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ENHANCING ASH GOURD GROWTH AND YIELD WITH GA_3 AND BORON APPLICATION

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Abstract
Ash gourd (Cucurbita moschata) is valued for its nutritional and commercial benefits, especially in regions with limited year-round vegetable availability like Pakistan. This study evaluated the effects of gibberellic acid (GA_3) and boron on ash gourd growth and yield using a randomized complete block design at Ghazi University, Dera Ghazi Khan (Nov 2022–Mar 2023). GA_3 significantly enhanced vegetative growth by increasing vine length, leaf number, and fruit size, while boron improved flowering, fruit set, and development. Combined application of GA_3 and boron boosted fruit number, weight, and overall yield compared to controls. Results varied by genotype and application method, indicating the need for further research to optimize rates and timing. Integrating GA_3 and boron shows promise for improving ash gourd productivity and profitability.

INTRODUCTION

Ash gourd (*Cucurbita moschata*) is an important sub-tropical and tropical cucurbitaceous vegetable. C. moschata cultivars are generally more tolerant of hot, humid weather than cultivars of c. maxima and c. pepo. It is an annual vine trailing on the ground, grown for its flesh fruit at immature stage the fruit is fuzzy, after maturity the fruit drops its hairs and develops a waxy coating, giving rise to the name 'wax gourd', and providing a long shelf life. Northern China has a long history of plant cultivation, including native and introduced Cucurbitaceae species. Currently, 12 genera and 18 species are cultivated, with some endemic to Indochina and others introduced from Western Asia and the New World. These cucurbits are used extensively as immature vegetables, fruits, medicines, and for various other purposes, as documented in traditional stories and ancient texts (Swamy, 2022). Gourd vegetables, including ash, bottle, and bitter gourds, are nutrient-rich with low fat, containing essential vitamins, minerals, and protective phytochemicals like flavonoids and polyphenolics. They offer various health benefits, such as reducing blood glucose, lipids, blood pressure, and inhibiting cancer growth. Bitter gourd, in particular, demonstrates strong antidiabetic, antiulcerogenic, and antioxidant effects (Hadi et al., 2022). Ash Gourd, or Benincasa, is a monotypic genus in the Cucurbitaceae family, known for its long storage life and medicinal properties, especially in Ayurveda. Rich in minerals (K, Na, Zn, P, Ca, Mg, Fe, Mn) and vitamins, it has low calories and no fat. Cultivated mainly in Asian tropics, it's used for the sweet 'Petha' and village nuggets (Pradhan, Nandi, Rout, et al., 2020). It is a vital Asian crop valued for its large, edible fruit and traditional medicinal uses. It's low-calorie, rich in vitamin C, potassium, magnesium, fiber, and antioxidants, aiding digestion, inflammation, diabetes prevention, and kidney health. Young gourds are sweet for cooking, while mature ones are pickled. Genetic resources are crucial for breeding demand-based cultivars, with most conserved in Asia (Sagar et al., 2025). The methanolic extract of the fruit is reported to possess antihistaminic, antidepressant activities (Kumar & Ramu, 2002). It has been used in traditional Chinese medicine to treat hypertension and inflammation. Its mature fruits are traditionally used for the treatment of week nervousness and debility (Nadhiya et al., 2014). Ash gourd is a vital vegetable across Asia and Latin America, prized for its high mineral and vitamin content, low calories, and medicinal properties (Ayurveda, traditional Chinese medicine). It's used in sweets, as a vegetable, and its various parts treat ailments from hemorrhages to diabetes. Recently, it's gained attention as a rootstock, imparting disease resistance and increasing melon yields (Pandey et al., 2015).

In Pakistan, vegetable production is not uniform throughout the year and most of the vegetables are produced in winter. So, there is a scarce of vegetable in summer season. The ash gourd production can meet up this crisis (Rahman, 1994). It has a yield potential of 20-25 tones/ha. There are several causes of such low yield. The most important one is the lack of high yielding varieties. The five major ash gourd producing countries in the world are China, India, Ukraine, Egypt and United States (Wehner et al., 2020). The Food and Agriculture Organization of the United Nations (FAO) reported that these top five squash-producing countries were stable between 2005 and 2009 for ash gourd production. By 2012, Iran had moved into the 5th slot, with Egypt falling to 6th. According to the latest data of Food and Agriculture Organization of the United Nations (FAO) the annual production of ash gourd in different Countries is as China 6,140,840 tons, India 4,424,200 tons, Russia 988,180, USA 778,630 and Iran 695,600.

Ash gourd-carrot juice, stabilized with 0.35% pectin and heat-treated at 95°C for 10 minutes, demonstrated acceptable quality for 8 weeks at 4°C and 28°C. While pH, TSS, acidity, sugar, and sensory scores remained stable, cloud stability and nutrient content (β-carotene, polyphenols) decreased. The findings support its potential for commercialization as a nutritious beverage (Lele, 2021). Blending ash gourd or bottle gourd with Kawanda significantly enhanced polyphenols, antioxidant activity, and sensory qualities of juices. Optimal blends (AgK 35:35, BgK 35:30) showed enzyme inhibitory activities. While antioxidants remained stable, polyphenols and anthocyanins decreased during storage, especially with sugar addition in BgK, which also saw higher nutrient reduction during digestion (Purohit et al., 2019).

An experiment on 46 ash gourd genotypes revealed significant variability in yield and yield-contributing traits. BH21 excelled in fruit number and yield per plant. BH16 produced the heaviest fruits, while BH17 yielded the lightest. Genetic divergence analysis grouped genotypes into eight clusters, but no correlation with geographic distribution was observed (Rabbani et al., 2013). Ash gourd genotype G-12 as ideal for high yield (6.72 kg/plant) and short-fruited cultivation under a pandal system, showing superior vine length and internodes. G-5 had the most fruits (6.6) but lowest yield, while G-6 had the heaviest fruits (2.60 kg) but fewest. Earliness varied among genotypes G-1, G-2, and G-3 (Tadkal et al., 2019). Another study analyzed 18 ash gourd genotypes over two rainy seasons (2015, 2016) to understand yield relationships. Yield per vine positively correlated with traits like branches, female flowers, sex ratio, fruit size, average fruit weight, seed weight, and vine length. Conversely, it negatively correlated with node to first female flower and days to first fruit setting. Path analysis showed that number of female flowers, vine length, fruit diameter, fruit length, days to first fruit setting, branches, and seed weight directly contributed to ash gourd yield (Pradhan, Nandi, Das, et al., 2020).

Gibberellic acid (also called Gibberellin GA, and GA3) is a gibberellin which is a growth promoter and N-(2-chloro-4-pyridyl)-N-phenylurea (CPPU) is a cytokinin. This Freesia 'Golden Melody' study in Baghdad explored GA3 and CPPU sprays. GA3 at 100 mg/L significantly improved vegetative growth and flowering parameters, including plant height, leaf area, chlorophyll, and flower number. CPPU at 20 mg/L also boosted vegetative growth and flowering, notably increasing leaf number and advancing bloom. Combined treatments further enhanced most measured characteristics (AL-Chalabi & Al-Khafaji, 2016). CPPU, a cytokinin, induces melon fruit set by increasing cell density and size, comparable to pollinated fruits. It promotes gibberellin (GA) and auxin accumulation while decreasing abscisic acid. CPPU specifically upregulates CmGA20ox1, a GA synthase, via CmRR2 in the cytokinin pathway. This reveals CPPU-induced fruit set relies on GA biosynthesis, offering insights for parthenocarpic melon breeding (Liu et al., 2023). A Faisalabad study examined GA3's effect on wheat under water stress. 200 mg L-1 GA3 mitigated negative impacts of skipping irrigation at grain filling, improving plant height, spike length, 1000-grain weight, protein content, and harvest index. GA3 and water regime interactions significantly affected protein and harvest index, suggesting GA3 can partially offset water stress (Nouman et al., 2025).

In cantaloupe effect of ethephon was investigated and results revealed that with a high dose of ethephon (200 ppm) at all stages of growth there was reduction of yield and female to male flowers (Arabsalmani et al., 2012). Seedlings of snake gourd were sprayed with ethephon (0, 25, 50, 100 ppm) at 2nd and 4th true leaf stages.

In ridge gourd (Luffa *acutangula L. Roxb*), GA3 (50 ppm,) Ethrel (500 ppm), NAA (100 ppm) and control (water spray) with three different stages of spray were used. Maximum number of branches per vine were recorded with spraying of Ethrel (500 ppm) at 4th leaf, flower and fruit initiation stage (Hilli et al., 2010). The effects of naphthaleneacetic acid (NAA), gibberellic acid (GA3), 6-benzylaminopurine (BA), N-(2-chloro-4-pyridyl)-N-phenylurea (CPPU) N, N%-diphenyl urea (DPU) and N-(4-pyridyl)-N%-phenylurea (4-PU) on fruit set of Chinese white flowered gourd (*Lagenaria leucantha*) was investigated which revealed that CPPU has high tendency towards parthenocarpy development. Also, CPPU increased fruit set percentage and growth (Yu, 1999).

Three plant growth regulators were sprayed, separate and in different combinations, at the two, four and six leaf and full-bloom stage in cucumber. Results revealed that the influence of the plant growth regulators was variable on the morphological characters of cucumber but the floral and yield traits were significantly affected by a combined application of 100 ppm maleic hydrazide and 100 ppm ethephon (Thappa et al., 2011).

The maximum fruit yield was observed by spraying of NAA (50 ppm) which was higher than control. Application of GA3 at 25 ppm recorded maximum number of fruits per plants (15.8) (Dostogir Hossain et al., 2006). GA3 (10 ppm) at two and four true leaf stages in watermelon recorded maximum fruit yield over control. The total fruit yield per hectare increased with the application of GA3 (5 ppm) at 21 and 28 days after sowing in bottle gourd (Mishra et al., 1972). It was reported that the seed treated with GA3 (100, 200, 300 ppm) improved its germination. They attributed this may be due to its effect on various metabolic activities, as it stimulates synthesis of hydrolytic enzymes, secreted and act on starchy endosperm in turn affecting physiology of seed germination and establishment of seedling but not significantly superior over control (Bhat & Singh, 1996).

A pot experiment to study the effect of GA3 and cytokinin on vegetative growth of soybean. GA3 (50 mg L-I) was applied as seed treatment and plants with water application as control. GA3 (100 mg L-l) and cytokinin (30 mg L-I) were sprayed on leaves at the physiological stage V3/V4 and 15 days after. Seed treatment decreased plant emergence and initial soybean root growth, but as the season progressed, differences in root growth disappeared; plants were shorter and presented a decrease in number of nodes, stem diameter, leaf area and dry matter yield. Conversely, foliar application of GA3 led to an increase in plant height, first node height and stem diameter. Leaf area and dry matter production also increased as a result of GA3 foliar application. There was no effect of exogenous gibberellin and cytokinin on the number of soybean leaves, number of stem branches and root dry matter. Joint application of gibberellin and cytokinin tend to inhibit gibberellin effects. Cytokinin applied to leaves during soybean vegetative growth was not effective in modifying any of the evaluated plant growth variables (Leite et al., 2003).

Materials and Methods

This research work was conducted to determine the effect of GA3 and Boron on the growth and yield of Ash gourd. Research work was conducted at "Ghazi University", Dera Ghazi Khan, Punjab, Pakistan, from November 2022 to March 2023. The location of the experiment was 23° 46°N latitude and 90 22°E longitude with 10-meter elevation from Sea level.

Materials

Plant material

Seeds of ash gourd were purchased from the local market of Dera Ghazi Khan.

Plant Growth Regulators (PGPRs)

Different plant growth regulators were used in the experiment and Ash gourd seeds were treated according to research treatments.

Methodology

3.1.3.1. Climate of the Experimental Area:

The experimental area was characterized by subtropical rainfall during the month of May and September and scattered rainfall during the rest of year.

Soil:

A deep loamy soil with the pH range of 5-7.5 is suitable. A warm tropical climate is ideal for higher yield.

Seed Rate:

2.5 kg of seed was used for one hectare.

Seed Treatment:

Seeds were soaked in double quantity of water for 30 minutes and incubated for 6 days. The seeds were treated with Carbendazim 2 g/kg of seeds before sowing.

Field Preparation:

Field was ploughed for 3-4 times. Then pits of 30 cm x 30 cm x 30 cm at a spacing 2 x 1.5 m were made with basins.

Experimental Layout:

Randomized complete block design (RCBD) was used with three replications.

Seed Sowing:

Five to six seeds were sown in each pit. After germination, the seedlings were thinned to two per pit.

Cultural Practices:

Hoeing and weeding was done as and when necessary. Ethrel 250 ppm (2.5 ml/10 lit of water) was sprayed four times at weekly intervals commencing from 15th days after sowing. (pl. confirm it 1st if Ethrel was used, if it was not used then delete these highlighted lines).

RESULTS AND DISCUSSIONS

Main Vine Length (cm)

Statistical analysis of the data showed significant results for the main vine length of ash gourd (Table 1). Among all treatments T4 (0.05% Boron + 50 ppm GA3) depicted good results with maximum main vine length of 364.42 cm followed by the other three treatments T3 (GA3 100 ppm) 355.29 cm, T2 (Boron 0.05%) 348.7 cm and T1 (GA3 50 ppm) 348.7 cm, all these treatments are statistically at par with each other. Untreated/control plants where no treatment was used showed minimum vine length of 335.81 cm (Fig. 1).

Our results were in a line with the findings of Ingle et al. (2000) they noticed the effect of GA3 on bottle gourd. They reported that GA3 @ 20 ppm increased the main vine length (473.33 cm) and number of branches (10.66) of bottle gourd. Only a minute quantity of GA3 can positively affect the growth- and growth-related traits of the plants.

Table 1: Analysis of Variance (ANOVA) for Main Vine Length (cm).

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	19.22	9.612		
Treatments	4	1323.67	330.916	236.69	

Error	8	11.18	1.398		
Total	14	1354.07			

*** = Highly significant at P ≤ 0.001
** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

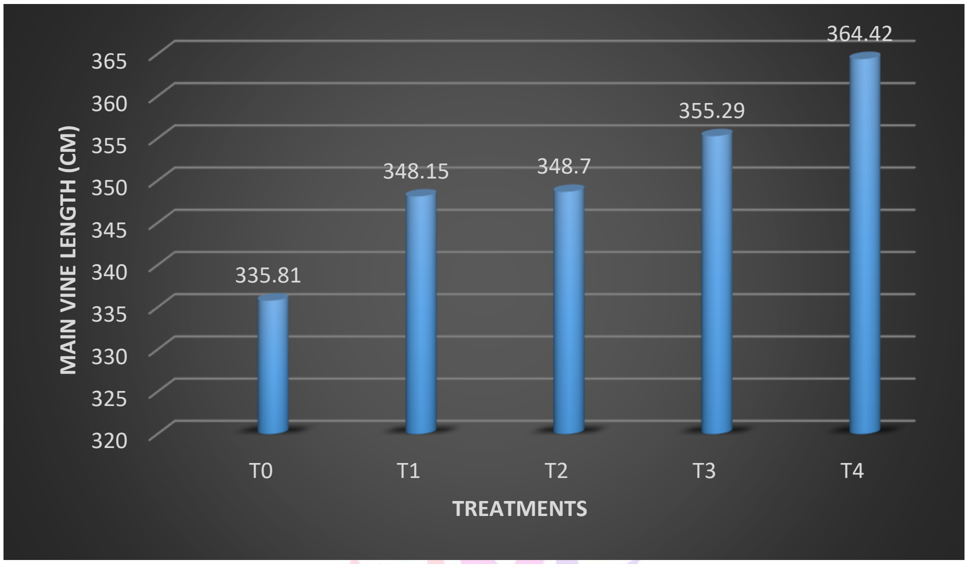


Fig. 1. Effect of GA3 and Boron on Main Vine Length.

Number of Leaves/Vine:
Statistical analysis of the data revealed significant differences for the number of leaves per vine (Table 2). Among all treatments T4 (0.05% Boron + 50ppm GA3) showed maximum number of leaves 59.000, followed by T3 (GA3 100 ppm) 57.000 and T2 (Boron 0.05%) 55.000 that were statistically at par with each other. Whereas, minimum number of leaves per vine were observed in control/To (50.000) where no treatment was applied (Fig. 2).

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	8.400	4.2000		
Treatments	4	159.600	39.9000	199.50	0.0000
Error	8	1.600	0.2000		
Total	14	169.600			

Table 2: Analysis of Variance (ANOVA) for the No. of Leaves/Vine.
*** = Highly significant at P ≤ 0.001

** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

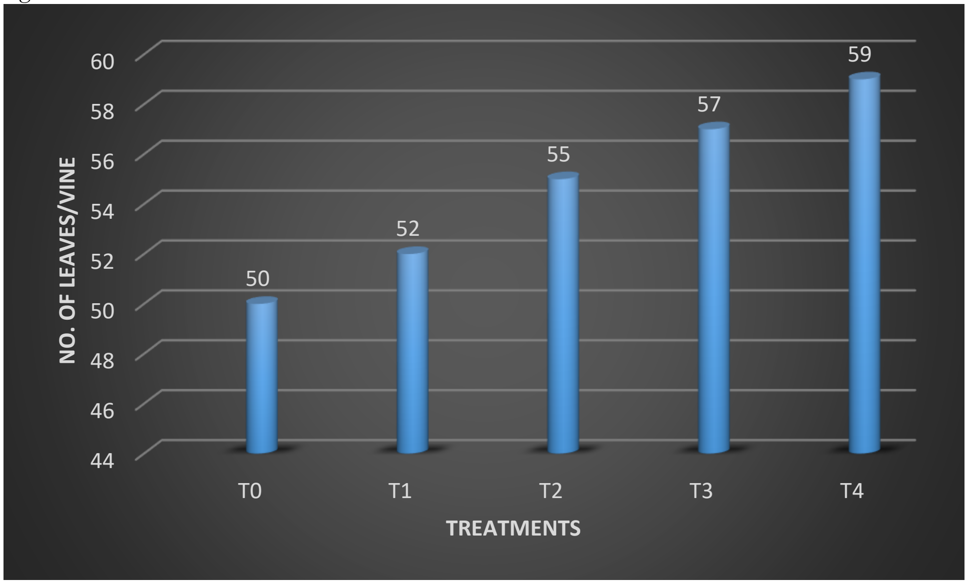


Fig. 2. Effect of GA3 and Boron on No. of Leaves/vine.

No. of Nodes/Vine

Significant differences for no. of nodes per vine were observed among different treatments (Table. 3). Different treatments affect significantly on number of nodes per vine. T4 (0.05% Boron + 50ppm GA3) showed maximum number of nodes/vines 14.4, followed by T3 (GA3 100 ppm) 12.15 and T2 (Boron 0.05%) 11.333 statistically at par with each other. T1 where only GA3 50 ppm was used and control/To give minimum number of nodes per vine 7.9 and 6.293 respectively (Fig. 4.3).

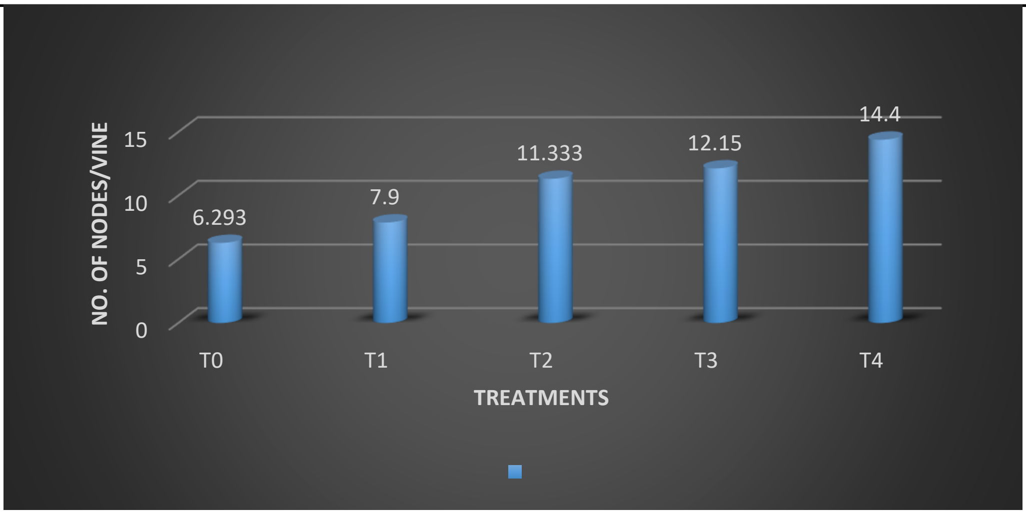
Our results were similar with the findings reported for obtaining maximum number of nodes per plant by the application of PGPRs (Almeida & Pereira, 1996).

Table 3: Analysis of Variance (ANOVA) for Number of Nodes/Vine.

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.548	0.2739		
Treatments	4	129.141	32.2854	292.92	0.0000
Error	8	0.882	0.1102		
Total	14	130.571			

*** = Highly significant at P ≤ 0.001
** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

Fig. 3. Effect of GA3 and Boron on the No. of Nodes/Vine.



No. of Branches/Vine

Statistical analysis of the data revealed significant differences for number of branches per vine with different treatments (Table 4). T4 (Boron (0.05%) + GA3 50 ppm) showed maximum number of branches (5.30) followed by T3 (GA3 50ppm) 4.616. Whereas, minimum number of branches were counted in control/To (2.130) statistically similar with number of branches present in T1 (GA3 50 ppm) 2.86 (Fig. 4).

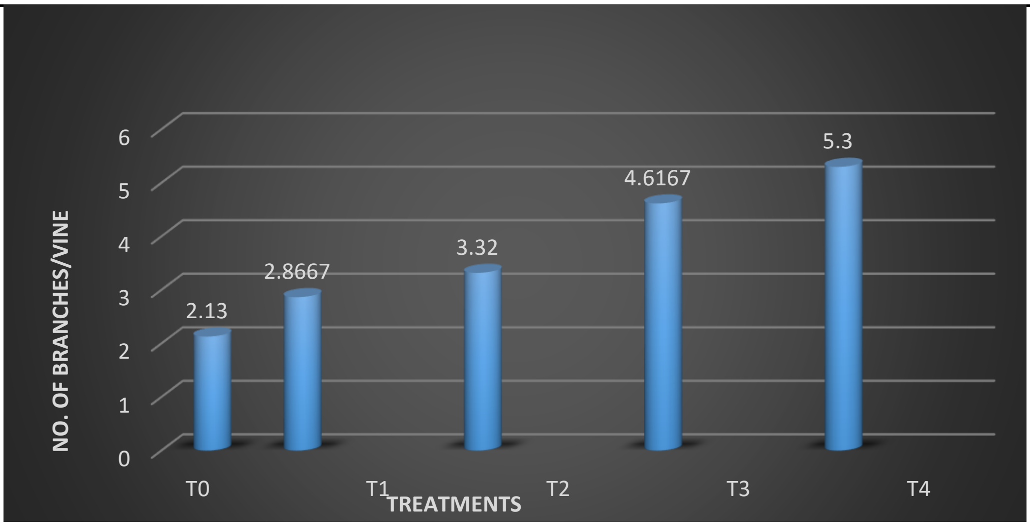
Our results were in a line with the findings were noticed the effect of GA3 on the bottle gourd vines. They reported that GA3 @ 20 ppm increased the number of branches/vine (10.66). Our findings were also similar with the findings of Mangal et al. (1981) they recorded the reduction in plant height and increase in number of branches with the application of Ethrel 500 ppm at four leaf stage in bitter gourd (Ingle et al., 2000).

Table 4: Analysis of Variance (ANOVA) for the Number of Branches/Vine.

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.2546	0.12729		
Treatments	4	20.0694	5.01735	741.12	0.0000
Error	8	0.0542	0.00677		
Total	14	20.3781			

*** = Highly significant at P ≤ 0.001
** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

Fig. 4. Effect of GA3 and Boron on the No. of Branches/Vine.



Internodal Length on Main Vine

Statistical analysis of the data showed significant results for the intermodal length on main ash gourd vine (Table 5). T4 (0.05% Boron + 50 ppm GA3) depicted minimum intermodal length on the main vine 7.07 cm followed by T1 (GA3 50 ppm) 7.15 cm and T2 (Boron 0.05%) with 7.19 cm. whereas, T3 (GA3 100 ppm) showed maximum intermodal length on main vine 7.67 cm (Fig. 5).

Our findings were opposed with the findings considerable increase in internodes' distance (13.5 cm) when GA3 was applied @ 25 ppm in Pumpkins (Arora & Partap, 1988).

Table 5: Analysis of Variance (ANOVA) for Intermodal Length on Main Vine (cm).

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.36532	0.18266		
Treatments	4	0.67463	0.16866	5.25	0.0225
Error	8	0.25681	0.03210		
Total	14	1.29676			

*** = Highly significant at P ≤ 0.001
** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

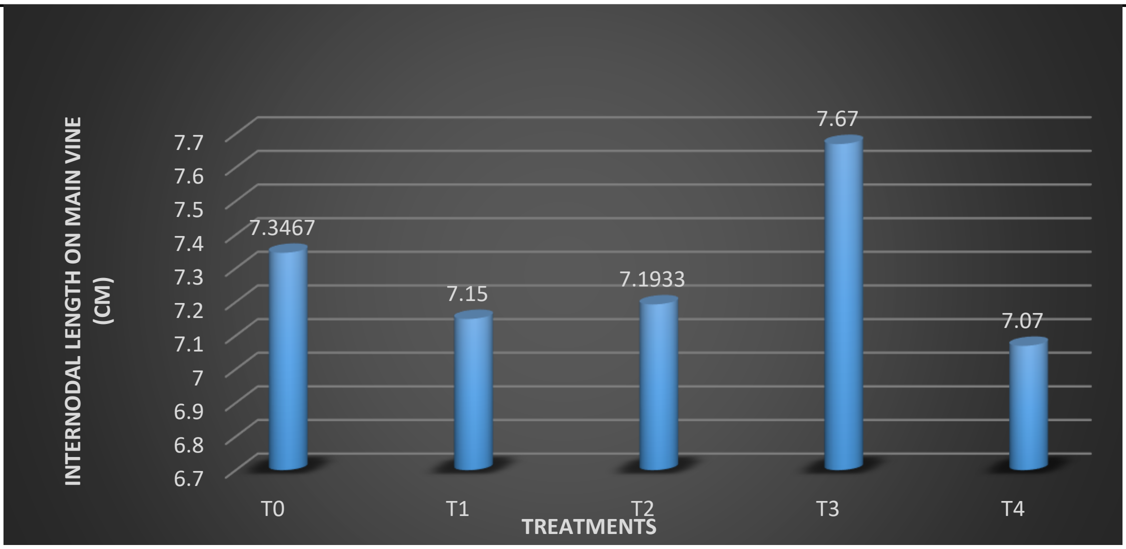


Fig. 5. Effect of GA3 and Boron on the Internodal Length on the Main Vine (cm).

Physiological Parameters

No. of Days to 1st Male Flower

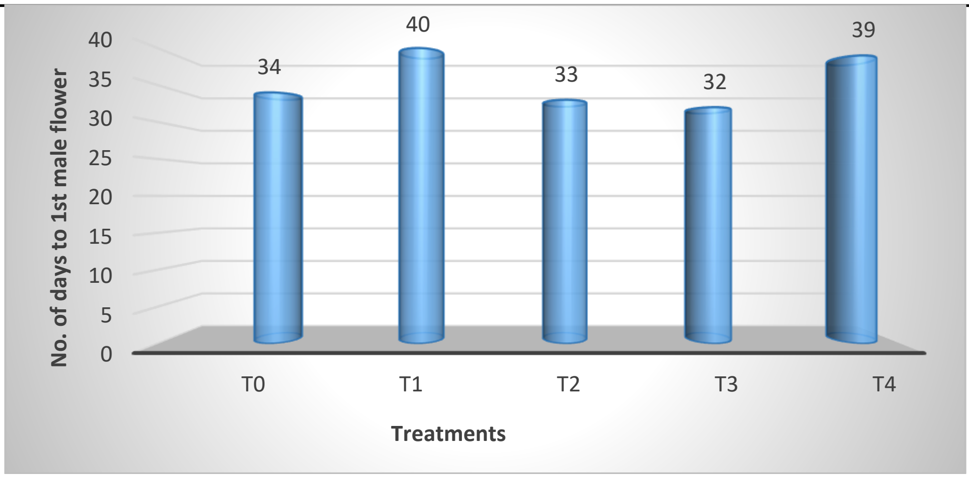
Analysis of variance of the data regarding no. of days to 1st male flower initiation depicted significant results among all treatments (Table 6). Minimum days to 1st male flower initiation were taken by T3: GA3 100 ppm (32 days) and T2: (Boron 0.05%) (33 days), statistically at par with control to (34 days). While, T1 (GA3 50 ppm) took maximum days to 1st male flower initiation (40 days) with statistically similar values of T4: 0.05% Boron + 50 ppm GA3 (39 days) (Fig. 6). Our findings were justified by the findings, they observed a smaller number of days taken to 1st male flower appearance (35 days) with the application of GA3 @ 25 ppm in ridge gourd (Arora et al., 1987).

Table 6: Analysis of Variance (ANOVA) for the no. of Days to 1st Male Flower.

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.378	0.01889		
Treatments	4	30.4319	7.60798	267.78	0.0000
Error	8	0.2273	0.02841		
Total	14	30.6970			

*** = Highly significant at $P \leq 0.001$
** = Significant at $P \leq 0.05$
NS = Non-Significant at $P > 0.05$

Fig. 6. Effect of GA3 and Boron on the No. of Days to 1st Male Flower.



No. of Days to 1st Female Flower

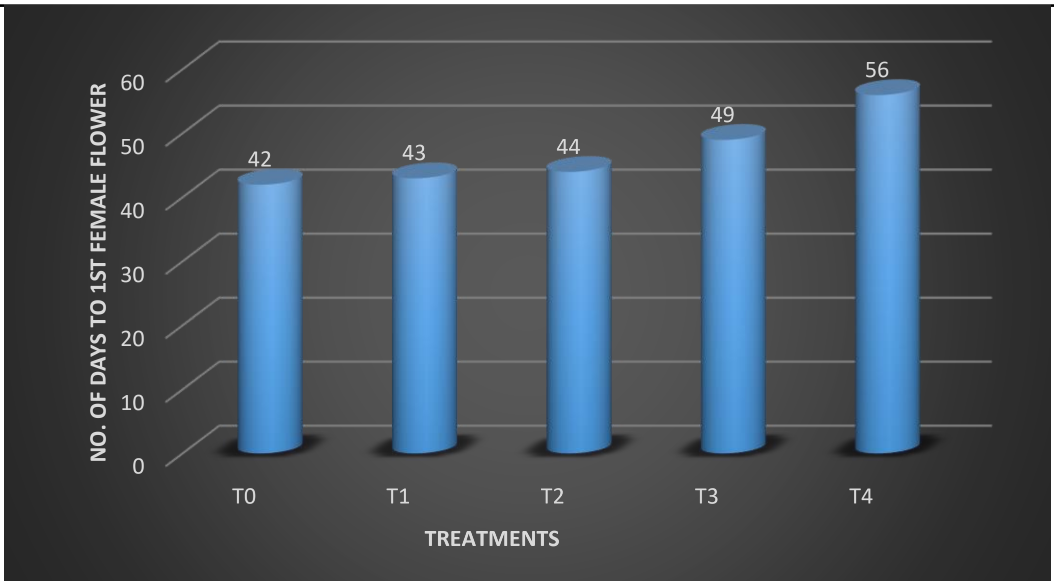
Analysis of variance of the data regarding no. of days to 1st female flower initiation depicted significant results among all treatments (Table 7). Minimum no. of days to 1st female flower initiation were taken by Control/To, without any treatment (42 days), followed by T1: GA3 50 ppm (43 days) and T2: Boron 0.05% (44 days), that were statistically at par with each other. Whereas, T4: 0.05% Boron + 50 ppm GA3 took maximum days to 1st female flower initiation (56 days) (Fig. 7). Our results were antagonistic to the findings, observed that bitter gourd plants treated with GA3 at 35 ppm produced the earliest female flowers (Gedam et al., 1998). GA3 at two- and four-leaf stages in bitter gourd and observed earliness in the initiation of first female flower (43.5 days) as compared to control and other chemicals (Verma et al., 1984).

Table 7: Analysis of Variance (ANOVA) for the Number of Days to 1st Female Flower.

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.378	0.01889		
Treatments	4	30.4319	7.60798	267.78	0.0000
Error	8	0.2273	0.02841		
Total	14	30.6970			

*** = Highly significant at $P \leq 0.001$
** = Significant at $P \leq 0.05$
NS = Non-Significant at $P > 0.05$

Fig. 7. Effect of GA3 and Boron on the No. of Days to 1st Female Flower.



No. of Male Flowers/Vine

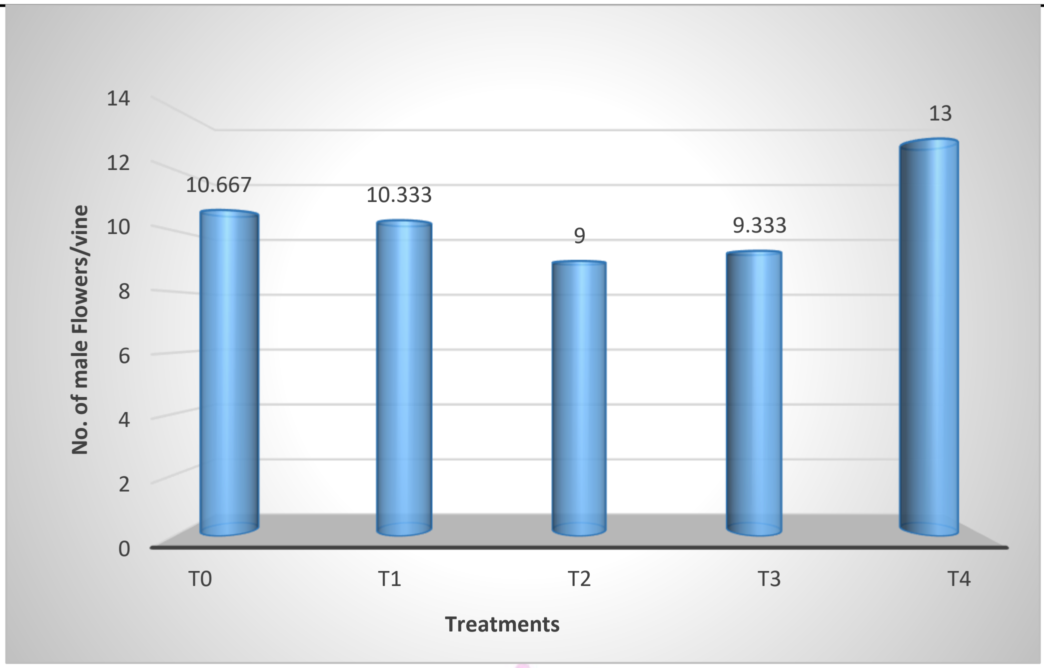
Statistical analysis of the data revealed significant differences for number of male flowers per vine with different treatments (Table 8). T4 (Boron (0.05%) + GA3 50 ppm) showed maximum number of male flowers/vine (13) followed by control/To (10.667) statistically similar with number of male flowers present in T1 (GA3 50 ppm) treated plants (10.333) (Fig.8). Whereas, minimum number of male flowers/vines were counted in T2: Boron 0.05% (9) statistically at par with T3: GA3 50 ppm (9.333). Our results were in a line with the findings, that application of GA3 at the rate of 40 ppm at two to four leaf stages gave a greater number of male flowers and also the early appearance of first male flower bud and decreased sex ratio (18.8 to 6.4) as compared to lower 20 ppm and higher 80 ppm concentration of GA3 and control in bitter gourd (Ghosh & Basu, 1982).

Table 8: Analysis of Variance (ANOVA) for the No. of Male Flowers/Vine.

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.5333	0.26667		
Treatments	4	29.7333	7.43333	5.19	0.0233
Error	8	11.4667	1.43333		
Total	14	41.7333			

*** = Highly significant at $P \leq 0.001$
** = Significant at $P \leq 0.05$
NS = Non-Significant at $P > 0.05$

Fig. 8. Effect of GA3 and Boron on the No. of Male Flowers/Vine.



No. of Female Flowers/Vine

Statistical analysis of the data revealed significant differences for number of female flowers per vine with different treatments (Table 9). T4 (Boron (0.05%) + GA3 50 ppm) showed maximum number of female flowers/ vine (9.66) followed by T3: GA3 50 ppm (9.00). Whereas, minimum number of female flowers/ vine were counted in control/To (6.33) (Fig 9).

Our results were justified by the findings of Ghosh and Basu (1982) they observed that application of GA3 at the rate of 40 ppm at two to four leaf stages gave a greater number of female flowers and also the early appearance of first female flower bud.

Table 9: Analysis of Variance (ANOVA) for the No. of Female Flowers/Vine.

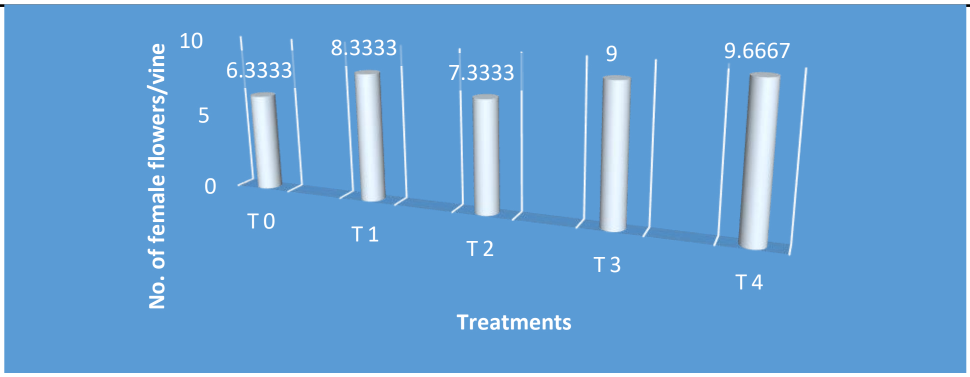
Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.5333	0.26667		
Treatments	4	21.0667	5.26667	4.16	0.0412
Error	8	10.1333	1.26667		
Total	14	31.7333			

*** = Highly significant at $P \leq 0.001$

** = Significant at $P \leq 0.05$

^{NS} = Non-Significant at $P > 0.05$

Fig. 9. Effect of GA3 and Boron on the No. of Female Flowers/Vine.



Fruit Characters of ash gourd

Fruit Length (cm)

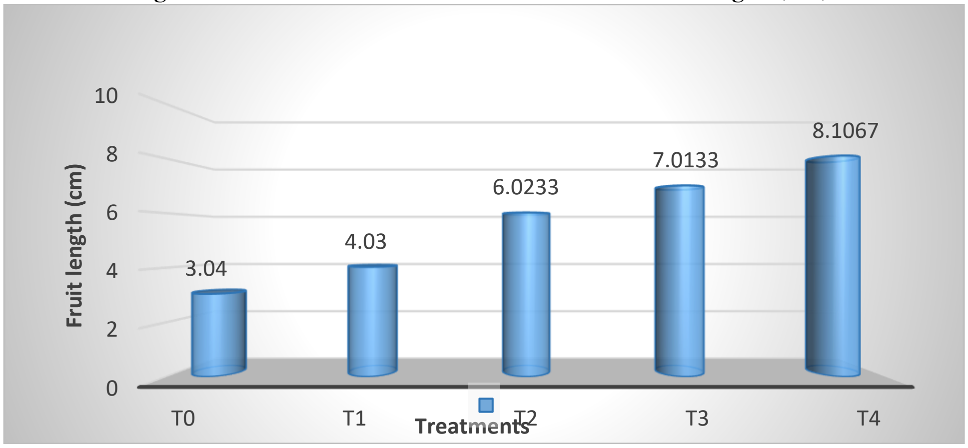
Statistical analysis of the data showed significant results for ash gourd fruit length (Table 10). Among all treatments T4 (0.05% Boron + 50 ppm GA3) give good results with maximum fruit length of 8.106 cm followed by the other two treatments T3 (GA3 100 ppm) 7.013 cm and T2 (Boron 0.05%) 6.023 cm. Whereas, minimum fruit length of 3.04 cm was observed in controlled conditions (To) (Fig. 10). Our findings were supported by the findings, obtained maximum fruit length by the application of PGPRs. Similar results were also obtained and observed 132.23 cm Okra fruit length (Hye et al., 2002).

Table 10: Analysis of Variance (ANOVA) for the Fruit Length (cm).

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.9636	0.4818		
Treatments	4	52.4085	13.1021	523.07	0.0000
Error	8	0.2004	0.0250		
Total	14	53.5725			

*** = Highly significant at P ≤ 0.001
** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

Fig. 10. Effect of GA3 and Boron on the Fruit Length (cm).



Fruit Diameter (cm)

Analysis of variance of the data revealed significant results for fruit diameter (Table 11). All treatments showed good results, especially treatment T4 (0.05% Boron + 50 ppm GA3) that depicted maximum fruit diameter of 16.303 cm followed by the other two treatments T3 (GA3 100 ppm) 13.933 cm and T2 (Boron 0.05%) 13.17 cm. Whereas, the minimum fruit diameter of 8.0 cm was observed in control (To) (Fig. 11).

Our findings were supported by the findings, obtained maximum fruit diameter by the application of PGPR. Similar results were also obtained and reported that there was fruits diameter (Pirlak et al., 2007)

Table 11: Analysis of Variance (ANOVA) for Fruit Diameter (cm).

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.015	0.0077		
Treatments	4	129.689	32.4222	321.78	0.0000
Error	8	0.806	0.1008		
Total	14	130.510			

*** = Highly significant at P ≤ 0.001
** = Significant at P ≤ 0.05
NS = Non-Significant at P > 0.05

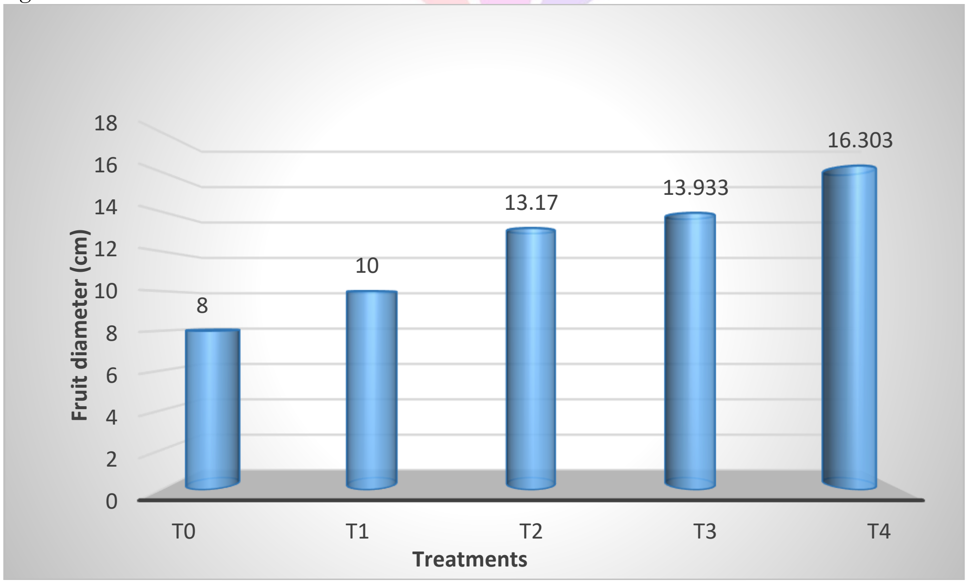


Fig. 11. Effect of GA3 and Boron on the Fruit Diameter (cm).

No. of Fruits/Vine

Statistical analysis of the data revealed significant differences for number of fruits/vines with different treatments (Table 12). T4 (Boron (0.05%) + GA3 50 ppm) showed maximum number of fruits/vine (7.583) followed by T3: GA3 50 ppm (6.193) statistically similar with T2: Boron 0.05% (5.09) (Fig. 12). Whereas, minimum number of fruit/vines were counted in to (1.88).

Our findings were supported with the maximum number of fruits per plant by the application of PGPR (Orhan et al., 2006).

Table 4.12: Analysis of Variance (ANOVA) for the No. of Fruits/Vine.

Sources of Variations	Degree of Freedom	Sum of Squares	Means Square	F-Value	P-Value
Replications	2	0.2822	0.1411		
Treatments	4	62.1430	15.5358	293.76	0.0000
Error	8	0.4231	0.0529		
Total	14	62.8483			

Conclusions:

The study conclusively demonstrates that foliar application of gibberellic acid (GA_3) and boron significantly enhances the growth and yield parameters of ash gourd (*Cucurbita moschata*). Combined treatment with 50 ppm GA_3 and 0.05% boron showed superior results in increasing vine length, number of leaves, branches per vine, and fruit yield compared to individual treatments or control. GA_3 primarily stimulated vegetative growth by promoting cell elongation, whereas boron improved reproductive traits such as flowering, fruit set, and development, which collectively contributed to enhanced yield and fruit quality. The interaction effects were highly significant, underlining the importance of integrating growth regulators and micronutrients in crop management strategies. However, the study also noted variability in responses depending on application timing and genotype, suggesting the need for optimized protocols. Further research should focus on fine-tuning the concentration and timing of GA_3 and boron applications for different ash gourd cultivars under varied agro-climatic conditions to maximize benefits. Additionally, exploring the molecular mechanisms underlying the synergistic effects of GA_3 and boron could enable development of precision agriculture applications. Integrating these growth regulators with sustainable nutrient and pest management practices could significantly boost productivity and profitability for growers. Expansion of such treatments to related cucurbits can also diversify and stabilize off-season vegetable supply, particularly in regions with limited summer vegetable production.

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