Journal of Advances in Biology & Biotechnology

Volume 27, Issue 6, Page 293-301, 2024; Article no.JABB.116839
ISSN: 2394-1081

Effect of Plant Growth Regulators on Growth, Fruit Yield and Quality of Kharif Season Bitter Gourd (*Momordica charantia* L.)

Ram Gopal [a++*], Vijay Bahadur [a#] and Samir E Topno [a†]

[a] Department of Horticulture, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i6888

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/116839

Original Research Article

Received: 07/03/2024
Accepted: 10/05/2024
Published: 13/05/2024

ABSTRACT

The present was conducted at Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during the session 2022 - 2024. The experiment was laid out in randomized block design with three replications, and the study consists of ten treatment combinations including control. The best treatment was T12 (NAA200ppm) &T11 (NAA150ppm) which shows highest values in all the parameters viz., day to germination (10.20), survival % (71.02%), vine length at last harvest (228.02), number of days to

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[++] *M.Sc. Scholar;*
[#] *Associate Professor and Head;*
[†] *Assistant Professor;*
**Corresponding author: E-mail: ramgopalchoudhary78956@gmail.com;*

Cite as: *Gopal, R., Bahadur, V., & Topno, S. E. (2024). Effect of Plant Growth Regulators on Growth, Fruit Yield and Quality of Kharif Season Bitter Gourd (Momordica charantia L.). Journal of Advances in Biology & Biotechnology, 27(6), 293–301. https://doi.org/10.9734/jabb/2024/v27i6888*

first male flower appearance (43.10), number days to first female flower appearance (53.67), number of days to 50% flower first picking (61.85), number fruit per vine (31.23), average fruit length (20.79cm), average fruit diameter (4.34), average fruit weight (88.05 g), average fruit yield per plant (49.83 kg), TSS (189 °brix), vitamin C (85.33). Increased flowering, fruit yield, quality and economics might be due to the increased absorption of nutrients when given as foliar application.

Keywords: Bitter gourd; NAA; growth regulators.

1. INTRODUCTION

"Bittergourd (*Momordica charantia* L.) is one of the most important cucurbitaceous vegetable widely cultivated in India. The importance of bittergourd has long been recognized due to its high nutritive value and medicinal properties. The fruit is a rich source of vitamin C, iron, phosphorous and carbohydrates" [1]. "A compound known as charantin, present in the bittergourd is used in the treatment of diabetes inreducing blood sugar level. This vegetable is a different nature's bountiful gifts to mankind, which does not only have fabulous digestional properties, but also it is a storehouse of remedies for many common ailment such as diabetes, rheumatism and gout" [2].

With an annual production of 11,37,000 tonnes and a productivity of 11.72 t ha, the crop is grown over 97,000 hectares in India" [3] Kerala, Tamil Nadu, Maharashtra, and Karaataka are the main states in India that grow bitter gourds. 2,880 hectares of bitter gourd are grown in Kerala, where 42,250 tonnes are produced annually [4]. The short harvest length combined with the high market price makes it profitable for Keralan vegetable growers. With an average yield of 25–30 t/ha, preethi is a bitter gourd variety that yields well and is commonly planted in Kerala.

"Gibberellins are the most powerful growth promoters because they increase internodes spacing, induce and promote flowering in many plants and modify the flower sex expression in some plants" [5]. "There are four types of gibberellins but gibberellic acid, GA_3 is best known. It promote growth, cell elongation, cambial activity, stimulate nucleic acid and protein synthesis, seed germination and help in breaking dormancy, fruit set and leaf expansion" [5].

Although the PGRs have a great potential to influence plant growth morphogenesis, it is important to carefully plan their application and accrual assessments in terms of the best concentrations, application stages, species specificity, and seasons, which are the main barriers to the PGRs' applicability. Due to their sensitivity, different plant stages are the main factors taken into account while applying PGR. "Applying plant growth regulators at the 2-leaf and flower initiation stage significantly improves early flowering, harvesting, and maximum fruit setting" [6].

"Among the growth promoters, GA_3 and NAA play a key role in improving plant growth and vegetable harvesting. GA_3 is one of the key growth factors that promote cell division and cell proliferation, thus contributing to the growth and development of many plants. NAA affects body processes, speeds up maturation and improves the quality of vegetables and fruits. The use of crop growth controllers to improve yields and the quality of many vegetable crops was emphasized by a few workers" [7].

2. MATERIALS AND METHODS

This experiment was laid out during the July 2023 to Oct. 2024 at Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The horticulture research farm is situated at 25^0 39" 42" N latitude, 81^0 67" 56" E longitude and at an altitude of 98 m above mean sea level. The treatment consisted of T_0 Control, T_1 - GA_3 75ppm, T_2 - GA_3 100ppm, T_3 - GA_3 150ppm, T_4 - GA_3 200ppm, T_5 - Ethrel 300 ppm, T_6 - Ethrel 400 ppm, T_7 - Ethrel 500 ppm, T_8 - Ethrel 600 ppm, T_9 - NAA 50 ppm, T_{10} - NAA 100 ppm, T_{11} - NAA 150 ppm, T_{12} - NAA 200 ppm. The experiment was laid out in a Randomized Block Design with 13 treatments and replicated thrice. Data recorded on different aspects of fruit crop, *viz.,* growth, yield were subjected to statistically analysis by analysis of variance method [8] and economic data analysis mathematical method.

3. RESULTS AND DISCUSSION

3.1 Germination Parameters

Days to Germination: The data on days to germination of Bitter gourd as influenced by growth regulator are summarized in Table 1.

The data reveals that the days to germination of bitter gourd increased significantly by the application of NAA under experiment over the control. The minimum days to germination (10.20) was recorded with treatments 12 (NAA 200 ppm) while the maximum Days to germination (12.36) was recorded under control. Further, the interaction effect of NAA significantly influenced the days to germination.

The minimum in number of Days to germination of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Ajay et al. [9]. While the maximum value in treatment T0 (control) may owe to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters (number of days to germination use of NAA may be due to its effect in cell division and cell enlargement Kumar et al. [10].

Survival Percentage (%): The data on survival percentage (%) of Bitter gourd as influenced by growth regulator are summarized in Table 1.

The data reveals that the survival % of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum survival % (71.02%) was recorded with treatments 12 (NAA 200 ppm) while the minimum number Survival % (47.08%) was recorded under control. Further, the interaction effect of NAA significantly influenced the survival %.

The maximum survival % of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Kumar et al. [11]. While the maximum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters Survival %use of NAA may be due to its effect in cell division and cell enlargement Anayat et al. [12].

3.2 Quality Parameter

TSS °Brix: The data on TSS °Brix of Bitter gourd as influenced by growth regulator are summarized in Table 1.

The data reveals that the TSS °Brix of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum TSS °Brix (189) was recorded with treatments 12 (NAA 200 ppm) while the minimum TSS °Brix (1.42) was recorded under control. Further, the interaction effect of NAA significantly influenced the TSS °Brix.

Table 1. Effect of plant growth regulators on germination and quality of Bitter

Treatment Symbol	Treatment combinations	Days to germination	Survival %	TSS °Brix	Vitamin C (mg/100ml)
T_0	Control	12.36	47.08	1.42	69.96
T_1	GA_3 75ppm	11.23	62.21	1.54	78.00
T_2	GA_3 100ppm	11.23	58.87	1.48	77.00
T_3	GA_3 150ppm	11.26	53.31	1.42	76.00
T_4	GA_3 200ppm	11.53	49.47	1.38	73.00
T_5	Ethrel 300 ppm	10.66	69.00	1.79	80.66
T_6	Ethrel 400 ppm	10.93	68.21	1.74	82.00
T_7	Ethrel 500 ppm	11.06	68.81	1.67	81.00
T_8	Ethrel 600 ppm	11.07	66.7	1.63	80.00
T_9	NAA 50 ppm	11.07	66.01	1.59	79.00
T_{10}	NAA 100 ppm	10.60	69.41	1.82	84.00
T_{11}	NAA 150 ppm	10.62	69.84	1.86	85.00
T_{12}	NAA 200 ppm	10.20	71.02	1.89	85.33
	F-test	**S**	**S**	S	S
	SEm(±)	0.35	1.92	0.08	2.45
	CD (p=0.05)	1.02	5.61	0.24	7.14

Maximum TSS °Brix in treatment- NAA might be attributed to rapid mobilization of sugars and other soluble solids to developing fruits Rajashree and Deepanshu [13]. It may be due to fact that NAA increases palatability of fruit by influencing blend of TSS, total sugar, vitamin C and juice content as observed by, Kokkirala et al. [14].

Vitamin C (mg/100ml): The data on Vitamin C of Bitter gourd as influenced by growth regulator are summarized in Table 1.

The data reveals that the Vitamin C of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum Vitamin C (85.33) was recorded with treatments 12 (NAA 200 ppm) while the minimum Vitamin C (69.96) was recorded under control. Further, the interaction effect of NAA significantly influenced the Vitamin C.

The maximum Vitamin C of Bitter gourd due to treatment might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Khatoon et al*.* [15]. While the minimum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters Vitamin C use of NAA may be due to its effect in cell division and cell enlargement Kumar et al*.* [16].

3.3 Vegetative Parameters

Vine length at last harvest (cm): The data on vine length at last harvest of bitter gourd as influenced by growth regulator are summarized in Table 2.

The data reveals that the vine length at last harvest of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum Vine length at last harvest (228.02) was recorded with treatments 12 (NAA 200 ppm) while the minimum vine length at last harvest (71.35) was recorded under control. Further, the interaction effect of NAA significantly influenced the vine length at last harvest

The maximum in vine length at last harvest of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Kumar et al*.* [11]. While the maximum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters number of Vine length at last harvest use of NAA may be due to its effect in cell division and cell enlargement Anayat et al*.* [12].

Days to first male flower appearance: The data on days to first male flower appearance of Bitter gourd as influenced by growth regulator are summarized in Table 2.

Table 2. Effect of plant growth regulators on vegetative growth of Bitter gourd

Treatment Symbol	Treatment combinations	Vine length at last harvest (cm)	Days to first male flower appearance	Days to first female flower appearance
T_0	Control	171.35	49.63	63.32
T_1	GA_3 75ppm	196.40	47.11	65.00
T_2	GA_3 100ppm	183.65	59.08	60.19
T_3	GA_3 150ppm	177.70	60.19	59.09
T_4	GA_3 200ppm	172.89	65.00	47.11
T_5	Ethrel 300 ppm	214.72	53.46	62.31
T_6	Ethrel 400 ppm	211.09	54.23	55.13
T_7	Ethrel 500 ppm	209.83	56.30	56.30
T_8	Ethrel 600 ppm	205.06	55.13	54.23
T_9	NAA 50 ppm	200.11	62.31	53.67
T_{10}	NAA 100 ppm	222.26	43.36	54.21
T_{11}	NAA 150 ppm	227.45	43.45	55.10
T_{12}	NAA 200 ppm	228.02	43.10	53.46
	F-test	**S**	**S**	**S**
	SEm(±)	5.92	1.36	1.67
	CD (p=0.05)	17.28	3.96	4.87

The data reveals that the no. of days to first male flower appearance of bitter gourd increased significantly by the application of NAA under experiment over the control. The minimum no of days to first male flower appearance (43.10) was recorded with treatments 12 (NAA 200 ppm) while the maximum no of days to first male flower appearance (49.63) was recorded under control. Further, the interaction effect of NAA significantly influenced the no. of days to first male flower appearance.

The minimum in no of days to first male flower appearance of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Samapika et al. [17]. While the maximum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters no of days to first male flower appearance use of NAA may be due to its effect in cell division and cell enlargement Meshram et al. [18].

3.4 Yield Parameter

No of Days to 50% Flowering First Picking: The data on no. of days to 50% flowering first picking of Bitter gourd as influenced by growth regulator are summarized in Table 3.

The data reveals that the no. of days to 50% flowering first picking of bitter gourd increased significantly by the application of NAA under experiment over the control. The minimum no. of days to 50% flowering first picking (61.85) was recorded with treatments 12 (NAA 200 ppm) while the maximum no. of days to 50% flowering first picking (72.11) was recorded under control. Further, the interaction effect of NAA significantly influenced the no. of days to 50% flowering first picking.

The minimum in number of no. of days to 50% flowering first picking of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Kumar et al. [11]. While the maximum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters No of days to 50% flowering first picking use of NAA may be due to its effect in cell division and cell enlargement Anayat et al. [12]

No. of Fruits Per Vine: The data on no. of fruits per vine of bitter gourd as influenced by growth regulator are summarized in Table 3.

The data reveals that the no. of fruits per vine of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum no. of fruits per vine (31.23) was recorded with treatments 12 (NAA 200 ppm) while the minimum No of fruits per vine (16.87) was recorded under control. Further, the interaction effect of NAA significantly influenced the no. of fruits per vine.

The maximum no. of fruits per vine of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Barot [19]. While the minimum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters No. of fruits per vine use of NAA may be due to its effect in cell division and cell enlargement Kokkirala et al. [14].

Average Fruit Length (cm): The data on average fruit length (cm) of bitter gourd as influenced by growth regulator are summarized in Table 3.

The data reveals that the average fruit length of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum average fruit length (20.79 cm) was recorded with treatments 12 (NAA 200 ppm) while the minimum average fruit length (12.05 cm) was recorded under control. Further, the interaction effect of NAA significantly influenced the average fruit length.

The maximum average fruit length (cm) of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Ajay et al. [9]. While the minimum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters on Average fruit length (cm) use of NAA may be due to its effect in cell division and cell enlargement Kumar et al. [10].

Table 3. Effect of plant growth regulators on yield of Bitter gourd

Treatment Symbol	Treatment combinations	No of days to 50% flowering first picking	No. of fruits per vine	Average fruit length (cm)	Average fruit diameter (cm)	Average fruit weight (g)	Fruit yield per plant (kg)
T_0	Control	72.11	16.87	12.05	2.41	50.28	1.07
T_1	GA_3 75ppm	66.26	22.85	15.49	3.23	69.75	1.23
T_2	GA_3 100ppm	66.77	22.7	14.78	3.10	68.90	1.15
T_3	GA_3 150ppm	68.13	22.18	14.00	3.08	65.12	1.14
T_4	GA_3 200ppm	70.08	19.78	13.98	2.55	65.07	1.13
T_5	Ethrel 300 ppm	62.16	27.50	20.14	3.46	75.07	1.51
T_6	Ethrel 400 ppm	63.26	26.39	19.81	3.33	75.05	1.38
T_7	Ethrel 500 ppm	64.30	25.56	18.85	3.32	72.07	1.45
T_8	Ethrel 600 ppm	65.00	25.31	18.82	3.26	72.07	1.3
T_9	NAA 50 ppm	65.40	23.87	16.80	3.25	71.60	1.24
T_{10}	NAA 100 ppm	62.11	30.16	20.31	3.78	80.03	1.52
T_{11}	NAA 150 ppm	61.85	31.16	20.32	3.85	86.05	1.65
T_{12}	NAA 200 ppm	60.16	31.23	20.79	4.34	88.05	1.66
	F-test	**S**	**S**	**S**	**S**	**S**	S
	SEm(±)	1.94	0.85	0.52	0.35	2.25	0.04
	CD (p=0.05)	5.66	2.48	1.53	1.02	6.58	0.12

Average Fruit Diameter (cm): The data on average fruit diameter (cm) of bitter gourd as influenced by growth regulator are summarized in Table 3.

The data reveals that the average fruit diameter of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum average fruit diameter (4.34 cm) was recorded with treatments 12 (NAA 200 ppm) while the minimum average fruit diameter (2.21 cm) was recorded under control. Further, the interaction effect of NAA significantly influenced the Average fruit diameter.

The maximum average fruit diameter (cm) of bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Kumar et al*.* [11]. While the minimum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters Average fruit diameter (cm) use of NAA may be due to its effect in cell division and cell enlargement Anayat et al*.* [12].

Average Fruit Weight (g): The data on average fruit weight (g) of Bitter gourd as influenced by growth regulator are summarized in Table 3.

The data reveals that the average fruit weight (g) of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum average fruit weight (88.05 g) was recorded with treatments 12 (NAA 200 ppm) while the minimum average fruit weight (50.28 g) was recorded under control. Further, the interaction effect of NAA significantly influenced the Average fruit weight.

The maximum average fruit weight (g) of Bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Rajashree and Deepanshu [13]. While the minimum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters Average fruit weight (g) use of NAA may be due to its effect in cell division and cell enlargement Choudhary et al*.* [20].

Average Fruit Yield Per Plant (kg): The data on average fruit yield per plant of Bitter gourd as influenced by growth regulator are summarized in Table 3.

The data reveals that the average fruit yield per plant of bitter gourd increased significantly by the application of NAA under experiment over the control. The maximum average fruit yield per plant (49.83 kg) was recorded with treatments 12 (NAA 200 ppm) while the minimum average fruit yield per plant (32.1 kg) was recorded under control. Further, the interaction effect of NAA significantly influenced the Average fruit yield per plant.

The maximum average fruit yield per plant of Bitter gourd due to treatment 12 might be due to fact that NAA regulate the growth by causing cell division and cell elongation in plant system. These results are in conformity with Kumar et al*.* [11]. While the minimum value in treatment T0 (control) may owes to its inhibitory effect because this treatment occupy only recommended dose of fertilizers in bitter gourd. Increase in growth parameters Average fruit yield per plant use of NAA may be due to its effect in cell division and cell enlargement Anayat et al*.* [12].

Economics: The data on economics of bitter gourd as influenced by growth regulator are summarized in Table 4.

The data reveals that the economics bitter gourd increased significantly by the application of growth regulator under experimentation over the control.

The maximum cost of cultivation (78000 Rs.) was recorded with treatments 12 (NAA 200 PPM) while the minimum cost of cultivation (60000 Rs.) was recorded under control.

The maximum gross return (332000 Rs.) was recorded with treatments 12 (NAA 200 ppm) while the minimum gross return (214000 Rs.) was recorded under control.

The maximum net return (254000 Rs.) was recorded with treatments 12 (NAA 200 ppm) while the minimum net return (141000 Rs.) was recorded under treatment 4 (GA_3 200).

The maximum B:C ratio 3.26 was recorded with treatments 12 (NAA 200 ppm) while the minimum B:C ratio 1.66 was recorded under treatment 4 (GA_3 200).

Table 4. Effect of plant growth regulators on economics of Bitter gourd

Treatment Symbol	Total cost of cultivation	Yield (kg/ha)	Sale rate Rs/kg	Gross return	Net return	B:C
T_0	60000	10700	20	214000	154000	2.57
T_1	70000	12300	20	246000	176000	2.51
T_2	72500	11500	20	230000	157500	2.17
T_3	80000	11400	20	228000	148000	1.85
T_4	85000	11300	20	226000	141000	1.66
T_5	72000	15100	20	302000	230000	3.19
T_6	76000	13800	20	276000	200000	2.63
T_7	80000	14500	20	290000	210000	2.63
T_8	84000	13000	20	260000	176000	2.10
T_9	74000	12400	20	248000	174000	2.35
T_{10}	77000	15200	20	304000	227000	2.95
T_{11}	79000	16500	20	330000	251000	3.18
T_{12}	78000	16600	20	332000	254000	3.26

4. CONCLUSION

Based on the results of the present study, it is concluded that, overall treatment T_{12} (NAA 200 ppm) performed best in terms Germination as well as in vegetative growth, yield and quality of bitter gourd and the maximum survival % was also obtained from this treatment.

The maximum benefit cost ratio was observed in T_{12} (NAA 200 ppm) followed by T_{11} (NAA 150ppm) while the minimum benefit cost ratio was observed in T_4 (GA_3 200ppm).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/116839