Research article
J. Adv. Nutri. Sci. Technol. 3(3-4): 63-71, 2023 **DOI:10.15228/ANST.2023.v03.i03-4.p07**

Effect of Nitrogen Sources and Stages on Yield Components of Wheat

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Abstract

A field trial examined the impact of nitrogen sources and application stages on yield components. The research was conducted at the Agronomy Research Farm, The University of Agriculture Peshawar, during the winter of 2022. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of three factors: the first factor involved Nitrogen Levels (NL) (100, 120, and 140 kg. ha^{-1}), the second factor pertained to application sources (S), urea and Farm Yard Manure (FYM) (urea + FYM), and the third factor addressed application stages (A) (sowing, tillering, and stem elongation). Nitrogen levels significantly affected spikes m^{-2} (255.0), net grains weight spike^{-1} (2.6 g), grains spike^{-1} (52.2) and thousand grains weight (48.1 g), respectively. Application stages significantly affected net gain weight (2.5 g) and thousand grains weight (46.9 g). Applications sources also significantly affected grains spike^{-1} (52.7). The interaction NL × S significantly affected grains spike^{-1}. Similarly, the interaction S × A also suggestively affected grains spike^{-1}. The interaction NL × A affected the thousand-grain weight significantly. The research concluded that applying integrated nitrogen sources (Urea + FYM) at a rate of 120 kg. ha^{-1} at an application stage of stem elongation gives a higher yield and is recommended to the end users.

Keywords: Field trial, nitrogen sources and level, yield components, Urea, FYM, thousand grains weight, spikes m^{-2}, net grains weight spike^{-1}

Highlights:

1. The yield components of wheat were significantly affected by Nitrogen levels and application sources (S).
2. The interaction between nitrogen levels and application sources had significant pretentious components of wheat crops.
3. Applying integrated nitrogen sources at a specific stage resulted in stem elongation and higher yield.

1. Introduction

Wheat (*Triticum aestivum* L.) belongs to the family Poaceae and is a significant food source for the people on this planet (Khan et al., 2021). Wheat is cultivated worldwide, including in Pakistan. Its grains are inexpensive energy sources, giving 20% of calories and protein to more than 4.5 billion people in 94 developing countries. It also offers digestible fibers, vitamins, beneficial phytochemicals and minerals (Braun et al., 2010). Globally, Pakistan holds the 8th position among leading wheat-producing countries. Wheat contains substantial dietary nutrients constituting 70%, 22%, 14%, 14%, 2%, and 1.8% of carbohydrates, crude fiber, proteins, water, lipids, and minerals, respectively (Farooq et al., 2015). Its cultivation extends both irrigated and rainfed areas worldwide. According to the reports of the Ministry of National Food Security and Research (2018), Pakistan's total wheat-growing area was 8972.5 thousand hectares (K.ha), yielding a total production of 26673.6 metric tons, with an average production of 2973 kg ha^{-1}. In Khyber Pakhtunkhwa (KP), wheat is cultivated on a total area of 748.7 K.ha, producing 1365.1 million tons. Ministry of Finance (2009) reports indicated that wheat contributes 14% of agriculture's value and 3% to Pakistan's GDP. The Pakistan Economics Survey for 2018-2019 revealed that the wheat area and production were 8,825 thousand ha; the report of Pakistan Economic Survey showed that the area and production of wheat was 8,825 thousand ha and 25 million tons, respectively, making a 1.8 and 2.50 increase from the previous year. After ten years (in 2030), the world population is projected to be approximately 8.5 billion (UN DESA, 2015). Population pressure and growing food demand are linked, so we need maximum production for this vast population. During 2020-2021, wheat was 8.7% with 1.7%, with country wheat production 24 crore, 90 lac tons. Wheat cultivated area increased 1.7 lac. The reduction in wheat yield in Pakistan can be attributed to various factors. The leading causes of this decline in wheat production include water scarcity, calcareous soil conditions, shrinking cultivated areas, changing rainfall patterns, traditional farming practices, imbalanced nutrient availability, extended sugarcane crushing seasons, weed infestation, and fog and smog during November to January. However, wheat production has increased by 2.5% in the current period due to an expansion in cultivated areas, reaching 8,825 hectares (Pakistan Economic Survey, 2019-2020). Applying Nitrogen (N) fertilizer is essential for crop production and successful wheat cultivation. Among the essential macronutrients, N holds particular significance in plant nutrition as it increases wheat yield, elevated crude protein content, enhanced grain gluten content, and overall seed quality (Ali et al., 2011; Litke et al., 2018; Abbas et al., 2023). Nitrogen is recognized as a crucial macronutrient affecting wheat productivity and Nitrogen Use Efficiency (NUE) (Chen et al., 2020). In recent years, nitrogen has been extensively utilized in wheat production, resulting in a notable increase in wheat yield (Duan et al., 2019). The annual fertilizer requirement in Pakistan is approximately 8 million tons, with urea accounting for 5.6 million tons. However, there are challenges associated with urea usage, including volatilization, denitrification, leaching, and economic issues. As a widely used nitrogen fertilizer, urea faces problems such as ecological impact, loss through volatilization, and economic challenges due to its low price. Pakistan has experienced a loss of about 5.7 kilograms of nitrogen per hectare in urea application, resulting in a total loss of 3.4 million tons and a cost of approximately 40.5 billion US dollars (Pakistan Economic Survey, 2012-13). Organic sources also serve as a valuable nitrogen supply for plants, which must transform into inorganic forms such as ammonium (NH_4^+) or nitrate (NO_3^-) before being utilized by plants. Compost, manures, cover crops, crop residues, and city waste products are examples of organic nitrogen sources (Bakhtiar et al., 2017; Mikkelsen and Hartz, 2008). Applying a combination of 120 kg N per hectare from organic and inorganic sources in different ratios has been shown to enhance the crop stand of wheat (Belete et al., 2018; Khan et al., 2021; Naz et al., 2023). Adding Farm Yard Manure (FYM) to the soil improves water penetration. It increases the concentration of residual nitrate (NO_3^-) in the top 50-55 cm of soil compared to using only urea fertilizer. Additionally, the integrated use of farmyard manure and urea results in higher wheat production than Urea or FYM alone while reducing nitrate leaching compared to urea alone (Mazhar et al., 2018; Naz et al.,2023).

Organic manures release nutrients slowly, but their interaction with beneficial microbes can expedite the nutrient-release process (Shaheen et al., 2017). The microorganisms present in FYM play a crucial role in producing hormones and enzymes, stimulating photosynthesis, preventing soil diseases, and initiating organic matter decomposition. Lactic acid bacteria, part of plant growth-promoting bacteria, enhance the availability of nutrients from organic sources and defend plants from biotic and abiotic stresses (Lamont et al., 2017). Photosynthetic bacteria can fix nitrogen, produce growth hormones and antiviral factors (Katsuda et al., 2004), enhance root growth (Kuo et al., 2014), improve photosynthesis and chlorophyll content, and mitigate the toxic effects of heavy metals (Nunkaew et al., 2014). Using beneficial microorganisms in agriculture has gained attraction among Pakistani farmers as a technology to enhance soil fertility and productivity. Organic fertilizers like farmyard manure can reduce the reliance on inorganic fertilizers, and these technologies play an energetic role in boosting the production of agronomic crops (Bremner & Mulvaney, 1982; Naveed et al., 2015). Adequate rates of the application of organic sources result in the prosperity of organic farming (Vermeulen et al., 1993; Ram et al., 2014). Therefore, this study was planned to apply FYM with different N levels on wheat crops to meet the nutrient requirements of wheat through organic means.

2. MATERIALS AND METHOD

2.1. Selection of Research Farm.

The experiment utilized the essential facilities at the Research Farm of Agronomy, University of Agriculture, Peshawar.

2.2. Soil Testing

Before starting the experiment, conduct a thorough soil analysis to assess the soil's electrical conductivity (EC, 309±0.2 µS/cm), pH (7), texture, and other relevant properties. This information will help determine the initial soil conditions and the need for nutrient amendments.

2.3. Plot Layout and Marking

Plan the layout of experimental plots. Based on the information, each plot should be 1.8m × 5m, with six rows spaced 30 cm apart. Mark the plots accurately on the field.

2.4. Phosphorus Application

The basal phosphorus (P) dose at 60 kg ha^{-1} was applied uniformly across the experimental plots, followed by using phosphorus in the soil during soil preparation.

2.5. Nitrogen Application

The calculated amounts of nitrogen from FYM were applied one month before wheat was sowed. It involved spreading the FYM evenly over the plots and incorporating it into the soil.

2.6. Irrigation Management

Irrigation schedules based on crop water requirements ensure that each plot receives the appropriate amount of water to maintain optimal growth conditions.

2.7. Sowing Wheat

Khaista 2017 was selected as a stress-tolerant and high-yielding wheat variety for planting. The seeds were sowed in the prepared plots according to the designated row spacing and seeding rate, ensuring an even distribution of seeds within each row.

2.8. Nitrogen Application (Urea)

Apply inorganic nitrogen (Urea) at the specified rates and stages of sowing, first tiller emergence, and 5 nodes detectable at stem elongation. This can involve careful application of urea near the base of the wheat plants.

2.9. Weed and Pest Management

It has implemented proper weed and pest management practices to prevent interference with the experiment. Regularly monitor and control any negative factors that may affect the crop's growth.

2.10. Irrigation Management

Constant irrigation of the plots is needed throughout the growing season, ensuring that the wheat crop obtains adequate water for optimum development.

2.11. No. of spikes. m^{-2}

A number of spikes were counted in four different rows, and it was converted into a number of spikes m^{-2} using the following formula:

$$\text{Spikes } m^{-2} = \frac{spikes\ counted}{No.of\ selected\ rows \times R{-}R\ distance \times row\ length} \times 1\ m^2 \qquad (1)$$

Where R-R is $Row\text{-}row\ distance\ (m)$

2.12. Net grains weight spike^{-1} (g)

Four spikes at the anthesis stage were taken. They were then oven-dried and weighed. After that, 4 spikes at maturity were taken before harvesting and weighed; then, the weight of oven-dried spikes at anthesis was subtracted from the weight of spikes taken at maturity and then averaged.

2.13. Grains spike^{1}

Grains spike^{-1} were counted randomly in five spikes, and then averaged.

2.14. 1000 grains weight (g)

After threshing and cleaning the seeds, a thousand grains were taken from each plot and weighed by electronic balance up to two decimals.

Data Analysis: Analyze the collected data statistically to assess the effects of integrated nitrogen application on wheat yield and its components. Compare the different nitrogen application rates and stages to determine any significant differences.

Statistical analysis

The data was subjected to statistical analysis for the Randomized Complete Block Design (RCBD). This technique allowed us to account for the block variability and test the treatments' effects. The F-test results were significant at the 0.05 level, representing that there were noteworthy differences among the treatment means

3. Result and Discussion

3.1. Number of spikes m^{-2}

The data (Table 1) reveals the correlation between the number of spikes per square meter and different nitrogen levels, application stages, and the inclusion of FYM. Data was recorded in three rows of one meter and then converted to spikes per m^2 (Equation 1). Analysis of the data revealed that nitrogen level has a substantial impact on spikes m^{-2}. The number of spikes m^{-2} was higher (229) at a nitrogen level of 120 kg ha^{-1} and lowest (219) at a nitrogen level of 100 kg ha^{-1}. NL × S, NL × A, S × A, and NL × S × A all had no statistically significant effects on spike m^{-2}. The difference in mean between the control group and the rest group was determined to be substantial. In comparison, lesser spikes m^{-2} (216) were revealed in the plot when Urea and FYM were administered, and higher spikes m^{-2} (234).

Nitrogen levels significantly affect spikes m^{-2}. Higher spikes of m^{-2} are obtained at a nitrogen level of 120 kg $ha^{-1,}$ while the lower spikes of m^{-2} obtained at a nitrogen level of 100 kg ha^{-1} mean that either the crop is nitrogen responsive or the soil is deficient in nitrogen. The control Vs rest also showed a significant effect on spikes m^{-2}. Higher spikes of m^{-2} were gained in the plot where nitrogen and FYM were applied, while lower spikes of m^{-2} were obtained in the control plot where no nitrogen and FYM were applied. These findings align with the results of Ali *et al.* (2011), who also reported higher spikes^{-2} in the plot where nitrogen and FYM were applied (Hooda & Malik 2019).

Table. 1 Effect of N sources and application stages on spikes m^{-2}:

Nitrogen level (NL) (kg ha^{-1})	Application source (S)	Application stages (A)			NL × A
		Sowing	First Tiller	Stem Elongation	
100	Urea	217.9	207.9	233.8	219.9
	Urea + FYM	200.2	231.8	219.9	217.3
120	Urea	211.3	234.1	236.6	227.3
	Urea + FYM	224.6	241.3	227.4	231.1
140	Urea	249.9	234.3	266.2	250.1
	Urea + FYM	267.1	252.1	260.3	259.8
100		209.1	219.9	226.8	218.6 b
120		217.9	237.7	232.0	229.2 b
140		258.5	243.2	263.2	255.0 a
	Urea	226.4	225.4	245.5	232.4
	Urea + FYM	230.6	241.7	235.9	236.1
		228.5	233.6	240.7	
Control Vs. Rest	Control	216 ab			
	Rest	234.2531a			
SOV (full form)		L			
N Levels (N)		21.73			
Application stages (A)		NS			
Application Sources (S)		NS			
NL × S		NS			
NL × A		NS			
S × A		NS			
NL × S × A		NS			

Means of the same category followed by different letter(s) are significantly different at 5% level of probability using the LSD test.

3.2. Net grains weight spike^{-1}

The effects of nitrogen levels, application stages, and nitrogen levels combined with FYM on net grain weight per spike (g spike^{-1} are shown in Table 2. The study of the data shows that nitrogen levels have a considerable impact on net grain weight per spike^{-1}. Notably, a nitrogen level of 140 kg ha^{-1} produced the highest net grain weight, which was 2.6 grams, while a nitrogen level of 100 kg ha^{-1} produced a significantly lower net grain weight, 2.2 grams. The application stage also considerably impacted the net grain weight per spike^{-1}. Meanwhile, the planting stage produced a lower net grain weight. The stem elongation stage showed a greater net grain weight of 2.5 grams. However, the sowing phase decreased net grain weight by 2.2 grams. However, the application procedure had no statistically significant impact on net grain weight. Similar to the interactions between nitrogen levels and application stages, nitrogen levels and application methods, application stages and methods, and the combined interaction of all factors (NL × S × A), none of these interactions significantly impacted net grains weight per spike^{-1}.

Nitrogen levels significantly affected net grain's weight spike^{-1}. Higher net grain weight was recorded at a nitrogen level of 140 kg ha$^{-1,}$ while lower net grain weight spike^{-1} was recorded at a nitrogen level of 100 kg ha^{-1}. Application stages also influenced net grain significantly. Higher net grain was obtained at an application stage of stem elongation, while lower net grain weight was recorded at an application stage of sowing. The mean comparison between control Vs rest significantly affected net grain weight. Higher net grain weight was recorded in the plot where nitrogen level and FYM were applied, while lower net grain weight was recorded in control plots. Our findings align with the results of Choudhary et al. (2022), who also recorded higher net grain weight (3g) at 25% RDF + FYM @ 18 t ha^{-1} (Fattah et al.,2015).

Table 2. Effect of N sources and application stages on average net grain weight spike^{-1} (g)

Nitrogen level (NL) (kg ha^{-1})	Application source (S)	Application stages (A)			NL × A
		Sowing	First Tiller	Stem Elongation	
100	Urea	2.134167	2.141667	2.129167	2.135
	Urea + FYM	2.1	2.4	2.2	2.2
120	Urea	2.0	2.3	2.4	2.3
	Urea + FYM	2.1	2.4	2.7	2.4
140	Urea	2.5	2.5	2.7	2.6
	Urea + FYM	2.3	2.5	3.1	2.6
100		2.1	2.3	2.2	2.2 b
120		2.1	2.4	2.6	2.3 b
140		2.4	2.5	2.9	2.6 a
	Urea	2.2	2.3	2.4	2.3
	Urea + FYM	2.2	2.4	2.6	2.4
		2.2 b	2.4 ab	2.5 a	
Control Vs. Rest	Control	1.9233 b			
	Rest	2.3725 a			

Source of Variance	LSD
N Levels (N)	0.24
Application stages (A)	0.24
Application Sources (S)	NS
NL × S	NS
NL × A	NS
S × A	NS
NL × S × A	NS

Means of the same category followed by a different letter(s) are significantly different at a 5% level of probability using the LSD test.

3.3. Grains spikes^{-1}

The information in Table 3 illustrates the effects of N concentrations, N concentrations mixed with FYM, and different application phases on the quantity of grains per spike (grains spike^{-1}) in wheat. The data shows that nitrogen concentrations significantly affect the number of grains spike^{-1}. In particular, at a N level of 140 kg per ha, more grains per spike (52) were recorded, but at a N level of 100 kg per ha, less grains per spike (40) were seen. The influence on application phases was found to be insignificant. However, the selection of application sources has a significant effect. When Urea and FYM were combined, the number of grains per spike increased (53) but decreased (50) when just urea was used. While the interaction between application stages and techniques (S × A) substantially impacted grains per spike, the interaction between nitrogen levels and application stages (NL × S) was insignificant. This study showed that urea+ FYM enhanced the number of grains per spike at all stages.

Nonetheless, all-encompassing interaction (NL × S × A) was shown to be non-significant. Nitrogen levels have a significant impact on the number of grain spikes^{-1}**.** A higher number of grain spike-1 was recorded using N at a rate of 140 kg ha-1, while a lower number of grain spike^{-1} was recorded using N at a level of 100 kg ha^{-1}. Different application sources also had a significant effect on no of grains spike^{-1}. The higher number of grain spike-1 was recorded when urea was applied in integration with FYM while a lower number of grain spike^{-1} was recorded when only urea was applied. The effect was found significant in the interaction NL × S. In the case of interaction, S × A showed a significant impact on the number of grains spike^{-1}. The comparison between control Vs rest also showed a significant effect, where a higher number of grain spike-1 was recorded in the plot where Urea and FYM were applied, and a lower number of grain spike^{-1} was recorded in the control plot. These results conform with Kavita et al. (2019), who also reported that utilizing 120 kgN.ha^{-1} significantly enhanced growth parameters, yield, and yield attributes compared to the control group. Furthermore, the combined application of 15 t / ha FYM with 120 kg N/ha demonstrated a substantial improvement in both the growth and yield of wheat (Baillot et al., 2018).

Table 3. Effect of N level, FYM and application stages on grains spike^{-1}

Nitrogen level (NL) (kg ha^{-1})	Application source (S)	Application stages (A)			NL × A
		Sowing	First Tiller	Stem Elongation	
100	Urea	49.7	49.7	48.3	49.2
	Urea + FYM	48.7	51.0	52.5	50.7
120	Urea	49.8	50.3	49.7	49.9
	Urea + FYM	53.3	54.0	56.3	54.6
140	Urea	50.0	52.0	50.0	50.7
	Urea + FYM	54.0	50.3	53.9	52.8
100		49.2	50.3	50.4	50.0 b
120		52.0	51.2	52.0	51.7ab
140		51.6	52.2	53.0	52.2 a
	Urea	49.8	50.7	49.3	49.9 b
	Urea + FYM	52.0	51.8	54.2	52.7 a
		50.9	51.2	51.8	
Control Vs. Rest	Control	46.33333b			
	Rest	51.30741a			

Source of Variance	LSD
N Levels (N)	1.27
Application stages (A)	NS
Application Sources (S)	1.03
NL × S	*
NL × A	NS
S × A	*
NL × S × A	NS

3.4. Thousand-grain weight (g)

The data in Table 4 illustrates the impact of several N levels, application stages, and the integration of nitrogen levels with farmyard manure (FYM) on a thousand-grain weight. Data analysis showed that the N level significantly affected the weight of a thousand grains. A higher thousand-grain weight (48.1g) was recorded using a nitrogen level at a rate of 140 kg.ha$^{-1,}$ while lower thousand-grain weight (44.3 g) was recorded at 100 kg.ha^{-1} nitrogen level.

Furthermore, application stages also exhibited a significant effect on thousand-grain weight. The maximum weight (46.9 g) occurred during the stem elongation stage, while the minimum weight (44.66 g) was recorded at the sowing time stage. However, the source of application had a non-significant effect on the grain weight. Similarly, the interaction between nitrogen levels and application stages (NL × S) showed a non-significant effect on thousand-grain weight (Hammad et al., 2011). Conversely, the interaction (NL × A) demonstrated a significant impact, indicating that increasing nitrogen levels across all application stages increased the thousand-grain weight. Interactions (S × A) and (NL × S × A) were found to be non-significant. The planned mean combinations exhibited a significant effect on thousand-grain weight. The highest weight (45.6 g) was observed in plots where nitrogen and FYM were applied, and the lowest weight (42.3 g) was recorded in the control plots (Horvat et al.,2021; Khan et al.,2023; Khan et al., 2013; Walsh et al., 2018).).

Results showed that nitrogen levels significantly affected the weight of thousands of grains. A higher thousand-grain weight was recorded using the N level at 140 kg ha$^{-1,}$ while a lower thousand-grain weight was recorded at 100 kg ha^{-1} nitrogen level. Application stages also significantly affected thousand-grain weight. Higher thousand-grain weight was recorded at an application stage of stem elongation, while lower thousand-grain weight was recorded at an application stage of sowing time. The planned mean combination significantly affected thousand-grain weight (Memon et al.,2013). Higher thousand-grain weight in plots where N level and FYM were applied, while lower thousand-grain weight was recorded in the control plots. These findings are similar to the conclusion of Muhammad et al. (2013), who reported that a maximum thousand-grain weight was produced where FYM + Full NPK was applied while a minimum thousand-grain weight was recorded where no FYM and NPK was applied (Mahmood et al., 2023; Rathwa et al., 2018).

Table 4. Effect of N level, FYM and application stages on 1000 grains weight (g).

Nitrogen Level (NL) (kg ha^{-1})	Application source (S)	Application stages (A)			NL × A
		Sowing	First Tiller	Stem Elongation	
100	Urea	44.7	44.3	43.7	44.2
	Urea + FYM	44.0	45.0	44.3	44.4
120	Urea	43.0	44.0	43.7	43.6
	Urea + FYM	44.0	47.0	45.0	45.3
140	Urea	45.7	45.3	52.0	47.7
	Urea + FYM	46.0	46.7	53.0	48.6
100		44.3	44.7	44.0	44.3 b
120		43.5	45.5	44.3	44.4 b
140		45.8	46.0	52.5	48.1 a
	Urea	44.4	44.6	46.4	45.1
	Urea + FYM	44.7	46.2	47.4	46.1
		44.6b	45.3ab	46.9 a	
Control Vs. Rest	Control	42.33333b			
	Rest	45.62963a			
Source of Variance		LSD			
N Levels (N)		1.85			
Application stages (A)		1.85			
Application Sources (S)		NS			
NL × S		NS			
NL × A		**			
S × A		NS			
NL × S × A		NS			

Means of the same category followed by a different letter(s) are significantly different at a 5% level of probability using the LSD test.

4. Conclusion

In this investigation, integrated nitrogen sources (Urea + FYM) at a rate of 120 kg ha^{-1} significantly influence the application stage of stem elongation, give a higher yield and increase the spike numbers, indicating the potential provides a reference for the rational application recommended to the end users.

Acknowledgement:

We want to thank all the authors who contributed to this paper. Their expertise, insights, and feedback were invaluable for shaping the research question, methodology, analysis, and discussion. We also appreciate their patience and cooperation throughout the writing and revision process. Without their support and collaboration, this paper would not have been possible.

Conflict of interest: No conflict of interest exists among the authors

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Received:10th September, 2023. **Accepted: 26th December, 2023.**