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Impact of Naphthalene Acetic Acid (NAA) on Growth, Quality and Yield of Eggplants

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ABSTRACT

The present investigation was conducted to study the effect of Naphthalene Acetic Acid (NAA) on the growth, quality, and yield of eggplants. The research was conducted at the Agriculture Research farm of Kabul University from April to September 2024. A Randomized Complete Block Design (RCBD) with three replications and five treatments was employed: T1 (40 ppm), T2 (50 ppm), T3 (60 ppm), T4 (70 ppm), and T5 (Control). Data were collected on various growth parameters, fruit quality traits, and yield components. The recorded data were analyzed using the Statistical Tools for Agricultural Research (STAR) software. Results showed that NAA significantly enhanced eggplant growth, yield, and quality. T1 (40 ppm NAA) had the highest plant height (73.73 cm), branch number (9.20), leaf count (97), and leaf area (235.75 cm^2), while the control group had the lowest values. T1 also produced the longest fruit (23.87 cm), largest diameter (4.21 cm), highest weight (186.67 g), and most fruits per plant (10.11). Similarly, T1 yielded the highest per plant (1.31 kg) and per hectare (41.9 metric tons), whereas the control recorded the lowest. Post-harvest results indicated no significant difference in shelf life. T1 had the best fruit appearance, texture, and flavor, with the highest overall acceptability (Like Moderately), while the control had the least (Neither Like nor Dislike). The results can be concluded that spraying eggplants with 40 ppm Naphthalene Acetic Acid (NAA) at two stages (50% flowering and 20 days after the first application) can significantly improve their growth, quality, and yield. Farmers can spray this concentration of NAA to achieve vigorous growth, higher yield, and improved fruit quality.

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INTRODUCTION

Eggplant (*Solanum melongena* L., 2n = 24), also known as Brinjal or aubergine, is a major vegetable crop cultivated across tropical, subtropical, and temperate regions (Durai, 2021; Misu et al., 2023). Belonging to the Solanaceae family, it is the second most important solanaceous fruit crop (Afrin et al., 2024; Singh et al., 2021). Originating in Southeast Asia, particularly South India, it is widely cultivated in Asia, Africa, America, and Europe, with leading producers including China, Turkey, Japan, Egypt, Indonesia, Iraq, Italy, Syria, and Spain (Afrin et al., 2024; Bhattarai et al., 2021; Durai, 2021; Misu et al., 2023; Patel et al., 2022).

Eggplant is a tropical, warm-season, herbaceous perennial that is commercially cultivated as an annual crop (Afrin et al., 2024; Kumar et al., 2024; Misu et al., 2023). It produces purple flowers classified into four types based on the length of their style: long-styled, medium-styled, pseudo-short-styled, and true short-styled. Fruit set occurs in long- and medium-styled flowers but not in short- and long-styled flowers. Depending on genotype, 43.6%–75.6% of flowers are long- and medium-styled, while 20.5%–45.5% are short-styled.Though naturally self-pollinated, 50%–70% of fruit set occurs through cross-pollination due to heterostyly (Afrin et al., 2024; Caruso et al., 2017; Hoque et al., 2018; Khaleghi et al., 2021; Moniruzzaman et al., 2014; Veeresha et al., 2018).

Eggplant varieties differ in fruit shape and color, ranging from oval to long and club-shaped, with colors including white, yellow, green, purple, and almost black. The purple color in flowers and fruits is due to anthocyanins, natural pigments that provide antioxidant benefits. Anthocyanins, synthesized in the cytosol and stored in vacuoles, contribute to eggplant's health-promoting properties (Alam & Salimullah, 2021; Misu et al., 2023; Singh et al., 2021; Ujjwal et al., 2018).

As a warm-season crop, eggplant thrives in temperatures ranging from 22°C to 30°C, with optimal fruit set occurring at temperatures between 18°C and 21°C. Temperatures above 35°C can cause flower drop, resulting in reduced yield. It grows best with an annual rainfall of 1000–1500 mm and at altitudes of 0–1600 meters. Excessive rainfall negatively affects plant growth and flower formation. The ideal pollen germination temperature ranges from 20°C to 27°C, with failure occurring below 15°C or above 30°C (Abraham & Shumbulo, 2024; Akhtar et al., 2017; Parvin et al., 2022; Patel et al., 2022).

Eggplants prefer deep, fertile, well-drained sandy loam soils with a pH range of 5.5–6.8 and high organic matter content. The optimal plant spacing for yield and quality is approximately 40 cm. Heavy rainfall and suboptimal temperatures can hinder its growth, affecting fruit set and development (Abraham & Shumbulo, 2024; Caruso et al., 2017; Hassan et al., 2018).

Nutritionally, eggplant is rich in carbohydrates, proteins, vitamins, minerals, and bioactive compounds. It is among the top ten vegetables with high antioxidant capacity due to its phenolic content, including anthocyanins in the peel and phenolic acids in the flesh. Secondary metabolites, particularly polyphenols like flavonoids and phenolic acids, offer health benefits, including potential protection against cardiovascular diseases, obesity, and type 2 diabetes. Hydroxycinnamic acid derivatives in eggplant have shown promising effects in managing these conditions. Purple varieties contain higher anthocyanin levels, enhancing their nutritional value (Afful et al., 2019; Blekkenhorst et al., 2018; Caruso et al., 2017; Lyu et al., 2025; Niño-Medina et al., 2017; Quamruzzaman et al., 2020; Sharma & Kaushik, 2021).

Eggplant is one of the most widely cultivated vegetables globally. It ranks sixth among vegetable crops after tomatoes, watermelon, onions, cucumbers, and cabbage. Some reports place it as the fifth most popular vegetable worldwide, while recent statistics rank it seventh, with a total production of 59.3 million tons in 2024. Spain led global eggplant exports in 2023 with $222.8 million in exports, followed by the Netherlands with $99.8 million (Chioti et al., 2022; Eggplant Global Exports and Top Exporters, 2024; Lyu et al., 2025). With its diverse varieties, adaptability, and nutritional benefits, eggplant remains a significant crop for global food production and health.

Plant growth regulators, also known as phytohormones, are organic substances synthesized in higher plants that regulate growth, environmental responses, and physiological functions at sites distinct from their production (Agudelo-Morales et al., 2021; Bisht et al., 2018; Jiang & Asami, 2018). The five main plant hormone classes are auxins, gibberellins, cytokinins, ethylene, and abscisic acid (Agudelo-Morales et al., 2021; Bisht et al., 2018; Salari & Amin, 2024). Other signaling molecules, such as brassinosteroids, Jasmonic acid, and salicylic acid, also play crucial roles (Agudelo-Morales et al., 2021; Sebastian et al., 2019).

Phytohormones regulate various aspects of plant growth, including seed development, flowering, fruit ripening, and senescence (Agudelo-Morales et al., 2021; Sebastian et al., 2019). Auxins, the first discovered plant hormones, promote growth along the plant's longitudinal axis (Bisht et al., 2018; Sebastian et al., 2019). They are produced in shoot and root apices and include compounds like IAA, IBA, NAA, and 2,4-D (Agudelo-Morales et al., 2021; Jiang & Asami, 2018). Auxins influence organogenesis, vascular differentiation, apical dominance, root initiation, and tropism (Khan & Nabi, 2023; Misu et al., 2023). Naphthalene acetic acid (NAA), a synthetic auxin, is used to reduce fruit drop and induce root formation in cuttings (Khan & Nabi, 2023; Kumar et al., 2024; Sharif et al., 2022).

A study found that spraying 40 ppm NAA on eggplants at the first flowering stage, followed by two additional sprays at 14-day intervals, resulted in optimal physiological and morphological characteristics in BARI Begun-5, including enhanced photosynthesis, flower formation, and significantly improved yield components (Moniruzzaman et al., 2014). Additionally, the combined application of GA3 (10 ppm), NAA (20 ppm), and 2,4-D (1 ppm) at 30, 60, and 90 days after transplanting significantly improved growth, yield, and quality attributes (Netam & Sharma, 2014).

A 25 ppm GA3 treatment positively influenced plant height, leaf number, and leaf dimensions, with 40 ppm NAA further enhancing these parameters (Bhattarai et al., 2021). Applying 40 ppm of NAA resulted in maximum plant height, branch number, leaf number, and early flowering (Singh et al., 2021). Similarly, 80 ppm NAA improved all growth parameters, achieving the highest plant height, spread, leaf count, and number of primary branches (Basnet et al., 2021).

Spraying NAA + GA3 (40 ppm + 50 ppm) three times at 30, 45, and 60 days post-transplantation resulted in the best growth, yield, and quality attributes (Patel et al., 2022). Applying 60 ppm GA3 and NAA four times at 35, 50, 65, and 80 days post-transplanting improved growth and yield components in saline soils (Misu et al., 2023). The combination of 200 ppm GA3 and 200 ppm zinc, or NAA (100 ppm) + Zn (200 ppm) during the flowering stage, improved growth, yield, and quality components (Afrin et al., 2024). Experiments on Brinjal (cv. Azad Kranti) indicated that 40 ppm NAA + 50 ppm GA3 produced the best growth, yield, and quality, followed by 40 ppm NAA + 25 ppm GA3 (S. Kumar et al., 2024). Additionally, NAA (90 ppm) significantly enhanced growth and overall yield (Ahmad et al., 2025).

Considering the above facts, this study was conducted to determine the effect of different concentrations of Naphthalene Acetic Acid (NAA) on the growth, quality, and yield of eggplants.

Eggplant production in Afghanistan is limited by low yields, poor fruit quality, and a lack of knowledge about hormone use. Challenges such as water scarcity, soil infertility, and climate variability further reduce productivity. Farmers often lack guidance on the effective use of plant growth regulators, such as Naphthalene Acetic Acid (NAA). This research aims to evaluate the impact of NAA on vegetative growth, yield, and fruit quality of eggplants. It seeks to determine the optimal concentration and timing of NAA application to enhance crop performance and support sustainable, high-quality eggplant production under field conditions.

METHODS AND MATERIALS

The present research was conducted under open-field conditions at the Research Farm of the Faculty of Agriculture, Kabul University, Kabul, Afghanistan, from April 7, 2024, to September 29, 2024. The Experimental site is located at 34°31'02.4"N latitude and 69°08'15.7"E longitude, at an elevation of 1,808.0 meters. The experimental field has a uniform topography and a consistent textural makeup. The soil structure of the experimental farm was characterized by a pH of 8.1 and a silty clay texture.

In Afghanistan's central climate, Kabul has hot, dry summers and cold, snowy winters, with temperatures ranging from -4°C to 34°C. The coldest month, January, averages -4°C to 7°C. Annual rainfall was 312 mm, with the rainy season lasting 9.8 months (January–November) and peaking in March (47 mm). The driest period (November–January) saw minimal rainfall, with December averaging 8 mm (Kabul Climate, Weather Spark, 2024).

This experiment used the Eggplant (Kemer-F1) variety as planting materials. Planofix from Bayer Company, a 4.39% solution of 1-naphthaleneacetic acid (NAA), was used as the source of NAA. The treatments were as follows: T1, NAA at 40 ppm; T2, NAA at 50 ppm; T3, NAA at 60 ppm; T4, NAA at 70 ppm; and T5, control. The field experiment was designed using a Randomized Complete Block Design (RCBD) with three replications. The nursery was established on the mentioned farm to cultivate the eggplant (Kemer-F1) variety. It covers an area of 1.5 square meters under greenhouse conditions. To improve soil fertility, 20 tons of farmyard manure (FYM) per hectare were applied to the nursery soil.

The seed sowing date was April 6, 2024, and the seedlings were maintained in the nursery for up to 48 days, taking into account the prevailing climatic conditions. The land was plowed to a depth of 30 cm, and 10 tons of farmyard manure were added per hectare, with no chemical fertilizers used. Weeds and stones were removed, and the field was divided into three blocks, each with five plots. Furrows and ridges were created, and plants were sown on ridge edges. Forty-eight days old, healthy plants were transplanted on May 27, 2024. They were uniform in height, color, and the number of leaves. Planted in the afternoon with 45 cm between plants and 80 cm between rows, with 24 plants per plot

The first irrigation was carried out on the day of transplantation, the second irrigation was done one day after transplantation, and subsequent irrigations were conducted at one-week intervals. Weed control in the field was carried out at one-week intervals, and no herbicides were used for weed management. Soil hilling was done 30 days after transplanting to promote root penetration and nutrient accumulation. 120 kg of urea and 60 kg of DAP were applied per hectare during hilling. No second hilling occurred, but 15 days later, an additional 60 kg of urea per hectare was applied to enhance soil fertility.

Cutworms, fruit, and shoot borers were the primary pests, which were controlled mechanically due to their low populations, with no chemicals used. Late blight appeared in late September, affecting the first treatment (T1) of the first block. The disease spread similarly across all treatments, showing that the Kemer-F1 eggplant variety is susceptible to late blight. The plant hormone was applied at two different stages. The first application stage occurred at 50% flowering on July 24, 2024, and the second application was made 20 days after the first stage.

This study focused on three-parameter categories: growth (plant height, branches, leaves, and leaf area), yield (fruit length, diameter, weight, number of fruits, and marketable yield), and quality (shelf life, sensory evaluation, appearance, color, texture, flavor, and overall acceptance). Growth parameters were recorded at 45 and 90 days after transplantation. The data collected from various parameters in the experiment were compiled and analyzed statistically using the analysis of variance (ANOVA) technique. The analysis was performed using the computer software Statistical Tools for Agricultural Research (STAR). Differences between pairs of means were compared using the Least Significant Difference (LSD) method.

FINDINGS

Plant Height

Five plants were randomly selected from each treatment to determine plant height. The statistical analysis at $P < 0.05$ showed that the maximum plant height at 45 days was recorded in the control (15.67 cm), while at 90 days, the highest plant height was observed in T1 (73.73

cm). The minimum plant height was recorded at 45 days in T3 (14.47 cm), and at 90 days, it was observed in the control (64.33 cm). At 45 days, there was no significant difference in plant height among the treatments; however, at 90 days, a significant difference was observed.

Number of Branches per Plant

Five plants were randomly selected to determine the average number of branches per plant. Statistical analysis at $P < 0.05$ showed that the maximum number of branches per plant at 45 days was recorded in the control and T4 (3.87), while at 90 days, the highest number of branches per plant was observed in T1 (9.20). The minimum number of branches per plant at 45 days was recorded in T3 (3.33), and at 90 days, it was observed in the control (7.67). At 45 days, there was no significant difference in the number of branches per plant among the treatments; however, at 90 days, a significant difference was observed.

Number of Leaves Per Plant

The number of leaves per plant was assessed from five randomly selected plants. Statistical analysis at $P < 0.05$ revealed that at 45 days, the highest leaf count per plant was recorded in the control group (4.67), while at 90 days, the maximum was observed in T1 (97.00). The lowest number of leaves per plant at 45 days was found in T2 (3.87), whereas at 90 days, the control group had the minimum count (75.33). No significant difference in leaf count was observed among treatments at 45 days; however, a significant difference was noted at 90 days.

Leaf Area

Leaf width and length were collected from five randomly selected leaves for leaf area calculation.

***Table 1**: The effect of Naphthalene Acetic Acid on growth of eggplants*

Treatments	Growth Parameters							
	45 Days (Before Spray)				90 Days (After Spray)			
	Plant Height (cm)	Number of Branch Plant^{-1}	Number of Leave Plant^{-1}	Leaf Area	Plant Height (cm)	Number of Branch Plant^{-1}	Number of Leave Plant^{-1}	Leaf Area (Cm^2)
T1 (NAA 40 ppm)	15.20	3.67	4.07	95.74	73.73a	9.20a	97.00a	235.75a
T2 (NAA 50 ppm)	15.60	3.73	3.87	93.57	70.93ab	8.67ab	91.93ab	213.44ab
T3 (NAA 60 ppm)	14.47	3.33	4.13	101.68	65.33b	8.07bc	82.20bc	181.07bc
T4 (NAA 70 ppm)	15.13	3.87	4.07	107.61	73.07a	8.13bc	85.27abc	207.82ab
T5 (Control)	15.67	3.87	4.67	126.33	64.33b	7.67c	75.33c	157.86c
F-test	Ns	Ns	Ns	Ns	*	*	*	*
LSD (0.05)					6.83	0.93	12.79	47.56
CV %					5.22	5.9	7.86	12.68

CV: Coefficient of Variation, **LSD**: Least Significant Difference, NS: Not Significant, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference.

Statistical analysis at $P < 0.05$ revealed that at 45 days, the control group had the largest leaf area (126.33 cm^2), whereas, at 90 days, the highest value was observed in T1 (235.75 cm^2). The smallest leaf area was observed in T2 at 45 days (93.57 cm^2), while at 90 days, the control group had the lowest value (157.86 cm^2). No significant differences in leaf area were detected among treatments at 45 days; however, a significant difference was noted at 90 days.

Fruit length

Five fruits were randomly selected to determine the average fruit length. Statistical analysis at $P < 0.05$ revealed that the longest fruit was recorded in T1 (23.87 cm), while the shortest was observed in the control group (16.60 cm). A significant difference in fruit length was found among the treatments.

Fruit diameter

Five fruits were randomly selected from each treatment to determine the diameter. The statistical analysis at $P < 0.05$ showed that the maximum fruit diameter was recorded in T1 (4.21 cm), while the minimum fruit diameter was observed in the control (3.14 cm). There was a significant difference in fruit diameter among the treatments.

Fruit weight

Five fruits were randomly selected to measure the average fruit weight. Statistical analysis at $P < 0.05$ indicated that T1 had the highest fruit weight (186.67 g), while the control group had the lowest (118.13 g). The results revealed a significant difference in fruit weight among the treatments.

Number of Fruits Per Plant

Five plants were randomly selected from each treatment to determine the average number of fruits per plant. The statistical analysis, with $P < 0.05$, showed that the maximum number of fruits per plant was recorded in T1 (10.11), while the minimum number was observed in the control (5.83). There was a significant difference in the number of fruits per plant among the treatments.

Marketable Yield

A significant difference in yield per plant and per hectare was observed among the treatments. Statistical analysis at $P < 0.05$ revealed that T1 had the highest yield per plant (1.31 kg), while the control group had the lowest (0.88 kg). Similarly, the highest yield per hectare was observed in T1 (41.9 metric tons), while the lowest was recorded in the control group (28.07 metric tons).

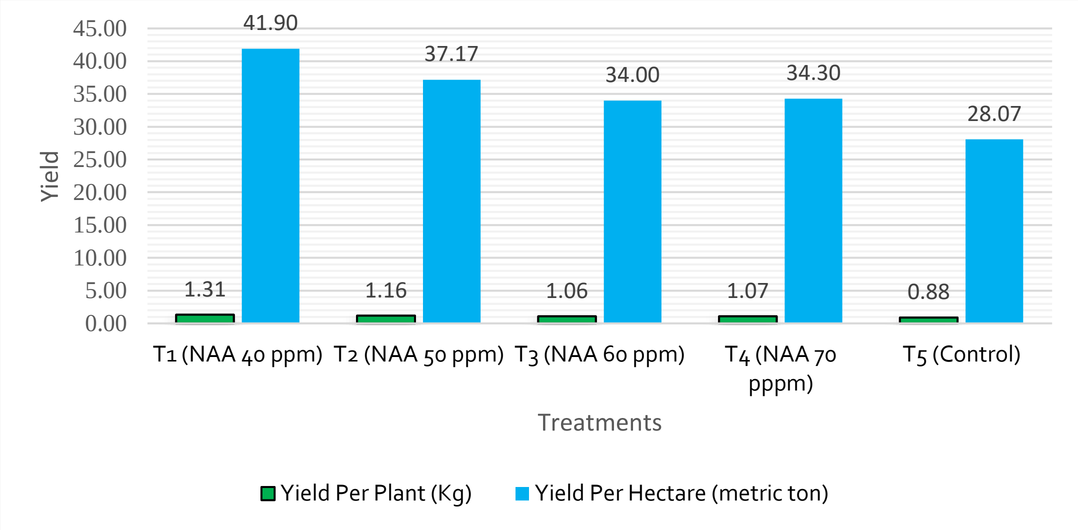

Figure 1: Show the marketable yield plant $^{-1}$ and hectare $^{-1}$

Non-Marketable Yield

In this case, the statistical analysis at $P < 0.05$ showed that the maximum non-marketable yield per plot was recorded in the control (2021.13 g). In comparison, the minimum non-marketable yield per plot was observed in T1 (1028.31 g). There was a significant difference in non-marketable yield per plot.

Table 2: The effect of Naphthalene Acetic Acid on yield of eggplants

Treatments	Yield Parameters						
	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Wight (g)	Number of Fruit Plants $^{-1}$	Yield Plant^{-1} (kg)	Yield Hectare^{-1} (mt)	Non-marketable Yield Plot^{-1} (g)
T1 (NAA 40 ppm)	23.87a	4.21a	186.67a	10.11a	1.31a	41.90a	1028.31c
T2 (NAA 50 ppm)	22.67a	3.93a	167.20a	8.21ab	1.16ab	37.17ab	1427.91bc
T3 (NAA 60 ppm)	19.40ab	3.57ab	148.00ab	7.73bc	1.06bc	34.00bc	1515.51abc
T4 (NAA 70 ppm)	19.73ab	3.81a	165.27a	7.38bc	1.07abc	34.30abc	1676.00ab
T5 (Control)	16.60b	3.14b	118.13b	5.83c	0.88c	28.07c	2081.13a
F-Test	*	*	*	*	*	*	*
LSD (0.05)	4.66	0.64	39.66	2.34	0.24	5.89	7.82
CV (%)	12.1	9.18	13.41	15.86	11.75	11.84	20.29

CV: Coefficient of Variation, **LSD**: Least Significant Difference, NS: Not Significant, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference.

Shelf Life

In this investigation, five fruits from each treatment were stored at room temperature (with an average temperature of 25.1°C) and 43% average relative humidity. The statistical analysis at $P < 0.05$ showed that the maximum fruit shelf life was recorded at T1 (4.67 days), while the minimum fruit shelf life was recorded at control (3.67 days). There was no significant difference in fruit shelf life.

Organoleptic Test

In this evaluation, six fruits from each treatment, combined with three replications, were assessed by eleven experienced individuals. The assessment was based on appearance, color, texture, flavor, and overall acceptability, with each parameter rated on a 5-point scale: 1 (Dislike Extremely), 2 (Dislike Moderately), 3 (Neither Like nor Dislike), 4 (Like Moderately), and 5 (Like Extremely).

There is a noticeable difference in the appearance of the fruit. The statistical analysis ($P < 0.05$) showed that the best fruit appearance was observed at T1 (Moderately Like), while the weakest fruit appearance was observed at the Control (Neither Like nor Dislike). No significant difference in fruit color was observed among the treatments. A significant variation in fruit texture was observed among the treatments. The results indicated that T1 had the most favorable fruit texture (Like Moderately), whereas the control group exhibited the least favorable texture (Neither Like nor Dislike). A significant difference in fruit flavor was noted among the treatments. T1 had the most preferred fruit flavor (Like Moderately), whereas the control group had the least favorable flavor (Neither Like nor Dislike). In the case of overall acceptance, statistical analysis at $P < 0.05$ indicated that T1 had the highest overall fruit acceptability (Like Moderately). In contrast, the control group had the lowest (Neither Like nor Dislike). A significant difference in overall fruit acceptability was observed among the treatments.

Table 3: The effect of Naphthalene Acetic Acid on the quality of eggplants

Treatments	Quality Parameters					
	Shelf life	Organoleptic characteristics				
		Appearance	Color	Texture	Flavor	Overall Acceptable
T1 (NAA 40 ppm)	3.67	4.36a	4.55	4.73a	4.64a	4.73a
T2 (NAA 50 ppm)	3.33	4.18a	4.45	4.36ab	4.45a	4.55a
T3 (NAA 60 ppm)	3.00	4.09a	4.09	4.27ab	4.09ab	4.27ab
T4 (NAA 70 ppm)	3.33	4.00ab	4.36	4.27ab	4.27ab	4.45a
T5 (Control)	2.33	3.55b	4.00	3.91b	3.73b	3.91b
F-Test	Ns	*	Ns	*	*	*
LSD (0.05)		0.54		0.51	0.58	0.53
CV (%)	17.96	15.42	15.44	13.66	15.93	13.95

CV: Coefficient of Variation, **LSD**: Least Significant Difference, NS: Not Significant, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference.

DISCUSSION

The present investigation demonstrates that the application of NAA at 40 ppm, 50 ppm, 60 ppm, and 70 ppm at two different times had a significant effect on plant height, with the most effective treatment being T1 (40 ppm). NAA increases stem height as it is a growth-promoting hormone that enhances cell division and cell elongation in plants. A similar result was reported by Singh et al. (2021), who showed that the application of 40 ppm NAA had a significant effect on plant height. Additionally, Kumar et al. (2024) noted that the application of 40 ppm NAA + 50 ppm GA_3 had a significant effect on plant height.

The statistical analysis, with $P < 0.05$, showed that NAA at 40 ppm, 50 ppm, 60 ppm, and 70 ppm had a significant effect on the number of branches per plant. NAA promotes lateral growth, resulting in an increase in the number of branches per plant through its function within the plant. Similar results were reported by Bhattarai et al. (2021), who found that NAA @ 40 ppm significantly increased the number of branches per plant. Additionally, Misu et al. (2023) reported that NAA @ 60 ppm induced the number of branches per plant. Patel et al. (2022) also observed that a combination of NAA @ 40 ppm and GA_3 @ 50 ppm significantly increased the number of branches per plant. The best treatment was T1 (NAA @ 40 ppm); however, based on the LSD (0.05) test, T1 (NAA @ 40 ppm) and T2 (NAA @ 50 ppm), T3 (NAA @ 60 ppm) and T4 (NAA @ 70 ppm) had the same result, which was different from T5 (Control).

The result of this experiment showed that the 40 ppm, 50 ppm, 60 ppm, and 70 ppm concentrations of NAA had a significant effect on the number of leaves per plant. NAA increases the number of leaves per plant. Kumar et al. (2024) and Patel et al. (2022) reported that the combination of NAA @ 40 ppm and GA_3 @ 50 ppm significantly increased the number of leaves per plant. Additionally, Misu et al. (2023) found that NAA @ 60 ppm induced an increase in the number of leaves per plant. However, Hoque et al. (2018) noted that the application of NAA @ 40 ppm NAA at different times did not have a significant effect on the number of leaves per plant.

In this case, statistical analysis at $P < 0.05$ revealed that NAA at concentrations of 40 ppm, 50 ppm, 60 ppm, and 70 ppm had a significant effect on plant leaf area, as NAA increased both leaf length and width. A similar result was reported by Bhattarai et al. (2021), who described how the application of 40 ppm NAA had a significant effect on leaf length and leaf width, which were used for calculating leaf area. In this investigation, the most effective treatment was T1 (NAA at 40 ppm). However, based on the LSD (0.05) test, T1 (NAA @ 40 ppm), T2 (NAA @ 50 ppm), and T4 (NAA @ 70 ppm) had the same result and were significantly different from T5 (Control).

The results of this experiment indicate that the application of NAA had a significant effect on fruit length, with T1 (40 ppm) identified as the most effective treatment. NAA enhances fruit length by promoting cell division and cell elongation. A similar result was reported by Singh et al. (2021), who found that the application of 40 ppm NAA significantly influenced fruit length. Additionally, Kumar et al. (2024) noted that the combined application of 40 ppm NAA and 50 ppm GA_3 had a significant effect on fruit length, while Misu et al. (2023) reported that the application of 60 ppm NAA also had a significant effect.

This investigation demonstrates that the application of NAA had a significant effect on fruit diameter, with T1 (40 ppm) showing the most favorable results. NAA promotes fruit enlargement by enhancing cell division and expansion. A similar result was reported by Singh et al. (2021), who found that NAA @ 40 ppm increased fruit diameter. Additionally, Basnet et al. (2021) reported that NAA @ 40, 60, and 80 ppm increased fruit diameter, while Misu et al. (2023) observed a significant effect with the application of NAA @ 60 ppm. Ahmad et al. (2025) also reported that NAA @ 90 ppm increased fruit diameter.

According to statistical analysis at $P < 0.05$, the application of NAA significantly influenced fruit weight, with T1 (40 ppm) proving to be the most effective treatment. NAA enhanced individual fruit weight by stimulating cell division. A similar result was reported by Singh et al. (2021), who found that NAA at 40 ppm significantly increased individual fruit weight. Similarly, Basnet et al. (2021) reported an increase in individual fruit weight with NAA @ 80 ppm. Misu et al. (2023) observed a similar effect of NAA @ 60 ppm, while Ahmad et al. (2025) also noted an increase with the application of NAA @ 70 ppm.

This study found that the application of NAA significantly affected the number of fruits per plant. Among these treatments, T1 (40 ppm) was the most effective. NAA enhanced fruit production by promoting the development of long- and medium-styled flowers. A similar result was reported by Singh et al. (2021), who described that NAA @ 40 ppm significantly increases the number of fruits per plant; additionally, Basnet et al. (2021) noted that NAA @ 80 ppm increases the number of fruits per plant, while Misu et al. (2023) reported that NAA @ 60 ppm increases the number of flowers per plant.

The current study reveals that the application of NAA has a significant influence on the marketable yield per plant. Among these, T1 (40 ppm) was found to be the most effective. NAA improved the yield by enhancing the fruit set and promoting the development of long-styled flowers. A similar result was reported by Singh et al. (2021) and Salari and Amin et al. (2024), who found that the application of 40 ppm NAA significantly improved eggplant yield. Additionally, Kumar et al. (2024) noted that the combined application of 40 ppm NAA and 50 ppm GA_3 had a significant effect on yield per plant, while Misu et al. (2023) reported that the application of 60 ppm NAA also had a significant effect on yield per plant.

This investigation shows that the application of NAA had no significant effect on fruit shelf life.

This study demonstrates that applying NAA significantly influenced fruit appearance, with T1 (40 ppm) proving to be the most effective treatment. NAA enhanced fruit appearance by promoting larger fruit size and intensifying the purple color. The effect of NAA on color was non-significant. A similar result was noted by Patel et al. (2022), who described that the application of NAA and GA_3 at different concentrations had no significant effect on fruit color. The application of NAA significantly affected fruit texture, with T1 (40 ppm) identified as the most effective treatment. Afrin et al. (2024) reported that the combined application of NAA @ 100 ppm + Zn @ 200 ppm or GA3 @ 200 ppm + Zn @ 200 ppm significantly affected eggplant fruit lipid and fiber content. The investigation reveals that the application of NAA has a significant impact on fruit flavor, with T1 (40 ppm) identified as the most effective treatment. NAA enhanced fruit flavor by increasing Total Soluble Solids TSS. Kumar et al.

(2024) reported that the application of NAA at 40 ppm + GA_3 at 50 ppm had a significant effect on fruit total soluble solids (TSS). This study revealed that applying NAA significantly influenced overall fruit acceptability, with T1 (40 ppm) proving to be the most effective treatment.

CONCLUSION

Based on the findings of this study, it is concluded that foliar application of 40 ppm Naphthalene Acetic Acid (NAA) at two growth stages—50% flowering and 20 days after the initial Spray—can significantly enhance the growth, yield, and fruit quality of eggplants. Future research will focus on a comparative evaluation of Naphthalene Acetic Acid (NAA) and Indole-3-Butyric Acid (IBA) in order to determine their relative effectiveness in enhancing vegetative growth, yield components, and fruit quality of eggplants under field conditions.

RECOMMENDATION

The 40-ppm concentration of NAA is recommended for farmers aiming to achieve more vigorous plant development, increased productivity, and superior fruit characteristics.

AUTHOR CONTRIBUTION

- G.R. Samadi conceptualized and supervised the study.
- M. Amin and M.K. Rashidi conducted the study in the field and collected the raw data.
- M. Amin, M.K. Rashidi, and H. Salari processed and analyzed data (equally).
- M. Amin and H. Salari wrote the manuscript with input from all authors.
- All authors reviewed and approved the final version.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available upon request from the corresponding author, subject to the approval of the relevant ethics committee.

REFERENCES

Afful, N. T., Nyadanu, D., Akromah, R., Amoatey, H. M., Annor, C., & Diawouh, R. G. (2019). Nutritional and Antioxidant Composition of Eggplant Accessions in Ghana. *African Crop Science Journal*, 27(2). https://doi.org/10.4314/acsj.v27i2.6

Afrin, S., Islam, N., Mustaki, S., Araf, T., & Choudhury, S. (2024). Impact of Micronutrients and Plant Growth Regulators on Brinjal (Solanum melongena L.) Growth, Yield and Quality. *Asian Journal of Soil Science and Plant Nutrition*, 10(2), 72–79. https://doi.org/10.9734/ajsspn/2024/v10i2262

Agudelo-Morales, C., Lerma, T., Martínez Lara, J., Palencia, M., & Combatt, E. (2021). Phytohormones and Plant Growth Regulators—A Review. *Journal of Science with Technological Applications*, 10, 27–65. https://doi.org/10.34294/j.jsta.21.10.66

Akhtar, S., Solankey, S.S., Kumari, R., Rani, N., 2017. Crucial Reproductive Traits as Indices for Screening Brinjal (Solanum melongena L.) under High-Temperature Stress. *Indian Journal of Ecology* 44, 331–336. Link

Alam, I., & Salimullah, M. (2021). Genetic Engineering of Eggplant (Solanum melongena L.): Progress, Controversy and Potential. *Horticulturae*, 7, 78. https://doi.org/10.3390/horticulturae7040078

Bhattarai, B. R., Pal, A. K., & Amgain, L. P. (2021). Response of varying levels of phyto-hormones and micro-nutrients on growth and yield of Brinjal (Solanum melongena L.) in sub-tropical Terai region of India. *Journal of Agriculture and Natural Resources*, 4(2). https://doi.org/10.3126/janr.v4i2.33654

Bisht, T. S., Rawat, L., Chakraborty, B., & Yadav, V. (2018). A Recent Advances in Use of Plant Growth Regulators (PGRs) in Fruit Crops—A Review. *International Journal of Current Microbiology and Applied Sciences*, 7(5), 1307–1336. https://doi.org/10.20546/ijcmas.2018.705.159

Blekkenhorst, L. C., Sim, M., Bondonno, C. P., Bondonno, N. P., Ward, N. C., Prince, R. L., Devine, A., Lewis, J. R., & Hodgson, J. M. (2018). Cardiovascular Health Benefits of Specific Vegetable Types: A Narrative Review. *Nutrients*, 10(5). https://doi.org/10.3390/nu10050595

Caruso, G., Pokluda, R., Sękara, A., Kalisz, A., Jezdinský, A., Kopta, T., & Grabowska, A. (2017). Agricultural practices, biology and quality of eggplant cultivated in Central Europe. A review. *Horticultural Science*, 44(4), 201–212. https://doi.org/10.17221/36/2016-HORTSCI

Chioti, V., Zeliou, K., Bakogianni, A., Papaioannou, C., Biskinis, A., Petropoulos, C., Lamari, F. N., & Papasotiropoulos, V. (2022). Nutritional Value of Eggplant Cultivars and Association with Sequence Variation in Genes Coding for Major Phenolics. *Plants*, 11(17). https://doi.org/10.3390/plants11172267

Durai, R., 2021. Effect of different growth regulators and their response to physiological and biochemical attributes in Brinjal (Solanum melongena L.). *The Pharma Innovation Journal* 10, 1328–1332. Link

Eggplant global exports and top exporters 2024. (n.d.). Tridge. Retrieved November 12, 2024, *from* Link

FAOSTAT. (n.d.). Retrieved November 12, 2024, *from* Link

Hassan, F. I. M., Eisa, Y. A., & Adlan, A. M. A. (2018). Effect of Intra-Row Spacing on Growth and Yield of Two Eggplant (Solanum melongena L.) Cultivars under Blue Nile State Conditions, Sudan. *Net Journal of Agricultural Science*, 6(2), 11–15. Link

Hoque, A. K. M., Ahmed, Q., Rahman, M., & Islam, M. (2018). Effect of application frequency of naphthalene acetic acid on histomorphological characters and yield of Brinjal. *Research in Agriculture Livestock and Fisheries*, 5, 151–155. https://doi.org/10.3329/ralf.v5i2.38051

Jiang, K., & Asami, T. (2018). Chemical regulators of plant hormones and their applications in basic research and agriculture*. *Bioscience, Biotechnology, and Biochemistry*, 82(8), 1265–1300. https://doi.org/10.1080/09168451.2018.1462693

Kabul Climate, Weather By Month, Average Temperature (Afghanistan)—Weather Spark. (2024). Retrieved January 9, 2025, *from* Link

Khaleghi, S., Baninasab, B., Mobli, M., Khaleghi, S., Baninasab, B., & Mobli, M. (2021). Relationship Between Floral Morphology, Fruit Setting Behavior And Final Yield In Some Eggplant (Solanum Melongena) Genotypes From Iran. *Chilean Journal of Agricultural & Animal Sciences*, 37(2), 128–135. https://doi.org/10.29393/chjaas37-15rbsm30015

Khan, M. N., & Nabi, G. (2023). Role of Auxin in vegetative growth, flowering, yield and fruit quality of Horticultural crops—A review. *Pure and Applied Biology (PAB)*, 12(2). Link

Kumar, S., Kumar, J., Silas, V. J., Quatadah, S. M., Agrahari, A., Khan, R., Singh, R., & Singh, S. (2024). Effect of gibberellic acid and NAA on growth, yield, and quality of Brinjal (Solanum melongena L.) in cv. Azad Kranti. *International Journal of Advanced Biochemistry Research*, 8(5), 461–465. https://doi.org/10.33545/26174693.2024.v8.i5f.1105

Lyu, J., Jin, N., Ma, X., Yin, X., Jin, L., Wang, S., Xiao, X., & Yu, J. (2025). A Comprehensive Evaluation of Nutritional Quality and Antioxidant Capacity of Different Chinese Eggplant Varieties Based on Multivariate Statistical Analysis. *Antioxidants*, 14(1). https://doi.org/10.3390/antiox14010010

MFK. (2024, July 11). Most Produced Vegetables in the World 2024. *Worldostats*. Link

Misu, I. J., Ali, M. S., Rony, A. I., Siddike, M. N., Payel, N. A., Islam, M. F., Tanvir, S., Shikder, M. M., & Mohsin, G. M. (2023). Effect of Plant Growth Regulators on Growth, Yield, and

Yield-Contributing Characters of Brinjal (Solanum melongena L.) in the Coastal Zone of Bangladesh. *Research in Agriculture Livestock and Fisheries*, 10(2). https://doi.org/10.3329/ralf.v10i2.68752

Moniruzzaman, M., Khatoon, R., Hossain, M. F. B., Jamil, M., & Islam, M. (2014). Effect of ga and naa on physio-morphological characters, yield, and yield components of Brinjal (Solanum melongena L.). *Bangladesh Journal of Agricultural Research*, 39, 397–405. https://doi.org/10.3329/bjar.v39i3.21983

Netam, J., & Sharma, R. (2014). Efficacy of plant growth regulators on growth characters and yield attributes in brinjal (Solanum melongena L.) cv. Brinjal 3112. *IOSR Journal of Agriculture and Veterinary Science*, 7, 27–30. https://doi.org/10.9790/2380-07732730

Niño-Medina, G., Urías-Orona, V., Muy-Rangel, M. D., & Heredia, J. B. (2017). Structure and content of phenolics in eggplant (Solanum melongena)—A review. *South African Journal of Botany*, 111, 161–169. https://doi.org/10.1016/j.sajb.2017.03.016

Parvin, M., Hasan, M., & Rahman, P. (2022). Effect of Temperature and BSFB Population on the Growth and Yield of Brinjal *International Journal of Science and Management Studies (IJSMS)*, 342–350. https://doi.org/10.51386/25815946/ijsms-v5i4p135

Patel, S., Verma, S., Maurya, B. K., Maurya, S. K., Patel, Y., & Prakash, S. (2022). Effects of GA 3 and NAA on Growth and Yield of Brinjal (Solanum melongena L.) cv. Kashi Sandesh. *International Journal of Plant & Soil Science*, 6, 71–76. https://doi.org/10.9734/IJPSS/2022/v34i2231356

Quamruzzaman, A. K. M., Khatun, A., & Islam, F. (2020). Nutritional Content and Health Benefits of Bangladeshi Eggplant Cultivars. *European Journal of Agriculture and Food Sciences*, 2(4). https://doi.org/10.24018/ejfood.2020.2.4.76

Salari, H., & Amin, M. (2024). د سبو د کیفیت بنه کولو په موخه د اکسین هورمون کارول—مرور. *Journal of Natural Sciences – Kabul University*, 7(3). https://doi.org/10.62810/jns.v7i3.80

Sebastian, K., Arya, M. S., Reshma, U. R., Anaswara, S. J., & Thampi, S. (2019). Impact of Plant Growth Regulators on Fruit Production. *International Journal of Current Microbiology and Applied Sciences*, 8, 800–814. https://doi.org/10.20546/ijcmas.2019.802.092

Sharif, R., Su, L., Chen, X., & Qi, X. (2022). Hormonal interactions underlying parthenocarpic fruit formation in horticultural crops. *Horticulture Research*, 9, uhab024. https://doi.org/10.1093/hr/uhab024

Sharif, R., Su, L., Chen, X., Qi, X., Sharif, R., Su, L., Chen, X., & Qi, X. (2022). Involvement of auxin in growth and stress response of cucumber. *Vegetable Research*, 2(1), 1–9. https://doi.org/10.48130/VR-2022-0013

Sharma, M., & Kaushik, P. (2021). Biochemical Composition of Eggplant Fruits: A Review. *Applied Sciences*, 11(15). https://doi.org/10.3390/app11157078

Singh, D.S., Saxena, D.A., Chand, V. (2021). INFLUENCE OF PLANT GROWTH REGULATORS (GA 3) AND (NAA) ON GROWTH AND YIELD ATTRIBUTES OF BRINJAL (SOLANUM MELONGENA L.). *International Research Journal of Modernization in Engineering Technology and Science*, 2582–5208. Link

Singh, S. K., Kumar, A., Beer, K., Singh, V. P., & Patel, S. K. (2018). Effect of Naphthalene Acetic Acid (NAA) and Gibberellic Acid (GA3) on Growth and Fruit Quality of Tomato (Lycopersicon esculentum Mill*.). International Journal of Current Microbiology and Applied Sciences*, 7(3), 306–311. https://doi.org/10.20546/ijcmas.2018.703.036

Sosnowski, J., Truba, M., & Vasileva, V. (2023). The Impact of Auxin and Cytokinin on the Growth and Development of Selected Crops. *Agriculture*, 13(3). https://doi.org/10.3390/agriculture13030724

Ujjwal, V., Singh, M. K., Dev, P., Chaudhary, M., Kumar, A., & Maurya, R. L. (2018). Impact of foliar application of different levels of GA3 and NAA on reproductive and quality parameters of tomato (Solanum Lycopersicum L.) . *Journal of Pharmacognosy and Phytochemistry*, 7(5S), 84–86. Link

Veeresha, S. M., Tirakannanavar, S., Masuti, D. K., Shet, R. C. J. R. M., & Gowda, V. H. (2018). Effect of Time of Pollination and Period of Pollen Storage on Seed Yield and Quality of Brinjal Hybrid (Solanum melongena L.). *International Journal of Current Microbiology and Applied Sciences*, 7(7), 1783–1791. https://doi.org/10.20546/ijcmas.2018.707.211