Effect of Seeding rate and NPK Fertilizer Levels on Growth and Production of Forage and Grain Yield of Triticale (*Triticosecale Wittmack*)

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Abstract

The field experiment for cultivating triticale was conducted during the 2024–2025 growing season in farmers' fields in Nineveh Governorate at two locations: the first in Omar Qabaji village, affiliated with Bashiqa District, and the second in Al-Qunsiya village, affiliated with Al-Ahmediyat District. The study aimed to determine the role of seeding rates and NPK fertilizer levels and their effects on the growth and productivity of triticale. The experiment according design (RCBD) with a factorial Experiment. The study included two factors: the first was three seeding rates (120, 160, and 200 kg ha^{-1}), and the second was three levels of NPK fertilizer (120, 160, and 200 kg ha^{-1}), with three replications. The results showed the superiority of the highest seeding rate (200 kg ha^{-1}) at both Omar Qabaji and Al-Qunsiya locations in terms of number of tillers (779.11 and 625.93 tillers m^{-2}), number of spikes (574.89 and 506.22 spikes m^{-2}), green forage yield (5515.3 and 3568.7 g m^{-2}), dry forage yield (1092.63 and 887.60 g m^{-2}), and grain yield (1056.53 and 627.44 g m^{-2}), respectively. The highest NPK fertilizer level (200 kg ha^{-1}) was superior at both locations in plant height (108.66 and 98.96 cm, respectively), and it did not significantly differ from the 160 kg ha^{-1} level in most of the studied traits at both locations. It was concluded that the interaction between the seeding rate of 200 kg ha^{-1} and the fertilizer level of 200 kg ha^{-1} had a positive effect on increasing most of the studied traits as well as the forage and grain yields of triticale.

Keywords: sustainability, triticale, NPK fertilizer, seeding rate.

Introduction

Triticale (*Trititcosecale Wittmack*) is considered one of the relatively modern cereal crops, as it combines the high yield potential of wheat with the environmental stress tolerance characteristic of rye. This combination has enabled triticale to grow and produce under a wide range of agro-ecological conditions [10]. This hybridization has resulted in a crop with high efficiency in utilizing available resources, in addition to its ability to withstand harsh environmental conditions, making it one of the promising crops for enhancing and sustaining forage production. Moreover, triticale has gained considerable attention in many countries seeking to increase green and dry forage production, due to its high biomass yield and elevated protein content in both grain and green forage. Accordingly, it represents an important tool for improving feed efficiency and achieving economic benefits in mixed farming systems [2]. Triticale is also characterized by its good growth performance in poor and moderately fertile soils compared with wheat, which reinforces its role in the efficient utilization of agricultural resources.

The seeding rate is considered one of the important factors affecting the growth of triticale, as it is directly associated with plant density and inter-plant competition for growth resources, and consequently influences both forage yield and grain yield as well as

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production quality. Numerous studies have indicated that selecting an appropriate seeding rate contributes to improving yield and achieving a balance between quantitative and qualitative traits [3].

Among the decisive factors controlling plant growth and development is NPK fertilization, due to the fundamental physiological roles of nitrogen, phosphorus, and potassium. Nitrogen is involved in the synthesis of proteins and plant biomass, phosphorus contributes to root system development and improves flowering and fruiting, while potassium enhances stress tolerance and improves water-use efficiency. Therefore, determining the optimum level of NPK fertilization is a crucial step toward achieving the highest possible productivity [12].

This study aims to determine the appropriate seeding rate and the optimum fertilizer level to achieve the highest forage and grain yield of triticale, in addition to identifying the best interaction between seeding rates and fertilizer levels to obtain superior plant performance that positively reflects on increasing green biomass and grain yield.

Materials and Methods

The experiment was conducted during the 2024–2025 growing season to cultivate triticale (cv. Admiral) in Nineveh Governorate. The study relied on two geographically distinct experimental locations: the first was located in Omar Qabaji village within Bashiqa District, northeast of Mosul, while the second was in Al-Qunsiya village, affiliated with Hamidat District, northwest of Mosul. The first location is approximately 22 km from the center of Mosul, whereas the second is about 31 km away, with a distance of nearly 50 km between the two locations. Both locations lie within semi-rainfed areas, and sprinkler irrigation was used during periods of rainfall shortage. A factorial experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. The experiment included two factors: the first factor consisted of three seeding rates 120, 160, and 200 kg ha^{-1}, while the second factor comprised three levels of NPK fertilizer 120, 160, and 200 kg ha^{-1}. Land preparation at both locations involved plowing, harrowing, and leveling, after which the field at each location was divided into three blocks. Each block contained nine experimental units, with each unit measuring 4 × 4 m.Sowing was carried out manually using the designated seeding rates, and the fertilizer treatments were applied at sowing. Seeds were planted in parallel rows spaced 20 cm apart, with a distance of 60 cm between experimental units and 100 cm between blocks at both locations. Soil samples were collected from both locations and analyzed to determine their physical and chemical properties at the laboratories of the Department of Soil and Water Resources, College of Agriculture and Forestry, University of Mosul. Green forage was cut at the early booting stage at both locations. Harvesting was carried out on 22 May 2025 at the Omar Qabaji location and on 23 May 2025 at the Al-Qunsiya location.

Studied Traits:

1. **Plant height cm**

Stem length was measured for ten randomly selected plants from each experimental unit at the end of the flowering stage. Measurement was taken from the stem base at soil surface up to the tip of the spike, excluding the awns. The average value was then calculated to represent plant height for that unit.

2. **Flag leaf area cm^{-2}**

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Twenty plants were randomly selected from each experimental unit. The flag leaf area of each plant was estimated using the following equation: [23] **Flag leaf area cm^{-2} = maximum leaf length × maximum leaf width × 0.95**

3. Number of tillers per square meter tillers m^{-2}

The number of tillers was estimated at the flowering stage within an area of one square meter by counting the tillers in three central rows, each one meter in length. The average of these three counts was calculated and converted to represent the number of tillers per square meter.

4. Number of spikes spikes m^{-2}

After harvesting, the number of spikes within one square meter was counted for each experimental unit. This value was then used to compute the average spike density for each treatment.

5. Green forage yield g m^{-2}

An area of one square meter was cut from the central rows of each experimental unit at the early booting stage. The green forage yield was measured directly in the field using an electronic balance.

6. Dry forage yield g m^{-2}

A sample weighing 150 g of fresh forage was taken and dried in an electric oven at the Seed Technology Laboratory, Department of Field Crops, at 70°C for 72 hours until a constant weight was obtained. The dry sample was then weighed using a sensitive electronic balance. Based on the obtained dry weight, moisture content was calculated using the following equation: [25]

Moisture content (%) = 100 × (fresh sample weight − dry sample weight) ÷ fresh sample weight.

Thereafter, dry matter percentage was calculated as:

Dry matter (%) = 100 − moisture content (%).

Dry forage yield per square meter was estimated by multiplying the green forage yield by the dry matter percentage to determine dry forage weight (g m^{-2}).

7. Grain yield g m^{-2}

Grains were separated from the spikes collected from one square meter in each experimental unit and weighed using a sensitive electronic balance. Grain yield per square meter was thus determined for each treatment.

After completing data collection for all studied traits, the results were subjected to statistical analysis according to the Design (RCBD) in a factorial arrangement using the SAS statistical software. The means were compared using Duncan's Multiple Range Test (DMRT) at the 5% probability level [6].

Results and discussion

1. Plant height cm

Table 1 shows that there were significant differences among seeding rates in plant height at both study locations. At the Omar Qabaji location, the seeding rates of 160 and 200 kg ha^{-1} were significantly superior to the 120 kg ha^{-1} rate and recorded the highest mean values for plant height, reaching 102.24 and 102.22 cm, respectively. At the Al-Qunsiya location, the highest seeding rate 200 kg ha^{-1} was significantly superior to the seeding rates of 160 and 120 kg ha^{-1} and recorded the highest mean value of plant height 97.33 cm. In contrast, the lowest plant height in both locations was recorded at the lowest seeding rate (120 kg ha^{-1}), reaching 99.69 and 90.14 cm at Omar Qabaji and Al-Qunsiya, respectively. High plant density leads to increased shading, which enhances the production of auxins that stimulate cell elongation and stem growth. Conversely, plant height decreases at low seeding rates due to reduced competition, which allows light to reach plants easily and reduces the need for vertical growth. These results are consistent with the findings of [4]and [21], who reported an increase in plant height with increasing seeding rate.

Table 1 shows that NPK fertilizer levels had a significant effect on plant height at both study locations. The fertilizer level of 200 kg ha^{-1} was significantly superior to the levels of 160 and 120 kg ha^{-1}, recording the highest mean plant height at the Omar Qabaji and Al-Qunsiya locations, which reached 108.66 and 98.96 cm, respectively. In contrast, the lowest mean plant height at both locations was recorded at the fertilizer level of 120 kg ha^{-1}, amounting to 93.92 and 86.78 cm at Omar Qabaji and Al-Qunsiya, respectively. The increase in plant height with increasing fertilizer levels, particularly nitrogen and phosphorus, can be attributed to their role in enhancing chlorophyll formation, protein synthesis, and enzyme activity, which in turn increases photosynthetic efficiency and stimulates cell division and elongation. Moreover, the major nutrients contribute to activating the production of plant hormones such as gibberellins and auxins, which are directly responsible for promoting stem elongation. This result is in agreement with the findings of [16]who reported that increasing fertilizer application had a significant positive effect on plant height.

The results presented in the table indicated a significant effect of the two-factor interaction between seeding rate and NPK fertilizer levels on plant height at both study locations, The treatment with a seeding rate of 200 kg ha^{-1} combined with a fertilizer level of 200 kg ha^{-1} was superior, recording the highest mean plant height at the two study sites, Omar Qabaji and Al-Qunsiya, reaching 110.22 and 101.88 cm, respectively. At the Omar Qabaji location, this treatment did not differ significantly from the seeding rates of 120 and 160 kg ha^{-1} at the fertilizer level of 200 kg ha^{-1}, which recorded mean plant heights of 108.24 and 107.51 cm, respectively. Similarly, at the Al-Qunsiya location, no significant differences were observed between this treatment and the seeding rate of 200 kg ha^{-1} at the fertilizer level of 160 kg ha^{-1}, as well as the seeding rate of 160 kg ha^{-1} at the fertilizer level of 200 kg ha^{-1}, which recorded mean values of 98.92 and 98.99 cm, respectively. These results demonstrate that the effect of increasing fertilizer levels on plant height was more pronounced than that of increasing the seeding rate. In contrast, the treatment combining a seeding rate of 120 kg ha^{-1} with a fertilizer level of 120 kg ha^{-1} recorded the lowest mean plant height at the Omar Qabaji and Al-Qunsiya locations, reaching 92.33 and 81.64 cm, respectively.

Table 1: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Plant Height (cm) during the 2024–2025 Growing Season.

Omar Qabji				
Seeding Raet	**Fertilizer NPK**			**Means Seeding Raet**
	120 kg ha^{-1}	**160 kg ha^{-1}**	**200 kg ha^{-1}**	
120 kg ha^{-1}	92.33 e	98.48 d	108.24 a	99.69 b
160 kg ha^{-1}	96.87 d	102.34 c	107.51 ab	102.24 a
200 kg ha^{-1}	92.56 e	103.87 b c	110.22 a	102.22 a
Means of Fertilizer	93.92 c	101.56 b	108.66 a	——
Al-Qunisiyah				

120 kg ha^{-1}	81.64 f	92.76 cd	96.01 bc	90.14 c
160 kg ha^{-1}	87.51 e	95.31 bc	98.99 ab	93.94 b
200 kg ha^{-1}	91.19 de	98.92 ab	101.88 a	97.33 a
Means of Fertilizer	86.78 c	95.66 b	98.96 a	——

2. Flag leaf area cm²

Table 2 shows a significant effect of seeding rates on flag leaf area at both study locations. At the Omar Qabaji location, the seeding rate of 120 kg ha^{-1} was significantly superior to the seeding rates of 160 and 200 kg ha^{-1} and recorded the highest mean flag leaf area, reaching 27.07 cm². At the Al-Qunsiya location, the seeding rates of 120 and 160 kg ha^{-1} were significantly superior to the seeding rate of 200 kg ha^{-1}, recording the highest mean values of 19.22 and 19.63 cm², respectively. In contrast, the highest seeding rate 200 kg ha^{-1} recorded the lowest mean values for this trait, amounting to 22.94 and 18.11 cm² at the two locations, respectively. The reduction in flag leaf area at high seeding rates is attributed to the increased competition among plants for light, water, and nutrients. High plant density limits light penetration and restricts normal leaf growth. This finding is consistent with the results reported by [5]and [11].

The results presented in Table 2 indicate a significant effect of NPK fertilizer levels on flag leaf area at both study locations, Omar Qabaji and Al-Qunsiya. The fertilizer levels of 160 and 200 kg ha^{-1} were significantly superior to the 120 kg ha^{-1} level, recording the highest mean values of flag leaf area, reaching 25.29 and 27.35 cm² at the Omar Qabaji location, and 20.10 and 19.32 cm² at the Al-Qunsiya location, respectively. In contrast, the fertilizer level of 120 kg ha^{-1} recorded the lowest mean values for this trait, amounting to 22.19 and 17.54 cm² at the Omar Qabaji and Al-Qunsiya locations, respectively. The reduction in flag leaf area at lower NPK fertilizer levels is attributed to the deficiency of essential nutrients required for chlorophyll formation and the activation of photosynthesis, which limits carbohydrate production and weakens cell division and elongation, thereby resulting in smaller leaf size. This finding is consistent with the results reported by [26]who confirmed a decrease in flag leaf area with reduced fertilizer levels.

Table 2 also shows a significant effect of the interaction between seeding rates and NPK fertilizer levels on flag leaf area at both study locations. At the Omar Qabaji location, the treatment of the 120 kg ha^{-1} seeding rate combined with the 200 kg ha^{-1} fertilizer level recorded the highest mean value for this trait 29.64 cm² and differed significantly from most other treatments, except for the treatments of the 120 kg ha^{-1} seeding rate at the 160 kg ha^{-1} fertilizer level and the 160 kg ha^{-1} seeding rate at the 200 kg ha^{-1} fertilizer level, which did not differ significantly and recorded mean values of 27.41 and 27.19 cm², respectively. At the Al-Qunsiya location, the treatments of the 120 and 160 kg ha^{-1} seeding rates at the 160 kg ha^{-1} fertilizer level recorded the highest mean values 20.23 and 20.20 cm² respectively, and did not differ significantly from most treatments. Conversely, the treatment of the highest seeding rate 200 kg ha^{-1} combined with the lowest fertilizer level 120 kg ha^{-1} recorded the lowest mean values for this trait, reaching 20.38 and 16.50 cm² at the Omar Qabaji and Al-Qunsiya locations, respectively. This interaction demonstrates that achieving a balance between seeding rate and fertilizer level ensures adequate plant nutrition, which is positively reflected in increasing the flag leaf area.

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Table 2: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Flag leaf area (cm^2) during the 2024–2025 Growing Season.

Seeding Raet	Fertilizer NPK 120 kg ha^{-1}	160 kg ha^{-1}	200 kg ha^{-1}	Means Seeding Raet
Omar Qabji				
120 kg ha^{-1}	24.16 cde	27.41 ab	29.64 a	27.07 a
160 kg ha^{-1}	22.03 ef	26.16 bcd	27.19 abc	25.13 b
200 kg ha^{-1}	20.38 f	23.20 def	25.23 b-e	22.94 c
Means of Fertilizer	22.19 b	25.59 a	27.35 a	——
Al-Qunisiyah				
120 kg ha^{-1}	17.50 bc	20.23 a	19.97 ab	19.23 ab
160 kg ha^{-1}	18.63 abc	20.20 a	20.03 ab	19.62 a
200 kg ha^{-1}	16.50 c	19.87 ab	17.97 abc	18.11 b
Means of Fertilizer	17.54 b	20.10 a	19.32 a	——

3. Number of tillers tillers m^{-2}

The results presented in Table 3 indicate a significant effect of seeding rates on the number of tillers at both study locations. It was clearly observed that increasing the seeding rate was associated with a significant increase in the number of tillers at both locations. The seeding rate of 200 kg ha^{-1} was significantly superior to the seeding rates of 120 and 160 kg ha^{-1} for this trait, recording the highest mean values of 779.11 and 625.93 tillers m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. In contrast, the lowest seeding rate 120 kg ha^{-1} recorded the lowest mean values of tiller number, amounting to 646.74 and 472.44 tillers m^{-2} at the two locations, respectively. The increase in the number of tillers with increasing seeding rate is attributed to the rise in plant density, which increases the total number of tillers per unit area despite a lower number of tillers per individual plant. Moreover, inter-plant competition contributes to stimulating tiller formation. This result is consistent with the findings of [7]and [8]who reported a significant increase in the number of tillers with increasing seeding rates.

Table 3 shows clear significant differences among NPK fertilizer levels in the number of tillers at both study locations. At the Omar Qabaji location, the highest NPK fertilizer level 200 kg ha^{-1} was significantly superior to the 120 and 160 kg ha^{-1} levels and recorded the highest mean value for this trait, reaching 786.15 tillers m^{-2}. At the Al-Qunsiya location, the fertilizer levels of 200 and 160 kg ha^{-1} were significantly superior to the lowest fertilizer level 120 kg ha^{-1}, recording the highest mean values of 593.78 and 574.67 tillers m^{-2}, respectively. In contrast, the lowest fertilizer level 120 kg ha^{-1} recorded the lowest mean values for number of tillers at both study locations, amounting to 646.78 and 478.52 tillers m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. The increase in the number of tillers with higher fertilizer levels, particularly nitrogen and phosphorus, is attributed to the activation of basal buds and the stimulation of cell division as a result of improved nutrient supply. Nitrogen enhances photosynthetic activity, while phosphorus contributes to root development and tiller formation, which is positively reflected in increased plant density and productivity. This result is in agreement with the findings of [16]and [22].

The results revealed that the interaction between seeding rates and NPK fertilizer levels had a significant effect on the number of tillers at both study locations. The treatment of the highest seeding rate 200 kg ha^{-1} combined with the highest fertilizer level 200

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kg ha^{-1} recorded the highest mean values for number of tillers at both the Omar Qabaji and Al-Qunsiya locations, reaching 863.89 and 685.33 tillers m^{-2}, respectively. This treatment did not differ significantly from the treatment of the 160 kg ha^{-1} seeding rate at the 160 kg ha^{-1} fertilizer level, and the treatment of the 200 kg ha^{-1} seeding rate at the 160 kg ha^{-1} fertilizer level at the Al-Qunsiya location, which recorded 601.78 and 644.44 tillers m^{-2}, respectively. In contrast, the lowest mean values for number of tillers were recorded for the treatment of the lowest seeding rate 120 kg ha^{-1} combined with the lowest fertilizer level 120 kg ha^{-1}, reaching 552.67 and 411.11 tillers m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. The reduction in both seeding rate and fertilizer level led to weak vegetative growth, low plant density, and limited nutrient availability, which in turn restricted tiller formation.

Table 3: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Number of tillers tillers m^{-2} during the 2024–2025 Growing Season.

Omar Qabji				
Seeding Raet	**Fertilizer NPK**			**Means Seeding Raet**
	120 kg ha^{-1}	**160 kg ha^{-1}**	**200 kg ha^{-1}**	
120 kg ha^{-1}	552.67 d	664.89 c	722.67 bc	646.74 c
160 kg ha^{-1}	684.89 c	701.44 bc	771.89 b	719.41 b
200 kg ha^{-1}	702.78 bc	770.67 b	863.89 a	779.11 a
Means of Fertilizer	646.78 c	712.33 b	786.15 a	——
Al-Qunisiyah				
120 kg ha^{-1}	411.11 e	477.78 de	528.44 cd	472.44 c
160 kg ha^{-1}	476.44 de	601.78 abc	567.56 bcd	548.59 b
200 kg ha^{-1}	548.00 bcd	644.44 ab	685.33 a	625.93 a
Means of Fertilizer	478.52 b	574.67 a	593.78 a	——

4. Number of spikes spikes m^{-2}

Data presented in Table 4 indicate a significant effect of seeding rates on the number of spikes at both study locations. The highest seeding rate 200 kg ha^{-1} was significantly superior to the seeding rates of 120 and 160 kg ha^{-1}, recording the highest mean number of spikes at the Omar Qabaji and Al-Qunsiya locations, reaching 574.89 and 506.22 spikes m^{-2}, respectively. In contrast, the lowest seeding rate 120 kg ha^{-1} resulted in the lowest mean number of spikes at both locations, amounting to 462.07 and 400.00 spikes m^{-2} at Omar Qabaji and Al-Qunsiya, respectively. The superiority of the high seeding rate in increasing the number of spikes can be attributed to the increased plant density and the associated rise in the number of tillers Table 3, which contributed to a greater number of formed spikes. Conversely, the reduction in plant density at the lower seeding rate led to fewer tillers and, consequently, a lower mean number of spikes at both study locations. This result is in agreement with the findings of [7]and [9]who reported that the number of spikes increases with increasing seeding rate.

Table 4 reveals significant differences among NPK fertilizer levels in the number of spikes at both study locations. At the Omar Qabaji location, the highest fertilizer level 200 kg ha^{-1} was significantly superior to the lowest level 120 kg ha^{-1}, recording the highest mean number of spikes 541.85 spikes m^{-2}, and it did not differ significantly from the 160 kg ha^{-1} fertilizer level, which recorded 518.37 spikes m^{-2}. At the Al-Qunsiya location, the fertilizer levels of 200 and 160 kg ha^{-1} were significantly superior to the 120 kg ha^{-1} level, recording the highest mean values of 483.85

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and 469.48 spikes m^{-2}, respectively. In contrast, the lowest fertilizer level 120 kg ha^{-1} resulted in the lowest mean number of spikes at both study locations, amounting to 486.44 and 394.67 spikes m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. The superiority of the higher NPK fertilizer levels in increasing the number of spikes is mainly attributed to the increase in the number of tillers Table 3 resulting from improved plant nutrition. Conversely, the reduction in fertilizer level led to weaker growth, fewer tillers, and consequently a lower number of spikes. This result is consistent with the findings of [16]and [24]who reported that the increase in the number of tillers at higher fertilizer levels was positively reflected in a greater number of spikes.

The results also indicate a significant interaction between seeding rates and NPK fertilizer levels in influencing the number of spikes at both locations. At the Omar Qabaji location, the treatment of the 200 kg ha^{-1} seeding rate combined with the 200 kg ha^{-1} fertilizer level recorded the highest mean value for this trait 616.22 spikes m^{-2}, and it did not differ significantly from some other treatments. At the Al-Qunsiya location, the same treatment 200 kg ha^{-1} seeding rate × 200 kg ha^{-1} fertilizer level also produced the highest mean number of spikes 560.00 spikes m^{-2}, and it did not differ significantly from the treatment of the 200 kg ha^{-1} seeding rate combined with the 160 kg ha^{-1} fertilizer level, which recorded 520.00 spikes m^{-2}. In contrast, the lowest mean number of spikes was recorded at the lowest seeding rate 120 kg ha^{-1} combined with the lowest fertilizer level 120 kg ha^{-1}, reaching 435.56 and 359.56 spikes m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. The superiority of this interaction is attributed to the high seeding rate, which increases plant density and the number of tillers, thereby enhancing spike formation. Conversely, the combination of low seeding rate and low fertilizer level resulted in weak plant growth and a reduced number of spikes.

Table 4: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Number of spikes spikes m^{-2} during the 2024–2025 Growing Season.

Omar Qabji				
Seeding Raet	**Fertilizer NPK**			**Means Seeding Raet**
	120 kg ha^{-1}	**160 kg ha^{-1}**	**200 kg ha^{-1}**	
120 kg ha^{-1}	435.56 d	469.78 cd	480.89 bcd	462.07 b
160 kg ha^{-1}	485.11 bcd	515.56 bcd	528.44 a-d	509.70 b
200 kg ha^{-1}	538.67 abc	569.78 ab	616.22 a	574.89 a
Means of Fertilizer	486.44 b	518.37 ab	541.85 a	——
Al-Qunisiyah				
120 kg ha^{-1}	359.56 e	418.67 cd	421.78 cd	400.00 c
160 kg ha^{-1}	385.78 de	469.78 bc	469.78 bc	441.78 b
200 kg ha^{-1}	438.67 cd	520.00 ab	560.00 a	506.22 a
Means of Fertilizer	394.67 b	469.48 a	483.85 a	——

5. Green Forage yield g m^{-2}

The results presented in Table 5 indicate a significant effect of seeding rates on green Forage yield at both study locations. The highest seeding rate 200 kg ha^{-1} was significantly superior to the 120 and 160 kg ha^{-1} rates, recording the highest mean green Forage yields of 5515.3 and 3568.7 g m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. In contrast, the lowest seeding rate 120 kg ha^{-1} resulted in the lowest mean green Forage yields, reaching 3990.5 and

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2669.0 g m^{-2} at the two locations, respectively. The superiority of the high seeding rate in green Forage yield is attributed to the increased plant density and the associated rise in tiller number Table 3, leaf area, and plant height Table 1, as well as improved utilization of water, light, and nutrients. These factors enhance photosynthetic efficiency and, consequently, increase yield. Conversely, a lower seeding rate leads to fewer plants and tillers, reducing green Forage yield. These results are consistent with the findings of [14]and [21] who reported that increasing the seeding rate per unit area positively affects green Forage yield.

The results presented in Table 5 show significant differences among NPK fertilizer levels in green Forage yield at both study locations. The fertilizer levels of 200 and 160 kg ha^{-1} were significantly superior to the 120 kg ha^{-1} level, recording the highest mean green Forage yields of 5061.9 and 4768.7 g m^{-2} at the Omar Qabaji location, and 3669.5 and 3433.0 g m^{-2} at the Al-Qunsiya location, respectively. In contrast, the lowest fertilizer level 120 kg ha^{-1} resulted in the lowest mean green Forage yields, reaching 4151.1 and 2153.3 g m^{-2} at Omar Qabaji and Al-Qunsiya, respectively. The superiority of the higher NPK levels in green Forage yield is attributed to the integrated role of the macronutrients in enhancing vegetative growth, increasing the number of tillers Table 3, expanding leaf area, and improving photosynthetic efficiency. These factors collectively contribute to greater accumulation of green biomass and higher yield, whereas reduced fertilizer levels limit plant growth and productivity. This finding aligns with the results of [15]and [17]who reported that increased fertilizer levels positively affect green Forage yield.

The results in Table 5 also indicate significant effects of the interaction between seeding rates and NPK fertilizer levels on green Forage yield. At the Omar Qabaji location, the treatment of the highest seeding rate 200 kg ha^{-1} combined with the highest fertilizer level 200 kg ha^{-1} was significantly superior to the other treatments, recording the highest mean yield of 6504.0 g m^{-2}. At the Al-Qunsiya location, the same treatment 200 kg ha^{-1} seeding rate × 200 kg ha^{-1} fertilizer level was also superior, though it did not differ significantly from some other treatments, recording 4142.2 g m^{-2}. In contrast, the lowest green Forage yields were recorded for the treatment of the lowest seeding rate 120 kg ha^{-1} combined with the lowest fertilizer level 120 kg ha^{-1}, reaching 3763.6 and 1838.2 g m^{-2} at Omar Qabaji and Al-Qunsiya, respectively. These results indicate that combining high plant density with high fertilizer levels enhances vegetative growth and increases green Forage yield, whereas low seeding rates combined with low fertilizer levels result in reduced growth and lower yield.

Table 5: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Green Forage yield g m^{-2} during the 2024–2025 Growing Season.

Omar Qabji				
Seeding Raet	**Fertilizer NPK**			**Means Seeding Raet**
	120 kg ha^{-1}	**160 kg ha^{-1}**	**200 kg ha^{-1}**	
120 kg ha^{-1}	3763.6 d	3972.9 d	4235.1 cd	3990.5 b
160 kg ha^{-1}	4090.4 cd	4890.4 bc	4446.7 cd	4475.9 b
200 kg ha^{-1}	4599.3 cbd	5442.7 b	6504.0 a	5515.3 a
Means of Fertilizer	4151.1 b	4768.7 a	5061.9 a	——
Al-Qunisiyah				
120 kg ha^{-1}	1838.2 d	2812.4 bc	3356.4 ab	2669.0 b

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160 kg ha^{-1}	2029.3 cd	3515.1 ab	3509.8 ab	3018.1 b
200 kg ha^{-1}	2592.4 bcd	3971.6 a	4142.2 a	3568.7 a
Means of Fertilizer	2153.3 b	3433.0 a	3669.5 a	——

6. Dry Forage yield g m^{-2}

The results presented in Table 6 indicate that seeding rates had a significant effect on dry Forage yield at both study locations. The highest seeding rate 200 kg ha^{-1} was significantly superior to the 120 and 160 kg ha^{-1} rates, recording the highest mean dry Forage yields of 1092.63 and 887.60 g m^{-2} at the Omar Qabaji and Al-Qunsiya locations, respectively. In contrast, the lowest seeding rate 120 kg ha^{-1} resulted in the lowest mean dry Forage yields, reaching 782.56 and 621.89 g m^{-2} at the two locations, respectively. The superiority of the high seeding rate in dry Forage yield is attributed to the increase in green Forage yield Table 5 resulting from higher plant density, enhanced vegetative growth, and accumulation of green biomass, which provides more dry matter after drying. Conversely, lower seeding rates lead to reduced plant density and vegetative growth, thereby decreasing dry Forage yield. These results are in agreement with [4]and [14]who reported that dry Forage yield increases with higher seeding rates per unit area.

The results presented in Table 6 indicate that dry Forage yield was significantly influenced by NPK fertilizer levels at both study locations. At the Omar Qabaji location, the 200 and 160 kg ha^{-1} fertilizer levels were significantly superior to the 120 kg ha^{-1} level, recording the highest mean yields of 1025.23 and 948.47 g m^{-2}, respectively. At the Al-Qunsiya location, the highest fertilizer level 200 kg ha^{-1} was significantly superior to both the 120 and 160 kg ha^{-1} levels, recording a mean dry Forage yield of 993.82 g m^{-2}. In contrast, the lowest fertilizer level 120 kg ha^{-1} resulted in the lowest mean dry Forage yields at both locations, reaching 784.48 and 476.62 g m^{-2} at Omar Qabaji and Al-Qunsiya, respectively. The superiority of higher NPK levels in dry Forage yield is attributed to the increase in green Forage yield at the same fertilizer levels Table 5, due to the availability of essential nutrients, particularly nitrogen, which enhanced vegetative growth and the accumulation of green biomass that can be converted into dry matter. Conversely, low fertilizer levels led to limited growth and reduced dry Forage yield. These findings are consistent with the results of [19]and [20] who reported a positive correlation between increased fertilizer levels and higher dry Forage yield.

The interaction between seeding rates and NPK fertilizer levels also had a significant effect on dry Forage yield at both study locations. At Omar Qabaji, the treatment combining the highest seeding rate 200 kg ha^{-1} with the highest fertilizer level 200 kg ha^{-1} was significantly superior to all other treatments, recording the highest mean dry Forage yield of 1307.66 g m^{-2}. The lowest yield was observed for the treatment of 160 kg ha^{-1} seeding rate combined with the lowest fertilizer level 120 kg ha^{-1}, which recorded 722.47 g m^{-2}. At Al-Qunsiya, the same treatment 200 kg ha^{-1} seeding rate × 200 kg ha^{-1} fertilizer level achieved the highest mean dry Forage yield of 1132.30 g m^{-2}, which did not differ significantly from the treatment of 160 kg ha^{-1} seeding rate combined with the 200 kg ha^{-1} fertilizer level. Conversely, the lowest yield was recorded at the treatment of 120 kg ha^{-1} seeding rate with 120 kg ha^{-1} fertilizer level, reaching 369.96 g m^{-2}. These results indicate that dry Forage yield decreases under low seeding rates combined with low fertilizer levels due to reduced plant density and weaker vegetative growth.

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Table 6: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Dry Forage yield g m⁻ ² during the 2024–2025 Growing Season.

Seeding Raet	Fertilizer NPK 120 kg ha^{-1}	160 kg ha^{-1}	200 kg ha^{-1}	Means Seeding Raet
Omar Qabji				
120 kg ha^{-1}	731.59 e	776.79 de	839.30 de	782.56 b
160 kg ha^{-1}	722.47 e	997.77 bc	928.73bcd	882.99 b
200 kg ha^{-1}	899.38 b-e	1070.85 b	1307.66 a	1092.63 a
Means of Fertilizer	784.48 b	948.47 a	1025.23 a	——
Al-Qunisiyah				
120 kg ha^{-1}	369.96 f	602.90 de	892.80 bc	621.89 b
160 kg ha^{-1}	433.23 ef	743.33 cd	956.36 ab	710.97 b
200 kg ha^{-1}	626.67 de	903.83 bc	1132.30 a	887.60 a
Means of Fertilizer	476.62 c	750.02 b	993.82 a	——

7. Grain yield g m⁻ ²

The data presented in Table 7 indicate that seeding rates had a significant effect on grain yield at both study locations. At the Omar Qabaji location, the highest seeding rate 200 kg ha⁻ ¹ achieved the best performance, being significantly superior to the 120 and 160 kg ha⁻ ¹ rates, and recording the highest mean grain yield of 1056.53 g m⁻ ². At the Al-Qunsiya location, the 200 kg ha⁻ ¹ seeding rate was significantly superior to the lowest rate 120 kg ha⁻ ¹, recording the highest mean yield of 627.44 g m⁻ ², and did not differ significantly from the 160 kg ha⁻ ¹ rate. Conversely, the lowest grain yield was observed at the lowest seeding rate 120 kg ha⁻ ¹ at both locations, reaching 824.53 and 507.41 g m⁻ ² at Omar Qabaji and Al-Qunsiya, respectively. The superior performance of higher seeding rates in grain yield is attributed to increased plant density and higher numbers of tillers and spikes per unit area Tables 3 and 4, which positively influenced grain productivity. In contrast, lower seeding rates resulted in reduced plant density, fewer spikes, and lower grain yield, with the results reported by [13].

The data presented in Table 7 indicate that NPK fertilizer levels had a significant effect on grain yield at both study locations. At the Omar Qabaji location, the 200 and 160 kg ha⁻ ¹ NPK levels were significantly superior to the 120 kg ha⁻ ¹ level, recording the highest mean grain yields of 996.19 and 955.79 g m⁻ ², respectively. At the Al-Qunsiya location, the highest NPK level 200 kg ha⁻ ¹ was significantly superior to the other two levels 120 and 160 kg ha⁻ ¹, achieving the highest grain yield of 668.95 g m⁻ ². In contrast, the lowest grain yield was observed at the lowest NPK level 120 kg ha⁻ ¹ at both locations, reaching 865.54 and 435.85 g m⁻ ² at Omar Qabaji and Al-Qunsiya, respectively. The superior performance of high NPK levels in increasing grain yield is attributed to their positive effect on yield components, particularly the increase in spike number Table 4, which directly enhanced total grain production. Conversely, lower fertilizer levels resulted in reduced yield components and lower overall productivity. These findings are consistent with the results reported by [1]and [18]who indicated that higher fertilizer levels contributed to increased grain yield.

The results also revealed that the interaction between seeding rates and NPK levels had a significant effect on grain yield at both study locations. At Omar Qabaji, the treatment combining the highest seeding rate 200 kg ha⁻ ¹ with the highest NPK level 200 kg ha⁻ ¹ recorded the highest mean grain yield of 1167.91 g m⁻ ² and did not differ significantly from the treatment with the same seeding rate at 160 kg ha⁻ ¹ NPK. At Al-Qunsiya, the same

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treatment 200 kg ha^{-1} seeding rate × 200 kg ha^{-1} NPK achieved the highest mean grain yield of 747.91 g m^{-2}, without significant difference from the 200 kg ha^{-1} seeding rate × 160 kg ha^{-1} NPK and 160 kg ha^{-1} seeding rate × 200 kg ha^{-1} NPK treatments. Conversely, the lowest grain yield was recorded at the combination of the lowest seeding rate 120 kg ha^{-1} with the lowest NPK level 120 kg ha^{-1}, reaching 734.38 and 403.00 g m^{-2} at Omar Qabaji and Al-Qunsiya, respectively. This interaction clearly demonstrates that high seeding rates combined with high fertilizer levels positively influenced crop productivity, whereas the use of low seeding and fertilizer rates resulted in a pronounced decline in grain yield.

Table 7: Effect of Seeding Rate, NPK Fertilizer, and Their Interaction on Dry Grain yield g m^{-2} during the 2024–2025 Growing Season.

Omar Qabji				
Seeding Raet	**Fertilizer NPK**			**Means Seeding Raet**
	120 kg ha^{-1}	**160 kg ha^{-1}**	**200 kg ha^{-1}**	
120 kg ha^{-1}	734.38 c	869.47 bc	869.76 bc	824.53 c
160 kg ha^{-1}	884.49 bc	974.00 b	950.89 b	936.46 b
200 kg ha^{-1}	977.76 b	1023.91 ab	1167.91 a	1056.53 a
Means of Fertilizer	865.54 b	955.79 a	996.19 a	——
Al-Qunisiyah				
120 kg ha^{-1}	403.00 d	507.44 cd	611.80 bc	507.41 b
160 kg ha^{-1}	435.78 d	625.84 b	647.16 ab	569.59 ab
200 kg ha^{-1}	468.78 d	665.62 ab	747.91 a	627.44 a
Means of Fertilizer	435.85 c	599.64 b	668.95 a	——

Conclusion

The findings indicate that increasing the seeding rate and NPK fertilizer level significantly enhances the growth and productivity of triticale. The combination of 200 kg ha^{-1} seeding rate with 200 kg ha^{-1} NPK fertilizer produced the highest yields at both locations, and therefore can be recommended for improving triticale forage and grain production under similar conditions.

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