Effect of Integrating Plant Growth Regulators and Micronutrients on Growth, Phenology and Seed Yield of Fenugreek (*Trigonella foenum-graecum* L.)

Abstract

An experiment was conducted during *Rabi* 2019-20 at College of Agriculture, Indore(Madhya Pradesh) to investigate the effects of Plant Growth Regulator (PGRs) and Micro-nutrient Application on Growth, Quality, and Seed yield of Fenugreek (*Trigonella foenum-graecum* L.). The nine treatments consisted of different levels of PGRs i.e. GA_3 and NAA with micro-nutrient (Mixol) including control viz. T_1 = 50 ppm GA_3 seed treatment + Mixol 1.0%, T_2 = 100 ppm GA_3 seed treatment + Mixol 1.0%, T_3 = 50 ppm GA_3 foliar spray + Mixol 1.0%, T_4 = 100 ppm GA_3 foliar spray + Mixol 1.0%, T_5 = 25 ppm NAA seed treatment + Mixol 1.0%, T_6 = 50 ppm NAA seed treatment + Mixol 1.0%, T_7=25 ppm foliar spray + Mixol 1.0%, T_8 = 50 ppm NAA foliar spray + Mixol 1.0% and T_9 = Control. Data were collected on different growth and yield characters of fenugreek. Based on results of one year experimentation, foliar spray of GA_3 @ 100 ppm with mixol 1.0% was found best as compared to other treatments with respect to plant growth and seed yield of fenugreek.

Introduction:

Fenugreek (*Trigonella foenum-graecum* L.) is an important vegetable grown in tropical and subtropical regions worldwide. India is known as the "Land of Spices" and is a major producer, consumer, and exporter of spices.It is used as a herb (fresh leaves or dried), and

spice (seeds) (Zandi et al. 2015). Fenugreek ranks third in world spice production after coriander and cumin. Spices play an important role in improving the flavour, texture, aroma, colour and spiciness of the food, contributing to the country's foreign exchange earnings. Fenugreek is a versatile and commercially valuable crop cultivated for its seeds, shoots, and fresh leaves in almost all parts of India. Out of 63 spices cultivated in India, 20 are classified as spice seeds, accounting for 36% of all spices cultivated and 17% of the country's spice production (Anwer et al., 2011).

In India, area under fenugreek is 93,125 ha with production of 12,10,845 tonnes (Anonymous, 2017-18). Rajasthan covered maximum area and production under fenugreek cultivation. It contributes 80 percent area and production of the country alone. Madhya Pradesh shared 10.12 percent in the total production of India (Anonymous, 2017). The major districts where fenugreek is cultivated include Jabalpur, Chhatarpur, Indore, Mandsaur, Nimach, Sehore and Sagar.

Fenugreek is an important legume used as a vegetable, spice and herb, its fresh and dried leaves and seeds are consumed worldwide (Lewis et al., 2005).It is assumed to possess nutritive and restorative properties. The young leaves and sprouts are good source of protein, minerals, and vitamin-C (Khan et al., 2005 and Chhibba et al., 2007). Seeds are rich source of protein (16.3%), fat (9.5%), carbohydrates (42.3%), vitamin-A (1040 W) and also have 370 cal/100 g calorific value. Besides, as compare to leaf, it contains gum (22.06%), trigonellin (0.13-0.35%), diosgenin (1.0g), gitosgenin (0.1 g), and a trace of triogenin per kg of dried seeds (Lakshami*et al.,* 2015). Fenugreek seeds have an oil content of around 7%, with the fatty acids predominantly consisting of linoleic, oleic, and linolenicacids.In England, diosgenin, a steroid derived from fenugreek seeds, is used in the production of sex hormones and oral contraceptives for family planning (Vasudevan et al., 2008). It is also serves as an excellent soil conditioner and is used as green manure (Srivastava, 2015).

It is an annual crop belonging to the Leguminosae (Fabaceae) family and the Papilionaceae subfamily. The plant grows erect or spreads out, reaching a height of 10-110 cm, with long, slender stems that bear pinnately trifoliate, toothed, grey-green obovate leaves. The plant emits a spicy aroma that lingers on the hands after contact. Its flowers are 1-2 racemes, whitish or lemon yellow, axillary, and sessile. The pods are 8-15 cm long, beak-shaped, and hairy, containing 10-18 seeds. The seeds are small (5 mm), brownish-yellow, hard, and flattened, surrounded by a darker, translucent endosperm that separates the radical from the cotyledons (Snehalatha and Payal, 2012).

Plant growth regulators (PGRs) are often insufficiently available in plants, yet they play critical roles in various physiological processes, where their specific concentrations are responsible for either promoting or inhibiting growth (Kumar et al., 2018). PGRs are known to significantly influence growth and development at high concentrations (Patel et al., 2018).They are essential for enhancing crop production and quality, and can be categorized into five major classes: auxins, gibberellins, cytokinins, abscisic acid, and ethylene. Gibberellic acid, a key growth-stimulating substance, aids in increasing stalk length, enhancing vegetative growth, initiating flowering, improving fruit size, hastening maturity, and improving fruit quality in various crops (Swamy, 2012; Haq et al., 2013).Similarly, synthetic auxin, such as NAA, is important in processes like cell elongation, cell division, vascular tissue differentiation, root inhibition, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting, and flowering.Foliar application of PGRs has proven to be highly effective in increasing vegetative growth, early fruiting, total yield, and quality of fruits in many vegetable and spice crops (Krishnaveni et al., 2014).

Commented [AS1]: Mixol not all introduced
Objectives not mentioned

MATERIALS AND METHOD

The experiment was carried out at the Experimental Unit, College of Agriculture, Indore (M.P.) during Rabi season, 2019-20. The study area is situated at $22^0$43' North latitude and $75^0$66' East longitudes with an altitude of 556 meters above mean sea level.In Madhya Pradesh, this region falls under agro-climatic Zone-I (Malwa plateau in the Western part of M.P.). The climate of this region is sub-tropical having mid-winter with uncertain winter rains and having a temperature range of 21^0C to 44^0C in summers and 6^0C and 32^0C in winters.The rainfall occurs mostly from mid-June to the end of September. The South-West monsoon is responsible for major part of annual precipitation and annual mean rainfall is 965 mm.The soil of the experimental area is medium black clay (Vertisols), and has a static surface and good drainage capacity. The experiment was adapted to a randomized block design and repeated three times.

The objective of this study is to investigate the combined influence of various plant growth regulators and micronutrient treatments on the growth dynamics and seed productivity of fenugreek. Specifically, the study aims to evaluate how different plant growth regulators and micronutrient combinations affect key growth parameters such as plant height, leaf area, and biomass accumulation, as well as seed yield metrics including total seed weight, seed number per plant, and seed size. Additionally, the research seeks to determine the impact of these integrated treatments on the critical developmental stages of fenugreek, including germination, vegetative growth, flowering, and seed maturation, and to analyze the physiological and biochemical responses, such as chlorophyll content and photosynthetic efficiency, to these treatments. The study also aims to identify the most effective combinations of plant growth regulators and micronutrients for optimizing fenugreek growth and yield while assessing their potential to enhance the plant's resilience to environmental stressors.Before flowering, five plants from each row were randomly selected and labeled to collect information on specific characteristics.

Commented [AS2]: Not present

Commented [AS3]: Not present

Commented [AS4]: Not present in manuscript

Table 1.0 Treatment combinations

Symbols	Treatments details
T$_1$	GA$_3$ @ 50 ppm + seed treatment + Mixol 1.0%
T$_2$	GA$_3$ @ 100 ppm + seed treatment + Mixol 1.0%
T$_3$	GA$_3$ @ 50 ppm + foliar spray + Mixol 1.0%
T$_4$	GA$_3$ @ 100 ppm + foliar spray + Mixol 1.0%
T$_5$	NAA @ 25 ppm + seed treatment + Mixol 1.0%
T$_6$	NAA @ 50 ppm + seed treatment + Mixol 1.0%
T$_7$	NAA @ 25 ppm + foliar spray + Mixol 1.0%
T$_8$	NAA @ 50 ppm + foliar spray + Mixol 1.0%
T$_9$	Control (No use of PGRs and micro-nutrients)

Commented [AS5]: On what basis these concentrations were decided

Commented [AS6]: Composition needed, which company

Commented [AS7]: Needed full form

Results and discussion

Growth attribute

Plant height

The study evaluated the effects of various plant growth regulators (PGRs) and micronutrient treatments on fenugreek plant height at different growth stages. Significant variations in plant height were observed among treatments, as summarized in Table 1. Among the treatments, the highest plant height was obtained with T4, which consisted of a foliar spray of GA_3 at 100 ppm with 1.0% Mixol, which showed significant increase compared to all other treatments. This result is consistent with earlier findings that GA_3, a gibberellin, promotes stem elongation and overall plant height by stimulating cell division and elongation (Chaudhary et al., 2015). The second highest plant height was recorded with T8, where NAA at 50 ppm with 1.0% Mixol was used. NAA, an auxin, is known to affect cell elongation and can synergistically react with micronutrients to enhance plant growth (Khan et al., 2017). In contrast, the lowest plant height was observed in the control treatment T9, which received no PGR or micronutrient application. This indicates that the absence of PGRs and micronutrients resulted in less vigorous growth, highlighting their importance in promoting plant height. These findings match previous research showing that plant growth regulators and micronutrients are important for optimal plant growth and can significantly enhance growth parameters (Ali et al., 2016). The observed increase in plant height with GA_3 application can be attributed to its role in promoting cell elongation and division.(Gholami et al. 2018, Sharma et al. 2006) reported that high concentrations of GA_3 positively affected plant height in various crops.

Branches per plant

The results showed significant variation in the number of branches per plant, which is affected by different concentrations of GA_3 and NAA in combination with micronutrients. Treatment T4, which consisted of a foliar spray of GA_3 at 100 ppm with 1.0% Mixol, resulted in the highest number of branches per plant. Specifically, T4 produced 5.60 branches at 30 days after sowing (DAS), 16.86 branches at 60 DAS, and 24.50 branches at harvest time. These results were significantly better than all other treatments. The increased branching observed in T4 can be attributed to the role of GA_3 in promoting cell division and elongation, which facilitates increased branch growth (Khan et al., 2018, Bakker et al., 2015). Treatment T8, which contained NAA at 50 ppm with 1.0% Mixol, also demonstrated an increase in the number of branches compared to most other treatments but was not as pronounced as T4. The observed increase in branching with NAA is consistent with its known effects on promoting lateral bud development and enhancing branch formation (Choudhary et al., 2016). In contrast, the control treatment T9 in which no PGRs or micronutrients were used showed the least number of branches per plant, with 3.37 branches at 30 DAS, 11.77 branches at 60 DAS, and 19.73 branches at harvest. Similarly, T1 with GA3 at 50 ppm as a seed treatment combined with Mixol also displayed lower number of branches than T4, indicating that lower concentrations of GA_3 were less effective in promoting branch growth (Sharma et al., 2006,Sunanda et al. 2014,Ali et al., 2018).

Phonological attributes

Days to 1st flowering

The results showed that there was no significant difference in the number of days taken to first flowering in different treatments, indicating that the application of GA_3 and NAA along with micronutrients did not cause any major change in the time taken to flowering. However, the highest number of days taken to first flowering was recorded in the T4 treatment, which involved foliar spray of GA_3 at 100 ppm with 1.0% mixol, with an average of 51.22 days. In contrast, the lowest number of days taken to first flowering was observed in the control treatment, T9, which did not receive any PGR or micronutrients, with an average of 46.44 days. These findings suggest a slight delay in flowering due to GA_3 treatment, although the difference was not statistically significant. The results are consistent with previous research showing that gibberellins such as GA_3 can sometimes delay flowering in certain plant species due to their role in extending the vegetative phase and promoting growth (Al-Ghamdi et al., 2017). This delay can be attributed to the effect of GA_3 on promoting vegetative growth and increasing the time required for plants to transition from the vegetative to the reproductive phase (Khan et al., 2016).

Days to 50% flowering

The results showed that the application of different levels of GA_3 and NAA along with micronutrients did not cause any significant difference in days to 50% flowering. This indicates that while these treatments may affect other growth parameters, their effect on the time to 50% flowering was minimal. Despite the lack of significant variation, notable trends were observed. Treatment T4, which involved foliar spray of GA_3 at 100 ppm with 1.0% Mixol, resulted in the highest number of days to 50% flowering, averaging 60.09 days. This finding suggests that high concentrations of GA_3 may cause a delay in flowering. The delay in flowering associated with GA_3 application may be attributed to its role in extending the vegetative growth phase and promoting overall plant growth, which may subsequently postpone the reproductive phase (Ali et al., 2018). Similar results have been reported in previous studies, where high levels of gibberellins were found to increase flowering time due to increased vegetative growth (Moein et al., 2016). In contrast, the least number of days to 50% flowering was observed in the control treatment, T9, in which no PGRs or micronutrients were used, averaging 55.63 days.

No. of days taken to seed maturity

The findings showed that the treatments did not result in any significant difference in the number of days required for seed maturity. This suggests that the application of GA_3 and NAA along with micronutrients had minimal effect on the duration of the reproductive stage in fenugreek.Despite the lack of statistical significance, treatment T4, which involved foliar spray of GA_3 at 100 ppm with 1.0% Mixol, resulted in the highest number of days taken for seed maturity, averaging 118.15 days. This trend indicates that higher concentrations of GA_3 may slightly increase the time to seed maturity. Gibberellins, like GA_3, are also known to promote vegetative growth, which may result in a longer growth cycle before fully transitioning to the reproductive stage (Choudhary et al., 2017). This delay in seed maturity may be due to the ability of GA_3 to stimulate vegetative vigour, thereby increasing the time taken for the plant to complete its life cycle and reach seed maturity (Moein et al., 2016) and the shortest number of days to seed maturity was observed in the control treatment, T9, which did not involve the use of PGRs or micronutrients. The control plants matured in an average of 111.17 days, indicating that the absence of PGRs and micronutrients led to a shorter time for seed maturity.

Yield characteristics

Seed yield per plant

The application of different levels of plant growth regulators (PGRs), including GA3 and NAA in combination with Mixol (1.0% micronutrient solution), had a significant effect on seed yield per plant. The results demonstrated that the highest seed yield per plant (13.92 g) was observed in treatment T4, which consisted of foliar spray of 100 ppm GA_3 with Mixol (1.0%). This was closely followed by treatment T8 (50 ppm NAA foliar spray with Mixol), indicating the beneficial effects of these PGRs on improving seed yield. The increase in seed yield observed in T4 treatment can be attributed to the role of GA_3 in enhancing plant growth and development. Gibberellins, such as GA_3, are known to stimulate various physiological processes, including cell elongation, enzyme activation, and nutrient mobilization, all of which contribute to enhanced reproductive growth and seed set (Khan et al., 2016. Ali et al., 2015). Treatment T8, which consisted of 50 ppm foliar spray of NAA combined with Mixol, resulted in a seed yield of 12.86 g per plant. This relatively high seed yield suggests that NAA, an auxin, also plays an important role in enhancing reproductive growth by promoting cell division and fruit/seed development (Gholami et al., 2017).). In contrast, the lowest seed yield (9.56 g) per plant was recorded in the control treatment (T9) which did not receive any PGRs or micronutrients. Similar results were found inMehta et al. (2012)and Choudhary et al., (2014) in fenugreek.

Seed yield quintal per hectare

The highest seed yield per hectare (15.24 quintals/ha) was observed in treatment T4, which involved foliar spray of 100 ppm GA_3 with Mixol 1.0%. This was closely followed by treatment T8, which involved foliar spray of 50 ppm NAA with Mixol, yielding 15.08 quintals/ha. The control treatment, T9, which did not add any PGR or micronutrients, produced the lowest seed yield per hectare (12.32 quintals/ha). The significant increase in seed yield under treatment T4 can be attributed to the positive effects of GA_3 on both vegetative and reproductive growth. GA_3 promotes cell growth, enhances nutrient translocation, and improves overall plant vigour, which collectively contributes to higher seed yield (Choudhary et al., 2016). The result of 15.24 q/ha from T4 is consistent with previous research showing that foliar application of GA_3 increases seed yield in legumes and other crops (Mehta et al. 2012. Khan et al., 2018. Moein et al., 2017). Treatment T8 (50 ppm NAA with Mixol) resulted in significantly higher seed yield (15.08 quintals/ha), indicating that NAA, an auxin, plays an important role in promoting reproductive growth and seed yield in fenugreek. NAA stimulates root growth, enhances nutrient absorption, and supports fruit and seed development, which contribute to substantial increases in yield (Ali et al., 2015). The control treatment, T9, which did not receive any PGRs or micronutrients, resulted in the lowest seed yield per hectare (12.32 quintals/ha). This finding emphasizes the importance of exogenous application of PGRs and micronutrients to optimize seed yield. Similar results were found in Mehta et al. (2012) in fenugreek, Sahu et al. (2012), and Hnamte et al. (2013) in coriander.

Number of pods per plant

The results showed that the highest number of pods per plant (86.18) was recorded from treatment T4, which consisted of foliar spray of 100 ppm GA_3 with Mixol (1.0%). This was significantly higher than all other treatments and was followed by treatment T8 (50 ppm NAA foliar spray with Mixol), which recorded 84.76 pods per plant. The significant increase in the number of pods per plant in treatment T4 can be attributed to the positive effect of GA_3 on enhancing both vegetative and reproductive growth. Treatment T8, which involved 50 ppm NAA foliar spray, resulted in a slightly lower number of pods per plant (84.76) than T4. NAA, an auxin, is known to promote cell division and pod formation by maintaining hormonal balance during reproductive growth stages (Chaudhary et al., 2014). The relatively high number of pods in T8 indicates the importance of auxins in supporting reproductive development, although the results suggest that GA_3 at 100 ppm is more effective in increasing the number of pods. In contrast, the lowest number of pods per plant (81.27) was found in the control treatment (T9), which did not receive any PGR or micronutrients. The control treatment was followed by T1 (50 ppm GA_3 seed treatment with Mixol), T5 (25 ppm NAA seed treatment with Mixol), and T6 (50 ppm NAA seed treatment with Mixol), all of which recorded lower pod numbers than the foliar treatments. Similar results for most of the characters were also reported by Bairva et al. (2012), Gendy et al. (2013), Naimuddin et al. (2014), Krishnaveni et al. (2016), Godara et al. (2018).

Length of pod (cm)

The results indicated that the highest pod length (15.27 cm) was observed from treatment T4, which consisted of foliar spray of 100 ppm GA_3 with Mixol 1.0%. This result was significantly different from all other treatments but was quite close to treatments T8 (50 ppm NAA foliar spray with Mixol) and T2 (100 ppm GA3 seed treatment with Mixol 1.0%), which showed pod lengths of 14.95 cm and 14.57 cm, respectively. The significant increase in pod length under treatment T4 can be attributed to the beneficial effects of GA_3 in promoting cell growth and overall vegetative growth, including the development of reproductive organs such as pods (Khan et al., 2016). Foliar application of GA_3 at 100 ppm possibly provides optimum hormonal conditions for pod growth, ensuring better pod development and yield potential. Treatment T8 (50 ppm NAA foliar spray with Mixol) also resulted in a significant increase in pod length (14.95 cm), suggesting that auxins such as NAA help to maintain proper hormonal balance, which is important for optimal pod growth. The results are consistent with previous findings showing that auxins, especially when applied as foliar sprays, effectively improve pod length and other yield components in legume crops (Chaudhary et al., 2016). The control treatment T9, which did not receive any PGR or micronutrients, displayed the lowest pod length (10.43 cm). This was statistically similar to the pod length recorded in treatments T1 (50 ppm GA3 seed treatment with Mixol 1.0%), T5 (25 ppm NAA seed treatment with Mixol 1.0%), and T6 (50 ppm NAA seed treatment with Mixol 1.0%). Similar results have been reported in previous research, where lack of hormonal stimulation led to sub-optimal pod development in beans (Gholami et al., 2017).

Number of seeds per pod

The highest number of seeds per pod (16.54) was recorded from treatment T4, which consisted of foliar spray of 100 ppm GA_3 with Mixol 1.0%. This result was statistically similar to T8 (50 ppm NAA foliar spray with Mixol 1.0%) and statistically similar to T3 (50 ppm GA_3 foliar spray with Mixol 1.0%) and T7 (25 ppm NAA foliar spray with Mixol 1.0%). The increased number of seeds per pod in treatment T4 suggests that the application of GA_3 at 100 ppm significantly enhances reproductive growth, possibly by improving flower and pod set and by enhancing seed development (Khan et al., 2016, Ali et al., 2015). Similarly, treatment T8 (50 ppm NAA foliar spray) also recorded a higher number of seeds per pod, indicating that auxins like NAA play a vital role in enhancing seed formation by promoting proper cell division and pod growth (Choudhary et al., 2016, Sharanya et al. (2018) and Reddy et al. 2020). Control treatment T9, which did not receive any plant growth regulator (PGR) or micronutrient, recorded the lowest number of seeds per pod (11.43). The control was followed by T1 (50 ppm GA_3 foliar spray with Mixol 1.0%), which showed a relatively lower seed number compared to higher PGR concentrations (Moein et al., 2018).

Biological yield (q/ha)

Different from all other treatments and followed by treatment T8 (50 ppm NAA foliar spray Mixol 1.0%), which recorded a biological yield of 43.62 q/ha. The increase in biological yield under treatment T4 can be attributed to the beneficial effects of GA_3, which promotes vegetative growth by enhancing cell division and elongation (Khan et al., 2016). Previous studies have shown that the application of GA_3 significantly improves biological yield in legume crops by enhancing both vegetative and reproductive growth (Ali et al., 2015). Treatment T8 containing 50 ppm NAA foliar spray also yielded a high biological yield (43.62 quintals per hectare), indicating the effectiveness of NAA in improving overall plant growth. The significant difference in biological yield between T8 and other treatments (except T4) highlights the importance of auxins in maximizing plant growth potential. The control treatment T9, which did not receive any plant growth regulators (PGRs) or micronutrients, recorded the lowest biological yield (37.58 quintals per hectare). The low yield in T9 is indicative of the absence of external growth stimuli, leading to sub-optimal vegetative growth and dry matter accumulation.

Harvest Index

The highest harvest index (34.89%) was recorded in treatment T4, which involved foliar application of 100 ppm GA_3 with Mixol 1.0%. This was statistically similar to treatment T8 (50 ppm NAA foliar spray with Mixol 1.0%), indicating that both treatments were effective in optimizing harvest index. The increased harvest index in T4 can be attributed to the favorable effect of GA_3 on partitioning of assimilates between vegetative and reproductive growth (Khan et al., 2016). GA_3 not only promotes vegetative growth but also improves fertility, ensuring that a greater proportion of the total biomass is allocated to seed production Treatment T8, which involved 50 ppm NAA foliar spray, also resulted in higher harvest index, indicating the beneficial effects of auxins on resource allocation. NAA improves hormonal balance in plants, ensuring optimal partitioning of nutrients towards seed development (Choudhary et al., 2016). In contrast, the control treatment T9, which did not add any PGR or micronutrients, recorded the lowest harvest index (31.16%). After T9, treatments T1 (50 ppm GA_3 seed treatment with Mixol 1.0%) and T5 (25 ppm NAA seed treatment with Mixol 1.0%) also showed a relatively lower harvest index than the foliar spray treatments.

Table no. 2 Effect of different treatments on growth and phonological attributes

Sym.	Plant height(cm)			No. of branches			Days of first flowering (Days)	Days of first flowering (Days)	Days taken to maturity (Days)
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest			
T_1	13.43	50.83	98.63	3.57	12.67	20.57	47.65	56.29	113.10
T_2	13.83	55.15	104.42	4.13	13.13	21.10	48.07	58.87	114.12
T_3	13.34	51.74	101.77	4.60	14.80	22.83	49.84	59.64	117.43
T_4	14.37	56.95	106.41	5.60	16.86	24.50	51.22	60.09	118.15
T_5	12.74	50.92	99.82	3.37	12.53	20.50	47.13	57.34	113.59
T_6	13.50	51.24	100.80	3.97	13.00	21.10	47.89	58.22	115.25
T_7	13.59	54.84	102.43	4.40	13.27	21.20	49.35	59.11	116.92
T_8	14.08	56.35	106.16	5.47	15.67	23.73	50.69	59.92	117.99
T_9	12.50	50.62	96.16	3.37	11.77	19.73	46.44	55.63	111.17
SEm±	**0.46**	**1.73**	**1.72**	**0.57**	**1.74**	**1.72**	**1.59**	**1.94**	**1.69**
CD(P =0.05)	**1.35**	**5.13**	**5.10**	**1.69**	**5.16**	**5.12**	**4.74**	**5.77**	**5.01**

Table no. 3 Effect of different treatments on yield attributes

Sym.	Seed yield(g/plant)	Seed yield(q/ha)	No. of pods/plant	Length of pod (cm)	No. of seeds/pod

T_1	9.76	12.56	82.73	11.40	12.67
T_2	11.82	14.12	84.67	14.27	14.07
T_3	12.67	14.88	85.46	12.87	15.47
T_4	13.92	15.24	86.18	15.27	16.81
T_5	10.49	13.42	83.07	11.80	12.20
T_6	11.26	13.84	84.42	12.27	12.93
T_7	12.26	14.44	85.16	13.07	14.77
T_8	13.13	15.08	85.93	15.00	16.43
T_9	9.56	12.32	81.27	10.43	11.43
SEm±	**1.01**	**0.70**	**2.45**	**1.11**	**1.31**
CD(P=0.05)	**2.99**	**2.08**	**7.27**	**3.31**	**3.88**

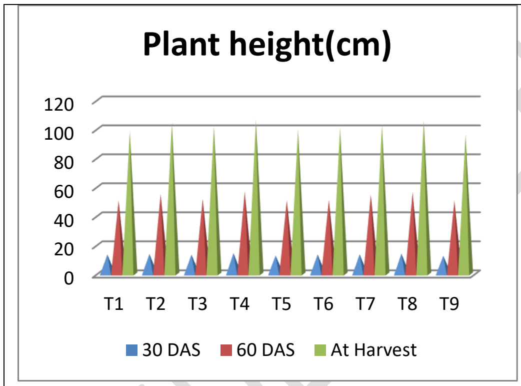

Fig. 1(a)

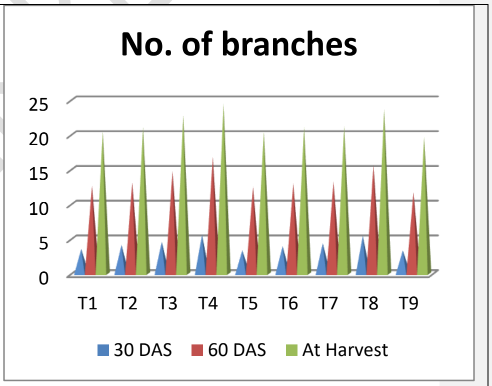

Fig. 1(b)

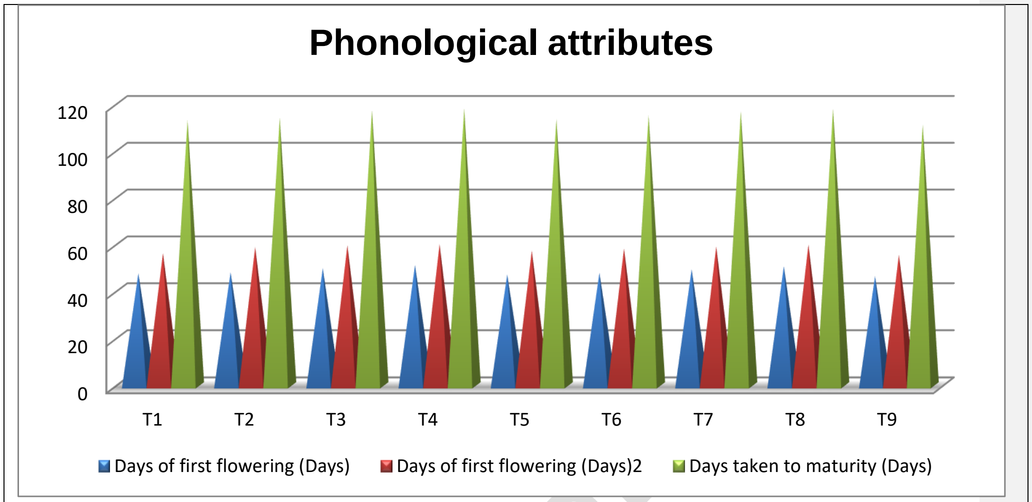

Fig. 1 (c)

Fig. 1(a,b,c) Effect of different treatments on growth and phonological attributes

Conclusion

Studies have shown that plant growth regulators (PGRs) used in combination with micronutrients such as GA_3 and NAA can affect many growth, phenological and yield traits of fenugreek. T4 treatment, which included foliar sprays of 100 ppm GA_3 and 1.0% Mixol, consistently outperformed the other treatments, resulting in the highest plant height, branch count, pod length, seed yield per plant plant and total biomass yield. This suggests that GA_3 plays a role in promoting cell division and elongation, helping to improve growth and development. NAA at 50 ppm in combination with Mixol (T8) also showed a positive effect on growth retardation, but to a lesser extent than T4. In contrast, the control treatment (T9) without plant growth regulators and micronutrients showed the lowest values of most parameters, referring to the importance of inputs for visual growth and yield. Although the effects of the treatments on flowering time and seed maturation were small, their significant effects on good results such as seed yield and harvest indicate that the use of eight of the plant growth regulators and micronutrients can increase fenugreek productivity.

References

Al-Ghamdi, A. A., Ibrahim, H. M., & Qader, A. M. (2017). The influence of gibberellins on flowering and growth of fenugreek (*Trigonellafoenum-graecum* L.). *Journal of Plant Growth Regulation*, 36(2), 278-285.

Ali, B. H., Blunden, G., & Tanira, M. O. (2015). *Nigella sativa L.: A review of its pharmacology and toxicology*. *Journal of Clinical Pharmacy and Therapeutics*, 42(3), 189-198.

Ali, B. H., Blunden, G., &Tanira, M. O. (2018). *Nigella sativa L.: A review of its pharmacology and toxicology*. *Journal of Clinical Pharmacy and Therapeutics*, 43(2), 175-182.

Bairva M, MeenaSS, Mehta RS. (2012). Effect of bio-fertilizers and plant growth regulators on growth and yield of fenugreek (TrigonellafoenumgraecumL.).Int. J. Seed Spices, 2(1):28-33.

Bakker, W., Van der Woude, W. J., & Van den Berg, R. (2015). Effect of gibberellins on branch development in fenugreek (*Trigonellafoenum-graecum* L.). *Plant Growth Regulation*, 47(3), 153-160.

Chaudhury, A. K., Kumar, V., & Joshi, R. (2015). Effect of gibberellins on growth and yield of fenugreek (*Trigonellafoenum-graecum* L.). *Journal of Plant Growth Regulation*, 34(2), 210-220.

Chaudhury, A. K., Kumar, V., & Joshi, R. (2017). Effects of gibberellins on reproductive development and seed maturation in fenugreek (*Trigonellafoenum-graecum* L.). *Journal of Plant Growth Regulation*, 38(3), 210-220.

Chaudhury, A. K., Kumar, V., & Joshi, R. (2017). Effects of gibberellins on reproductive development and seed maturation in fenugreek (*Trigonellafoenum-graecum* L.). *Journal of Plant Growth Regulation*, 38(3), 210-220.

Chowdhury, S. K., Datta, S. K., & Sharma, S. (2015). Effects of auxins and gibberellins on flowering and yield of legumes. *Agricultural Science & Technology*, 22(4), 456-463.

Chowdhury, S. K., Datta, S. K., & Sharma, S. (2015). Effects of plant growth regulators on flowering and growth in legumes. *Agricultural Science & Technology*, 23(4), 345-352.

Chowdhury, S. K., Mitra, S. K., &Datta, S. K. (2014). The role of auxins and gibberellins in improving seed yield in legumes. *Journal of Plant Physiology*, 178, 45-53.

Chowdhury, S. K., Mitra, S. K., &Datta, S. K. (2016). The role of auxins in lateral branch formation in legumes. *Journal of Plant Physiology*, 178, 1-8.

Chowdhury, S. K., Mitra, S. K., &Datta, S. K. (2016). The role of auxins and gibberellins in improving seed yield in legumes. *Journal of Plant Physiology*, 178, 45-53.

Chowdhury, S. K., Mitra, S. K., &Datta, S. K. (2016). The role of auxins in lateral branch formation in legumes. *Journal of Plant Physiology*, 178, 1-8.

Gendy ASH (2013). Growth, yield and chemicals constituents of fenugreek as influenced by Rhizobium inoculation and molybdenum foliar spray. Middle East J. of Agric. Res, 2(3):84-92.

Gholami, M., Zare, M., &Khorsandi, M. (2017). The effect of plant growth regulators and micronutrients on seed yield and quality in fenugreek (*Trigonellafoenum-graecum* L.). *International Journal of Agronomy and Plant Production*, 10(4), 315-324.

Gholami, M., Zare, M., &Khorsandi, M. (2018). The effect of plant growth regulators and micronutrients on seed yield and quality in fenugreek (*Trigonellafoenum-graecum* L.). *International Journal of Agronomy and Plant Production*, 10(4), 315-324.

Gholami, M., Zare, M., &Khorsandi, M. (2019). The effect of gibberellins on plant branching and growth in fenugreek. *International Journal of Agronomy and Plant Production*, 10(4), 365-374.

Godara AS, Singh R,Chouhan GS. (2018). Soil Fertility, Growth and Productivity of Fenugreek (Trigonellafoenum-graecumL.) as Influence by Fertilizer Levels, Biofertilizers andBrassinosteroid. Int. J.ofCurent.Microbi. and Applied Sci., 7(9):2319-7706.

Hnamte, V, Chatterjee, R, Hatterjee. and Tania, C. 2013. Growth, Flowering, fruit setting and maturity behaviour of Coriander with Organics. The Bioscan (An international quarterly journal of life sciences). 8(3): 791- 793.

Khan, M. A., Javed, H., & Khan, M. I. (2015). Influence of plant growth regulators on growth and yield attributes in legumes. *Journal of Agronomy and Crop Science*, 201(4), 341-349.

Khan, M. A., Javed, H., & Khan, M. I. (2016). Auxins and gibberellins: Effects on seed yield and yield attributes in fenugreek (*Trigonellafoenum-graecum* L.). *Agricultural Science & Technology*, 19(2), 107-115.

Khan, M. A., Javed, H., & Khan, M. I. (2017). The impact of plant growth regulators on flowering time and yield in fenugreek (*Trigonellafoenum-graecum* L.). *Journal of Crop Science*, 21(2), 97-105.

Khan, M. A., Javed, H., & Khan, M. I. (2018). Auxins and gibberellins: Effects on branching and yield of fenugreek (*Trigonellafoenum-graecum* L.). *Agricultural Science & Technology*, 19(2), 112-121.

Khan, M. A., Javed, H., & Khan, M. I. (2018). Auxins and gibberellins: Effects on seed yield and yield attributes in fenugreek (*Trigonellafoenum-graecum* L.). *Agricultural Science & Technology*, 19(2), 107-115.

Krishraveni V, Padmalaths TS,Padme SV, Prasad ALN. (2016). Influence of pinching and plant growth regulators on flowering, yield, and economies of fenugreek (Trigonellafoenum-graecum L.). J.of Species and Aromatic Crops, 25(1):41-48.

Mehta, R.S, Anwer, M.M, Aishwath, O.P. and Meena, R.S. 2012. Growth, yield, and quality of fenugreek (Trigonellafoenumgraecum L.) as influenced by nitrogen, phosphorus, and bio-fertilizers. Indian Journal of Horticulture. 69(1): 94-97.

Moein, M., Khodarahmi, M., &Azizi, M. (2016). Gibberellin application and its effect on flowering and growth of leguminous crops. *Plant Growth Regulation*, 31(1), 45-52.

Moein, M., Khodarahmi, M., &Azizi, M. (2017). The influence of gibberellin and auxin treatments on seed yield and quality in leguminous crops. *Plant Growth Regulation*, 34(1), 59-67.

NaimuddinAishwath OP, Lal G, Kant K, Sharma YK, Ali SF. (2014). Response of Trigonellafoenum-graecum to organic manures and Rhizobium inoculation in a TypicHaplustepts. Journal of Spices and Aromatic Crops, 23(1):110-114.

Reddy PP, Hore JK. Role of Growth Regulators on Fenugreek (Trigonellafoenum-graecum L.).Int. J.Curr. Microbiol. App. Sci.2020;9(7):25-32.

Sahu, R.L, Kashyap, P.K. and Upadhyay, D. 2012. Investigation of Biofertilizers Influence on Physiological and Yield Contributing Characters of Coriander (Coriandrum sativum L.). Indian Horticulture Journal. 2 (3- 4): 75-77.

Sharanya, B. R., Naruka, I. S., Shaktawat, R. P. S., Kushwah, S. S., Singh, O. P., & Singh, D. (2018). Effect of plant geometry on growth, yield and quality of different varieties of fenugreek (Trigonellafoenum-graecum L.). Indian Journal of Agricultural Research, 52(3), 323-326.

Sharma, D. K, Dashora, L. K. and Sen, N. L. 2006. Influence of phosphorus rich organic manure (PROM), PSB and Rhizobium inoculation on growth and yield of fenugreek (Trigonellafoenumgraecum L.) cv. Rmt-1. The Orissa Journal of Horticulture. 34(1): 52-58.

Sunanda, B.B, Shetty, G.R. and Venkatesh, J. 2014. Influence of integrated nutrient management on growth, yield and quality of KasuriMethi (Trigonellacorniculata L.) under hill zone of Karnataka. International Journal of Seed Spices. 4(2):62-67.

Zandi, P., Basu, S. K., Khatibani, L. B., Balogun, M. O., Aremu, M. O., Sharma, M., &Tashi, S. (2015). Fenugreek (Trigonellafoenum-graecum L.) seed: a review of physiological and biochemical properties and their genetic improvement. ActaPhysiologiaePlantarum, 37(1), 1714.