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# Effect of plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum* L.)

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**Abstract**
A field experiment was conducted on clayey soil at the instructional farm of the College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during the *rabi* season. The experiment followed a randomized block design with three replications, encompassing nine treatments. These treatments involved four plant growth regulators at two levels: $GA_3$ (gibberellic acid) at 25 and 50 ppm, NAA (naphthalene acetic acid) at 25 and 50 ppm, Seaweed extract at 5% and 10%, and triacontanol at 250 and 500 ppm. Foliar sprays were applied at 25 and 50 days after sowing (DAS), and a control group received water spray. The results indicated that the foliar application of $GA_3$ at 50 ppm at both 25 and 50 DAS resulted in significantly higher values for various growth parameters, including primary and secondary branches per plant, as well as yield attributes such as the number of pods per plant, number of seeds per pod, pod length, number of seeds per plant, and test weight. This treatment also exhibited superior seed and stover yields, as well as biological yield, compared to the control (water spray). Notably, the performance of $GA_3$ at 50 ppm was comparable and not significantly different from $GA_3$ at 25 ppm and NAA at 50 ppm, especially concerning seed and stover yields. Furthermore, the foliar application of $GA_3$ at 50 ppm at 25 and 50 DAS resulted in a notable enhancement in nutrient content (N, P, and K) and their uptake by fenugreek seeds and stover. This improvement was more pronounced compared to the control and $GA_3$ at 25 ppm. Economic analysis of the plant growth regulator treatments indicated that the foliar application of $GA_3$ at 50 ppm at 25 and 50 DAS was the most profitable, with a net return of 50937 $ha^{-1}$, surpassing the other treatments. In summary, the study suggests that optimal crop yield and higher net returns per hectare in fenugreek can be achieved through the foliar application of $GA_3$ at 50 ppm at 25 and 50 DAS.

**Keywords:** Plant growth regulators, fenugreek, $GA_3$, NAA, seaweed, yield

## Introduction
Fenugreek (*Trigonella foenum-graecum* L.) is an annual spice herb in the Papilionaceae subfamily of the Leguminaceae family. It is a diploid, self-pollinated legume with a chromosome number of 2n=16, valued not only as a spice but also for its potential source of diosgenin. Recognized as one of the oldest medicinal plants, it has its origins in the Indian sub-continent and the Eastern Mediterranean Region. Cultivated globally, fenugreek thrives in warm temperate and tropical regions, exhibiting adaptability to semi-arid conditions and tolerance to mild salinity. India, renowned as the "Land of Spices," takes the lead as the largest producer, consumer, and exporter of spices. The seed spices group, encompassing annuals with seeds used as spices, sees significant contributions from Gujarat and Rajasthan, together constituting over 80% of total seed spice production in the country. Fenugreek holds a vital place in Indian agriculture, being the third-highest seed spice after coriander and cumin. Its historical presence in the Indian diet spans over 3000 years. Rich in essential amino acids and trigonelline, fenugreek seeds find diverse uses in medicinal applications, spice blends, and culinary preparations. Chemical analysis of fenugreek seeds reveals a nutrient-rich profile, including water, protein, fat, fibers, carbohydrates, calcium, phosphorus, iron, calories, and carotene. The seeds are known for their health benefits, aiding digestion, reducing inflammation, and promoting breastfeeding, among other advantages. Utilized for its pleasantly bitter taste and distinct aroma, fenugreek seeds enhance the flavor of curry powders, spices, and meat products. In India, the crop is grown on approximately 50,400 ha, with a production of 62,800 tons and a productivity of 1245 kg $ha^{-1}$. Notably, Gujarat achieved the highest productivity (2011 kg $ha^{-1}$) in the country in 2017-18. (Anon., 2017) [2].
Plant growth substances play a pivotal role in diverse physiological processes governing the growth and development of crops. It is evident that alterations in endogenous hormone levels, triggered by both biotic and abiotic stress factors, can significantly impact crop growth.

Any form of manipulation, including the exogenous application of growth substances, emerges as a strategy to enhance yield or, at the very least, sustain the crop. Typically, hormones traverse within the plant, moving from their production site to the targeted action site. Phytohormones, acting as vital intercellular messengers, play a crucial role in orchestrating the entire life cycle of a plant. This cycle spans germination, rooting, growth, flowering, fruit ripening, foliage development, and ultimately, the natural life conclusion. In recent times, the strategic utilization of plant growth regulators (PGRs) has emerged as a pivotal avenue for achieving remarkable strides in crop production and overall productivity. The application of these regulators has been documented to enhance the physiological efficiencies of plants, notably elevating their photosynthetic capabilities. This, in turn, has translated into superior growth and increased yields of agronomic crops, all achieved without a significant escalation in production costs. The application of exogenous plant growth regulators (PGRs) has been widely acknowledged for its transformative impact on crop growth and yield across various studies PGRs play a pivotal role in regulating the physiological functions of plants, as noted by researchers emphasizing the positive outcomes achieved through PGR spraying on crop plants. Noteworthy among the diverse PGRs are NAA and GA3, recognized for their efficacy in enhancing growth, yield, and quality attributes in crops such as dill fenugreek. Additionally, the application of Triacontanol (TRIA) has demonstrated a notable impact, improving leaf size and dry weight, thereby increasing the number of branches, umbels per plant, and seed yield in coriander. Furthermore, the foliar application of NAA has proven effective in enhancing the physiological efficiency, including the photosynthetic ability of plants. This application has been shown to boost the growth and yield of various vegetable and agricultural crops without a significant upswing in production costs. These findings underscore the potential of PGRs as a strategic tool for optimizing crop performance and ensuring sustainable agricultural practices.

## Materials and Methods

The experiment took place during the Rabi season in Junagadh, located in the South Saurashtra Agro-climatic Zone of Gujarat, known as the oil bowl of the country. This region has a typical subtropical climate characterized by a cold and dry winter, hot and dry summer, and warm and moderately humid monsoon. The soil in the experimental plot was clayey with a slightly alkaline reaction, having a pH of 7.9 and EC of 0.49 dS/m. The soil exhibited low availability of nitrogen (285 kg/ha), high availability of phosphorus (68 kg/ha), and medium availability of potash (232 kg/ha). Throughout the crop season, the minimum and maximum temperatures ranged from 10.2 oC to 18.7 oC and 27.3 oC to 36.6 oC, respectively. Gujarat Fenugreek-2 (GF-2) was sown at 30 cm x 10 cm with the recommended dose of fertilizer. The experimental setup included nine treatments arranged in a Randomized Block Design with three replications. The treatments were as follows: $T_1$-control, $T_2$-NAA @ 25 ppm, $T_3$-NAA @ 50 ppm, $T_4$-GA3 @ 25 ppm, $T_5$-GA3 @ 50 ppm, $T_6$-Seaweed at 5%, $T_7$-Seaweed at 10%, $T_8$-Triacontanol @ 250 ppm, and $T_9$-Triacontanol @ 500 ppm. All treatments were applied by spray at 25 & 50 DAS (Days After Sowing). Throughout the period from germination to harvest, various plant growth parameters were meticulously recorded at frequent intervals. Additionally, after harvest, several yield parameters were documented.

## Results and Discussion

### Effect on Yield attributes

The results indicated a significant improvement in yield-related characteristics with the foliar application of plant growth regulators. Among the various regulators applied, 50 ppm $GA_3$ ($T_5$) exhibited the most favorable outcomes, resulting in the highest number of primary branches per plant (7.55), secondary branches per plant (12.97), number of pods per plant (25.04), number of seeds per pod (15.36), pod length (11.94 cm), and test weight (17.24 g). This performance was closely followed by 25 ppm GA3 ($T_4$) and 50 ppm NAA ($T_5$) in all parameters except for pod length and test weight. The observed increase in the number of primary and secondary branches due to $GA_3$ may be attributed to its antagonistic action against auxins, which are responsible for apical dominance. This antagonistic action suppresses terminal bud growth, allowing accumulated metabolites to translocate towards the auxiliary buds, thereby stimulating lateral growth. These findings align with previous studies by Gangaram (2011) [4], Talab *et al.* (2014) [10], and Tariq *et al.* (2015) [11] in fenugreek, as well and Haokip *et al.* (2016) [5] in coriander. The rise in the number of pods per plant could be linked to the increased number of both primary and secondary branches induced by gibberellic acid. Similar results were reported by Bairwa and Kaushik (2007) [3] and Gangaram (2011) [4] in fenugreek.

### Effect on seed and stover yield

Foliar application of plant growth regulators, specifically $GA_3$ at 50 ppm, resulted in significantly higher seed yield (1686 kg/ha) and stover yield (3051 kg/ha). This performance was statistically comparable to $GA_3$ at 25 ppm ($T_4$) and NAA at 50 ppm ($T_3$) but remained higher than the other treatments, including the control (water spray), which recorded lower seed and stover yields. The enhanced vegetative growth attributed to the application of plant growth regulators, along with increased photosynthates, likely contributed to greater mobilization of photosynthesis towards reproductive sites. This dual effect led to improvements in both growth and yield attributes. Consequently, the cumulative impact of these enhancements resulted in a significant increase in seed yield. The improved vegetative growth also contributed significantly to the increase in stover yield. These findings closely align with previous studies by Gangaram (2011) [4] and Tariq *et al.* (2015) [11] in fenugreek, as well as Vasudevan *et al*. (2008) [12], Prajapat *et al.* (2015) [9], and Haokip *et al*. (2016) [5] in coriander, and Mohit *et al.* (2016) [7] in ajwain.

### Effect on nutrient content and uptake

The nutrient content of nitrogen (N), phosphorus (P), and potassium (K) in both seed and stover (Table 2) was significantly influenced by the application of plant growth regulators. Treatment $T_5$ ($GA_3$ 50 ppm) exhibited significantly higher values for these parameters, remaining on par with treatments $T_4$ ($GA_3$ 25 ppm) and $T_3$ (NAA 50 ppm) concerning N, P, and K content in both seed and stover. Conversely, the control group (water spray) showed lower nutrient content in both seed and stover. The application of gibberellic acid likely enhanced the metabolic processes of plants, promoting better growth and development, resulting in increased nutrient absorption from the rhizosphere. This effect may have stimulated root growth and their functional activity, leading to a higher extraction of nutrients from the soil environment to the aerial parts of the plant. Similar results have been reported by Verma and Sen (2006) [13, 14], Gangaram (2011) [4] in fenugreek, and Idrees *et al.* (2010) [6] in coriander.

Additionally, the uptake of N, P, and K by seed and stover (Table 3) significantly increased due to $GA_3$ 50 ppm ($T_5$), which was statistically on par with $GA_3$ 25 ppm ($T_4$) and NAA 50 ppm ($T_3$) in terms of N, P, and K uptake by seed and stover. Lower nutrient uptake was recorded in the control group (water spray). The quantum of nutrient uptake by the crop is dependent on the extent of biomass production and the concentration of nutrients at the cellular level. Since the concentration of nutrients is improved by the application of plant growth regulators (Table 3), the total biomass production is primarily responsive to the quantum of nutrient uptake. Similar results have been reported by Nehara *et al.* (2006) [8], in fenugreek and Mohit *et al.* (2016) [7] in ajwain.

**Economics**

The data in (Table 4) clearly indicates that the maximum net return of Rs. 50,937 per hectare was obtained with $GA_3$ 50 ppm, followed by Rs. 50,012 per hectare with $GA_3$ 25 ppm. However, the maximum benefit-cost ratio of 2.48 was achieved with $GA_3$ (25 ppm), followed by 2.44 with $GA_3$ (50 ppm), whereas lower net returns of Rs. 24,422 per hectare and a benefit-cost ratio of 1.75 were noted under the control (water spray).

**Table 1:** Effect of plant growth regulators on yield attributing character, seed and stover yield of fenugreek

| Treatments | No. of primary branches/plant at Harvest | No. of secondary bra./ lant at Harvest | No. of pods per plant | No. of seeds per pod | Length of pod (cm) | Test weight (g) | Seed yield (kg/ha) | Stover yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| $T_1$ – Control | 5.49 | 8.34 | 18.34 | 10.98 | 9.15 | 14.20 | 1091 | 2211 |
| $T_2$ – NAA 25 ppm | 6.37 | 9.83 | 21.71 | 12.67 | 9.83 | 15.02 | 1385 | 2601 |
| $T_3$ – NAA 50 ppm | 6.81 | 11.43 | 22.03 | 13.67 | 11.14 | 14.98 | 1574 | 2695 |
| $T_4$ –$GA_3$ 25 ppm | 7.14 | 11.66 | 23.68 | 14.01 | 10.19 | 16.38 | 1616 | 2840 |
| $T_5$ – $GA_3$ 50 ppm | 7.55 | 12.97 | 25.04 | 15.36 | 11.94 | 17.24 | 1686 | 3051 |
| $T_6$ – Seaweed 5% | 6.46 | 10.64 | 20.99 | 12.66 | 10.63 | 14.90 | 1385 | 2459 |
| $T_7$ - Seaweed 10% | 6.53 | 10.99 | 21.99 | 12.66 | 10.99 | 16.15 | 1397 | 2554 |
| $T_8$ – Triacontanol 250 ppm | 6.40 | 9.45 | 19.71 | 12.66 | 9.45 | 16.19 | 1259 | 2388 |
| $T_9$ – Triacontanol 500 ppm | 6.17 | 8.99 | 19.03 | 11.31 | 9.18 | 14.61 | 1164 | 2347 |
| S.Em.± | 0.35 | 0.51 | 1.05 | 0.83 | 0.47 | 0.62 | 84.58 | 148.41 |
| C.D. at 5% | 1.05 | 1.54 | 3.17 | 2.49 | 1.43 | 1.86 | 253.59 | 444.93 |
| C.V. % | 9.31 | 8.55 | 8.57 | 11.06 | 8.08 | 7.01 | 10.50 | 9.99 |

**Table 2:** Effect of plant growth regulators on nitrogen, phosphorus and potash content in seed and stover of fenugreek

| Treatments | N content (%) | | P content (%) | | K content (%) | |
|---|---|---|---|---|---|---|
| | Seed | Stover | Seed | Stover | Seed | Stover |
| $T_1$ – Control | 3.16 | 1.80 | 0.29 | 0.20 | 0.51 | 0.50 |
| $T_2$ – NAA 25 ppm | 3.43 | 2.02 | 0.34 | 0.20 | 0.58 | 0.53 |
| $T_3$ – NAA 50 ppm | 3.72 | 2.28 | 0.41 | 0.25 | 0.62 | 0.59 |
| $T_4$ –$GA_3$ 25 ppm | 3.75 | 2.40 | 0.45 | 0.26 | 0.64 | 0.61 |
| $T_5$ – $GA_3$ 50 ppm | 3.83 | 2.53 | 0.47 | 0.29 | 0.68 | 0.63 |
| $T_6$ – Seaweed 5% | 3.30 | 2.12 | 0.35 | 0.22 | 0.57 | 0.51 |
| $T_7$ - Seaweed 10% | 3.52 | 2.10 | 0.36 | 0.23 | 0.58 | 0.54 |
| $T_8$ – Triacontanol 250 ppm | 3.36 | 2.06 | 0.31 | 0.22 | 0.54 | 0.53 |
| $T_9$ – Triacontanol 500 ppm | 3.29 | 1.90 | 0.31 | 0.22 | 0.52 | 0.52 |
| S.Em.± | 0.09 | 0.04 | 0.006 | 0.005 | 0.01 | 0.01 |
| C.D. at 5% | 0.29 | 0.13 | 0.02 | 0.01 | 0.04 | 0.04 |
| C.V. % | 4.93 | 3.77 | 3.33 | 4.54 | 4.60 | 4.84 |

**Table 3:** Effect of plant growth regulators on nitrogen, phosphorus and potash uptake by seed and stover of fenugreek

| Treatments | N uptake (kg/ha) | | P uptake (kg/ha) | | K uptake (kg/ha) | |
|---|---|---|---|---|---|---|
| | Seed | Stover | Seed | Stover | Seed | Stover |
| $T_1$ – Control | 34.64 | 39.84 | 3.19 | 4.42 | 5.59 | 11.14 |
| $T_2$ – NAA 25 ppm | 47.55 | 53.51 | 4.70 | 5.35 | 7.99 | 13.83 |
| $T_3$ – NAA 50 ppm | 58.68 | 62.36 | 6.41 | 6.66 | 9.68 | 15.92 |
| $T_4$ –$GA_3$ 25 ppm | 60.61 | 67.99 | 6.99 | 7.43 | 10.21 | 17.38 |
| $T_5$ – $GA_3$ 50 ppm | 64.55 | 77.00 | 7.98 | 8.82 | 11.37 | 19.07 |
| $T_6$ – Seaweed 5% | 45.85 | 52.81 | 4.79 | 5.50 | 7.83 | 12.56 |
| $T_7$ - Seaweed 10% | 48.93 | 53.67 | 5.07 | 5.88 | 8.13 | 13.78 |
| $T_8$ – Triacontanol 250 ppm | 42.35 | 49.39 | 3.90 | 5.35 | 6.75 | 12.64 |
| $T_9$ – Triacontanol 500 ppm | 38.38 | 44.47 | 3.57 | 5.17 | 6.04 | 12.19 |
| S.Em.± | 3.84 | 4.45 | 0.35 | 0.49 | 0.56 | 1.04 |
| C.D. at 5% | 11.51 | 13.34 | 1.07 | 1.48 | 1.68 | 3.13 |
| C.V. % | 13.56 | 13.85 | 12.01 | 14.11 | 11.93 | 12.67 |

**Table 4:** Effect of plant growth regulators on economics of fenugreek

| Treatments | Gross Returns (Rs./ha) | Cost of production (Rs./ha) | Net returns (Rs./ha) | B:C ratio |
|---|---|---|---|---|
| $T_1$ – Control | 56767 | 32344 | 24422 | 1.75 |
| $T_2$ – NAA 25 ppm | 71852 | 33506 | 38346 | 2.14 |
| $T_3$ – NAA 50 ppm | 81412 | 34667 | 46746 | 2.34 |
| $T_4$ –$GA_3$ 25 ppm | 83790 | 33778 | 50012 | 2.48 |
| $T_5$ – $GA_3$ 50 ppm | 86151 | 35214 | 50937 | 2.44 |
| $T_6$ – Seaweed 5% | 71702 | 32348 | 39353 | 2.21 |
| $T_7$ - Seaweed 10% | 72384 | 32354 | 40033 | 2.23 |
| $T_8$ – Triacontanol 250 ppm | 65313 | 33654 | 31659 | 1.94 |
| $T_9$ – Triacontanol 500 ppm | 60569 | 34963 | 25606 | 1.78 |

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