EFFECT OF NAPHTHALENE ACETIC ACID, GIBBERELLIC ACID AND BENZYLAMINOPURINE ON GROWTH AND YIELD OF MUNGBEAN [*Vigna radiata* (L.) Wilczek]

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CERTIFICATE

This is to certify that the thesis entitled ***"Effect of Naphthalene Acetic Acid, Gibberellic Acid and Benzylaminopurine on Growth and Yield of Mungbean [Vigna radiata (L.) Wilczek]"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRICULTURAL BOTANY,*** *embodies the results of a piece of bona-fide research work carried out by* ***KAMANASHIS SARKAR,*** *Registration No.* ***11-04256*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

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ABSTRACT

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh to study theeffect of NAA, GA_3 and BAP (cytokinin) on growth and yield of mungbean [*Vigna radiata* (L.) Wilczek] from March to June 2017. BARI mungbean-6 variety was used as test crop.The experiment consisted of 7 treatments *viz*. NAA (Naphthalene Acetic Acid) 100 ppm, GA_3 (Gibberellic Acid) 150 ppm, BAP (Benzylaminopurine) 100 ppm, GA_3 150 ppm and BAP 100 ppm, GA_3 150 ppm and NAA 100 ppm, GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm and Control. The experiment was laid out at randomized complete block design (RCBD) with four replications. Data were recorded on different growth, morpho-physiological characters, yield contributing characters and yield attributes. Most of the cases, GA_3 150 ppm and NAA 100 ppm gave the best performance. The highest plant height (69.28 cm), highest dry weight plant^{-1} (26.13 g), crop growth rate (11.57 mg cm^{-2} day^{-1} at 40 DAS - At harvest), chlorophyll content (1.05 μg g^{-1} at 50 DAS), number of pods plant^{-1} (23.28), highest number of seeds pod^{-1} (12.62), highest pod length (8.60 cm), highest seed yield plant^{-1} (4.37 g), highest seed yield ha^{-1} (1.31 t ha^{-1}), highest stover yield ha^{-1} (1.65 t ha^{-1}), highest biological yield ha^{-1} (2.96 t ha^{-1}) and highest harvest index (44.20%) were obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) where control gave the lowest. GA_3 150 ppm and BAP 100 ppm also provided the highest number of leaves plant^{-1} (23.25 at harvest), branches plant^{-1} (3.10 at harvest), leaf area index (5.67 at harvest) and 1000 seeds weight (46.88 g) where control gave the lowest.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Mungbean [*Vigna radiata* (L.) Wilczek] also called green gram, golden gram, mung, mug, is an important pulse crop in the world, because it produces high quality and quantity protein (Tomooka *et al*., 2002). In Bangladesh it is also called "Sonamung" due to its golden colour and high market price.

Mungbean is used as whole or split seed as Dal (soup) in home and restaurant, and fried Dal in agro-industries but in Southeast and East Asia, mungbean is used to make various kinds of sweets, bean jam, sweetened bean soup, vermicelli and bean sprouts. The grain contains carbohydrate (51%), protein (26%), moisture (10%), mineral (3-4%) and vitamins (3%) (Afzal *et al*., 1998). Besides providing valuable protein in the diet, it helps to fix atmospheric nitrogen to the root rhizobia and enrich the soil (BINA, 2004).

It ranks fifth both in acreage and production and contributes 6.5% of the total pulse production in Bangladesh (Anon., 1998). The area under pulse crops in Bangladesh is 0.406 million hectares with a production of 0.322 million tons where mungbean is cultivated in the area of 0.108 million hectares with production of 0.03 million tons (BBS, 2015). It is considered as a quality pulse in the country but production per unit area is very low (736 kg/ha) as compared to other countries of the world (BBS, 2006). Although, mungbean plays an important role to supplement protein in the cereal-based low-protein diet of the people of Bangladesh but the acreage production of mungbean is gradually declining (BBS, 2010).

The yield of mungbean plant^{-1} as well as unit area^{-1} is very low. Average yield as low as 736 kg ha^{-1} (BBS, 2015) but its production needs to be increased even more

than three folds (BARI, 2010). That is why, increasing yield of mungbean by proper management practices need urgent attention.

Plant growth regulators are used to change the morphological characters in many crops. The various application of optimum quantity of growth regulators play an important role in high germination and vigour percent in mungbean (Aldesuquy *et al*., 2007) and (Algan *et al*., 2011). Plant growth regulators are one of the most important factors for increasing higher yield in leafy vegetables. Application of growth regulators has good management effect on growth and yield of field crops. Hormones regulate physiological process and synthetic growth regulators may enhance growth and development of field crops thereby increased total dry mass of a field crop (Islam, 2007; Cho *et al*., 2008).

These plant growth regulators (PGRs) in general, help to increase the number of flowers on the plant when applied at the time of flowering. The flower and pod drop may be reduced to some extent by spraying various growth regulators on foliage (Ramesh and Thirumuguran, 2001). The foliar application of PGRs and urea significantly increased seed yield per plant (Patil *et al*., 2005).

Growth regulator NAA (Naphthalene acetic acid) may influence on the factors, which are accelerating the morphological characters of mungbean. Yield characters are positively or negatively related with morphological characters. There are scopes for improving yield through changing the morphological characters by using plant growth regulators (PGRs) and manipulation of different management practices like irrigation. Recently, there has been global realization of the important role of PGRs in agriculture for better growth and yield of crop (Shohag*et al*., 2008).

Gibberellic acid (GA_3) is known to be importantly concerned in the regulation of plant responses to the external environment (Chakrabarti and Mukherji, 2003).For normal growth and development, gibberellic acid (GA_3) is a phytohormone that is

needed in small quantities at low concentration to accelerate plant growth and development. GA_3 enhances growth activities to plant, stimulates stem elongation and increases dry weight and yield (Deotale *et al*., 1998).

Considering the above views, the present study was undertaken with the following objectives:

a) To observe the effect of NAA, GA_3 and BAP (cytokinin) on growth characters of mungbean and
b) To identify the best combination of NAA, GA_3 and BAP for higher yield of mungbean.

CHAPTER II

REVIEW OF LITERATURE

Among the different pulse crops, mungbean is an important crop considering nutrition value, area coverage and production status as well as popularity depending on its flavor and test. The proper agronomic management practice and foliar application of plant growth regulators (PGRs) influences it's morphological characters and yield performance. Experimental evidences showed that there is a profound influence of different growth regulators on this crop. A brief of the relevant works performed on mungbean and also on other crop influenced by different growth regulators are presented in this Chapter.

2.1 Effect of Naphthalene Acetic Acid (NAA) on growth and yield

Chakma (2005) conducted an experiment to determine the effect of NAA on growth, yield and yield attributes of mungbean and it was found that the foliar application of 120 ppm NAA showed increased plant height, number of branches per plant, number of leaves per plant, leaf area index, dry matter, pod number per plant, number of seeds pod^{-1}, pod length, 1000 seeds weight, grain yield and harvest index of mungbean significantly.

Samsuzzaman (2004) carried out an experiment to determine the effect of GABA and NAA on growth and yield contributing characters of groundnut and found that the foliar spray of 100 ppm GABA (GA_3 + Abscisic acid) and 200 ppm NAA increased plant height significantly number of branches per plant, dry weight of groundnut, number of pod per plant and 1000 seeds weight of groundnut.

An experiment was conducted by Mondol (2003) in the farm of BINA to determine the effect of NAA and IBA on growth and yield contributing characters of groundnut and found that application of 80 ppm NAA increased plant height, leaf area index, dry matter production and seed yield significantly.

Ahmed (2006) stated that application of plant growth regulators had no significant effect on number of seeds pod^{-1}.

Mia (2007) found non-significant influence with the application of PGR on 1000 seeds weight of mungbean.

Foysalkabir *et al*. (2016) conducted a field experiment to find out the effect of plant growth regulator (NAA) and row spacing on growth and yield of mungbean and found that plant growth regulator play an important role of crops yield especially in mungbean. The experiment consists of four levels of NAA *viz*., 0, 20, 40 and 60 ppm and three different spacing *viz*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The result indicated significant variations of plant height, number of branches plant^{-1}, leaf dry weight, stem dry weight, root dry weight, 1000 seeds weight, grain yield due to plant growth regulator (NAA). The maximum 1000 seeds weights, highest grain yield were found when mungbean was sown when treated with 40 ppm NAA.

Shohag *et al*. (2008) conducted the study to investigate the effect of two levels of irrigation (Irrigated and non-irrigated) and five concentrations of growth regulator (0, 50, 100, 150 and 200 ppm NAA) on morphological parameters *viz*., plant height, root length, number of branches plant^{-1}, number of leaves plant^{-1}. Among the concentrations of growth regulator, 200 ppm NAA showed remarkable results on almost all these parameters. The interactions between irrigation and PGR showed better performance in most cases. The results revealed that NAA might be used under irrigated condition for better performance on morphological characters of mungbean.

Asaduzzaman (2013) conducted an experiment at agronomy field of Sher-e-Bangla Agricultural University to study the effect of variety and NAA (*viz*., 0, 20, 40, 60 and 80 ppm) on water relations and yield of mungbean and found that the

tallest plant was obtained from 80 ppm NAA and the longest pod, the highest number of pod & the highest seed yield were obtained from 20 ppm NAA.

Shahrior (2007) investigated the effect of NAA on morphological, growth and yield contributing characters of sesame (Binatil-1) at the Field Laboratory of the Department of Crop Botany, BAU, Mymensingh from February to May 2007. Different concentrations of NAA viz., 0, 50, 100, 150, 200 ppm were applied as seed treatment, foliar spray and seed treatment with foliar spray at 25 DAS. In most of the cases, growth and yield were increased with increasing of concentration and NAA at 200 ppm concentration was found to be the best for morphological growth, yield and yield contributing attributes of sesame.

Garai *et al*. (1990) was conducted a field trials in the rabi seasons during (1982-84). Mustard was given 10, 20 or 40 ppm. NAA, 5, 10 or 20 ppm. 2,4-D or no growth regulators. In a 2nd trial in the pre-kharif seasons of (1982-83) sesame cv. B14 was given 10, 20 or 40 ppm. NAA, 25, 50 or 100 ppm. IBA, 5, 10 or 20 ppm 2,4-D or no growth regulators. Seed yields of *B. juncea* and sesame were increased by all growth regulators tested except 20 ppm. 2,4-D. Seed and oil yields were highest with 20 ppm. NAA in *B. juncea* and with 25 ppm IBA in sesame.

Rajendran *et al*. (1998) conducted a field investigation which carried out during the summer of 1998 to evaluate the efficacy of various growth regulating chemicals such as NAA, CCC, ethrel, mepiquat chloride and methanol on the growth and yield of mungbean. The treatments consisted of foliar application of the following chemicals at the pre-flowering stage of the crop: NAA (50 ppm), CCC (100 ppm), ethrel (100 ppm), mepiquat chloride (125 ppm) and methanol (5.0%) with a control, using a randomised block design. The results of the study revealed that the yield and its various attributes, the methanol treatment performed the best followed by NAA and ethrel.

Anonymous (2003) the seed yield in green gram was significantly higher with NAA (40 ppm) sprayed at twice 25 and 40 DAS and the increase in yield was due to maximum number of seeds plant^{-1}, pod length, number of pods plant^{-1}, pod weight, test weight and harvest index.

Dod *et al.* (1989) reported that the application of 50 ppm or 100 ppm NAA at full bloom stage resulted in significant enhance morphological character *viz.* plant height and number of branches over control.

Reddy *et al.* (1987) reported that crop growth rate significantly increased with the foliar application of 2% DAP + 10 ppm NAA, or individually at flowering and pod formation stages of the pigeonpea crop. The results also indicated that foliar application of 2% DAP + 10 ppm NAA, or individually at flowering and pod formation stages of the crop, pod number and seed yield were significantly increased in pigeonpea.

Sengupta and Sen (1989) revealed that the application of 50 ppm NAA significantly increased the grain yield of green gram by 13.78 per cent and 38.02 per cent over control in respective season. The pods plant^{-1}, grains pod^{-1} and dry matter production also increased significantly.

Setia *et al.* (1993) reported that foliar application of NAA @ 50 and 100 ppm to lentil caused increase in pods plant^{-1} with consequent enhancement in seed yield and harvest index.

Sharma *et al.* (1989) reported that the foliar application of NAA at anthesis and 10 days after anthesis in mung bean increased the number of pods plant^{-1}, seeds pod^{-1}, 1000 seed weight and gave higher seed yield over control.

Shinde *et al.* (1991) reported that the foliar spray of growth regulators NAA with KNO3 can enhanced weight of individual pod and ultimately resulted in elevating the yield by 33 per cent in cowpea.

Upadhyay (2002) noted that the foliar spray of NAA @ 20 ppm affects significantly higher number of buds plant^{-1}, number of flowers plant^{-1}, pod length, circumference of pod, number of seeds pod^{-1}, number of pods plant^{-1}, biological weight and test weight in chickpea.

Vikhe *et al.* (1983) noticed that pigeonpea responded to morphological characteristics significantly to NAA 100 ppm spray at flowering and twice thereafter.

Udensi *et al.* (2013) reported that treating pigeonpea seeds with paclobutrazol caused reduction in plant height and inter-node length, which did not translate to higher yield. Plants raised from pigeonpea seeds soaked in 100 and 150 mg/l paclobutrazol + NAA did excellently well in both yield and yield related traits.

2.2 Effect of GA_3 on growth and yield

Nabi *et al*. (2014) carried out an experiment to study on growth and yield performance of cowpea cv. BARI Falon-1 under different treatment of GA_3 as foliar spray to investigate the responses and most optimum level of gibberellic acid regarding growth and yield that are suitable to cultivate in coastal region of Bangladesh. Among the GA_3 treatments, 33.33 ppm GA_3 produced significantly the tallest plant (61.07 cm), maximum leaves and branches plant^{-1} (28.50 and 19.73, respectively), higher LAI (1.10) and higher TDM plant^{-1} (81.95 g) comparatively than that of other GA_3 levels while control had lower on the above characters. Growth characters such as CGR, RGR and NAR had also higher (0.99 and 1.65 mg cm^{-2} day^{-1} for CGR, 0.43 and 0.72 g g^{-1} day^{-1} for RGR and 0.027 and 1.275 mg cm^{-2} day^{-1} for NAR) in 33.33 ppm GA_3 at the stage between 30 to 60 DAS and 60 to 90 DAS, respectively. Yield contributing characters Among other observation of yield and yield contributing characters, 33.33 ppm GA_3 further registered the maximum pods plant^{-1} (11.50), longest pod (17.05 cm), higher

weight fresh (3.78 g) and dry pod (1.99 g), higher weight of 100–seed (12.25), seed yield (18.57 g plant^{-1} and 2986.72 kg ha^{-1}) and higher HI (22.45%).

Kumar *et al.* (2014) conducted a study to determine the effects of Gibberellic acid on growth, fruit yield and quality of tomato. The experiment consisted of one tomato variety- Golden and six treatments with five levels of gibberellic acid (GA_3- 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm). The highest plant height, Number of leaves, Number of fruits, Fresh fruit weight has been observed and ascorbic acid, total soluble solid (TSS) was estimated for GA_3 50 ppm.

Islam *et al*. (2009) conducted an investigation to find out the effect of GABA (a mixture of Gibberellic acid (GA_3) and abscisic acid (ABA) on growth characters and yield of blackgram (*Vigna mungo* L.). The crop was grown under field conditions and GABA was applied at 0.00, 0.25, 0.50, 1.00 and 2.00 mg L^{-1} as foliar spray at 18 days after sowing (DAS). It was found that the plant growth characters such as leaf area index, dry weight of leaf, shoot and root, and crop growth rate increased appreciably due to application of GABA as recorded at 40, 50, 60 and 70 DAS. Its effect was more prominent at 40 and 70 DAS than 50 and 60 DAS. At 80 DAS, dry matter of different plant parts and seed yield were greatly influenced by the plant growth regulator (PGR). Higher increase in all parameters was corroborated with higher concentration of the PGR up to 1.00 mg L^{-1}. The highest growth of leaf, shoot, root and pod and seed yield were achieved with 1.00 mg L^{-1}, which was followed by 2.00, 0.50 and 0.25 mg L^{-1}. So, GABA at 1.00 mg L^{-1} was noted as the best treatment to increase growth characters and seed yield of blackgram.

Gelmesa *et al.* (2012) conducted an experiment with the objective of determining the effects of different concentrations and combinations of the plant growth regulators (PGRs) 2,4-D and GA_3 spray on fruit setting and earliness of tomato varieties. The experiment consisted three levels of 2,4-D (0, 5 and 10 ppm) and

four levels of GA_3 (0, 10, 15 and 20 ppm). The study indicated that application GA3 extended flowering and maturity time and increased fruit number per cluster, fruit set percentage and marketable fruit.

Choudhury *et al*. (2013) carried out a field experiment to assess the effect of different plant growth regulators on tomato during summer season 2011. Different plant growth regulators (PGR) *viz*. PGR_0 = Control, PGR_1 = 4-CPA (4-chloro phenoxy acetic acid) @ 20 ppm, PGR_2 = GA_3 (Gibberellic Acid) @ 20 ppm and PGR_3 = 4-CPA + GA_3 @ 20 ppm of each were used in the study. The growth and yield contributing characters were significantly differed due to different plant growth regulators. The maximum plant height at 60 DAT (86.01cm), number of flowers cluster per plant (10.60), number of flowers per plant (39.69), number of fruits per plant (36.54), single fruit weight (74.01 g) and yield (28.40 t ha^{-1}) were found in PGR_3 and the minimum were found in control (PGR_0) treatment.

Bhadra (2004) stated that 150 mgL^{-1} of GA_3 significantly increased plant height, number of branches per plant, number of pods per plant, total dry matter, leaf area, relative growth rate, crop growth rate, net assimilation rate, 1000 seeds weight and seed yield.

Singh and Jain (1982) reported that the application of PGRs influenced the accumulation of dry matter in chickpea in general and the allocation pattern in particular. The PGRs increased the allocation of dry matter to the pods thereby indicating their influence in stimulating the plant reproductive potential.

Singh (1986) reported auxin are chemical messenger influencing pattern of plant development processes like cell elongation, cell differentiation, abscission, flower initiation, fruit set, fruit growth and also indicated it may enhance the fruit set by thinning of excessive number of flower.

Chakraborty and Sharma (1992) found that application of 10 ppm and 100 ppm of GA_3 at different stages of vegetative growth in French bean showed increased flower production per plant.

Haque (2002) conducted an experiment with a high yielding variety of wheat (shatabdi) to evaluate the effect of IAA, GABA and TNZ-3003 by soaking seeds in 0.16, 0.33 and 0.66 mlL^{-1} aqueous solution and found that the GABA at 0.33 mlL^{-1} produced the tallest plant and maximum number of leaves at 60 and 90 DAS. GABA at 0.33 mlL^{-1} also produced the highest higher filled grain $spike^{-1}$and highest yield and harvest index followed byTNZ-303 and CL-IAA.

Kene *et al.* (1995) recorded foliar application of IBA (Indole butyric acid), GA_3 and IAA @ 15 ppm significantly increased seed yield of sunflower.

Ngatia *et al.* (2004) reported that the application of GA_3 led to increased yield per plant, pods per plant, 100 - seed mass and harvest index.

Rahman *et al.* (1989) observed that application of GA_3, increased seed weight of grass pea.

Shende and Berore (1985) noticed that significantly maximum LAI, dry matter production, test weight and yield of pea due to application of GA_3 10 ppm at pre-flowering stage.

Swami *et al.* (1983) reported that the GA_3 sprayed at pre-flowering stage on pea @ 40 ppm was found best in increasing plant height and early flowering of the pea crop.

2.3 Effect of Benzylaminopurine (BAP) on growth and yield

Cytokinin helps to stimulate stomatal opening and leads to increase transpiration and thereby to amino acid accumulation in cytokinin treated site (Kuraishi and

Ishikawa, 1977). By cytokinin application, amino acid accumulation stimulates chlorophyll synthesis (Gersani and Kende, 1982). Cytokinin plays important role in development of root at low concentration and root dry matter and therefore facilitates more water extraction (Arora and Gupta, 2003).

Cytokinin enhances osmolites or ion uptake and thereby reduces osmotic potential gradient along the phloem and also increased the root mass and seed yield of sunflower (Kumari and Bharti, 1988). Reduce in osmotic potential by increasing osmolites or ion uptake with cytokinin application was also reported by Kuraishi and Ishikawa (1977) in *Brassica* species.

Islam (2008) stated that in ML 613, all the NAA treatments and combination of 100 ppm BAP & 100 ppm NAA treatments enhanced stem dry matter at 40 DAE, whereas, all the BAP treatments and combination of 100 ppm NAA & 100 ppm BAP enhanced stem dry matter at 55 DAE and 70 DAE. Application of BAP increased the remobilization of photo-assimilates towards grain by increasing sink strength.

Gaspera *et al*. (2016) conducted an investigation to study to study the effect of an exogenous BAP spray on biomass accumulation and yield in pumpkin plants grown in commercial facilities and found that benzyl adenine (BAP) stimulates dry matter accumulation in two possibilities likely: (i) higher photo-assimilate partitioning towards the shoot; or (ii) increased in the photosynthetic efficiency of leaves. Results showed that, the relative growth rate of Butternut squash plants grown under commercial plant density did not change and that yield was the same in both BAP-sprayed and control plants. However, a single BAP application decreased leaf size and total leaf area per plant but increased the rate of leaf appearance. This findings suggest the possibility of an increase in plant populations through changes in crop architecture and an increase in yield on a field area basis.

Payghamzadeha and Kazemitabar (2010) studied with a view to the effects of Benzylaminopurine (BAP) and Indole butyric acid (IBA) hormones and genotypes on *in vitro* germination of immature embryos in walnut (*Juglans regia* L.). Significant differences were observed among different cultivars and different concentration of BAP and IBA. The BAP and IBA induced the shoot, root and callus proliferation and embryo germination, but it was dependent on genotypes and hormones concentrations. The best performing medium for immature embryos germination was supplemented with 1 mg L^{-1} alone and 1.5 mg L^{-1} BAP in conjunction with 0.01, 0.05 and 0.1 mg L^{-1} IBA (germination ratio vary between 49.32% and 67.76%). Percent germination of immature embryos was more when BAP and IBA were simultaneously applied as compared to those when applied separately.

Barclay and Mcdavid (1998) observed that the application of 6- benzyl amino purine (BAP) at 2, 20, and 200 ppm sprayed during early fruit set resulted in longer racemes with larger fruits and leaves than control racemes in pigeonpea. Total seed mass (TSM) was greatest with 20 ppm while at higher concentration it was declined to control level.

2.4 Combined effect of different growth regulators on growth and yield

Awan *et al*. (2015) conducted the present study to evaluate the effect of the plant growth regulators naphthalene acetic acid (NAA) and benzylaminopurine (BAP), on the growth and yield of organic spinach (*Spinacia oleracea* L.). Different combinations and concentrations of NAA and BAP were tested to evaluate different vegetative parameters. Maximum plant height at 40 DAS was recorded for the combined effect of NAA and BAP at a concentration of 1000 µM (each), while BAP alone at 100 µM concentration showed maximum plant height at 60 DAS. Maximum number of leaves was shown by NAA (10 µM) both at 40 and 60 DAS. Increase in leaf length was observed for NAA (10 µM) and BAP (100 µM)

both at 40 and 60 DAS. Significant increases in root length were recorded where maximum root length was in plots treated with BAP (1000 μM) applied 40 DAS while the mixture of BAP (10 μM) and NAA (10000 μM) induced significant increases in root length when applied 60 DAS. Maximum fresh weight of shoot was observed for NAA (1000 μM) and BAP (1000 μM) while maximum shoot dry weight was observed in plots treated with NAA and BAP at a concentration of (1000 μM) each. Similarly, a significant effect of plant growth regulators was observed on root dry weight where highest dry weight was noted in the plants treated with NAA at the rate of 1000 μM.

An experiment was carried out by Haque (2005) at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during March to July, 2005 to investigate the effect of GA_3 and NAA on morphological, growth and yield contributing characters of sesame (Binatil-l). Different concentrations of GA_3 and NAA viz., 0, 20, 40, 60, 80 ppm were applied as foliar spray at 25 DAS. In most of the cases, growth and yield were increased along with increased in concentration of GA_3 and NAA were noticed. The results of the experiment revealed that GA_3 and NAA at 80 ppm as foliar spray had positive regulatory effect on morphological growth, yield and yield contributing attributes of sesame.

Deotale *et al.* (1998) observed that significant increase in morpho-physiological parameters of soybean due to seed soaking treatment of GA_3 and NAA recorded. Highest value for plant height, number of leaves, number of branches, leaf area and dry matter were obtained, with GA_3 and NAA treatment @ 10 ppm and 100 ppm, respectively.

Singh *et al.* (1999) found that the highest values for standard germination, tetrazolium test, speed of germination, field emergence index and seedling establishment, vigour, germination percentage and field establishment after BAP

treatment were not significantly different to GA_3 treatment, while distilled water gave lower values for all parameters than all growth regulator treatments. BAP gave the highest dehydrogenase activity and respiration rate, and distilled water the lowest values.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out in the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh from March to June 2017 to study the effect of NAA, GA_3 and BAP (cytokinin) on growth and yield of mungbean**.** The materials and methods for the experiment were presented in this chapter under the following headings:

3.1 Location of the experimental site

The experiment was conducted in the Sher-e-Bangla Agricultural University Farm**,** Sher-e-Bangla Nagar, Dhaka-1207. The site location is 90°33´ E longitude and 23°77´ N latitude having an elevation of 8.2 m from sea level. The location of the site is shown in Appendix I.

3.2 Experimental period

The experiments were conducted in the kharif-I season started from March 2017 to June 2017.

3.3 Soil

The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28 (FAO, 1988). Top soil was silty clay in texture, soil pH was 5.6 with organic carbon 0.45%. The plot was situated in medium high land with available irrigation and drainage system. The plot was flat. The descriptions were presented in Appendix II.

3.4 Climate

The location of experimental plot was under subtropical climate, differentiated by 3 distinct seasons, Rabi, Kharif-I and Kharif-II. The experiment was conducted in Kharif-I (March-June). Temperature, relative humidity, rainfall and sunshine hour

data were collected from Weather Station of Bangladesh, Sher-e-Bangla Nagar, showed in Appendix III.

3.5 Crop

Mungbean [*Vigna radiata* (L.) Wilczek] is an important pulse crop of the world because it produces high quality and quantity protein. It is also known as green gram, golden gram, mung, mug. It belongs to the family Leguminosae (Fabaceae), sub-family Papilionoinaceae. It is originated from India, Mayanmar, Thailand of South and Southeast Asia. Mungbean contains carbohydrate 51%, protein 26%, moisture 10%, mineral 4% and vitamin 3%. Grain is characterizedby good flavor, digestibility, high protein content and absence of any flatulence effects. Mungbean seed is more palatable, nutritive, digestible and non-flatulent than other pulses.The agro-ecological condition of Bangladesh is suitable for cultivating this crop.It can be grown in both late winter and summer season in Bangladesh and gives higher yield under summer cultivation than late winter season.

3.6 Seed collection

The mungbean variety used in the experiment was "BARI mung-6". This is a highyielding variety introduced by BARI (Bangladesh Agricultural Rice Research Institute). Seeds were collected from pulse research center of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.7 Fertilizers

The following doses of fertilizers were used

Fertilizer	Dose ha^{-1}
Urea	50 kg
TSP	85 kg
MOP	35 kg

3.8 Treatments of experiment

The treatments comprised of seven treatments as follows:

1. T_1 = Control
2. T_2 = NAA (Naphthalene Acetic Acid) 100 ppm
3. T_3 = GA_3 (Gibberellic Acid) 150 ppm
4. T_4 = BAP (Benzylaminopurine) 100 ppm
5. T_5 = GA_3 150 ppm and BAP 100 ppm
6. T_6 = GA_3 150 ppm and NAA 100 ppm
7. T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm

3.9 Preparation of NAA 100ppm, GA_3 150ppm, BAP 100ppm and Control solution

100 ppm of NAA was prepared by dissolving 100 mg NAA of it with distilled water. Then distilled water was added to make the volume 1 liter 100 ppm solution.150 ppm of GA_3 was prepared by dissolving 150 mg GA_3 of it with distilled water. Then distilled water was added to make the volume 1 liter 150 ppm solution.100 ppm of BAP was prepared by dissolving 100 mg BAP of it with distilled water. Then distilled water was added to make the volume 1 liter 100 ppm solution.

An adhesive, Tween-20 @ 0.1% was added to each solution. Control plots were treated with distilled water along with Tween-20. Treatments were sprayed at 25 and 45 DAS at afternoon according to Bhadra (2004), Asaduzzaman (2013), Foysalkabir *et al*. (2016).

3.10 Design of the experiment

The experiment was carried out in randomized complete block design (RCBD) with four replications.

3.11 Land preparation

A piece of medium high land with well drainage system was selected. The experimental field was first ploughed on 20 March 2017. To obtain desirable tilth the land was ploughed thoroughly with a power tiller and then laddering wasdone. The clods of the land were hammered tomake the clods into small pieces. Weeds, stubbles and crop residues were cleaned from the land.

3.12 Layout

The field layout was done as per experimental design on 27March, 2017. The field was divided into four replications each having seven treatments. The unit plot size was 1 m × 4 m and plot to plot distance was 0.6 m.

3.13 Sowing of seeds

Selected healthy and disease free seeds were sowed in the experimental field. After sowing of seeds, it was watered by watering cane.

3.14 Intercultural operations

3.14.1 Thinning and weeding

Thinning and hand weeding were done after 10 and 20 days after emergence (DAE) respectively. 2^{nd} and 3^{rd} weeding were done at 35 and 50 DAS, respectively.

3.14.2 Irrigation and drainage

Due to sufficient amount of moisture available in soil by irregular rainfall in this season there was less scarcity of irrigation. Irrigation was given to the plot after weeding and thinning and care was taken to avoid water logging. Well drainage system between plot to plot distances was made to remove excess water from the experiment plot to avoid water logging condition.

3.14.3 Gap filling

For the entire plots first gap filling was done at 10 days after sowing (DAS) by planting same aged and same sources seedlings.

3.14.4 Plant protection

The young plants were attacked byfew hairy caterpillar and virus vectors (jassid) at early stage of growth and pod borer attacked the plantat later stage of growth. Hairy caterpillar and pod borer were effectively controlled by the foliar application of Diazinon 50 EC and Ripcord @ 1 L ha^{-1} on the time of 50% pod formation stage.

3.15 Harvesting, threshing and cleaning

The crop was harvested at full maturity stage and harvesting was done manually from each plot. The harvested crop of each plot was collected separately, properly tagged and brought to threshing floor. Proper care was taken for harvesting, threshing and also cleaning of mungbean seed. Fresh weight of grain and stover were measured for each plot. The grains were cleaned and finally the weight was adjusted to at 12% moisture content. The stover was sun dried and the yields of grain and stover $plot^{-1}$ were measured and converted to t ha^{-1} and recorded.

3.16 Data collection

3.16.1 Growth and morpho-physiological characters

1. Plant height
2. Leaves $plant^{-1}$
3. Branches $plant^{-1}$
4. Leaf area index
5. Dry weight $plant^{-1}$
6. Crop growth rate
7. Chlorophyll content

3.16.2 Yield contributing characters

1. Pods plant^{-1}
2. Seeds pod^{-1}
3. Pod length
4. 1000 seeds weight
5. Seed yield plant^{-1}

3.16.3 Yield attributes

1. Seed yield
2. Stover yield
3. Biological yield
4. Harvest index (%)

3.17 Procedure of recording data

Randomly 5 plants were selected to measure morphological and physiological parameters and randomly 10 plants were selected to measure yield contributing attributes of mungbean from each plot. The procedures of recording data were as follows:

3.17.1 Growth and morpho-physiological characters

3.17.1.1 Plant height

Plant height was measured and recorded in centimeter at the time of 20, 40 DAS and at harvest. Data were taken as average of 5 plants at random selection from inner rows of each plot. The measurement of the height was done from the ground level to the tip of the leaves.

3.17.1.2 Leaves plant^{-1}

Number of leaves plant^{-1} was counted at the time of 20, 40 DAS and at harvest and measured as counting of all leaves of 5 plants at random selection from inner rows

of each plot and mean was calculated.

3.17.1.3 Branches plant^{-1}

Number of branches plant^{-1} was counted at an interval of 20 days starting from 20 DAS till to at harvest (60 DAS). Number of branches was measured by randomly selected 5 plants from inner rows of each plot and mean was calculated.

3.17.1.4 Leaf area index

At first leaf area was measured with Portable Area Meter Model LI-3000, USA and then leaf area index (LAI) was worked out by using the following formula -

$$LAI = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

3.17.1.5 Dry weight plant^{-1}

Randomly selected ten plants were taken and sun dried. After sun drying of freshplants, it was kept in oven for 72 hours at 80^{o}C for each treatment then dry weightwas taken by balance. Mean dry weight was calculated and expressed in gram.

3.17.1.6 Crop growth rate

CGR was computed using the following formula (Hunt, 1978),

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{P} \text{ mg cm}^{-2} \text{ day}^{-1}$$

Where,

W_1 = total dry weight of the plant at time t_1
W_2 = total dry weight of the plant at time t_2
P = Ground area
t_2 and t_1 = time interval in days

3.17.1.7 Chlorophyll content

Chlorophyll content was estimated from the fully expanded uppermost leaf samples using the method described by Witham *et al.* (1986).

Procedure

The fresh leaf sample of 20 mg were taken in small vials containing 20 ml of 80% acetone and covered with aluminum foil and preserved in dark for 72 hours. Then reading was taken at 663 nm and 645 nm wavelengths by a visible spectrophotometer and the result was expressed as mg g^{-1} fresh weight. The formula for computing chlorophyll a, b and total chlorophyll were-

Chlorophyll a (mg g^{-1} fresh weight)= $[12.7(D_{663})-2.69(D_{645})]\times [V/1000\times W]$

Chlorophyll b (mg g^{-1} fresh weight) = $[22.9(D_{663}) - 4.68(D_{645})]\times [V/1000\times W]$

Total Chlorophyll (mg g^{-1} fresh weight) = $[20.2(D_{663}) + 8.02(D_{645})]\times[V/1000\times W]$

Where,

D (663, 645) = Optical density of the chlorophyll extract at wave length of 663 and 645 nm respectively.

V = Final volume (ml) of the 80% acetone with chlorophyll extract.

W = Weight of fresh leaf sample in gram.

1mg g^{-1} = 1000 μg g^{-1}

3.17.2 Yield contributing characters

3.17.2.1 Pods plant^{-1}

Number of pods plant^{-1} was counted from randomly selected 10 plants of each plot and then average number of pods per plant was calculated.

3.17.2.2 Seeds pod^{-1}

Number of seeds pod^{-1} was counted by randomly selected 10 competitive plants and mean was calculated.

3.17.2.3 Pod length

Pod length measured in centimeter by randomly selected 10 pods plant^{-1} and then the average was calculated.

3.17.2.4 1000 seeds weight

One thousand clean sun dried seeds were counted from seed stock obtained from the sample plants and weighted by electronic balance.

3.17.2.5 Seed yield plant^{-1}

Total weight of seeds from 10 plants was counted by randomly selected and mean weight was calculated.

3.17.3 Yield attributes

3.17.3.1 Grain yield ha^{-1}

The plants of the central 1.0 m^2 from the plot were harvested for taking grain yield. The grains were threshed from the plants, cleaned, dried and then weighed. The yield of grain in kg plot^{-1} was adjusted at 12% moisture content of grain and then it was converted to t ha^{-1}.

3.17.3.2 Stover yield ha^{-1}

The stover of the harvested crop in each plot was sun dried to get a constant weight. Then the stover was weighted and thus the stover yield plot^{-1} was measured. The yield of stover in kg plot^{-1} was converted to t ha^{-1} and recorded.

3.17.3.3 Biological yieldha^{-1}

Biological yield was measured from grain yield and stover yield. The biological yield was determined with the following formula:

Biological yield = Grain yield + Stover yield.

3.17.3.4 Harvest index (%)

Harvest index was measured from the ratio of grain yield to biological yield and expressed in percentage. It was determined with the following formula.

$$HI\ (\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.18 Data analysis

The data obtained for different parameters were statistically analyzed to observe significant difference among the treatment by using computer based software like MSTAT-C. The mean values of all parameters were calculated and analysis of variance was performed. Gomez and Gomez (1984) observed that the significance of the difference among the treatments means was measured by the latest significant different test at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to investigate the effect of NAA, GA_3 and BAP (cytokinin) on growth and yield of mungbean [*Vigna radiata* (L.) Wilczek]. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices. The analyses of variance of data in respect of all the parameters have been shown in Appendix V-XIII. The results have been presented and discussed and possible interpretation has been given under different sub-headings.

4.1 Growth characters

4.1.1 Plant height

Plant height was significantly varied at different growth stages due to different growth regulators (NAA, GA_3 and BAP) (Figure 1 and Appendix V). Results indicated that the highest plant height (19.28, 56.58 and 69.28 cm at 20, 40 DAS and at harvest, respectively) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was statistically similar with T_3 (GA_3 150 ppm) at 40 DAS.The lowest plant height (15.91, 54.75 and 61.98 cm 20, 40 DAS and at harvest, respectively) was obtained from the treatment, T_1 (Control) which was significantly different from all other treatments statistically similar to T_4 (BAP 100 ppm), T_5 (GA_3 150 ppm and BAP 100 ppm) and T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm). Similar results on plant height were also observed by Awan *et al*. (2015), Deotale *et al.* (1998), Chakma (2005) and Kumar *et al*. (2014).

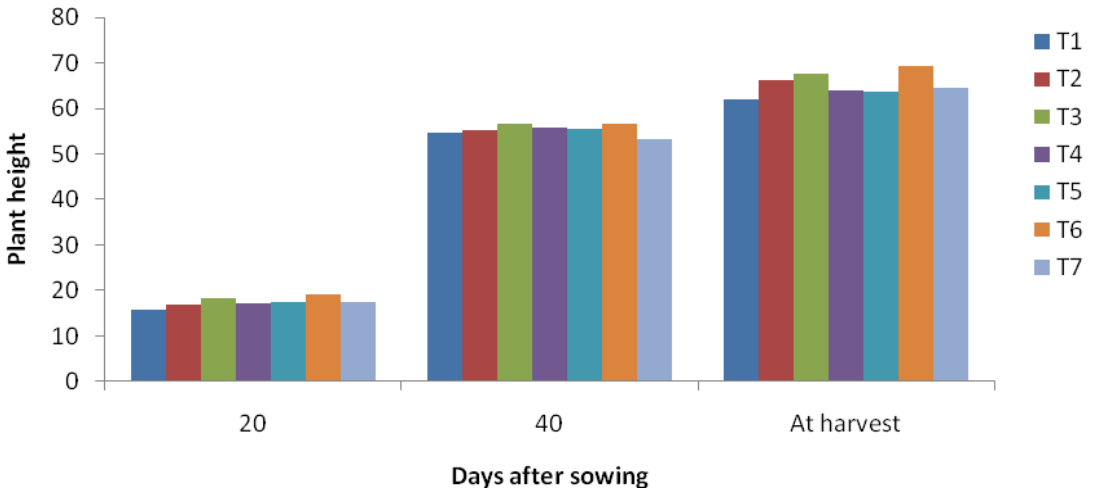

Figure 1. Effect of NAA, GA_3 and BAP (CK) on plant height of mungbean at different growth stages

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.1.2 Leaves plant^{-1}

Significant influence was recorded on number of leaves plant^{-1} at different growth stages affected by different growth regulators (NAA, GA_3 and BAP) except 20 DAS (Figure 2 and Appendix VI). Under the present study, the highest number of leaves plant^{-1} (8.70, 17.25 and 23.25 at 20, 40 DAS and at harvest, respectively) was obtained from the treatment, T_5 (GA_3 150 ppm and BAP 100 ppm) which was significantly different from all other treatments but closed to the treatment of T_3 (GA_3 150 ppm) and T_4 (BAP 100 ppm).The lowest number of leaves plant^{-1} (7.95, 13.50 and 16.00 at 20, 40 DAS and at harvest respectively) was obtained from the treatment, T_1 (Control) which was also significantly different from all other treatments but nearest to the treatment T_6 (GA_3 150 ppm and NAA 100 ppm). Similar findings were also observed by Awan *et al*. (2015), Deotale *et al.* (1998), Chakma (2005), Shohag *et al*. (2008), Nabi *et al*. (2014), Kumar *et al.* (2014) and Gaspera *et al*. (2016).

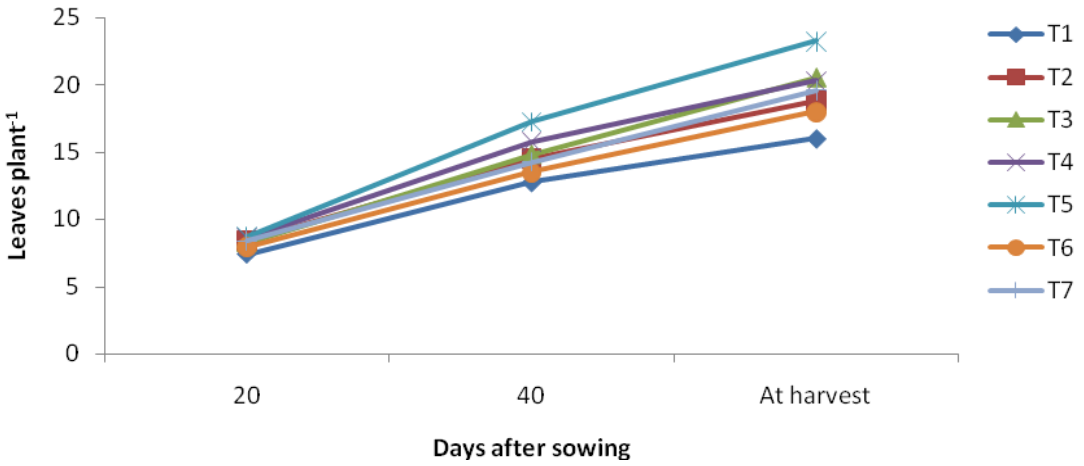

Figure 2. Effect of NAA, GA_3 and BAP (CK) on number of leaves plant^{-1} of mungbean at different growth stages

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.1.3 Branches plant^{-1}

Significant variation was found on number of branches plant^{-1} at different assessment stages affected by different growth regulators (NAA, GA_3 and BAP) (Table 1 and Appendix VII). Results revealed that the highest number of branches plant^{-1} (1.66 and 3.10 at 40 DAS and at harvest, respectively) was obtained from the treatment, T_5 (GA_3 150 ppm and BAP 100 ppm) which was statistically identical with T_6 (GA_3 150 ppm and NAA 100 ppm) and significantly similar with T_4 (BAP 100 ppm) and T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) at 40 DAS. But at the time of harvest, treatment T_5 (GA_3 150 ppm and BAP 100 ppm) was significantly different from all other treatments followed by T_6 (GA_3 150 ppm and NAA 100 ppm) and T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm).The lowest number of branches plant^{-1} (1.32 and 2.23 at 40 DAS and at harvest, respectively) was obtained from the treatment, T_1 (Control) which was significantly similar with T_2 (NAA 100 ppm) followed by T_3 (GA_3 150 ppm). The

results obtained from the present study were similar with the findings of Deotale *et al.* (1998), Samsuzzaman (2004), Foysalkabir *et al*. (2016) and Nabi *et al*. (2014).

Table 1. Effect of NAA, GA_3 and CK (BAP) on number of branches plant^{-1} of mungbean at different growth stages

Treatments	Number of branches plant^{-1}	
	40 DAS	At harvest
T_1	1.32 c	2.23 e
T_2	1.43 bc	2.35 de
T_3	1.38 c	2.48 cd
T_4	1.56 ab	2.60 c
T_5	1.66 a	3.10 a
T_6	1.63 a	2.90 b
T_7	1.60 ab	2.78 b
$LSD_{0.05}$	0.162	0.163
CV (%)	3.871	6.224

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.1.4 Leaf area index

Leaf area index was significant influenced at different growth stages by different growth regulators (NAA, GA_3 and BAP) (Figure 3 and Appendix VIII). It was observed that the highest leaf area index (1.73, 3.99 and 5.67 at 20, 40 DAS and at harvest, respectively) was obtained from the treatment, T_5 (GA_3 150 ppm and BAP 100 ppm) which was statistically identical with T_6 (GA_3 150 ppm and NAA 100 ppm) at the time of harvest. The lowest leaf area index (1.07, 2.6 and 3.95 at 20, 40 DAS and at harvest respectively) was achieved from the treatment, T_1 (Control) followed by T_2 (NAA 100 ppm). The results obtained from the findings of Awan *et al*. (2015), Deotale *et al.* (1998), Gaspera *et al*. (2016), Islam *et al*. (2009) and Mondol (2003) were similar to the present study.

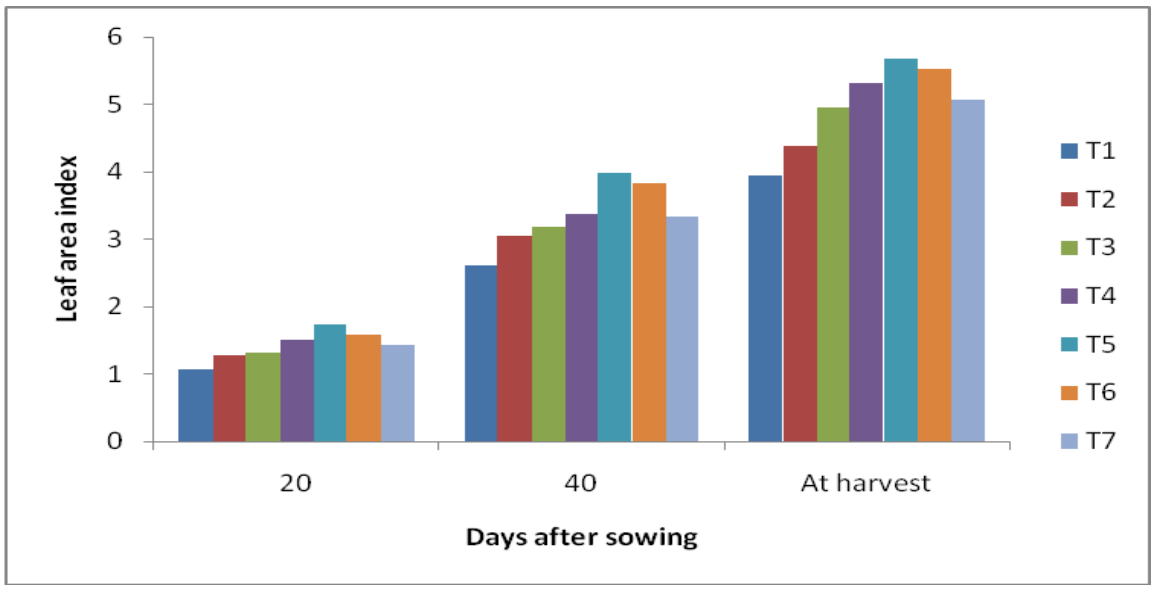

Figure 3. Effect of NAA, GA_3 and BAP (CK) on leaf area index of mungbean at different growth stages

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.1.5 Dry weight plant^{-1}

Remarkable variation was identified in terms of dry weight plant^{-1} at different growth stages influenced by different growth regulators (NAA, GA_3 and BAP) (Table 2 and Appendix IX). It was noted that the highest dry weight plant^{-1} (8.42, 18.15 and 26.13 g at 20, 40 DAS and at harvest, respectively) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments followed by T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) and T_5 (GA_3 150 ppm and BAP 100 ppm) at the time of harvest. The lowest dry weight plant^{-1} (5.34, 11.78 and 17.48 g at 20, 40 DAS and at harvest respectively) was obtained from the treatment, T_1 (Control) which was also significantly different from all other treatments followed by T_2 (NAA 100 ppm) and T_4 (BAP 100 ppm). Deotale *et al.* (1998), Awan *et al.* (2015), Samsuzzaman (2004), Foysalkabir *et al.* (2016), Islam *et al.* (2009) and Arora and Gupta (2003) also found similar results to the present study.

Table 2. Effect of NAA, GA_3 and BAP (CK) on dry weight plant^{-1} of mungbean at different growth stages

Treatments	Dry weight plant^{-1} (g)		
	20 DAS	40 DAS	At harvest
T_1	5.34 e	11.78 f	17.48 e
T_2	5.77 d	13.75 e	20.16 d
T_3	7.22 c	15.37 cd	22.04 c
T_4	6.13 d	14.48 de	20.90 d
T_5	7.58 bc	15.62 c	23.64 b
T_6	8.42 a	18.15 a	26.13 a
T_7	7.84 b	17.06 b	24.16 b
$LSD_{0.05}$	0.375	0.994	1.046
CV (%)	6.397	7.554	10.418

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.2 Physiological characters

4.2.1 Crop growth rate

Crop growth rate was significant influenced at different growth stages by different growth regulators (NAA, GA_3 and BAP) (Table 3 and Appendix X). Results signified that the highest crop growth rate (6.49 and 11.57 mg cm^{-2} day^{-1} at 20 - 40 DAS and 40 DAS - At harvest, respectively) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments) at all growth stages followed by T_7 (GA_3 150 ppm and NAA 100 ppm and BAP 100 ppm) and T_5 (GA_3 150 ppm and BAP 100 ppm). The lowest crop growth rate (4.29 and 6.49 mg cm^{-2} day^{-1} at 20 - 40 DAS and 40 DAS - At harvest respectively) was obtained from the treatment, T_1 (Control) which was also significantly different from all other treatments followed by T_2 (NAA 100 ppm). The results obtained from the present study were similar to the findings of Awan *et al*. (2015), Reddy *et al.* (1987), Islam *et al*. (2009) and Gaspera *et al*. (2016).

Table 3. Effect of NAA, GA_3 and BAP (CK) on crop growth rate plant^{-1} of mungbean at different growth stages

Treatments	Crop growth rate (mg cm^{-2} day^{-1})	
	20 - 40 DAS	40 DAS - At harvest
T_1	4.29 d	6.49 e
T_2	5.32 c	7.07 d
T_3	5.43 c	8.45 c
T_4	5.57 c	8.20 c
T_5	5.36 c	9.41 b
T_6	6.49 a	11.57 a
T_7	6.15 b	9.88 b
$LSD_{0.05}$	0.281	0.497
CV (%)	4.771	6.385

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.2.2 Chlorophyll content

Significant variation was observed on chlorophyll content of mungbean leaf at different growth stages (Table 4 and Appendix XI). It was found that at 30 DAS the highest total chlorophyll content (1.46 µg g^{-1}) was obtained from T_3 (GA_3 150 ppm) treatment which was statistically identical with T_6 (GA_3 150 ppm and NAA 100 ppm) treatment. Here, it can be noted that total chlorophyll content is a sum of total of 'chlorophyll a' and 'chlorophyll b'. At 30 DAS, the highest 'chlorophyll a' content (0.84 µg g^{-1}) was achieved from T_6 (GA_3 150 ppm and NAA 100 ppm) treatment but highest 'chlorophyll b' content (0.67 µg g^{-1}) was achieved from T_3 (GA_3 150 ppm) treatment. At 50 DAS, the highest 'chlorophyll a' and 'chlorophyll b' content (0.46 and 0.59 µg g^{-1} respectively) were achieved from T_6 (GA_3 150 ppm and NAA 100 ppm) treatment which was statistically similar to T_3 (GA_3 150 ppm), T_5 (GA_3 150 ppm and BAP 100 ppm) and T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) treatments. The lowest chlorophyll content was found

from T_1 (Control) treatment at all growth stages (Table 4) which was significantly different from all other treatments. At 30 DAS, T_1 (Control) treatment gave lowest chlorophyll a' (0.40 μg g^{-1}), 'chlorophyll b' (0.31 μg g^{-1}) and total chlorophyll content (0.72 μg g^{-1}). At 50 DAS, T_1 (Control) treatment also gave lowest chlorophyll a', 'chlorophyll b' and total chlorophyll content (0.28, 0.49 and 0.77 μg g^{-1} respectively). Similar result was also found by Gersani and Kende, (1982).

Table 4. Effect of NAA, GA_3 and BAP (CK) on chlorophyll content of mungbean

Treatments	Chlorophyll (Chl) content (μg g^{-1})					
	30 DAS			50 DAS		
	Chl-a	Chl-b	Total	Chl-a	Chl-b	Total
T_1	0.40 f	0.31 d	0.72 e	0.28 e	0.49 c	0.77 e
T_2	0.60 d	0.38 c	0.99 d	0.33 d	0.54 b	0.87 cd
T_3	0.78 b	0.67 a	1.46 a	0.37 c	0.56 ab	0.93 b
T_4	0.77 b	0.58 b	1.36 b	0.42 b	0.41 d	0.84 d
T_5	0.56 e	0.39 c	0.95 d	0.34 d	0.57 ab	0.92 bc
T_6	0.84 a	0.59 b	1.43 a	0.46 a	0.59 a	1.05 a
T_7	0.72 c	0.56 b	1.29 c	0.32 d	0.55 ab	0.88 cd
$LSD_{0.05}$	0.029	0.042	0.051	0.029	0.042	0.051
CV (%)	2.317	1.654	3.228	2.118	2.637	3.357

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.3 Yield contributing characters

4.3.1 Pods plant^{-1}

Number of pods plant^{-1} was significantly varied due to different growth regulators (NAA, GA_3 and BAP) (Table 5 and Appendix XII). Results signified that the highest number of pods plant^{-1} (23.28) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was statistically identical with T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) followed by T_5 (GA_3 150 ppm and

BAP 100 ppm) and T_3 (GA_3 150 ppm). The lowest number of pods plant^{-1} (15.32) was obtained from the treatment, T_1 (Control) which was significantly similar to T_2 (NAA 100 ppm) followed by T_4 (BAP 100 ppm). Chakma (2005), Samsuzzaman (2004), Nabi *et al*. (2014) and Ngatia *et al.* (2004) also found similar results to the present study.

4.3.2 Seeds pod^{-1}

Significant influence was recorded on number of seeds pod^{-1} affected by different growth regulators (NAA, GA_3 and BAP) except 20 DAS (Table 5 and Appendix XII). It was noted that the highest number of seeds pod^{-1} (12.62) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was statistically identical with T_7 (GA_3 150 ppmand NAA 100 ppm and BAP 100 ppm) followed by T_5 (GA_3 150 ppm and BAP 100 ppm) treatment and T_3 (GA_3 150 ppm) treatments. The lowest number of seeds pod^{-1} (10.40) was obtained from the treatment, T_1 (Control) treatment which was statistically identical with T_2 (NAA 100 ppm) treatment. Samsuzzaman (2004), Nabi *et al*. (2014) and Ngatia *et al.* (2004) also found similar results to the present study.

4.3.3 Pod length

Signification variation was identified in terms pod length of mungbean influenced by different growth regulators (NAA, GA_3 and BAP) (Table 5 and Appendix XII). Results revealed that the highest pod length (8.60 cm) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments. But the treatment T_5 (GA_3 150 ppm and BAP 100 ppm) and T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) also gave higher pod length which was significantly same with each other but significantly different from T_6 (GA_3 150 ppm and NAA 100 ppm). The lowest pod length (7.33 cm) was obtained from the treatment, T_1 (Control) which was statistically identical with T_2 (NAA 100 ppm) and significantly similar to T_4 (BAP 100 ppm). This result on pod

length achieved from the present study was similar with the findings of Asaduzzaman (2013), Chakma (2005) and Upadhyay (2002).

4.3.4 1000 seed weight

Variation on 1000 seeds weight among the different treatments under different growth regulators (NAA, GA_3 and BAP) was significant (Table 5 and Appendix XII). Results showed that the highest 1000 seeds weight (46.88 g) was obtained from the treatment, T_5 (GA_3 150 ppm and BAP 100 ppm) treatment which was significantly different from all other treatments. Treatment T_6 (GA_3 150 ppm and NAA 100 ppm) and T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) showed comparatively higher 1000 seeds weight which was significantly same with each other but significantly different from T_5 (GA_3 150 ppm and BAP 100 ppm). The lowest 1000 seed weight (43.67 g) was obtained from the treatment T_1 (Control) which was also significantly different from all other treatments but close to the treatment of T_2 (NAA 100 ppm). Similar results were also observed by Samsuzzaman (2004), Ahmed (2006) and Foysalkabir *et al*. (2016).

4.3.5 Seed yield plant^{-1}

Signification variation was found in case of seed yield plant^{-1} of mungbean influenced by different growth regulators (NAA, GA_3 and BAP) (Table 5 and Appendix XII). Results indicated that the highest seed yield plant^{-1} (4.37 g) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was statistically identical with T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) followed by T_5 (GA_3 150 ppm and BAP 100 ppm) and T_3 (GA_3 150 ppm).The lowest seed yield plant^{-1} (3.30 g) was obtained from the treatment, T_1 (Control) which was nearest to the treatment of T_2 (NAA 100 ppm) but

significantly different. Awan *et al*. (2015) and Ngatia *et al.* (2004) also found similar results on seed yield plant^{-1} which supported the present study.

Table 5. Effect of NAA, GA_3 and BAP (CK) on yield contributing characters of mungbean

Treatments	Yield contributing characters				
	Pods plant^{-1}	Seeds pod^{-1}	Pod length (cm)	1000 seeds weight (g)	Seed yield plant^{-1} (g)
T_1	15.32 d	10.40 d	7.33 d	43.67 e	3.30 e
T_2	16.70 cd	10.75 d	7.48 d	44.20 d	3.60 d
T_3	19.75 b	11.66 bc	7.85 bc	44.92 c	3.83 bc
T_4	17.88 c	11.28 c	7.60 cd	44.58 cd	3.76 cd
T_5	20.48 b	11.90 b	8.04 b	46.88 a	4.01 b
T_6	23.28 a	12.62 a	8.60 a	45.76 b	4.37 a
T_7	22.44 a	12.40 a	8.18 b	46.24 b	4.21 a
$LSD_{0.05}$	1.763	0.398	0.352	0.497	0.187
CV (%)	9.718	6.714	5.286	8.449	4.337

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

4.4 Yield Attributes

4.4.1 Seed yield ha^{-1}

Signification variation was remarked in terms of seed yield ha^{-1} of mungbean influenced by different growth regulators (NAA, GA_3 and BAP) (Table 6 and Appendix XIII). Results revealed that the highest seed yield ha^{-1} (1.31 t ha^{-1}) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments where 2nd and 3rd highest seed yield was achieved from the treatment T_7 (GA_3 150 ppm and BAP 100 ppm and NAA

100 ppm) (1.26 t ha^{-1}) and T_5 (GA_3 150 ppm and BAP 100 ppm) (1.20 t ha^{-1}) respectively which was also significantly different from all other treatments. The lowest seed yield ha^{-1} (0.99 t ha^{-1}) was obtained from the treatment, T_1 (Control) which was significantly varied from other treatments. Treatment T_2 (NAA 100 ppm) also showed lower seed yield ha^{-1} (1.08 t ha^{-1}) but significantly different from T_1 (Control). The highest result on seed yield ha^{-1} was found from the treatment of T_6 (GA_3 150 ppm and NAA 100 ppm) and this achievement might be due to cause of higher yield contributing characters like pods $plant^{-1}$, seeds $pod^{-1,}$ pod length and seed yield $plant^{-1}$ were also found from the same treatment. Similar results were also observed by Haque (2005), Samsuzzaman (2004), Foysalkabir *et al*. (2016), Shahrior (2007), Nabi *et al*. (2014), Kumar *et al.* (2014), Kumari and Bharti (1988) and Gaspera *et al*. (2016).

4.4.2 Stover yield

Stover yield ha^{-1} was significant influenced by different growth regulators (NAA, GA_3 and BAP) (Table 6 and Appendix XIII). It was identified that the highest stover yield ha^{-1} (1.65 t ha^{-1}) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments followed by T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm) and T_5 (GA_3 150 ppm and BAP 100 ppm). Treatment T_3 (GA_3 150 ppm) and T_4 (BAP 100 ppm) showed non-significant results between each other but significantly different from all other treatments. The lowest stover yield ha^{-1} (1.44 t ha^{-1}) was obtained from the treatment, T_1 (Control) which was significantly different from all other treatments but close to the treatment T_2 (NAA 100 ppm). Awan *et al*. (2015), Nabi *et al*. (2014) and Chakma (2005) also found similar results which supported the present study.

4.4.3 Biological yield

Signification variation was remarked in terms of biological yield ha^{-1} of mungbean influenced by different growth regulators (NAA, GA_3 and BAP) (Table 6 and

Appendix XIII). Results revealed that the highest biological yield ha^{-1} (2.96 t ha^{-1}) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments followed by T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm). Treatment T_5 (GA_3 150 ppm and BAP 100 ppm) also showed comparatively higher biological yield but significantly different from T_6 (GA_3 150 ppm and NAA 100 ppm). The lowest biological yield ha^{-1} (2.43 t ha^{-1}) was obtained from the treatment, T_1 (Control) followed by T_2 (NAA 100 ppm) treatment but significantly different from other treatments. The results obtained from this study was similar with the findings of Chakma (2005) and Nabi *et al*. (2014).

4.4.4 Harvest index

Signification variation was observed in terms of harvest index of mungbean influenced by different growth regulators (NAA, GA_3 and BAP) (Table 6 and Appendix XIII). Results showed that the highest harvest index (44.20%) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly similar to T_5 (GA_3 150 ppm and BAP 100 ppm) followed by T_7 (GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm). Treatment T_3 (GA_3 150 ppm) and T_4 (BAP 100 ppm) showed non-significant difference to each other but significantly different from T_6 (GA_3 150 ppm and NAA 100 ppm). The lowest harvest index (40.71%) was obtained from the treatment, T_1 (Control) which was significantly similar to T_2 (NAA 100 ppm). Similar results were also observed from the findings of Awan *et al*. (2015), Chakma (2005) and Nabi *et al*. (2014).

Table 6. Effect of NAA, GA_3 and BAP (CK) on yield attributes of mungbean

Treatments	Yield attributes			
	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
T_1	0.99 g	1.44 f	2.43 g	40.71 d
T_2	1.08 f	1.51 e	2.59 f	41.70 cd
T_3	1.14 d	1.54 d	2.68 d	42.73 bc
T_4	1.12 e	1.53 d	2.65 e	42.42 bc
T_5	1.20 c	1.58 c	2.78 c	43.21 ab
T_6	1.31 a	1.65 a	2.96 a	44.20 a
T_7	1.26 b	1.64 b	2.90 b	43.11 b
$LSD_{0.05}$	8.536	9.492	10.94	1.012
CV (%)	12.876	10.814	11.862	8.714

T_1 = Control, T_2 = NAA (Naphthalene Acetic Acid) 100 ppm, T_3 = GA_3 (Gibberellic Acid) 150 ppm, T_4 = BAP (Benzylaminopurine) 100 ppm, T_5 = GA_3 150 ppm and BAP 100 ppm, T_6 = GA_3 150 ppm and NAA 100 ppm & T_7 = GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out in Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh from March to June 2017 to increase the yield of mungbean by studying the effect of NAA, GA_3 and BAP on growth and yield of mungbean. BARI mungbean-6 variety was used for the present study. The experiment consisted of 7 treatments *viz*. T_1: Control, T_2: NAA (Naphthalene Acetic Acid) 100 ppm,T_3: GA_3 150 ppm, T_4: BAP (Benzylaminopurine) 100 ppm, T_5: GA_3 150 ppm and BAP 100 ppm, T_6: GA_3 150 ppm and NAA 100 ppm and T_7: GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm. The experiment was laid out at randomized complete block design (RCBD) with four replications.

Data were recorded on different growth, morpho-physiological characters, yield contributing characters and yield attributes. The studied parameters were plant height (cm),number of leaves plant^{-1}, number of branches plant^{-1}, leaf area index, dry weight plant^{-1} (g), crop growth rate (mg cm^{-2} day^{-1}), chlorophyll content (µg g^{-1}), number of pods plant^{-1}, number of seeds pod^{-1}, pod length (cm), 1000 seeds weight (g), seed yield plant^{-1} (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). Results revealed that all the studied parameters were significantly influenced by different growth regulators.

In terms of growth parameters, results signified that the highest plant height (19.28, 56.58 and 69.28 cm at 20, 40 DAS and at harvest, respectively) and highest dry weight plant^{-1} (8.42, 18.15 and 26.13 g at 20, 40 DAS and at harvest, respectively) were obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) where the highest number of leaves plant^{-1} (8.70, 17.25 and 23.25 at 20, 40 DAS and at harvest, respectively), highest number of branches plant^{-1} (1.66 and 3.10 at 40 DAS and at harvest, respectively) and highest leaf area index (1.73, 3.99 and 5.67 at 20, 40 DAS and at harvest, respectively) were obtained from the

treatment, T_5 (GA_3 150 ppm and BAP 100 ppm). The lowest plant height (15.91, 54.75 and 61.98 cm at 20, 40 DAS and at harvest, respectively), lowest number of leaves plant^{-1} (7.95, 13.50 and 16.00 at 20, 40 DAS and at harvest, respectively), lowest number of branches plant^{-1} (1.32 and 2.23 at 40 DAS and at harvest, respectively), lowest leaf area index (1.07, 2.6 and 3.95 at 20, 40 DAS and at harvest respectively) and lowest dry weight plant^{-1} (5.34, 11.78 and 17.48 g at 20, 40 DAS and at harvest, respectively) were obtained from the treatment, T_1 (Control).

In terms of morpho-physiological characters, the highest crop growth rate (6.49 and 11.57 mg cm^{-2} day^{-1} at 20 - 40 DAS and 40 DAS - At harvest, respectively) was obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) which was significantly different from all other treatments where the lowest crop growth rate (4.29 and 6.49 mg cm^{-2} day^{-1} at 20 - 40 DAS and 40 DAS - At harvest, respectively) was obtained from the treatment, T_1 (Control). The highest total chlorophyll content (1.46 µg g^{-1}) at 30 DAS was obtained from T_3 (GA_3 150 ppm) treatment which was statistically identical with T_6 (GA_3 150 ppm and NAA 100 ppm) treatment. But at 50 DAS, the highest 'chlorophyll a' and 'chlorophyll b' content (0.46 and 0.59 µg g^{-1} respectively) were achieved from T_6 (GA_3 150 ppm and NAA 100 ppm) treatment where the lowest total chlorophyll content (0.72 and 0.77 µg g^{-1} at 30 and 50 DAS respectively) was obtained from the treatment, T_1 (Control).

Considering yield and yield contributing characters, the highest number of pods plant^{-1} (23.28), highest number of seeds pod^{-1} (12.62), highest pod length (8.60 cm), highest seed yield plant^{-1} (4.37 g), highest seed yield ha^{-1} (1.31 t ha^{-1}), highest stover yield ha^{-1} (1.65 t ha^{-1}), highest biological yield ha^{-1} (2.96 t ha^{-1}) and highest harvest index (44.20%) were obtained from the treatment, T_6 (GA_3 150 ppm and NAA 100 ppm) but the highest 1000 seeds weight (46.88 g) was obtained from the treatment, T_5 (GA_3 150 ppm and BAP 100 ppm) where the lowest number of pods

plant^{-1} (15.32), lowest number of seeds pod^{-1} (10.40), lowest pod length (7.33 cm), lowest 1000 seed weight (43.67 g), lowest seed yield plant^{-1} (3.30 g), lowest seed yield ha^{-1} (0.99 t ha^{-1}), lowest stover yield ha^{-1} (1.44 t ha^{-1}), lowest biological yield ha^{-1} (2.43 t ha^{-1}) and lowest harvest index (40.71%) were obtained from the treatment, T_1 (Control).

Based on the experimental results, it may be concluded that-

i) GA_3 150 ppm and NAA 100 ppm combination exerted the highest positive effect on growth characters {plant height (19.28, 56.58 and 69.28 cm at 20, 40 DAS and at harvest, respectively), dry weight plant^{-1} (8.42, 18.15 and 26.13 g at 20, 40 DAS and at harvest, respectively)} and physiological character {crop growth rate (6.49 and 11.57 mg cm^{-2} day^{-1} at 20 - 40 DAS and 40 DAS - At harvest, respectively), the highest 'chlorophyll a' content (0.84 µg g^{-1} at 30 DAS) and 'chlorophyll a' and 'chlorophyll b' content (0.46 and 0.59 µg g^{-1} at 50 DAS respectively)}.

ii) Higher yield was obtained from application of GA_3 150 ppm and NAA 100 ppm combination in mungbean (1.31 t ha^{-1}) followed by GA_3 150 ppm and BAP 100 ppm and NAA 100 ppm combination (1.26 t ha^{-1}) & GA_3 150 ppm and BAP 100 ppm combination (1.20 t ha^{-1}).

Recommendation

1. GA_3 150 ppm and NAA 100 ppm combination showed relatively higher yield than the other treatments. Farmers may use this treatment for better yield.
2. Further study is needed for ensuring the different levels of plant growth regulators in relation to growth and yield performance in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

CHAPTER VI

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APPENDICES

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

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from March to June, 2017

Month	RH (%)	Air temperature (^{o}C)			Rainfall (mm)
		Max.	Min.	Mean	
March	52.44	35.20	21.00	28.10	0
April	65.40	34.70	24.60	29.65	165
May	68.30	32.64	23.85	28.25	182
June	71.28	27.40	23.44	25.42	190

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

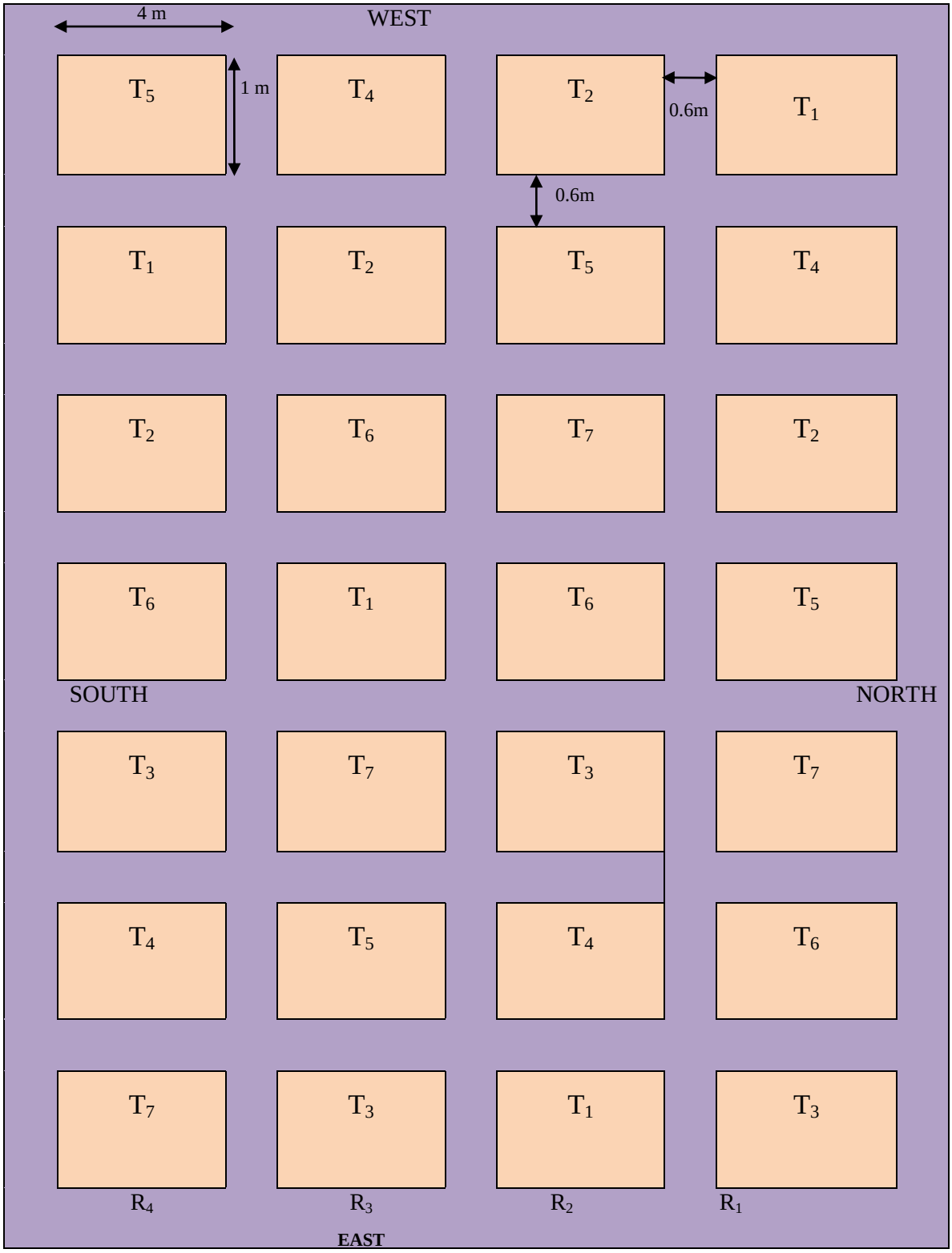
Source: Soil Resource Development Institute (SRDI)

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



Appendix V. Mean square plant height of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square plant height		
		20 DAS	40 DAS	At harvest
Replication	3	0.542	1.314	2.056
Factor A	6	12.322*	18.390*	23.480*
Error	18	1.507	2.347	2.448

*and** indicate significance at 5% and 1% level respectively

Appendix VI. Mean square of number of leaves plant^{-1} of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of leaves plant^{-1}		
		20 DAS	40 DAS	At harvest
Replication	3	0.004	0.156	0.247
Factor A	6	NS	6.347**	8.319*
Error	18	0.014	1.227	1.044

* and ** indicate significance at 5% and 1% level respectively

Appendix VII. Mean square of branches plant^{-1} of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of branches plant^{-1}	
		40 DAS	At harvest
Replication	3	0.011	0.075
Factor A	6	2.017**	7.228*
Error	18	0.026	0.211

* and ** indicate significance at 5% and 1% level respectively

Appendix VIII. Mean square of leaf area index of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of leaf area index		
		20 DAS	40 DAS	At harvest
Replication	3	0.116	0.148	0.228
Factor A	6	4.218**	7.379**	8.204*
Error	18	0.162	0.312	0.417

* and ** indicate significance at 5% and 1% level respectively

Appendix IX. Mean square of dry weight plant^{-1} of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of dry weight plant^{-1}		
		20 DAS	40 DAS	At harvest
Replication	3	0.014	0.337	1.074
Factor A	6	6.482**	10.349*	13.546*
Error	18	0.234	1.006	1.252

* and ** indicate significance at 5% and 1% level respectively

Appendix X. Mean square of crop growth rate plant^{-1} of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of crop growth rateplant^{-1}	
		20-40 DAS	40 DAS- At harvest
Replication	3	0.026	0.112
Factor A	6	2.421**	6.237**
Error	18	0.042	0.128

* and ** indicate significance at 5% and 1% level respectively

Appendix XI. Mean square of chlorophyll content of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of chlorophyll content					
		30 DAS			50 DAS		
		Chl- a	Chl- b	Total	Chl-a	Chl-b	Total
Replication	3	0.004	0.003	0.007	0.001	0.006	0.008
Factor A	6	0.370**	0.360**	0.440**	0.280**	0.032**	0.041**
Error	18	0.003	0.004	0.006	0.002	0.003	0.005

* and ** indicate significance at 5% and 1% level respectively

Appendix XII. Mean square of yield contributing characters of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of yield contributing characters				
		Pods plant^{-1}	Seeds pod^{-1}	Pod length (cm)	1000 seeds weight (g)	Seed yield plant^{-1} (g)
Replication	3	0.322	0.418	0.258	0.344	0.014
Factor A	6	10.482*	7.906*	8.216*	14.621*	6.211**
Error	18	1.302	1.216	0.421	1.103	0.047

* and ** indicate significance at 5% and 1% level respectively

Appendix XIII. Mean square of yield attributes of mungbean influenced by NAA, GA_3 and BAP (CK) at different growth stages

Sources of variation	Degrees of freedom	Mean square of yield attributes			
		Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Replication	3	4.520	6.480	8.120	1.100
Factor A	6	59.860*	66.490*	55.160*	10.290*
Error	18	10.541	14.316	15.227	0.738

* and ** indicate significance at 5% and 1% level respectively