Effect of nitrogen fertilizer levels on yellow rust incidence and yield components in bread wheat under rainfed conditions

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Abstract

The current study was conducted to evaluate four different levels of nitrogen fertilizers on the incidence of yellow rust disease, yield and yield components in five bread wheat varieties during the 2024/25 growing season in Sulaymaniyah. Results revealed significant differences between treatments for yellow rust disease severity and the coefficient of infection, indicating that the Adana control recorded the lowest mean coefficient of infection for yellow rust disease at 5.87. In contrast, the highest mean coefficients of infection for yellow rust disease were recorded by Hsad (120 kg N/ha). Additionally, the Sulaimani-2 treatment at 120 kg N/ha showed a 15–35% increase in yellow rust severity compared to the Sulaimani-2 control. Third nitrogen applications changed the infection type of Baraka from moderately susceptible to susceptible. Furthermore, the results showed significant differences between the varieties for all the yield and its component characteristics. Baraka control had the highest spike length of 16.77 cm. The maximum awn length recorded by Baraka (120 kg N/ha). Adana (120 kg N/ha) exhibited the highest spike density per square meter. The highest spike weight, grain weight per spike and thousand-grain weight were observed in the (40 kg N/ha) in the Sulaimani-2 variety. The highest grain number/spike was recorded by Baraka (120 kg N/ha). Furthermore, Sulaimani-2 (40 kg N/ha) had the highest grain yield with 865.50g/m², while recommend use of nitrogen fertilizer (80 kg N/ha) on susceptible bread wheat variety Hsad produced the lowest grain yields, at 554.45g/m².

Keywords: Fungal Diseases, Yellow rust disease, Nitrogen fertilizer, Susceptible wheat varieties, Yield and yield component.

Introduction

Yellow (stripe) rust, caused by the pathogen *Puccinia striiformis* f. sp. *tritici*, is an airborne and foliar disease that impacts wheat crops. This disease holds significant economic importance, particularly in temperate regions with prevalent wheat cultivation [1]. The disease has been observed in nearly every country where wheat is grown and has been reported in over 60 countries worldwide. Approximately 88% of the world's wheat varieties are susceptible to yellow rust infection, although the frequency and significance of yellow rust vary in all countries [2, 3]. Epidemics of yellow rust can occur frequently (every 2-5 years) in all regions where wheat is grown, resulting in 5-10% grain losses. When susceptible varieties are grown and environmental conditions are favourable for disease development, yield losses can exceed 90% [4].

The estimated global annual losses due to yellow rust diseases are 5.5 million metric tons of yield and £1 billion. This condition can reduce the number, size, and weight of grains in the spike, and also affect root growth, plant height, and the number of spikes. Additionally, yellow rust-infected plants produce seeds with poor emergence and reduced plant vigour [5, 6].

IDM programs effectively manage rust disease by integrating agricultural control methods, genetic resistance, and fungicide applications. However, cultural practices like delayed planting, crop rotation, consistent irrigation, minimizing excessive nitrogen application, early maturing varieties, high-yielding but susceptible varieties, multiline or varietal mixtures, and eradicating weed and volunteer plants may not be economically viable as standalone solutions [5,7].

Nitrogen is vital for plant growth, including grains, as it forms part of nucleoplasm, polypeptides, nucleotides, catalysts, and proteins. It is a key macronutrient used by farmers, essential for processes like metabolism, growth, enzyme activity, chlorophyll production, and overall plant health. Since it's part of proteins, vitamins, hormones, and other substances, nitrogen is crucial for plants and animals, affecting life, and playing a role in photosynthesis and plant metabolism [8].

The level of yellow rust infection is influenced by nitrogen nutrition in agricultural practices, with greater disease severity observed with higher nitrogen levels. High nitrogen levels can increase disease severity; subsequently, yellow rust reduces nitrogen remobilization to grains [9].

A number of pathways have been proposed to mediate this response. High crop and canopy density associated with nitrogen fertilization have been shown in previous studies to be conducive to the development of yellow rust [10]. On the other hand, certain studies have indicated that nitrogen's effect on yellow rust results from the high nitrogen content within wheat tissues, creating nutrient-rich tissues that favor pathogen growth, but not from any modifications to the canopy microclimate [11, 12].

The addition of nitrogen to the wheat crop in the presence of yellow rust might enhance the disease's severity. The disease itself may decrease the quantity of nitrogen exported in grains. It is imperative to understand the interactions among these factors when evaluating the effects of rust management strategies on productivity, particularly in terms of yield and quality parameters [9].

This research examines the relationship between nitrogen fertilization levels and the incidence of stripe rust disease, as well as the impact of nitrogen fertilizer on wheat yield and its components under rain-fed conditions.

Materials and Methods

Plant Materials and Field Experiment

In this experiment, we used five different local bread wheat varieties to investigate the effect of varying nitrogen application levels on yellow rust disease in adult wheat plants, as well as the overall yield and its components in the field. The seeds of each variety were planted in December 2024, with 60 treatments in two rows, each 2 meters long. The space between rows was 25cm, and the distance between plots and blocks was 160 cm. The study involved three replications of a Factorial Randomized Complete Block Design (RCBD), with Factor A including five bread wheat varieties: Hsad, Tamuz 3, Baraka, Sulaimani 2 and Adana (Table 1), at a rate of 200 kg/ hectare and Factor B consisting of four different nitrogen fertilizer applications: 0 (control), 40 kg N/ha as Urea 46% (less than recommended), 80 kg N/ha (recommended), and 120 kg N/ha (more than recommended). Nitrogen fertilizer was applied in two splits: 50% at sowing and 50% at the tillering stage (early March). This method prevents excessive early-season growth and reduces the risk of disease. Agronomic practices, including soil preparation and weed control, were carried out at the experimental field station of the Agricultural Research Centre in Sulaimaniyah, Bakrajo, located at Latitude N 35° 32.30; Longitude E 045° 21.00; and Elevation 760m, Iraq. Table 2 displays several physical and chemical properties of the soil used in the experiment.

Table (1): Names, Pedigree/origin and Year of release of bread wheat varieties used in the study.

No.	Variety name	Scientific name	Pedigree	Year of release	Origin
1.	Sulaimani-2	*T. aestivum*	Kauz(2	2016	CIMMYT
2.	Baraka	*T. aestivum*	IARI(STD	2013	Iraq
3.	Hsad	*T. aestivum*	SNB//CMH79A955/3(CNO79/3/ATTILA	2014	Iraq
4.	Adana	*T. aestivum*	PFAU/SERI-M-82/BOBWHITE	2012	Turkey
5.	Tamuz 3	*T. aestivum*	Sab./Max.(AbuGh. (Rad.)	1992	Iraq

Table (2): Some chemical and physical characteristics of the soil of the Agricultural Research Centre in Sulaimaniyah /Bakrajo experimental field station.

Soil Properties	Values
Soil texture (PSD)	Silty Clay
EC (dS.m-1)	0.2
PH	7.6
O.M. (g.kg-1)	15.3
$CaCO_3$ (g.kg-1)	275
Available P(ppm)	12.6
Total N %	0.15
Soluble K^+ (mmol-L)	0.06
Na^+ (ppm)	27.66
Soluble Ca^{2+} (mmol-L)	0.75
Soluble Mg^{2+} (mmol-L)	0.5
Cl^- (mmol-L)	1
HCO_3(mmol-L)	0.5

PSD: Particle Size Distribution, EC: Electrical Conductivity, ($dS{\cdot}m^{-1}$): decisiemens per meter, O.M: Organic Matter: ($g{\cdot}kg^{-1}$): grams per kilogram of soil, ppm: Part per million and mmol-L: millimoles per liter.

Disease Scoring

The severity of yellow rust disease was evaluated using a revised Cobb scale. This scale measures the extent of infection on wheat leaves on a scale of 0-100 compared to a standard diagram. Observations in the field were made at regular intervals starting at the tillering stage, with the final assessment conducted at the late-dough or physiological maturity stage. The classical ordinal scale S, MS, MR, and R is used to score the type of infection. In some cases, this scale is augmented by three additional classes based on practical experience in scoring the disease: MS-S (between MS and S), MR-MS (between MR and MS) and R-MR (between R and MR). This study uses this seven-class system to classify (IT) infection types [13].

The coefficient of infection (CI) for yellow rust disease was evaluated for each variety by multiplying the severity by a predetermined value called the host response coefficient. The designated values were: S=1.0, MS-S=0.9, MS=0.8, MR-MS=0.6, MR=0.4, R-MR=0.3, and R=0.2. This approach facilitates straightforward comparison and ranking of different varieties using statistical analysis [14].

The measurements of the yield and yield component traits for each treatment were conducted. This encompassed:

1- Spike length: At maturity, the average of ten wheat spikes randomly chosen, excluding the awn, was measured in centimetres.

2-Awn length: The ruler measured the average length of ten spikes chosen from the end of the spike to the end of an awn in centimetres.

3- Spike number/m^2: The spike number per square meter was calculated by counting the number of spikes within a one-meter length located at the centre of each plot and then converted into square meters.
3- Spike weight (g): The number of grains per spike is determined by counting the grains from 10 randomly chosen spikes in each experimental plot and then finding the average number per spike.
4- Using a traditional balance, the average grain weight per spike is measured by selecting 10 random spikes per plot.
5- Grain number/spike: Calculated by counting grains from 10 selected spikes randomly for each experimental plot, then converted to the average number per spike.
6- The thousand-grain weight in grams is picked randomly from each replicate of the bulk grain yield.
7- The grain yield of the variety is determined at the maturity stage when the grain moisture is at 14% by randomly harvesting spikes from one meter at the centre of each plot. The harvested spikes are then threshed, and the weight of the grain is calculated per square meter [15].

Statistical analysis

Data were tested for normality and homogeneity of variance before performing ANOVA. Recorded data for the CI, yield, and yield components characteristics were analysed by OPSTAT and SPSS software to evaluate the source of variance and compare genotypes. Duncan's multiple tests at a 5% probability level were used to compare the means of the traits.

Results and Discussion

Table 3 and Appendix 1 illustrate the effect of four levels of nitrogen fertilizer on the occurrence of yellow rust disease in five bread wheat varieties during the 2024/25 growing season at the Agricultural Research Centre in Sulaimaniyah, Bakrajo, Iraq. The results showed significant differences between treatments, indicating that the Adana control and Adana (40kg/ha) treatments recorded the lowest mean coefficient of infection for yellow rust disease at 5.87 and 8.80, respectively. In contrast, the highest mean coefficient of infection for yellow rust disease was recorded by Hsad (120 kg N/ha) and Hsad (80 kg N/ha) at 76.67 and 68.33, respectively. It's noted that the coefficient of infection and disease severity was highest at 120 kg/ha nitrogen and lowest at (0 kg/ha) nitrogen for all varieties. On the other hand, the Sulaimani-2 (120kg N/ha) treatment resulted in increases of 15% to 35% in yellow rust severity compared to the Sulaimani-2 (control treatment, while the Tamuz-3 (120kg N/ha) treatment resulted in increases of 45% to 63.33% compared to the control application (Fig. 1). It is noted that disease severity was highest at 120 kg N/ha and lowest in the 0 kg N/ha treatment across all varieties. The type of yellow rust infection changed from moderately susceptible to susceptible in some varieties following the Baraka Control treatment compared to other treatments. The yellow rust infection type changed from MS to S in the fourth application of the Sulaimani-2 variety. It clearly shows the effect of nitrogen fertilizer in this change. In contrast, Adana recorded MS infection types across all applications.

Significant differences were observed in the mean CI of certain treatments. The yellow rust CI in the treatment of Hsad (120 kg N/ha) 76.67 was significantly higher than all other treatments. In contrast, there is no significant difference between Hsad with (40 and 80 kg N/ha) applications. The results of the experiment indicate that an increase in nitrogen fertilizer leads to a greater incidence of yellow rust disease on wheat. The low severity of yellow rust disease was attributed to the low precipitation in Iraqi Kurdistan Region during the 2024-25 growing season (Fig. 2).

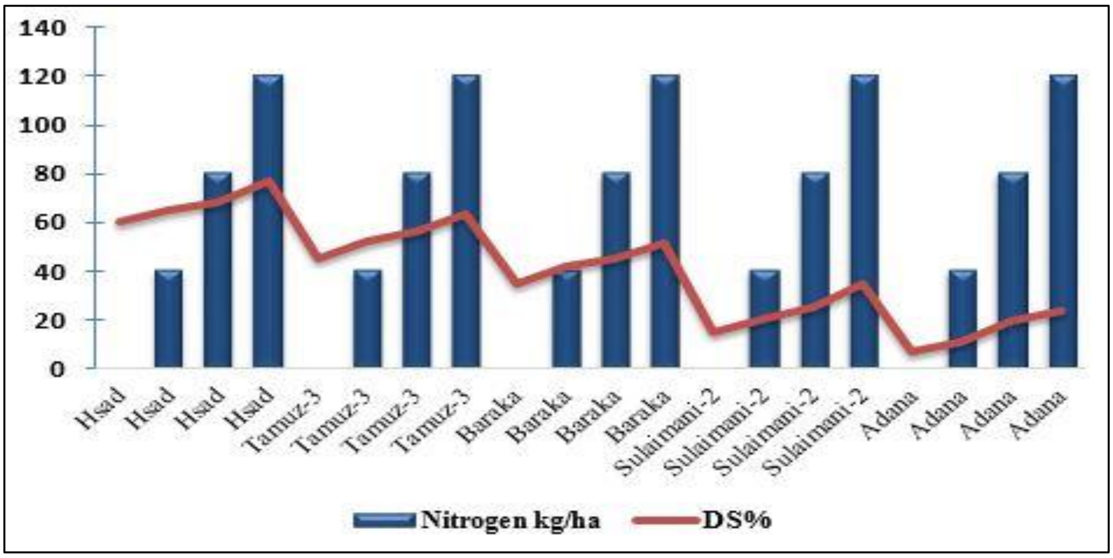

Figure (1): Effect of nitrogen fertilizers on the severity of yellow rust disease in five susceptible wheat varieties during the 2024/25 growing season. DS – disease severity and kg/ha: kilograms per hectare.

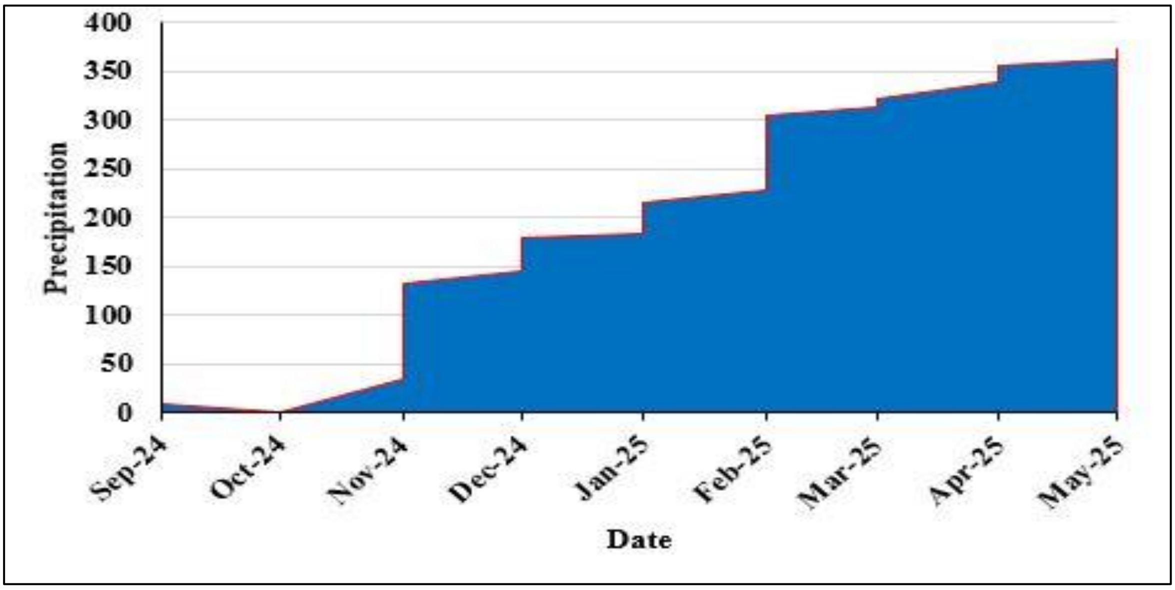

Figure (2): Average precipitation during the experimental period between September and May at the Agricultural Research Centre in Sulaimaniyah, Bakrajo, Sulaymaniyah, in 2024/25.

Table (3): Efficiency of various levels of nitrogen fertilizer on the yellow rust disease occurrence on five wheat varieties during the 2024/25 growing season.

Varieties	Nitrogen kg/ha	IT	DS%	CI
Hsad	Control	S	60.00	60.00[cd]
	40	S	65.00	65.00[bc]
	80	S	68.33	68.33[b]
	120	S	76.67	76.67[a]
Tamuz-3	Control	S	45.00	45.00[fg]
	40	S	52.67	52.67[e]
	80	S	56.00	56.00[de]
	120	S	63.33	63.33[bc]
Baraka	Control	MS	35.00	28.00[i]
	40	S	42.33	42.33[g]
	80	S	45.00	45.00[fg]
	120	S	51.67	51.67[ef]
Sulaimani-2	Control	MS	15.00	12.00[kl]
	40	MS	20.67	16.53[Jk]
	80	MS	25.00	20.00[j]
	120	S	35.00	35.00[h]
Adana	Control	MS	7.33	5.87[l]
	40	MS	11.00	8.80[l]
	80	MS	20.00	16.00[jk]
	120	MS	23.33	18.67[jk]

DS – disease severity; IT – infection type; MS – moderately susceptible; S – susceptible; CI – coefficient of infection, calculated by multiplying the DS value by IT [14]. Each number is a mean of three replicates; numbers followed by the same symbols are not significantly different at the 0.05 level according to Duncan's multiple test analysis.

A rain-fed field planted with a susceptible wheat variety during a cool, wet spring is highly likely to experience an outbreak of stripe rust. The rise in disease severity and CI with increased nitrogen fertiliser aligns with the understanding that nitrogen nutrition affects stripe rust infection levels, with higher nitrogen levels linked to more severe disease severity. Several mechanisms have been proposed to influence this reaction. Some research indicates that increased crop and canopy density from nitrogen fertilization creates a more favourable environment for yellow rust development.

In contrast, other studies suggest that the effect of nitrogen on yellow rust is driven by elevated nitrogen levels in host tissues, which provide a medium for pathogen growth, rather than by changes in the plant canopy [11].

Applying nitrogen to wheat affected by yellow rust may increase disease severity. Consequently, the disease may decrease the nitrogen content in grains. Understanding how these factors interact is crucial when estimating the productivity impacts of yellow rust management, particularly in terms of the quantity and quality of yield. These results indicate that chemical nitrogen application must be carefully managed, as high use can lead to increased wheat susceptibility to yellow rust diseases. Furthermore, nitrogen needs should be applied according to the results of soil tests and the target yield [9].

Robert *et al.* [16], showed that unaffected photosynthesis leaves by yellow rust from other parts of the leaves affected by wheat rust. It is possible that even with increased severity of yellow rust at higher nitrogen applications, the overall amount of leaf area was maintained due to the rise in leaf area index (LAI). The processes by which rusts reduce nitrogen yield are still unclear. Yield losses result from the reduction of photosynthetic area [16].

Typically, a decline in carbohydrate availability for grain filling would lead to an increase in the relative protein content, as is often observed when necrotrophic foliar diseases decrease yield [9].

Stripe rust can negatively impact the economics of nitrogen fertilization, and applying more nitrogen results in more severe yellow rust diseases and a higher infection coefficient. Bryson *et al.* [17] found that higher N levels intensified rust severity during grain filling; however, N application also increased grain yield and its components. Dimmock *et al.* [18] found that this is frequently seen when necrotrophic leaf diseases lower the yield. The results of this study demonstrate that nitrogen's effect on disease is related to the nitrogen levels in the host tissue, rather than changes in the canopy microclimate resulting from an increase in canopy size.

Table (4): Mean squares of the variance analysis of the studied yellow rust coefficient of infection efficiency of some bread wheat varieties under different levels of nitrogen fertilizers.

S.O. V	d.f	Mean squares
		Coefficient of infection
Variety	4	6273.33**
Nitrogen fertilizers	3	933.93**
Replication	2	54.04
Variety*Nitrogen fertilizers	12	22.75**
Error	38	15.45

Note S.O.V = Source of Variance, d.f= Degree of Freedom, ** = significant at $p \leq 0.01$.

A study in Table 5 and Table 6 Analyzed the influence of nitrogen applications on yield and its components in five bread wheat varieties. The results showed significant differences between the varieties for all the studied characteristics. Additionally, the interaction between variety and treatment was significant. The significant differences between varieties and treatments indicated differences in the response of varieties to nitrogen fertilizers. Understanding the Variety and treatment interaction is essential for improving crop yield. The spike length is one significant trait in determining grain production and yield per plant. Long spikes with high fertility of florets are associated with higher grain yields. Spike length is determined by genetics and can also be affected by environmental factors. According to Table 4, Baraka Control had the highest spike length of 16.77 cm, while Hsad (80 kg N/ha) recorded the lowest at (10.34cm). However, there were no significant differences between the Baraka and Nitrogen applications, but it surpassed all other treatments. These results agree with those obtained by [19], indicating that spike length is a quantitative trait affected by numerous genes and abiotic factors such as nitrogen fertiliser, which cause significant variability.

There were significant differences between treatments for Awn length. Character Awn's contribution to wheat's grain yield filling is confirmed by [20], as it is part of the photosynthetic organ of the spike. The maximum awn length recorded by Baraka (80 kg N/ha) was 8.84 cm, while the minimum value was 6.18 cm observed in Hsad (80 kg N/ha). Otherwise, there were no significant differences between the interaction between Baraka and Nitrogen applications, but it surpassed all other treatments.

For most cereals, the economic grain yield depends on the number of spikes/area. This already depends on the genetic makeup and condition of the environment during crop growth. Data regarding the 2024-25 growing season, Adana (120 kg N/ha) exhibited the highest value of spike/m^2 with 461.28, while the lowest values of this trait were 252.03, as shown by Hsad (120 kg N/ha). These findings are possibly explained by the genetic variability among the tested varieties to yellow rust disease. The Adana variety has MS infection type and low DS and CI. In contrast, Hsad has S Infection type and the highest DS and CI. These results are in harmony with those obtained [21].

This study showed the impact of different bread wheat varieties with various nitrogen applications on the weight of the spike. However, Sulaimani-2 (40 kg N/ha) recorded the highest value of spike weight by 5.16g, while Hsad (120 kg N/ha) had the lowest value by 2.59g. These differences could be attributed to the use of less than recommended nitrogen fertilizer (40kg/ha), MS infection type and low disease severity of yellow rust by the Sulaimani-2 variety, and overuse of (120kg/ha) of nitrogen fertilizer to the highly susceptible Hsad variety. According to El-Ashmouny *et al.* [22], the spike weight characteristic differences in varieties may be affected by genetic and environmental factors such as nitrogen applications, which can impact wheat yield.

The grain number/spike in bread wheat is an important yield component, and any differentiation in this number will impact the grain yield of the wheat varieties [21]. According to the results of this study, the highest grain number/spike was recorded by Baraka (120 kg N/ha) with 81.18, followed by Sulaimani-2 (120 kg N/ha) recorded 73.88. There was no significant difference between them, while the lowest average value was by the Hsad control, recorded 50.42; this is likely due to improved root growth, increased nutrient uptake, and overall better growth. Adequate nitrogen ensures proper flowering, leading to a higher grain number/spike. It's noted that in some treatments, such as Sulaimani-2 Control, Hsad Control, and Adana Control produced low grain number/spike, may be due to nitrogen deficiency can reduce the grain number due to poor development of spikelet or yellow rust damages leaf tissue, reducing the wheat's ability to produce energy for grain development, infected wheat spikes may produce lower number of grains or poorly developed grains [14].

Grain weight per spike is a vital parameter for increasing bread wheat grain yield [21]. Recently released high-yield potential wheat varieties are characterised by a high grain weight/spike. There were significant differences between treatments. The highest grain weight per spike was observed in the lower than recommended use of nitrogen fertilizer 40 kg N/ha in the Sulaimani-2 variety at 3.91g, the lowest spike grain weight was recorded in Hsad (120 kg N/ha) at 1.80g. There were no significant differences between the interaction between Sulaimani-2, Adana varieties and Nitrogen applications, but it surpassed all other treatments, reducing grain weight per spike with high N fertilizer in some treatments, especially in highly susceptible varieties such as Hsad. This result is possibly caused by Sulaimani-2 (40 kg N/ha) recorded the highest value of spike weight; this was affected by grain weight. Furthermore, excess nitrogen late in the season may delay maturity and reduce grain weight, and the high severity of yellow rust disease reduces photosynthetic activity during the grain filling stage, resulting in lighter grains. Severe infections can cause shrivelled grains with poor market value [21].

The weight of a thousand grains is one of the key parts of the final grain yield in bread wheat. The study detected significant effects of bread wheat varieties with nitrogen applications on thousand-grain weight. Sulaimani-2 (40 kg N/ha), with 40.47g of thousand-grain weight, surpassed all other interactions. In contrast, Hsad (80 kg N/ha) had the lowest thousand-grain weight values of 32.88g, followed by Tamuz-3(80 kg N/ha) with 33.21g. This result may be related to grain weight/ spike and spike weight because Sulaimani-2 (40kg N/ha) recorded the highest values of these two characters. Thousand-grain weight is influenced by biotic and abiotic stresses, such as nitrogen fertilizers, and is heavily influenced by grain filling during the later stages of growth [23].

These findings demonstrated that the recommended nitrogen fertilizer amount is significant and impacts grain yield, as shown in Table 4. Results indicate a significant variation in grain yield per square meter among bread wheat varieties with nitrogen applications. Sulaimani-2 (40kg N/ha) had the highest grain yield with 865.50g/m^{2}, followed by Sulaimani-2 control with 853.89g. While recommending the use of nitrogen fertilizer, 80 kg N/ha on the highly susceptible bread wheat variety Hsad, produced the lowest grain yields, at 554.45g/m^{2}. This result clearly shows that increased nitrogen fertilizer resulted in low grain yield in Hsad and Tamuz-3 varieties due to these two varieties being susceptible to yellow rust diseases with high DS and CI. While the lower use of recommended nitrogen fertilizer on varieties with low DS and CI, such as Sulaimani-2, Adana and Baraka varieties, increased grain yield. Furthermore, the highest grain yield by Sulaimani-2 (40kg N/ha) is related to other characters such as the weight of a thousand grains, grain weight/ spike and spike weight because these characters recorded the highest value by the Sulaimani-2 (40 kg N/ha). On the other hand, Differences in grain yield are mainly attributed to the interaction between the genetic makeup of the varieties during growth periods and the prevailing environmental factors during their development. The findings from the present study indicated that grain weight in some varieties rose with higher nitrogen application. This could also be attributed to the effective allocation of nitrogen to the flag leaf, which contributed to greater dry matter accumulation, enhanced plant vitality, and prolonged stay-green period. [24].

Table (5): Effect of some nitrogen applications on grain yield and yield components in five bread wheat varieties at Bakrajo field, Sulaymaniyah, Iraq.

Varieties	Nitrogen kg/ha	Spike Length (cm)	Awn Length (cm)	No. of Spike/ m^{2}	Spike Weight (g)	No. of Grains /Spike	Grain Weight/ Spike(g)	1000 Grain weight(g)	Grain Yield (g/m^{2})
Hsad	Control	10.63^{h}	6.44^{f-h}	340.95^{b-f}	2.97^{e-g}	50.42^{h}	2.35^{e-g}	34.25^{b-e}	618.77^{g-i}
	40	10.72^{gh}	6.76^{c-h}	342.53^{b-f}	3.09^{e-g}	55.96^{gh}	2.42^{e-g}	35.33^{b-e}	652.30^{e-h}

	80	10.34^{h}	6.18^{gh}	322.55^{d-f}	2.69^{fg}	58.50^{e-h}	1.99^{fg}	32.88^{e}	539.60^{j}
	120	10.78^{gh}	6.86^{c-g}	252.03^{f}	2.59^{g}	59.36^{e-h}	1.80^{g}	33.52^{c-e}	554.45^{ij}
Tamuz-3	**Con-trol**	12.27^{def}	7.36^{b-d}	341.01^{b-f}	2.88^{e-g}	66.14^{b-f}	2.01^{fg}	34.90^{b-e}	633.30^{f-h}
	40	12.01^{ef}	7.47^{bc}	337.16^{b-f}	2.78^{fg}	61.42^{d-g}	2.11^{fg}	34.26^{b-e}	644.78^{e-h}
	80	11.87^{e-g}	7.7^{b}	324.21^{d-f}	2.87^{e-g}	62.76^{c-g}	2.42^{e-g}	33.21^{de}	585.19^{h-j}
	120	11.25^{f-h}	7.27^{b-d}	294.82^{ef}	2.73^{fg}	57.91^{f-h}	2.25^{e-g}	34.70^{b-e}	590.87^{h-j}
Baraka	**Con-trol**	16.77^{a}	8.6^{a}	308.09^{ef}	3.44^{de}	73.70^{ab}	2.68^{c-f}	34.41^{b-e}	616.96^{hi}
	40	15.89^{a}	8.5^{a}	351.17^{b-e}	3.39^{de}	68.44^{b-d}	2.95^{b-e}	36.64^{b-e}	745.48^{b-d}
	80	16.56^{a}	8.84^{a}	315.21^{d-f}	3.20^{ef}	71.21^{bc}	2.63^{d-f}	37.12^{a-c}	647.56^{e-h}
	120	16.65^{a}	8.82^{a}	327.82^{c-f}	3.88^{cd}	81.18^{a}	2.92^{b-e}	36.32^{b-e}	684.59^{d-g}
Sulai-mani-2	**Con-trol**	11.48^{e-h}	6.51^{e-h}	418.79^{a-c}	4.53^{b}	65.36^{b-f}	3.38^{a-c}	37.26^{a-c}	853.89^{a}
	40	12.57^{c-e}	7.2^{be}	426.27^{ab}	5.16^{a}	67.16^{b-e}	3.91^{a}	40.47^{a}	865.50^{a}
	80	13.71^{bc}	6.05^{h}	362.56^{b-e}	4.62^{b}	70.17^{b-d}	3.42^{a-c}	37.18^{a-c}	704.77^{de}
	120	14.21^{b}	7.03^{b0f}	355.06^{b-e}	4.29^{bc}	73.88^{ab}	3.56^{ab}	37.96^{ab}	808.83^{ab}
Adana	**Con-trol**	12.31^{d-f}	6.64^{d-h}	421.22^{ab}	4.10^{bc}	67.33^{b-e}	3.68^{ab}	37.14^{a-c}	770.63^{bc}
	40	13.33^{b-d}	6.77^{c-h}	385.39^{a-e}	4.23^{bc}	69.81^{b-d}	3.45^{ab}	36.82^{a-d}	785.06^{bc}
	80	13.59^{bc}	6.33^{f-h}	406.23^{a-d}	4.10^{bc}	69.87^{b-d}	3.23^{a-d}	34.91^{b-e}	697.77^{d-f}
	120	14.12^{b}	6.68^{d-h}	461.28^{a}	4.25^{bc}	69.57^{b-d}	3.55^{ab}	34.94^{b-e}	722.55^{cd}

Grain yield in small cereal crops was determined through three yield components: the number of spikes per m^2, the number of grains per spike, and the weight of the grain, which is the result of the action and interaction of many components such as plant height, number of tillers and number of grains per spike and harvest index [25]. The interaction of multiple factors determines wheat grain yield and is a reliable measure for assessing the effectiveness of different inputs in a specific situation. Achieving high grain yield is the primary objective of any agricultural study.

The increased nitrogen levels boosted vegetative growth because of their vital role in cell division, proliferation, and root development, resulting in larger leaf area, higher photosynthesis rates, and greater transfer of carbohydrates from sources to grains, ultimately causing more dry matter accumulation and extending the vegetative phase. The improper use of nitrogen fertilizers greatly contributes to crop diseases and reduces yields, as demonstrated in the Hsad and Tamuz-3 varieties. Wheat can be impacted by yellow rust throughout its growth stages. The leaves become coated with uredinia, which are produced by the fungus. These fungi take up water and nutrients from the plant, leading to higher rates of transpiration and respiration while hindering photosynthesis. This can harm the plants by stunting their growth, decreasing the number of tillers, and reducing both the weight of the spikes and the number of grains they produce. Furthermore, the infected leaf tissues restrict the plant's photosynthetic capacity and cause excessive water loss. As a result, yellow rust negatively affects yield by diminishing the area of green foliage, which influences the sugar supply available for developing seeds [21].

Conversely, it was observed that increasing nitrogen (N) application levels did not lead to a significant increase in grain yield across all treatments. Interestingly, at the highest rate of N application, both the Hsad and Tamuz-3 varieties produced lower grain yields compared to the other N application levels. Medium nitrogen levels (less than recommended at 40 kg/ha) provide an optimal balance between disease control and yield maximization. Additionally, splitting nitrogen applications helps balance plant growth and reduces the risk of disease outbreaks. Proper nitrogen management and disease control are critical for optimizing these components. Choose bread wheat varieties with genetic resistance to stripe rust because resistant varieties reduce the need for chemical control and perform better under high nitrogen levels. A farmer in a rain-fed region plants a resistant variety, applies (40 kg/ha) nitrogen in two splits, rotates wheat with legumes, and applies fungicides only when necessary. This approach minimizes stripe rust severity and ensures stable yields.

Table (6): Mean squares of the variance analysis of the effect of nitrogen fertilizers on yield and its components in five bread wheat varieties.

S.O. V	d.f	Mean							
		Spike Length (cm)	Awn Length (cm)	No. of Spike/ m^2	Spike Weight (g)	No. of Grains /Spike	Grain Weight/ Spike (g)	1000 Grain weight (g)	Grain Yield (g/m^2)
Variety	4	57.33**	9.91**	26265.52**	7.94**	577.06**	5.53**	34.62**	98052.46**

Nitrogen fertilizers	3	1.51**	0.384$^{n.s}$	3319.18**	0.15**	49.83**	0.14**	7.36**	28615.74**
Replication	2	0.17	0.06	2871.49	0.11	22.60	0.03	9.89	132.85
Variety*Nitrogen fertilizers	12	1.46**	0.26**	2930.46**	0.18**	42.36**	0.14**	3.32**	3202.94**
Error	38	0.433	0.15	2267.20	0.09	22.27	0.16	3.75	1252.58

Note S.O.V = Source of Variance, d.f= Degree of Freedom, ** = significant at p≤0.01, $^{n.s}$= non-significant at p≤0.01

The findings suggest that there are positive correlations between nitrogen application levels and both the yield output and the occurrence of yellow rust diseases in different wheat varieties. Nitrogen levels above 80 kg N/ha increase disease risk in susceptible varieties. Therefore, select bread wheat varieties with genetic resistance to stripe rust, such as the resistant variety (Sulaimani-2) perform better under moderate N. Apply (40 kg/ha) nitrogen in two splits and avoid high N in rust-prone environments. This implies that nitrogen plays a vital role in affecting growth traits and the evolution of pathogen systems in wheat, which in turn influences crop productivity.

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