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Effect of nitrogen and boron on growth and yield attributes of chia (*Salvia hispanica* L.)

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Abstract

A field experiment was conducted during Rabi season 2024 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) to study the effect of different nitrogen and boron levels on the growth and yield attributes of Chia (*Salvia hispanica* L.). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and three replications. The treatments comprised combinations of three nitrogen levels (80, 100, and 120 kg/ha) and three boron (boric acid) levels (50, 75, and 100 ppm), along with one control (N:P: K: 60:40:40 kg/ha).

The results revealed that the treatment T6 (100 kg N/ha + 100 ppm B) recorded the highest plant height (60.9 cm) and T8 with dry weight (34.87 g/plant), number of seeds per spike (315.31), number of spikes per plant (32.66), seed yield (1.12 t/ha), and stover yield (3.41 t/ha). Crop Growth Rate (CGR) were found maximum in T6 (Nitrogen 100 kg/ha + Boron 100 ppm) and Relative Growth Rate (RGR) were found maximum in T5 (Nitrogen 100 kg/ha + Boron 75 ppm) during later growth stages. On the other hand, the lowest values for all these parameters were observed in the control plot. The significant improvement in growth and yield attributes under higher nitrogen and boron levels demonstrates the synergistic effect of balanced nutrient application in chia cultivation.

Keywords: Chia, nitrogen, boron, growth, yield, CGR, RGR, randomized block design

Introduction

Chia (*Salvia hispanica* L.) is an ancient oilseed crop belonging to the family Lamiaceae, native to southern Mexico and northern Guatemala. It was a staple food in the diet of Aztec and Mayan civilizations and has gained renewed interest globally due to its exceptional nutritional profile and functional food properties (Ayerza and Coates, 2005) [2]. Chia seeds are rich in omega-3 fatty acids, particularly α -linolenic acid, dietary fibre, proteins, antioxidants, and essential minerals such as calcium, magnesium, and phosphorus (Mohd Ali *et al.*, 2012) [13]. Because of these attributes, chia is now recognized as a “superfood” and is cultivated extensively in South America, Australia, and parts of Asia, including India.

In recent years, chia cultivation has spread into non-traditional areas due to increasing demand in health-conscious markets. India has favourable agro-climatic conditions suitable for chia production during the rabi season. The crop is drought-tolerant and requires minimal water input compared to other oilseed crops (Ayerza, 2011) [3]. It is grown primarily for its seed, which contains about 25-35% oil, with omega-3 fatty acids contributing up to 60% of the total lipid content (Ixtaina *et al.*, 2008) [9]. The increasing focus on sustainable agriculture and health-based food products has made chia an attractive alternative to conventional oilseed crops.

Chia is a short-day plant that grows well in subtropical regions. It thrives in well-drained loamy soils with a neutral to slightly acidic pH. The crop typically matures in 90-120 days and is suited to diverse agro-ecological zones (Jamboonsri *et al.*, 2012) [10]. Despite its potential, chia remains under-researched in terms of agronomic practices, particularly nutrient management. Among various agronomic inputs, the role of macronutrients and micronutrients is crucial in achieving optimal productivity and quality.

Chia's nitrogen requirement may vary based on soil type, variety, and growing conditions. In light soils, nitrogen leaching can be a concern, and split applications or the use of slow-release

formulations may be beneficial. Integrated nutrient management approaches combining organic and inorganic sources are also being explored to enhance nitrogen use efficiency and soil health.

Boron (B) is a vital micronutrient required in small quantities but critical for various physiological processes in plants. It plays a major role in cell wall synthesis, membrane integrity, sugar transport, and reproductive development. In oilseed crops like chia, boron is particularly important for pollen viability, flower retention, and seed set.

Despite its potential, the crop remains underutilized in mainstream Indian agriculture, and research on its nutrient requirements, optimum agronomic practices, and genotype adaptability is still in its infancy. One of the major limitations has been the lack of location-specific fertilizer recommendations and comprehensive nutrient response studies under Indian conditions. Most chia cultivation in India currently relies on generalized or borrowed agronomic practices from South American or Australian research, which may not be entirely suitable for Indian soils and climate.

2. Materials and Methods

The present investigation entitled “Effect of nitrogen and boron on growth and yield attributes of Chia (*Salvia hispanica* L.)” was carried out at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during the winter (Rabi) season of 2024-2025. The area of Prayagraj district comes under subtropical belt in the Southeast of Uttar Pradesh, which experience extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 32°C - 34°C and seldom falls as low as 4°C - 5°C. The relative humidity ranged between 20 to 94 per cent. The average rainfall in this area is around 1013.4 mm annually. The date of crop sowing was on 19/10/2024 during Rabi season. The experiment was laid out in a RBD with three replications. The experimental area was divided into plots of 3m x 3m=9m² size. The experiment was carried out with ten treatments [T₁(Nitrogen 80 kg/ha + Boron50 ppm), T₂(Nitrogen 80 kg/ha + Boron75 ppm), T₃(Nitrogen 80 kg/ha + Boron100 ppm), T₄(Nitrogen 100 kg/ha + Boron50 ppm), T₅(Nitrogen 100 kg/ha + Boron75 ppm), T₆(Nitrogen 100 kg/ha + Boron100 ppm), T₇(Nitrogen 120 kg/ha + Boron50 ppm), T₈(Nitrogen 120 kg/ha + Boron75 ppm), T₉(Nitrogen 120 kg/ha + Boron100 ppm), T₁₀(control plot with RDF- N:P:K:: 60:40:40)]. The plants were spaced at 45cm between the rows and 15 cm between the plants. Observations were recorded on five randomly selected plants of each treatment to assess the effect of treatments on growth and yield of chia in the following characters viz., plant height (cm), dry weight (g/plant), Crop Growth Rate (g/m²/day), Relative growth rate (g/g/day), Number of spikes (m²), Number of seed per spike, Test weight (1000seeds), Seed yield(t/ha), Stover yield(t/ha) and Harvest index (%). The data recorded during investigation was subjected to statistical analysis by Analysis of variance technique. The data were statistically analysed using the F-test as per the procedure given by Gomez and Gomez (1984)^[7].

3. Results and Discussion

The effect of different nitrogen and boron levels on the growth and yield attributes of chia was found to be significant. The data revealed substantial differences among treatments with respect to plant height, dry matter accumulation, crop growth rate (CGR), relative growth rate (RGR), number of seeds per spike, test weight, seed yield, stover yield, and harvest index.

3.1 Growth Attribute

3.1.1 Plant Height and Dry Matter Accumulation

At 120 DAS, the tallest plants (60.90 cm) were recorded in the treatment with 120 kg N/ha + 50 ppm boron (T₇), followed closely by 120 kg N/ha + 75 ppm boron (T₈: 50.14 cm) and 120 kg N/ha + 100 ppm boron (T₉: 52.33 cm). These results are in alignment with the findings of Gopalan *et al.*, (2020)^[8], who reported increased vegetative growth in chia under higher nitrogen levels. The lowest plant height (40.91 cm) was observed in the control treatment (T₁₀).

Similarly, the highest plant dry matter accumulation per plant (34.87 g) was recorded under T₈ (120 kg N/ha + 75 ppm boron), followed by T₉ (32.24 g) and T₇ (29.19 g). These results suggest a synergistic effect of nitrogen and boron in enhancing assimilate production, as supported by studies from Yadav *et al.*, (2022)^[15], who noted increased dry matter accumulation with balanced boron and nitrogen fertilization in chia and quinoa.

3.1.2 Crop Growth Rate (CGR) and Relative Growth Rate (RGR)

The highest CGR was observed in T₇ (12.83 g/m²/day), significantly outperforming all other treatments, followed by T₅ (9.87 g/m²/day) and T₃ (10.56 g/m²/day). The lowest CGR was recorded in the control plot (6.48 g/m²/day). Enhanced CGR is closely associated with increased canopy development and photosynthetic efficiency due to optimal nutrient supply (Jamboonsri *et al.*, 2012)^[10].

Regarding RGR, the maximum value (0.038 g/g/day) was found in T₅ (100 kg N/ha + 75 ppm boron), followed by T₃ (0.033 g/g/day) and T₇ (0.034 g/g/day). These findings concur with the work of Meena *et al.*, (2020)^[12], who observed improved RGR in chia with integrated nitrogen and micronutrient application.

3.2 Yield attributes

Number of seeds per spike was highest in T₈ (315.31), followed by T₉ (314.46) and T₆ (308.22), suggesting that increased nitrogen and boron levels positively influence floral fertility and seed set, corroborating the findings of Yadav *et al.*, (2022)^[15]. The lowest number of seeds per spike was noted in T₂ (215.99). Number of spikes per plant was also maximum in T₈ (32.66), followed by T₉ (31.48) and T₇ (29.93), while the control treatment (T₁₀) showed the minimum spike count (25.66). This reflects the role of nitrogen in enhancing sink capacity, as noted by Jamboonsri *et al.*, (2012)^[10].

Test weight (1000-seed weight) was highest in T₉ (1.56 g), followed by T₈ (1.50 g) and T₆ (1.49 g), showing the beneficial effects of boron on seed development. The lowest test weight was observed in T₁ (1.34 g).

3.2.1 Seed Yield and Stover Yield

The maximum seed yield (1.12 t/ha) was obtained from T₈ (120 kg N/ha + 75 ppm boron), followed by T₉ (1.09 t/ha) and T₇ (0.89 t/ha). The lowest yield (0.69 t/ha) was recorded in the control treatment (T₁₀). The increase in seed yield can be attributed to enhanced vegetative growth, reproductive success, and seed filling due to optimum nutrient supply (Singh *et al.*, 2021)^[14].

In terms of stover yield, T₈ again recorded the highest value (3.40 t/ha), followed by T₉ (3.34 t/ha) and T₇ (2.83 t/ha). These values indicate that improved biomass production accompanies increased nutrient availability, in agreement with findings by Kumar *et al.*, (2020)^[11].

3.2.2 Harvest Index (HI)

The harvest index, representing the efficiency of the plant in converting total biomass to economic yield, was highest in T₉ (33.75%), followed by T₈ (31.52%) and T₇ (29.27%). The lowest

HI was found in T₃ (24.12%). Higher HI indicates better translocation of assimilates toward seed production, as emphasized by Jamboonsri *et al.*, (2012)^[10] and Kumar *et al.*, (2020)^[11].

Table 1: Effect of nitrogen and boron on growth attributes of Chia (*Salvia hispanica* L.).

Treatment	Treatment Combination	Plant height (cm)	Dry Weight (g/plant)	CGR (g/m ² /day) 80-100 DAS	RGR (g/g/day) 80-100 DAS
T ₁	Nitrogen 80 kg/ha + Boron 50 ppm	50.49	24.79	4.18	0.0096
T ₂	Nitrogen 80 kg/ha + Boron 75 ppm	51.22	26.75	3.97	0.0114
T ₃	Nitrogen 80 kg/ha + Boron 100 ppm	49.92	27.36	10.56	0.0330
T ₄	Nitrogen 100 kg/ha + Boron 50 ppm	49.02	22.52	2.61	0.0084
T ₅	Nitrogen 100 kg/ha + Boron 75 ppm	48.79	26.63	9.87	0.0382
T ₆	Nitrogen 100 kg/ha + Boron 100 ppm	60.9	28.06	12.83	0.0345
T ₇	Nitrogen 120 kg/ha + Boron 50 ppm	48.34	29.19	6.52	0.0167
T ₈	Nitrogen 120 kg/ha + Boron 75 ppm	50.14	34.87	5.53	0.0159
T ₉	Nitrogen 120 kg/ha + Boron 100 ppm	52.33	32.24	2.72	0.0069
T ₁₀	Control Plot (N:P: K:: 60:40:40 kg/ha)	40.91	20.49	6.48	0.0273
	F-Test	NS	NS	S	S
	S.Em (±)	4.83	2.81	1.93	0.01
	C.D. at 5%	14.35	8.35	5.73	0.02

Table 2: Effect of nitrogen and boron on yield attributes of Chia (*Salvia hispanica* L.).

Treatment	Treatment Combination	No. of seeds/spike	No. of spike/plant	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
T ₁	Nitrogen 80 kg/ha + Boron 50 ppm	286.88	26.9	1.34	0.79	2.37	25.09
T ₂	Nitrogen 80 kg/ha + Boron 75 ppm	215.99	25.8	1.38	0.73	2.16	24.98
T ₃	Nitrogen 80 kg/ha + Boron 100 ppm	289.90	28.8	1.40	0.76	2.29	24.12
T ₄	Nitrogen 100 kg/ha + Boron 50 ppm	284.89	29.6	1.33	0.82	2.48	24.99
T ₅	Nitrogen 100 kg/ha + Boron 75 ppm	300.59	28.9	1.33	0.85	2.57	26.39
T ₆	Nitrogen 100 kg/ha + Boron 100 ppm	308.22	30	1.39	0.89	2.65	26.28
T ₇	Nitrogen 120 kg/ha + Boron 50 ppm	302.11	29.9	1.45	0.95	2.83	29.27
T ₈	Nitrogen 120 kg/ha + Boron 75 ppm	315.31	32.6	1.50	1.12	3.40	31.52
T ₉	Nitrogen 120 kg/ha + Boron 100 ppm	314.46	31.8	1.56	1.09	3.34	33.75
T ₁₀	Control Plot (N:P: K:: 60:40:40 kg/ha)	212.67	25.6	1.38	0.69	2.09	25.31
	F-Test	S	S	NS	S	S	S
	S.Em. (±)	14.26	1.24	0.06	0.04	0.19	1.15
	C.D. at 5%	42.37	3.67	0.18	0.12	0.56	3.40

4. Conclusion

Based on present investigation, it is concluded that the T₈ (120 kg N/ha + 75 ppm boron) was found to be the most suitable over all the other treatments in relation to growth and yield of Chia. The T₆ [Nitrogen 100 kg/ha + Boron 100 ppm] was recorded Higher plant height (60.9 cm) whereas, T₈ [Nitrogen 120 kg/ha + Boron 75 ppm] recorded Maximum Number of spike /plant(32.66), plant dry weight (34.87 g), no. of seeds/spike (315.31) and also recorded highest seed yield(1.12t/ha), and stover yield (3.41 t/ha), were recorded as compared to the other treatments. And T₉ [Nitrogen 120 kg/ha + Boron 100 ppm] recorded highest test weight (1.56 g) as compared to the other treatments. Whereas the maximum benefit cost ratio (1:3.54) was found in T₈ [Nitrogen 120 kg/ha + Boron 75 ppm]. However, since this is based on one - season experiment, further trails may be needed to substantiate the results.

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