, leading to fewer

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spikes overall despite improved individual growth. These results are consistent with Omer and Abbas (2022), who observed that increasing seeding rate raised total spike number per unit area by promoting more tiller formation.

The interaction between sowing date and seeding rate (D × S) was also significant. The combination of early sowing (D1) with the medium seeding rate (S2) achieved the highest mean spike density of 638.67 spikes $m^{-2}$, which did not differ significantly from D1 × S3 (622.46 spikes $m^{-2}$). In contrast, the latest sowing date with the lowest seeding rate (D3 × S1) produced the lowest mean spike density at 397.92 spikes $m^{-2}$.

**Table (5): The effect of Sowing dates and seeding rates on spike number (spike $m^{-2}$) of triticale**

| D×S | Seeding Rates | | | Mean |
|---|---|---|---|---|
| **Sowing Dates** | **S1** | **S2** | **S3** | |
| **D1** | 593.71 | 638.67 | 622.46 | 626.70 |
| **D2** | 551.67 | 587.83 | 568.92 | 596.50 |
| **D3** | 397.92 | 450.08 | 448.83 | 474.00 |
| Mean | 540.90 | 570.60 | 586.10 | |
| LSD $_{p \leq 0.05}$ | S | D | D×S | |
| | 4.74 | 16.59 | 16.26 | |

**3. Number of Grains per Spike (grains $spike^{-1}$):**

The results in Table 6 reveal a significant effect of sowing date on the number of grains per spike. The second sowing date (D2: 5 November) produced the highest mean grain number (52.22 grains $spike^{-1}$) compared with the other dates. This superiority is attributed to the favorable environmental conditions of temperature and photoperiod during flowering and pollination (Table 1), which enhanced floret fertility and reduced floret abortion, thereby increasing the number of fully developed grains. In contrast, delaying sowing to D3 (20 November) significantly reduced the grain number to 49.47 grains $spike^{-1}$, likely because plants experienced relatively higher temperatures and shorter day lengths during flowering and fertilization, which negatively affected pollination efficiency and grain set. These findings are consistent with Mohammed and Mohammed (2022), who reported that a 5 November planting date produced the greatest grains per spike in triticale due to optimal conditions during flowering and grain filling.

Table 6 also shows a significant effect of seeding rate. The lowest seeding rate (S1) recorded the greatest mean grain number per spike (55.47 grains), whereas the count declined progressively with increasing seeding rate, reaching 54.52 grains at S2 and 52.25 grains at S3. This advantage is closely related to greater spike length at the lower density, which allowed more spikelets and grains per spike. Lower plant density reduces competition for light, nutrients, and water, improving resource allocation and enhancing pollination efficiency and grain formation. These results align with Liu et al. (2024), who noted that moderate to low seeding rates improve yield components by enhancing photosynthetic efficiency and optimizing resource distribution within the crop stand, whereas higher seeding rates can reduce photosynthetic efficiency due to shading and intense competition.

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The interaction between sowing date and seeding rate (D × S) was not significant for grains per spike.

**Table (6): The effect of Sowing dates and seeding rates on number of grains per spike (grains spike⁻¹) of triticale**

| D×S | Seeding Rates | | | Mean |
|---|---|---|---|---|
| **Sowing Dates** | **S1** | **S2** | **S3** | |
| **D1** | 54.46 | 52.59 | 51.49 | 54.07 |
| **D2** | 54.93 | 51.95 | 49.77 | 56.26 |
| **D3** | 52.70 | 49.83 | 45.88 | 51.92 |
| Mean | 55.47 | 54.52 | 52.25 | |
| LSD $_{p \leq 0.05}$ | S | D | D×S | |
| | 1.21 | 0.02 | N.S | |

**4. Thousand-Grain Weight (g):**

The results in Table 7 show a significant effect of sowing date on thousand-grain weight. The earliest sowing date (D1) recorded the highest grain weight of 40.21 g, while grain weight declined progressively with later planting, reaching the lowest value of 34.55 g at the latest date (D3). This superiority of early sowing is attributed to the favorable environmental conditions during the grain-filling stage, where a longer photoperiod and moderate temperatures supported sustained photosynthesis and greater carbohydrate deposition in the grains, thereby increasing grain weight. In contrast, delayed sowing exposed plants to relatively higher temperatures during grain filling, shortening this period, hastening maturity, and ultimately reducing grain weight. These findings agree with those of Lakhani et al. (2025) on wheat, who reported that timely sowing enhances grain specific weight by aligning grain filling with optimal environmental conditions. Similarly, Noaema et al. (2020) found that early sowing of triticale produced the highest thousand-grain weight compared with later sowings that experienced heat stress and a shortened filling period, confirming that early planting provides ideal conditions to prolong grain filling and increase grain weight, thereby improving yield components and final productivity.

Table 7 also demonstrates a significant influence of seeding rate on thousand-grain weight. The lowest seeding rate (S1) achieved the greatest mean grain weight of 39.66 g, followed by the medium rate (S2), whereas the highest rate (S3) resulted in a significant decrease to 35.88 g. This effect is explained by the reduced competition for light and nutrients at lower plant densities, which allows better conditions for grain filling. These results align with El Hag (2024) and Liu et al. (2024), who reported that increased plant density reduces grain weight due to intensified intra-plant competition, while low to moderate seeding rates provide a better balance among yield components.

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The interaction between sowing date and seeding rate (D × S) was also significant. The combination of early sowing with the lowest seeding rate (D1 × S1) produced the highest thousand-grain weight (41.31 g), whereas the latest sowing combined with the highest seeding rate (D3 × S3) recorded the lowest value (31.87 g).

**Table (7): The effect of Sowing dates and seeding rates on thousand- grain weight (gm) of triticale**

| D×S | **Seeding Rates** | | | Mean |
|---|---|---|---|---|
| **Sowing Dates** | **S1** | **S2** | **S3** | |
| **D1** | 41.31 | 39.30 | 40.03 | 40.21 |
| **D2** | 40.11 | 38.92 | 35.75 | 38.26 |
| **D3** | 37.56 | 34.23 | 31.87 | 34.55 |
| Mean | 39.66 | 37.48 | 35.88 | |
| LSD $_{p \le 0.05}$ | S | D | D×S | |
| | 0.44 | 0.06 | 0.63 | |

**5. Grain Yield (t ha⁻¹):**

The results in Table 8 show that sowing date had a significant effect on grain yield. The earliest sowing date (D1) produced the highest mean yield of 4.94 t $ha^{-1}$, whereas yield declined steadily with delayed planting, reaching the lowest value of 3.77 t $ha^{-1}$ at D3. This superiority of early sowing reflects its positive influence on yield components: D1 recorded the greatest spike number (618.28 spikes $m^{-2}$), longer spikes (9.98 cm), more grains per spike (52.85 grains), and the heaviest thousand-grain weight (40.21 g). Together, these components directly contributed to higher grain yield. In contrast, late sowing exposed plants to unfavorable conditions such as higher temperatures, accelerated maturity, and a shortened grain-filling period, all of which reduced assimilate accumulation in the grain. These findings agree with Tomple and Jo (2019), Liu et al. (2021), and Kanapickas et al. (2024), who emphasized that the combined performance of yield components is the principal determinant of yield differences among sowing dates, with early sowing achieving the greatest grain yield in triticale.

Table 8 also indicates a significant effect of seeding rate. The medium seeding rate (S2) achieved the highest mean yield of 4.54 t $ha^{-1}$, compared with 4.34 t $ha^{-1}$ at the low rate (S1) and 4.47 t $ha^{-1}$ at the high rate (S3). The advantage of S2 is attributed to its optimal balance among yield components, particularly its high spike density (558.86 spikes $m^{-2}$), which provided more productive units without a marked reduction in thousand-grain weight. This finding confirms that a medium seeding rate creates a favorable equilibrium among yield components, thereby enhancing grain yield. Similar results were reported by Abdulkerim et al. (2015) for triticale, where a seeding rate of 160 kg $ha^{-1}$

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was most efficient in increasing grain yield through a balanced contribution of its components compared with lower or higher rates.

The sowing date × seeding rate interaction (D × S) was also significant. The combination of early sowing with the medium seeding rate (D1 × S2) produced the highest grain yield (4.92 t ha⁻¹), not differing significantly from D1 × S1 (4.82 t ha⁻¹). Conversely, the latest sowing combined with the highest seeding rate (D3 × S3) recorded the lowest mean grain yield (3.85 t ha⁻¹), highlighting the negative effect of late planting coupled with high plant density on final yield.

**Table (8): The effect of Sowing dates and seeding rates on grain yield (t ha⁻¹) of triticale**

| D×S | Seeding Rates | | | Mean |
|---|---|---|---|---|
| **Sowing Dates** | **S1** | **S2** | **S3** | |
| **D1** | 4.82 | 4.92 | 5.07 | 4.94 |
| **D2** | 4.53 | 4.84 | 4.57 | 4.65 |
| **D3** | 3.68 | 3.85 | 3.79 | 3.77 |
| **Mean** | 4.43 | 4.54 | 4.47 | |
| LSD $_{p \leq 0.05}$ | S | D | D×S | |
| | 0.09 | 0.06 | 0.14 | |

**6. Biological Yield (t ha⁻¹):**

The results in Table 9 show that sowing date had a significant effect on biological yield. The earliest planting date (D1) achieved the highest mean yield of 16.27 t ha⁻¹, while yield declined progressively with delayed planting, reaching the lowest mean of 14.22 t ha⁻¹ at D3. This superiority of early sowing reflects its direct influence on yield components, including the highest spike number (618.28 spikes m⁻²), greatest grains per spike (52.85 grains spike⁻¹), and heaviest thousand-grain weight (40.21 g). These attributes enhanced grain yield and, combined with favorable conditions for vegetative growth and photosynthetic efficiency, contributed to the higher total biological yield. Similar findings were reported by Tahir et al. (2019) and Ali et al. (2021) for triticale, where early planting (1 November) significantly improved plant height, spike length, spike number, grain yield, and biological yield, whereas delaying sowing to 1 December reduced all growth and productivity traits. Thus, early planting (D1) provided optimal environmental conditions for balanced vegetative and reproductive growth, which translated into greater total biomass, while delaying planting to D3 caused a decline in both yield and its components.

Table 9 also demonstrates a significant effect of seeding rate. The medium seeding rate (S2) recorded the highest mean biological yield of 15.97 t ha⁻¹, compared with 15.58 t ha⁻¹ at the low rate (S1) and 14.43 t ha⁻¹ at the high rate (S3). This advantage of the medium rate is attributed to its better balance between plant density and resource utilization

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(light, water, and nutrients). Moderate density reduced interplant competition and provided favorable conditions for dry matter accumulation, ultimately increasing biological yield. These findings are consistent with Al-Dahi and Al-Taweel (2021), who concluded that moderate seeding rates provide the best balance among yield components, while excessive plant density increases competition and limits dry matter accumulation.

The sowing date × seeding rate interaction was also significant. The combination of early sowing with the medium seeding rate (D1 × S2) achieved the highest biological yield of 16.57 t ha⁻¹, whereas the latest sowing with the highest seeding rate (D3 × S3) recorded the lowest mean of 13.18 t ha⁻¹.

**Table (9): The effect of Sowing dates and seeding rates on biological yield (t ha⁻¹) of triticale**

| D×S | **Seeding Rates** | | | Mean |
|---|---|---|---|---|
| **Sowing Dates** | **S1** | **S2** | **S3** | |
| **D1** | 16.10 | 17.03 | 15.67 | 16.27 |
| **D2** | 15.67 | 16.34 | 14.45 | 15.48 |
| **D3** | 14.96 | 14.54 | 13.18 | 14.42 |
| Mean | 15.58 | 15.97 | 14.43 | |
| LSD $_{p \leq 0.05}$ | S | D | D×S | |
| | 0.24 | 1.47 | 1.44 | |

## IV. Conclusion:

This study demonstrated that both sowing date and seeding rate exert a significant influence on the growth traits and yield performance of triticale under the arid conditions of Basrah, Iraq. Early planting on 20 October provided the most favorable environment for vegetative growth and grain filling, resulting in the highest spike length, spike number, grains per spike, thousand-grain weight, and consequently the greatest grain and biological yields. Among the seeding rates, 160 kg ha⁻¹ achieved the best balance between plant density and resource use, maximizing productivity without compromising grain size. The interaction of early sowing with the medium seeding rate further enhanced yield potential, confirming that this combination offers the optimal agronomic practice for triticale production in similar arid environments.

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