Pakistan Journal of Multidisciplinary Innovation (PJMI)

ISSN Print: 2957-501X
ISSN Online: 2957-5028
Volume 4, Number 1, 2025, Pages 49 – 59
Journal Home Page
https://journals.airsd.org/index.php/pjmi

Insights into Nitrogen-Wheat Relationships: A Field Perspective Review

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ARTICLE INFO

Article History:

Received:	*February*	*12, 2025*
Revised:	*March*	*26, 2025*
Accepted:	*April*	*10, 2025*
Available Online:	*April*	*16, 2025*

Keywords:

Nitrogen; wheat growth; Leaf area index; Photo-synthetically active radiation

OPEN ACCESS

ABSTRACT

Chlorophyll requires nitrogen as an essential element and metabolic processes to perform fundamental functions. Proteins that support plant essential functions utilize nitrogen as an essential substance to enhance Leaf Area Index (LAI) through better leaf development along with increased leaf expansion rates. Improved PAR (photosynthetic active radiation) interception leads to increased dry matter production as a result of this process. The practice of nitrogen application represents an essential approach used to enhance wheat yield across specific areas of cultivation land. The various plant growth factors which nitrogen (N) affects most notably include square meter tiller number along with spikelet number per spike and grain number per spike and spike length and 1000-grain weight. The increase of crop yield demands nitrogen application through chemical fertilizer. Farm economic sustainability depends on proper nitrogen fertilizer allocation since it enables wheat production enhancement.

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Introduction

Wheat (Triticum aestivum L.) is extensively grown crop globally due to its capacity to thrive in diverse environmental conditions. Wheat is highly regarded as one of the most widely cultivated staple crop on a global scale. It is the top-ranked cereal crop globally, representing 30% of all cereal meals consumed worldwide (Mălinaş et al., 2022). It is a primary source of sustenance for almost 10 billion people in 43 countries and accounts for around 20% of the total calorie consumption for the worldwide population (de Oliveira Silva et al., 2020). Sustainable agriculture aims to minimize the utilization of various inputs, particularly chemical inputs, in order to mitigate the negative impacts on the environment. Undoubtedly, N is a crucial component for the growth of plants and its scarcity is a significant issue that restricts agricultural output on a global scale (Fathi & Zeidali, 2021). Plant physiological and metabolic processes can be influenced by several types of nitrogen (N), including nutrient uptake, enzyme function, photosynthetic and respiratory rates, water regulation and signalling pathways. These factors eventually impact plant growth and crop productivity (Ding et al., 2015).

Impact of nitrogen (N) on crucial stages of growth

When the nitrogen is scarce to the growing wheat crops, then the yield of the crop and subsequently the earnings from such a crop will be low as compared to a fertilizer-enhanced crop. The continence of water stress from the establishment phase up to the flowering phase of crown roots was detrimental to wheat (Ullah et al., 2018). Water with holding study revealed that only with holding irrigation at booting stage was not significantly reduced the wheat grain yield as compared to the treatment which received five irrigations starting from crown root initiation tillering, booting, flowering and dough stage (Khalid et al., 2023).

The impact of nitrogen (N) on the growth of roots and the use of soil water

According to the research studies, Rasmussen et al. (2015) focused on the effects of nitrogen fertilization on growth of the winter wheat root system as well as the uptake of water in the soil. According to his experiments, the intensity of using water in the soil and root development reducing depend on nitrogen fertilization rates. High nitrogen fertilizer rate reduces the root growth in that they reduce the capability to access the nitrate and water in the deeper soils. The use of nitrogen caused a significant impact on the LAI which further had a positive impact on the head and biomass yield (Wang et al., 2020).

According to Ali et al. (2012), the action of nitrogen fertilizer was studied under different conditions of soil moisture tension and it was found that the optimal crop yield was obtained with the rate of 240 kg N ha^{-1} in non-stressed plants and 180 kg N ha^{-1} in drought scenario. In the current study, wheat went through two treatments of nitrogen (normal nitrogen or high nitrogen) and three levels of soil moisture well-watered plants, plants with moderate water stress, and plants with severe water stress. According to Hussain et al. (2023), results suggested that kernel weight was reduced under low water conditions under normal nitrogen or without nitrogen, while it was enhanced under high nitrogen condition in contrast to the well watered corresponding treatments. Similar results were obtained for the results related to grain yield.

The impact of nitrogen (N) on Leaf area index (LAI) and net assimilation rate (NAR)

The growth of LAI and NAR expanded significantly because of increased P application at low and medium nitrogen levels. The RGR did not experience significant changes under different phosphorus levels although the addition of fixed N rates as phosphorus treatment strengthened RGR results (Eshetu Tesema, 2022). The research by Boulelouah et al (2022) evaluated the relationship between N fertilizer applications and durum wheat yield in semi-arid cultivation areas for matter production and grain yield together with radiation and water use efficiency. The research team demonstrated that nitrogen application caused universal dry matter increases because it produced beneficial effects on leaf area index development and crop green growth. The total dry matter quantity increased together with radiation and water usage efficiency under these conditions.

The results showed that rice LAI exhibited considerable effects due to changes in nitrogen application at every stage of development from 0 to 90 kg ha-1. According to Bashir et al, (2017) the plot that received irrigation at five life stages showed the maximum Leaf Area

Index value. It was found that winter nitrogen increases led to greater LAI in irrigated crops than in non-irrigated crops, according to You et al. (2022). Research data showed that wheat canopy variables expanded due to nitrogen fertilizer application including ground biomass, LAI, percentage of PAR and grain yield (Jia et al., 2021). Diverse plant traits including LAI, CGR, yield, number of spikes per unit area and weight and number of kernels per spike alongside NAR and RGR improved when plants received different levels of nitrogen fertilizer ranging from 0 to 120 kg N fed^{-1}(Che et al., 2020). Khan et.al (2016) performed a study where they evaluated the influence of nitrogen fertilizer rates at 0, 60, 120, 180 Kg ha^{-1} on wheat growth and yield outcomes. A rise in N fertilizer levels led to increased recording of LAI during tillering and booting stage along with both number of tillers and NAR, RGR and weight of grain and grain yield.

The impact of nitrogen (N) on crop yield and its various components

Sharma et al. (2023) discovered that wheat yields during North Indian winter season mostly depended on spike density per meter unit according to their yield performance study in the northwest region. High fertilizer doses lead to increases in grain weight per spike together with spike grain numbers as well as laden spikelet numbers per spike. The research data showed that grain yields increased as nitrogen (N) application rates went up. Specifically, the grain yield rose from 2.37 metric tonnes per hectare with a nitrogen rate of 37 kilogrammes to 2.80 metric tonnes per hectare with a nitrogen rate of 120 kilogrammes (Khan et al., 2016). Data shows that increasing soil nitrogen rates results in superior yields for spikes per square metre and number of kernels per spike as well as biological yield and grain yield (Molla & Tana, 2019). According to Farooq et al., (2018) the enhancement of fertilizer amount led to positive results on plant attributes such as height and number of tillers and spike length and grain numbers and weighing one thousand grains and total contractual yields including grain and straw yields. The following table presents several studies with a link to the selected topic.

Table 1: Impact of Nitrogen Rates on Wheat Yield Components

Nitrogen Rate (kg/ha)	*Key Yield Parameters Affected*	*Yield Increase (%)*	*References*
0-120	*Spikes/m², grains/spike,1000-grain weight*	*18.1% (2.37 to 2.80 t/ha)*	*Khan et al., 2016*
100-140	*Water use efficiency, grain protein*	-	*Proud et al., 2023*
120	*Maximum yield in coastal plains*	-	*Zhang et al., 2022*
125	*Optimal for agro-ecological conditions*	*5.34 t/ha max yield*	*Jaenisch et al., 2022*
150	*Full dose at sowing (3385 kg/ha)*	-	*Plaza-Bonilla et al., 2021*
170	*Productive tillers, grains/spike*	*170*	*Jemal et al., 2022*

Ali (2017) studied how snow accumulation together with nitrogen fertilizer management affects the growth of hard red-spring wheat. The study determined water use as the primary factor which affected all characteristics in the semi-arid region. Straw yield together with number of heads per plant as well as grain yield demonstrated positive relationships with water consumption levels and the amounts of both natural soil nitrogen and applied fertilizer nitrogen. Results showed that more increase occurred as the levels of available water grew higher. Another experimental part studied nitrogen fertilizer management in wheat fields by investigating various application rates along with placement methods and timing effects. The reaction of grain yield to nitrogen fertilizer application increased intensely as application rates fell below higher levels. The application of nitrogen fertilizer failed to show any yield increases in crop cultivation during dry years where the water use remained at 165 mm or below. The application of 50 to 75 kg ha^{-1} fertilizer N produced the best crop yield during normal yearly rainfall levels. An increase in irrigation frequency together with higher nitrogen rates has improved the net return for wheat. According to Agegnehu et al. (2023) a rise in both irrigation frequency and nitrogen rate heightened grain yield numbers for bread wheat and durum wheat crops (Aseefa et al., 2023). The research by Russell et al (2020) examined red winter wheat while testing it with four distinct nitrogen concentration levels. Research findings demonstrated that kernel density across the head rose with each increment in nitrogen quantity while the specific kernel weight decreased simultaneously.

The application of N fertilizer at levels up to 140 Kg ha^{-1} resulted in substantial improvements of water use efficiency alongside enhanced grain output and grain protein content and protein yield totals. The amount of N entering the plant material decreased through this period. Table 2 establishes the effects of nitrogen-water interplay on the system. The research revealed that grain yields would benefit from applying 100-140 kg N ha^{-1} (Proud et al., 2023). Winter wheat crops received N fertilizer sustainably over all developmental stages starting from sowing to tillering until heading in conditions of no irrigation and two levels of irrigation (50% and 100% of the full rate). The research revealed that grain harvests rose from 3.28 to 5.55 and finally to 6.33 t ha^{-1} as irrigation increased progressively. The percentage of N recovered by the crop demonstrated higher numbers in irrigation treatment conditions. When applying N during the tillering stage the crop gained maximum N recovery at both irrigation levels according to Kubar et al. (2022)..

Table 2: Nitrogen-Water Interaction Effects

Irrigation Condition	*Nitrogen Rate (kg/ha)*	*Yield Response*	*Key Findings*	*References*
Well-watered	*240*	*Optimal*	*Best yield in non-stress*	*Ali et al., 2012*
Drought	*180*	*Optimal*	*Adaptation to water stress*	*Ali et al., 2012*
50% irrigation	*-*	*5.55 t/ha*	*69% increase over dry*	*Kubar et al., 2022*
100% irrigation	*-*	*6.33 t/ha*	*93% increase over dry*	*Kubar et al., 2022*
95mm SI + 60N	*-*	*20.1 kg/mm WP*	*Best water productivity*	*Li et al., 2023*

During grain-filling on the south coast plain farmers should supply additional nitrogen to water sources in order to boost photosynthetic speed and duration. The highest grain production along with increased 1000-grain weight and grains per spike per square meter was achieved by using the maximum nitrogen application amount of 120 kg N ha^{-1} (Zhang et al., 2022). Research determined that 100 kg N ha^{-1} stood as the most appropriate nitrogen application level among all tested options. The application of enhanced nitrogen amounts result in the improvement of tillering numbers and enhances plant spike length alongside increasing 1000 grain weight and leading to higher grain yield production in plants (Ul Haq et al., 2023). The crop yield achieved its highest value at 4.71 mt ha^{-1} through testing different nitrogen levels with access to 65% soil water while applying 120 kg ha^{-1} of nitrogen (Ahmed et al., 2023).

Moghaddam et al (2023) conducted research about initial irrigation timing at three different stages of 20, 30 and 40 days after sowing and five nitrogen treatments. The study showed maximum grain production when the first irrigation started twenty days after planting combined with the use of ninety kilograms of nitrogen per hectare. More tillers developed when farmers applied their first irrigation at the 20 sowing days. Wheat crop performance through nitrogen application appeared crucial for all metrics related to tiller production per hectare area and their ability to bear spikes as well as spike grain weight and 1000-grain weight and grain yield and straw yield (Ranjan et al., 2016). Su et al (2021) found about two winter wheat varieties Norstar and Roughrider which examined the impact of conventional tillage and minimum tillage and no tillage combined with nitrogen fertilizer rates at 34, 67 and 101 kg N/ha. Results showed the grain yield reached 1953 kg ha^{-1} with 67 kg N ha-1 N application compared to 34 kg N ha $^{-1}$ which reached 1844 kg ha $^{- 1}$. Application of 101 kg per hectare nitrogen amount the crop was achieved at its highest recorded production level which averaged 2111 kg per hectare. The reduced speed of nitrogen application led to higher seedling numbers per plant and better results for plant height and all studied parameters including fertile tillers, grains per spike, spikelets per spike, 1000 grain weights and harvest index. The examined research data established 5.34 t ha^{-1} of grain yield occurred when nutrient application reached 125 kg ha^{-1} (Jaenisch et al., 2022).

The research conducted by Niu et al (2022) involved the application of N at rates ranging from 0 to 50 to 100 up to 150 kg per hectare of wheat field area. Plants of wheat received different types of irrigation regimes including no irrigation with three variations of SI from one-third to two-third to full SI to fight against moisture stress. The study determined that higher irrigation amounts corresponded with rising yields yet inching nearest to the maximum yield at a usage rate of two-thirds of the complete irrigation system. The local conditions allowed farmers to achieve excellent crop yields reaching 100 kilograms of nitrogen per hectare. Omara et al (2020) performed an experimental research which investigated wheat productivity by testing various densities of plants and nitrogen fertilization rates across specific agro-ecological territories. The experiment included seeding rates of 100, 150 and 200 kg ha^{-1} with two treatments; no N application and 125 kg and 175 kg ha^{-1} N application. This research revealed that increasing seeding density resulted in higher m^{-2} values when nitrogen levels were at their maximum points. The plants reached increased heights because the application of nitrogen resulted in growth promotion. Under the stated conditions the highest wheat grain yield amounted to 5.34 tons per hectare from a density of 200 kilograms per hectare seeded with 125 kilograms per hectare nitrogen. Wheat grain production rose by 9.6% following the application of 90 kg/ha P2O5 and K2O as compared to the control. The yield study revealed that wheat produced 20.3%, 33.7%, 57.2%, 60.2% and 50. 8% of its control level when nitrogen treatment reached 100, 150, 400, 600 and 800 kg per hectare respectively. Traditional tillage methods produced greater wheat yields than other approaches throughout all nitrogen application rates according to study data. The total number of heads per square meter increases when N rates are raised. In the wet growing season wheat showed positive nitrogen (N) response up to 100 kg N ha^{-1} application while it remained unresponsive during dry years (Li et al., 2021). The plots that received 150 kg per hectare nitrogen application at sowing stage achieved the maximum grain yield of 3,385 kg per hectare while their protein content reached 12.26% and harvest index (Plaza-Bonillan et al., 2021).

Table 3: Growth Parameter Responses to Nitrogen

Parameter	*Response to Nitrogen*	*Maximum Effect Level*	*Reference*
Leaf Area Index (LAI)	*Linear increase up to 90-120 kg/ha*	*5-stage irrigation*	*Bashir et al., 2017*
Root Depth	*Reduced at high N (shallow roots)*	-	*Rasmussen et al., 2015*
Tillering	*Increased with N rate*	*200 kg seeding rate*	*Omara et al., 2020*
Photosynthesis	*Enhanced during grain-filling*	*120 kg/ha + irrigation*	*Zhang et al., 2022*
Protein Content	*Increased linearly*	*140-170 kg/ha*	*Jemal et al., 2022*

More water must be applied to the south coast plain during grain-filling to boost photosynthetic rate and duration through enhanced nitrogen fertilization in the spring season. Research findings showed that applying 120 kg N ha^{-1} produced the optimal response for enhancing grain yield along with 1000-grain weight and grains per spike per square metre measurements (Zhang et al., 2022). Among all the nitrogen (N) application rates the 100 kg N ha^{-1} proved suitable for optimal performance. Plants experience a substantial increase of tiller production together with longer spike lengths and heavier 1000-grain weights along with enhanced grain yield when treated with this mode of nitrogen application (Ul Haq et al., 2023). A combination of decreasing soil water access to 65% with applying 120 kg of nitrogen per hectare led to the highest yield at 4.71 mt ha^{-1} (Ahmed et al., 2023). Moghaddam et al (2023) examined irrigation intervals set 20, 30, and 40 days after planting as well as five nitrogen solutions in their investigation. The experimental combination yielding the most grains occurred with the initial irrigation given at day 20 along with the application of 90 kg nitrogen per hectare. Irrigating wheat at the 20 sowing days resulted in more tillers than applying water at any other initial fertilization period. Research found that measurements of wheat crop tillers, spike-bearing tillers and grain weights per spike as well as 1000 grain weight and grain and straw yields demonstrated considerable response to nitrogen dosage (Ranjan et al., 2016). The research by Su et al (2021) studied how conventional tillage combined with minimum tillage and no tillage practice along with nitrogen fertilizer application rates of 34, 67 and 101 kg N/ha influenced two winter wheat varieties Roughrider and Norstar. The experiment showed that wheat produced 1953 kg grain per hectare with 67 kg N ha^{-1} application which yielded greater value than the 1844 kg grain quantity obtained with 34 kg N ha $^{-1}$ treatment. böylelikle workflow received 101 kg of nitrogen per hectare obtained an average crop production of 2111 kg per hectare which became the highest recorded amount. A gradual release of nitrogen led to the multiplication of seedlings and increased plant height and fertile tillers together with enhanced numbers of grain per spike and spikelet per spike and 1000 grain weight measurements and harvest index. The study established that the best nitrogen rate to achieve 5.34 t ha^{-1} grain yield reached 125 kg ha^{-1} (Jaenisch et al., 2022).

Wheat cultivation used nitrogen levels ranging from 0 to 50, 100 and 150 kg N per hectare in the field study (Niu et al., 2022). The research conducted irrigation treatments of different water levels on wheat plants by applying no irrigation and three different ratios of SI including one-third, two-third, and full SI against moisture stress. The test showed growing irrigation volumes boosted yield results yet highest production occurred when irrigation amount matched two-thirds of complete supply. The research area achieved maximum crop yields when farmers applied 100 kg of nitrogen for each hectare of land. Omara et al (2020) established an experimental design for increasing wheat soil population density and nitrogen fertilizer application to reach higher productivity levels in selected agricultural regions. Seedlings at 100, 150 and 200 kg ha^{-1} received either no nitrogen application or 125 or 175 kg ha^{-1} nitrogen in addition to other experimental treatments. The findings showed that seed density elevation at m^{-2} resulted from nitrogen concentration changes. The plant height showed enhancement when nitrogen application occurred in the experiment. Wheat production reached its peak of 5.34 tons per hectare through combining 200 kilograms per hectare planting density with 125 kilograms per hectare nitrogen application considered under those conditions. The application of 90 kg/ha P_2O_5 and K_2O along with 80 kg/ha N resulted in a 9.6% improvement of wheat grain yield over unamended land. A rate of 100 kg N/ha led to 20.3% yield followed by 33.7% yield at 150 kg N/ha and 57.2% yield at 400 kg N/ha. The rate of 600 kg N/ha gave 60.2% yield while 800 kg N/ha led to a yield of 50.8%. The control yield was the reference. Wheat production reaches higher levels when farmers employ traditional tillage techniques at every applied level of nitrogen. The number of heads per square meter raises directly with the increasing N rates. Wheat showed positive nitrogen (N) responses up to rates of 100 kg N per hectare in the wet year although it failed to respond during drought years (Li et al., 2021). The wheat plots administered 150 kg per hectare nitrogen at sowing generated the maximum grain yield of 3,385 kg per hectare alongside 12.26% protein content and harvest index results (Plaza-Bonillan et al., 2021).

Conclusion

The research findings demonstrate that the optimal nitrogen treatment level has substantially enhanced wheat output. Nitrogen enhances leaf area index (LAI) and ultimately contributes to the overall production of dry matter. Nitrogen is influencing the density of tillers per square meter, the number of spikelet per spike, the number of grains per spike, the length of the spike, and the weight of 1000 grains. To enhance wheat output per hectare it is crucial to apply nitrogen in a balanced manner.

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