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Research Article

Growth and Yield Response of BAU Chia-1 (*Salvia hispanica*) to Nitrogen Fertilizer

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ABSTRACT

Chia (*Salvia hispanica* L.) is a newly introduced drought-tolerant crop in Bangladesh and registered as BAU chia-1 in 2019 for countrywide cultivation. Its seeds are considered a superfood because of having a large amount (57-65%) of α-linolenic acid (ω-3 fatty acid). This study aims to determine the amount of optimum nitrogen fertilizer to get a good yield in Bangladesh. A field experiment was conducted from November 2023 to February 2024, to assess the influence of nitrogen in the growth and yield of BAU chia-1. A randomized complete block design was conducted with four nitrogen fertilizer treatments (T_0 = control/ 0 kg N ha^{-1}, T_1= 90 kg N ha^{-1}, T_2 = 120 kg N ha^{-1}, T_3= 150 kg N ha^{-1}) with three replications. The vegetative growth (plant height, fresh weight plant^{-1}, dry weight plant^{-1}, leaf number plant^{-1}) was higher in the case of T_3, but in case of yield contributing attributes (number of inflorescence plant^{-1}, main inflorescence length, number of spikes inflorescence^{-1}, number of spikelet spike^{-1}) and seed yield T_2 showed the highest value. Though, SPAD was also the highest in T_3, leaf area and fluorescence was higher in T_2 than others. Finally, main inflorescence length (39.4 cm), number of inflorescences plant^{-1} (21), spikes main inflorescence^{-1} (20), spikelet spike^{-1} (24) and seed yield (1066 kg ha^{-1}) were higher in T_2 treatment than the others. The optimal nitrogen level for BAU chia-1 cultivation appears to be 120 kg N ha^{-1}. However, further multi-location trials are required to validate these findings before making any recommendations.

Introduction

Chia (*Salvia hispanica* L.) is an annual herbaceous plant belonging to the Lamiaceae family (Hossain et *al.* 2016). This crop is native to the mountain areas of Mexico and Guatemala (Ixtaina *et al.,* 2008; Sosa-Baldivia *et al.,* 2018) and was an important staple crop during pre-Columbian times in Mexico (Cahill, 2003). It was first introduced in Bangladesh, in 2010 and registered as BAU chia-1 by the Ministry of Agriculture in 2019 (Shorna, 2024). This macro-thermal short-day species produces purple or white flowers and brown or white colour seeds with oppositely arranged leaves. Its seed is oval-shaped and small in size, a couple of millimetres in length (Muñoz *et al.,* 2013). However, chia is gaining popularity due to its high nutritional value, especially the presence of ω-3 fatty acid (~67%) and dietary fibre. According to USDA Food Data Central, 100g of chia seed contains 17.8g of Polyunsaturated Fatty Acid (ALA; 18:3). Additionally, it contains protein (16.5g 100g^{-1}), lipid (30.7g 100g^{-1}), carbohydrate (42.1 g 100g^{-1}), dietary fibre (42.1g 100g^{-1}), minerals (Ca, Fe, Mg, P, K etc.) and so on. Moreover, some researchers found that phenolic and antioxidant substances are high in chia seeds (da Silva Marineli *et al.,* 2014). The potential health benefit of chia was reported by a group of pharmaceuticals and nutraceuticals researchers (Ulbricht *et al.,* 2009; Ali *et al.,* 2012; Katunzi-Kilewela *et al.,* 2021). This is the only reason the EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA) announced chia seeds as novel foods (NFs) under Regulation (EU) 2015/2283 (Dinçoğlu *et al.,* 2019; Suri *et al.,* 2015).

The area under cultivation of BAU chia-1 is expected to rise in the coming days as it requires less water and is a drought-resistant crop that comes up very well under adverse climatic conditions (Harisha *et al.,* 2023). However, being a new crop, the optimization of different agronomic management practices is very scarce under Bangladesh conditions, which is necessary

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for harvesting maximum yield. Very few works addressed the effect of sowing date (Karim *et al.* 2015), sowing method (Biswas *et al.* 2020) and sowing density (Sumi *et al.* 2023) or sowing density in combination with fertilization strategies (Rahman *et al.* 2023) for good harvest of BAU chia seed in the climatic condition of Bangladesh. In addition to above mentioned agronomic practices, nitrogen fertilization plays a critical role concerning seed yield and seed quality traits. An assessment of optimized nitrogen fertilization is necessary to evaluate the direct effects on plant growth, maturity, yield contributing characters and seed yield as well. Therefore, the present study aimed to evaluate the response of BAU chia-1 to nitrogen fertilization under subtropical conditions in Bangladesh.

Materials and Methods

The study investigated the growth, yield, and physiological characteristics of BAU chia-1 under different nitrogen treatments at the Crop Botany Research Field of Bangladesh Agricultural University, Mymensingh. The seeds were authenticated and the experiment was conducted from November 2023 to February 2024. The field was prepared by tilling and levelling, followed by the application of fertilizers: 20 kg N ha^{-1} as urea, 40 kg P ha^{-1} as TSP, and 20 kg K ha^{-1} as MoP. The remaining nitrogen fertilizer was top dressed at 30 DAS according to the experimental design.

The experiment followed a Randomized Complete Block Design with four nitrogen levels (T_0 = control / 0 kg N ha^{-1}, T_1 = 90 kg N ha^{-1}, T_2= 120 kg N ha^{-1}, T_3= 150 kg N ha^{-1}) and three replications. As a basal dose, 20 kg of nitrogen is initially applied to the field. After 30 days, the remaining amount of nitrogen, as specified by the experimental design, is spread over the field. Each plot measured 20 m^2 (5m × 4m). The plots were arranged in three blocks based on similar soil characteristics, and treatments were randomly assigned within each block. Seeds were sown at the rate of 2.5 kg ha^{-1} following broadcasting method. The crop was grown without irrigation due to sufficient soil moisture and managed manually for weeds at 25 and 40 DAS. No pesticides were applied because pest infestations were minimal.

Parameters recorded during the growing period included plant height, root length, fresh and dry weight $plant^{-1}$, leaf number, leaf area, and SPAD value (a measure of chlorophyll content). Measurements of plant height and root length were taken using a centimeter ruler, while fresh and dry weights were recorded using a digital scale. Plants were dried at 70°C for 72 hours to determine dry weight. The leaf area was measured using an LI-3100 Area Meter, and chlorophyll content was assessed with a SPAD 502 plus chlorophyll meter. The potential quantum yield of PSII in dark-adapted leaves (Fv/Fm) was measured at 10-day intervals from 30 DAS using a Hansatech Pocket PEA Chlorophyll Fluorimeter.

At harvest, yield contributing parameters such as the number of inflorescences $plant^{-1}$, main inflorescence length, number of spikes $inflorescence^{-1}$, number of spikelets $spike^{-1}$, and seed yield were recorded from 10 plants of each replication. The total number of leaves, inflorescences, and spikes were counted from randomly selected plants in each plot. After harvesting, seeds were cleaned, and the seed yield was measured.

Table 1. Effect of nitrogen fertilizer level on plant height of chia at different days after sowing (DAS)

N level (Kg ha^{-1})	Plant height (cm)									
	Days after Sowing (DAS)									
	10	20	30	40	50	60	70	80	90	100
0 (Control)	3.7±0.21^{b}	16.1±0.4^{ab}	30.8±3.2^{a}	47.5±0.7^{c}	63.3±1.8^{d}	85.8±2.8^{b}	102.7±1.7^{a}	107.7±5.6^{b}	110.3±1.5^{c}	128.9±3.1^{b}
90	5.3±0.08^{a}	16.9±0.2^{ab}	32.8±1.1^{a}	55.7±0.6^{b}	76.2±0.9^{c}	111.5±2.4^{a}	113±2.7^{a}	116.1±0.6^{ab}	134.4±2.2^{b}	139.5±1.04^{b}
120	4.4±0.12^{b}	17.7±0.08^{a}	29.1±1.4^{a}	65.7±1.9^{a}	84.8±2.2^{b}	105.4±7.5^{a}	113.7±1^{a}	115.5±1.7^{ab}	132.3±1.2^{b}	151.7±1.7^{a}
150	5.5±0.15^{a}	14.4±1.05^{b}	34.1±4.9^{a}	63.4±1.6^{a}	89.5±1.3^{a}	108.3±2.8^{a}	113±4.3^{a}	124.6±2.02^{a}	147.7±1.5^{a}	160.6±1.2^{a}
CV (%)	17.92	8.70	6.89	14.19	14.68	11.27	4.75	5.96	11.81	9.54

In a column figures with same letter do not differ significantly.

Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program Minitab.

Results and Discussion

Plant height

In this study, chia plant height was measured at 10-day intervals that were treated with nitrogen fertilizer at 30 DAS. Initially, the plant's height was uniform but by 40 DAS, differences observed due to nitrogen application (Table 1). However, at 40 DAS, the observed plant height was 47.5 cm, 55.7 cm, 65.7 cm, and 63.4 cm in control, T_1, T_2, and T_3 respectively. So the timing of nitrogen application is essential for proper vegetative growth. Notably, T_1 showed the tallest plants at 60 DAS (111.5 cm). By 70 DAS, no significant differences were observed in plant height. From 80 DAS to 100 DAS, T_3 had the tallest plant. This observation suggests that higher nitrogen levels boost growth by increasing proteins and amino acids, which promote cell elongation and multiplication. It is noteworthy that, the chia plant was uprooted for data collection, so the measurement was not obtained from the same individual plants throughout the study. Thus, there may be some variability in this data. This finding aligns with the research of Njoka *et al.,* (2022). According to their research, the application of the highest nitrogen fertilizer increased vegetative growth.

Root length

Root length exhibited an opposite pattern of plant height, showing decreases in treated groups compared to control (Table 2). Initially, there were no significant differences in the root length of chia plants up to the application of nitrogen fertilizer. However, at 40 DAS, the root length of control plots (7.4 cm) surpassed the treated plots (T_1 = 6 cm, T_2= 4.9 cm, T_3 = 6.2 cm). This result may indicate some factors that influence the root development, such as nutrient availability, and physiological responses to external stimuli. The highest nitrogen application (T_3) surprisingly resulted in the shortest (8.9 cm) root length of the chia plant in the final harvest. This may be ascribed the variations in soil nutrient availability (López-Bucio *et al.,* 2023). Furthermore, data collection was not conducted on the same individual plant, similar to plant height.

Table 2. Effect of nitrogen fertilizer level on root length of chia at different days after sowing (DAS)

N level (Kg ha^{-1})	Root length (cm)									
	Days after Sowing (DAS)									
	10	20	30	40	50	60	70	80	90	100
0 (Control)	2.3±0.23^{a}	3.4±0.06^{a}	5.5±0.77^{a}	7.4±0.17^{a}	9.6±0.18^{a}	9.6±0.32^{a}	14.9±0.46^{a}	13.8±0.17^{a}	13.8±0.4^{a}	12.2±0.17^{a}
90	2.4±0.21^{a}	3.6±0.09^{a}	5.2±0.29^{a}	6.0±0.21^{ab}	8.4±0.15^{b}	8.7±0.14^{b}	10±0.40^{b}	9.0±0.12^{b}	8.6±0.58^{b}	8.1±0.64^{b}
120	2.7±0.12^{a}	3.4±0.17^{a}	4.3±0.26^{a}	4.9±0.46^{b}	8.7±0.17^{b}	9.4±0.21^{a}	12.4±0.64^{ab}	10.3±0.35^{b}	11.0±0.55^{b}	10.3±0.94^{ab}
150	2.9±0.03^{a}	3.4±0.54^{a}	5.9±0.25^{a}	6.2±0.14^{ab}	7.8±0.20^{b}	9.3±0.13^{a}	11.9±0.45^{b}	9.2±0.60^{b}	9.1±0.23^{b}	8.9±0.48^{ab}
CV (%)	10.72	3.74	12.99	16.24	9.00	3.99	16.50	20.95	22.27	18.37

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Fresh weight plant^{-1}

The fresh weight plant^{-1}, represented in Figure 1, showed a consistent increase over time in all treatments, though the control plants exhibited lower fresh weights compared to other treatments. The lower value in control plants describes the necessity of nitrogen fertilizer in biomass accumulation. T_3 recorded the highest fresh weight from the beginning to harvesting and T_2 showed the second highest fresh weight. However, there is no significant difference in T_2 and T_3. El-Desouky *et al.,* (2022) put nitrogen as an amino acid and found that the highest fresh weight at the harvesting time was obtained from the higher amino acid application which aligns with this study.

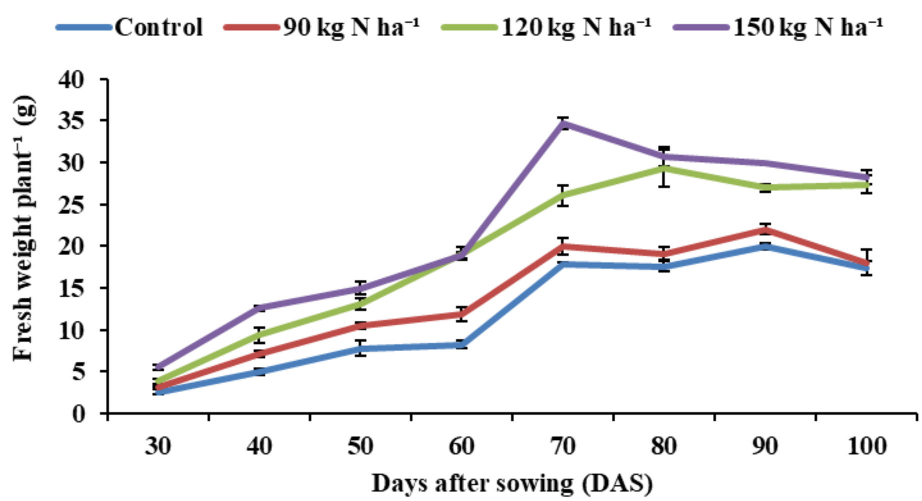

Figure 1. Fresh weight of chia at different growth stages as affected by nitrogen fertilizer level. The vertical bars represent the standard error.

Dry weight plant^{-1}

Plants treated with nitrogen fertilizer always displayed greater dry matter production than the control (Figure 2). At 60 DAS, T_2 showed the highest (3.7 g) dry matter accumulation. Subsequently, at 70 DAS, both T_2 and T_3 demonstrated nearly equivalent (T_2 = 6.7 g, T_3= 6.8 g) dry matter production. However, from 80 DAS up to harvesting, T_3 continuously displayed the highest values of dry matter accumulation. This indicates that nitrogen fertilizer application is essential for dry matter accumulation. Again, nitrogen fertilizer is a fundamental building block for essential molecules involved in growth and development, which is essential for photosynthesis, respiration and protein synthesis. Moreover, it mitigates nutrient deficiencies, enhances stress tolerance, and improves overall plant vigour, finally contributing to increased dry matter accumulation. Souza and Chavez (2017) found 8.06 g $plant^{-1}$ dry matter after applying 125 kg N ha^{-1} due to the acceleration of cell division and expansion, whereas in this study, the highest dry matter during harvesting was 8.25 g $plant^{-1}$ in T_3. El-Desouky *et al.,*(2022) also mentioned high dry matter accumulation in higher amino acid application. A similar result was recorded by Njoka *et al.,* (2022) that the highest nitrogen application is responsible for higher dry matter accumulation.

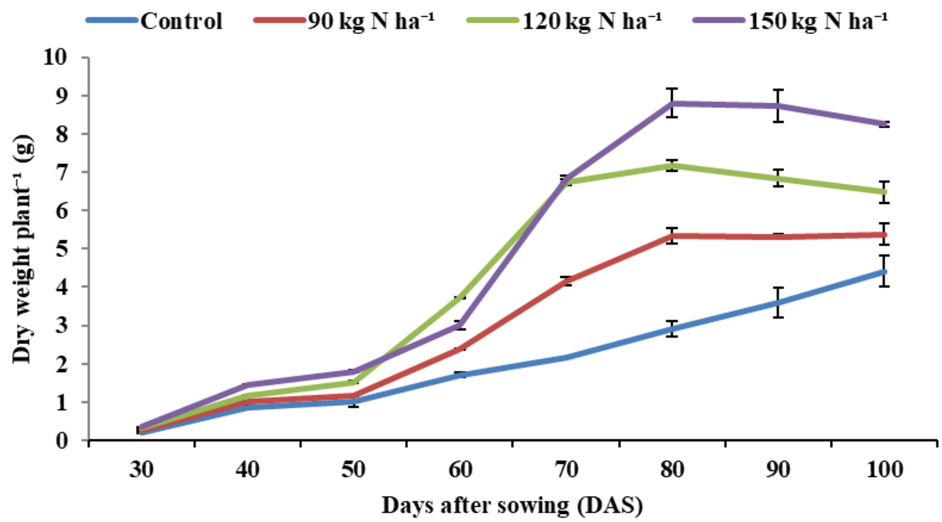

Figure 2. Dry weight of chia at different growth stages as affected by nitrogen fertilizer level. The vertical bars represent the standard error.

Number of leaves plant⁻¹

The ontogeny of the leaf number increment of the chia plant is represented in Table 3. There was less difference in leaf number before nitrogen fertilizer application. After nitrogen fertilizer application, the control plants exhibited inferior leaf numbers. Leaf number was the highest at T_3 all over the growing period. Therefore, a low dose of nitrogen fertilizer may be responsible for lower leaf numbers. At the final harvest, the leaf number of the chia plant in control, T_1, T_2, and T_3 was 36, 41, 47.3, and 56.7, respectively. Adequate nitrogen availability promotes the production of new leaves, so the leaf number increases in higher nitrogen fertilizer application. Njoka *et al.,* (2022) also mentioned higher leaf numbers in higher nitrogen application.

Table 3. Effect of nitrogen fertilizer level on number of leaves $plant^{-1}$ of chia at different days after sowing (DAS)

N level (Kg ha^{-1})	Leaf number $Plant^{-1}$									
	Days after Sowing (DAS)									
	10	20	30	40	50	60	70	80	90	100
0 (Control)	5.7±0.3^{a}	9±0.6^{a}	12.3±0.3^{b}	17±0.6^{c}	18.3±0.3^{d}	20±0.6^{b}	22.3±1.3^{b}	29.3±2.7^{b}	31.3±3.7^{b}	36±1.2^{b}
90	7±0.6^{a}	8.3±0.7^{a}	15.7±0.9^{a}	20±0.6^{b}	22±0.6^{c}	23±1^{b}	24±0.6^{b}	33.3±2.9^{ab}	35.3±1.7^{ab}	41±3^{b}
120	7.3±1.2^{a}	9±0.6^{a}	15±0.6^{ab}	23±0.6^{a}	26.3±0.3^{b}	31.7±0.9^{a}	34.7±0.7^{a}	38.3±1.8^{ab}	44.7±2.4^{a}	47.3±2.7^{ab}
150	7.3±0.3^{a}	9±0.6^{a}	17±1.5^{a}	20±0.6^{b}	29.7±0.9^{a}	32±1.5^{a}	37±2.5^{a}	42±4.2^{a}	46.7±4.4^{a}	56.7±3.3^{a}
CV (%)	11.61	3.77	13.08	12.25	20.57	22.85	25.11	15.55	18.61	19.69

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SPAD value

Figure 3 demonstrated that plants treated with nitrogen fertilizer had higher SPAD values, indicating increased chlorophyll content compared to the control. Therefore, a consistent pattern of higher SPAD values was observed in T_3, indicating that the higher nitrogen dose enhances optimal chlorophyll synthesis. However, there were inconclusive results in T_1 and T_2. The main factor influencing this variation may be due to N_2 which is the key component of chlorophyll ($C_{55}H_{72}N_4Mg$). Relative chlorophyll content will decrease due to lower nitrogen as it is essential for chlorophyll synthesis (Bidwell, 1974; Lambers *et al.,* 2011). A similar result was also recorded in Esmail *et al.,* (2022), when SPAD value increased in higher nutrient supply.

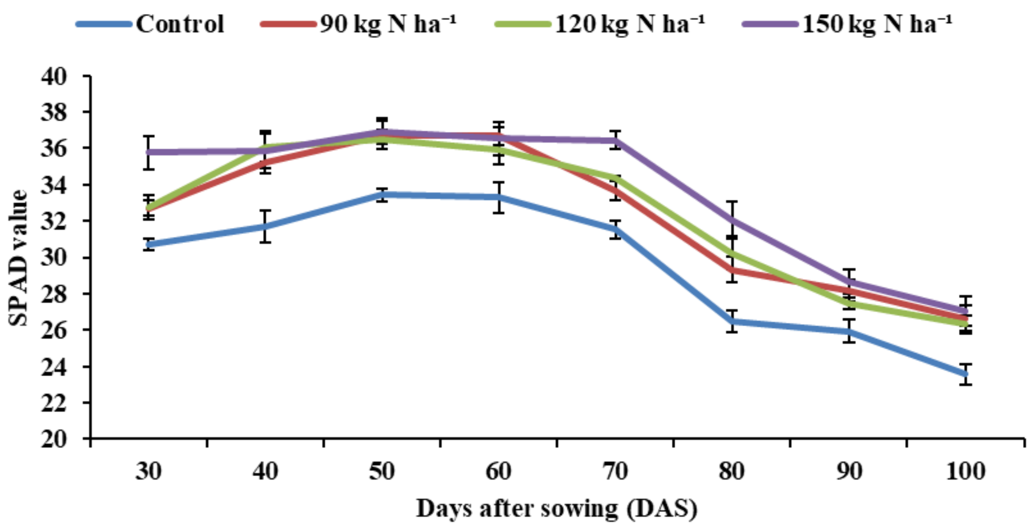

Figure 3. SPAD value of chia at different growth stages as affected by nitrogen fertilizer level. The vertical bars represent the standard error.

Leaf area plant^{-1}

The leaf area of chia was increased gradually till the reproductive stage and declined subsequently (Table 4). This shows the natural pattern of leaf growth and senescence. At 60 DAS, all treatments showed the maximum leaf area, except T_1. Interestingly, at 70 DAS, T_1 showed the highest leaf area, which suppresses T_3. Among all the treatments, T_2 resulted in the highest leaf area till harvesting. This indicates that optimum nitrogen (T_2) is essential for leaf growth and canopy development. A unique result was found at 90 DAS when T_2 and T_3 showed approximately same values. This result reveals that excessive nitrogen isn't always better. In this case, T_2 may be more beneficial for leaf development compared to T_3. Though Mack *et al.,* (2017) revealed that higher nitrogen application (40 kg N ha^{-1}) is responsible for higher leaf area in chia.

Table 4. Effect of nitrogen fertilizer level on leaf area of chia at different days after sowing (DAS)

N level (Kg ha^{-1})	Leaf area (cm^2)							
	Days after Sowing (DAS)							
	30	40	50	60	70	80	90	100
0 (Control)	27.4± 1.8^c	36.5± 2.04^c	53.5± 2.4^b	57± 3.4^b	53.5± 2.5^b	49.5± 4.6^b	42.1± 1.2^c	37.9± 0.65^c
90	37.8± 3.04^{bc}	42.5± 2.42^{bc}	56.3± 0.53^b	66.2± 2.8^b	79.8± 3.9^a	67.2± 1.05^a	50.9± 1.05^b	47.2± 0.5^{bc}
120	55.1± 2.7^a	70.4± 3.41^a	68.9± 1.9^a	98.3± 1.9^a	79.6± 1.7^a	77.9± 2.9^a	64.5± 1.04^a	63.3± 2.02^a
150	49.8± 3.19^{ab}	52.2± 3.49^b	60.2± 2.77^{ab}	84.3± 4.2^a	68.4± 3.6^{ab}	65.7± 1.8^a	63.7± 1.8^a	56.8± 3.3^{ab}
CV (%)	29.15	29.30	11.21	24.16	17.64	18.05	19.45	21.73

In a column figures with same letter do not differ significantly.

Fluorescence

This study investigates the impact of varying nitrogen application rates on chlorophyll fluorescence in chia plants (Table 5). Mean Fv/Fm values, indicating photosynthetic efficiency, ranged from 0.66 to 0.79 across nitrogen treatments depicted in Table 5. The control plant had the lowest fluorescence, while T_2 consistently showed the highest levels, indicating optimal PS-II efficiency with higher photosynthetic performance. Also, the leaf area of T_2 was higher than other treatments. Conversely, the lowest fluorescence level was recorded in T_3 among all the treatments, possibly due to physiological stress from excessive nitrogen. Notably, the plants of T_1 showed higher fluorescence levels compared to T_3. At 60 DAS, T_2 demonstrated the highest Fv/Fm, indicating that the photosystems were operating at 81% efficiency during the entire growth period. In contrast, T_1 achieved 78.3% efficiency at 80 DAS, while T_3 maintained approximately 76% efficiency at 50 DAS, 60 DAS, and 70 DAS throughout the growth period. DaMatta *et al.,* (2002) showed that nitrogen deficiency may affect PSII photochemistry because it decreases the quantum yield of PSII electron transport and Fv/Fm. Again, Shelly *et al.,* (2007) demonstrate that NH_4^+ additions produce more complex effects on fluorescence than NO_3^- additions.

Table 5. Effect of nitrogen fertilizer levels on fluorescence of chia at different days after sowing (DAS)

N level (Kg ha^{-1})	Fluorescence							
	Days after Sowing (DAS)							
	30	40	50	60	70	80	90	100
0 (Control)	0.69± 0.01^{a}	0.69± 0.003^{b}	0.73± 0.005^{b}	0.74± 0.008^{b}	0.75± 0.006^{a}	0.74±0.03^{a}	0.72± 0.003^{b}	0.67± 0.02^{a}
T_1	0.70± 0.01^{a}	0.74± 0.02^{ab}	0.76± 0.006^{ab}	0.77± 0.01^{ab}	0.77± 0.03^{a}	0.78± 0.02^{a}	0.76± 0.02^{ab}	0.72± 0.01^{a}
T_2	0.73± 0.02^{a}	0.77± 0.02^{a}	0.79± 0.008^{a}	0.81± 0.005^{a}	0.79± 0.02^{a}	0.79± 0.01^{a}	0.78± 0.007^{a}	0.73± 0.02^{a}
T_3	0.72± 0.01^{a}	0.75± 0.01^{ab}	0.76± 0.006^{ab}	0.76± 0.02^{ab}	0.77± 0.03^{a}	0.75± 0.03^{a}	0.74± 0.02^{ab}	0.71± 0.01^{a}
CV (%)	2.49	4.40	3.06	3.98	2.00	3.65	3.38	3.97

In a column figures with same letter do not differ significantly.

Main inflorescence length

This study found significant variations in the main inflorescence length among different nitrogen fertilizer applications (Figure 4). Plants in the control group exhibited relatively shorter main inflorescence, with an average of 20.33 cm. In contrast, plants of T_2 displayed the longest main inflorescence, with an average of 39.4 cm, which indicates the necessity of nitrogen fertilizer in inflorescence elongation. Interestingly, T_1 showed a slightly lower (27.9 cm) average main inflorescence length compared to T_2. Further, the main inflorescence length was intermediate in T_3 treatment, averaging 33.2 cm. This indicates that excessive nitrogen application may not be necessary for the increase of main inflorescence length and lower nitrogen availability may stimulate the length. The moderate nitrogen fertilizer application can influence inflorescence elongation. The length was recorded 17.8 cm where no additional fertilizer was applied (Biswas *et al.,* 2020), whereas Rahman *et al.,* (2023) recorded the inflorescence length above 30 cm where different doses of fertilizers was applied.

Number of inflorescences plant^{-1}

Figure 4 shows a significant impact of different nitrogen levels on inflorescence development. Chia plants with no nitrogen application exhibited an average of 9 inflorescences per plant. However, as nitrogen dosage increased, there was variation in inflorescence production. Specifically, plants of T_1 showed an average of 6.66 inflorescences plant^{-1}. Further, T_3 resulted in an average of 11.33 inflorescences plant^{-1}. The number of inflorescences was 21 in T_2, and it was the highest among the treatments. This finding indicates that optimum nitrogen fertilizer is essential to maximize reproductive development, and excessive nitrogen may not be used by the plants or leaching out to the soil (Jensen *et al.,* 2005).

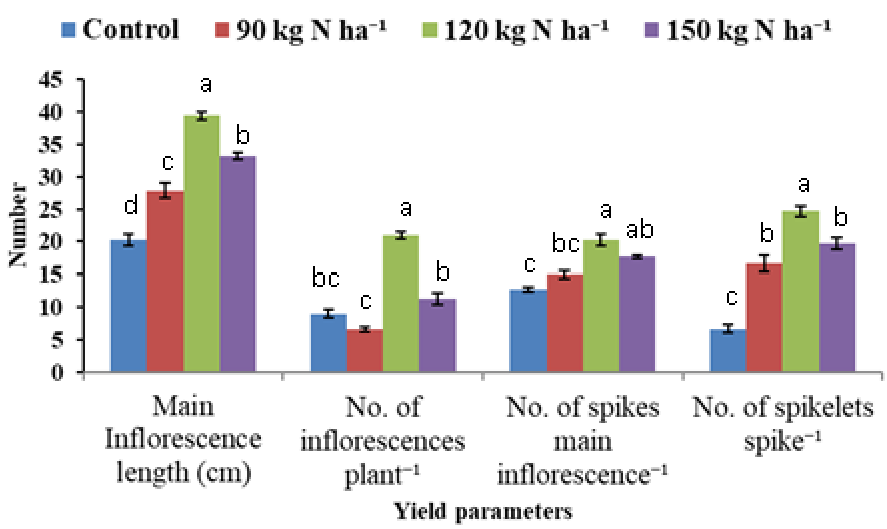

Figure 4. Main inflorescence length, No. of inflorescence number plant^{-1}, No. of spike main inflorescence^{-1}, and No. of spikelet spike^{-1} of chia at different growth stages as affected by nitrogen fertilizer level. The vertical bars represent the standard error (n=3).

Number of spikes main inflorescence^{-1}

This study showed variations in spike production in the chia plant over different nitrogen fertilizer applications delineated in Figure 4. Control plants showed the lowest (average 12.66) spikes main inflorescence^{-1}. T_1 resulted in an increased average of 15 spikes main inflorescence^{-1}. Furthermore, plants of T_2 exhibited a substantial rise in spike production, averaging 20.33

spikes main inflorescence^{-1}. Similarly, T_3 showed an average of 17.66 spikes main inflorescence^{-1}. This finding indicates the importance of optimum nitrogen fertilizer application in spike formation (Marschner, 2012).

Number of spikelets spike^{-1}

There is a significant difference in different levels of nitrogen fertilizer application on spikelet production spike-1 (Figure 4). Control plants showed an average of 6.66 spikelets spike-1. With an average of 16.66 spikelets spike-1 was seen in T1. Additionally, plants of T2 showed a significant increase in the number of spikelets production – an average of 24.66 spikelets spike-1. Also, 19.66 spikelets on average were produced in T3. Biswas et al., (2020) recorded about 16 spikelet spike-1 in chia plants which justify this result.

Seed yield

Doses of nitrogen fertilizer significantly impacted the seed yield of BAU chia-1 displayed in Figure 5. The lowest seed yield, 530kg ha^{-1} was recorded in the control. As the nitrogen doses increased, the yield of T_1 rose to 750 kg ha^{-1}. Further, at T_2, the yield significantly increased to 1066 kg ha^{-1}. However, the yield of T_3 decreased to 750 kg ha^{-1}. It meant that there was no additional benefit observed in the case of a higher dose of nitrogen fertilizer application. Our results are in agreement with the findings of Singh *et al.,*(2023), who got 1020 kg ha^{-1} seeds in higher nitrogen application, and 709 kg ha^{-1} seeds in lower nitrogen fertilizer application.

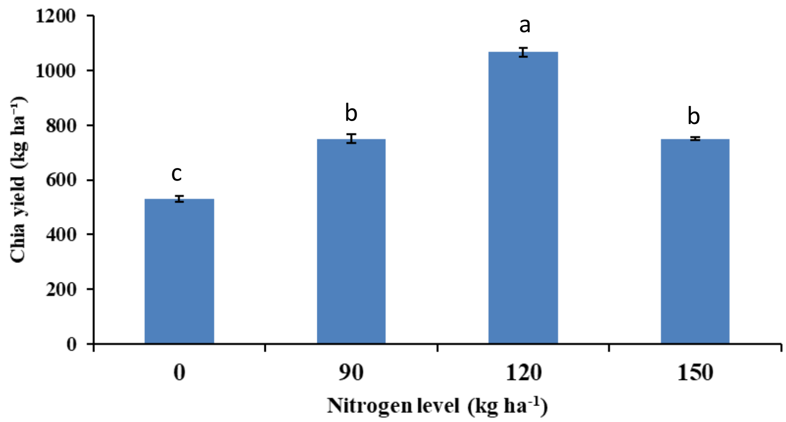

Figure 5. Seed yield of chia at different growth stages as affected by nitrogen fertilizer level. The vertical bars represent the standard error (n=3).

Conclusion

This study confirms the importance of optimum nitrogen fertilizer dose, which influenced different agronomic parameters and yield components in BAU chia-1 grown in Bangladesh. 150 kg N ha^{-1} played a significant role in increasing vegetative growth and biomass accumulation. However, the yield potential was significantly the highest at 120 kg N ha^{-1}. Therefore, 120 kg N ha^{-1} seems to be the best nitrogen level for BAU chia-1 cultivation. Further multilocation trials are needed to confirm this finding before making any recommendations.

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