Original Research Article

Optimizing Hybrid Eggplant Production: A Comparative Assessment of Drip Fertigation and Conventional Fertilization on Vegetative Growth, Agricultural Productivity, and Water Utilization Efficiency

ABSTRACT

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| --- |
| This study aimed to evaluate the comparative effects of drip fertigation and conventional fertilization on vegetative growth, fruit yield, and water utilization efficiency in hybrid eggplant (Solanum melongena L.) cultivation, with a focus on identifying an economically optimal fertigation level. A field experiment was conducted using a Randomized Block Design (RBD) with five treatments and four replications at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, during the Rabi season (November 2021 to May 2022). Treatments included drip fertigation at 75%, 100%, 125%, and 150% of the Recommended Dose of Fertilizers (RDF) and a control with conventional fertilization at 100% RDF. Key parameters such as plant height, number of branches, fruits per plant, total yield, and water utilization efficiency were assessed. Results indicated that all drip fertigation treatments significantly outperformed conventional fertilization. The highest yield (470.33 q/ha) and water use efficiency (8.54 q/ha-cm) were recorded in the 150% RDF drip fertigation treatment, followed closely by 125% RDF (467.98 q/ha), with both showing statistical parity. The lowest yield and efficiency were observed under conventional fertilization. Based on the findings, drip fertigation at 125% RDF is recommended as the most agronomically efficient and economically viable approach for maximizing hybrid eggplant productivity while optimizing resource use. |

*Keywords: Eggplant, drip fertigation, recommended dose of fertilizer, water utilization efficiency*

1. INTRODUCTION

Eggplant (*Solanum melongena* L.), commonly known as aubergine, brinjal, berenjena, or Guinea, is a non-tuberous crop belonging to the Solanaceae (nightshade) family. It is an agronomically and economically important species cultivated for centuries across Asia, Africa, Europe, and the Near East (Bohs & Weese, 2010). Eggplant is a high-yielding crop well-adapted to hot and humid environments and has been widely used in traditional medicine for treating various ailments. In some parts of Asia, the vegetative aerial parts of *S. americanum*/*nigrum* were traditionally used for treating skin problems, as a purgative, and to ease urination (Meyer, Bamshad, Fuller, & Litt, 2014). Unlike other solanaceous crops that originated in the New World, eggplant is an Old World species. It shares botanical similarities with its relatives such as tomato and pepper, being an autogamous diploid with 12 chromosomes (2n=24). The fruit of eggplant is botanically classified as a berry and contains numerous soft edible seeds that are slightly bitter due to the presence of nicotinoid alkaloids. Although its domestication history is still debated, the most widely accepted theory suggests that eggplants were first domesticated over 4,000 years ago in Southeast Asia (Meyer, Karol, Little, Nee, & Litt, 2012). Area and production of brinjal in India during 2015-16 was 662.54 thousand hectares and 12510 thousand MT, respectively; with the productivity of 17.07 MT/ha. Whereas, in Maharashtra the area and production of brinjal was 21.09 thousand hectares and 407.64 thousand MT, respectively; with the productivity of 19.33 MT/ha. (Anonymous, 2017).

Eggplant is also known for its rich content of bioactive secondary metabolites, which, although not essential for basic plant processes, are highly valued in both traditional and modern medicine. These compounds, particularly phenolics and carotenoids, are known for their antioxidant properties and play a significant role in promoting human health (Singh, Kaur, Shevkani, & Singh, 2015). Several studies have highlighted the therapeutic potential of eggplant fruit extracts, showing effectiveness in treating warts, burns, and various inflammatory conditions such as stomatitis, arthritis, and gastritis (Im et al., 2016). Furthermore, the high fiber content in eggplant aids in healthy digestion, helping to eliminate waste materials and harmful toxins from the body, thereby reducing the risk of colon and stomach cancer (Fraikue, 2016).

The growing competition for water resources among agricultural, industrial, and urban sectors necessitates continual advancements in irrigation practices within commercial agriculture. In South Asia, the commonly used method of flood irrigation, which is both inefficient and environmentally detrimental, should be phased out in favor of more efficient systems such as furrow, drip, or sub-irrigation (Lal, 2000; Aujla et al., 2005; Buttar et al., 2006). Numerous studies have documented that drip irrigation consistently results in higher yields and improved water use efficiency (WUE) compared to conventional methods across various vegetable crops, including potato (Unlu et al., 2006; Wang et al., 2006), cucumber (Yuan et al., 2006), capsicum (Antony and Singandhupe, 2004; Sezen et al., 2006), onion (Al-Jamal et al., 2001; Rajput and Patel, 2006), okra (Tiwari et al., 1998), cabbage (Tiwari et al., 2003), and eggplant (Chartzoulakis and Drosos, 1995).

Drip irrigation enhances water use efficiency, nutrient uptake, and the quality of produce. For instance, in watermelon cultivation, higher fruit yield, total soluble solids, and sugar content under drip irrigation were linked to increased uptake of N, P, K, Ca, and Mg compared to furrow irrigation (Srinivas et al., 1989). Similarly, in okra, applying fertilizers through drip irrigation significantly increased fruit yield compared to band placement, with liquid fertilizers showing high efficiency and offering the potential to save 25% of the total fertilizer requirement, thereby offsetting their higher cost (Tumbare et al., 1999).

Therefore, understanding the impact of drip fertigation versus traditional fertilizer application on the growth, yield, and water use efficiency in eggplant is essential for developing effective and sustainable production practices. The present investigation aimed to evaluate the effects of drip fertigation and conventional fertilizer application methods on the growth, yield, and water utilization efficiency of hybrid eggplant production.

2. material and methods

The experiment was conducted at the Instructional Farm of the Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the rabi season of 2021-2022. The field site was characterized by a uniformly level topography, providing an ideal setting for the study. One of the eleven districts in the Vidarbha area of Maharashtra state is Akola. It is located in the state's northernmost section, the Western Vidarbha region, which borders Madhya Pradesh. It lies between North latitudes 200 16**’** and 210 17**’** and East longitudes 760 38**’** and 770 38**’.** Average annual precipitation comes under sub-tropical zone. Its location is 307.415 metres above mean sea level (MSL). Over the area, the average yearly rainfall ranges from roughly 740 mm to 860 mm. For the past 10 years, from 2002 to 2011, the average annual precipitation varied from 602.41 mm (Balapur) to 856.70 mm (Patur).

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Figure 1. Study area map showing the location of the experimental site

### **2.1 Experimental Details**

 The specifics of the experiment are as outlined below

Table 1. Experimental details

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Particulars** | **Specifications** |
| 1 | Crop | Eggplant |
| 2 | Scientific name | *Solanum melongena* L. |
| 3 | Variety | Phule Krishna |
| 4 | Experimental Design | Randomized Block Design |
| 5 | Number of treatments | 5 |
| 6 | Number of replications | 4 |
| 7 | Number of plots | 20 |
| 8 | Plot size | 5.4 m × 3 m |
| 9 | Season | Rabi |
| 10 | Crop spacing | 0.90 m X 0.75 m |
| 11 | Crop period | 180 days |
| 12 | Recommended fertilizer dose | 150:75:75 |
| 13 | Date of sowing | 30/09/2021 |
| 14 | Date of transplanting | 16/11/2021 |
| 15 | Period of picking | 18/01/2022 to 01/05/2022 |

2.2 Details of experimentation

**2.2.1 Experimental design and treatments**

An overview of the experimental plot is presented in Figure 1, while the detailed descriptions of the treatments are provided in table number 2.

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Figure 2. Over all view of experimental plot

Table 2. Treatment details

|  |  |
| --- | --- |
| **Treatments** | **Specification** |
| T1 | Drip fertigation with 75% of RDF |
| T2 | Drip fertigation with 100% of RDF |
| T3 | Drip fertigation with 125% of RDF |
| T4 | Drip fertigation with 150% of RDF |
| T5 | Traditional application of fertilizer with 100% RDF (Soil application of basal dose of 50% N + 100% P + 100% through solid fertilizers at the time of transplanting and remaining 50% N in two equal splits at 30 and 45 DAT) – Control |

**2.3 Morphometric characteristics**

 To evaluate the impact of varying fertilizer levels and application methods on the growth and yield of eggplant, the following morphometric observations were meticulously recorded.

**2.3.1 Growth observations**

Five plants from the net plot of each replication were randomly selected and labeled to record various growth parameters. Observations were systematically gathered at regular intervals from the date of transplanting. Plant height was measured every 30 days throughout the growth period by assessing the length of the main shoot in centimeters from ground level. The number of branches was determined by counting the primary branches originating from the main stem and the secondary branches that developed over time, with the cumulative total recorded at 30-day intervals. Canopy cover was assessed by measuring the plant's spread in both North-South and East-West directions at noon.

### **2.4 Yield contributing observations**

The mean number of fruits per plant was calculated by considering the total number of fruits harvested from the designated observation plants at each picking. For the yield per plant, the weight of harvested eggplant from each observation plant was recorded at every picking, and the cumulative weight across the season was computed for each treatment. The overall yield of eggplant was determined by recording the total harvest from the net plot for each treatment at every picking.

## **2.5 Water Requirement of brinjal**

Before transplanting, to bring the soil at the field capacity in each plot common irrigation was applied on 16th November 2021. On 16th November 2021 healthy seedlings of brinjal were transplanted with spacing of 90 cm (row to row) and 75 cm (plant to plant). The successive first irrigation was given on 18th November 2021 and then irrigation was applied every alternate day according to the previous two days cumulative evaporation.

The depth of irrigation water required for all treatments to bring it up to field capacity was calculated by using equation 1

$d=\left(\frac{Mfc - Mbi }{100}\right)×γ× Z × 1000$ ...... (1)

Where,

|  |  |
| --- | --- |
| D | = Net depth of water to be applied during an irrigation, mm |
| Mfc | = Moisture content at field capacity, per cent |
| Mbi | = Moisture content before irrigation, per cent |
| Y | = Bulk density, g/cm3 |
| Z | = Depth of effective root zone, m |

The effective root zone depth was taken as 45 cm for calculating the net water requirement of brinjal crop. The moisture content before transplanting was taken and it was observed 26%. Accordingly, the depth of irrigation to be applied before transplanting was calculated.

### **2.5.1 Water requirement of brinjal under drip irrigation**

Considering the use of polyethylene mulch, which saves about 20% of irrigation water, the water requirement of brinjal crop under drip irrigation was worked out at 80% evapotranspiration level. It was worked out on the basis of pan evaporation.

The amount of water to be applied per plant was calculated by using formula given in equation 2

Q = A x B x C x D ...... (2)

Where,

|  |  |
| --- | --- |
| Q | = Water requirement per plant (lit/plant) |
| A | = ETo = Epan x Kp (mm) |
| B | = Crop coefficient (KC) |
| C | = Canopy factor |
| D | = Area allotted per plant (m2) |
| Epan | = Cumulative evaporation for two days |
| Kp | = Pan coefficient (0.8) |

The values of crop coefficient used for different growth stages of brinjal crop are shown in Table 3.

**Table 3. Crop coefficient values of brinjal**

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Growing Period** | **Crop coefficient (Kc)** |
| 1 | 16th November to 25th November 2021 | 0.60 |
| 2 | 26th November to 5th December 2021 | 0.65 |
| 3 | 6th December to 15th December 2021 | 0.74 |
| 4 | 16th December to 25th December 2021 | 0.83 |
| 5 | 26th December to 4th January 2022 | 0.92 |
| 6 | 5th January to 14th January 2022 | 0.99 |
| 7 | 15th January to 24th January 2022 | 1.05 |
| 8 | 25th January to 3rd February 2022 | 1.09 |
| 9 | 4th February to 13th February 2022 | 1.11 |
| 10 | 14th February to 23rd February 2022 | 1.11 |
| 11 | 24th February to 5th March 2022 | 1.11 |
| 12 | 6th March to 15th March 2022 | 1.09 |
| 13 | 16th March to 25th March 2022 | 1.08 |
| 14 | 26th March to 4th April 2022 | 1.04 |
| 15 | 5th April to 14th April 2022 | 1.00 |
| 16 | 15th April to 24th April 2022 | 0.94 |
| 17 | 25th April to 4th May 2022 | 0.87 |

### **2.5.2 Irrigation scheduling**

Data of open pan evaporation and other climatic parameters were collected daily from the Agricultural Meteorological Observatory, Department of Agronomy, Dr. P.D.K.V., Akola.

 Achievement of optimum and efficient production and productivity, irrigation was scheduled to brinjal crop on every alternate day by considering the cumulative pan evaporation of previous two days. In case of precipitation, it was cumulated for the same previous two days and cumulative rainfall subtracted from cumulative evaporation. If cumulative evaporation was more than cumulative rainfall, then remaining evaporation was taken for calculating the water requirement. But if cumulative rainfall was more than cumulative evaporation, then irrigation was not applied on that scheduled day. Moreover, irrigation was not applied for next two days due to excess rainfall than evaporation and considering the two days (48 hrs.) period for getting soil to reach its field capacity.

### **2.5.3 Fertilizer application, scheduling and doses**

The recommended fertilizer dose of 150:75:75 N:P:K Kg/ha was taken. In case of treatments T1 to T4, water soluble fertilizers (source- 19:19:19 WSF complex and urea) through drip fertigation was applied in 15 splits at an interval of 10 days. Out of which, during first 60 days after transplanting (DAT) i.e. in vegetative growth stage; half of respective total fertilizer dose was applied in 6 equal splits at an interval of 10 days and remaining half of respective total fertilizer dose was applied after 60 DAT in 9 equal splits at an interval of 10 days as per fertilizer level in respective treatment.

In control treatment T5, soil application of basal dose of 50% N + 100% P + 100% K (sources – Urea, SSP, and MOP) were given as traditional fertilization through solid fertilizers at the time of transplanting and remaining 50% of N (source-Urea) was given in two equal splits at 30 and 45 DAT through drip fertigation, as mulching were provided.

**Table 4. Schedule of fertigation in drip fertigation treatments (T1 to T4)**

|  |  |
| --- | --- |
| **Split number** | **Date** |
| I | 16th November 2021 |
| II | 26th November 2021 |
| III | 6th December 2021 |
| IV | 16th December 2021 |
| V | 26th December 2021 |
| VI | 5th January 2022 |
| VII | 15th January 2022 |
| VIII | 25th January 2022 |
| IX | 4th February 2022 |
| X | 14th February 2022 |
| XI | 24th February 2022 |
| XII | 6th March 2022 |
| XIII | 16th March 2022 |
| XIV | 26th March 2022 |
| XV | 5th April 2022 |

3. results and discussion

**3.1 Morphometric characteristics**

The morphometric characteristics of the eggplant crop, as influenced by varying levels of drip fertigation and the traditional method of fertilizer application, were thoroughly investigated. Field observations for each morphometric parameter were meticulously recorded from five randomly selected plants per plot and subsequently analyzed. The findings are elaborated upon in the following discussion.

### **3.1.1 Growth observations**

#### **3.1.1.1 Plant height**

Plant height in the eggplant crop was measured at 30-day intervals from transplanting, with the mean heights, influenced by different drip fertigation levels and traditional fertilization methods, graphically illustrated in Figure 3. An overall increase in plant height was observed across all treatments as the crop progressed, with the maximum height recorded at the harvest stage. Initially, during the early growth phases (30 and 60 DAT), the control treatment T5, involving traditional fertilization with 100% RDF, exhibited the highest plant height, likely due to the complete application of fertilizers at the outset. However, significant differences emerged from 90 DAT onwards, with treatment T4 showing the tallest plants, statistically similar to T3 indicating a shift in growth dynamics favoring the drip fertigation treatments in the later stages. (Adawadkar et. al. 2019) reported the similar trends in the plant height.

Figure 3. Plant height as influenced by drip fertigation with different fertilizer levels and traditional method of fertilizer application

#### ***3.1.1.2 Number of branches per plant***

The average number of branches per eggplant plant, as influenced by varying drip fertigation levels and traditional fertilizer application, is graphically depicted in Figure 4. The data reveal a progressive increase in branch count over time, reaching its peak at the harvest stage. While early growth stages (30 and 60 days after transplanting, DAT) showed no significant differences among treatments, the later stages exhibited notable variation, with branch numbers increasing alongside higher proportions of the recommended fertilizer dose. Initially, treatment T5 recorded the highest number of branches, likely due to the complete fertilizer application within the first 60 DAT, highlighting its initial impact on plant development. At 90, 120 DAT, and at harvest, treatment T4 exhibited the highest number of branches per plant, statistically on par with treatment T3. In contrast, the lowest branch count was observed in treatment T5, similar to T1. At 120 DAT and at harvest, treatment T4 (Drip fertigation at 150% RDF) showed significantly highest number of branches per plant over other treatments. However, it was at par with treatment T3. Whereas lowest number of branches per plant was observed in treatment T5 (Traditional fertilization at 100% RDF) and was found at par with treatment T1 (Adawadkar et. al., 2019).

Figure 4. Number of branches per plant as influenced by drip fertigation with different fertilizer levels and traditional method of fertilizer application

#### **3.1.1.3 Canopy cover**

Canopy cover, a critical indicator of vigorous crop growth under varying fertilizer levels with mulch, was measured and is graphically depicted in Figure 5. Initially, at 30 DAT, no significant differences were noted, though treatment T5 exhibited the highest canopy cover numerically. Non-significant differences were observed initially at 30 and 60 DAT of eggplant crop (Londhe, 2020). By 60 DAT, T5 continued to show superior canopy coverage compared to drip fertigation treatments, likely attributed to the complete fertilizer application during the early growth stages (up to 45 DAT) in T5, enhancing early vegetative development.

Figure 5. Canopy cover as influenced by drip fertigation with different fertilizer levels and traditional method of fertilizer application

### At 90 DAT, treatment T4 exhibited the highest canopy cover, statistically comparable to treatments T3 and T2. Conversely, treatment T5 recorded the lowest canopy cover, which was on par with treatments T1 and T2. At harvest, treatment T3 demonstrated the highest canopy cover, statistically comparable to T4, while T5 continued to show the lowest, similar to T1.

### **3.2 Yield contributing observations**

#### **3.2.1 Number of fruits per plant**

The data on the number of fruits harvested per plant, as influenced by varying drip fertigation levels and traditional fertilization, is illustrated in table 5. The results indicate that an increase in fertigation level corresponded with a rise in the number of fruits per plant. The highest number of fruits per plant (82.70) was observed in treatment T4, which was statistically similar to treatment T3. Significantly highest number of fruits per plant 78.50 was recorded in treatment T3 (Londhe, 2020). Treatment T4 consistently outperformed treatments T1, T2, T3, and T5 in terms of fruit count. On the other hand, treatment T5 recorded the lowest number of fruits per plant (55.25), statistically comparable to treatment T1. Additionally, treatment T2 yielded significantly more fruits than treatment T5.

Table 5. Number of fruits per plant as influenced by drip fertigation with different fertilizer levels and traditional method of fertilizer application

|  |  |
| --- | --- |
| **Treatments** | **Number of fruits per plant** |
| T1 (Drip fertigation at 75% RDF) | 60.85 |
| T2 (Drip fertigation at 100% RDF) | 72.60 |
| T3 (Drip fertigation at 125% RDF) | 78.50 |
| T4 (Drip fertigation at 150% RDF) | 82.70 |
| T5 (Traditional fertilization at 100%RDF) | 55.25 |
| F test  | Sig. |
| SE (m) ± | 2.95 |
| CD at 5 % | 9.10 |
| CV % | 8.44 |

#### **3.2.2 Yield of fruit per plant**

The yield of fruits per plant, influenced by varying drip fertigation levels and traditional fertilization methods, is presented in table 6. The results indicated a positive correlation between fertigation levels and fruit yield, with treatment T4 yielding the highest number of fruits per plant, statistically comparable to treatment T3. The lowest yield was recorded in treatment T5, which was on par with treatment T1. Treatment T2 also outperformed treatment T5 in terms of fruit yield. The highest yield of fruits per plant were observed in drip fertigation treatments as compared to traditional method of fertilizer application with solid fertilizers (Adawadkar et. al. 2019).

Table 6. Yield of fruit per plant as influenced by drip fertigation with different fertilizer levels and traditional method of fertilizer application

|  |  |
| --- | --- |
| **Treatment**  | **Yield per plant (gm)** |
| T1 (Drip fertigation at 75% RDF) | 3123.83 |
| T2 (Drip fertigation at 100% RDF) | 3557.33 |
| T3 (Drip fertigation at 125% RDF) | 4420.86 |
| T4 (Drip fertigation at 150% RDF) | 4574.38 |
| T5 (Traditional fertilization at 100%RDF) | 2927.70 |
| F test  | Sig. |
| SE (m) ± | 151.21 |
| CD at 5 % | 465.91 |
| CV % | 8.13 |

## **3.2.3** **Yield of eggplant and water utilization efficiency**

The total eggplant yield, harvested over 15 pickings, is presented in table 7. The yield was significantly influenced by the different fertigation levels, with treatment T4 achieving the highest yield (470.33 q/ha), followed by treatments T3, T2, and T1. Treatment T4 was statistically similar to treatment T3, which produced a yield of 467.98 q/ha. In contrast, treatment T5 yielded the lowest (346.65 q/ha), due to the application of the entire fertilizer dose during the vegetative growth stage, limiting nutrient availability during the flowering and fruiting phases. Although treatment T4 outperformed T3 in terms of yield, it required 25% more fertilizer. Therefore, considering the lower fertilizer requirement, treatment T3 (drip fertigation at 125% RDF) is recommended as the optimal treatment for eggplant production. Treatment T4 exhibited the highest water utilization efficiency 8.54 q/ha-cm, followed by treatments T3, T2, T1, and T5. The lower water use efficiency in treatment T5 can be attributed to its lower yield. Treatments T3 showed 8.79 q/ha-cm water use efficiency (Londhe,2020).

Table 7. Yield of eggplant and water use efficiency as influenced by drip fertigation with different fertilizer levels and traditional method of fertilizer application

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Yield (q/ha)** | **Amount of water applied(ha-cm)** | **Water use efficiency****(q/ha-cm)** |
| T1 (Drip fertigation at 75 % RDF) | 362.04 | 55.09 | 6.57 |
| T2 (Drip fertigation at 100 % RDF) | 415.39 | 7.54 |
| T3 (Drip fertigation at 125 % RDF) | 467.98 | 8.50 |
| T4 (Drip fertigation at 150% RDF) | 470.33 | 8.54 |
| T5 (Traditional fertilization at 100 % RDF) | 346.65 | 6.29 |
| F Test | Sig. | - | - |
| SE (m) ± | 16.67 | - | - |
| CD at 5% | 51.38 | - | - |
| CV% | 8.09 | - | - |

4. Conclusion

Drip fertigation in the cultivation of hybrid eggplant crop is crucial because it synchronizes water and nutrient application with the crop's specific growth stages, ensuring optimal uptake and reducing resource wastage. This method not only boosts yield and quality in eggplant but also promotes sustainability by conserving water, preventing soil nutrient depletion, and minimizing environmental contamination. The morphometric parameters of eggplant, including plant height, number of branches, canopy cover, fruit number, and yield, were significantly influenced by drip fertigation at varying fertilizer levels. At 90 DAT, 120 DAT, and harvest, treatment T4 consistently exhibited the highest plant height, which was statistically similar to T3. Number of branches showed non-significant differences at early growth stages (30 and 60 DAT), but by 90 DAT and harvest, T4 demonstrated the highest number of branches, with T4 and T3 being statistically at par. Canopy cover was highest in treatment T5 at 60 DAT, but by 90 DAT and harvest, T4 outperformed all other treatments, showing values statistically at par with T3. Similarly, number of fruits and yield per plant were highest in T4, with T4 and T3 yielding statistically similar results. T5 recorded the lowest fruit number and yield per plant. Overall, T4 resulted in the highest eggplant yield (470.33 q/ha), followed by T3 (467.98 q/ha), while T5 yielded the least. Water use efficiency was highest in T4, followed by T3, T2, T1, and T5, with the latter showing the lowest due to reduced yield. Considering 25% reduction in the fertilizer application drip fertigation at 125% RDF, combined with 80% of crop evapotranspiration (ETc) and silver-black polyethylene mulch, proved to be the most effective strategy for maximizing eggplant yield.

Consent (where ever applicable)

“All authors have read and approved the final version of the manuscript.
Informed consent was obtained from all participants involved in the study, where applicable.”

Ethical approval (where ever applicable)

“The field experiment was conducted in accordance with institutional guidelines and approved by the departmental research committee of Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola. All necessary permissions for conducting the field study were obtained prior to the initiation of the research.”

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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