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Optimizing Growth and Yield of Okra (Abelmoschus esculentus) through Varied Nitrogen Fertilizers

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ABSTRACT

This research investigates the efficacy of different nitrogen fertilizers—urea, ammonium nitrate, potassium nitrate, calcium nitrate, and a control with no fertilizer—on optimizing the growth and yield of okra (Abelmoschus esculentus). Conducted under controlled conditions, the study assesses key growth parameters such as plant height, leaf area, flowering patterns, and fruit development. Each nitrogen fertilizer treatment is meticulously applied at recommended rates during specific growth stages to evaluate their individual impacts on okra physiology. Preliminary findings reveal nuanced variations in growth patterns among the different nitrogen fertilizer treatments. Urea, known for its high nitrogen content, demonstrates a notable influence on vegetative growth, while ammonium nitrate exhibits distinct effects on flowering dynamics. Potassium nitrate and calcium nitrate, with their unique nutrient profiles, contribute to specific aspects of fruit development. The control treatment provides a baseline for comparison, enabling a comprehensive evaluation of the botanical potential inherent in each nitrogen fertilizer. This study not only contributes to the understanding of nitrogen fertilizer impacts on okra growth but also has practical implications for sustainable agricultural practices. The results aim to guide farmers in the selection and application of nitrogen fertilizers tailored to optimize okra yield while minimizing environmental impact. The findings underscore the importance of targeted nutrient management in enhancing crop productivity and advancing sustainable approaches in modern agriculture.

Introduction:

Agriculture, as the primary driver of global food production, constantly grapples with the challenge of balancing the increasing demand for food against the imperative to sustain ecosystems and conserve natural resources [1,2,3,4,5]. Among the myriad factors influencing crop productivity, the judicious use of fertilizers, especially nitrogen-based fertilizers, plays a pivotal role in achieving optimal growth and yield [6,7]. Okra (*Abelmoschus esculentus*), a versatile and nutritionally valuable crop, is particularly sensitive to nitrogen availability, making it an ideal candidate for exploring the impacts of different nitrogen fertilizers on its growth and productivity [8,9].

Nitrogen is an essential nutrient that forms an integral component of amino acids, proteins, and chlorophyll—critical elements for plant growth and development [10]. However, the form in which nitrogen is supplied significantly influences plant physiology and crop performance [11,12]. As modern agriculture seeks to adopt more sustainable practices, understanding the nuanced effects of varied nitrogen fertilizers on specific crops becomes paramount [13].

The optimization of okra growth and yield through the application of different nitrogen fertilizers is very keenly observed previously [14]. The selection of these fertilizers is strategic, representing a spectrum of nitrogen sources with distinct chemical compositions and nutrient profiles [15]. The aim was not only to unravel the individual impacts of these fertilizers on okra physiology but also to provide valuable insights for farmers and agronomists seeking precision in nutrient management [16].

The importance of nitrogen in promoting vegetative growth, flowering, and fruit development is well-established [17]. However, the varied responses of crops to different nitrogen sources are less explored, and this study aims to bridge that knowledge gap [18]. By investigating the specific effects of urea, ammonium nitrate, potassium nitrate, and calcium nitrate, we anticipate uncovering differential impacts on okra growth parameters, offering a nuanced perspective on fertilizer selection for optimal crop performance.

As the global population burgeons, the need for sustainable and efficient agricultural practices intensifies. Nitrogen fertilizers, while enhancing productivity, are also associated with environmental concerns such as nitrogen runoff, greenhouse gas emissions, and soil degradation [19]. Therefore, a critical evaluation of the effectiveness of different nitrogen sources in promoting okra growth not only contributes to the crop-specific understanding of nutrient management but also aligns with broader efforts towards sustainable agriculture.

The structure of this research involves systematically assessing various growth parameters of okra under different nitrogen fertilizer treatments. The experimental design, which includes a control group with no fertilizer, ensures a comprehensive evaluation of the inherent botanical potential of each nitrogen source. This investigation aims to discern not only which nitrogen fertilizer leads to optimal growth but also to identify specific physiological responses influenced by the varied nitrogen compositions.

Materials and Methods:

1. Experimental Design:

The study was conducted in a controlled environment at AZRC DI Khan. A randomized complete block design (RCBD) was employed to minimize bias and account for potential spatial variability. Each nitrogen fertilizer treatment—urea, ammonium nitrate, potassium nitrate, calcium nitrate—and a control with no fertilizer were assigned to separate blocks. The blocks were randomly arranged to ensure a representative distribution of treatments across the experimental area.

2. Okra Cultivar and Seedling Preparation:

Okra (*Abelmoschus esculentus*) seeds of a uniform cultivar were obtained from a reputable supplier. Seeds were germinated in a controlled nursery environment, and uniform seedlings were selected for transplantation to ensure consistent starting conditions for each treatment.

3. Soil Preparation:

The experimental site's soil was characterized by clay loam texture, low organic matter and mineral soil. Prior to planting, the soil was thoroughly tilled and homogenized. Soil samples were collected and analyzed for baseline nutrient levels, ensuring uniformity across the experimental plots.

4. Application of Nitrogen Fertilizers:

The nitrogen fertilizer treatments included urea, ammonium nitrate, potassium nitrate, calcium nitrate, and a control with no fertilizer. Fertilizer application rates were determined based on regional recommendations and soil nutrient analyses. The fertilizers were applied at specific growth stages: seedling establishment, vegetative growth, and flowering. Care was taken to avoid contact between the fertilizers and the plant parts.

5. Planting and Plot Maintenance:

Okra seedlings were transplanted into the prepared plots following recommended spacing guidelines. Standard agronomic practices were employed for plot

maintenance, including regular irrigation, pest control, and weed management. Any deviations or challenges encountered during the growth period were documented.

6. Data Collection:

Throughout the growth cycle, key growth parameters were meticulously monitored. These included:

- *Plant Height:* Measured from the base of the plant to the tip of the tallest shoot.
- *Leaf Area:* Determined using non-destructive methods, such as image analysis.
- *Flowering Patterns:* Recording the number of flowers per plant and assessing the time to first flowering.
- *Fruit Development:* Monitoring fruit set, measuring fruit dimensions, and recording the number of fruits per plant.

7. Harvesting and Yield Measurement:

Okra fruits were harvested at maturity, and the yield was recorded for each treatment. Fruits were weighed, and relevant yield parameters, such as marketable yield and total biomass, were documented.

8. Statistical Analysis:

Collected data were subjected to statistical analysis using appropriate software. Analysis of variance (ANOVA) and post-hoc tests were employed to discern significant differences among treatments. The statistical significance level was set at 5%.

Results:

1. Plant Growth Parameters:

- *Plant Height:* Urea and ammonium nitrate treatments resulted in significantly taller okra plants compared to the control. Potassium nitrate and calcium nitrate also showed improvements, although not as pronounced. The control group exhibited the shortest plants.
- *Leaf Area:* Urea and ammonium nitrate treatments led to a significant increase in leaf area, indicating enhanced vegetative growth. Potassium nitrate and calcium nitrate treatments showed moderate improvements, while the control had the smallest leaf area.

Table 1. Effect of different nitrogen fertilizers on plant height and leaf area of Okra

Nitrogen Fertilizer Treatments	Plant Height (cm)	Leaf Area (cm^2)
Control	106.13	12.48
Urea	145.97	19.11
Amonium Nitrate	138.31	17.92
Potassium Nitrate	131.34	15.49
Calcium Nitrate	128.31	15.68

2. Flowering Patterns:

- *Time to First Flowering:* Urea and ammonium nitrate treatments accelerated the time to first flowering, indicating earlier reproductive onset. Potassium nitrate and calcium nitrate treatments exhibited moderate effects, while the control group flowered last.
- *Flower Count:* Urea and ammonium nitrate treatments significantly increased the number of flowers per plant. Potassium nitrate and calcium nitrate also demonstrated positive effects, albeit to a lesser extent. The control group had the fewest flowers.

Table 2. Effect of different nitrogen fertilizers on flowering time and count of Okra

Nitrogen Fertilizer Treatments	Flowering time (cm)	Flower Count
Control	83.58	100.12
Urea	71.33	177.19
Amonium Nitrate	75.91	159.82
Potassium Nitrate	76.18	146.74
Calcium Nitrate	77.11	143.99

3. Fruit Development and Yield:

- *Fruit Set:* Urea and ammonium nitrate treatments promoted a higher rate of fruit set compared to other treatments. Potassium nitrate and calcium nitrate treatments showed moderate effects, while the control exhibited the lowest fruit set.
- *Yield:* Urea treatment resulted in the highest overall okra yield, significantly surpassing all other treatments. Ammonium nitrate also contributed to increased yield, although to a lesser extent. Potassium nitrate and calcium nitrate treatments showed moderate improvements, while the control group had the lowest yield.

Table 3. Effect of different nitrogen fertilizers on fruit set and yield of Okra

Nitrogen Fertilizer Treatments	Fruit Set	Okra Yield (ton ha^{-1})
Control	39.23	2.58
Urea	65.12	3.86
Amonium Nitrate	61.76	3.49
Potassium Nitrate	53.67	3.29
Calcium Nitrate	51.01	3.09

Discussion:

The observed variations in growth and yield parameters among different nitrogen fertilizer treatments highlight the significance of nitrogen source selection in optimizing okra cultivation. Urea, characterized by high nitrogen content, emerged as a potent promoter of both vegetative and reproductive growth, resulting in taller plants, increased leaf area, accelerated flowering, and ultimately, the highest yield [20]. Ammonium nitrate, another readily available nitrogen source, demonstrated similar positive effects on plant height, leaf area, flowering dynamics, and fruit set, albeit with slightly lower efficacy compared to urea [21]. This aligns with the known benefits of ammonium-based fertilizers in promoting robust vegetative growth and early reproductive onset [22]. Potassium nitrate and calcium nitrate treatments, while contributing to improvements in growth parameters, exhibited intermediate effects compared to urea and ammonium nitrate. These fertilizers, rich in potassium and calcium, respectively, may play specific roles in certain physiological aspects, such as fruit development, without exerting the same overall growth-promoting effects observed with urea and ammonium nitrate [23]. The control group, representing the absence of nitrogen fertilization, consistently exhibited the lowest values for all measured parameters, underscoring the essential role of nitrogen in optimizing okra growth and yield. The findings from this study provide valuable insights for farmers and agronomists in tailoring nitrogen fertilizer strategies for okra cultivation. Considering the trade-offs between different nitrogen sources in terms of cost, environmental impact, and efficacy, the choice of fertilizer should be context-specific and aligned with desired outcomes in vegetative and reproductive aspects.

Conclusion:

In this study sheds light on the pivotal role of nitrogen fertilizers in optimizing the growth and yield of okra (Abelmoschus esculentus). Urea and ammonium nitrate emerged as potent promoters of both vegetative and reproductive aspects, showcasing significant increases in plant height, leaf area, flowering patterns, and fruit development. These findings underscore the importance of nitrogen source selection in tailoring nutrient management strategies for optimal okra cultivation. The observed variations in growth parameters provide valuable insights for farmers seeking to enhance crop productivity while considering factors such as cost and environmental impact. As agriculture evolves towards more sustainable practices, the precise understanding of nitrogen fertilizer impacts on crop physiology contributes to the ongoing discourse on efficient and eco-friendly approaches to meet global food demands.

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