EFFECT OF GIBBERELLIC ACID ON MORPHOLOGY, VEGETATIVE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum* L.)

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF GIBBERELLIC ACID ON MORPHOLOGY, VEGETATIVE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum* L.)"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **MD. SHAHIN ALAM**, Registration No. **12-04883** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

June, 2018

Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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The Author

EFFECT OF GIBBERELLIC ACID ON MORPHOLOGY, VEGETATIVE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum* L.)

ABSTRACT

The study was carried out at Sher-e-Bangla Agricultural University (SAU) farm, Dhaka, Bangladesh during the rabi season from November 2017 to March 2018 to investigate the effect of gibberellic acid on morphology, vegetative growth and seed yield of fenugreek (*Trigonella foenum-graecum* L.). The treatment consisted of seven levels of GA_3 including control *viz*. T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3 and T_7 = 150 ppm GA_3. The experiment was laid out in a randomized completely block design (RCBD) with three replications. Data were collected on different growth, morphological, yield and yield contributing characters of fenugreek. Results revealed that the treatment T_4 (75 ppm GA_3) gave the maximum plant height (84.48 cm) and number of leaves plant^{-1} (132.4) at harvest, and the highest chlorophyll content (57.99 and 59.58 at 60 and 75 DAS, respectively) and highest absorbance reading by spectrophotometer at 645 ɳm (0.197 and 0.184 at 60 and 75 DAS, respectively) and at 663 ɳm (0.235 and 0.222 at 60 and 75 DAS, respectively). This treatment also showed highest total chlorophyll content at 45 and 60 DAS (1.488 and 1.067 µg g^{-1}, respectively). The highest productivity (13.32 kg/ha/days), number of primary branches plant^{-1} (6.73), number of pods plant^{-1} (54.20), number of seeds pod^{-1} (14.87), number of seeds plant^{-1} (805.90), seed weight plant^{-1} (5.11 g), 1000 seed weight (10.47 g), pod length (7.46 cm), seed yield ha^{-1} (1582.00 kg), stover yield ha^{-1} (3230.00 kg), biological yield ha^{-1} (4878.00 kg) and harvest index (32.42%) were also found from the treatment, T_4 (75 ppm GA_3) compared to control.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MilliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) locally known as 'Methi' belonging to the family Leguminosae and sub family Papilionaceae. This crop is native to an area extending from Iran to northern India and widely cultivated in China, India, Egypt, Ethiopia, Morocco, Ukraine, Greece, Turkey, etc. with 80 species (Danesh-Talab *et al*., 2014).

Fenugreek leaves and seeds are consumed in different countries around the world for different purposes such as medicinal uses, making food, roasted grain as coffee-substitute, controlling insects in grain storages, and perfume industries (Mehrafarin *et al*., 2011). It is also a commercially important annual spice crop grown almost in every part of the country. It is used as condiment, leafy vegetable, seed, green fodder and green manure crop. It is rich in proteins, iron, calcium, vitamin A, B_2 and C. Seeds have strong aroma and are bitter in taste. It reduces blood cholesterol and blood sugar levels. It adds flavor and also act as a nutritive food. The value added products of fenugreek such as fenugreek powder and oleoresins are exported (Krishnaveni *et al*, 2014). This plant is used in therapy atherosclerosis (Nandini *et al*., 2007), rheumatism (Vyas-Amit *et al*., 2010), sugar lowering (Gupta *et al*., 2009), blood lipids lowering (Xue *et al*., 2007), appetizer (Max, 2007) and contain antioxidant activity (Birjees Bukhar *et al*., 2008).

In spite of great utility and importance as spice, leafy vegetable, medicinal and cosmetic value, a little attention has been paid to evolve suitable package of practices for profitable cultivation of fenugreek. The production of fenugreek as vegetable and/or seed purpose can be increased remarkable using phytohormone like Gibberellins (GAs).

A phytohormone is an organic substance synthesized in defined organs of the plant that can be translocated to other sites, where it triggers specific biochemical, physiological, and morphological responses. Research findings showed that growth regulators also play an important role in increasing the growth and productivity of many crops. The role of plant growth regulators in enhancing the production and quality of crops has long been recognized and now this low cost technology has emerged as a boon for enhancing the production at an unprecedented rate. Plant hormones play important role as the small quantities, regulate the various physiological processes and balance the source and sink thereby increase the productivity (Meena *et al*, 2014).

Gibberellins (GAs) are a large group of important diterpenoid acids among commercial phytohormones (Martin *et al*. 2000). Gibberellins are tetracyclic diterpenoid acids those are involved in a number of developmental and physiological processes in plants (Crozier *et al*. 2000). These processes include seed germination, seedling emergence, stem and leaf growth, floral induction and flower and fruit growth (King and Evans, 2003; Sponsel, 2003). Gibberellins are also implicated in promotion of root growth, root hair abundance, and inhibition of floral bud differentiation in woody angiosperms, regulation of vegetative and reproductive bud dormancy and delay of senescence in many organs of a range of plant species (Reinoso *et al*., 2002).

Gibberellins (GA_3) is a type of plant growth substances, which is stimulating cell division and cell elongation and other regulatory function, it has been used as standard in bioassay systems (Arteca, 1996). Gibberellic acid (GA_3) is a phytohormone that is needed in small quantities at low concentration to accelerate plant growth and development. So, favorable condition may be induced by applying growth regulator exogenously in proper concentration at a proper time in a specific crop by GA_3. Gibberellic acid is such a plant growth regulator, which can manipulate a variety of growth and development phenomena in various crops. GA_3 enhances growth activities to plant, stimulates stem elongation (Deotale *et al*., 1998; Abd, 1997; Lee, 1990), and increases dry weight and yield (Deotale *et* *al*., 1998 and Maske *et al*., 1998). Gibberellins (GA_3) have been used in increasing stalk length and vegetative growth, flower initiation, increasing fruit size, hastening maturity and improving fruit quality in many crops. Gibberellins play an important role in enhancing the growth and flowering in fenugreek (Pariari *et al*., 2007). GA_3 play an important role in enhancing the growth and yield in fenugreek (Badge *et al*., 1993). Exogenous growth regulator treatments – gibberellins (usually gibberellic acid; GA_3) have been shown to break dormancy in many seed species (Karam and Al-Salem, 2001).

Considering the numerous effects of gibberellins, it seems logical that it can be used in commercial applications for fenugreek production. Keeping the above facts in mind the present experiment entitled 'Effect of gibberellic acid on morphology, vegetative growth and seed yield of fenugreek (*Trigonella foenum-graecum* L.)' was carried out with the following objectives:

1. To investigate the influence of GA_3 on the growth and morphology of fenugreek
2. To find out the suitable dose of GA_3 for higher seed yield of fenugreek

CHAPTER II

REVIEW OF LITERATURE

The present study was, therefore, conducted with suggested concentrations of GA_3 as foliar spray to determine the effective concentrations promoting growth, yield and quality in commercial cultivation of fenugreek.The relevant available literature on fenugreek and other crops on various aspect related to present investigation has been reviewed below.

2.1 Effect of GA_3

Kumar *et al*. (2018) conducted an experiment to study the effect of gibberellic acid on growth and seed yield of coriander (*Coriandr umSativum* L.) cv. Hisar Sugandh and Hisar Bhoomit. In the present experiment, gibberellic acid concentration 50 ppm was used at three different stages of crop growth (seed soaking, spray at leaf stage and spray at 50% flowering). Gibberellic acid was sprayed in eight treatment combinations of three stages. Gibberellic acid improved the growth, yield of coriander seeds. Seed soaking + spray at leaf stage + spray at 50% flowering stage was the right combination for gibberellic acid application to improve the growth and yield of coriander. In case of spray at two stage, (seed soaking + spray at leaf stage) was the right combination to improve the biological yield, whereas, (spray at leaf stage + spray at 50% flowering) was the right combination to improve the seed yield. With the combination of Seed soaking + Spray at leaf stage + Spray at 50% flowering, the variety Hisar Sugandh found better for seed yield.

Faysal *et al*. (2017) carried out a study using pots (capacity, 4kg soil/pot) in the glasshouse and different concentrations of gibberellic acid (0, 25, 50 and 100) ppm and different levels of superphosphate (0.25, 0.50 and 100) gm/kg: soil/Pot. The results could be summarized that the treatments by gebberllic acid (GA_3) alone showed significant increase in absolute growth, biomass, chlorophyll content, protein percentage and medical compounds. The interaction between GA_3 and phosphate fertilizer showing the best results in all growth characters for all plants in this experiment, specially the treatment with 50 ppm of GA_3 with 0.50 gm/pot and 1.0 gm/pot of superphosphate fertilizer gave the highest values of studied compared with control treatment.

Akand *et al.* (2015) conducted an experiment on tomato crop at Sher-e- Bangla Agricultural University, Dhaka, Bangladesh. The experiment consisted three concentration of GA_3 i.e. 75ppm, 100ppm and 125 ppm. Among the concentration of GA_3 they found highest yield (92.99 t/ha) with GA_3 @ 125 ppm where as the G0 (no GA_3) gave lowest yield (60.46 t/ha).

Vandana *et al*. (2014) conducted an experiment on Sweet Pepper cultivar “Indra” under green house confined that maximum height (30.15 cm) with GA_3 @ 50 ppm and maximum number of branches (5.52) with etheral @ 100 ppm. Maximum yield/plant (1.84kg) and yield/ha (244.65 q/ha) recorded with GA_3 @ 50 ppm.

Netam *et al.* (2014) observed the effect of PGR in Brinjal var. Brinjal-3112 at SHIATS, UP. They observed highest number of leaves, plant height, fresh and dry weight of fruit with GA_3 @ 50 ppm. Highest TSS, nitrate reductase activity was recorded by treatment combination of GA_3 @ 10 ppm, NAA @ 20 ppm. They concluded that the combined application of 1 ppm respectively had significantly on plant growth, flowering, quality and potential.

Moniruzzaman *et al.* (2014) conducted an experiment on brinjal having six PGR *Viz.,* GA_3 30, 40, 50 ppm and NAA @ 20, 40, 60 ppm respectively and two varieties *Viz.,* “BARI Begun-5” and “BARI Begun-10 during rabi season for determine suitable dose of PGR for brinjal production. The variety “BARI Begun-5” was earlier to 100% flowering which took 44 days after transplanting which out yielded BARI Bgun-10. NAA @ 40 ppm coupled with BARI Begun-5 gave the highest fruit yield 49.73 t/ha.

Kumar *et al.* (2014) conducted an experiment on tomato crop at SHIATS, Allahabad, UP. The experiment consisted of one tomato variety "Golden" and five levels of GA_3 *i.e.* (10, 20, 30, 40 and 50 ppm). The highest plant height (38.17 cm) at 20 DAT, number of leaves (39.51) and fresh fruit weight was found 1.10 kg. Highest yield were estimated for GA_3 @ 50 ppm followed by GA_3 @ 40 ppm.

Krishnaveni *et al.* (2014) carried out an experiment to find out the effect of pinching and plant growth regulators on growth and flowering of fenugreek cv. APHU Methi-1. The treatments consisted of pinching *viz.*, no pinching (P_0), single pinching at 25 DAS (P_1), single pinching at 45 DAS (P_2), double pinching at 25 and 45 DAS (P_3) and plant growth regulators *viz.*, control (water spray) (G_0), 50 ppm GA_3 (G_1), 75 ppm GA_3 (G_2), 50 ppm NAA (G_3) and 75 ppm NAA (G_4). Among the growth regulators, foliar spraying of GA_3 50 ppm (G_1) thrice (25, 45 and 65 DAS) resulted in best performance of the parameters like plant height, number of branches, fresh weight, dry weight and number of flowersper plant. Early flower initiation was observed with application of GA_3 75 ppm (G_2). Among the interactions between pinching and plant growth regulators, the treatment combination of no pinching with application of GA_3 50 ppm (P_0G_1) resulted in maximum plant height. Maximum number of branches and number of flowers were recorded with single pinching at 25 DAS and application of GA_3 50 ppm (P_1G_1).

Kazemi *et al.* (2014) investigated the effect of 2 levels of GA_3 (10^{-4} and 10^{-8} mm) and 2 levels of potassium nitrate (6 and 8 mm) spray on growth, leaf NPK - content, University, karaj, Iran. With regard to fruit quality, the application of GA_3 at 10^{-8} mm and potassium nitate at 8mm increased fruit lycopene content and TSS. They concluded that GA_3 was suitable for increasing vegetative growth and reproductive characteristics of tomato.

Danesh-Talab *et al*. (2014) carried out an experiment for evaluation of growth, phytochemical and morpho-physiological properties in fenugreek (*Trigonellafoenum- graecum* L.) under application of plant growth regulators (PGRs). The experiment consist of 13 treatments; giberrellic acid (GA_3) and naphthalene acetic acid (NAA) each at 25 and 50 ppm by either a pre-plant soaking, a spraying at 20 days after planting, and a combination of pre-plant soaking plus a spraying at 20 days after planting along with control (distilled water application). Application of PGRs (GA_3 and NAA 50 ppm) through combination of pre-plant soaking plus a spraying significantly increased shoot dry weight, 1000-seeds weight, number of seeds per pod, content of seed trigonelline, leaf area per plant (p.0.01), and also, plant height, stem diameter, number of pods per plant, content of seed mucilage, and root, stem, leaf and pod dry weight (p.0.05). Of course, application of PGRs had no significant effect on the amount of SPAD value and number of leaves per plant.

Arora *et al.* (2014) found in pant C-1 variety of chilli at GBPAU, Pantnagar, NAA @ 45 ppm superior to all other treatments in respect of plant growth and flowering characters, while, among methods of application, seedling root dip for 30 minutes alone with double spray at flower bud initiation stage and 20 days later to it NAA @ 45 ppm promoted fruit set and influencing the percentage (68.60%) of short styled flowers in chilli cv. Pant C-1.

Tuan and Chung–Ruey (2013) observed the effects of gibberellic acid and 2,4-dichlorophenoxy acetic acid((2,4-D) on flower number, fruit growth and fruit quality of wax apple. GA_3 and 2,4-D were applied at small bud and petal fall stage. Results indicated that spraying with 10 ppm GA_3 had the best results in number of flower. GA_3 spray at 30 ppm gave the faster rate of fruit growth than the other treatments. Fruit set, fruit size as well as fruit weight markedly improved by spraying 30 ppm GA_3, followed by 10 ppm GA_3 compared to untreated control. Spray of GA_3 at 30 ppm was the most effective and increased total soluble solids, reduced titratableacidity and fruit drop. On the other hand, it was noticed that 10 ppm 2,4-D application also enhanced the fruit growth rate, improved physiological and biochemical characters of fruit compared to untreated control. It was concluded that both GA_3 and 2,4-D spray have positive effects on fruit development, reduced fruit drop, fruit crack and improved fruit quality of wax apple under field conditions.

Shahid *et al.* (2013) observed that performance of okra plants treated with individual PGR was better than the untreated plants. The number of leaves and plant highest was higher in plants when sprayed with GA_3 and NAA @ 200 and 100 ppm, respectively. Their results were signify the role of GA_3 and NAA in okra pod production for fresh consumption as well as for seed yield.

Jagtap *et al*. (2013) carried out the present study, to observe the influence of Vermiwash (20%) and Gibberellic acid (50 ppm) on fenugreek (*Trigonellafoenum-graecum* L.) var. early bunching during seed germination by using Petri-plate method. Distilled water was considered as control. GA treatment remarkably enhanced shoot length while vermiwash treatment showed upper hand in root length. Vermiwash and GA treatments significantly increased amount of total carbohydrates, soluble proteins and activities of enzymes like amylase, catalase and protease. The study revealed that vermiwash and GA exhibit superiority in germination and growth process and significantly improve phyto-chemical values.

Ayyub *et al.* (2013) found that exogenous application of GA_3 hastens the vegetative and reproductive growth of growth. The foliar application of GA_3 (100 mg kg^{-1}) was performed after 3 weeks from sowing while next there applications with regular interval of one weak. It was found that application at different growth stages of okra predominantly boosted the stem elongation, number of leaves, number of pods per plant, seeds per pod, seed weight and seed yield.

Reddy and Prasad (2012) studied the effects of plant growth regulators on fruit characters and yield in pomegranate cv. Ganesh. Nine treatments with three growth regulators, viz., NAA at 20, 30 and 40 ppm; 2,4-D at 20, 30 and 40 ppm, GA_3 at 25, 50 and 75 ppm and control (water spray) were sprayed three times starting at full bloom and, subsequently, at 45 and 90 days after fruit set. Results revealed that application of 2 4-D at 40 ppm gave significantly high fruit size in length, breadth and volume and higher fruit weight (262.23g), higher aril percent, maximum number of fruits (64.00) which resulted in highest fruit yield of 16.78 kg/plant, as against 7.41 kg in the control.

Kumar *et al.* (2012) reported that the influence of GA_3, CCC and triacontanol on picking time and yield of strawberry cv. Sweet Charlie, revealed that plants treated with GA_3 75 ppm showed the highest fruit yield in 4th picking (59.48 gram per plant) was recorded.

Jamal *et al.* (2012) reported that the application of GA_3 at 50, 75 and 100 ppm on strawberry, maximum number of flowers (28.7), number of fruits (25.9/ plant), fruit weight (13.2g) and yield (336.6 gram per plant) was obtained with 75 ppm GA_3 application, whereas the minimum was recorded in control.

Desai *et al.* (2012) conducted an experiment on tomato variety GT-3 (Gujarat tomato-3) at JAU, Junagarh, India. They found maximum fruit length (7.57 cm) , girth (6.47 cm) and pulp seed ratio (12.93) with GA_3 @ 75 ppm, whereas fruit weight (57 g), yield plant^{-1} (2.47 kg) and yield ha^{-1} (913.258 q/ha) found with NAA @ 75 ppm.

Syamal *et al.* (2010) reported that application of GA_3 at 100 and 150 ppm at 4 -leaf stage increased physical characters in terms of length, diameter and weight in papaya fruit.

Ouzounidou *et al.* (2010) investigated pre and post-harvest physiology and quality response of green pepper standard P. 13/0211003 - Agris on exogenous GA_3 (100 mm), Cycocel (100 mg/l) and Ethaphon (100 mg/l) applied as foliar sprays at TEIT, sindos, Greece. GA_3 @ 100 mm was effective in promoting flowering and better for vegetative charateristics. The Brix content and the 'maturity index' were depressed after prohexadione - calcium, Cycocel and Ethephon application.

Idrees *et al.* (2010) applied two well known growth regulators, Triacontonol (TRIA) and GA_3 on coriander at AMU, Aligarh, India. Among the treatments, a combined foliar spray of 10^{-6} T + 10^{-6} G on coriander plant was highly effective for productivity with increased essential oil content and it promotes the physiological and biochemical parameters like total chlorophyll, carotenoid, leaf nitrogen, leaf phosphorus content, nitrate reductage activity, including essential oil content ant yield characteristics.

Gelmesa *et al.* (2010) conducted an experiment at Mekassa Agricultural Research Center, Ethiopia on tomato. The experiment consisted of two tomato varieties one for processing (Roma VF) and one for fresh market (Fetan), three levels of 2,4-D (0, 5, 10 mg l^{-1}) and 4 levels of GA_3 (0, 10, 15 and 20 mg l^{-1}) were applied. They found increase in fruit length from 5.44 to 6.72 cm at 10 mg l^{-1} 2,4-D combined with 10 mg l^{-1} GA_3. The marketable fruit yield of "Rome-VF was obtained 69.50 t ha^{-1} with 10 mg l^{-1} GA_3 followed by 67.92 t ha^{-1} with 15 mg l^{-1} GA_3. For *cv.* "Fetan", marketable yield obtained 74.39 t ha^{-1} yield with 10+15 mg l^{-1} GA_3 followed by 74.20 t ha^{-1} yield with 5 mg l^{-1} 2,4-D. the results indicated that PGRs are improve fruit yield.

Roussos *et al.* (2009) treated strawberry cv. Camarosa with different plants growth stimulators and reported that application of GA_3 + auxin significantly increased marketable yield.

Perez *et al.* (2009) reported that the exogenous application of GA_3 at 20 ppm resulted maximum number of inflorescences and flowers in strawberry cv. Chandler.

Canli and Orhan (2009) observed the effects of preharvestbenzyladenine (BA) and BA plus gibberellins application on fruit quality of “Alayank” apricot. BA (50, 100 and 150 ppm) and BA plus gibberellic acid (12.5, 25 and 50 ppm) were applied at the beginning of pit hardening stage. When fruit reached their maturity, sample were harvested and evaluated in term of: weight, size, firmness, soluble solids content, acidity and pH. Fruit treated with BA were heavier and larger than fruit not treated, and there were significantly difference in fruit size with in the BA treated fruit. The heaviest and largest fruit were obtained from 100 to 150 ppm BA concentration. BA plus gibberellins treatment did not affect fruit size. Application of 100 ppm BA and 25 ppm BA plus gibberellins increase fruit firmness. At harvest, SSC, pH and acidity were unaffected by the application. The result obtained from the study showed the practical benefit of a single application of BA at the end of pit hardening for improving apricot quality. Fruit treated with the optimum dose of BA (100 ppm) were larger and firmer than the untreated fruit.

Sharma and Singh (2008) studied the effect of growth regulators GA_3 10 and 20 ppm, BA 5 and 10 ppm, promalin 250 and 500 ppm, 10 ppm, GA_3 + 5 ppm BA, 20 ppm GA_3 + 500 ppm promalin, 10 ppm GA_3 + 250 ppm promalin, 20 ppm GA_3 + 500 ppm promalin and control (no spray) were applied either once at full bloom or twice at full bloom and petal fall stage on Baggugosha pear trees. They observed that combined treatment of 20 ppm, GA_3 +10ppm BA , 10 ppm GA_3 + 5 ppm BA and 10 ppm GA_3 + 250 ppm promalin when applied as single spray at full bloom increased fruit set, fruit retention, yield efficiency and fruit quality. All the treatments of growth regulators significantly increased the fruit set as compared to control, however, the highest increase was achieved with the application of 20 ppm GA_3 + 10 ppm BA (21.3%), followed by the treatments of 10 ppm GA_3 + 250 ppm Promalin (20.8%) and 10 ppm BA (20.7%) in decreasing order. Repeat application of growth regulators at petal fall stage however, did not exerted as additional.

Patil *et al.* (2008) concluded that seed treatment with GA_3 and MH in okra cultivars "ParbhaniKranti” at PDKV Akola in their experiment. Seeds were soaked for 24 hours and sown directly in field at 45×30 cm spacing. Germination and vegetative characters with GA_3 @ 50 ppm concentration exhibit statistically maximum value amongst all other treatments followed by 80 ppm MH.

Akter *et al*. (2007) conducted an experiment in pot house at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during to evaluate the effects of Gibberellic Acid (GA_3) on growth, and yield of mustard var. Binasarisha-3. Four concentrations *viz*., 0, 25, 50 and 75 ppm of GA_3 were sprayed on canopy at 30 days after sowing. The results showed that different levels of GA_3 significantly influenced the plant height, number of fertile siliqua/plant, number of seeds/siliqua, number of flowers/plant, setting of siliqua/plant (%), and harvest index. Results revealed that GA_3 at 50 ppm significantly increased plant height, number of fertile siliqua/plant, number of flowers/plant, setting of siliqua/plant (%), dry matter yield, number of seeds/siliqaua, and harvest index, while the number of flowers/plant was significantly increased with the application of 75 ppm GA_3. The highest seed yield/plant was recorded from the application of 50 ppm GA_3 at optimum harvest date. The seed yield/plant was positively correlated with plant height, number of seeds/siliqua, number of fertile siliqua/plant and % of setting siliqua/plant.

Akter *et al.* (2007) conducted an experiment in net house in Mustard at Bangladesh Institute of Nuclear Agriculture (BINA) and evaluate the effects of GA_3 on growth and yield mustard variety Binasarisha-3. They observed the highest seed yield/plot with application of GA_3 @ 50 ppm. While the number of flowers plant^{-1} was significantly increased with the application of 75 ppm GA_3.

Webster *et al.,* (2006) reported that the yield of sweet cherry could be improved by foliar sprays of gibberellic acid (GA_3) or aminoethoxy vinyl glycine (AVG) applied post blossoming stage.

Tripathi and Shukla (2006) evaluated the effect of NAA, GA_3, CCC and BA on growth, yield and quality of strawberry cv. Chandler. Growth regulators were sprayed at different concentration on the plant before flower bud initiation stage. Plants treated with GA_3 at 100 ppm concentration produced maximum length (3.09) and weight of berries (8.28 g).

Singh and Singh (2006) applied the growth regulators like GA_3 at 50 ppm and 100 ppm, NAA at 50 and 100 ppm and Benzyladenin (BA) at 50 and 100 ppm on strawberry cv. Sweet Charlie. Plant treated with GA_3 at 100 ppm showed the earliest flowering (116.50 days), produced the maximum number of flower per trusses, fruit set, better yield and yield attributes characters.

Lenahan *et al.,* (2006) reported that two applications of GA_3 at 50 ppm, and 100 mg/l increased the soluble solids by 12 % firmness by 15 - 20 % and weight by 7 % to 14 % in sweet cherry cv.Bing.

EL-Keltawi *et al*. (2000) assessed different methods of GA application and found that two supplemental sprays in addition to the initial fruit soaking increased vegetative growth and yield of cumin compared to soaking alone and control.

Verma *et al.,* (2005) reported that a significant increase in the yield was obtained with the application of 200 g N / tree in winter along with 100 mg GA_3/L in autumn in plum cv. Titron.

Panwar *et al.,* (2005) observed that pre-harvest application of GA_3 at 75 ppm is very effective to increased yield in pomegranate cv. Mridula.

Natesh *et al.* (2005) conducted an experiment on chilli variety "Byagikaddi" at University of Agriculture Sciences, Dharwad and confined that application of growth regulators at flowering stage increased the growth and seed yied of chilli. Among them, GA_3 @ 100 ppm spray at flowering stage recorded higher fruit and seed yield followed by GA_3 @ 50 ppm and NAA @ 20 ppm, indicating their utility in enhancing seed production of chilli.

Sharma and Ananda, (2004) reported that application of GA_3 at 10 ppm and NAA at 5 ppm gave the best quality fruits in terms of firmness, total soluble solids and total sugar in apple cv. Starking Delicious.

Rahman *et al*. (2004) conducted an experiment was conducted to study the effect of plant growth regulators and their time of spray on morphology, yield and yield contributing characters of soybean. Sprayed three times (T_1 = spray at 15 DAS, T_2 = spray at 30 DAS and T_3 = spray at 45 DAS) with two concentrations (100 and 200 ppm) of gibberellic acid (GA_3) and maleic hydrazide (MH). T_2 followed by T_3 produced the tallest plant with the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield (t ha^{-1}). T_1 produced the least of them. GA_3 was more effective than MH. GA_3 at 100 ppm followed by GA_3 at 200 ppm produced the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield (t ha^{-1}) while 200 ppm MH was least effective to produce them. The present study clearly shows that almost all the plants treated with growth regulators performed better than control. However, interaction effect indicated that 100 ppm GA_3 treated plants sprayed at 30 DAS (T_2C_3) showed the best performance.

Gadal *et al*. (2003) studied the correlation between capsanthin content and other traits of *Capsicum annum* was studied in 36 genotypes grown in Bangalore, Karnataka, India during the *kharif* season of 2000. They found phenotypic and genotypic levels, Ascorbic acid content (red chilli) had a positive correlation with capsanthin content. The positive association of plant spread, number of fruits per plant, fruit length, fruit yield and ascorbic acid content (green chilli) with capsanthin content was mainly due to indirect effects through ascorbic acid (red). Fruit rot was negatively correlated with capsanthin content due to its indirect effect through ascorbic acid (red). Seed weight showed direct and indirect positive correlation with capsanthin content.

Verma (2002) conducted and experiment and observed that 50 ppm GA_3 through soaking+spraying resulted in increased plant growth and yield parameters of coriander.

Singh *et al.* (2002) reported in onion crop that the growth regulators at 10 and 50 ppm significantly enhanced growth and yield. The higher concentration (100 ppm) resulted in the substantial reduction in all parameters. The plants treated with GA_3 @10 ppm recorded the greatest plant height (44.40 cm), number of leaves per plant, bulb diameters (4.36 cm) and bulb yield (120.69 q/ha).

Qayum *et al.,* (2002) reported that preharvest application of GA_3 at 30 ppm improved fruit length, diameter, shape, weight, red colouration, TSS, acidity and TSS / acid ratio in apple cv. Red Delicious.

Paroussi *et al.* (2002) studied the effect of gibberellic acid (GA_3) on the flowering characteristics and yield of three strawberry cultivars, Camarosa, Laguna and Seascape, and they obtained that GA_3 at 50 ppm resulted in early inflorescence, accelerated flowering, earlier fruit setting and maturation in Seascape.

Ozguven and Yilmaz (2002) studied that the application of GA_3 at 5, 10 and 20 ppm in strawberry cv. Camarosa resulted in early flowering with increasing GA_3 doses and the highest yield was obtained using 5 and 10 ppm of GA_3.

Bhosle *et al.* (2002) found in tomato that the number of flowers per cluster, fruit weight and marketable yield increased with increasing rates of the plant growth regulators. Treatment with GA_3 @ 30 ppm resulted in the tallest plants, whereas treatment with 25 ppm 4-CPA and 45 ppm GA_3 resulted in the highest number of primary branches of tomato cultivars Dhanashree (4.16) and Rajashree (5.38), respectively.The highest marketable yield of Dhanashree and Rajashree resulted from treatment with 4-CPA @ 75 ppm.

Balraj *et al.* (2002) found in chilli that GA_3 @ 20 ppm was the best treatment for improving plant height and number of branches, while NAA @ 20 ppm was best for improving yield. Application of plant growth regulators at both 35 and 50 DAT was the most efficient for improving the growth and yield of the plants. Yield was highest when NAA @ 20 ppm was applied at 35 and 50 DAT.

Willemsen (2000) observed that Gibberellic acid (Pro-Gibb 4%L) applied 3 weeks before harvest delayed maturity from 3 to 7 days in cherries and gave larger fruit.

Shankaranarayana *et al.* (2000) reported in a field experiment during *kharif* 1994/95, 1995/96 and 1996/97 at Chintamani, Karnataka, India, groundnuts *cv.* K-134 were intercropped with Pigeon peas *[Cajanuscajan] cv.* TTB-7, sunflowers *cv.* KBSH-1, soyabeans cv. KHSB-2 or chilli*[Capsicum annum] cv.*PusaJwala. Groundnut yield was highest when sole cropped. Groundnut equivalent yield, land equivalent ratio, income equivalent ratio and returns in the intercrops were greatest with groundnuts + pigeon peas and groundnuts + chillies.

Kumar and Ray (2000) found that foliar application of GA_3 (50 and 100 ppm), IBA (5 and 10ppm) and NAA (100 and 200 ppm) significantly increased curd circumference and curd yield but GA_3 at both levels produced maximum and significantly higher plant height, curd circumference and curd yield in cauliflower.

Geetha *et al.* (2000) carried out an experiment and obtained highest seed weight per plant, seed weight per hectare and test weight in China aster after foliar application of 200 ppm GA_3.

Bassel *et al.,* (2000) reported that when GA_3 applied at the concentration of 100 ppm, at petal fall stage, significantly increased the fruit yield in 'LeConte' pear.

EL-Keltawi (2000) assessed different methods of GA application and found that two supplemental sprays in addition to the initial fruit soaking increased vegetative growth and yield of cumin compared to soaking alone and control.

Arora *et al.* (2000) conducted a laboratory study to evaluate the effect of GA_3 treatment on the shelf-life of chilli*cv.*PusaJwala. Chilli fruits were treated with 0, 50, 100, and 200 ppm GA_3 for 10 minutes and air-dried before packing. Data on physiological loss in weight (PLW), fruit decay loss, total chlorophyll and vitamin C content were recorded at 5-day-intervals until day 25. PLW increased with increasing period of storage in all treatments, with GA_3 at 200 ppm exhibiting the lowest PLW (20.8% on the 25th day of storage, compared with 33.4% in the control). Decay loss increased with increasing period of storage in all treatments. No decay loss was observed on the 5th day of storage, but the highest decay loss on the 25th day of storage was observed in the control (12.7%) compared with GA_3-treated fruits. Total chlorophyll content decreased during storage in all treatments; the highest chlorophyll content on the 25th day of storage (1.6 mg/100g) was recorded with GA_3 at 200 ppm. Ascorbic acid content increased with increasing period of storage, the highest (165 mg/100g) being observed with GA_3 at 100 and 200 ppm on the 25th day of storage.

Singh *et al.* (1999) reported from an experiment that increase in number of fruits per plant and seed yield of okra [*Abelmoschusesculentus* (L.) Moench] with foliar application of GA_3 (20, 30 and 40ppm).

Bhople *et al.,* (1999) conducted an experiment and found that foliar application of triacontanol (2.5, 5.0, 7.5 and 10.0 ppm), NAA (25, 50 and 75 ppm) and GA_3 (25, 50, 75 ppm) significantly increased the yield attributes and seed production of onion but the highest values were obtained with 75 ppm GA_3.

Belakbir *et al.* (1998) test the effectiveness of different bioregulators in enhancing bell pepper yield and quality at SCRI, Scotland. The commercial bio regulators CCC, NAA, GA_3 and biozyme were sprayed at flower initiation followed by two additional applications at 30 day intervals. Treatment with NAA produced highly marketable fruits. GA_3 increase Ascordic acid and Citric acid concentration and Biozyme increased TSS, carotenoid, lycopene, sucrose, fructose concentration.

Singh and Sharma (1996) conducted a field experiment and obtained the highest yield attributes and yield of cowpea cv. ArkaGarima with foliar application of 40 ppm GA_3.

Khan (1996) conducted an experiment and found that in case of mustard cv. T-59 application of 50 pM GA_3 enhanced plant height, test weight, number of pods and seed yield.

Paspatis (1995) carried out an experiment and reported that there was significant increase in yield attributes and yield of celery by the application of GA_3 combined with nitrogenous fertilizer.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at theSher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2017 to March 2018 to study the effect of gibberellic acid (GA_3) on morphology, vegetative growth and seed yield of fenugreek (*Trigonellafoenum-graecum* L.). The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris*et al*., 1979). Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Test crop and variety

High yielding variety of fenugreek (cv. BARI Methi 1) developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur was used as experimental material. The seed was collected from Regional Spices Research Centre, BARI, Joydebpur, Gazipur.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of 7 GA_3 concentrationsas follows:

1. T_1 = 0 ppm GA_3 (Tap water spray)
2. T_2 = 25 ppm GA_3
3. T_3 = 50 ppm GA_3
4. T_4 = 75 ppm GA_3
5. T_5 = 100 ppm GA_3
6. T_6 = 125 ppm GA_3
7. T_7 = 150 ppm GA_3

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the concentration of growth regulators including control. The seven (7) treatments of the experiment were assigned at random into 21 plots. The size of each unit plot was 3 m × 1 m (= 3 m^2). The distance between blocks and plots were 0.5 m and 0.5 m respectively. The layout of the experiment field is presented in Appendix IV.

3.6 Preparation of the field

The plot selected for the experiment was opened in the last week of November, 2017 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing. The land operation was completed on 1stDecember 2017. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Fertilizers and manure application

Manures and fertilizers were applied at the following doses,KrishiProjukti Hat Boi, 2016

Manure and fertilizer	Doses ha^{-1}
Cowdung	10 t
Urea	175 kg
TSP	175 kg
MoP	135 kg

One third (1/3) of whole amount of Urea and full amount of cowdung, TSP andMoP were applied at the time of final land preparation. The remaining urea was top dressed in two equal installments- at 25 days after sowing (DAS) and 50 DAS respectively.

3.8Sowing of seeds

Fenugreek seeds were soaked in water for 6 hours to enhance germination. Seeds were also treated with Bavistin at the rate of 2 g per kg of seeds before sowing. The seeds were sown in rows made as per treatment continuously by hand @ 15 kg/ha (Anon., 2010). To allow uniform sowing in rows seeds were mixed with some loose soil (about four to five times of weight of seeds). The seeds were covered with good pulverized soil just after sowing and gently pressed by hands.

The sowing was done on November 25, 2014 with slight watering just to supply sufficient moisture needed for quick germination. Seedlings of the plots were thinned later to maintain 10 cm intra spacing (plant to plant distance) 25 days after sowing (DAS).

3.9Spray of GA_3

GA_3at different concentrationsas per treatment were sprayed to the crops at 25, 45 and 60 days after sowing (DAS).

3.10 Intercultural operations

The desired population density was maintained by thinning plants 20 DAS. Irrigation, mulching, weeding and plant protection measures etc. were performed for better crop establishment and proper plant growth.

3.10.1 Weeding

The field was kept free by hand weeding. First weeding was done after 2 days after sowing (DAS). Plant thinning was also done at the time of weeding. Second and third weeding was done after 35 and 50 DAS, respectively.

3.10.2 Irrigation

For good germination water was given to the plots every two days by water can with fine mashed nozzle till germination. Then three irrigations were given at 30, 60 and 90 days after sowing.

3.11 Harvesting

Seeds were harvested on 8 March 2018 when pod colour changed into yellowish brown in colour (Anon., 2010). To avoid shattering of pods, harvesting of seed plant was cut to the base by sickles in the early morning. Then the stalks with seeds were dried in the sun. Seeds (grains) were separated by beating with sticks and cleaned by winnowing and dried properly (10% moisture of seed).

3.12 Data collection and recording

Five plants were selected randomly from each unit plot for recording data on crop parameters and the yield of grain and straw were taken plot wise. The following parameters were recorded during the study:

1. Number of plants m^{-2}
2. Plant height (cm)
3. Number of leaves $plant^{-1}$
4. SPAD value by SPAD meter
5. SPAD value by Spectophotometer
6. Days to first flowering
7. Days to 50% flowering
8. Days to reproductive days
9. Days to pod development
10. Productivity (kg/ha/days)
11. Days to maturity
12. Number of primary branches $plant^{-1}$
13. Number of pods $plant^{-1}$
14. Number of seeds pod^{-1}
15. Number of seeds $plant^{-1}$
16. Seed weight $plant^{-1}$ (g)
17. 1000 seed weight (g)
18. Pod length (cm)
19. Seed yield ($kgha^{-1}$)
20. Straw yield (kg ha^{-1})
21. Biological yield ($kgha^{-1}$)
22. Harvest index (%)

3.13 Procedure of recording data

3.13.1 Number of plants m^{-2}

Number of plants m^{-2} was counted during data collection of fenugreek plant.

3.13.2Plant height (cm)

The height of plant was recorded in centimeter (cm) at different days after sowing of crop duration. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves. Data was taken at 30, 45, 60, 75, 90, 105 days after sowing (DAT) and at harvest.

3.13.3 Number of leaves plant^{-1}

Number of leaves plant-1 was counted five times at 15 days interval such as 35, 50, 65 and 80 DAS of fenugreek plants. Mean values of data were calculated and recorded.

3.13.4 SPAD value by SPAD meter

SPAD value was measured at 50 days after sowing (DAS) with the help of SPAD-502 meter.The SPAD-502 meter is a hand-held device that is widely used for the rapid, accurate and non-destructive measurement of leaf chlorophyll concentrations. It has been employed extensively in both research and agricultural applications, with a range of different plant species. However, its utility has not been fully exploited in relation to the most intensively studied model organism for plant science research, Arabidopsis thaliana. Measurements with the SPAD-502 meter produce relative SPAD meter values that are proportional to the amount of chlorophyll present in the leaf. In order to convert these values into absolute units of chlorophyll concentration, calibration curves must be derived and utilized. Calibration equations for Arabidopsis that can be used to convert SPAD values into total chlorophyll per unit leaf area (nmol/cm(2); R(^{2}) = 0.9960) or per unit fresh weight of leaf tissue (nmol/mg; R(^{2}) = 0.9809) (Ling*et al*., 2011)..

3.13.5 SPAD value by SPAD meter and Absorbance reading by Spectophotometer

Absorbance reading was measured at 50 days after sowing (DAS) with the help of Spectophotometer (Online, 2004). A spectrophotometer will direct light of a specific wavelength (from 650 ɳm to 400 ɳm) on the solution. This light is the incident light. The light that passes through the solution is the transmitted light.

The absorbance (A) of the solution is the log of the ratio of these two measures:

A (Absorbance or Optical Density) = log10 (Intensity of incident light / Intensity of transmitted light)

The spectrophotometer will calculate and display the absorbance. The absorbance, concentration of the solution follows from the Beer-Lambert equation:

$$A = E \times C \times L$$

Where,

E (Molar Absorption) = absorbance of a l M solution of the substance measured through a l-cm light path. This is a constant for the substance at a given wavelength.

C = concentration, in moles/liter.

Therefore, since L equals 1, C = A / E.

3.13.6 Chlorophyll Content Determination

After took of absorbance reading was measured at 50 days and 65 days after sowing (DAS) with the help of Spectrophotometer (Online, 2004). A spectrophotometer will direct light of a specific wavelength (from 645 ɳm and 663 ɳm) on the solution.

The following calculations will be made to ascertain sample chlorophyll concentrations. Concentrations will be expressed on an area basis.

Chlorophyll a [milligrams/milliliter (mg mL^{-1})] = 12.7 A663 - 2.69 A645

Chlorophyll b (mg/mL) = 22.9 A645 - 4.68 A663; where: A645 = absorbance at a wavelength of 645 nm; A663 = absorbance at a wavelength of 663 nm.

Total Chlorophyll (mg/mL) = Chlorophyll a + Chlorophyll b.

Total Chlorophyll (mg) in original tissue sample = Total Chlorophyll (mg mL^{-1}) × final volume (mL).

Total Chlorophyll a (mg) in original tissue sample = Chlorophyll a (mg mL^{-1}) × final volume (mL).

Total Chlorophyll b (mg) in original tissue sample = Chlorophyll b (mg mL^{-1}) × final volume (mL).

To express on the basis of area, divide the amount of chlorophyll by the area (mm^2) in the tissue sample analyzed.

Area of a circle = π ($radius^2$) = 3.1416(r^2)

3.13.7 Days to first flowering

Days to first (1^{st}) flowering was recorded from the date of sowing to when 1^{st} flower is appeared in the plant.

3.13.8 Days to 50% flowering

In each plot 10 plants were tagged and dates of first flowering from each tagged ten plants were counted gradually. When five plants flowered, five dates of flowering were taken, added and the added values were divided by five. This parameter was treated as days to 50% flowering.

3.13.9 Duration to reproductive stage

Days to first (1^{st}) reproductive was recorded from the date of sowing to when 1^{st} reproductive stage is appeared in the plant.

3.13.10 Duration to pod development period

Days to first (1^{st}) pod was recorded from the date of sowing to when 1^{st} pod is appeared in the plant.

3.13.11 Productivity (kg/ha/days)

Productivity of plants was measured from each plot and expressed as kg/ha/days

3.13.12 Days to maturity

Days to 1^{st} maturity was calculated from the date of sowing upto the attainment of 1^{st} pod maturity stage.

3.13.13 Number of primary branches plant^{-1}

Number of branches was counted from randomly selected ten plants from each plot and mean values were calculated and recorded.

3.13.14 Number of pods plant^{-1}

Pods of 5 randomly selected plants of each replication were counted and then the average number of fruits for each plant was determined. It was done continued up to final harvesting.

3.13.15 Number of seeds pod^{-1}

Ten pods of each of randomly selected 5 plants were considered and then seeds per pod were counted from all the pods and the average data were taken as number of seeds pod^{-1}.

3.13.16 Number of seeds plant^{-1}

Seeds of randomly selected 5 plants from each plot were considered and then seeds were counted from all plants and the average data were taken as number of seeds plant^{-1}.

3.13.17 Weight of seeds plant^{-1} (g)

Seed weight plant^{-1}(g) was measured by Electric Balance in gram (g). Seeds from 5 selected plants from each unit plot were collected and divided by 5 to calculate weight of seeds per plant.

3.13.18 Weight of 1000 seeds (g)

1000 seed weight was measured by Electric Balance in gram (g). 1000 seed from each treatment were counted and then weighed.

3.13.19 Pod length (cm)

Pod length was calculated from randomly selected 20 pods from each plot and average value was taken. It was measured with a meter scale from base to top of the pod and was expressed in centimeter (cm).

3.13.20 Seed yield (kg ha^{-1})

After maturity seeds of all plants except 10 selected plants were harvested and cleaned. Then seed was measured with electric balance in gram. Then this weight was added to seed weight of 10 selected plants to obtain seed yield plot^{-1}.Seed yield plot^{-1} (g) was converted to per hectare yield (kg ha^{-1}).

3.13.21 Straw yield (kg ha^{-1})

After seed collection all plant of each unit plot were dried in the sun. Then total plants of each unit plot were weighed to get weight of straw plot^{-1}. Straw yield plot^{-1} (g) was converted to per hectare straw yield (kg ha^{-1}).

3.13.22Biological yield (kg ha^{-1})

Biological yield was calculated by the following formula

$$\text{Biological yield (kg ha}^{-1}\text{)} = \text{Grain yield (kg ha}^{-1}\text{)} + \text{Straw yield (kg ha}^{-1}\text{)}$$

3.13.23 Harvest index (%)

Harvest index was calculated by the following formula

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.14 Statistical analysis

The data in respect of growth and yield components were statistically analyzed to find out the significance of the experimental results. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by F test. The difference among the treatment means was evaluated by DMRT test (Gomez and Gomez, 1984) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The result obtained with different levels of GA_3 was presented and discussed in this chapter. Data on morphological parameters, yield contributing characters and seed yield of fenugreek were in both Tables and Figures have been shown under the following headings.

4.1 Growth and morphological parameters

4.1.1 Plant height (cm)

Significant variation was observed on plant height at different growth stages affected by different levels of GA_3 (Fig.1). Results showed that the highest plant height (23.27, 59.10, 73.80, 77.10, 79.31 and 82.48 cm at 45, 60, 75, 90, 10 DAS and at harvest, respectively)was found from the treatment, T_4 (75 ppm GA_3) which was significantly different from all other treatments followed by T_3 (50 ppm GA_3). The lowest plant height (19.33, 46.13, 64.07, 67.50, 69.44 and 72.21 cm at 45, 60, 75, 90, 10 DAS and at harvest, respectively)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was significantly different from all other treatments followed by T_7 (150 ppm GA_3).This result indicated that plant height was increased with the increasing of GA_3levels to at a certain levels. This might be due to cause of higher levels of GA_3might be toxic to plants and resulted lower plant height. Similar result was also observed by Vandana*et al*. (2014) and Netamand Sharma(2014) and they found that GA_3 increased plant height to a certain level which supported the present study.

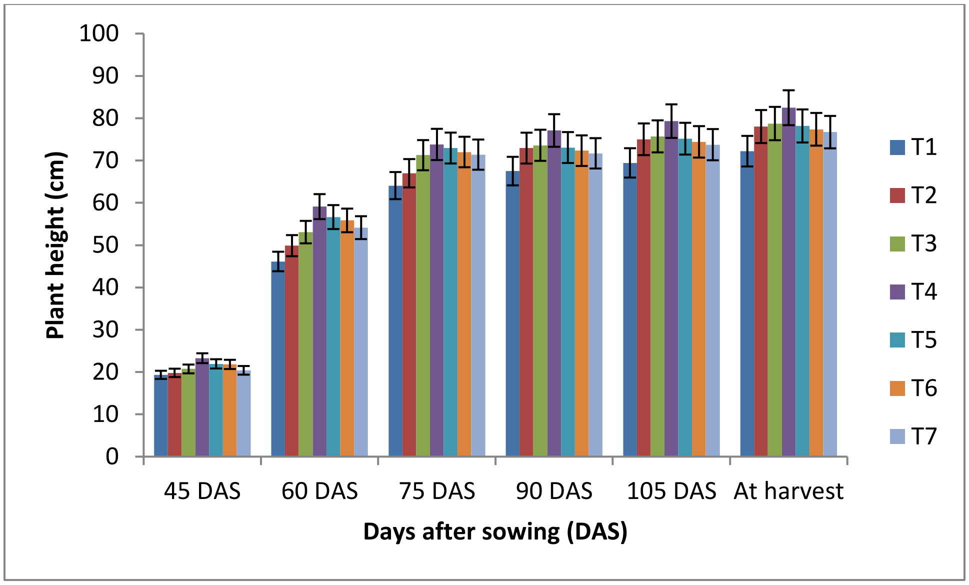

Fig.1. Plant height of fenugreek affected by different GA_3levels

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

4.1.2 Number of leaves plant^{-1}

Significant variation was observed on number of leaves plant^{-1} at different growth stages influenced by different levels of GA_3(Fig.2). Results revealed that the highest number of leaves plant^{-1} (33.00, 82.33, 103.90, 120.80, 128.60 and 132.40 at 45, 60, 75, 90, 10 DAS and at harvest, respectively)was found from the treatment, T_4 (75 ppm GA_3) which was significantly different from all other treatments followed by the treatment T_5 (100 ppm GA_3). Again, the lowestnumber of leaves plant^{-1} (24.47, 75.27, 75.60, 77.87, 82.92 and 87.05 at 45, 60, 75, 90, 10 DAS and at harvest, respectively)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) followed by T_2 (25 ppm GA_3).This result indicated that an increasing trend was found with the increasing of GA_3 levels to at a certain level (75 ppm GA_3). The result obtained from the present study was similar with the findings Kumar *et al.* (2014) and Danesh-Talab*et al.* (2014).Kumar *et al.* (2014) found highest leaf number in tomato with 50 ppm GA_3.

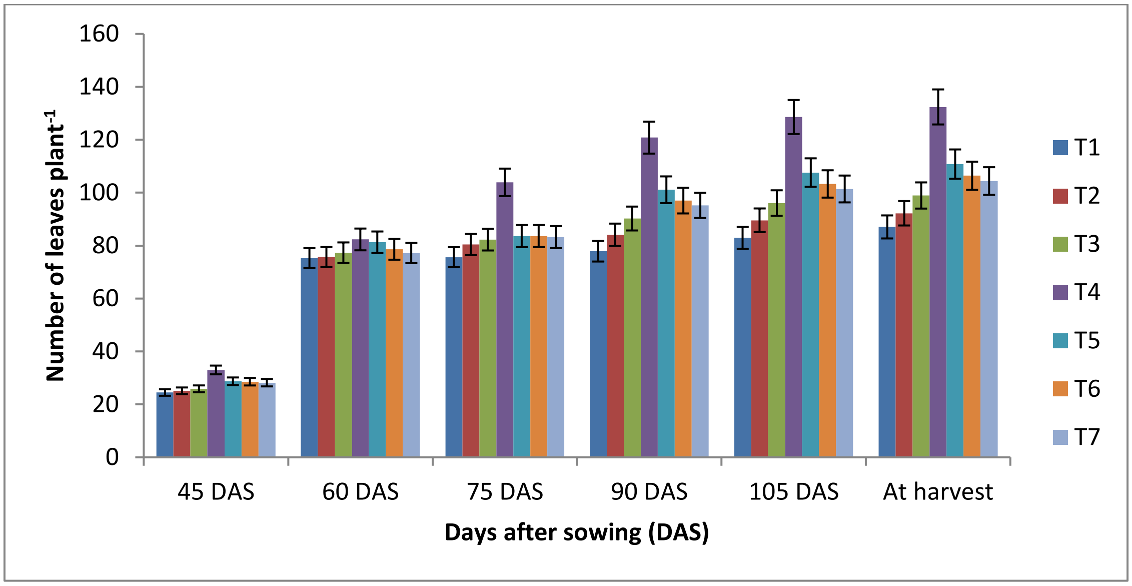

Fig.2. Number of leaves plant^{-1}at different levels of GA_3

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

4.1.3 SPAD value

4.1.3.1 SPAD valueby SPAD meter

Significant variation was observed on spade values by SPAD meter at different growth stages influenced by different levels of GA_3 (Table 1). Results revealed that the highest spade valuesby SPAD meter (57.99 and 59.58 at 60 and 75 DAS, respectively)was found from the treatment, T_4 (75 ppm GA_3) where the lowest spad valueby SPAD meter (50.42 and 52.74 at 60 and 75 DAS, respectively)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray). The value obtained from all other treatments was significantly different from T_4 (75 ppm GA_3) and T_1 (0 ppm GA_3; tap water spray). Similar result was also observed by Danesh-Talab*et al.* (2014) which supported the present study.

4.1.3.2 Absorbance reading by spectrophotometer

Significant influence was found on absorbance reading by spectrophotometer affected by different levels of GA_3 (Table 1). Results showed that the highest by spectrophotometer at 645 ηm (0.197 and 0.184 at 60 and 75 DAS, respectively)was found from the treatment, T_4 (75 ppm GA_3) and the highest absorbance reading by spectrophotometer at 663 ηm (0.253 and 0.222 at 60 and 75 DAS, respectively)was also found from the treatment, T_4 (75 ppm GA_3). Similarly, the lowest absorbance reading by spectrophotometer at 645 ηm (0.103 and 0.108 at 60 and 75 DAS, respectively)was found from the treatment, T_1 (0 ppm GA_3; tap water spray) where the lowest absorbance reading by spectrophotometer at 663 ηm (0.122 and 0.138 at 60 and 75 DAS, respectively)was also found from the treatment, T_1 (0 ppm GA_3; tap water spray).

Table 1. SPAD Values and absorbance reading of fenugreek affected by different levels of GA_3application

Treatment	SPAD value					
	SPAD Vale by SPAD meter		Absorbance readingby spectrophotometer at 645 ηm		Absorbance readingby spectrophotometer at 663 ηm	
	60 DAS	75 DAS	60 DAS	75 DAS	60 DAS	75 DAS
T_1	50.42 d	52.74 d	0.103 d	0.108 c	0.122 c	0.138 d
T_2	54.09 b	54.46 bc	0.113 cd	0.123 c	0.225 a	0.145 cd
T_3	53.30 bc	55.35 b	0.135 b	0.146 b	0.229 a	0.147 cd
T_4	57.99 a	59.58 a	0.197 a	0.184 a	0.235 a	0.222 a
T_5	54.77 b	55.33 b	0.187 a	0.176 a	0.226 a	0.190 b
T_6	53.85 b	54.97 b	0.127 bc	0.125 c	0.169 b	0.157 c
T_7	51.85 cd	53.75 cd	0.105 d	0.115 c	0.123 c	0.161 c
CV (%)	8.29	9.34	3.42	6.68	4.72	3.88

Means showing different letters are significantly different at 5% level of probability by DMRT

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

This result indicated that GA_3showed significant influence on absorbance reading but it was increased up to a certain limit and after that it was decreased with increasing GA_3 application. Danesh-Talab *et al.* (2014) also found similar result with the present study.

4.1.3.3 Chlorophyll Content

Significant variation was observed on chlorophyll content of fenugreek leaf at 45 days after sowing affected by different levels of GA_3 application (Table 2). It was observed that at 45 DAS the highest total chlorophyll content (1.488 µg g^{-1}) was obtained from T_4 (75 ppm GA_3) treatment which was statistically identical with T_6 (125 ppm GA_3) treatment. Here, it can be noted that total chlorophyll content is a sum of total of 'chlorophyll a' and 'chlorophyll b'. At 45 DAS, the highest 'chlorophyll a' content (0.856 µg g^{-1}) and 'chlorophyll b' (0.698 µg g^{-1}) content was achieved from T_4 (75 ppm GA_3) treatment. Likewise, at 45 DAS, the lowest chlorophyll content of chlorophyll a, chlorophyll b and total chlorophyll content (0.403 and 0.329 and 0.734 µg g^{-1}, respectively) were found from T_1 (0 ppm GA_3; tap water spray) treatment.

Table 2. Effect of GA_3application on chlorophyll content of Fenugreek

Treatments	Chlorophyll (Chl) content (µg g^{-1})					
	45 DAS			60 DAS		
	Chl-a	Chl-b	Total	Chl-a	Chl-b	Total
T_1	0.403 d	0.329 c	0.734 d	0.294 c	0.420 c	0.781 c
T_2	0.799 ab	0.611 ab	1.453 a	0.471 a	0.590 ab	0.949 ab
T_3	0.624 c	0.411 c	1.005 c	0.350 bc	0.558 ab	0.895 bc
T_4	0.856 a	0.698 a	1.488 a	0.480 a	0.617 a	1.067 a
T_5	0.746 b	0.576 b	1.302 b	0.387 abc	0.568 ab	0.903 bc
T_6	0.780 ab	0.601 ab	1.368 ab	0.433 ab	0.573 ab	0.937 ab
T_7	0.585 c	0.392 c	0.975 c	0.343 bc	0.507 bc	0.848 bc
$LSD_{0.05}$	0.097	0.093	0.138	0.095	0.094	0.137
CV (%)	2.342	2.711	3.526	1.589	3.274	3586

Means showing different letters are significantly different at 5% level of probability by DMRT

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

At 60 DAS, Significant variation was observed on chlorophyll content of fenugreek leaf affected by different levels of GA_3 application (Table 2). At 60 DAS, the highest ‘chlorophyll a’ and ‘chlorophyll b’ content and total chlorophyll content (0.480, 0.617 and 1.067 μg g^{-1}, respectively) were achieved from T_4 (75 ppm GA_3) treatment which was statistically similar with T_2 (25 ppm GA_3) and T_6 (125 ppm GA_3) treatments. The lowest chlorophyll content of chlorophyll a, chlorophyll b and total chlorophyll content (0.294 and 0.420 and 0.781 μg g^{-1}, respectively) at 60 DAS were found from T_1 (0 ppm GA_3; tap water spray) treatment which was significantly similar with T_7 (150 ppm GA_3) treatment.

4.2 Yield contributing parameters

4.2.1 Days to 1stflowering

Significant variation was not observed on days to 1st flowering affected by different levels of GA_3 (Table 3). However, the highest days to 1stflowering (37.99)was found from the treatment, T_2 (25 ppm GA_3) and the lowest days to 1stflowering(37.58)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray).

4.2.2 Days to 50% flowering

Days to 50% flowering was not significant with the application of different levels of GA_3 (Table 3). However, the highest days to 50% flowering(44.99)was found from the treatment, T_2 (25 ppm GA_3) and the lowest days to 50% flowering(44.58)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray).

4.2.3 Duration to reproductive stage

Days to reproductive stage was not significantly influence by different levels of GA_3 (Table 3). However, the highest days to reproductive stage (16.00)was found from the treatment, T_7 (150 ppm GA_3) and the lowest days to reproductive stage (15.42)was found from the treatment, T_5 (100 ppm GA_3).

4.2.4 Duration to pod development period

Significant variation was not found on days to pod development period influenced by different levels of GA_3 (Table 3). However, the highest days to pod development period (23.63)was found from the treatment, T_7 (150 ppm GA_3) and the lowest days to pod development period (22.76)was found from the treatment, T_5 (100 ppm GA_3).

4.2.5 Productivity (kg/ha/days)

Significant influence was achieved on productivity fenugreek affected by different levels of GA_3 (Table 3). It was found that the highest productivity (13.32 kg/ha/days)was found from the treatment, T_4 (75 ppm GA_3) which was significantly different from all other treatments followed by T_5 (100 ppm GA_3).

Table 3. Yield contributing parameters of fenugreek affected by different levels of GA_3application

treatment	Yield contributing parameters				
	Days to 1st flowering	Days to 50% flowering	Days to reproductive stage	Days to pod development period	Days to maturity
T_1	37.58	44.58	15.82	23.37	119.1
T_2	37.99	44.99	15.53	22.93	119.0
T_3	37.96	44.96	15.79	23.32	119.2
T_4	37.90	44.90	15.70	23.18	118.8
T_5	37.78	44.78	15.42	22.76	119.1
T_6	37.80	44.80	15.66	23.13	118.9
T_7	37.95	44.95	16.00	23.63	119.9
CV (%)	7.79	8.04	6.37	5.24	6.71

Means showing without letters are not significantly different at 5% level of probability by DMRT

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

The lowest productivity (5.28 kg/ha/days)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was also significantly different from all other treatments. The result obtained from the present study was similar with the findings of Idrees*et al.* (2010).

4.2.6 Days to maturity

Non-significant variation was found on days to maturity affected by different levels of GA_3 (Table 3). However, results indicated that the highest days to maturity (119.9) was found from the treatment, T_7 (150 ppm GA_3) whereas the lowest days to maturity (118.8) was found from the control treatment, T_4 (75 ppm GA_3).

4.2.7 Number of primary branches plant^{-1}

Number of primary branches plant^{-1} at harvest was significantly varied due to different levels of GA_3 (Table 4). Results revealed that the highest number of primary branches plant^{-1}(6.73)was found from the treatment, T_4 (75 ppm GA_3) which was statistically identical with the treatment T_5 (100 ppm GA_3).

Table 4. No. of primary branches plant^{-1} at harvest as affected by different levels of GA_3 application

Treatments	No. of primary branches plant^{-1} at harvest
T_1	3.70 d
T_2	3.82 cd
T_3	4.20 c
T_4	6.73 a
T_5	6.53 a
T_6	5.50 b
T_7	5.19 b
CV (%)	6.24

Means showing different letters are significantly different at 5% level of probability by DMRT
T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

The lowest number of primary branches plant^{-1}(3.70)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was statistically similar with T_2 (25 ppm GA_3). This result indicated that GA_3 gave higher primary branches plant^{-1} and it increased with increasing of GA_3 rate but it to certain limit and after that it was decreased with increasing of GA_3. This was might be due to cause of toxicity of plants due to extra doses of GA_3.Rahman *et al*. (2004) and Bhosle*et al.* (2002) also found similar results with the present study.

4.2.8 Number of pods plant^{-1}

Number of pods plant^{-1} was significantly influence by different levels of GA_3 (Table 5). It was observed that the highest number of pods plant^{-1} (54.20)was found from the treatment, T_4 (75 ppm GA_3) which was significantly different from all other treatments followed by T_5 (100 ppm GA_3). The lowest number of pods plant^{-1} (28.73) was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was also significantly different from all other treatments followed by T_2 (25 ppm GA_3), T_3 (50 ppm GA_3) and T_7 (150 ppm GA_3).This result revealed that GA_3 has ability to produce higher number of pods plant^{-1} under a limited dose. Similar result was also observed by Danesh-Talab*et al*. (2014) and Rahman *et al*. (2004) which supported the present study.

4.2.9 Number of seeds pod^{-1}

Number of seeds pod^{-1} was significantly varied due to the application of different levels of GA_3 (Table 5). The highest number of seeds pod^{-1} (14.87)was found from the treatment, T_4 (75 ppm GA_3) which was statistically identical with T_5 (100 ppm GA_3) and statistically similar with T_6 (125 ppm GA_3) and statistically similar with T_6 (125 ppm GA_3). The lowest number of seeds pod^{-1} (12.47)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was significantly different from all other treatments followed by T_7 (150 ppm GA_3). Similar result was also observed by Danesh-Talab*et al*. (2014) andAyyub*et al.* (2013) which supported the present study.

4.2.10 Number of seeds plant^{-1}

Significant influence was noted on number of seeds plant^{-1} affected by different levels of GA_3 (Table 5). Results indicated that the highest number of seeds plant^{-1} (805.90)was found from the treatment, T_4 (75 ppm GA_3)which was significantly different from all other treatments followed by T_5 (100 ppm GA_3). The lowest number of seeds plant^{-1} (358.70)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray)followed by T_7 (150 ppm GA_3). The result obtained from the present study was similar with the findings of Danesh-Talab*et al*. (2014).

4.2.11 Seed weight plant^{-1} (g)

Significant influence was noted on seed weight plant^{-1} affected by different levels of GA_3 (Table 5). Results showed that the highest seed weight plant^{-1} (5.11 g)was found from the treatment, T_4 (75 ppm GA_3) which was immediate higher then T_5 (100 ppm GA_3) where the lowest seed weight plant^{-1} (2.01 g)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) followed by T_7 (150 ppm GA_3) and T_2 (25 ppm GA_3).Ayyub*et al.* (2013) and Rahman *et al*. (2004) also found similar result

4.2.12 Weight of 1000 seeds (g)

Weight of 1000 seeds was significantly varied due to different levels of GA_3 application (Table 5). It was noted that the The highest 1000 seed weight (10.47 g)was found from the treatment, T_4 (75 ppm GA_3) which was statistically similar with the treatment, T_5 (100 ppm GA_3). The lowest 1000 seed weight (9.29 g)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was statistically identical with T_2 (25 ppm GA_3). Similar result was also observed by Danesh-Talab*et al*. (2014).

4.2.13 Pod length (cm)

Pod length was significantly varied due to the application of different levels of GA_3 (Table 5). Results indicated that the highest pod length (7.46)was found from the treatment, T_4 (75 ppm GA_3) which was significantly different from all other treatments but nearest to the treatment T_6 (125 ppm GA_3) and T_7 (150 ppm GA_3). The lowest pod length (6.52)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was statistically similar with T_2 (25 ppm GA_3), T_3 (50 ppm GA_3) and T_5 (100 ppm GA_3).

Table 5. Yield contributing parameters of fenugreek affected by different levels of GA_3application

Treatment	Yield contributing parameters					
	No. of pods plant^{-1}	No. of seeds pod^{-1}	No. of seeds plant^{-1}	Seed weight plant^{-1} (g)	1000 seed weight (g)	Pod length (cm)
T_1	28.73 e	12.47 d	358.70 f	2.01 f	9.29 c	6.52 c
T_2	37.00 d	13.87 bc	513.10 d	2.97 de	9.57 c	6.73 bc
T_3	37.07 d	14.00 bc	519.10 d	3.16 d	10.00 b	6.76 bc
T_4	54.20 a	14.87 a	805.90 a	5.11 a	10.47 a	7.46 a
T_5	49.33 b	14.73 a	727.70 b	4.50 b	10.20 ab	6.79 bc
T_6	42.00 c	14.33 ab	602.10 c	3.66 c	10.03 b	6.85 b
T_7	35.00 d	13.47 c	471.30 e	2.87 e	10.03 b	6.92 b
CV (%)	7.93	6.37	10.28	5.87	6.14	5.83

Means showing different letters are significantly different at 5% level of probability by DMRT

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

4.3 Yield parameters

4.3.1 Seed yield ha^{-1} (kg)

The recorded data on seed yield ha^{-1}was significant affected by the application of different levels of GA_3 (Table 6). Results revealed that the highestseed yield ha^{-1}(1582.00 kg)was found from the treatment, T_4 (75 ppm GA_3) where the 2nd

highest seed yield ha^{-1}(1411 kg) was found from the treatment T_5 (100 ppm GA_3). The lowest seed yield ha^{-1}(628.30 kg)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was immediate lower than the treatment T_7 (150 ppm GA_3).This result indicated that seed yield of fenugreek was increased by GA_3 application to a certain level and after that yield is decreased with increasing GA_3. This might be due to cause of higher yield contributing parameters were obtained with the same GA_3 dose. The result obtained from the present study was similar with the findings of Idrees*et al.* (2010), Danesh-Talab*et al*. (2014), Ayyub*et al.* (2013) and Bhosle*et al.* (2002) who found higher yield with GA_3 at a definite rate.

4.3.2 Stover yield ha^{-1} (kg)

Considerable influence was observed on stover yield ha^{-1}persuaded by different levels of GA_3 application (Table 6). Results indicated that the highest stover yield ha^{-1}(3230.00 kg)was found from the treatment, T_4 (75 ppm GA_3) followed by T_5 (100 ppm GA_3). The lowest stover yield ha^{-1}(2383.00 kg)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was significantly different from all other treatments followed by T_7 (150 ppm GA_3). It can be stated that the result obtained from the present study showed significant influence on stover yield which might be due to cause of growth promoting characters. GA_3 also helps to cell elongation which might be another cause of higher stover yield. Higher doses of GA_3 gave lower stover yield which might be toxic to plants.

4.3.3 Biological yield ha^{-1} (kg)

Remarkable variation was identified on biological yield ha^{-1}due to the effect of different levels of GA_3 (Table 6). Results signified that the highest biological yield ha^{-1}(4878.00 kg)was found from the treatment, T_4 (75 ppm GA_3) which was significantly different from all other treatments followed by T_5 (100 ppm GA_3). The lowest biological yield ha^{-1}(2944.00 kg)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) which was also significantly different from all other treatments followed by T_7 (150 ppm GA_3).Biological yield depends on seed and stover yield, hence higher biological yield increased significantly with the increasing of seed yield and stover yield.

4.3.4 Harvest index (%)

Considerable variation was found on harvest index affected by different levels of GA_3 (Table 6). Results showed that the highest harvest index (32.42%)was found from the treatment, T_4 (75 ppm GA_3) which was statistically identical with the treatment, T_5 (100 ppm GA_3). The lowest harvest index (21.34%)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray) followed by T_3 (50 ppm GA_3) and T_7 (150 ppm GA_3).Generally, harvest index depends on seed yield and stover yield and harvest index is increased with increasing seed yield. Similar result was also observed by Akter*et al*. (2007) which supported the present study.

Table 6. Yield parameters of fenugreek affected by different levels of GA_3

treatment	Yield parameters			
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Biological yield ha^{-1} (kg)	Harvest index (%)
T_1	628.30 g	2383.00 g	2944.00 g	21.34 d
T_2	923.70 e	2669.00 e	3593.00 e	25.73 bc
T_3	975.90 d	2962.00 c	3937.00 d	24.77 c
T_4	1582.00 a	3230.00 a	4878.00 a	32.42 a
T_5	1411.00 b	3074.00 b	4485.00 b	31.41 a
T_6	1143.00 c	2886.00 d	4028.00 c	28.36 b
T_7	892.80 f	2647.00 f	3540.00 f	25.21 c
CV (%)	11.26	11.32	10.78	8.39

Means showing without letters are not significantly different at 5% level of probability by DMRT

T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3, T_3 = 50 ppm GA_3, T_4 = 75 ppm GA_3, T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3, T_7 = 150 ppm GA_3

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at Sher-e-Bangla Agricultural University (SAU) farm, Dhaka, Bangladesh during the rabi season from November 2017 to March 2018 to find out the effect of Gibberellic acid on morphology, vegetative growth and seed yield of fenugreek (*Trigonellafoenum-graecum* L.). The treatment consisted of seven levels of GA_3 including control *viz*. T_1 = 0 ppm GA_3 (Tap water spray), T_2 = 25 ppm GA_3,T_3 = 50 ppm GA_3,T_4 = 75 ppm GA_3,T_5 = 100 ppm GA_3, T_6 = 125 ppm GA_3 and T_7 = 150 ppm GA_3. The experiment was laid out in a randomized completely bock design (RCBD) with three replications. Data were collected on different growth, morphological, yield contributing characters and yield characters of fenugreek. Collected data were statistically analyzed to compare the mean effects.

It was found that several parameters under the present study days to 1st flowering, days to 50% flowering, days to reproductive stage, days to pod development period and days to maturity were not significantly influenced by GA_3 treatments but rest of the studied parameters were significantly influenced by GA_3 treatments.

Considering growth and morphological parameters, results revealed that the highest plant height (23.27, 59.10, 73.80, 77.10, 79.31 and 82.48 cm at 45, 60, 75, 90, 10 DAS and at harvest, respectively) and number of leaves plant^{-1} (33.00, 82.33, 103.90, 120.80, 128.60 and 132.40 at 45, 60, 75, 90, 10 DAS and at harvest, respectively)were found from the treatment, T_4 (75 ppm GA_3). The lowest plant height (19.33, 46.13, 64.07, 67.50, 69.44 and 72.21 cm at 45, 60, 75, 90, 10 DAS and at harvest, respectively)and number of leaves plant^{-1} (24.47, 75.27, 75.60, 77.87, 82.92 and 87.05 at 45, 60, 75, 90, 10 DAS and at harvest, respectively)were found from the control treatment, T_1 (0 ppm GA_3; tap water spray). The highest number of primary branches plant^{-1} at harvest (6.73) was found from T_4(75 ppm

GA_3) treatment and the lowest number of primary branches plant^{-1} (3.70) T_1 (0 ppm GA_3; tap water spray)..

The highest SPAD valuesby SPAD meter (57.99 and 59.58 at 60 and 75 DAS, respectively)was found from the treatment, T_4 (75 ppm GA_3). The highest absorbance readingby spectrophotometer at 645 ɳm (0.197 and 0.184 at 60 and 75 DAS, respectively)and at 663 ɳm (0.253 and 0.222 at 60 and 75 DAS, respectively)were also found from the treatment, T_4 (75 ppm GA_3). The lowest SPAD valuesby SPAD meter (50.42 and 52.74 at 60 and 75 DAS, respectively)was found from the control treatment, T_1 (0 ppm GA_3; tap water spray). The lowestabsorbance readingby spectrophotometer at 645 ɳm (0.103 and 0.108 at 60 and 75 DAS, respectively)andat 663 ɳm (0.122 and 0.138 at 60 and 75 DAS, respectively)were also found from the treatment, T_1 (0 ppm GA_3; tap water spray). Again, at 45 DAS, the highest 'chlorophyll a, chlorophyll b' and total (0.856, 0.69 μg g^{-1}and 1.488 μg g^{-1}, respectively) was obtained from T_4 (75 ppm GA_3) whereas the lowest (0.403 and 0.329 and 0.734 μg g^{-1}, respectively) were found from T_1 (0 ppm GA_3; tap water spray) treatment. At 60 DAS, the highest 'chlorophyll a' and 'chlorophyll b' content and total chlorophyll content (0.480, 0.617 and 1.067 μg g^{-1}, respectively) were achieved from T_4 (75 ppm GA_3) treatment whereas the lowest chlorophyll content of chlorophyll a, chlorophyll b and total chlorophyll content (0.294 and 0.420 and 0.781 μg g^{-1}, respectively) at 60 DAS were found from T_1 (0 ppm GA_3; tap water spray) treatment

Considering yield contributing parameters and yield parameters, the highest productivity (13.32 kg/ha/days), number of pods plant^{-1} (54.20), number of seeds pod^{-1} (14.87), number of seeds plant^{-1} (805.90), seed weight plant^{-1} (5.11 g), 1000 seed weight (10.47 g), pod length (7.46 cm), seed yield ha^{-1} (1582.00 kg),stover yield ha^{-1} (3230.00 kg), biological yield ha^{-1} (4878.00 kg) and harvest index (32.42%) were also found from the treatment, T_4 (75 ppm GA_3).The lowest productivity (5.28), number of pods plant^{-1} (28.73), number of seeds pod^{-1} (12.47), number of seeds plant^{-1} (358.70), seed weight plant^{-1} (2.01 g), 1000 seed weight (9.29 g), pod length (6.52), seed yield ha^{-1} (628.30 kg),stover yield ha^{-1} (2383.00 kg), biological yield ha^{-1} (2944.00 kg) and harvest index (21.34%)were found from the control treatment, T_1 (0 ppm GA_3; tap water spray).

From the above findings, it can be concluded that the T_4 (75 ppm GA_3) showed best performance regarding maximum growth, morphological and yield contributing parameters and yield of fenugreek. So, this treatment, T_4 (75 ppm GA_3) can be considered as the best among the entire treatments.

Recommendations

1. Spray of 75 ppm GA3 three times at 25, 45 and 60 days after sowing might be recommended for higher yield of fenugreek.
2. Similar study with some other concentration of GA_3 application on fenugreek may be conducted in other part of Bangladesh to reach the final recommendation.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

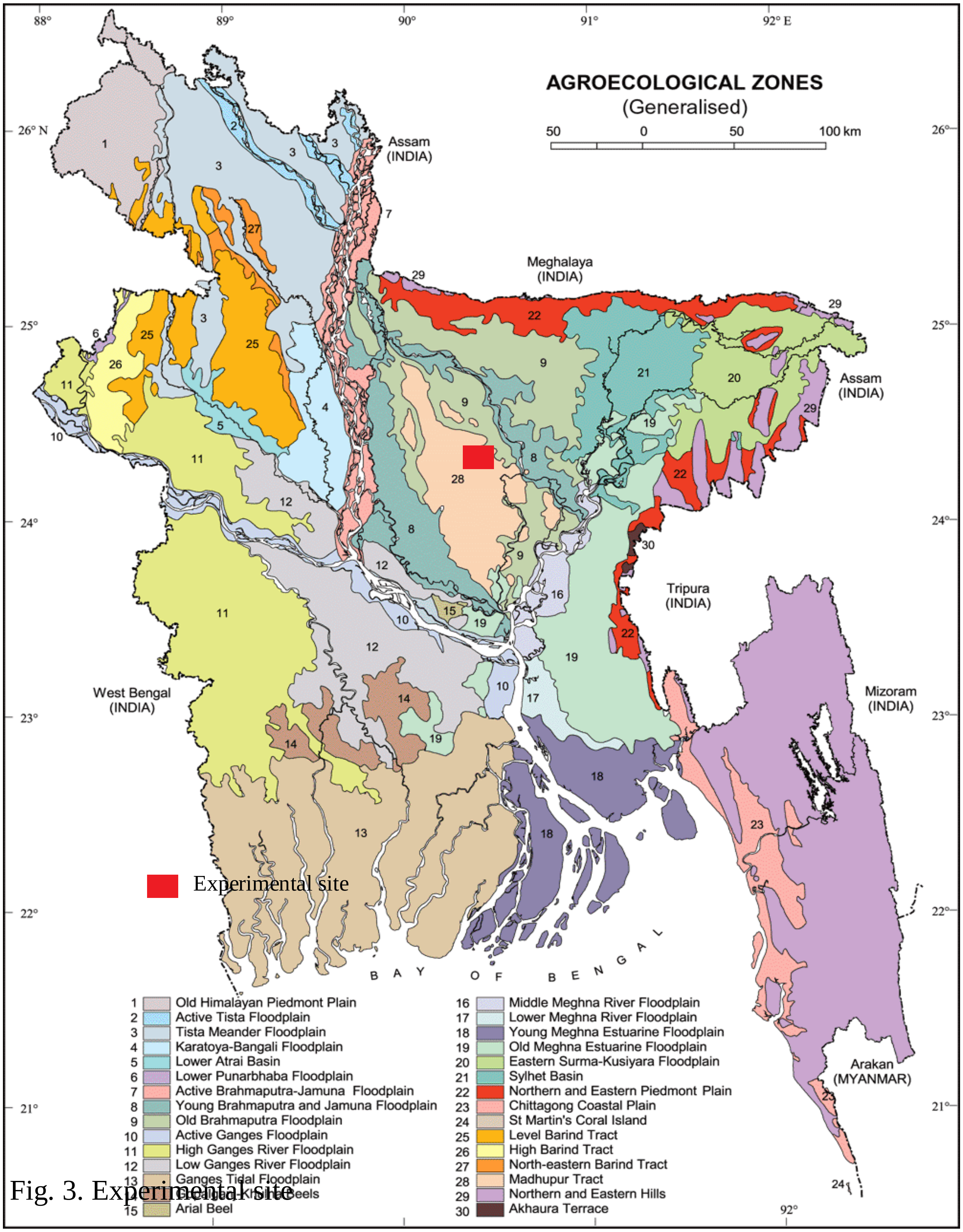


Fig. 3. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from January 2018 to December 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	November	28.60	8.52	18.56	56.75	14.40
2017	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0
2018	March	35.20	21.00	28.10	52.44	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

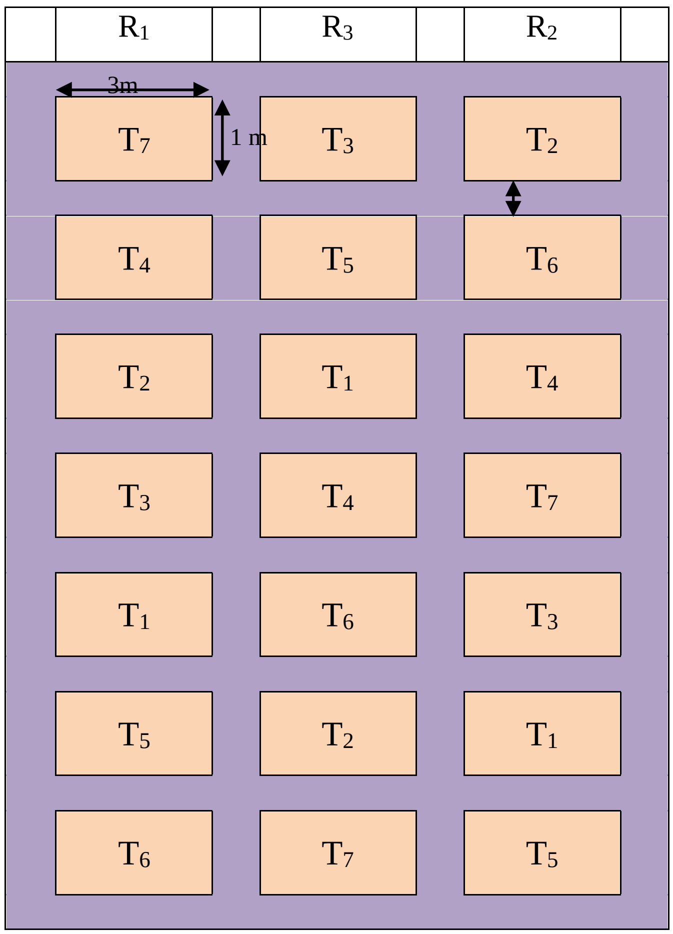
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

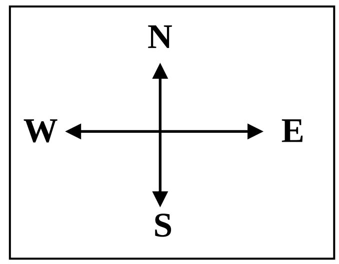
Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field



Legend



Treatments

1. T_1 = 0 ppm GA_3 (Tap water spray)
2. T_2 = 25 ppm GA_3
3. T_3 = 50 ppm GA_3
4. T_4 = 75 ppm GA_3
5. T_5 = 100 ppm GA_3
6. T_6 = 125 ppm GA_3
7. T_7 = 150 ppm GA_3

Plot size = 3 × 1 m^2

Fig. 4. Layout of the experimental plot

Appendix V. Mean square of plant height (cm)

Source	DF	Mean squareof plant height					
		45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At harvest
Replication	2	0.282	4.034	8.415	1.233	1.459	1.579
Factor A	6	5.644**	57.34*	36.99*	24.23*	25.63*	27.75*
Error	12	1.475	4.371	1.773	6.067	6.428	6.954

Appendix VI. Mean square of number of leaves plant^{-1}

Source	DF	Number of leaves plant^{-1}					
		45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At harvest
Replication	2	5.475	1.063	46.834	1.908	7.011	12.812
Factor A	6	25.28**	21.69*	240.89*	569.84*	646.60*	654.98*
Error	12	6.654	2.894	28.052	3.599	4.189	3.187

* = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of no. of primary branches plant^{-1} at harvest

Source	DF	No. of primary branches plant^{-1}
Replication	2	0.042
Factor A	6	4.625*
Error	12	0.057

* = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of chlorophyll content and absorbance reading of fenugreek affected by different levels of GA_3 application

Source	DF	SPAD value					
		Chlorophyll content by SPAD meter		Absorbance reading by spectrophotometer at 645 ηm		Absorbance reading by spectrophotometer at 663 ηm	
		60 DAS	75 DAS	60 DAS	75 DAS	60 DAS	75 DAS
Replication	2	12.765	2.450	0.001	0.001	0.001	0.001
Factor A	6	17.04*	13.96*	0.004**	0.008**	0.003**	0.004**
Error	12	2.702	7.823	0.001	0.0010	0.000	0.002

* = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of yield contributing parameters of fenugreek affected by different levels of GA_3 application

Source	DF	Mean square of yield contributing parameters					
		Days to 1st flowering	Days to 50% flowering	Days to reproductive stage	Days to pod development period	Productivity (kg/ha/days)	Days to maturity
Replication	2	2.042	2.042	0.481	0.646	0.371	0.433
Factor A	6	NS	NS	NS	NS	22.781*	0.391*
Error	12	1.958	1.958	0.374	0.814	0.533	0.726

* = Significant at 5% level ** = Significant at 1% level

Appendix X. Mean square of yield contributing parameters of fenugreek affected by different levels of GA_3 application

Source	DF	Mean square of yield contributing parameters					
		No. of pods $plant^{-1}$	No. of seeds pod^{-1}	No. of seeds $plant^{-1}$	Seed weight $plant^{-1}$ (g)	1000 seed weight (g)	Pod length (cm)
Replication	2	1.767	0.236	455.092	0.023	0.207	0.081
Factor A	6	230.34*	2.022*	70870.9*	3.321*	0.465*	0.254*
Error	12	5.094	0.387	2156.79	0.065	0.070	0.101

* = Significant at 5% level ** = Significant at 1% level

Appendix XI. Mean square of yield parameters of fenugreek affected by different levels of GA_3

Source	DF	Mean square of yield parameters			
		Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Biological yield ha^{-1} (kg)	Harvest index (%)
Replication	2	528.552	73.463	289.95	1.434
Factor A	6	3196.07*	2768.05*	1226.95*	46.23*
Error	12	72.233	488.124	74.440	2.738

* = Significant at 5% level ** = Significant at 1% level