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EFFECT OF NITROBENZENE AND GIBBERELLIC ACID ON GROWTH, YIELD AND ECONOMIC RETURNS OF LATE-SOWN LENTIL (*LENS CULINARIS* L.)

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Abstract

Plant Growth Regulators (PGRs) mitigate yield losses in late-sown lentils (*Lens culinaris* L.) by enhancing nutrient uptake and photosynthetic efficiency. A field experiment was conducted during the Rabi season of 2024-25 to evaluate the effects of different PGRs on growth, yield and economic performance of late sown lentil. The experiment utilized a Randomized Complete Block Design with five treatments and four dispersed replications. Treatments were T_1: Flora (20% nitrobenzene) @ 2 ml L^{-1} sprayed twice (35 and 50 DAS), T_2: Flora @ 2 ml L^{-1} sprayed once (50 DAS), T_3: GA_3 @ 0.2 g L^{-1} sprayed twice (25 and 50 DAS), T_4: GA_3 @ 0.2 g L^{-1} sprayed once (50 DAS) and T_5: control. Results indicated that PGR application significantly enhanced the growth, yield and yield contributing characters. The highest seed yield (1.94 t ha^{-1}) was obtained from T_1 due to the highest number of pods $plant^{-1}$ (50.6), while the lowest yield (1.43 t ha^{-1}) was achieved in control (T_5). Treatment T_1 providing a 35.7% yield increase over the control. T_1 also exhibited the maximum value of harvest index (63.8%) and the most profitable, obtaining the highest gross return (BDT 180,100 ha^{-1}), gross margin (BDT 100,300 ha^{-1}), and benefit–cost ratio (2.26). Results suggest that two foliar applications of 20% nitrobenzene @ 2 ml L^{-1} (at 35 and 50 DAS) are more effective than gibberellic acid for maximizing the yield and profitability of late-sown lentil.

Keywords: Gibberellic acid, late-sown, lentil, nitrobenzene, profitability, yield.

Introduction

Lentil (*Lens culinaris* L.) is one of the most important pulse crops of the Fabaceae family and has been consumed by humans since ancient times (Montejano-Ramírez and Valencia-Cantero, 2024; Hossain *et al.,* 2019). It is widely cultivated in South Asia, particularly in Bangladesh and India, due to its high nutritional value and adaptability to diverse agro-ecological conditions. Lentil seeds are a rich source of protein (about 25%), carbohydrates, dietary fiber, vitamins and essential

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minerals, making them an affordable and nutritious food for human diets (Dhull *et al.,* 2023; Hossain *et al.,* 2019). In Bangladesh, increasing population pressure has led to intensive cultivation of cereal crops on fertile lands, forcing pulse crops like lentil to be grown mostly on marginal, low-fertility soils under rainfed conditions. Despite this limitation, lentil remains vital for human nutrition and livestock feed, offering higher digestible protein, calcium, and phosphorus than cereal residues (Samaranayaka, 2017). Lentil cultivation contributes significantly to soil health improvement and sustainability of cropping systems. As a leguminous crop, lentil can fix atmospheric nitrogen through symbiotic association with Rhizobium bacteria, thereby enriching soil nitrogen and organic matter. This biological nitrogen fixation reduces dependence on chemical fertilizers and enhances soil fertility, particularly in intensive cropping systems (Tairo and Ndakidemi, 2013). Approximately 85% of the nitrogen requirement of lentil is met through this natural process, which can substantially improve crop growth, grain quality and yield potential, reaching up to 2.0 t ha^{-1} under favorable management conditions (Ferdous, 2019). In the Faridpur region, lentil is cultivated on about 44 thousand hectares with a total production of nearly 57 thousand metric tons; however, the average yield remains relatively low (BSS, 2026). One of the major constraints to higher yield is delayed sowing caused by unexpected rainfall before or after the recommended sowing period. Late sowing shortens the vegetative phase and forces the crop to enter the reproductive stage prematurely, resulting in poor growth, reduced pod formation and ultimately lower yield (Jianghui Yu *et al*., 2024). To mitigate the adverse effects of late sowing, farmers in the Faridpur region often apply plant growth regulators (PGRs) without proper knowledge of appropriate dose and timing, which may increase production costs and pose potential environmental risks. Plant growth regulators such as nitrobenzene and gibberellic acid (GA_3) are widely used to manipulate plant physiological processes including vegetative growth, branching, flowering and yield formation (Vishnu and Brar, 2020; Kohombange *et al*., 2019).

Nitrobenzene, commonly formulated as 20% liquid, acts as a plant energizer and flowering stimulant. It enhances nutrient uptake efficiency, promotes vigorous vegetative growth and improves flower retention, resulting in increased pod formation and yield (Deb *et al.,* 2012). Nitrobenzene is readily absorbed by plant tissues and influences biochemical pathways associated with nutrient assimilation and reproductive development. Gibberellins, particularly GA_3, are known for their role in promoting stem elongation and shoot growth, especially during early developmental stages. They are also involved in seed germination by breaking dormancy and stimulating enzyme activity for mobilization of stored food reserves. In addition, gibberellins regulate flowering by influencing the transition from vegetative to reproductive growth and contribute to seed size and weight through regulation of cell division and reserve accumulation (Hedden and Sponsel, 2015; Mahmood *et al.,* 2023 a,b). Although the use of gibberellic acid has been reported in various crops, the application of nitrobenzene-based PGRs such as Flora (20% EW) in lentil cultivation is still limited, particularly under late sowing conditions. There is insufficient scientific information regarding the comparative effectiveness of nitrobenzene and GA_3 on growth, yield and economic performance of late sown lentil. Therefore, the present study was undertaken to evaluate the effects of Flora (nitrobenzene 20% EW) and gibberellic acid (GA_3) at different spraying frequencies on yield performance and profitability of late sown lentil in the Faridpur region of Bangladesh.

Materials and methods

The experiment was conducted during the Rabi season of 2024–2025 at the Farming Systems Research and Development (FSRD) site of the Bangladesh Agricultural Research Institute (BARI) in Faridpur, Bangladesh. Geographically, the site is situated in a subtropical agro-ecological region at approximately 23°36' N latitude and 89°50' E longitude, with an elevation between 8 and 12 m above mean sea level. The study site is characterized by calcareous soil with a clay loam texture, classified as an Inceptisol order (specifically a Haplaquept suborder) within the Gopalpur soil series of the Low Ganges River Floodplain (AEZ-12) (Quddus *et al.,* 2020). Topographically, the site occupies medium-high to high land. The soil exhibits a pH of 6.8–7.2, providing an optimum environment for lentil cultivation. With an organic matter content of 1.0–1.2% and electrical conductivity (EC) between 0.30 and 0.45 dS m^{-1}. However, the soil is categorized as low organic matter content and non-saline. The overall fertility status is moderate to low (FRG, 2018). The area is experienced a subtropical monsoon climate. During the crop growing period from November to March, the mean monthly temperature ranged from 17.5 to 25.8 °C, while the average relative humidity fluctuated between 65% and 78%. Precipitation was negligible throughout the growing season; consequently, the crop was cultivated under rainfed conditions, relying primarily on residual soil moisture.

The study utilized BARI Masur-8, a high-yielding lentil variety. The seeds were officially sourced from the Regional Pulses Research Station (RPRS) of the Bangladesh Agricultural Research Institute, located in Madaripur. The experimental plot was prepared using an engine-operated power tiller. The process involved four tilling followed by leveling to achieve a fine tilth. To maintain a clean experimental environment, all weeds and previous crop stubble were manually removed. The experiment was laid out using a Randomized Complete Block Design (RCBD), consisting of five distinct treatments replicated four times across dispersed blocks. Each unit plot was measured at 6m × 5m. The treatments were T_1: Flora (20% Nitro Benzene) spray @ 2 ml/L 2 times (35 and 50 DAS), T_2: Flora @ 2 ml/L 1 times (50 DAS), T_3: GA_3 Foliar spray 0.2g/litter 2 times (25 and 50 DAS), T_4: GA_3 Foliar spray 0.2g/litter 1 times (50 DAS), and T_5: control.

Blanket fertilizer doses of N-P-K-S-Zn-B were applied at a rate of 28-24-14-9-2-1.2 kg ha^{-1}, respectively, following the Fertilizer Recommendation Guide-2018 (FRG-2018). The elemental nutrients like N, P, K, S, Zn and B were sourced from urea, triple superphosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate, and boric acid, all of which were applied as basal doses during final land preparation. The plant growth regulators like nitrobenzene and gibberellic acid (Lab grade), were procured from a local commercial supplier.

Lentil seeds were treated with the fungicide Provex 200 (at a rate of 2.5 g kg^{-1}) prior to sowing to control root rot disease. The treated seeds were manually sown on 02 December 2024 at a rate of 40 kg ha^{-1}, with a 30 cm row spacing and continuous seeding within the rows. The application of growth regulators followed a specific treatment schedule. For T_1, the initial nitrobenzene spray was administered at 35 days after sowing (DAS). At 50 DAS, a second nitrobenzene spray was applied to T_1, corresponding with the first nitrobenzene application for T_2. Regarding the treatments of gibberellic acid, T_3 received its first spray at 25 DAS. Subsequently, at 50 DAS, a second spray was applied to T_3, while T_4 received its initial application.

Manual weeding was performed three times at 25, 45, and 60 days after sowing (DAS). To manage fungal diseases, the fungicide Amister Top 325 SC was applied at a concentration of 1 ml per liter before flowering and again during the podding stage. For pest control, the insecticide Imitaf 20 SL was sprayed at 0.5 ml per liter during the vegetative and podding stages to protect against aphids and pod borers. The irrigation schedule was adjusted according to the plants' specific water requirements throughout the growth cycle. The mature lentil crop was harvested on 12 March 2025.

Seed yield (t ha^{-1}) was determined on a whole-plot basis and standardized to 10% moisture content. To determine stover yield, mature plants were collected from two 1m^2 quadrats in each plot; after sun-drying, the stover was weighed and the values were converted to t ha^{-1}. Percentage of harvest index (HI) was determined by the formula outlined by Hossain *et al.* (2019):

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100 \qquad (1)$$

Where, biological yield= Seed yield (t ha^{-1}) + Stover yield (t ha^{-1})

Plant population was determined by counting individuals within a 1 m^2 area in each plot. Plant height and the number of pods per plant were recorded from ten randomly selected plants per plot and subsequently averaged. The number of seeds per pod was determined by averaging the seed counts from ten randomly detached pods per plot. The 1000-seed weight (g) was calculated by weighing 100 randomly selected seeds per plot and extrapolating the total weight.

Economic analysis was performed on a per-hectare basis for late-sown lentil cultivation. The total variable cost (TVC) was calculated by aggregating expenses for agronomic operations including tillage, labor and plant protection alongside inputs such as seeds, inorganic fertilizers and PGRs. Fixed costs specifically land rent were excluded from the analysis. Gross return was determined by multiplying the seed and stover yields (converted to t ha^{-1}) by prevailing local market prices. The gross margin was then derived by subtracting the TVC from the gross return. The Benefit-Cost Ratio (BCR) was calculated according to the formula outlined by Quddus *et al.* (2026):

$$\text{BCR} = \frac{\text{Gross Return}}{\text{Total variable cost}} \times 100 \qquad (2)$$

Data regarding growth, yields and yield attributes were analyzed using R statistical software. Significant treatment effects were determined via an analysis of variance (ANOVA), with mean comparisons performed using the least significant difference (LSD) test.

Result and discussion

Growth and yield attributes of late-sown lentil

Foliar application of plant growth regulators, specifically nitrobenzene and gibberellic acid significantly influenced the growth and yield attributes of late-sown lentil (Table 1). Significant differences in plant height was observed across treatments, with T_3 (GA_3 foliar spray @ 0.2 g L^{-1} applied twice at 25 and 50 DAS), producing the tallest plants (47.7 cm) followed by T_4 (45.3 cm) treatment. The control (T_5) treatment was produced the shortest plant (38.4 cm). The tallest plant observed in T_3 (GA_3 foliar spray @ 0.2 g L^{-1} applied twice at 25 and 50 DAS) highlighted the efficiency of gibberellic acid in promoting sub-apical meristem activity. This is consistent with the findings of Taiz *et al.,* 2015, who reported that foliar application of gibberellic acid (GA_3) enhances the endogenous hormonal level, leading to rapid cell division and elongation in pulse crops. Similar findings were reported by Rahman *et al.* (2016), who observed that GA_3 application increased plant height in lentil. This trend is consistent with results seen in other grain legumes (Solaimalai *et al.,* 2001; Vaishnavi and Mehera, 2022). While GA_3 is an effective stimulator of cell elongation and internode expansion, this enhanced vegetative vigor did not translate into a commensurate increase in seed yield under late-sown conditions. In this study, although GA_3 treatments producing the tallest plants, they did not achieve the highest seed yield. This indicates that under the shortened growing windows and terminal heat stress typical of late sowing, reproductive efficiency specifically pod setting and grain filling becomes the key determinant of yield (Alam, 2016). Excessive vegetative growth in these environments may act as a "metabolic drain," diverting photo-assimilates away from reproductive sinks and toward stem elongation (Ozga *et al.*, 2017; Kywe *et* *al.,* 2025). Consequently, while the plant appears healthier, the Harvest Index (HI) often declines. This occurs because the source (leaves and stems) outcompetes the sink (seeds) for limited carbohydrates during the critical reproductive phase.

Plant population m^{-2} did not vary significantly among treatments, indicating that PGR application had no effect on crop establishment. This finding indicates that the observed yield differences were mainly due to changes in reproductive traits rather than plant stand density. However, the number of pods $plant^{-1}$ was significantly affected by the treatments. The maximum number of pods $plant^{-1}$ (50.6) was obtained from T_1 (Flora @ 2 ml L^{-1} applied twice at 35 and 50 DAS) which was statistically superior to all other treatments, while the lowest number was recorded in T_5 (34.3). This increase may be attributed to improved flower retention and reduced pod abscission caused by nitrobenzene application. Earlier studies reported that nitrobenzene enhances reproductive efficiency by improving source–sink relationship and reducing flower drop in pulses (Sivasubramanian *et al.,* 2008; Patel *et al.,* 2019). Under late sowing conditions, lentil often faces higher temperature and moisture stress during flowering and pod setting. Such stress accelerates flower drop and reduces pod formation. Therefore, treatments (T_1) that improve reproductive stability, such as nitrobenzene application, become particularly effective in sustaining pod development. The number of seeds pod^{-1} ranged from 1.60 to 1.70. Although the number of seeds pod^{-1} showed statistically significant variation, the range was narrow, indicating that this trait is relatively stable and less responsive to PGR application. Similar observations were reported by Yadav *et al.* (2017) in lentil. Thousand seed weight was also not significantly affected by PGR treatments, suggesting that seed size is largely governed by genetic factors rather than external hormonal application, as also reported by Kumar *et al.* (2016).

Table 1. Effect of nitrobenzene and gibberellic acid on growth and yield attributes of late-sown lentil

Treatment	Plant height (cm)	Plant population m^{-2}	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Thousand seed wt. (g)
T_1	42.7 c	121.3 a	50.6 a	1.63 ab	20.9 a
T_2	40.6 d	121.8 a	43.2 c	1.60 b	20.8 a
T_3	47.7 a	121.5 a	46.4 b	1.65 ab	20.8 a
T_4	45.3 b	120.0 a	39.9 d	1.70 a	20.8 a
T_5	38.4 e	121.0 a	34.3 e	1.70 a	20.8 a
LSD_{005}	1.24	3.87	2.52	0.05	0.08
CV (%)	1.87	2.07	3.82	2.19	0.27

T_1: Flora (20% Nitro Benzene) spray @ 2 ml/L 2 times (35 and 50 DAS), T_2: Flora @ 2 ml/L 1 times (50 DAS), T_3: GA3 Foliar spray 0.2g/litter 2 times (25 and 50 DAS), T_4: GA3 Foliar spray 0.2g/litter 1 times (50 DAS) and T_5= control

Yields and harvest index of late-sown lentil

Seed yield, stover yield and harvest index were significantly influenced by the different PGR treatments (Table 2). The highest seed yield (1.94 t ha^{-1}) was recorded in T_1, followed by T_3 (1.80 t ha^{-1}) and T_2 (1.68 t ha^{-1}), while the lowest yield was obtained from the control (1.43 t ha^{-1}). Compared to the control, seed yield was increased by 35.7%, 25.9%, and 17.5% in treatments T_1, T_3 and T_2, respectively. The higher yield under T_1 was mainly attributed to increased number of pods $plant^{-1}$, suggesting that pod number was the major contributor to yield improvement under late sowing conditions. Seed yield was significantly enhanced by PGR application, with the highest yield recorded in T_1, followed by T_3 and T_2. The superior yield performance of T_1 was mainly attributed to the significantly higher number of pods $plant^{-1}$, indicating that pod number was the major contributor to yield improvement under late sowing conditions. Strong positive associations between pod number and seed yield in lentil have also been reported by Singh *et al.* (2015) and Rahman *et al.* (2016). The results further indicated that spray frequency played a crucial role, as treatments receiving two sprays consistently outperformed those with a single spray. Repeated application at critical growth stages possibly maintained hormonal balance for a longer duration, leading to improved reproductive development. Comparison between nitrobenzene and gibberellin treatments showed that nitrobenzene was more effective than GA_3 in increasing seed yield of late sown lentil. While GA_3 mainly enhanced vegetative growth, nitrobenzene proved more efficient in improving reproductive traits, particularly pod number. Similar conclusions were drawn by Solaimalai *et al.* (2001) and Patel *et al.* (2019) in pulse crops. In this study, significant variations in stover yield were observed across treatments. The highest stover yield (1.19 t ha^{-1}) was produced by T_3 (GA_3 foliar spray @ 0.2 g L^{-1} applied twice at 25 and 50 DAS), followed by the T_1 treatment (1.10 t ha^{-1}). This represents an 11.2% increase over the control. The superior performance of T_3 might be attributed to the role of Gibberellic Acid (GA_3) in enhancing physiological activity and stimulating rapid cell division, which ultimately results in higher biomass production. These results are aligned with the findings of Taiz *et al.* (2015), who noted that exogenous GA_3 application boosts endogenous hormonal levels, promoting cell elongation during the vegetative phase of pulse crops. Also, several studies (Vishnu and Brar. 2020; Sivakumar *et al.,* 2022) confirm that GA_3 optimizes the source-to-sink relationship, significantly improving dry matter accumulation in legumes.

The application of various plant growth regulators significantly influenced the harvest index of late-sown lentils (Table 2). The highest harvest index (63.8%) was observed in treatment T_1 (Flora @ 2 ml L^{-1} applied at 35 and 50 DAS), which was significantly superior to the control. This was followed by the T_2 treatment, whereas the minimum harvest index was recorded in the T_5 (control) treatment. The significant increase in the harvest index under treatment T_1

(Nitrobenzene/Flora) suggests a more efficient translocation of photosynthates from vegetative parts (source) to the developing seeds (sink). In late-sown conditions, lentils often suffer from a shortened reproductive phase due to rising temperatures. Nitrobenzene acts as a plant energizer that enhances nutrient uptake and reduces flower drop, thereby stabilizing the sink strength even under environmental stress (Kohombange *et al*., 2018). The superiority of T_1 (Nitrobenzene/Flora) over T_3 (Gibberellic Acid) may be attributed to the specific role of nitrobenzene in increasing the number of flowers and their subsequent conversion into pods. While GA_3 (T_3) promotes vegetative elongating and initial flowering, nitrobenzene ensures the "stay-green" quality of leaves, providing a sustained supply of carbohydrates during the critical grain-filling stage (Singh *et al.,* 2022). These findings align with the studies suggesting that foliar-applied stimulants can compensate for the yield losses typically associated with delayed sowing in pulse crops (Mishra *et al.,* 2025).

Table 2. Effect of nitrobenzene and gibberellic acid on yields and harvest index of late-sown lentil

Treatment	Seed yield (t ha^{-1})	% seed yield increase over T_5	Stover yield (t ha^{-1})	Harvest index (%)
T_1	1.94 a	35.7	1.10 ab	63.8
T_2	1.68 c	17.5	0.97 c	63.4
T_3	1.80 b	25.9	1.19 a	60.2
T_4	1.59 d	11.2	1.07 b	59.8
T_5	1.43 e	-	1.07 b	57.2
LSD_{005}	0.08	-	0.07	
CV (%)	3.09	-	3.80	

T_1: Flora (20% Nitro Benzene) spray @ 2 ml/L 2 times (35 and 50 DAS), T_2: Flora @ 2 ml/L 1 times (50 DAS), T_3: GA3 Foliar spray 0.2g/litter 2 times (25 and 50 DAS), T_4: GA3 Foliar spray 0.2g/litter 1 times (50 DAS) and T_5= control.

Economic performance analysis

Economic analysis revealed that PGR application substantially improved profitability of late sown lentil (Table 3). The highest gross return (BDT 180,100 ha^{-1}) and gross margin (Tk 100,300 ha^{-1}) were obtained from T_1, followed by T_3. Although T_1 involved a higher variable cost than the control, it generated the highest benefit–cost ratio (2.26) due to its superior gross return. The control treatment (T_5) recorded the lowest gross return, gross margin and BCR (1.84), reflecting poor economic performance in the absence of PGR application. Overall, foliar application of Flora @ 2 ml L^{-1} applied twice at 35 and 50 DAS proved to be the most effective and economically profitable treatment for late sown lentil. These findings align with earlier studies reporting improved returns from PGR use in pulse crops (Patel et al., 2019).

Table3. Effect of nitrobenzene and gibberellic acid on cost and return analysis of late sown lentil

Treatment	Gross return (BDT ha^{-1})	Total variable cost (BDT ha^{-1})	Gross margin (BDT ha^{-1})	BCR
T_1	180100	79800	100300	2.26
T_2	156050	76070	79980	2.05
T_3	167950	78990	88960	2.13
T_4	148450	75620	72830	1.96
T_5	133150	72520	60630	1.84

T_1: Flora (20% Nitro Benzene) spray @ 2 ml/L 2 times (35 and 50 DAS), T_2: Flora @ 2 ml/L 1 times (50 DAS), T_3: GA3 Foliar spray 0.2g/litter 2 times (25 and 50 DAS), T_4: GA3 Foliar spray 0.2g/litter 1 times (50 DAS) and T_5= control, BCR= Benefit cost ratio.

Variable cost (input Prices+others): Seed (BARI Masur-8) = BDT 130 kg^{-1}, Urea= BDT 27 kg^{-1}, DAP= BDT 21 kg^{-1}, MoP= BDT 20 kg^{-1}, Gypsum= BDT 13 kg^{-1}, Zink sulphate= BDT 260 kg^{-1}, Boric acid= BDT 320 kg^{-1}, Flora= BDT 120/100 ml, GA_3= BDT 120/10 g, Provax 200 WP= BDT 450/100g, Amister Top 325 SC= BDT 400/100 ml, Imitaf 20 SL= BDT 250/50 ml , Tillage = BDT 1500 ha^{-1} (one pass), Wage rate= BDT 500 day^{-1}

Output price: Lentil seed (BARI Masur-8) = BDT 90 kg^{-1} and stover/straw = BDT 5.0 kg^{-1}. Gross returns were calculated based on the current market value of lentil seed and stover in Faridpur, Bangladesh.

Conclusion

Results indicate that both nitrobenzene and gibberellic acid (GA_3) effectively enhance the growth, yield, harvest index and economic performance of late-sown lentil. Among the treatments, Flora (20% nitrobenzene) applied at 2 ml L^{-1} twice at 35 and 50 DAS (T_1) resulted in a significant increase in pods per plant and yields compared to the control. Economically, this treatment (T_1) maximized gross returns and the benefit-cost ratio. Furthermore, nitrobenzene proved more effective than gibberellic acid in improving productivity of late sown lentil. These findings suggest that a double foliar application of nitrobenzene is a sustainable and effective practice for late-sown lentil cultivation.

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