Al-Muthanna J. For Agric Sci

Online ISSN:2572-5149
Print ISSN: 2226-4086

Vol. 12 , Issue 2. 2025

https://muthjas.mu.edu.iq/ http://doi.org/10.52113/mjas04/12.2/19

Effect of Nitrogen Fertilization Levels and Mowing on Yield and Quality of European Rye

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ABSTRACT

The field experiment was conducted at the Second Research Station of the College of Agriculture, Muthanna University, in Al-Bandar region during the winter season (2023-2024) to study the effect of cutting frequency and nitrogen fertilizer levels on the growth and yield of European rye and to determine the best interactions between the factors. The experiment using a split-plot design within a randomized complete block design (RCBD) with three replicates, where nitrogen levels were placed in the main plots and cutting frequencies were placed in the subplots. The results showed the following; The results of the statistical analysis showed a significant effect of cutting frequency on several traits. The control treatment (no cutting) excelled in plant height and number of grains per spike, with averages of 141.10 cm and 42.89 grains spike-1, respectively. However, the second cutting treatment excelled in number of tillers, green fodder yield, and number of spikes, with averages of 329.4 tillers m-2, 28.40 tons ha-1, and 313.1 spikes m-2, respectively. Nitrogen fertilizer levels also had a significant effect on several traits. The N3 level excelled in plant height, number of tillers, green fodder yield, number of spikes, and grain yield, with averages of 130.95 cm, 325.8 tillers m-2, 27.92 tons ha-1, 282.7 spikes m-2, and 2.615 tons ha-1, respectively. However, the N1 level excelled in number of grains per spike, with an average of 43.66 grains spike-1. The results also showed a significant effect of the interaction between the factors. The combination (N3_M0) excelled in plant height, with an average of 146.43 cm. The combination (N3_M2) excelled in number of spikes and grain yield, with

averages of 355.0 spikes m-2 and 2.737 tons ha-1, respectively. The combination (N1*M0) excelled in number of grains per spike, with an average of 56.90 grains spike^{-1}.

Keywords: European Rye, Nitrogen Fertilization, Mowing, fertilization.

INTRODUCTION

Rye (*Secale cereal* L.) is considered one of the important crops in human and animal nutrition due to its good nutritional and economic value. In recent years, the importance of rye cultivation has increased, and some of its varieties are used in broiler chicken feed (Milczarek et al., 2020). Rye is one of the cereal crops belonging to the Poaceae family. Globally, the importance of rye cultivation has increased, with an estimated 4 million hectares of cultivated area and a production of 13 million tons. Europe alone accounts for 75% of global production, making rye a significant crop in Northern and Eastern Europe. In Poland, the cultivated area is estimated at 903,800 hectares, in Germany at 636,300 hectares, in Denmark at 146,600 hectares, and in the Baltic countries at 113,200 hectares (FAO, 2021).

Which is characterized by its tolerance to unfavorable environmental conditions, including high and low temperatures, drought, and soil conditions such as salinity and soil pH. Rye is a rich source of fiber, which is important for weight management and maintaining digestive health. It also contains starch, which is a significant source of energy in the diet, and is rich in proteins. Rye is used in the production of baked goods and beverages and has several health benefits (Kaur et al., 2021). Rye is the second most important crop after wheat as a raw material for bread and bakery products. It is one of the best sources of dietary fiber and bioactive compounds. Additionally, rye is increasingly being used in other food products such as breakfast cereals, pasta, and snack products (Nemeth and Tomoskozi, 2021).

The problem of feed scarcity, especially green feed, is one of the obstacles to developing livestock production. Green feed is one of the cheapest sources of energy and protein for farm animals, compared to concentrated feed, which is expensive and affects the prices of animal products. Therefore, providing green feed is a factor that helps reduce the prices of animal products. To address the problem of feed scarcity, farmers have resorted to expanding the cultivation of fodder crops, such as rye, to obtain the highest yield of feed.

Nitrogen fertilization is one of the factors affecting fodder production, as it stimulates plant growth and development. However, excessive use of nitrogen fertilization can lead to environmental problems, such as nitrate leaching and soil acidity, which can lead to decreased soil fertility (Hao et al., 2022).

Materials and methods

Field soil descriptions and preparation

The field experiment was conducted in Muthanna Governorate during the winter season 2024-2025 at the Second Agricultural Research and Experiment Station, College of Agriculture, Muthanna University, in Al-Bandar region, which is located 3 km west of the city center at longitude 45.26° E and latitude 31.31° N. The experiment aimed to study the effect of cutting frequency and nitrogen fertilizer levels on the growth and yield of European rye and to determine the best interaction between them that achieves the best growth and yield characteristics of rye in silty clay soil, the characteristics of which are shown in Table (1). Random soil samples were taken from the experimental field before planting at a depth of 0-30 cm, and chemical and physical analyses were conducted on them.

Table1. Some of physical and chemical pre-planting properties of the field soil used in the experiment

Property		Value
Physical	Sand	34.78%
	Silt	28.27%
	Clay	36.95%
	Soil texture- clay	
Chemical	EC	7.89 dSm m^{-1}
	pH	8.82
	Organic matter %	0.393%
	Available N	20.90 Mg Kg^{-1} soil
	Available P	10.80 Mg Kg^{-1} soil
	Available K	140.3 Mg Kg^{-1} soil

Experimental factors and design

The experiment was conducted using a split-plot design within a randomized complete block design (RCBD) with three replicates. The main plots included nitrogen fertilizer levels, and

the subplots included cutting frequencies.

The experiment included the study of two factors:

Factor 1: Nitrogen levels

- Four levels of nitrogen: 0, 50, 100, and 150 kg/ha, denoted as N0, N1, N2, and N3, respectively.

Factor 2: Mowing frequency

- Three levels of cutting: no cutting, one cut, and two cuts, denoted as C0, C1, and C2, respectively.

Field operations.

The field operations included land preparation and soil service before planting. The land was plowed and then leveled using a leveler. The experimental field was divided into 36 experimental units according to the design used, with each unit having an area of 4m² (2m x 2m). A manual device was used to divide each unit into 10 rows, each 2m long, with a distance of 20cm between rows.

The Horyzo variety was planted on November 1, 2024 (Altai et al., 2024), at a depth of 4cm with a seed rate of 100kg/ha (Al-Hmadi, 2024). Nitrogen fertilizer was applied in the form of urea (46% N) according to the recommended fertilizer rates, which were 50, 100, and 150kg/ha, divided into three doses: the first dose one month after planting at the elongation stage, and the other doses after each cutting.

Phosphorus fertilizer was applied in the form of triple superphosphate (21% P), and potassium fertilizer was applied in the form of potassium sulfate according to the recommended fertilizer rates (80kg/ha) before planting in a single dose (Al-Aabedi, 2011).

The studied traits:

1. Plant height (cm): Plant height was measured from the soil surface to the end of the terminal spike, the average height of ten main stems was taken from each experimental unit.

2. Number of tillers (tiller/m²): The number of tillers was counted in a middle row of each experimental unit after excluding the guard plants.

3. Green fodder yield (ton/ha): Green fodder yield was calculated for each cutting of each experimental unit, and harvesting was done at a height of 35-40 cm. The yield was weighed after harvesting and then converted from g/m² to ton/ha.

4. Number of spikes per square meter (spike/m²): The number of spikes was counted for the experimental unit from the two middle rows after harvesting.

5. Number of grains per spike (grain/spike): The number of grains per

spike was calculated from the average number of grains of ten spikes taken randomly.

6. Grain yield (ton/ha): Grain yield was estimated for the total plants harvested from the two middle rows of each experimental unit and then weighed using a sensitive balance.

Statistical Analysis

The agronomic characteristics studied were analyzed statistically using the Genstat statistical program and the least significant difference test (LSD) was used to compare the mean averages of the coefficients at the level 0.05 (Al-Rawi and Khalaf Allah,1980).

Results and discussion

1- Plant height (cm):

The results of the statistical analysis showed a significant effect of the number of cuttings, nitrogen fertilization, and the interaction between them on the trait of plant height. The results in Table (2) indicated a significant effect of the number of cuttings on the trait of plant height, as the control treatment (M0) without cutting achieved the highest average of 141.10 cm compared to the second cutting, which recorded the lowest average of 105.05 cm. Thus, the percentage of decrease in the first cutting compared to the control treatment was 4.36%, compared to the second cutting, which a decrease percentage of 25.55% had compared to the control treatment. Perhaps the reason for this increase in the control treatment is due to the sufficient time available for growth and thus the formation of new vegetative growth, as well as not being exposed to external factors, including the cutting process, which led to an increase in height. This result agrees with what was found by (Al-Habash, 2024), who indicated an increase in plant height with the control treatment for rye crop.

The results of the same table showed a significant effect of nitrogen fertilizer levels, as the N3 level (150 kg ha-1) achieved the highest average of 130.95 cm, while the control treatment N0 achieved the lowest average without a significant difference from the N2 level, with averages of 124.96 and 125.04 cm, respectively. Perhaps this increase occurred because nitrogen is one of the major elements that plants need, as it is involved in the composition of chlorophyll, which is responsible for the photosynthesis process, and amino acids that are involved in cell

formation. Increasing the availability of nitrogen stimulates cell elongation, which causes plant height to increase. This result agrees with what was found by (Harba et al., 2021), who indicated an increase in plant height of rye crop with increasing nitrogen levels.

The results of Table (2) also showed that there is a significant effect of the interaction between the factors, as the combination (N3_M0) achieved the highest average of 146.43 cm compared to the combination (N0_M2), which recorded the lowest average of 100.94 cm. Perhaps this superiority occurred when the factors interacted due to the superiority of the factors individually.

Table (2) effect of mowing, nitrogen fertilization levels and their interaction on plant height (cm)

Mowing number	Nitrogen fertilization levels				Mowing Average
	N0	N1	N2	N3	
M0	137.80	145.81	134.37	146.43	141.10
M1	136.13	132.83	136.23	134.55	134.94
M2	100.94	102.88	104.52	111.85	105.05
Fertilization Average	124.96	127.17	125.04	130.95	
L.S.D(0.05)	Nitrogen fertilization		Mowing number		Interaction
	1.725		1.348		2.605

2- Number of tillers (tiller m^2)

The results of the statistical analysis, Table (3), showed a significant effect of the number of cuttings and nitrogen fertilization, and there was no significant effect of the interaction between them on the trait of number of tillers. The results of Table (3) showed a significant effect of the number of cuttings, as the second cutting achieved the highest average of 329.4 tiller m2 compared to the comparison treatment, which gave the lowest average of 265.3 tiller m2. From the same table, we notice the percentage increase in cuttings, where the percentage increase in the first cutting compared to the comparison treatment was 17.45%, and the percentage increase in the second cutting compared to the no-cutting treatment was 24.16%. This increase occurred when the cutting process was repeated, perhaps because the cutting process eliminates the phenomenon of apical dominance and allows the opportunity for lateral branches to grow, which increases the number of tillers and thus increases the yield. This result contradicts what was found by (Al-Sukari

et al., 2024), who indicated a decrease in the number of tillers in the second cutting for oat crop.

From the results of the same table, it is observed that there is a significant effect of nitrogen fertilization, as the N3 level achieved an average of 325.8 compared to the N1 level, which recorded the lowest average of 272.3. The reason for the increase in the number of tillers may be due to the availability of nitrogen in sufficient quantities in the plant, which leads to an increase in the growth of tillers in the plant. This result agrees with what was found by (Latif, 2005), who found an increase in the number of tillers for rye crop with increasing nitrogen levels.

Table (3) effect of mowing, nitrogen fertilization levels and their interaction on Number of tillers (tiller m^2)

Mowing number	Nitrogen fertilization levels				Mowing Average
	N0	N1	N2	N3	
M0	258.3	237.7	289.0	276.3	265.3
M1	305.0	299.0	308.0	334.3	311.6
M2	333.3	208.3	337.3	366.7	329.4
Fertilization Average	298.9	272.3	311.4	325.8	
L.S.D(0.05)	Nitrogen fertilization		Mowing number		Interaction
	27.16		25.24		N.S

3- Green fodder yield (ton ha^{-1}):

The results of Table (4) confirmed a significant effect of the number of cuttings and nitrogen fertilization, and there was no significant effect of the interaction between them on this trait. The results of Table (4) showed a significant effect of the number of cuttings, as the second cutting achieved the highest average of 28.40 compared to the first cutting, which recorded the lowest average of 19.50. The percentage increase in the second cutting over the first was 45.64%. Perhaps the reason for this increase is due to the ability of the crop to regrow after cutting and increase the number of tillers, as well as the superiority of the second cutting in the trait of number of tillers, Table (3), which led to an increase in yield. This result agrees with what was found by (Mahmoud et al., 2017), who found an increase in green fodder yield for oat crop in the second cutting.

From the results of the same table, it was observed that there is a significant effect of nitrogen fertilizer levels, as the N3 level achieved the highest average of 27.92 compared to the control treatment N0, which recorded the lowest average of 20.93. This is also due to the superiority of this level in the trait of number of tillers, Table (3), which is reflected positively on the yield. This result agrees with what was found by (Jamel et al., 2023), who indicated an increase in green fodder yield for barley crop with increasing nitrogen levels.

Table (4) effect of mowing, nitrogen fertilization levels and their interaction on Green fodder yield (ton ha^{-1})

Mowing number	Nitrogen fertilization levels				Mowing Average
	N0	N1	N2	N3	
M1	15.23	22.57	15.93	24.27	19.50
M2	26.63	29.33	26.07	31.57	28.40
Fertilization Average	20.93	25.95	21.00	27.92	
L.S.D(0.05)	Nitrogen fertilization		Mowing number		Interaction
	4.379		3.880		N.S

4- Number of spikes (spike m2):

The results of Table (5) showed a significant effect of the number of cuttings, nitrogen fertilization, and the interaction between them on the trait of number of spikes. The results confirmed a significant effect of the number of cuttings, as the second cutting achieved the highest average of 313.1 compared to the comparison treatment, which recorded the lowest average of 213.4. The percentage increase in the first cutting compared to the comparison treatment was 16.30%, and the percentage increase in the second cutting compared to the no-cutting treatment was 46.71%. Perhaps the reason for the increase is due to the superiority of the second cutting in the trait of number of tillers, Table (3), and the trait of green fodder yield, Table (4), which led to an increase in the number of spikes, which is reflected positively on the yield components. This result contradicts what was found by (Al-Kanani et al., 2019, Al-Fraih et al., 2015), who indicated an increase in the number of spikes in the first cutting for barley crop.

The results of the same table also indicated a significant effect of nitrogen fertilization, as the N3 level achieved an average of 282.7 compared to the N1

level, without a significant difference from the N2 level, which gave the lowest averages of 248.3 and 249.0, respectively. Perhaps the reason for the increase in this trait is due to the superiority of the N3 level in the trait of plant height, Table (2), and the trait of number of tillers, Table (3), which was reflected positively on the yield components and thus increased production. This result agrees with what was found by Oral, 2018, who indicated an increase in the number of spikes for rye crop at high levels of nitrogen. A significant effect was also observed for the interaction between the factors, as the combination N3_M2 achieved an average of 355.0 compared to the combination N2_M0, which recorded the lowest average of 172.3. Perhaps the reason for the superiority when the factors interacted is due to their superiority individually.

Table (5) effect of mowing, nitrogen fertilization levels and their interaction on Number of spikes (spike m^2)

Mowing number	Nitrogen fertilization levels				Mowing Average
	N0	N1	N2	N3	
M0	239.0	213.3	172.3	229.0	213.4
M1	220.0	259.0	250.0	264.0	248.2
M2	300.0	272.7	324.7	355.0	313.1
Fertilization Average	253.0	248.3	249.0	282.7	
L.S.D(0.05)	Nitrogen fertilization		Mowing number		Interaction
	19.34		22.74		39.99

5- Number of grains per spike (grain spike^{-1}):

The results (6) showed a significant effect of the number of cuttings, nitrogen fertilization, and the interaction between them on the trait of number of grains per spike. The results of Table (6) indicated a significant effect of the number of cuttings, as the control treatment achieved an average of 42.89 compared to the second cutting, which recorded the lowest average of 36.10. The percentage decrease in the first cutting compared to the control treatment was 12.91-%, and the percentage decrease in the second cutting compared to the control treatment was 15.83-%. Perhaps the reason for the decrease in the second cutting is due to the increase in the number of spikes in this cutting, Table (5), which reduces competition between plants, which is reflected in the number of grains per spike

according to the principle of compensation. This result agrees with what was found by (Al-Fraih et al., 2015), who found a decrease in barley crop yield with repeated cutting.

From the results of the same table, it was observed that there is a significant effect of nitrogen fertilization, as the N1 level achieved an average of 43.66 compared to the N2 level, which recorded the lowest average of 34.08. Perhaps the reason for the increase in the number of grains at lower nitrogen levels is due to the same reason mentioned above for the number of cuttings. From the results of the table, it was also observed that there is a significant effect of the interaction between the factors, as the combination N1_M0 achieved an average of 56.90 compared to the combination N2_M1, which recorded the lowest average of 24.27. Perhaps this superiority occurred due to the superiority of the factors individually, which led to their superiority when interacting.

Table (6) effect of mowing, nitrogen fertilization levels and their interaction on Number of grains per spike (grain spike^{-1})

Mowing number	Nitrogen fertilization levels				Mowing Average
	N0	N1	N2	N3	
M0	38.60	56.90	43.32	32.73	42.89
M1	40.00	44.55	24.27	40.57	37.35
M2	35.28	29.53	34.67	44.90	36.10
Fertilization Average	37.96	43.66	34.08	39.40	
L.S.D(0.05)	Nitrogen fertilization		Mowing number		Interaction
	3.266		3.146		5.740

6- Grain yield (ton ha^{-1}):

The results of Table (7) showed a significant effect of nitrogen fertilization and the interaction between factors, and there was no significant effect of the number of cuttings on the trait of grain yield. The results of Table (7) indicated no significant effect of the number of cuttings on this trait, although the lack of significance is a positive thing because the grain yield is not affected by the cutting process when taking two cuttings from the crop, and thus the crop can be used for both fodder and grain purposes, which is reflected positively on the yield.

The results of Table (7) showed a significant effect of nitrogen fertilization, as the N3 level achieved the highest

average of (2.615) compared to the N1 level, which gave the lowest average of (1.762). Perhaps the reason for this is due to the superiority of the N3 level in the trait of number of tillers, Table (3), and the trait of number of spikes, Table (5), which is reflected in the increase in yield. This result agrees with what was found by (Rashid, 2023), who indicated an increase in yield for rye crop with increasing nitrogen levels.

The results of the same table also showed a significant effect of the interaction between factors, as the combination N3_M2 achieved the highest average of (2.737) compared to the combination N1_M1, which recorded the lowest average of (1.420). Perhaps the superiority of the nitrogen level N3 when interacting with the number of cuttings is due to its superiority individually.

Table (7) effect of mowing, nitrogen fertilization levels and their interaction on Grain yield (ton ha^{-1})

Mowing number	Nitrogen fertilization levels				Mowing Average
	N0	N1	N2	N3	
M0	2.039	2.058	1.987	2.439	2.131
M1	2.655	1.420	2.301	2.668	2.261
M2	1.450	1.808	2.357	2.737	2.088
Fertilization Average	2.048	1.762	2.215	2.615	
L.S.D(0.05)	Nitrogen fertilization		Mowing number		Interaction
	0.2007		N.S		0.2939

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