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# Effect of $GA_3$, NAA and biofertilizers on seedling and root growth of custard apple with economics

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**Abstract**
The present experiment entitled, "Effect of GA3, NAA and Biofertilizers on seedling and root growth of custard apple with economics" was designed with an objective to study the effect of different concentration of PGR and biofertilizers on seedling and root growth of custard apple. The experiment was conducted at the student instructional field and Shed-net House, Department of Horticulture, School of Agricultural Sciences, G. H. Raisoni University Saikheda, Dist.- Pandhurna (M.P.) during *Rabi* Season of Year 2024. The experiment was laid out in RBD (Randomized Block Design) with 11 treatments including control, the detail of experiment are, $T_1$- Control, $T_2$- Gibberellic Acid @ 50%, $T_3$- Gibberellic Acid @ 75%, $T_4$- Gibberellic Acid @ 100%, $T_5$- Naphthalene Acetic Acid @ 50%, $T_6$- Naphthalene Acetic Acid @ 75%, $T_7$- Naphthalene Acetic Acid @ 100%, $T_8$- Azatobactor (5 ml/l of water), $T_9$- Azatobactor (10 ml/l of water), $T_{10}$- Azospirillum (5 ml/l of water) and $T_{11}$- Azospirillum (10 ml/l of water). The observation on seedling growth number of leaves per seedling at 60 DAS, number of leaves per seedling at 90 DAS, root parameters like length of primary roots (cm), length of secondary roots (cm), number of roots per seedling at 60 DAS, fresh weight of root (g) at 60 DAS, dry weight of root (g) 60 DAS, economics gross return (₹), net profit (₹) and B:C Ratio. The result revealed that the maximum maximum number of leaves per seedling (6.23 at 60 DAS and 10.64 at 90 DAS), the longest primary (25.44 cm) and secondary (8.23 cm) roots, the highest number of roots per seedling (32.22 at 60 DAS), and the greatest fresh and dry root weights (12.21 g and 1.57 g at 60 DAS, respectively). These values were statistically at par with $T_6$ (NAA @ 75%) and $T_3$ ($GA_3$ @ 75 ppm), both of which also exhibited notable improvements over the control while the minimum value of all parameters was found under control.

**Keywords:** GA3, NAA, biofertilizers, root growth and custard apple

## Introduction

Custard apple (*Annona squamosa* L.), is a fruit crop that originated in Central America and spread to Mexico and Tropical America. It contain chromosome number (2n=14), a member of the Annonaceae family, is one of the best fruit that tropical America has provided to India. In Custard apple seeds may be due to dormancy or due to hard seed coat. The utility of GA3 from 150-500 ppm is helpful for getting better germination of custard apple seeds (Ratan and Reddy, 2004) [12]. As a result, pre-treating custard apple seeds with various organics and chemicals is critical in order to maximize germination. The use of plant growth regulators in proper concentration with scarification may regulate seed germination and seedling growth behaviour in many fruit crops. Seed requires pre-treatments prior to sowing in order to achieve higher and proper germination with vigorous seedling development. Treating seeds with GA3 also helps enhancing their growth (Chadha, 2010) [9]. For enhancing seed germination and growth of seedling GA3 was used.

The effect of NAA on plant growth is greatly dependent on the time of admission and concentration. NAA has been shown to greatly increase cellulose fibre formation in plants. (Mahaveer *et al.*, 2017) [6]. Biomix is the well balanced and a unique blend of selected species of microbes which fix atmospheric nitrogen in the soil making it available to plants. It also contain microbes which can solubilized residual Phosphate, Iron, and Magnesium etc. from soil making the more easily available to the plants. It stimulates sprouting and help to increase the water holding capacity of the soil. It playa multifunctional role: As vital components of organic amendments and composts, as a mean of suppressing insects and plant diseases, to improve crop quality and yields, restore soil microflora. Increase seed germination, promote deep rooting system, solubilize and remove phosphate residual from soil, enhance nutrients cycling. Biomix improve growth, yield and quality of crops adding to farm probability (Syed Shabnam, 2021) [17]. The resumption of successful embryonic growth that results in the emergence of a young plant is known as seed germination. Except under ideal conditions, many fruit crop seeds do not germinate. Such kind of dormancy in seeds may be due to presence of hard and impermeable seed coat, germination inhibitors and improper development of embryo. Such seeds may require special treatments like scarification, soaking in water, growth regulators etc. to overcome dormancy GA3 appears mainly to induce the activity of the gluconeogenic enzymes during early stages of seed germination. (Jain *et al.*, 2017) [10].

**Materials and Methods**

The present experiment entitled, "Effect of GA3, NAA and Biofertilizers on seedling and root growth of custard apple with economics" was designed with an objective to study the effect of different concentration of PGR and biofertilizers on seedling and root growth of custard apple. The experiment was conducted at the student instructional field and Shed-net House, Department of Horticulture, School of Agricultural Sciences, G. H. Raisoni University Saikheda, Dist.- Pandhurna (M.P.) during *Rabi* Season of Year 2024. The experiment was laid out in RBD (Randomized Block Design) with 11 treatments including control, the detail of experiment are, $T_1$- Control, $T_2$- Gibberellic Acid @ 50%, $T_3$- Gibberellic Acid @ 75%, $T_4$- Gibberellic Acid @ 100%, $T_5$- Naphthalene Acetic Acid @ 50%, $T_6$- Naphthalene Acetic Acid @ 75%, $T_7$- Naphthalene Acetic Acid @ 100%, $T_8$- Azatobactor (5 ml/l of water), $T_9$- Azatobactor (10 ml/l of water), $T_{10}$- Azospirillum (5 ml/l of water) and $T_{11}$- Azospirillum (10 ml/l of water). The observation on seedling growth number of leaves per seedling at 60 DAS, number of leaves per seedling at 90 DAS, root parameters like length of primary roots (cm), length of secondary roots (cm), number of roots per seedling at 60 DAS, fresh weight of root (g) at 60 DAS, dry weight of root (g) 60 DAS, economics gross return (₹), net profit (₹) and B:C Ratio.

**Gross Monetary Return (₹/ha):** Total income generated per hectare from sale of marketable seedlings or cuttings.

**Net Monetary Return (₹/ha):** The actual profit, calculated by subtracting the total cost of cultivation from the gross return. Net Return=Gross Return−Total Cost.

**Benefit-Cost Ratio (B: C Ratio):** An indicator of profitability, calculated by dividing the gross return by the total cost.

**Results and Discussion**

**Number of leaves per seedling at 60 and 90 DAS**

The maximum number of leaves per seedling at 60 and 90 days after sowing (DAS) was recorded under $T_4$ (Gibberellic Acid @ 100 ppm) with values of 6.23 and 10.64, respectively. This was statistically at par with $T_6$ (Naphthalene Acetic Acid @ 75%) at 6.11 and 10.48, and followed by $T_3$ (Gibberellic Acid @ 75 ppm) with 5.87 and 10.24. The minimum number of leaves was recorded under the control treatment ($T_1$) with 3.00 and 7.22 leaves at 60 and 90 DAS, respectively. The increase in the number of leaves per seedling under $GA_3$ and NAA treatments is largely due to their ability to enhance apical meristem activity, which leads to faster initiation and expansion of leaf primordia. Gibberellic acid ($GA_3$) facilitates cell division and elongation, resulting in vigorous vegetative growth and increased leaf initiation (Taiz *et al.*, 2015; Bewley *et al.*, 2013) [18, 1]. At higher concentrations like 100 ppm ($T_4$), $GA_3$ effectively improves shoot apical meristem function and internode elongation, which creates space for more leaf formation (Rajasekaran *et al.*, 2016; Giri *et al.*, 2021) [11, 2]. Similarly, Naphthalene Acetic Acid (NAA), a synthetic auxin, promotes lateral shoot and leaf development by stimulating auxin-responsive gene expression that governs cell division in shoot meristems and leaf initiation (Sarkar & Basu, 2019; Hasan *et al.*, 2010) [14, 3]. At the applied rate of 75 ppm ($T_6$), NAA was highly effective without producing toxic effects seen at higher doses (Jadhav *et al.*, 2017; Singh & Verma, 2020) [4, 16].

Plants in the control group ($T_1$), lacking exogenous hormonal input, exhibited fewer leaves due to slower growth and reduced metabolic activity. Similar observations were made in custard apple (Sharma and Trivedi, 2014) [15], guava (Patel *et al.*, 2020) [7], and citrus rootstocks (Patil *et al.*, 2020) [8], where the application of $GA_3$ and NAA significantly improved the number of leaves and vegetative vigor. Kumar *et al.*, (2021) [5] and Saran *et al.*, (2018) [13] also demonstrated that plant growth regulators are instrumental in enhancing leaf production in nursery crops.

**Length of primary and secondary roots (cm)**

The maximum length of primary and secondary roots was recorded under $T_4$ (Gibberellic Acid @ 100 ppm) with values of 25.44 cm and 8.23 cm, respectively. This was followed by $T_6$ (Naphthalene Acetic Acid @ 75%), recording 23.65 cm and 8.01 cm, and $T_3$ (Gibberellic Acid @ 75 ppm) with 22.34 cm and 7.43 cm. The minimum root length was noted in the control treatment ($T_1$), where the primary and secondary root lengths were 12.22 cm and 3.22 cm, respectively. The observed increase in both primary and secondary root length under $GA_3$ and NAA treatments can be attributed to the hormonal stimulation of cell division and elongation in root meristems. Gibberellic acid ($GA_3$) is known to enhance root elongation by promoting cell wall loosening, hydrolytic enzyme activity, and cell expansion, especially in the elongation zone of the root (Taiz *et al.*, 2015; Bewley *et al.*, 2013) [18, 1]. The 100 ppm concentration ($T_4$) likely provided an optimal hormonal environment for primary root extension and secondary root initiation, as also demonstrated in papaya and citrus (Rajasekaran *et al.*, 2016; Giri *et al.*, 2021) [11, 2]. Naphthalene Acetic Acid (NAA) plays a vital role in auxin-mediated root development, particularly in stimulating the formation and elongation of secondary (lateral) roots by enhancing the expression of auxin-responsive genes and increasing apoplastic calcium levels required for cell expansion (Hasan *et al.*, 2010; Sarkar & Basu, 2019) [3, 14]. At 75% concentration ($T_6$), NAA helped optimize root branching and lateral development, contributing to a robust and fibrous root system.

The lowest values in $T_1$ (Control) are indicative of slower root growth and limited meristematic activity in the absence of exogenous hormonal stimulation. This aligns with results reported in custard apple (Sharma & Trivedi, 2014) [15], guava (Patel *et al.*, 2020) [7], citrus (Patil *et al.*, 2020) [8], and pomegranate (Saran *et al.*, 2018) [13], where $GA_3$ and NAA were shown to significantly improve both taproot and lateral root growth.

**Number of roots per seedling at 60 DAS**

The maximum number of roots per seedling at 60 DAS was recorded under the treatment $T_4$ (Gibberellic Acid @ 100 ppm) with 32.22 roots, followed by $T_6$ (Naphthalene Acetic Acid @ 75%) with 29.12 roots, and $T_3$ (Gibberellic Acid @ 75 ppm) with 28.00 roots. The minimum number of roots was observed under the control treatment ($T_1$), with 19.21 roots per seedling. The higher number of roots in $GA_3$ and NAA-treated seedlings can be attributed to the stimulatory effects of plant growth regulators on root initiation and development. Gibberellic acid ($GA_3$), although primarily known for promoting shoot elongation, also facilitates root development by increasing enzyme activity and hormonal interaction that stimulate root meristem activity (Taiz *et al.,* 2015; Bewley *et al.,* 2013) [18, 1]. At 100 ppm ($T_4$), $GA_3$ likely supported an optimal physiological balance for root proliferation, as noted in similar studies on papaya, citrus, and guava (Rajasekaran *et al.,* 2016; Giri *et al.,* 2021) [11, 2]. Naphthalene Acetic Acid (NAA) is widely recognized for its strong influence on adventitious and lateral root formation, as auxins are directly involved in initiating root primordia from pericycle and callus tissues. At 75% concentration ($T_6$), NAA significantly increased root number, likely by stimulating the expression of auxin-responsive genes such as ARF (Auxin Response Factors) and LBD (Lateral Organ Boundaries Domain) families (Hasan *et al.,* 2010; Sarkar & Basu, 2019) [3, 14]. The lowest root count under the control treatment ($T_1$) reflects the absence of exogenous hormonal stimulation, limiting the capacity for secondary root initiation. Similar results were reported by Patel *et al.* (2020) [7] in guava, Saran *et al.,* (2018) [13] in pomegranate, and Sharma & Trivedi (2014) [15] in custard apple, where the application of $GA_3$ and NAA significantly enhanced root number and root biomass.

**Fresh and Dry weight of root (g) at 60 DAS**

The maximum fresh and dry weight of root at 60 days after sowing (DAS) was recorded under $T_4$ (Gibberellic Acid @ 100 ppm) with 12.21 g and 1.57 g, respectively. This was followed by $T_6$ (Naphthalene Acetic Acid @ 75%), which recorded 11.54 g and 1.54 g, and $T_3$ (Gibberellic Acid @ 75 ppm) with 10.22 g and 1.50 g. The minimum root fresh and dry weight was observed in the control treatment ($T_1$), with only 4.40 g and 0.12 g, respectively.

The increase in root biomass under treatments involving $GA_3$ and NAA can be attributed to their critical roles in modulating plant growth and metabolism. Gibberellic acid ($GA_3$) is known to improve cell division, elongation, and root system expansion, which in turn leads to greater absorption of water and nutrients and enhanced root mass (Taiz *et al.,* 2015; Bewley *et al.,* 2013) [18, 1]. At 100 ppm, $GA_3$ appears to have maximized these effects, resulting in significant gains in both fresh and dry root weight (Rajasekaran *et al.,* 2016; Giri *et al.,* 2021) [11, 2]. Naphthalene Acetic Acid (NAA), being a synthetic auxin, has a profound influence on adventitious and lateral root formation. It improves vascular differentiation and assimilate partitioning toward the root system, thereby contributing to increased root biomass (Sarkar & Basu, 2019; Hasan *et al.,* 2010) [14, 3]. At 75%, NAA effectively promoted root growth without hormonal stress, consistent with findings in fruit crops like guava (Patel *et al.,* 2020) [7] and pomegranate (Saran *et al.,* 2018) [13]. The low root biomass in the control treatment ($T_1$) reflects the absence of exogenous hormonal stimuli, limiting the extent of root system development, water uptake, and nutrient accumulation. Similar results were reported by Sharma and Trivedi (2014) [15] in custard apple and Patil *et al.,* (2020) [8] in citrus, where the application of plant growth regulators significantly improved root weight parameters.

**Economics**

The economic evaluation of treatments applied to 1,000 custard apple seedlings indicates that investing in plant growth regulators such as Gibberellic Acid ($GA_3$) and Naphthalene Acetic Acid (NAA) substantially enhances seedling survival, cutting production, and profitability. While the basic cost of seedling production remained uniform at ₹8,000, treatments with added inputs (₹100-₹200) resulted in significantly higher gross returns and net profits compared to the untreated control. Among the treatments, $T_4$ ($GA_3$ @ 100 ppm) emerged as the most economically efficient, yielding the highest survival rate (85%), gross return (₹17,000), net profit (₹8,800), and benefit-cost ratio (2.07). This demonstrates that a small additional investment in effective hormonal treatments can yield more than double returns. Treatments like $T_3$ ($GA_3$ @ 75 ppm) and $T_6$ (NAA @ 75%) also showed favorable economics with B:C ratios above 1.7, emphasizing the value of moderate hormonal inputs.

These findings align with previous studies showing that $GA_3$ and NAA enhance seedling vigor, root/shoot biomass, and survivability, all of which directly impact transplant success and propagation efficiency (Patel *et al.,* 2020; Sharma & Trivedi, 2014; Giri *et al.,* 2021) [7, 15, 2]. The observed increase in profitability further supports recommendations from horticultural economics literature advocating for judicious use of growth regulators in nursery production systems (Kumar *et al.,* 2021; Saran *et al.,* 2018) [5, 13]. In conclusion, the data strongly supports the use of growth regulators - especially $GA_3$ @ 100 ppm - as a cost-effective and profitable strategy for improving the commercial viability of custard apple seedling production.

**Table 4.12:** Effect of plant growth regulators and biofertilizers on number of leaves per seedling at 60 DAS of custard apple

| Treats. | Number of leaves per seedling at 60 DAS | Number of leaves per seedling at 90 DAS | Length of primary roots (cm) | Length of secondary roots | Number of roots per seedling at 60 DAS | Fresh weight of root (g) 60 DAS | Dry weight of root (g) 60 DAS | Gross Return (₹) | Net Profit (₹) | B:C Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 3.00 | 7.22 | 12.22 | 3.22 | 19.21 | 4.40 | 0.12 | 11,000 | 3,000 | 1.38 |
| $T_2$ | 5.21 | 9.58 | 17.89 | 6.55 | 26.56 | 8.23 | 1.38 | 15,000 | 6,900 | 1.85 |
| $T_3$ | 5.87 | 10.24 | 22.34 | 7.43 | 28.00 | 10.22 | 1.50 | 16,200 | 8,050 | 1.99 |
| $T_4$ | 6.23 | 10.64 | 25.44 | 8.23 | 32.22 | 12.21 | 1.57 | 17,000 | 8,800 | 2.07 |
| $T_5$ | 4.67 | 8.98 | 17.41 | 6.21 | 25.11 | 7.45 | 1.33 | 14,600 | 6,540 | 1.81 |
| $T_6$ | 6.11 | 10.48 | 23.65 | 8.01 | 29.12 | 11.54 | 1.54 | 16,600 | 8,510 | 2.05 |
| $T_7$ | 5.65 | 10.02 | 19.32 | 7.01 | 27.78 | 9.11 | 1.44 | 15,600 | 7,480 | 1.92 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_8$ | 4.01 | 8.32 | 15.33 | 5.44 | 23.54 | 5.89 | 1.21 | 13,600 | 5,598 | 1.70 |
| $T_9$ | 4.33 | 8.64 | 16.76 | 6.01 | 24.76 | 6.55 | 1.28 | 14,000 | 5,995 | 1.75 |
| $T_{10}$ | 3.12 | 7.34 | 13.32 | 4.21 | 20.13 | 4.88 | 0.31 | 12,000 | 3,998 | 1.50 |
| $T_{11}$ | 3.78 | 8.09 | 14.54 | 5.00 | 21.43 | 5.34 | 0.79 | 13,000 | 4,995 | 1.62 |
| S.Em.± | 0.047 | 0.050 | 0.173 | 0.063 | 0.162 | 0.109 | 0.020 | | | |
| CD at 5% Levels | 0.140 | 0.147 | 0.512 | 0.187 | 0.476 | 0.321 | 0.060 | | | |

**Conclusion**

The study clearly demonstrated that the treatments, $T_4$ (Gibberellic Acid @ 100 ppm) consistently recorded superior results across multiple parameters. It produced the maximum number of leaves per seedling (6.23 at 60 DAS and 10.64 at 90 DAS), the longest primary (25.44 cm) and secondary (8.23 cm) roots, the highest number of roots per seedling (32.22 at 60 DAS), and the greatest fresh and dry root weights (12.21 g and 1.57 g at 60 DAS, respectively). These values were statistically at par with $T_6$ (NAA @ 75%) and $T_3$ ($GA_3$ @ 75 ppm), both of which also exhibited notable improvements over the control.

From an economic standpoint, the integration of hormonal treatments, particularly $GA_3$ and NAA, substantially increased profitability. While the base cost of seedling production remained constant across treatments, the inclusion of growth regulators resulted in markedly higher survival rates and returns. $T_4$ ($GA_3$ @ 100 ppm) proved to be the most cost-effective, achieving the highest survival rate (85%), gross return (₹17,000), net profit (₹8,800), and benefit-cost ratio (2.07). Treatments $T_3$ and $T_6$ also yielded favorable economic outcomes with B ratios above 1.7, making them practical alternatives.

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