***Original Research Article***

**Impact of Nano Boron on the Growth and Productivity of Bitter Gourd (*Momordica charantia* L.) Varieties**

**ABSTRACT**

An experiment on bitter gourd was conducted from March to May 2024 at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India. The study aimed to evaluate the effects of foliar spraying of nano-boron at 50 ppm on plant growth, yield, and quality across seven varieties of bitter gourd: IET/2023/BIGVAR-1, IET/2023/BIGVAR-2, IET/2023/BIGVAR-3, IET/2023/BIGVAR-4, IET/2023/BIGVAR-5, IET/2023/BIGVAR-7, and JAUNPURI (check variety). The experiment followed a Randomized Block Design (RBD) with three replications.

Among the varieties, IET/2023/BIGVAR-3 demonstrated the best growth, achieving a vine length of 2.25 m and 38.38 nodes at the final harvest. IET/2023/BIGVAR-5 recorded the highest fruit production, with 31.29 fruits per plant and a fruit diameter of 46.67 mm. In terms of yield, IET/2023/BIGVAR-7 emerged as the top performer, producing 42.18 t/ha with a fruit length of 12.55 cm and an average fruit weight of 125.06 g. Regarding quality, IET/2023/BIGVAR-2 exhibited the highest ascorbic acid content (82.56 mg/100 g), IET/2023/BIGVAR-4 had the highest total soluble solids (TSS) at 5.36° Brix, and IET/2023/BIGVAR-5 recorded the highest moisture content at 92.28%. Additionally, IET/2023/BIGVAR-7 achieved the highest benefit-cost ratio (B:C) of 5.27.

***Key words:*** Bitter gourd, Nano boron, Variety

1. **INTRODUCTION**

Bitter gourd (Momordica charantia L.), a member of the Cucurbitaceae family with a chromosome number of 2n = 22 (McKay, 1930), is a monoecious crop known for its high heterozygosity and consequent cross-pollination. This horticultural plant thrives during warm seasons in subtropical and arid regions but is vulnerable to light frosts, often requiring partial shelter when grown in cooler months. Its vines grow best at temperatures between 24°C and 27°C. Commonly called bitter melon, bitter cucumber, balsam-pear, bitter apple, or bitter squash, every part of the plant is edible, though cultivation is primarily focused on its fruit. In many Asian cuisines, the fruits, flowers, and young shoots are used as flavor enhancers. For example, the fruits are typically combined with other vegetables especially in soups to impart a subtle bitterness, while in Indian culinary practices they are often blanched, parboiled, or soaked in salt water to lessen their natural harshness (Saeed *et al*., 2018). Moreover, bitter gourd may be canned, pickled, dehydrated, or fried; and in folk medicine, it is widely recognized as a remedy for diabetes in communities across Asia, South America, India, and East Africa (Joseph & Jini, 2013). Other plant parts—such as roots, leaves, and vines—are traditionally used to relieve toothaches, diarrhea, and furuncles, and products like bitter gourd tea are gaining popularity as herbal remedies (Jia *et al*., 2017).

**Role of Boron in Bitter Gourd Cultivation**

Boron is vital for the proper growth and development of bitter gourd. Scientific studies have demonstrated that boron application can significantly increase yield by boosting the number of female flowers, improving fruit set, and enlarging fruit size (Hooda *et al*., 1981; Maurya, 1987; Singh & Choudhury, 1989; Gedam *et al*., 1998; Ali-Mishaal et al., 1984; Verma *et al*., 1984). Conversely, boron deficiency is a common micronutrient problem that leads to diminished yields and reduced crop quality (Barker and Pilbeam, 2006). In plants, boron is involved in critical processes such as pollen grain germination, pollen tube elongation, hormone synthesis, and the transport of photosynthetic products. It also indirectly enhances enzyme activation (e.g., dehydrogenase), sugar translocation, nucleic acid synthesis, and overall fruit set, thereby promoting robust plant growth and productivity (Brady & Weil, 1996; El-Sheikh *et al*., 2007; Marschner, 2012).

**Genetic Diversity and Varietal Significance**

The genetic diversity among bitter gourd varieties allows for the selection of traits such as higher yield, disease resistance, and enhanced nutritional content. Varietal differences also facilitate adaptation to distinct climatic conditions, soil types, and cultural practices. This diversity means that some varieties may excel in nutrient content or medicinal properties while others are preferred for specific culinary uses. The availability of multiple varieties not only meets diverse market and consumer demands but also provides an important resource for comparative research and the development of new, improved hybrids thereby contributing to sustainable agricultural practices, food security, and nutritional well-being.

**Emergence of Nano-Fertilizers: The Case for Nano Boron**

Recent advancements in nanotechnology have given rise to nano-fertilizers, or “smart fertilizers,” which are increasingly favored for their affordability, ease of application, and environmentally friendly profile. Nano boron distinguishes itself from conventional fertilizers by its small particle size, which enables rapid absorption through soil, irrigation water, or foliar application. This enhanced bioavailability improves water and nutrient uptake, boosts plant growth, increases fruit yield and quality, and helps plants combat environmental stresses (Ghorbanpour *et al*., 2017). Thanks to its superior solubility and capacity for precise, controlled release, nano boron minimizes waste and optimizes the activation of vital plant processes. Furthermore, its low material cost contributes to reducing the overall economic burden on agricultural operations while potentially lessening the environmental footprint of farming (El-Khafagy *et al*., 2013).

**Study Rationale**

Given the multifaceted benefits of boron and the advancements in nano-fertilizer technology, this study was undertaken to evaluate the effects of nano boron on growth, yield, and quality across different bitter gourd varieties. In addition, the research aims to assess the economic viability of adopting nano boron treatments in bitter gourd cultivation.

**2. MATERIALS AND METHODS**

The present investigation was conducted from March to May 2024 at the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Uttar Pradesh). The study aimed to evaluate the effect of foliar application of nano-boron at a 50 ppm concentration on the growth, yield, and quality of various bitter gourd varieties.

The experimental field was prepared by ploughing with a tractor-drawn disc plough, followed by two rounds of cross harrowing and subsequent planking. The field was then thoroughly leveled using a leveller before layout. On March 17, 2024, 2–3 seeds were sown per hill at a spacing of 0.60 m between plants and 1.5 m between rows. Thinning and gap-filling operations were carried out 15 days after sowing to ensure a uniform seedling population; any gaps from non-germinated seeds were filled by resowing within a week.

To maintain a weed-free crop, 2–3 weeding operations were implemented. The first weeding was performed 21 days after sowing (April 9, 2024), with subsequent weeding conducted at monthly intervals. Uniform moisture around the root zone was ensured by administering light irrigation on the first and second days after sowing, and then at intervals of 5–6 days.

Fertilizer applications were adjusted based on the variety, soil fertility, climate, and season. In general, well-decomposed farmyard manure (15–20 t/ha) was mixed into the soil during ploughing. Nano-boron at 50 ppm was then applied via foliar spraying on the various bitter gourd varieties on the 30th day after sowing at 11:00 am.

 **Table 1. List of different varieties of bitter gourd and their sources**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl. No** | **Variety name** | **Symbol** | **Source** |
| 1. | IET/2023/BIGVAR-1 | V1 | IIVR, Varanasi |
| 2. | IET/2023/BIGVAR-2 | V2 | IIVR, Varanasi |
| 3. | IET/2023/BIGVAR-3 | V3 | IIVR, Varanasi |
| 4. | IET/2023/BIGVAR-4 | V4 | IIVR, Varanasi |
| 5. | IET/2023/BIGVAR-5 | V5 | IIVR, Varanasi |
| 6. | IET/2023/BIGVAR-7 | V6 | IIVR, Varanasi |
| 7. | JAUNPURI | V7 | Awadh Seeds PVT. LTD, Ayodhya |

**3. RESULTS AND DISCUSSION**

**3.1. Growth Parameters**

**3.1.1. Days to Germination**

The number of days to germination did not differ significantly among the bitter gourd varieties. The earliest germination, at 6.53 days, was observed in IET/2023/BIGVAR-1. This rapid germination can be attributed to optimal soil physical and chemical properties, which ensured an adequate nutrient supply to the seeds, as well as favorable temperature conditions (18°C–34°C) during the second week of March. Adequate oxygen and sunlight availability further supported the process. These findings are consistent with the reports of Khan *et al*., (2021) and Kumar and Topno (2022) in bitter gourd.

**3.1.2. Germination Percentage**

Germination percentage varied significantly among the different varieties. The highest rate (100%) was recorded in IET/2023/BIGVAR-7. Variations in germination percentage are influenced by multiple factors including seed quality (freshness, viability, and genetic makeup), and environmental conditions such as temperature, moisture, light, and oxygen availability. In addition, seed treatments (e.g., scarification or stratification) and soil properties (texture, pH, and nutrient availability) play crucial roles. These observations corroborate findings in summer squash (Merzah and Aboohanah, 2020) and further studies in bitter gourd (Khan *et al*., 2021).

**3.1.3. Chlorophyll Content (SPAD Value)**

Significant differences in chlorophyll content were observed among the varieties, with the highest value of 50.46 SPAD detected in IET/2023/BIGVAR-2. Foliar application of nano boron appears to enhance chlorophyll synthesis, which likely improves the photosynthetic activity and overall plant vigor. Optimizing the application rate and timing is essential to maximize benefits while avoiding potential toxicity. These results are in agreement with studies conducted on Vicia faba (Noaema *et al*., 2019; Dawood *et al*., 2025) and cabbage (Al-Jubouri and Abdulrahman, 2023).

**3.1.4. Number of Nodes at Last Harvest**

While the number of nodes at the last harvest did not show significant differences overall, IET/2023/BIGVAR-3 exhibited the highest count at 38.38 nodes. The application of nano boron seems to enhance node development, which is indicative of improved vegetative growth and promises potential benefits for fruiting and yield. Enhanced node formation suggests more efficient cell wall development and nutrient transport, contributing to overall plant health.

**3.1.5. Vine Length at Last Harvest (m)**

Vine length at the final harvest also did not differ significantly among the varieties, though IET/2023/BIGVAR-3 recorded the maximum length of 2.25 m. The foliar application of nano boron may promote increased vine growth through several mechanisms. First, the nano-sized particles offer a larger surface area, enhancing nutrient absorption and uptake. Second, direct foliar application bypasses soil-related nutrient losses, improving nutrient availability. Additionally, these particles might exert hormonal effects that stimulate plant growth. The current observations are in line with previous findings in bitter gourd (Khan *et al*., 2021; Kumar and Topno, 2022) and in cucumber (Adham *et al*., 2021).

**Table 2. Impact of Nano Boron Application on Growth Parameters in Various Bitter Gourd Varieties**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variety** | **Days to germination** | **Germination****Percentage** | **Chlorophyll content (SPAD value)** | **No. of nodes** | **Vine length (m)** |
| IET/2023/BIGVAR-1 | 6.53 | 77% | 47.65 | 35.95 | 1.97 |
| IET/2023/BIGVAR-2 | 7.47 | 90% | 50.46 | 36.23 | 2.02 |
| IET/2023/BIGVAR-3 | 7.53 | 60% | 40.10 | 38.38 | 2.25 |
| IET/2023/BIGVAR-4 | 7.27 | 77% | 45.31 | 34.63 | 1.59 |
| IET/2023/BIGVAR-5 | 7.20 | 73% | 39.91 | 35.07 | 1.60 |
| IET/2023/BIGVAR-7 | 6.87 | 100% | 40.21 | 35.40 | 1.77 |
| JAUNPURI | 7.00 | 83% | 41.95 | 37.55 | 2.06 |
| F-test | NS | S | S | NS | NS |
| C.D. (5%) | 0.67 | 0.12 | 0.56 | 5.54 | 0.21 |
| S.E.(d) | 1.45 | 0.25 | 1.23 | 12.07 | 0.49 |
| C.V. | 11.48 | 17.61 | 1.58 | 18.75 | 14.41 |

**3.2 Flowering Parameters**

**3.2.1. Days to Emergence of First Male Flower**

The number of days required for the emergence of the first male flower differed significantly among the bitter gourd varieties. The earliest male flowering was recorded at 37.13 days in IET/2023/BIGVAR-1. Foliar application of nano boron appears to promote earlier male flower initiation by enhancing pollen viability and improving fertilization. These effects may contribute to improved fruit set and increased yields, although the overall effectiveness depends on factors such as application rate, plant growth stage, and prevailing environmental conditions. These observations are in agreement with studies by Khan *et al*., (2021), Kumar and Topno (2022) in bitter gourd, and Gurjar *et al*., (2015) in bottle gourd.

**3.2.2. Days to Emergence of First Female Flower**

Significant variation was also noted in the days to the emergence of the first female flower among the varieties. The earliest female flowering, occurring at 38.60 days, was observed in IET/2023/BIGVAR-1. Similar to its effect on male flowers, nano boron application may benefit female flower development by enhancing overall flower formation and supporting reproductive processes such as pollen germination and fertilization. Consequently, these improvements can lead to better fruit set and higher yields. The present findings corroborate those reported by Khan *et al*. (2021) and Kumar and Topno (2022), as well as by Gurjar *et al*., (2015) in related cucurbit crops.

**3.2.3. Number of Nodes at Which the First Female Flower Appeared**

The number of nodes at which the first female flower emerged showed significant differences among the varieties. The lowest node count (8.20) was recorded in IET/2023/BIGVAR-2, while the other varieties exhibited moderately higher values. Nano boron may facilitate improved node development and earlier flowering, potentially allowing female flowers to appear at a lower, more optimal node. This adjustment in developmental timing can favor a better fruit set and overall productivity by promoting uniform and vigorous plant growth. These results are consistent with the findings of Kumar and Topno (2022) in bitter gourd.

**Table 3. Impact of Nano Boron Application on Flowering Parameters in Various Bitter Gourd Varieties**

|  |  |  |
| --- | --- | --- |
| **Variety** | **Days to first flowering** | **Node number bearing 1st male and female flower** |
| **Male flower** | **Female flower** | **Male flower** | **Female flower** |
| IET/2023/BIGVAR-1 | 37.13 | 38.60 | 8.13 | 9.07 |
| IET/2023/BIGVAR-2 | 38.33 | 39.41 | 7.17 | 8.20 |
| IET/2023/BIGVAR-3 | 38.20 | 38.73 | 8.87 | 10.00 |
| IET/2023/BIGVAR-4 | 38.73 | 39.00 | 6.80 | 10.07 |
| IET/2023/BIGVAR-5 | 40.64 | 41.58 | 7.67 | 9.03 |
| IET/2023/BIGVAR-7 | 38.67 | 39.33 | 10.47 | 11.27 |
| JAUNPURI | 38.13 | 38.87 | 8.87 | 9.45 |
| F-test | S | S | S | S |
| C.D. (5%) | 0.64 | 0.36 | 1.01 | 0.70 |
| S.E.(d) | 1.38 | 0.79 | 2.21 | 1.53 |
| C.V. | 2.02 | 1.13 | 14.97 | 8.96 |

**3.3 Yield Parameters**

**3.3.1. Days to First Fruit Harvest**

The duration until the first fruit harvest did not differ significantly among bitter gourd varieties. The earliest harvest was recorded in IET/2023/BIGVAR-8 at 53.73 days. Foliar application of nano boron may reduce the time to first fruit harvest by enhancing boron availability, thereby stimulating flower and fruit development and improving fruit set. These effects can lead to earlier fruiting and improved crop productivity, as supported by findings in summer squash (Merzah and Aboohanah, 2020) and bottle gourd (Yadav *et al*., 2021).

**3.3.2. Fruit Length (cm)**

Fruit length varied significantly among the varieties. IET/2023/BIGVAR-7 produced the longest fruits at 12.55 cm, whereas IET/2023/BIGVAR-5 yielded the shortest fruits at 4.82 cm (which were more globular in shape). Nano boron foliar application appears to enhance fruit length by promoting cell wall development and cell elongation, leading to healthier fruit growth, improved quality, and potentially higher yields. These results are consistent with observations in bitter gourd by Yadav *et al*., (2020) and Khan *et al*., (2021).

**3.3.3. Fruit Weight (g)**

There was significant variation in fruit weight among the varieties. The highest fruit weight was observed in IET/2023/BIGVAR-7 at 125.06 g, while IET/2023/BIGVAR-5 exhibited the lowest at 41.41 g, reflecting its globular fruit shape. Enhanced boron availability through nano boron application supports cell wall development and nutrient uptake, thereby promoting robust fruit growth and improved fruit weight and quality. These findings agree with reports by Yadav *et al*., (2020) and Khan *et al*., (2021) in bitter gourd, and Hussein and Alwan (2022) in pepper.

**3.3.4. Fruit Diameter (mm)**

Fruit diameter also varied significantly among varieties. The maximum diameter was recorded in IET/2023/BIGVAR-5 at 46.67 mm. Nano boron foliar application could increase the fruit diameter by promoting cell expansion and supporting enhanced cell wall development. Increased boron availability contributes to improved fruit size and overall quality. These results align with observations reported in broccoli by Shams and Abbas (2019) and in bitter gourd by Kumar and Topno (2022).

**3.3.5. Number of Fruits per Plant**

The number of fruits per plant did not show significant differences among the varieties. However, IET/2023/BIGVAR-5 produced the highest average number at 32.50 fruits per plant. Nano boron application may improve fruit set by enhancing flower retention, pollination, and fertilization, thereby supporting overall plant health and ultimately increasing fruit numbers. Similar improvements have been observed in cucumber (Adham, 2021), bitter gourd (Kumar and Topno, 2022), and tomato (Rahman *et al*., 2023).

**3.3.6. Fruit Yield per Plant (kg)**

Fruit yield per plant varied significantly among the varieties. IET/2023/BIGVAR-7 registered the highest yield at 3.92 kg per plant. The application of nano boron likely boosts yield per plant by promoting better fruit set and overall healthy fruit development, which results in enhanced crop performance. These findings concur with those observed in broccoli (Shams and Abbas, 2019), bitter gourd (Yadav *et al*., 2020) and sweet pepper (Hussein, 2022).

**3.3.7. Fruit Yield per Hectare (t/ha)**

Fruit yield per hectare varied significantly among the bitter gourd varieties, with IET/2023/BIGVAR-7 achieving the highest yield of 42.18 t/ha. A higher number of fruits per plant directly contributes to increased yield per hectare. Moreover, the direct foliar application of nano boron ensures rapid nutrient absorption, thereby enhancing overall nutrient availability for fruit development. This improved nutrient uptake underpins the higher fruit yields observed and is supported by studies in bitter gourd (Khan *et al*., 2021; Kumar and Topno, 2022), pepper (Hussein and Alwan, 2022), and tomato (Rahman *et al*., 2023).

**Table 4. Impact of Nano Boron Application on Yield Parameters in Various Bitter Gourd Varieties**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variety** | **Days to first fruit harvested** | **Fruit length (cm)** | **Fruit weight (g)** | **Fruit diameter (mm)** | **No. of fruits/plant** | **Fruit yield/plant (kg)** | **Fruit yield in ha****(t/ha)** |
| IET/2023/BIGVAR-1 | 54.53 | 10.22 | 52.24 | 30.45 | 30.21 | 1.57 | 17.48 |
| IET/2023/BIGVAR-2 | 57.33 | 9.45 | 50.43 | 37.23 | 31.24 | 1.43 | 15.93 |
| IET/2023/BIGVAR-3 | 59.67 | 9.13 | 50.11 | 34.21 | 31.26 | 1.56 | 17.33 |
| IET/2023/BIGVAR-4 | 55.40 | 8.45 | 53.77 | 38.40 | 30.71 | 1.64 | 18.26 |
| IET/2023/BIGVAR-5 | 55.00 | 4.82 | 41.41 | 46.67 | 32.50 | 1.34 | 14.89 |
| IET/2023/BIGVAR-7 | 54.13 | 12.55 | 125.06 | 32.18 | 31.29 | 3.92 | 42.18 |
| JAUNPURI | 53.73 | 10.46 | 51.78 | 39.81 | 31.12 | 1.61 | 17.85 |
| F-test | NS | S | S | S | NS | S | S |
| C.D. (5%) | 2.26 | 0.21 | 2.95 | 1.26 | 1.54 | 0.18 | 2.58 |
| S.E.(d) | 4.92 | 0.46 | 6.43 | 2.73 | 3.35 | 0.40 | 5.62 |
| C.V. | 4.96 | 2.76 | 5.95 | 4.16 | 6.05 | 12.08 | 15.35 |

**Table 5. Impact of Nano Boron Application on Quality Parameters in Various Bitter Gourd Varieties**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variety** | **TSS Content (° Brix)** | **Ascorbic acid mg/100g)** | **Moisture content (%)** |
| IET/2023/BIGVAR-1 | 4.03 | 80.55 | 91.80 |
| IET/2023/BIGVAR-2 | 3.77 | 82.56 | 83.23 |
| IET/2023/BIGVAR-3 | 4.43 | 80.78 | 90.78 |
| IET/2023/BIGVAR-4 | 5.36 | 81.33 | 82.27 |
| IET/2023/BIGVAR-5 | 3.53 | 78.86 | 92.28 |
| IET/2023/BIGVAR-7 | 3.57 | 80.50 | 91.54 |
| JAUNPURI | 2.97 | 79.80 | 92.07 |
| F-test | S | NS | S |
| C.D. (5%) | 0.45 | 6.23 | 1.23 |
| S.E.(d) | 0.97 | 13.57 | 2.68 |
| C.V. | 13.83 | 9.46 | 1.69 |

**3.4. Quality Parameters**

**3.4.1. Total Soluble Solids (°Brix)**

Total Soluble Solids (TSS) varied significantly among the bitter gourd varieties. The highest TSS was recorded in IET/2023/BIGVAR-4 at 5.36 °Brix. Foliar application of nano boron may enhance TSS by regulating nutrient uptake, stimulating carbohydrate metabolism, and improving sugar synthesis. These effects collectively contribute to superior fruit quality and increased sweetness. Such improvements in TSS are consistent with findings reported by Shams and Abbas (2019) in broccoli, Muhemed and Mijwel (2021) in cucumber, and Rajani *et al*., (2022) in tomato.

**3.4.2. Ascorbic Acid (mg/100 g)**

Variations in ascorbic acid content among the bitter gourd varieties were not statistically significant. The highest ascorbic acid concentration was observed in IET/2023/BIGVAR-2 at 82.56 mg/100 g. The foliar application of nano boron might enhance ascorbic acid levels by facilitating more efficient nutrient uptake, boosting antioxidant activity, and supporting overall plant health. These mechanisms potentially lead to higher vitamin C content in the fruits. These results align with observations in tomato **(Rajani *et al*., 2022)** and in bitter gourd **(Kumar and Topno, 2022).**

**Table 6. Colour and fruit shape of different varieties of Bitter gourd**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variety name** | **Symbol** | **Colour** | **Fruit shape** |
| IET/2023/BIGVAR-1 | V1 | Dark pale green | Oblong |
| IET/2023/BIGVAR-2 | V2 | Dark green | Cylindrical |
| IET/2023/BIGVAR-3 | V3 | Dark green | Oblong |
| IET/2023/BIGVAR-4 | V4 | Light green | Rhomboid |
| IET/2023/BIGVAR-5 | V5 | Very light green | Globular |
| IET/2023/BIGVAR-7 | V6 | Very light green | Oblong |
| JAUNPURI | V7 | Light green | Cylindrical |

**3.5 Economic Parameter**

Economic parameters for all bitter gourd varieties were assessed by tallying the expenditures incurred from sowing through to fruit harvest. The analysis included calculating the cost of cultivation, gross return, net return, and benefit-cost ratio. Notably, variety IET/2023/BIGVAR-7 demonstrated superior economic performance, recording the highest gross return of ₹632,700 per hectare, a net return of ₹512,635 per hectare, and a benefit-cost ratio of 5.27.

**Table 7. Benefit-Cost Ratios of Different Bitter Gourd Varieties**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Name of hybrid** | **Symbol** | **Fruit yield (t/ha)** | **Cost of cultivation (Rs/ha)** | **Gross** **Return (Rs/ha)** | **Net** **Return (Rs/ha)** | **Benefit Cost Ratio** |
| IET/2023/BIGVAR-1 | V1 | 17.48 | 120065 | 262200 | 142135 | 2.18 |
| IET/2023/BIGVAR-2 | V2 | 15.93 | 120065 | 238950 | 118885 | 1.99 |
| IET/2023/BIGVAR-3 | V3 | 17.33 | 120065 | 259950 | 139885 | 2.17 |
| IET/2023/BIGVAR-4 | V4 | 18.26 | 120065 | 273900 | 153835 | 2.28 |
| IET/2023/BIGVAR-5 | V5 | 14.67 | 120065 | 220050 | 99985 | 1.83 |
| IET/2023/BIGVAR-7 | V6 | **42.18** | 120065 | **632700** | **512635** | **5.27** |
| JAUNPURI | V7 | 17.85 | 120065 | 267750 | 147685 | 2.23 |

**CONCLUSION**

The study demonstrated distinct strengths among the bitter gourd varieties when treated with nano boron. **IET/2023/BIGVAR-3** excelled in vegetative growth, recording a vine length of 2.25 m and 38.38 nodes at the final harvest. In terms of yield attributes, **IET/2023/BIGVAR-7** produced fruits with an optimal length of 12.55 cm and weight of 125.06 g, and it also achieved the highest benefit-cost ratio of 5.27. Additionally, **IET/2023/BIGVAR-5** delivered the highest number of fruits per plant (31.29 fruits) and the largest fruit diameter (46.67 mm).

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