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Optimization of nitrogen and phosphorus doses on growth and yield of cotton (*Gossypium hirsutum* L.) under northeast climate of Afghanistan

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Abstract
An experimental trial was conducted at the Kunduz Spinzar Owned-Corporation farm in collaboration with the agriculture faculty of the University of Kunduz in Afghanistan's Kunduz province during the 2023 cotton growing season to assess the impact of different levels of nitrogen (N) and phosphorus (P) fertilizers on the growth and yield of cotton crops. The trial was set up using a randomized complete block design (RCBD) with each treatment replicated three times. The treatments included a control plots and various combinations of N and P fertilizers ranging from 40:20 to 280:140 kg N/ha+P_2O_5/ha. The highest yields of lint and seeds, reaching 1799 kg/ha and 3937 kg/ha respectively, were recorded in plots treated with 200 kg N/ha and 100 P/ha. Economic analysis revealed that this treatment also resulted in the highest lint yield (192835 AFN), seed yield (179928 AFN), gross return (372764 AFN/ha), net return (334284 AFN/ha), and a benefit-cost ratio of 8.687. In contrast, the plots in the absolute control plots exhibited the lowest growth and yield parameters. Farmers in northeast Afghanistan and similar agro-ecological regions should consider applying 200 kg N/ha and 100 P/ha to achieve optimal cotton yield and productivity in their fields.

Keywords: Cotton, growth, nitrogen, phosphorus, yield

Introduction
Cotton crop is scientifically known as (*Gossypium hirsutum* L.) and belonging to the Malvaceae family, is typically grown as an annual plant that requires reseeding each year. It is a significant cash crop in Northeast Afghanistan, especially after the discovery of its profitable potential due to the presence of oil (Khaleeq *et al*., 2023c) [13]. Cotton cultivation spans across more than 75 countries worldwide, covering approximately 32 million hectares of land with diverse agro-ecological conditions. The global cotton lint market generates over $20 billion annually (Saranga *et al*., 2001) [21]. The growth and yield of cotton crops are influenced by various factors such as cultivars, crop management practices, and environmental conditions (Gwathmey and Craig, 2003) [6]. Selecting cotton cultivars that mature at the right time is crucial for efficient harvesting (Faircloth, 2007) [3]. Phosphorus is an essential nutrient for various important processes in plant tissues, including plant respiration, photosynthesis, and the formation of phospholipids that make up plant structures (Taiz and Zeiger, 2003) [25]. Phosphorus fertilizers can be absorbed by leaves and developing cotton bolls, benefiting from the phosphorus stored in older plant tissues. Cotton crops typically require a phosphorus concentration ranging from 0.20% to 0.31% (Crozier *et al*., 2004) [2]. Both nitrogen and phosphorus fertilizers play a vital role in promoting the growth and yield of cotton (Khaleeq *et al*., 2023b) [8]. However, excessive nitrogen application can negatively impact cotton growth by disrupting the soil nutrient balance, leading to excessive vegetative growth at the expense of maturity and increasing the crop's susceptibility to diseases and pests (Khaleeq *et al*., 2023d) [12]. Conversely, nitrogen deficiency in cotton can result in stunted growth, yellowing of leaves, premature leaf shedding, and the formation of small, tough bolls (Khaleeq *et al*., 2023d) [12]. Phosphorus plays a crucial role in promoting growth and improving the root system's ability to uptake water and nutrients from the soil.

A lack of phosphorus in beans can lead to decreased yield, inefficient utilization of soil nitrogen, and limited crop productivity (Khaleeq *et al*., 2023a) [11]. Phosphorus fertilizer is essential for supporting crop nutrition and is vital for various genetic processes throughout plant growth, reproductive stages, and adaptation to different agricultural environments (Seleiman *et al*., 2020) [24]. It is essential for photosynthesis, nutrient absorption, the synthesis of organic compounds, phospholipids, enzyme activities, and genetic characteristics in plants (Lopez-Arredondo *et al*., 2014; Farkhari *et al*., 2023) [15, 4]. Applying phosphorus fertilizer can enhance soil phosphorus availability and boost biomass accumulation in cotton crops, particularly in reproductive tissues (Cheptoek *et al*., 2021) [1]. As cotton cultivation occurs in various regions worldwide with different economic conditions, the nutrient requirements of crops vary significantly. Providing the right amount of essential inorganic elements through well-balanced macro and micronutrient fertilizers is crucial for enhancing crop growth and increasing yields (Zubillaga *et al*., 2002; Khaleeq *et al*., 2023e) [26, 14]. The utilization of mineral fertilizers, including nitrogen and phosphorus, plays a crucial role in enhancing cotton crop productivity and quality worldwide. Optimal levels of these fertilizers are essential for achieving high lint yield, seed yield, and boll development in cotton cultivation, which is integral to the agricultural and commercial sectors. Furthermore, the production of high-quality cottonseed oil and other valuable by-products derived from cotton seeds further underscores the significance of cotton production in global trade. In various regions around the world, the utilization of phosphorus as a key nutrient in cotton production has become imperative for farmers seeking to enhance commercial productivity. Effective phosphorus fertilization is a fundamental component of profitable cotton crop production, as it contributes significantly to overall yield and quality. The implementation of appropriate agronomic practices, such as fertilizer application, plowing, pest management, seeding techniques, seedbed preparations, and other management strategies, phosphorus is crucial for optimizing yields in cotton and other crops grown under diverse environmental conditions. The importance of phosphorus in promoting cotton yield and quality has been highlighted in recent studies by Sadiq *et al*. (2023) [18] and Seerat *et al*. (2023) [23] emphasizing the critical role of balanced fertilization practices in maximizing agricultural productivity and profitability. Currently, the primary mineral fertilizer used for cotton crops is nitrogen, followed by phosphorus which is also essential for crop growth. Another crucial nutrient for crop development is zinc fertilizer, with phosphorus playing a significant role in directly affecting crop growth. Phosphorus helps in the expansion of bolls by influencing flower development and pollination in cotton. Despite continuous application of phosphorus fertilizer from both organic and mineral sources in deeply cultivated soils, the soil's phosphorus levels remain insufficient for optimal crop productivity. Phosphorus is vital for metabolic processes and structural development in plants, particularly in early root growth, photosynthesis, cell division, energy transfer, early boll expansion, and early maturation. (Hemmat *et al*., 2023; Khaleeq *et al*., 2024) [7, 7]. A deficiency in phosphorus fertilizer can lead to weakened plant membranes and reduced energy transfer within the crop (Oosterhuis *et al*., 2007; Khaleeq *et al*., 2024b) [17, 10].

Materials and Methods

A field trial was conducted at the Kunduz Spinzar State-Owned Corporation farm in collaboration with the agriculture faculty of Kunduz University during the 2023 growing season. The experimental site was located at 367388884 N latitude, 68.869858 E longitude, with an elevation of 356 meters above sea level. The temperature ranged from 23.20 °C to 46.2 °C, with humidity between 25.52% to 65.25%, and minimal rainfall was recorded. The soil at the site was identified as sandy clay loam with a pH of 7.3, characterized by low nitrogen content, medium availability of phosphorus and high levels of potassium. The experiment was designed in a randomized complete block design with a split arrangement, replicated three times, incorporating eight treatments including a control plots and various combinations of nitrogen and phosphorus fertilizers ranging from 40 kg N/ha:20 P_2O_5/ha to 280 kg N/ha:140 P_2O_5/ha. Phosphorus was applied in full dose and half of the nitrogen dose at sowing, while the remaining nitrogen was split and applied at 45 and 80 days after sowing. The cotton variety used was the local K-01 variety, with each experimental plot covering an area of 15 m^2 (3 m × 5 m). Planting was conducted on May 31, 2023, with two seeds placed 75 cm apart within each row and excess plants were thinned to maintain one seedling at the three-leaf stage. Urea and single superphosphate were utilized as nitrogen and phosphorus sources, respectively. Statistical analysis of the collected data was performed using ANOVA and mean comparisons were carried out using the critical difference (CD) at a significance level of 5%.

Results and Discussion

The results from the analysis of variance in Table (1) indicated that the application of various levels of nitrogen and phosphorus significantly influenced the growth and yield parameters of cotton crops. Specifically, the combinations of 200 kg N/ha + 100 P_2O_5/ha, 240 kg N/ha + 120 P_2O_5/ha, and 280 kg N/ha + 140 P_2O_5/ha were equally effective and demonstrated the highest plant height values (115.22 cm, 115.66 cm, and 117.00 cm, respectively). The application of 200 kg N/ha + 100 P_2O_5/ha resulted in the highest leaf area index (4.33), followed by the combination of 240 kg N/ha + 120 P_2O_5/ha. Similarly, the combinations of 160 kg N/ha + 80 P_2O_5/ha and 280 kg N/ha + 140 P_2O_5/ha showed equal effectiveness in terms of leaf area index. In terms of leaves per plant, the combinations of 280 kg N/ha + 140 P_2O_5/ha, 240 kg N/ha + 120 P_2O_5/ha, and 200 kg N/ha + 100 P_2O_5/ha were equally effective, with maximum values of 74.78, 73.55, and 70.88, respectively. Additionally, the combination of 200 kg N/ha + 100 P_2O_5/ha exhibited the highest values for sympodial branches per plant (16.22), bolls per plant (34.66), and seed cotton yield (3.19 t/ha), followed by the combinations of 240 kg N/ha + 120 P_2O_5/ha and 280 kg N/ha + 140 P_2O_5/ha, respectively. The findings of this study align closely with those of Khaleeq *et al*. (2023d) [12], who observed that the application of 90 kg P_2O_5/ha led to a significant enhancement in plant height, sympodial branches per plant, number of leaves per plant, and bolls per plant. Similarly, Samim *et al*. (2023) [20] noted that nitrogen fertilizer had a significant impact on plant height, dry matter accumulation, branches per plant, and leaf area index, with the most favorable growth outcomes observed at a rate of 100 kg N/ha compared to the control group. Furthermore, Nazir *et al*. (2022) [16] and Khaleeq *et al*. (2023a) [11] highlighted the influence of phosphorus fertilizer application on plant height, branches per plant, dry matter accumulation, and leaf area index, with the highest growth and yield parameters for common bean achieved at a rate of 100 kg N/ha.

Table 1: Impact of Nitrogen and phosphorus fertilizer on Plant Height (cm), Leave area index, Sympodial Branches/plant and Bolls/plant

Treatments	Plant Height (cm)	Leave Area Index	Leaves/plant	Sympodial Branches/plant	Bolls/plant
Absolute Control	66.00d	1.46c	25.11e	9.33c	15.33f
40 kg N/ha+20 P_2O_5/ha	72.22cd	1.46c	33.33d	10.22c	17.00ef
80 kg N/ha+40 P_2O_5/ha	78.00c	1.89c	38.66d	11.00bc	18.33de
120 kg N/ha+60 P_2O_5/ha	96.33b	2.11c	46.66c	12.33b	20.00d
160 kg N/ha+80 P_2O_5/ha	97.33b	3.48b	56.89b	10.33c	23.66c
200 kg N/ha+100 P_2O_5/ha	115.22a	4.33a	70.88a	16.22a	34.66a
240 kg N/ha+120 P_2O_5/ha	115.66a	3.50b	73.55a	12.33b	31.00b
280 kg N/ha+140 P_2O_5/ha	117.00a	3.48b	74.78a	12.33b	32.00b
SEm±	29.263	0.164	17.862	1.103	1.315
CD (P=0.05)	9.474	0.710	7.402	1.840	2.009

The empirical data depicted in Figures 1 and 2 illustrate the substantial influence of varying levels of nitrogen and phosphorus fertilizers on Cotton Lint yield and Cotton Seed yield. Among the different fertilizer treatments, the application of 200 kg N/ha + 100 P_2O_5/ha resulted in the highest Cotton Lint yield of (1799 kg/ha) and Cotton Seed yield of (3937 kg/ha), Cotton Lint yield (192835 AFN/ha) and Cotton Seed yield (179928 AFN/ha). This optimal fertilizer combination also yielded a gross return (372764 AFN/ha), net return (334284 AFN/ha) and a favorable B: Cost ratio of 8.687. These findings underscore the significant impact of specific nitrogen and phosphorus fertilizer levels on cotton production outcomes, highlighting the potential for enhanced agricultural productivity and economic returns through strategic fertilizer management practices. The findings of this study align with previous research by Saleem *et al*. (2010) [19] which demonstrated that higher levels of phosphorus fertilizer, specifically at 90 kg/ha, resulted in increased cotton seed yield and accelerated maturation compared to lower application rates. Consistent with the findings of Gadhiya *et al*. (2009) [5] and Sawan *et al*. (2008) [22], it was observed that phosphorus fertilizer application led to enhancements in seed cotton yield per plant and cotton seed yield per hectare by 9.34% to 14.95% in comparison to control treatments. Furthermore, Khaleeq *et al*. (2023d**)** [12] highlighted the significant impact of varying phosphorus fertilizer doses on lint and seed production as well as the economic viability of cotton cultivars. Their results indicated that the application of 90 kg P_2O_5/ha resulted in the highest Cotton Lint yield of 1,627.50 kg/ha, Cotton Seed yield of 3,110.38 kg/ha, Cotton Lint yield of 174,370 AFN/ha, Cotton Seed yield of 142,144 AFN/ha, gross return of 316,515 AFN/ha, net return of 297,790 AFN/ha, and a favorable B: Cost ratio of 7.67. This underscores the importance of phosphorus fertilizer management in optimizing cotton production outcomes and economic returns, with the 90 kg P_2O_5/ha dosage yielding the most favorable results compared to lower application rates and control treatments.

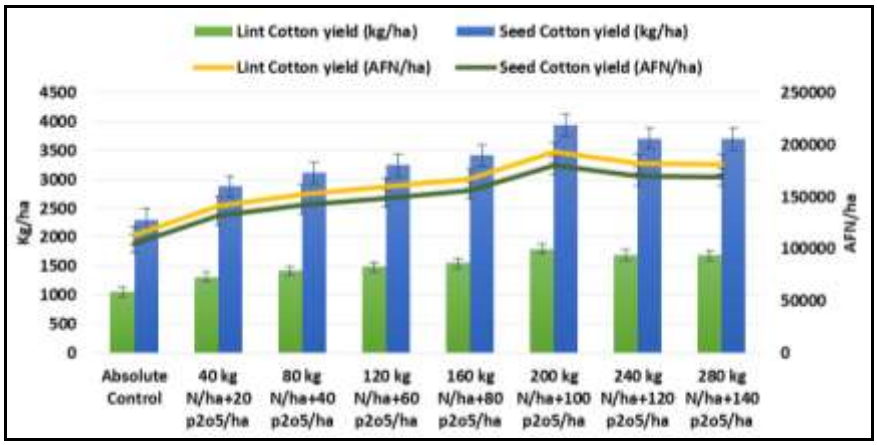

Fig 1: Impact of Nitrogen and Phosphorus fertilizers on Lint Cotton yield and Seed cotton yield

Fig 2: Impact of Nitrogen and Phosphorus fertilizers on Gross return, Net return and B: Cost ratio

Conclusion

From the present investigation it can be concluded optimization of Nitrogen and phosphorus is prim important for the optimum cotton production, application of 200 kg N/ha + 100 kg P_20_5/ha is best amount of Nitrogen and phosphorus level for cotton productivity and profitability. Further research is needed to optimizing of macronutrients in different part of the Afghanistan.

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