The Pharma Innovation Journal 2023; 12(9): 1653-1656

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 1653-1656

www.thepharmajournal.com
Received: 03-07-2023
Accepted: 09-08-2023

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Effect of foliar application of PGRs on seed yield and quality parameters of yard long bean (*Vigna unguiculata* sub sp *sesquipedalis* L.) var. Arka Mangala

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Abstract
The study conducted an experiment involving three replications and eleven different treatments to assess the seed yield and quality parameters of yard long bean. All of the treatments demonstrated superior results in terms of seed yield and quality. Treatment T_7, which consisted of NAA at 50 ppm and BAP at 50 ppm, exhibited remarkable improvements in various seed yield and quality characteristics. These improvements included the highest number of branches plant^{-1} (13.50), the highest number of pods plant^{-1} (19.17), the highest number of seeds pod^{-1} (20.67), seed yield plant^{-1} (89 g), seed yield ha^{-1} (10 q), test weight (238 g), and protein content (25.88%). On the other hand, Treatment T_3, which involved GA_3 at 50 ppm, showed the highest germination percentage (92.33%) and the highest seed vigor indices (both I and II) at 2803.50 and 137.95, respectively. Therefore, both Treatment T_7 and Treatment T_3 were significantly more effective than the other treatments in enhancing the seed yield and quality of yard long beans.

Keywords: Yard long bean, plant growth regulators, NAA, GA_3 and BAP

Introduction
Legumes are considered the second most important food source worldwide, right after cereals. They are highly valued as an economical and sustainable alternative to meat. Farmers play a crucial role in increasing domestic nitrogen production by cultivating legumes, which are known as natural nitrogen factories. Additionally, legumes help suppress weed growth by converting insoluble phosphorus in the soil into a soluble form, improving soil structure, promoting microbial activity, and replenishing organic matter.

The yard long bean, scientifically named *Vigna unguiculata* subsp. *sesquipedalis* L., is an important legume vegetable crop originating from East and South-East Asia. It is also known by various names such as asparagus bean, chinese long bean, pea bean, string bean, snake bean, and borboti (Bhagavati *et al*. 2019) [4]. This particular variety of cowpea has a chromosome number of 2n = 22 and is primarily grown for its exceptionally long immature pods, ranging from 35 to 75 cm in length, which are similar in usage to green beans. Yard long beans are typically cultivated as an annual crop and are highly self-pollinating. They are mainly cultivated for their tender green pods and are popular ingredients in various vegetable dishes.

Yard long beans, as leguminous vegetables, are highly regarded for their nutritional value. Both their pods (comprising 23.5 to 26.3% of the bean) and leaves contain a significant amount of easily digestible protein. Furthermore, yard long beans are abundant sources of essential nutrients such as vitamins A and C, calcium (72.0 mg), phosphorus (59 mg), iron (2.5 mg), carotene (564 mg), thiamine (0.07 mg), riboflavin (0.09 mg), and vitamin C (24 mg) per 100 grams of edible pods. Additionally, this crop contributes to soil fertility by fixing atmospheric nitrogen. It also contains crucial trace minerals, including 102.69-120.02 mg kg^{-1} of iron, 32.58-36.66 mg kg^{-1} of zinc, 2.92-3.34 mg kg^{-1} of manganese, and 0.33-0.57 mg kg^{-1} of cobalt (Ano and Ubochi, 2008) [1].

The ideal temperature range for optimal growth during the cultivation period is between 20 °C and 30 °C. Yard long beans thrive in full sunlight during their growth and development stages, and they tend to yield poorly in cloudy weather, which can lead to inadequate fruit formation and premature dropping of young pods. This crop can be successfully cultivated in different soil types, but loam soils with a pH level between 6.2 and 7.0 are particularly well-suited for yard long bean production. The duration of the yard long bean crop from planting to harvest typically spans 80 to 90 days, with fresh beans ready for harvesting within 70 to 90 days after planting.

Plant growth regulators, also known as plant hormones, possess the capacity to influence the metabolic and physiological responses of plants, ultimately impacting their growth and development. These regulators can be naturally occurring or synthetic compounds that are directly applied to specific plants with the aim of modifying their physiological processes or structure. The primary objectives often include improving quality, increasing yields, managing unwanted vegetative growth, stimulating fruiting, and facilitating harvesting (Sarkar *et al*. 2020) [10]. While different plant growth regulators may function similarly in various stages of the same plant, they can have distinct effects. In the context of enhancing yard long bean production, several growth regulators such as auxins, gibberellins, and cytokinins have been used to achieve desired outcomes. These substances have the potential to positively influence the growth and productivity of yard long bean plants.

Material and Methods

The research project titled "Effect of foliar application of PGRs on seed yield and quality parameters of yard long bean (*Vigna unguiculata* sub sp *sesquipedalis* L.) var. Arka Mangala" was conducted during the *Rabi* season of 2022-23 at the Krishi Vigyan Kendra Raipur farm, affiliated with Indira Gandhi Krishi Vishwavidyalaya in Chhattisgarh. This experiment utilized a randomized block design (RBD) with three replications, including both a control group and ten treatment groups. The treatments were as follows: T_1 (NAA 50 ppm), T_2 (NAA 100 ppm), T_3 (GA_3 50 ppm), T_4 (GA_3 100 ppm), T_5 (BAP 50 ppm), T_6 (BAP 100 ppm), T_7 (NAA 50 ppm + BAP 50 ppm), T_8 (NAA 100 ppm + BAP 100 ppm), T_9 (NAA 50 ppm + GA_3 50 ppm), and T_{10} (NAA 100 ppm + GA_3 100 ppm). The foliar application of these treatments occurred at 40, 55, and 70 days after sowing (DAS). Over the course of the study, various parameters related to seed yield and seed quality were recorded, including the number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} (g), seed yield ha^{-1} (q), test weight (g), protein content (%), germination percentage (%), and seed vigor index.

Results and Discussion

The results of this research offer compelling proof that the utilization of different plant growth regulators greatly improved numerous important factors associated with the seed production and seed quality of yard-long beans. These factors encompass the number of branches per plant, the number of pods per plant, the number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} (g), seed yield ha^{-1} (q), test weight (g), protein content (%), germination percentage (%), and seed vigor index.

The findings unequivocally indicate that the use of plant growth regulators had a beneficial influence on these factors when compared to the control group. Comprehensive average values for each seed yield and quality parameter associated with the particular plant growth regulators can be located in Table 1.

The highest recorded number of branches plant^{-1}, which was 13.50, was observed in treatment T_7 (NAA 50 ppm and BAP 50 ppm). Conversely, the lowest number of branches plant^{-1}, 9.00, was found in the control group (T_0) for yard long beans, followed closely by T_4 (GA_3 100 ppm) with 9.17 branches per plant. The increase in branch count per plant can be attributed to the application of NAA, which promotes the growth and elongation of shoot cells. This is because auxin and cytokinin, when used together, collaborate to regulate cell division, resulting in a synergistic effect that leads to a greater number of branches plant^{-1}. These findings are consistent with previous research on the application of NAA in cowpea conducted by Desai and Deore (1985) [5] as well as Thaware *et al*. (2006) [13].

The highest number of pods plant^{-1}, which was 19.17, was noted in treatment T_7 (NAA 50 ppm and BAP 50 ppm). Following closely were treatments T_8 (NAA 100 ppm + BAP 100 ppm) and T_4 (GA_3 100 ppm), which had 18.67 and 18.50 green pods per plant, respectively. In contrast, the control group (T_0) had the lowest number of pods plant^{-1}, with 15.00 pods, followed by T_9 (NAA 50 ppm + GA_3 50 ppm) with 16.17 pods plant^{-1}. The increase in pod count per plant can be attributed to a higher rate of pod formation resulting from the use of NAA and BAP. These findings are consistent with the results of previous research conducted on cowpea by Shinde *et al*. (1991) [12] and Thaware *et al*. (2008) [14].

The highest number of seeds pod^{-1}, 20.67, was observed in treatment T_7 (NAA 50 ppm and BAP 50 ppm). This was followed by treatment T_8 (NAA 100 ppm and BAP 100 ppm), resulting in 20.17 seeds pod^{-1}. In contrast, the control group (T_0) had the lowest number of seeds plant^{-1}, with an average of 14.17, followed by treatment T_3 (GA_3 50 ppm), resulting in 18.50 seeds pod^{-1}. The increased number of seeds per pod in treatments T_7 and T_8 could be attributed to the suppression of downward auxin movement, allowing more auxin to be used for seed development. These findings align with previous research on the use of NAA in cowpea conducted by Desai and Deore (1985) [5] and Thaware *et al*. (2006) [13].

The application of T_7 (NAA 50 ppm and BAP 50 ppm), resulted in the highest seed yield plant^{-1} (89.00 g). Following closely, T_8 (NAA 100 ppm and BAP 100 ppm), produced a seed yield of 85.00 g plant^{-1}. Conversely, the control group (T_0) had the lowest seed yield plant^{-1} at 62.67 g, followed by T_1 (NAA 50 ppm) recording 67.33 g plant^{-1}. The increase in seed yield can be attributed to several factors, including the promotion of more branches per plant, an increase in the number of pods per plant, a higher number of seeds per pod, and an increase in seed weight per plant. These positive effects were a result of the application of NAA and BAP at varying concentrations. These findings align with previous research on the use of NAA in cowpea conducted by Nisha *et al*. in 1996 [7], Ganiger *et al*. in 2002 [6], and Thaware *et al*. in 2008 [14].

The highest seed yield ha^{-1}, significantly recorded at 12.87 quintals, was achieved with the application of T_7 (NAA 50 ppm and BAP 50 ppm). Following closely, T_8 (NAA 100 ppm and BAP 100 ppm), resulted in a seed yield of 11.03 q ha^{-1}. On the other hand, the control group (T_0) had the lowest seed yield ha^{-1} at 7.04 quintals. The increase in seed yield can be attributed to the synergistic regulation of cell division by auxin and cytokinin. The application of NAA, in combination with BAP at different concentrations, led to an increase in the number of branches per plant, the number of pods per plant, the number of seeds per pod, and the seed weight per plant. This effect is due to the endogenous production of more auxin resulting from the application of cytokinin. These findings align with previous research conducted by Thaware *et al.* in 2008 [14] regarding the use of NAA and BAP in yard-long beans.

The highest test weight was observed in treatment T_7 (NAA 50 ppm and BAP 50 ppm), reaching 238.00 g, followed closely by T_8 (with 100 ppm NAA and 100 ppm BAP) at 230.67 g. In contrast, the control group (T_0) had the lowest test weight at 158.67 g, and T_6 (containing 100 ppm BAP) had a slightly higher test weight of 190.00 g. The increased pod weight observed with the application of NAA and BAP can be attributed to several factors. These growth regulators likely led to enlarged cell sizes, while also potentially boosting chlorophyll content in the leaves, resulting in increased photosynthesis and ultimately leading to higher seed weights. This could have resulted in a higher production of photosynthates, contributing to an increase in both seed and pod size. These findings align with the results reported by Thaware *et al*. in 2006 [13].

The protein content of yard long bean seeds ranged from 21.30% to 25.88%. The highest protein content, at 25.88%, was observed in treatment T_7 (NAA 50 ppm and BAP 50 ppm). This was followed by T_8 (with 100 ppm NAA and 100 ppm BAP) at 24.24%, and T_9 (containing 50 ppm NAA and 50 ppm GA_3) at 24.17%. In contrast, the lowest protein content was found in the control group (T_0) at 21.30%. These findings align with research conducted by Sarvaiya *et al*. (2021) [11], which also reported similar results in cowpea.

The percentage of germination in yard long bean seeds ranged from 71.67% to 92.33%. The highest germination rate of 92.33% was observed in T_3 (GA_3 at 50 ppm), followed by T_9 (NAA at 50 ppm + GA_3 at 50 ppm) with a germination rate of 90.33%, and T_{10} (with NAA at 100 ppm + GA_3 at 100 ppm) with a germination rate of 90.00%. In contrast, the lowest germination rate was recorded in the control group (T_0), at 71.67%. The increased germination percentage associated with the application of GA_3 can be attributed to the role of GA_3 in activating cytological enzymes. These enzymes stimulate the α-amylase enzyme, which converts insoluble starch into soluble sugars, and also promote the initial growth of the seedling by overcoming certain metabolic barriers. Additionally, GA_3 helps in leaching out inhibitors, which aids in breaking seed dormancy. Similar results have been reported by Babu *et al*. (2010) [3], Pandit *et al*. (2001) [8], and Anburani & Shakila (2010) [2].

The Seed vigour index I in yard long bean seeds ranged from 1209.02 to 2803.50. The highest vigour index I (2803.50) was observed in T_3 (treatment with GA_3 at 50 ppm), which was significantly better than T_5 (BAP at 50 ppm) with a vigour index I of 2705.85. In contrast, the lowest vigour index I was recorded in the control group (T_0), at 1209.02. The increased vigour index I associated with the application of GA_3 can be attributed to its positive impact on both seedling length and germination percentage. GA_3 plays a crucial role in influencing these factors in yard long bean, resulting in higher seedling vigour. This finding is consistent with the research of Thorat *et al*. (2017) [15].

The Seed vigour index II in yard long bean seeds varied from 59.55 to 137.95. The highest vigour index II (137.95) was observed in T_3 (treatment with GA3 at 50 ppm), which was significantly better than T_9 (NAA at 50 ppm + GA_3 at 50 ppm) with a vigour index II of 129.18. Conversely, the lowest vigour index II was recorded in the control group (T_0), at 59.55. The enhanced vigour index II associated with the use of GA_3 can be attributed to its positive influence on both germination percentage and seedling dry weight. GA_3 has a significant impact on these factors in yard long bean seeds under laboratory conditions, leading to higher seedling vigour. This outcome is consistent with the findings of Babu *et al*. (2010) [3] and Thorat *et al*. (2017) [15].

Table 1: The impact of plant growth regulators on the seed yield and quality parameters of yard long bean variety Arka Mangala

Treatments	No. of Branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (q)	Test weight (g)	Protein content (%)	Germination percentage (%)	Seed vigour index I	Seed vigour index II
T_0 Control (Water spray)	9.00	15.00	14.17	62.67	7.04	158.67	21.30	71.67	1209.02	59.55
T_1 NAA 50 ppm	9.33	17.50	18.83	67.33	9.67	221.67	24.07	90.33	2429.06	103.88
T_2 NAA 100 ppm	9.50	18.17	19.17	76.33	9.18	230.00	23.74	81.33	2226.06	95.16
T_3 GA_3 50 ppm	10.00	18.17	18.50	75.00	8.13	208.00	23.15	92.33	2803.50	137.95
T_4 GA_3 100 ppm	9.17	18.50	20.00	74.67	9.68	195.00	21.64	88.00	2621.52	115.28
T_5 BAP 50 ppm	9.67	18.33	18.83	75.33	7.38	197.67	24.04	85.00	2705.85	124.10
T_6 BAP 100 ppm	9.50	17.67	19.33	68.00	7.71	190.00	24.13	83.33	2407.50	100.83
T_7 NAA + BAP (50 ppm + 50 ppm)	13.50	19.17	20.67	89.00	10.00	238.00	25.88	89.00	2303.64	104.34
T_8 NAA + BAP is (100 ppm + 100 ppm)	9.33	18.67	20.17	85.00	9.78	230.67	24.24	80.00	2456.00	111.20
T_9 NAA + GA_3(50 ppm + 50 ppm)	9.33	16.17	18.67	75.33	9.16	204.00	24.17	90.33	2209.55	129.18
T_{10} NAA + GA_3 (100 ppm + 100 ppm)	.67	16.33	19.33	75.33	8.49	213.33	22.21	90.00	2231.10	98.10

Conclusions

The present study reveals that using a combination of two plant growth regulators, namely Naphthalene acetic acid (NAA) and 6-Benzyle amino purine (BAP), has a positive influence on both the quantity and quality of yard long bean seeds. The application of these sprays has yielded promising results in improving the seed yield and quality of yard long bean plants. Among the various treatments examined, Treatment T_7, which involved the use of NAA at 50 ppm and BAP at 50 ppm, demonstrated remarkable effectiveness in enhancing several parameters. These included the number of branches plant^{-1} (13.50), the number of pods plant^{-1} (19.17), the number of seeds pod^{-1}, seed yield plant^{-1} (g), seed yield ha^{-1} (q), test weight (g), and protein content (%). Conversely, Treatment T_3, involving GA_3 at 50 ppm, resulted in the highest germination percentage and seed vigor index. To sum up, the combined application of NAA and BAP offers significant advantages in increasing both the seed yield and quality of yard long beans.

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