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EFFECT OF DIFFERENT DOSAGES OF NITROGEN AND FOLIAR APPLICATION OF ZINC ON GROWTH AND YIELD OF HYBRID BT COTTON (*GOSSYPIUM HIRSUTUM* L.)

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2023-24 at the Research Farm, Faculty of Agriculture, Tantia University, Sri Ganganagar, to evaluate the effect of nitrogen and zinc application on the growth and yield of cotton variety Ajit-177 BG-2. The study was arranged in a Randomized Block Design (RBD) with nine treatments and three replications. Treatments consisted of varying levels of nitrogen (0, 100 and 120 kg/ha) and zinc (0%, 17.5%, and 39.5%). The experiment revealed that nitrogen and zinc application significantly influenced plant growth and yield attributes. The highest plant height (149.16 cm) at 150 DAS was observed in the treatment with 120 kg/ha nitrogen and 39.5% zinc (T9). Similarly, T9 also produced the highest number of bolls (64.76) and cotton yield (28.24 qt/ha). While seed quality parameters such as ginning percentage and seed index showed no significant differences, a slight improvement in fiber quality was noted with higher zinc doses. In conclusion, the combined application of nitrogen (120 kg/ha) and zinc (17.5% and 39.5%) proved to be the most effective in enhancing growth and yield in cotton cultivation.

Key words: BT Cotton, Nitrogen, Zinc, growth and yield

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the world's most important cash crop, it is mainly grown for fiber and oilseed. It is also known as the king of fiber. Cotton is highly valued and referred to as "White Gold" in India. BT cotton hybrid belongs to the *Malvaceae* family. It is a crucial cash and fiber crop in diverse agro-climatic regions. The primary product of cotton is lint that is essential for producing cotton fabric. In the world cotton scenario, currently (2023-24) China is the leading producer of cotton with 56.00 lakh tones equivalent to 329 lakh bales of 170 kg. India is the second largest producer of cotton with 53.85 lakh tones equivalent to 316 lakh bales of 170 kg followed by Brazil (33.00 lakh tones or 194 lakh bales) and USA (27.07 lakh tones, or 159 lakh bales). These countries contribute 70% of the world's cotton production from 63% of the world cotton area.

India has the World's highest area of more than 12.5 mha under cotton and is the second largest consumer (300 lakh bales) and third largest exporter (50-70 lakh bales). Cotton provides 59% of the raw materials used in the textile industry. Around 50 million people work in cotton processing and trading, while over 6.0 million cotton farmers produce cotton. Cotton based industry contributes 29.1% of total textile exports and 4.9% value of agriculture output. In Rajasthan estimate production of cotton in 2023-24 will reach 27.43 lakh bales of 170 kg each, cultivated from 7.91 mha with a productivity of 590 kg lint per hectare.

Fertilization must always provide and maintain an optimal level of nutrients within the root zone to ensure good crop growth and maximize potential yield. Nitrogen fertilizers, which are water-soluble, play a major role in the growth and development of cotton. Split application of fertilizers ensures that nutrients are provided at the right time and in the right quantity, leading to higher yields with minimal nutrient loss and increased fertilizer recovery. Tumbare *et al.*, (1999) reported that higher yields of seed cotton were achieved with more splits due to the efficient utilization of applied nitrogen through fertigation compared to band placement.

Nitrogen has significantly contributed to cotton production due to its pivotal role in enhancing growth, preventing the abscission of squares and bolls, and being essential for photosynthetic activity. It stimulates the mobilization and accumulation of metabolites in newly developed bolls, thereby increasing their number and weight (Niu *et al*., 2021; Sawan, 2021). Plants uptake nitrogen in two forms: ammonium (NH_4^+) and nitrate (NO_3^-). The NH_4^+ form is retained in the soil by negatively charged soil clays or colloids, whereas the NO_3^- form is repelled by soil particles and moves with water in the soil profile. The conversion of nitrogen from one form to another involves the generation or consumption of acidity. The uptake of ammonium or nitrate by plants also affects soil acidity; ammonium-based fertilizers acidify soil by generating two Hz ions for each ammonium molecule nitrified to nitrate (Reddy *et al*., 1996). However, it has been discovered that fertigation with nitrogen fertilizer or 100% water soluble fertilizer increases the effectiveness of fertilizer application in addition to reducing the amount of fertilizer used to BT cotton.

Cakmak (2000) speculated that Zn deficiency stress might inhibit the activities of several antioxidant enzymes, leading to extensive oxidative damage to membrane lipids, proteins, chlorophyll, and nucleic acids. Zinc affects carbohydrate metabolism at various levels, and the activity of the Zn-containing enzyme carbonic anhydrase declines sharply with Zn deficiency. Carbonic anhydrase, located in the cytoplasm and chloroplasts, facilitates the transfer of CO_2/HCO_3^- for photosynthetic CO_2 fixation (Sharma *et al*., 1982). Symptoms of zinc deficiency in cotton include small leaves, shortened internodes giving the plant a stunted appearance, reduced boll set, and small boll size (Oosterhuis *et al*., 1991). In micronutrient deficit soil foliar applications can satisfy the nutrient requirements if those nutrients were not applied to the soil before sowing. The timing of foliar applications should coincide with peak nutrient demands. The current objective of study was to study the effect of nitrogen and foliar application of zinc on growth and yield attributes of BT cotton.

Materials and Method

The field experiment was conducted in *kharif* Season of 2023 on Crop Research Farm, Department of Agronomy, Tantia University, Sri Ganganagar, Rajasthan, India. The city is located at 28.4° to 33.60° N latitude and 72.30° to 75.30° E longitude. 175.6 m above mean sea level. The study conducted on Growth attributing traits *viz.*, Plant height (cm), Number of monopodial branches per plant, Number of sympodial branches per plant, Dry matter accumulation (g/plant) and Leaf area index while, yield attributing traits *viz.*, Boll weight (g), Number of bolls per plant, cotton yield, Seed index (g) and Ginning percentage. The experiment was laid in RBD (Randomized Block Design), comprising of 9 treatment combinations each replicated thrice are given in Table 1.

Table 1: Treatment details.

Symbol	Treatment	Treatment description
T_1	$N_0 + Z_0$	Nitrogen (0kg/ha) + Zinc 0%
T_2	$N_0 + Z_1$	Nitrogen (0kg/ha) + Zinc 17.5%
T_3	$N_0 + Z_2$	Nitrogen (0kg/ha) + Zinc 39.5%
T_4	$N_1 + Z_0$	Nitrogen (100kg/ha) + Zinc 0%
T_5	$N_1 + Z_1$	Nitrogen (100kg/ha) + Zinc 17.5%
T_6	$N_1 + Z_2$	Nitrogen (100kg/ha) + Zinc 39.5%
T_7	$N_2 + Z_0$	Nitrogen (120kg/ha) + Zinc 0%
T_8	$N_2 + Z_1$	Nitrogen (120kg/ha) + Zinc 17.5%
T_9	$N_2 + Z_2$	Nitrogen (120kg/ha) + Zinc 39.5%

Statistical analysis

Experimental data were processed in Microsoft Excel-2019 and analyzed with the help of analysis of variance (ANOVA) technique for Randomized Block Design (RBD) (Gomez and Gomez, 1984). The significance of the treatments was tested using F test at 5% level of significance ($P \leq 0.05$) and means were compared using the critical difference (CD) test at $\alpha \leq 0.05$.

Results and Discussion

Effects of different dosages of nitrogen and foliar application of zinc on growth attributing traits

Effects of different dosages of nitrogen and foliar application of zinc on growth attributing traits *viz.*, Plant height (cm), Number of monopodial branches per plant, Number of sympodial branches per plant, Dry matter accumulation (g/plant) and Leaf area index tabulated in Table 2 and illustrated in Fig. 1.

Plant Height

Nitrogen, combined with foliar application of zinc, had a significant influence on the growth of the BT Cotton hybrid. Treatments with higher nitrogen levels (T8 and T9) consistently showed superior performance compared to those with lower or no nitrogen (T1, T2, and T3), underscoring the critical role of nitrogen in promoting

Table 2: Effects of different dosages of nitrogen and foliar application of zinc on growth attributing traits of cotton.

Treatments	Plant height	Monopodial branches	Sympodial branches	Leaf area index	Dry matter accumulation
T1- Nitrogen (0 kg/ha) + Zinc 0%	128.64	2.51	13.36	1.236	169.8
T2- Nitrogen (0 kg/ha) + Zinc 17.5%	133.49	2.58	15.66	1.292	179.2
T3-Nitrogen (0 kg/ha) + Zinc 39.5%	136.23	2.62	16.23	1.306	188.6
T4-Nitrogen (100 kg/ha) + Zinc 0%	138.86	2.65	17.57	1.326	196.8
T5-Nitrogen (100kg/ha) + Zinc 17.5%	144.33	2.72	18.92	1.397	216.7
T6-Nitrogen (100kg/ha) + Zinc 39.5%	145.82	2.78	19.22	1.401	218.1
T7-Nitrogen (120kg/ha) + Zinc 0%	141.32	2.68	18.25	1.396	212.2
T8-Nitrogen (120kg/ha) + Zinc 17.5%	148.66	2.79	20.08	1.439	220.5
T9-Nitrogen (120kg/ha) + Zinc 39.5%	149.16	2.82	20.86	1.592	222.9
S. Em ±	**2.4**	**0.033**	**0.31**	**0.025**	**2.662**
CD (P = 0.05)	**7.2**	**0.101**	**0.95**	**0.076**	**8.05**

vegetative growth (Table 2). Additionally, the application of zinc at higher doses (39.5%) significantly increased plant height across all growth stages when compared to treatments without zinc or those with lower concentrations.

Zinc plays a vital role in numerous enzymatic processes and is essential for auxin synthesis, which drives cell elongation and division. The improved plant height observed in treatments with foliar zinc application can be attributed to these physiological functions. These findings align with studies by Kumar *et al.*, (2022) and Patel *et al.*, (2021), who similarly reported enhanced growth parameters in cotton following nitrogen and zinc supplementation. Furthermore, the gradual increase in the C.D. values across growth stages indicates that the differences between treatments became more pronounced as the crop progressed, emphasizing the cumulative effects of nitrogen and zinc over time. This observation supports the conclusions of Singh *et al.*, (2020), who found similar patterns in cotton yield and growth attributes in response to integrated nutrient management practices.

Number of monopodial branches plant^{-1}

The data presented in Table 2 clearly show that increasing nitrogen rates, combined with higher levels of zinc in foliar applications, had a positive impact on the number of monopodial branches per plant in BT cotton hybrids. Treatments with higher nitrogen levels (T8 and T9) consistently recorded the greatest number of branches at all growth stages, likely due to the enhanced vegetative growth facilitated by nitrogen. As a key nutrient, nitrogen plays a crucial role in overall plant development, and its availability promotes the formation of additional branches, as supported by the findings of Sharma *et al.*, (2021).

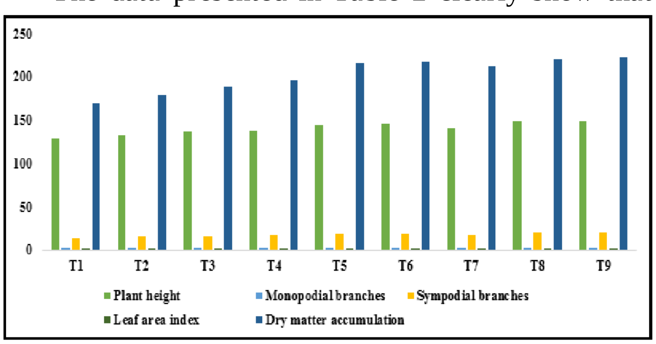

Fig. 1: Effects of different dosages of nitrogen and foliar application of zinc on growth attributing traits of cotton.

Zinc foliar application also significantly contributed to monopodial branch development. Zinc is involved in essential metabolic processes, including enzyme activation and protein synthesis, which support improved plant growth. The combination of higher nitrogen (120 kg/ha) and zinc (39.5%) resulted in the highest branch numbers, as observed in treatments T9 and T8. These results align with Reddy *et al.*, (2020), who similarly reported an increase in monopodial branching in cotton with the joint use of nitrogen and zinc. The control treatment (T1), which did not receive any nitrogen or zinc, consistently had the lowest number of monopodial branches, underscoring the importance of nutrient management in optimizing cotton growth, particularly in enhancing vegetative structures like monopodial branches, which are critical for maximizing cotton yield potential.

Number of sympodial branches plant^{-1}

The data from Table 2 show a clear positive relationship between higher dosages of nitrogen and zinc and the number of sympodial branches per plant. Treatments with elevated nitrogen levels (T8 and T9) consistently produced the highest number of sympodial branches, especially when combined with zinc foliar applications. Nitrogen is a vital nutrient that promotes overall vegetative growth, which in turn supports the formation of more branches. The application of nitrogen

Table 3: Effects of different dosages of nitrogen and foliar application of zinc on yield attributing traits of cotton.

Treatments	No. of bolls/plant	Boll weight (g)	Cotton yield (qt/ha)	Ginning (%)	Seed Index
T1- Nitrogen (0 kg/ha) + Zinc 0%	46.96	3.39	20.56	36.63	7.62
T2- Nitrogen (0 kg/ha) + Zinc 17.5%	49.91	3.43	21.18	36.86	7.64
T3-Nitrogen (0 kg/ha) + Zinc 39.5%	52.38	3.44	21.76	36.88	7.67
T4-Nitrogen (100 kg/ha) + Zinc 0%	55.33	3.49	22.06	36.93	7.60
T5-Nitrogen (100kg/ha) + Zinc 17.5%	59.39	3.88	24.36	37.45	7.74
T6-Nitrogen (100kg/ha) + Zinc 39.5%	61.16	3.97	25.86	37.46	7.76
T7-Nitrogen (120kg/ha) + Zinc 0%	56.09	3.76	22.48	37.42	7.73
T8-Nitrogen (120kg/ha) + Zinc 17.5%	62.82	4.08	27.30	37.48	7.77
T9-Nitrogen (120kg/ha) + Zinc 39.5%	64.76	4.14	28.24	37.62	7.81
S. Em $\pm$	**0.81**	**0.06**	**0.38**	**0.42**	**0.07**
CD (P = 0.05)	**2.47**	**0.18**	**1.13**	**NS**	**NS**

at 120 kg/ha (as in T8 and T9) significantly enhanced the development of sympodial branches compared to treatments with lower or no nitrogen application (T1 and T3).

Zinc is essential for various plant metabolic processes, such as enzyme activation, protein synthesis, and growth hormone regulation. The combined application of nitrogen and zinc, particularly at higher zinc levels (39.5%), resulted in a noticeable increase in sympodial branching, as seen in T9. These findings are consistent with those of Kumar *et al*., (2019), who demonstrated that foliar zinc applications can improve plant growth and branch formation. The synergistic impact of nitrogen and zinc was most evident in T9 (120 kg/ha Nitrogen + Zinc 39.5%), where the number of sympodial branches reached its highest values across all growth stages. This reinforces the importance of an integrated nutrient management strategy for enhancing vegetative growth in cotton, as suggested by Patel *et al.,* (2021).

Leaf Area Index (LAI)

The data indicate that nitrogen plays a pivotal role in increasing leaf surface area, a crucial factor for photosynthesis and overall plant growth. Zinc, particularly at 39.5%, further boosted LAI, likely due to its role in

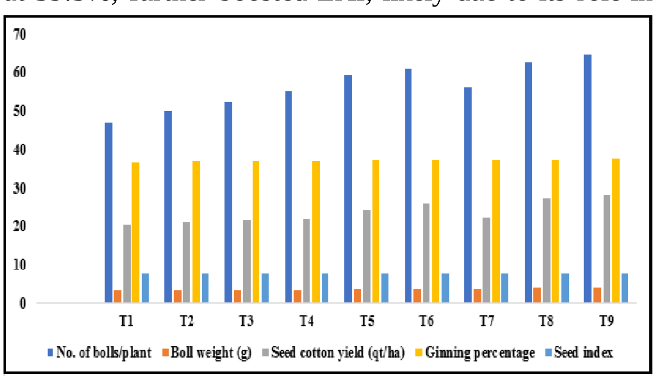

Fig. 2: Effects of different dosages of nitrogen and foliar application of zinc on yield attributing traits of cotton.

protein synthesis and enzyme activation, which are essential for plant development (Singh *et al.,* 2020).

The synergy between higher nitrogen doses and zinc foliar application (as seen in T9) was evident, suggesting that these combined treatments offer optimal conditions for maximizing leaf growth and improving crop productivity (Kumar *et al.*, 2019). These findings support the use of integrated nutrient management strategies that combine both macro and micronutrients for improving leaf growth and yield attributes in crops (Sharma *et al.,* 2021).

Dry Matter Accumulation (g) plant^{-1}

The results demonstrate that increasing nitrogen fertigation levels combined with foliar zinc application significantly enhances dry matter accumulation at all growth stages. The highest dry matter accumulation was recorded with the application of 120 kg/ha nitrogen and 39.5% zinc, particularly at 150 DAS, suggesting that both nutrients play a crucial role in maximizing plant growth and biomass production. Nitrogen is an essential macronutrient, responsible for promoting vegetative growth by enhancing protein synthesis, enzyme activity, and chlorophyll formation, all of which are critical for photosynthesis.

Zinc, although required in smaller amounts, plays a vital role in enzyme activation and various metabolic processes, including auxin synthesis, protein metabolism, and the regulation of photosynthetic activity. The significant increase in dry matter accumulation with higher zinc levels is consistent with previous studies that highlight zinc's positive impact on plant growth and nutrient uptake efficiency. The interaction between nitrogen and zinc was particularly pronounced, with higher nitrogen levels increasing the plant's zinc requirement. This synergistic relationship enhances overall growth and biomass accumulation.

Effects of different dosages of nitrogen and foliar application of zinc on yield attributing traits

Effects of different dosages of nitrogen and foliar application of zinc on yield attributing traits *viz.*, Boll weight (g), Number of bolls per plant, cotton yield, Seed index (g) and Ginning percentage tabulated in Table 3 and illustrated in Fig. 2.

Number of Bolls Plant^{-1}

There is a clear trend of increased boll formation with the application of both nitrogen and zinc. The lowest number of bolls per plant (46.96) was observed in the control treatment (T1: 0 kg N/ha + 0% Zinc). While, the highest number of bolls per plant (64.76) was recorded in the treatment (T9) with the highest levels of nitrogen (120 kg N/ha) and zinc (39.5%).

This suggests that the combined application of nitrogen and zinc significantly enhances boll formation. Zinc plays a vital role in enzyme activation and auxin synthesis, which may explain its impact on boll development alongside nitrogen, which promotes vegetative growth and boll initiation. These findings are consistent with previous studies indicating the positive effect of nitrogen and zinc on boll production in cotton (Rajput, 2020; Gupta, 2018).

Boll Weight

Boll weight was also positively influenced by the combination of nitrogen and zinc. The lowest boll weight (3.39 g) was observed in the control (T1), while the maximum boll weight (4.14 g) was found in T9 (120 kg N/ha + 39.5% Zinc). It is noteworthy that treatments with higher zinc levels showed increased boll weight, with significant differences observed between treatments.

It is noteworthy that treatments with higher zinc levels showed increased boll weight, with significant differences observed between treatments. The application of nitrogen alone increased boll weight to a lesser extent, but zinc's foliar application further boosted this parameter. These results are consistent with findings from studies such as those by Singh *et al.,* (2020), who also reported enhanced boll weight with combined nitrogen and zinc application.

Cotton Yield (qt/ha)

The cotton yield per hectare exhibited a similar trend to the number of bolls and boll weight. The increased yield in response to higher nitrogen and zinc levels can be attributed to the greater number of bolls and higher boll weight. The positive correlation between nitrogen and zinc application with yield parameters aligns with the results of several studies. For instance, Haider *et al.*, (2018) noted that the interaction of these two nutrients leads to improved photosynthesis, nutrient uptake, and partitioning of assimilates, which enhances seed cotton yield.

Ginning Percentage

The results of the study on the effect of nitrogen and zinc treatments on the ginning percentage of cotton revealed no significant differences across the various treatments. The ginning percentage ranged from 36.63% in treatment T1 (Nitrogen 0 kg/ha + Zinc 0%) to 37.62% in treatment T9 (Nitrogen 120 kg/ha + Zinc 39.5%). Although treatments with higher nitrogen levels generally exhibited slightly higher ginning percentages, these differences were statistically non-significant. This indicates that the application of nitrogen and zinc, at the levels tested, did not significantly influence the ginning percentage in cotton.

Seed Index

The highest seed index was observed in T9 (120 kg N/ha + 39.5% Zinc) at 7.81, followed closely by T8 (7.77) and T6 (7.76), highlighting the beneficial effects of combined high nitrogen and zinc treatments. Lower seed index values were recorded in T1 (7.62), T4 (7.6), and T7 (7.73), indicating that nitrogen-only treatments or those without zinc produced smaller seeds, which could negatively affect seed quality and vigor. Overall, higher zinc concentrations (17.5 and 39.5%) led to an increase in seed index, showing a strong correlation between zinc application and seed development.

Conclusion

The application of nitrogen and zinc had a significant impact on growth, yield attributes and yield as well as economic returns of cotton. Higher doses of nitrogen (100 and 120 kg/ha) combined with zinc (17.5% and 39.5%) resulted in increased plant height, more bolls, higher boll weight, and better seed cotton yield. Overall, the use of nitrogen and zinc together enhanced both growth and yield. Treatments with higher nitrogen and zinc levels also performed better in yield parameters such as the number of bolls per plant, boll weight, and cotton yield. Ginning percentage and seed index did not show significant differences between treatments, there was a slight trend of improvement with increasing zinc levels, indicating a potential for higher fiber quality at higher zinc doses. These results suggest that integrating balanced nutrient management practices involving nitrogen and zinc is essential for optimizing crop performance and improving economic viability for farmers.

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