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OPTIMIZING NITROGEN AND SEED RATES FOR ENHANCED WHEAT YIELD AND QUALITY

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Abstract

This study examined the effects of varying nitrogen levels (0-160 kg ha^{-1}) and seed rates (60-150 kg ha^{-1}) on wheat yield and quality at Bacha Khan Agriculture Research Farm, Pakistan, during the year 2017-18 fall season. Results indicated that optimal nitrogen application (120-160 kg ha^{-1}) and seed rates (120-150 kg ha^{-1}) significantly improved yield attributes, including leaf area index, plant height, biological and grain yield, and harvest index. Nitrogen and seed rates interaction had a significant impact on these parameters, with the highest values observed at 120-160 kg N ha^{-1} and 120-150 kg seed ha^{-1}. The results indicate that optimizing nitrogen levels and seed rates can enhance wheat productivity and quality.

Key words: *Agronomic management practices, Crop quality improvement, Nitrogen fertilization, Seed rate optimization, Wheat productivity*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is serving as a major source of food and nutrition for millions of people. In Pakistan, wheat is a staple crop, accounting for more than 70% of the country's total cereal production (1). However, wheat yields in Pakistan have been declining in recent years due to various factors, including soil fertility degradation, inadequate nutrient management, and suboptimal seed rates (2).

Nitrogen (N) is a critical nutrient for wheat production, playing a significant part in plant growth and development. Recent studies have shown that optimal N rates can significantly improve wheat yields and quality (3-4). For instance, a study found that N application at 120 kg ha^{-1} resulted in higher wheat yields and protein content compared to lower N rates (4). Similarly, seed rate is another crucial factor influencing wheat yields, with optimal seed rates varying depending on factors such as soil type, climate, and cultivar (4).

Despite the importance of N and seed rates in wheat production, there is limited information on the optimal N and seed rates for wheat crops in Pakistan. Therefore, this research sought to explore the outcomes of various nitrogen and seed rates on the qualitative and quantitative parameters of the wheat. With a view to identifying optimal management strategies for improving wheat yields and quality in Pakistan.

Nitrogen is a critical nutrient for wheat production, often limiting yields in both irrigated and high rainfall areas (5). Adequate nitrogen fertilizer application is essential for achieving high yields and protein content in wheat (6). Nitrogen plays a crucial role in plant development, initiating root, floret, and leaf development, and is a key component of photosynthesis and carbohydrate production (7). Optimal nitrogen application can improve protein concentration, kernel integrity, and milling qualities of wheat grain, as well as increase biomass yields and influence various crop parameters, including 1000-grains-weight, tillers per m-2, and biological yield (8-10). The purpose of this study was to examine the impact of different nitrogen rates on wheat production and identify optimal nitrogen application strategies for improved yields and quality.

Nitrogen is a crucial element for wheat production, influencing yield components, including grain weight and number (11-12). Optimal nitrogen supply is linked to high photosynthetic activity, vegetative growth, and carbohydrate utilization (13). Seed rate also plays a vital role in wheat productivity, with optimal seeding rates varying among areas, climatic conditions, soil types, and crop varieties (14-15). Excessive nitrogen application can lead to lodging, delayed maturity, and increased vulnerability to diseases and pests (16). The study aims to evaluate the effects of nitrogen levels and seed rates on wheat yield and quality, emphasizing their crucial roles in optimizing productivity while minimizing adverse environmental impacts.

MATERIALS AND METHODS

The study comprised four seed rates (60, 90, 120, and 150 kg ha^{-1}) and five nitrogen levels (0 (control), 40, 80, 120, and 160 kg ha-1), with phosphorus (P) applied uniformly at 80 kg ha^{-1} across all treatments. Agronomic parameters measured included leaf area index, plant height, biological yield, grain yield, harvest index, nitrogen concentration, and protein content in both grains and straw. Additionally, laboratory analyses were performed for soil texture (17), crude protein percentage in grain (18), and crude protein percentage in straw. The experimental soil's physicochemical properties were also evaluated (Table I).

Table I. Characteristics of the experimental soil: Physico-chemical properties

Parameters	Units	Value
Soil Ph	-	6.54-6.70
E. C	dS m^{-1}	0.18-0.22
Organic Matter	% (m/m)	0.56-0.69
Phosphorus	Mg-kg^{-1}	1.23-1.30
Nitrogen	Mg-kg^{-1}	0.23-0.28
Potassium	Mg-kg^{-1}	154.8-158.2

NITROGEN CONCENTRATION IN GRAINS

Total nitrogen (N) in wheat grain samples will be determined using the Kjeldahl method. Briefly, 0.2g of powdered wheat grain sample were digested with 3ml of concentrated H2SO4 and a digestion mixture, followed by distillation with 20ml of 40% NaOH solution and titration against 0.1N HCl solution, where 1ml of 1N HCl equals 14mg N (19).

NITROGEN CONCENTRATION IN STRAW

Total nitrogen (N) in wheat straw samples were measured using the Kjeldahl method. Briefly, 0.2g of powdered wheat straw sample will be digested with 3ml of concentrated H2SO4 and a digestion mixture, followed by distillation with 20ml of 40% NaOH solution and titration against 0.1N HCl solution, where 1ml of 1NHCl equals 14mg N (19).

PROTEIN (%) IN GRAINS AND STRAW

Near-infrared reflectance spectroscopy (20) was used to determine grain protein content (%).

STATISTICAL ANALYSIS

The research was implanted according to (RCBD) with (LSD) test at a 5% significance level (21).

RESULTS AND DISCUSSION

Leaf Area Index of wheat was markedly impacted by nitrogen, seeding rates, and their interaction (Table II). The maximum Leaf Area (5.2) was observed when 150 kg seed rate ha^{-1} was combined with 160 kg N ha-1. Nitrogen application alone resulted in a maximum Leaf Area (4.9) at 160 kg ha^{-1}, compared to a minimum (3.5) in control plots. Among seeding rates, 150 kg ha^{-1} yielded the highest LAI (4.5), while 60 kg ha^{-1} resulted in the lowest (4.1).

Table II. Leaf area index in wheat as influenced by nitrogen and seeding rates

Seed rates (kg ha^{-1})	Nitrogen (kg ha^{-1}) 0	40	80	120	160	Mean
60	3.2	4.0	4.2	4.2	4.7	4.1
90	3.5	4.3	4.3	4.4	4.9	4.3
120	3.6	4.5	4.4	4.6	5.0	4.4
150	3.8	4.2	4.7	4.8	5.2	4.5
Mean	3.5	4.2	4.4	4.5	4.9	

Plant height showed the significant response to nitrogen and seeding rates, exhibiting the maximum plant height (102 cm) recorded at 120 kg N ha^{-1} and 150 kg seed rate ha^{-1}, while the shortest plants (81 cm) were noted in N control plots (Table III).

Table III. Plant height (cm) in wheat as influenced by nitrogen and seeding rates

Seed rates (kg ha^{-1})	Nitrogen (kg ha^{-1}) 0	40	80	120	160	Mean
60	75	81	82	94	100	86
90	81	82	88	92	92	87
120	78	85	92	94	102	90
150	91	86	93	93	99	92
Mean	81	84	89	93	98	

Nitrogen levels, seeding rates, and their interaction significantly impacted crop yield (11791 kg ha^{-1} at 120 kg N ha^{-1} and 120 kg seed ha^{-1}) and grain yield (4109 kg ha^{-1} at 120 kg N ha^{-1}), with smallest yields in control plots (7925 kg ha^{-1} and 3021 kg ha^{-1}, respectively) (Tables IV and V).

Table IV. Biological yield (kg ha^{-1}) in wheat as influenced by nitrogen and seeding rates

Seed rates (kg ha^{-1})	Nitrogen (kg ha^{-1}) 0	40	80	120	160	Mean
60	6301	7373	7734	9166	7875	7690
90	7393	7484	8210	9635	8284	8201
120	9689	10412	10539	11791	11173	10721
150	8319	8793	9284	9652	9741	9158
Mean	7925	8515	8942	10061	9268	

Harvest index was also significantly influenced by nitrogen, seeding rates, and their interaction. The maximum harvest index (45%) Maximum protein (15.1%) was achieved with 120 kg N ha^{-1} and 150 kg seed rate ha^{-1}, while the control group had the lowest (38.3%) (Table VI).The effects of nitrogen and seeding rates on nitrogen and protein concentration in wheat straw and grain were evaluated.

Table V. Grain yield (kg ha^{-1}) in wheat as influenced by nitrogen and seeding rates

Seed rates (kg ha^{-1})	Nitrogen (kg ha^{-1}) 0	40	80	120	160	Mean
60	2451	2757	2940	3752	3090	2998
90	2875	3064	3267	3965	3358	3306
120	3472	3904	4067	4379	4154	3995
150	3284	3550	3841	4342	4133	3830
Mean	3021	3319	3529	4109	3684	

Table VI. Harvest index (%) in wheat as influenced by nitrogen and seeding rates

Seed rates (kg ha^{-1})	Nitrogen (kg ha^{-1}) 0	40	80	120	160	Mean
60	39	37	38	41	39	38.9
90	39	41	40	41	41	40.3
120	36	38	39	37	37	37.3
150	40	40	41	45	42	41.7
Mean	38.3	39.1	39.4	41.1	39.8	

Nitrogen concentration in straw varied significantly with nitrogen application, with maximum values (0.50, 0.51%) observed at 120-160 kg N ha^{-1}, and minimal (0.42%) in untreated plots (Fig. 1a). Similarly, nitrogen concentration in grain was significantly affected by nitrogen application, with maximal values (2.07%) observed at 120-160 kg N ha^{-1}, and minimal (1.92%) in untreated plots (Fig. 1b). Protein concentration in straw also varied significantly with nitrogen application, with maximal values (2.83, 2.89%) observed at 120-160 kg N ha^{-1}, and minimal (2.38%) in untreated plots (Fig. 1c). Protein concentration in grain was significantly affected by nitrogen application, with maximal values (11.82%) observed at 120-160 kg N ha^{-1}, and minimal (10.94%) in control plots (Fig. 1d).

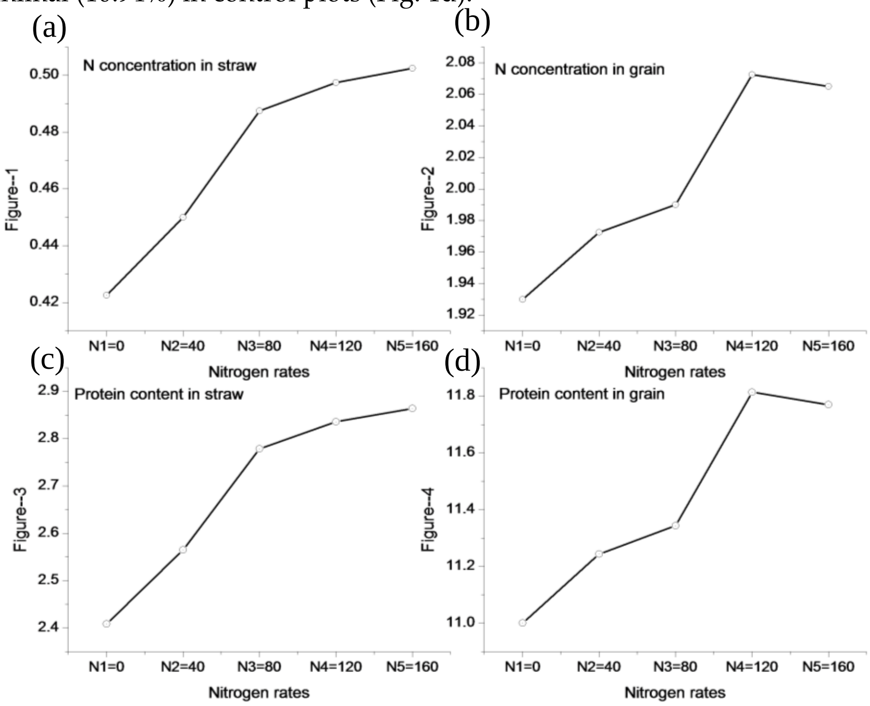

Fig. 1(a-d). Nitrogen and Protein concentration in wheat straw and grain as affected by nitrogen rates

DISCUSSION

The study evaluated the effects of nitrogen and seeding rates on wheat crop performance, revealing that while days to emergence were unaffected by nitrogen and seeding rates (22-23), emergence per m-2 was significantly influenced by seeding rates, with optimal rates at 120-150 kg ha-1 (24). Nitrogen levels, seeding rates, and their interaction significantly impacted various yield components, including tillers per m-2 (25-28), grains per spike-1 (29-30), leaf area index (LAI) (31), 1000-grain weight (32), plant height (33), spike length (34-35), spikes per m-2, biological yield (36-37), grain yield (38), and harvest index (39), with maximum values generally observed at 120-160 kg N ha-1 and 120-150 kg seed ha-1. Additionally, nitrogen application significantly affected nitrogen concentration and protein content in straw and grain (40-41). While the study observed that days to emergence remained unaffected by varying nitrogen and seeding rates, the emergence per square meter was significantly influenced by seeding rates, with optimal emergence noted at 120–150 kg ha^{-1}. This aligns with findings from Sarker *et al.* (2022), who reported that seeding rates within this range enhanced emergence and early vigor, contributing to uniform stand establishment (42).

Nitrogen levels, seeding rates, and their interaction significantly impacted key yield components. •

Increased N application up to 160 kg ha^{-1} promoted tillering, enhancing the potential for higher spike density. Optimal nitrogen levels improved grain number per spike, a critical determinant of yield. Enhanced LAI under higher nitrogen rates facilitated greater photosynthetic capacity, supporting biomass accumulation. Both parameters showed positive responses to increased nitrogen and optimal seeding rates, contributing to overall yield improvements. The combined application of 120–160 kg N ha^{-1} and 120–150 kg seed ha^{-1} resulted in maximum grain yield and harvest index. This synergistic effect underscores the importance of balanced nutrient and seeding strategies. Similar trends were observed by Wang *et al.* (2022), who reported that nitrogen application at 150–225 kg ha^{-1} under straw incorporation significantly improved grain yield and nitrogen use efficiency (43).

Nitrogen application significantly influenced the nitrogen concentration and protein content in both straw and grain. Moderate nitrogen levels (around 150 kg ha^{-1}) were found to enhance protein content without compromising yield. Excessive nitrogen, however, did not proportionally increase protein levels and could lead to environmental concerns. While nitrogen fertilization is essential for optimal wheat production, excessive application can lead to environmental issues such as nitrate leaching and greenhouse gas emissions. Studies emphasize the need for precision in nitrogen management to balance productivity with environmental sustainability.

CONCLUSION

In conclusion, this study revealed that the optimal application of nitrogen (N) at 120 kg ha^{-1} and seeding rate at 120 kg ha-1 significantly enhanced grain yield, protein content in grains and straw, and overall wheat production. These findings suggest that nitrogen application at 120 kg ha-1 is recommended to secure higher yields and protein content in wheat, while a seeding rate of 120 kg ha^{-1} is optimal for maintaining higher yields. The strategic optimization of nitrogen and seeding rates is pivotal for enhancing wheat yield and quality. By adopting balanced fertilization and seeding practices, farmers can achieve sustainable production goals while mitigating environmental impacts.

RECOMMENDATIONS

Applying nitrogen at 120–160 kg ha^{-1} is recommended to maximize yield and quality while minimizing environmental risks. A seeding rate of 120–150 kg ha^{-1} ensures adequate plant population and resource utilization. Combining appropriate nitrogen and seeding rates with practices like straw incorporation can enhance nitrogen use efficiency and soil health.

Ethical statement:

No ethical issues were raised during the course of study.

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Authors` contribution:

Concept: ZH, AK. Plan: ZH, WAS. Data analysis: RA, WAS. Writing, review and editing: RA, MA, WAS and MF. All authors have reviewed and consented to the final version of the manuscript for publication.

Conflict of interest:

Authors have no conflict of interest.

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