EFFECT OF FOLIAR APPLICATION OF IAA AND GA_3 ON GROWTH AND YIELD OF MUNGBEAN PLANT

A THESIS

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December, 2021

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REGISTRATION NO. 19-10395

A Thesis

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

IN

AGRICULTIRAL BOTANY

SEMESTER: JULY-DECEMBER, 2021

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF FOLIAR APPLICATION OF IAA AND GA_3 ON GROWTH AND YIELD OF MUNGBEAN PLANT**" 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 **MASTER OF SCIENCE (MS) IN AGRICULTURAL BOTANY**, embodies the result of a piece of bona-fide research work carried out by **YEASHINA NOURIN**, Registration no. **19-10395** under my supervision and guidance. No part of the 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.

……………………………………………

Dated; December, 2021

Place: Dhaka, Bangladesh

Prof. Dr. Md. Ashabul Hoque

Department of Agricultural Botany

Supervisor

Dedicated to

My

Beloved Daughter,

Parents

and

Respected Teachers

ACKNOWLEDGEMENTS

All praises are laid upon the Almighty "Allah" who kindly enabled the author to complete her research work and the thesis leading to Master of Science.

The author expresses the deepest sense of gratitude, sincere appreciation and profound gratitude to her research supervisor Dr. Md. Ashabul Hoque, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, innovative suggestions, constant supervision, inspiration, valuable advice and helpful criticism and whole hearted co-operation during carrying out the research work and preparation of this manuscript.

The author deems it a proud privilege to acknowledge her gratefulness, boundless gratitude and best regards to her respectable co-supervisor Dr. Mohammad Mahbub Islam, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, constructive criticism and factual comments in upgrading the research work and this thesis.

The author is highly grateful to Prof. Dr. Asim Kumar Bhadra, Chairman, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka along with all the teachers and staff members of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University for their co-operation and encouragement during the period of the study.

The author wishes to extend her special thanks to her classmates, parents and the relatives whose encouragement, inspiration, co-operation, sacrifice and continuous blessing paved the way to her higher education. May Allah bless and protect them all.

The Author

December, 2021

EFFECT OF FOLIAR APPLICATION OF IAA AND GA_3 ON GROWTH AND YIELD OF MUNGBEAN PLANT

ABSTRACT

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, during March to June, 2020 to study the Effect of Foliar Application of IAA and GA_3 on Growth and Yield of Mungbean Plant (BARI Mung-6). The experiment was consisted of two types of plant growth regulators, viz. i) Auxin (IAA-Indole acidic acid) and ii) Gibberellic acid (GA_3). Nine levels of foliar spray with IAA and GA_3 application viz. i) Control (T_0), ii) Spraying IAA @ 25 mg/L at 30 DAS (T_1), iii) Spraying IAA @ 50 mg/L at 30 DAS (T_2), iv) Spraying GA_3 @ 25 mg/L at 30 DAS (T_3), v) Spraying GA_3 @ 50 mg/L at 30 DAS (T_4), vi) Spraying IAA @ 25 mg/L + GA_3 @ 25 mg/L at 30 DAS (T_5), vii) Spraying IAA @ 25 mg/L + GA_3 @ 50 mg/L at 30 DAS (T_6), viii) Spraying IAA @ 50 mg/L + GA_3 @ 25 mg/L at 30 DAS (T_7) and ix) Spraying IAA @ 50 mg/L + GA_3 @ 50 mg/L at 30 DAS (T_8). The experiment was laid out in randomized complete block design (RCBD) with three replications. The data regarding on plant height, number of leaves, number of branches were recorded both 30 days after sowing (DAS) and at harvest. The other parameters were recorded meanwhile cultivation and at the time of harvest. Results revealed that in case of morphological parameters, plant height (57.50 cm), number of leaves (17.33) plant^{-1} and number of brunch (7.67) plant^{-1} were significantly higher in T_8 (IAA @ 50 mg/L + GA_3 @ 50 mg/L) treatment. In terms of growth characters; SPAD value (55%), days to flowering (27.33) and days to maturity (55.33) were also significantly higher in T_8 (IAA @ 50 mg/L + GA_3 @ 50 mg/L) treatment. The data regarding yield and yield attributes, number of pods plant^{-1} (37.66), pod length (14.99), number of seeds pod^{-1} (13.78), weight of 1000- seeds (54.95g), seed yield (1.62 t ha^{-1}), stover yield (1.78 t/ha), biological yield (3.74t/ha), and harvest index (37.75 %) were higher in T_8 (IAA @ 50 mg/L + GA_3 @ 50 mg/L) treatment. However, (T_0) untreated control (IAA 0.0 mg/L, GA_3 0.0 mg/L) showed the lowest performance in every stages. The result indicated that the plants treated with T_8 (IAA @ 50 mg/L + GA_3 @ 50 mg/L), performed better in respect of growth, yield and others yield contributing characters.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BARI	Bangladesh Agriculture Research Institute
CRRI	Central Rice Research Institute
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	Editors
et al.	et al (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
IAA	Indole-3-Acetic Acid
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IRRI	International Rice Research Institute
L.	Linnaeus
LSD	Least Significant Difference

i.e.	id est (that is)
MoP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	Namely

CHAPTER I

INTRODUCTION

Pulses are rich in protein and contain more than three times higher quality protein than cereals. In addition, Pulses contain vitamin B, minerals and also contain quality fibers, which is desirable in human diet, because of medical importance, pulse crops preserve and improve soil fertility through biological nitrogen fixation (BNF) in soil. Hence, pulses contribute a significant role in sustainable agriculture. Pulses are popularly known as the “poor man's meat” in most of the developing countries due to cheaper and availability than animal protein. Pulses occupy a strategic position in the agriculture economy of Bangladesh.

Mungbean [*Vigna radiata* (L.) R. Wilczek] belongs to the family Fabaceae and sub family papilionaceae, is an important pulse crop all over the world with an admirable economic importance and food value. The grains of mungbean contain 25.67% protein, 1–3% fat, 5.4% carbohydrates, 3.5–4.5% fibers, and 4.5–5.5% ash with very low amount of flatulence effects (Frauque *et al.* 2000; Ahmad *et al.,* 2008), and rich in folate and iron (Noble *et al.,* 2018). It is an antique crop in Bangladesh with dietary and nutritional value (Islam *et al.* 2017a). It is a vital crop to the small land-holdings Asian farmers, and is consumed as a soup of split seeds and spices called Dal or Dhal. It is easily digestible, and does not have any adverse effect on human bodies. It ranks 3rd position next to lentil and grasspea both in acreage and production in Bangladesh (Agriculture Information Service (AIS, 2019).

The area and production of mungbean is gradually decreasing regrettably (Agriculture Information Service (AIS, 2019) and it is indispensable to produce extra food from decreasing agricultural land area for mitigating the appropriate food requirements (Islam *et al.* 2017a). The crop fits well in multi-cropping systems, because of its rapid growth and early maturity. Since, the crop is widely grown in marginal and abiotically stressed agro-ecosystems (Raina *et al.,* 2016), but it experiences a considerable yield losses. Total pulses production must be increased urgently to meet the consumption and protein demand.

Due to lack of high yielding variety and proper production technology, the yield of mungbean is very low in Bangladesh as compared to other mungbean producing countries. BARI Mung-6 and BARI Mung-8 are the high yielding varieties but the yield in the farmer's field is very low as compared to their yield potential. Various management practices may help to achieve the desired yield potential of mungbean, and plant growth regulators (PGRs) application in different techniques seem to be the most significant one in view of cost and labor efficacy.

Improving physical, chemical and biological properties of soil by fixing nitrogen from atmosphere through symbiosis process is another important character of mungbean. The climatic condition of Bangladesh is friendly for winter farming of local mungbean but it can be cultivated in both summer and winter Bose (1982) and Miah *et al.*, (2009).

The response of the plant to PGRs may vary with species, varieties, environmental conditions, physiological and nutritional status, stage of development and endogenous hormonal balance Naeem *et al.* (2004) delays senescence Shah (2007). Plants have the ability to store excessive amounts of exogenously supplied hormones in the form of reversible conjugates which release active hormone when the plants need them during the growth period Davies (2004). Ammanullah *et al*. (2010) mentioned that plant growth substances are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates to sink there by helping in effective flower formation, fruit, and seed development and ultimately enhancing the productivity of crops.

Various plant growth regulators which regulate growth under normal or stress conditions are auxins. Generally, auxins are the best hormones for us because they are nontoxic to plants over a wide range of concentration and effective in promoting the root system of a large number of plant species. Auxins might regulate cell elongation, cell division, tissue swelling, formation of adventitious roots, callus initiation, induction of embryogenesis, and promoting cell wall loosening at very low concentrations Taiz and Zeiger (2006). The principal auxin in plants is indole-3-acetic acid (IAA) that produced mainly in the shoot apex bud and young leaves of plants. Other meristematic tissues, flowers, fruits, and young seeds have also been shown to be sites of this hormone production Sadak *et al*. (2013).

Gibberellins (GAs) are the most important natural growth regulators and generally involved in the growth and development of different plants. They control seed germination, leaf expansion, stem elongation, and flowering Magome *et al*. (2004) and Kumar *et al.*, (2018). Gibberellic acid (GA_3) is used to induce great changes in the growth characters, chemical composition, and yield criteria of the plant. Choudhury *et al.* (2013) stated that GA_3 treatment increased the growth and yield of the tomato plant. So, this study is an attempt to improve plant growth and yield quantity and quality of mungbean plant (BARI Mung-6) through improving some physiological and biochemical processes by using plant growth regulators like IAA and GA_3.

The present study was undertaken to:

1. To know the effect of plant growth regulators on growth and yield characters of mungbean
2. To find out appropriate concentration of IAA and GA_3 for yield and quality of mungbean

CHAPTER II

REVIEW OF LITERATURE

This chapter includes findings of different researchers in home and abroad regarding the effect of IAA and GA_3 on the growth and yield of mungbean. Since the work on the influence of plant growth regulators (PGRs) on mungbean is scanty, an attempt has therefore been made to review the work on mungbean and other crops. The information have been reviewed and cited under the following headings.

2.1. Role of IAA

2.1.1. Plant height

Total length of plant from ground level to the top of the leaf is a good indicator for overall development of any crop. Plant growth regulator like IAA can modify the plant height.

Abel and Theologis (2010) conducted an experiment and found that auxin is involved in mitotic activity in sub-apical tissues, resulting in increased plant growth. In a pot experiment Rastogi *et al.* (2013) found that auxin and gibberellic acid enhanced vegetative growth of linseed. They concluded that 0.5 mg L-1 dose of auxin is recommended for the enhancement of vegetative growth. However, it was observed that IAA had more promotory effects than GA_3 in the enlargement of vegetative growth. Among PGRs, auxin and gibberellin play vital role in regulating developmental processes within plant bodies Gou *et al.* (2010). A higher concentration of gibberellins increases plant growth Bora and Sarma (2006), while higher concentration of auxin inhibits the growth Hussain *et al.* (2010).

Muthulakshmi and Pandiyarajan (2015) conducted an experiment to study the IAA foliar spray on vegetative growth, physiological and biochemical constituents of *Chataranthus roseus* (L). Significant increase of vegetative growth characters such as shoot and root length, shoot and root fresh weights and dry weights, photosynthetic pigment, non-photosynthetic pigment composition and total soluble protein, total soluble glucose, free amino acid, starch, leaf nitrate and peroxidase activity were recorded after IAA treatment.

Reena *et al.* (1999) conducted an experiment on soybean at 25, 50, 75, 100, 125 and 150 ppm solution of IAA and concluded that 100 ppm was the most effective concentration in increasing plant height. However, Sontakey *et al.* (1991) sprayed IAA at pre-flowering stage with 100, 250 or 500 ppm in their experiment and reported increased plant height of sesame after the application of IAA. Rahman *et al.* (1989) found similar results of increased plant height at 50 mg IAA/ L of foliar application in a pot experiment with grasspea.

Mirhadi *et al.* (1979) mentioned about higher plant height of sorghum hybrid Hazara-728 sprayed with 100 ppm of IAA. Garg and Kumar (1987) sprayed aqueous solution of 10 ppm IAA four week old *Euphoria lathyrus* L. plants at weekly intervals for four weeks and found increased plant height compared to the control.

Lee (1990) conducted an experiment and reported that longer main stems of groundnut after soaking groundnut seed in 50, 100, and 200 ppm solution of IAA before sowing. In cowpeas, stem length increased only when IAA was applied at 10 or 50 mg/L at 25-65% water holding capacity Khalil and Mandurah (1989). Manikandan and Hakin (1998) mentioned about increased shoot length of groundnut when they applied IAA at 30 ppm as foliar spray and parthenium root extract in groundnut (*Arachis hypogaea* cv. Co-02)

2.1.2. Number of leaves plant^{-1}

Gurdev and Saxena (1991) conducted an experiment on wheat and reported that IAA applied at 10^{-4}M increased number of leaves plant^{-1}. Mathur (1971) also reported about similar increase in leaf number in onion treated with IAA at 100-300 ppm.

Khalil and Mandurah (1989) conducted 2 years of pot trails on cowpea and found that at 15, 25, 45 of 65% of water holding capacity of soil and sprayed with 0, 10, 50 or 100 ppm IAA at 4, 6 and 9 weeks after sowing, IAA increased the number of leaves only when applied at 10 of 50 ppm at 25-65% water holding capacity.

2.1.3. Number of branches plant^{-1}

Lee (1990) observed higher number of branches after soaking groundnut seed in solution of 50, 100 and 200 ppm IAA before sowing. IAA at 300, 600 and 900 ppm increased number of tiller plant^{-1} in wheat when IAA is applied at the beginning of tillaeing stage Saha *et al.* (1996). Awan and Alizai (1989) also mentioned about similar results of higher number of tiller in rice after the application of 100 ppm IAA at panicle emergence stage of rice cv. IR6.

Rahman *et al.* (1989) reported that 500 ppm IAA produced maximum number of plant branches in grasspea. Sontakey *et al.* (1991) reported that pre-flowering spray of sesame cv. 128 with 100, 250 of 500 ppm IAA increased branch number plant^{-1}.

2.1.4. Root

Fukaki *et al.* (2007) experimented on the developmental mechanisms of lateral root development and found that auxin has emerged as a central regulator of lateral root development. However, few scientists said that correct auxin localization and subsequent auxin response are crucial for lateral root development.

Auxin is found directly involved in activating the cell cycle during lateral root initiation and development Himanen *et al.* (2004) and the expression of genes downstream Himanen *et al.* (2004); Vanneste *et al.*, (2005).

Casimiro *et al.* (2003) found in an experiment that auxin is the major regulator of lateral root initiation, growth, differentiation and meristem specification. Manikandan and Hakin (1998) reported increased root length when IAA was applied at 30 ppm as foliar spray in the groundnut.

Mutants which overproduce auxin, like the *Arabidopsis* super root mutant, have increased numbers of lateral roots Boerjan *et al.* (1995) and similarly exogenous application of auxin also increases lateral root numbers Wightman *et al.* (1980);

Laskowski *et al.,* (1995). In contrast, mutants resistant to auxin show reduced numbers of lateral roots in plants De Smet *et al.* (2006).

2.1.6. Stover yield

Elshorbagi *et al.* (2008) conducted an experiment and mentioned about the role of IAA on the anatomical characteristics, stover and fiber yield and quality of Flax.

2.1.7. Biological yield

Sadak *et al.* (2013) conducted an experiment and found that that IAA treatments caused significant increases in seed yield/plant (g), yield attributes (number of pods/plant, pods yield/plant (g), 1000-seed weight (g) and biological yield/plant) of the two fababean cultivars.

2.1.8. Harvest index (%)

Quaderi *et al.* (2006) conducted an experiment and found that seed treatment with 200 ppm IAA resulted the highest relative growth rate (RGR), crop growth rate (CGR), net assimilation rate (NAR), higher yield, harvest index (38.48) of mungbean.

2.2 Role of GA_3

Chakrabarti and Mukherji (2003) reported that gibberellic acid is known to be importantly concerned in the regulation of plant responses to external environment.

Haroun *et al.* (1991) reported that application of GA_3 has increased the salt tolerance of many crop plants. GA_3 has also been shown alleviate the effects of salt stress on water use efficiency Aldesuquy and Ibrahim (2001).

Sure *et al.* (2012) mentioned that Gibberellic acid (GA_3) is an important plant growth regulator that affects plant growth and development by inducing metabolic activities and regulating nitrogen utilization.

Roy & Nasiruddin (2011) conducted an experiment and found that Gibberellic acid plays a significant role in seed germination, endosperm mobilization, stem elongation, leaf expansion, reducing the maturation time and increasing flower and fruit set and their composition.

2.2.1 Plant height

GA_3 is well known for its role in cell and stem elongation. The effect of GA_3 on plant height was studied on various part of all over the world.

In a field experiment in Maharashtra, soybean (cv. JS-335) seeds were treated with 0-150 ppm GA_3 and plant height was increased with 100 ppm concentration, the experiment was conducted by Deotale *et al.* (1998). Abd (1997) found that foliar spray of GA_3 increased plant height in broad bean cv. *Aquadolse.*

In French bean (*Phasaeolus vulgaris*), the regulatory effect of GA_3 on shoot elongation or in growth stimulation was observed by Beall *et al.* (1996). An increase in concentration of GA_3 influenced plant height in fababean observed by Omar *et al*. (1988). GA_3 spray on early maturing soybean grown in subtropical area during short days was found to increase stem elongation i.e. plant height experimented by Mislevy *et al.* (1989).

Previously, in an experiment it was reported that there is a continual effect of gibberellic acid on *Catharanthus roseus* L. plant phenotype. Earlier studies have shown that GA_3 application (at 50, 100 and 500 g m) as foliar spray on transplanted cutting of *Catharanthus roseus* L. increased plant height by increasing stem elongation. Gibberellins increased shoot length by increasing their rate of cell elongation in majority of the plants Shil *et al.* (2007).

2.2.2 Number of leaves plant^{-1}

Abd (1997) reported that GA_3 induced increased in number of leaves in faba bean. Gabal *et al.,* (1990) observed that 100 ppm of GA_3 was more effective over the control in increasing leaf number per plant in faba bean.

In soybean, Deotale *et al.* (1998) reported that number of leaves is increased when seeds were treated with 0 ppm and 150 ppm GA_3.

2.2.3 Number of brunches plant^{-1}

In grasspeas, foliar application of gibberellic acid at 50 ppm increased number of brunches per plant Rahman *et al.* (1989).

2.2.4 Leaf area

Foliar spray of GA_3 at the time of 6 month old seedlings, resulted in increased leaf area in faba bean Abd (1997)

2.2.5 Number of flowers plant^{-1}

Chakraborty and Sharma (1992) observed that application of 10 ppm and 100 ppm of GA_3 at different stages of French bean showed increased number of flower production per plant. Similar results were also found in faba bean in the experiment of Omar *et al.* (1988).

Lee (1990) found in an experiment that soaking of groundnut seeds in solutions of 0, 50, and 100 ppm of GA_3 before sowing produced plants with greater number of flowers than those of the control.

2.2.6 Number of pods plant^{-1}

Increasing concentration of GA_3 in faba bean resulted in an increased pod number per plant is observed by Omar *et al.* (1988).

Khan *et al.* (1997) conducted an experiment reported that application of GA_3 at 80 DAS in *Brassica juncea* increased in number of pods per plant. Similar result also found in Grass pea in the experiment of Rahman *et al.* (1989).

2.2.7 Thousand seeds weight

The effect of GA_3 on thousand seed weight was studied extensively all over the world by many workers. Increasing in seed weight after using GA_3 was found in grasspea. Rahman *et al.* (1989).

2.2.8 Seed yield

In an experiment of Khan *et al.*, (1997) GA_3 exerted a marked influence on seed yield per plant in gram. Treatment of green gram plant with 150 ppm of GA_3 significantly increased seed yield per plant compared to control.

Yuan & Xu (2001) found that gibberellic acid delays senescence, improves growth and development of chloroplasts, and intensifies photosynthetic efficiency which leads to increased yield.

Rahman *et al.* (1989) stated in a pot experiment on grass pea showed that foliar application of 50 mililiter of GA_3 increased seed yield.

2.2.9 Harvest index (HI%)

GA_3 at 75 mg/L was applied at the pre-flowering stage on Indian mustard (*Brassica juncea*) and was increased harvest index was experimented by Khan *et al.* (1997).

CHAPTER III

MATERIALS AND METHODS

This chapter consists of the materials and methods of the experiment along with a brief description of the experimental site, experimental design, soil, climate, land preparation, fertilizer application, planting materials, transplanting, intercultural operation, irrigation and drainage, data collection, data recording and their analysis. The details of the investigation for achieving stated objectives are described below.

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period of March to June, 2020 to study the on effect of IAA and GA_3 on growth and yield of BARI Mung-6. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1. Description of the experimental site

3.1.1 Location and time

The experiment was conducted at the research field premises of Sher-e-Bangla Agricultural University, Dhaka, during the period of March to June, 2020. The experimental site is located at 23.74^o N latitude and 90.35^o E longitude with an elevation of 8.2 m from the sea level (Khan 1997).

3.1.2. Agro-ecological region

The experimental site is under the agro-ecological zone of "Madhupur Tract", AEZ-28 (Anon 1988a). This was a region of complex relief and soils developed over the Madhupur clay soil, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as "islands" surrounded by the floodplain (Anon 1988b). For better understanding, a picture of the experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.1.3. Site and soil

The soil of the experimental area was to the general soil type series of shallow red brown terrace soils under the Tejgaon series. Upper level soils were clay loam in texture, olive-gray through common fine to medium distinct dark yellowish brown mottles under the Agro ecological Zone (AEZ- 28) and belong to the Madhupur Tract (UNDP and FAO, 1988). The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land, fertile, well drained, non-calcareous dark grey (Appendix III). Soil pH was 5.6 and had organic carbon 0.45%. The morphological, physical and chemical characteristics of the experimental soil is presented in Appendix III.

3.1.4. Climate and weather

The geographical location of the experimental area was under the sub-tropical climate characterized by three distinct seasons. Such as, the monsoon or rainy season extending from May to October, which is associated with high temperature, high humidity and heavy rainfall; the winter or dry season from November to February, which is associated with moderately low temperature and the pre-monsoon period or hot season from March to April, which is associated with some rainfall often and occasional gusty winds. Information regarding monthly average maximum and minimum temperature, total rainfall and average relative humidity and sunshine during the period of study of the experimental area was collected from Bangladesh Meteorological Department, Agargaon, Dhaka and is presented in Appendix II.

3.2 Crop Cultivation

3.2.1. Planting materials

BARI Mung-6 was used as planting or crop material. BARI Mung-6 was developed by Bangladesh Agricultural Research Institute (BARI) in 2003. The seeds of BARI Mung-6 were collected from BARI, Joydepur, Gazipur. The seeds were medium shaped, dull and greenish and free from mixture of other seeds, weed seeds and extraneous unwanted materials. It is known that the plant height of the variety ranges from 60-70 cm. It is resistant to Cercospora leaf spot and yellow mosaic diseases. Its life cycle ranges from 60-65 days after sowing (DAS) and average yield is 1400-1600 kg/ ha.

3.2.2. Treatments under investigation

The experiment comprised nine treatments including an untreated control. The details of the treatments are shown below:

1. T_0 = Untreated Control (IAA 0.0 mg/L , GA_3 0.0 mg/L);
2. T_1 = Foliar spray of IAA 25 mg/L at 30 DAS ;
3. T_2 = Foliar spray of IAA 50mg/L at 30 DAS;
4. T_3 = Foliar spray of GA_3 25 mg/L at 30 DAS;
5. T_4 = Foliar spray of GA_3 50 mg/L at 30 DAS;
6. T_5 = Foliar spray of IAA 25 mg/L + GA_3 25 mg/L at 30 DAS;
7. T_6 = Foliar spray of IAA 25 mg/L + GA_3 50 mg/L at 30 DAS;
8. T_7 = Foliar spray of IAA 50 mg/L + GA_3 25 mg/L at 30 DAS;
9. T_8 = Foliar spray of IAA 50 mg/L + GA_3 50 mg/L at 30 DAS.

3.3. 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 in order to distributing the treatments properly. Total area used for the experiment was 300 m^2. The experimental field was divided into 3 blocks and each block was again divided into 9 plots. The total numbers of unit plots of the experiment were (9 × 3) =27. The size of the unit plot was 3 m × 2 m (6 m^2). The distances between plot to plot and replication to replication were 0.50 m and 1.00 m, respectively. The treatments were randomly distributed to each block following the experimental design (Appendix IV).

3.4. Land preparation

The land was irrigated before ploughing. After having irrigated condition the land was first opened with the tractor. Ploughed soil was brought into desirable fine tilth by 3 ploughing and cross-ploughing, harrowing and laddering to get the desired sunlight which helps to destroy the soil borne pathogen. All weeds and other plant residues of previous crop were removed from the field. After having field capacity, land was allowed to attain at joo condition. On 17 March, 2020, the first ploughing was done and final land ploughing was done on 19 March, 2020. According to experimental layout the experimental field was divided and arranged. On 19 March, 2020, the basal fertilizer doses were applied. The experimental layout is presented in (Appendix IV).

3.5. Fertilizer application

In this experiment, the fertilizers were applied as per fertilizers recommendation guide which is recommended by Bangladesh Agricultural Research Institute (BARI, 2006). The applied manures were mixed properly with the soil in the plot using a spade.

The dose and method of application of fertilizers are shown in below:

Nutrient	Source	Dose (kg/ha)
N (Nitrogen)	Urea (46% N)	40
P (phosphorus)	TSP (48% P_2O_5)	80
K (potassium)	MoP (60% K_2O)	30

3.6 Seed treatments

Before planting seeds were treated with Vitavex-200 @0.25% to prevent seeds from the attack of soil borne disease. Furadan @1.2 kg ha^{-1} was also used as per treatment against mole cricket.

3.7. Sowing of seeds

The seeds of BARI Mung-6 were sown as per the sowing date 19 march 2020. 2-3 cm depth in rows having different distances of 20 cm, 30 cm and 40 cm. The seeds of mungbean were sown by hand in 25 cm apart from lines with continuous spacing at about 3 cm depth. Three seeds were sown in each hole.

3.8. Germination of seeds

Seed germination occurred from 3rd day of sowing. 50% seed germination was recorded on 24 March, 2020. On the 5th day the percentage of germination was more than 80%.

3.9. Preparation of Auxin (IAA) and Gibberellic acid (GA_3)

The experiment was done by the foliar application of plant growth regulators such as: Auxin and Gibberellic acid in order to increase the growth, yield and quality of mungbeans.

These solutions were applied to plants at 30 DAS (Days after sowing) as per treatment. The details are shown below:

Plant Growth Regulators (PGRs)	Concentration (ppm)
Indole-acetic acid (IAA)	0 ppm 25 ppm 50 ppm
Gibberellic acid (GA_3)	0 ppm 25 ppm 50 ppm

A concentration of 100 ppm of IAA was prepared by dissolving 100 mg of IAA in small quantity of ethanol prior to dilution with distilled water. The distilled water was added to make the volume of 1 Litre to get 100 ppm solution.

Solution of GA_3 were prepared in a similar process followed for the preparation of IAA solution.

3.10. Intercultural operations

3.10.1. Thinning

As the seeds were sown continuously into the line, so there were so many weak seedlings which need thinning. Emergence of seedling was completed within 10 days after sowing (DAS). Overcrowded and unhealthy seedlings were thinned out two times. First thinning was done after 15 days of sowing (DAS) which is done to remove unhealthy and lineless seedlings. The second thinning was done for the betterment at 10 days after first thinning.

3.10.2. Weed control

There were some common weeds found in mungbean field. First weeding was done at 30 DAS and then once a week to keep the plots free from weeds and to keep the soil loose and well aerated.

3.10.3. Irrigation and drainage

Two irrigations were applied on the experiment, first one at 10 DAS and second at 30 DAS. At later stage of experiment, there was little rainfall; so to drain out excess water drainage provision was well maintained.

3.10.4. Insect and pest control

Vitavex-200 and furadan were used as a precaution during the treatment of mungbean seeds. At the time of 50% pod formation stage, insecticide named Malathion 57EC was sprayed @ 1.5 t ha^{-1} to control pod borer.

3.11. General observation

The crops were monitored and evaluated frequently to note any change in the characters of plant. The crops were looked good since the primary stage and maintained a satisfactory growth till harvest.

3.12. Determination of maturity

At the time of being 80% of the pods turned into blakish in colour, the crops were seemed to be attained maturity.

3.13. Harvesting and sampling

The crops were harvested randomly from the central 1.0 m^2 area of each plot for biological yield data on different dates as the plants attained maturity. Five randomly selected plants from each of the plots were marked for recording data on plant height, no. of leaves $plant^{-1}$, no. of brunch $plant^{-1}$, SPAD value, days to flowering, days to maturity, pods $plant^{-1}$, no. of seeds pod^{-1}, 1000 seeds weight, seed yield, biological yield, stover yield and harvest index. Pods were collected thrice throughout the growing period of the plants.

3.14. Threshing

The crops were sun dried for three days by placing them on an open threshing floor. After that seeds were separated from the plants by beating the bundles with bamboo sticks.

3.15. Drying, cleaning and weighing

The seeds which were collected, dried in the sun for reducing the moisture in the seeds to a safe level. The dried seeds and straw were cleaned and weighed.

3.16. Recording of data

The data were recorded on the following parameters

A. Morphological parameters

a. Plant height (cm)

b. Number of leaves plant^{-1}

c. Number of branch plant^{-1}

B. Crop Growth parameters

a. SPAD value (%)

b. Days to flowering

c. Days to maturity

C. Yield contributing parameters

a. Pods plant^{-1} (no.)

b. Pod length (cm)

c. Seeds pod^{-1} (no.)

d. 1000 seeds weight (g)

D. Yields parameters

a. Grain yield (t/ ha)

b. Stover yield (t/ ha)

c. Biological yield (t/ ha)

d. Harvest index (%)

3.17. Procedures of Data Collection

i. Plant height (cm)

Five plants were collected randomly from each of the plots. The height of the plants were measured from the ground level to the tip of the plant at 30 and 60 days after sowing (DAS).

ii. Number of leaves plant^{-1}

Number of leaves per plant data was also recorded before and after flowering from the randomly selected five plants of inner rows of each plot**.**

iii. Number of branch plant^{-1}

Numbers of branches plant^{-1} were recorded at 30 DAS and at harvest. Data were recorded from 5 plant selected randomly from the outer side of the rows (started after 2 rows from outside) of each plot.

iv. SPAD value (%)

Five plants were collected randomly from each of the plots. The SPAD value (%) of the plants were measured from the plants at 30 days after sowing (DAS) and at harvest.

v. Pods plant^{-1} (no.)

Number of pods plant^{-1} was counted from the 5 plant sample and the average pod number was calculated.

vi. Pod length (cm)

The length of pods were measured from ten randomly selected pods which were collected from five randomly selected plants per plot at harvest and the average value was recorded.

vii. Seeds pod^{-1} (no.)

The pods from each of five plants plot^{-1} were separated. From which ten pods were selected randomly. The number of seeds pod^{-1} were counted and then average number of seeds per pod were determined.

viii. Weight of 1000 seeds (g)

1000 seeds were counted which were taken from the seeds sample of each plot separately. After that the seeds were weighed in an electrical balance and data were recorded.

ix. Seed yield (t/ ha)

Seed yield data was recorded on the basis of total harvested seeds per plot ($1m^2$) and was expressed in terms of yield (t/ha). Seed yield was adjusted to 12% of moisture content.

x. Stover yield (t/ ha)

After separation of seeds from the plants, the straw and shell of harvested area was sun dried. Then the weight was recorded and converted to t/ha.

xi. Biological yield (t /ha)

The summation of seed yield and above ground stover yield is called the biological yield.

Biological yield = Grain yield + Stover yield.

xii. Harvest index (%)

The harvest index denotes the ratio between economic yield (seed yield) and biological yield. It was calculated with the following formula.

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Seed weight)}}{\text{Biological Yield (Total dry weight)}} \times 100$$

3.18. Data analysis technique

The data which were collected on different parameters under the experiment were monitored, compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT- C developed by Russel (1986) and the differences between pairs of means were compared by Duncan’s New Multiple Range Test (DMRT).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter contains the presentation and discussion of the results which is obtained from the following experiment. Results have been presented, discussed and possible interpretations are made through some tables and graphs. The results obtained from this experiment have been presented under several headings and sub-headings are discussed below:

4.1. Morphological Parameters

4.1.1. Plant height

Application of IAA and GA_3 alone and together with different concentrations showed significant influence on the plant height of BARI Mung-6 (Appendix-V). Plant height was increased with the increasing concentration of IAA, GA_3 and both of them. The tallest plant of BARI Mung-6 was found in T_8 (50 ppm IAA and 50 ppm GA_3 foliar application) treatment at 30 DAS and at harvest (17.33 cm and 57.50 cm respectively) (Tab. 1). However, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically almost similar plant height of BARI Mung-6 at harvest. On the other hand, control treatment (T_0: No IAA or GA_3 foliar application) showed the lowest plant height of BARI Mung-6 at different growth stage (17.83 cm at 30 DAS and 40.50 cm at harvest).

This result is similar with the findings of (Mojtaba *et al.* 2014) who found significant effect of gibberellin on the plant height of mungbean. The maximum plant height found in treatments, 50 ppm gibberellin was obtained there. Gibberellins (GA_3) increases growth at most plant species especially rosette plants Archbold (1988).

IAA appears to be a pattern-determining global plant growth regulator, as well as a player in cell division, cell elongation, growth and vascular tissue differentiation. So, foliar application of IAA may enhance the physiological process of plant which could be the reason for higher plant height of the IAA treated plants in this experiment.

Abel and Theologis (2010) stated that exogenous application of IAA increased the plant growth. Rastogi *et al.* (2013); Sontakey *et al.* (1991) and Rahman *et al.*, (1989) also mentioned about the increasing higher plant height after IAA application.

Table 1. Effect of IAA and GA_3 on plant height of BARI Mung-6.

Treatments	Plant height at 30 DAS (cm)	Plant height at Harvest (cm)
T_0	17.83 ab	40.50 g
T_1	19.17 a	41.50 g
T_2	16.50 b	42.83 f
T_3	17.00 ab	44.67 e
T_4	18.50 ab	48.50 d
T_5	17.67 ab	49.50 d
T_6	17.17 ab	55.50 c
T_7	17.83 ab	54.10 b
T_8	17.33 ab	57.50 a
LSD $_{(0.05)}$	**1.61**	**2.21**
CV (%)	**8.55**	**9.46**

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3).

4.1.2. Number of leaves plant^{-1}

Significant influence of IAA and GA_3 was found on the number of leaves plant^{-1} of BARI Mung-6 (Table 2 and Appendix VI). The highest number of leaves plant^{-1} was recorded from higher concentration of IAA and GA_3 treated plants T_8 (50 ppm IAA and 50 ppm GA_3 application) throughout the plant growth period. The number of leaves in T_8 (50 ppm IAA and 50 ppm GA_3 foliar application) treatment at 30 DAS and at harvest were 5.33 and 16.33 respectively (Table no. 2). At 30 DAS and at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 application) treatment showed statistically similar results (4.00 and 17.33 respectively) to T_8 (50 ppm IAA and 50 ppm GA_3 application) treatment. Higher concentrated GA_3 and IAA treated plant showed significantly better performance than the plants in control throughout the growing period. The lowest number of leaves was recorded from control treatment (T_1: No IAA and GA_3 application) throughout the growth period of BARI Mung-6 (2.67 at 30 DAS and 10.00 at harvest).

Similar results were found in soybean with 0-150 ppm GA_3 (Deotale *et. al.* 1998) and in French bean (Gabal *et. al.,* 1990) with 100-300 ppm IAA. GA_3 plays significant role in increasing number of leaves plant^{-1}. Gurdev and Saxena (1991) reported that 10^{-4} M of IAA increased leaves number per plant of wheat. Khalil and Mandurah (1989) also mentioned that IAA application increased the number of leaves per plant. Similar increase in leaf number was also experimented with 100–300 ppm of IAA Mathur (1971) in onion.

Table 2. Effect of IAA and GA_3 on Number of Leaves $plant^{-1}$ of BARI Mung-6.

Treatments	Number of leaves $plant^{-1}$ at 30 DAS	Number of leaves $plant^{-1}$ at Harvest
T_0	2.67 b	10.00 f
T_1	4.00 ab	10.67 ef
T_2	4.00 ab	11.33 e
T_3	3.33 ab	13.00 d
T_4	4.33 ab	14.33 c
T_5	4.00 ab	15.67 b
T_6	5.33 a	16.33 ab
T_7	4.33 a	15.33 bc
T_8	4.00 ab	17.33 a
LSD (0.05)	**1.02**	**2.04**
CV (%)	**19.17**	**14.36**

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.
CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3)

4.1.3. No. of branch $plant^{-1}$

Different levels of IAA and GA_3 application caused significant increase of no. of branch of BARI Mung-6 compared to control treatment (Tab. 3). It was found that T_8 (50 ppm IAA and 50 ppm GA_3 application) treatment showed the highest number of branch plant^{-1} (7.67 at harvest) (Tab. 3). However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results to T_8 ((50 ppm IAA and 50 ppm GA_3 application)) treatment. On the other hand, plants treated with water (T_0: No IAA and GA_3 foliar application) showed the lowest number of brunch plant^{-1} (1.67 at 30 DAS and 3.33 at harvest) (Table. 3) compared to plants treated with different concentration of IAA and GA_3.

Gou *et al.* (2010) experimented that auxin and gibberellin play vital role to regulate developmental processes of plant. Quaderi *et a*l. (2006) and Rastogi *et al.,* (2013) also found similar results about the role of IAA and GA_3.

Swaraj *et al.* (1995) found the increasing number of secondary branch with the increasing of PGRs in chickpea. On the contrary, Hussain *et al.* (2010) found negative effect of auxin if it is applied at higher concentration. It is observed that GA_3 is more effective in increasing the number of branch per plant than those of auxin.

Table 3. Effect of IAA and GA_3 on Number of Branch Plant^{-1} of BARI Mung-6.

Treatments	**Number of branch plant^{-1}**	
	At 30 DAS	**At Harvest**
T_0	1.67 a	3.33 g
T_1	1.33 a	4.00 f
T_2	2.67 a	4.67 e
T_3	1.67 a	5.33 d
T_4	1.67 a	6.00 c
T_5	2.33 a	6.33 bc

(Cont'd Table 3)

T_6	2.33 a	7.33 a
T_7	1.67 a	6.67 b
T_8	2.00 a	7.67 a
LSD (0.05)	**1.45**	**1.60**
CV (%)	**13.55**	**6.08**

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA + 25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3).

4.2 Crop Growth Parameters

4.2.1 SPAD value (%)

The soil plant analysis development (SPAD) chlorophyll meter is one of the most commonly used diagnostic tools to measure crop nitrogen status. It measures the leaf transmittance in red light at 650 nm (at which chlorophyll absorbs) and in near-infrared light at 940nm (for the correction of leaf thickness). The ratio of these two transmission values is referred to as SPAD reading or SPAD values (Hoel and Solhaug 1998).

Application of IAA and GA_3 alone and together with different concentrations showed significant influence on the SPAD values of BARI Mung-6 (fig 1). SPAD values was increased with the increasing concentration of IAA, GA_3 and both of them. The significant result was found in T_8 (50 ppm IAA and 50 ppm GA_3 foliar application) treatment and it was 55% (Table 1). However, T_6 and T_7 treatment showed statistically almost similar SPAD values of BARI Mung -6 (52

% and 50% respectively). On the other hand, control treatment (T_0: No IAA or GA_3 foliar application) showed the lowest SPAD values of BARI Mung-6 at different growth stage (42.33%). The combination of IAA and Gibberellin is higher concentration in T_8, T_6 and T_7, causes higher amount of SPAD values in BARI Mung -6.

Yuan & Xu, (2001) found that gibberellic acid delays senescence, improves growth and development of chloroplasts, and intensifies photosynthetic efficiency which leads to increased yield.

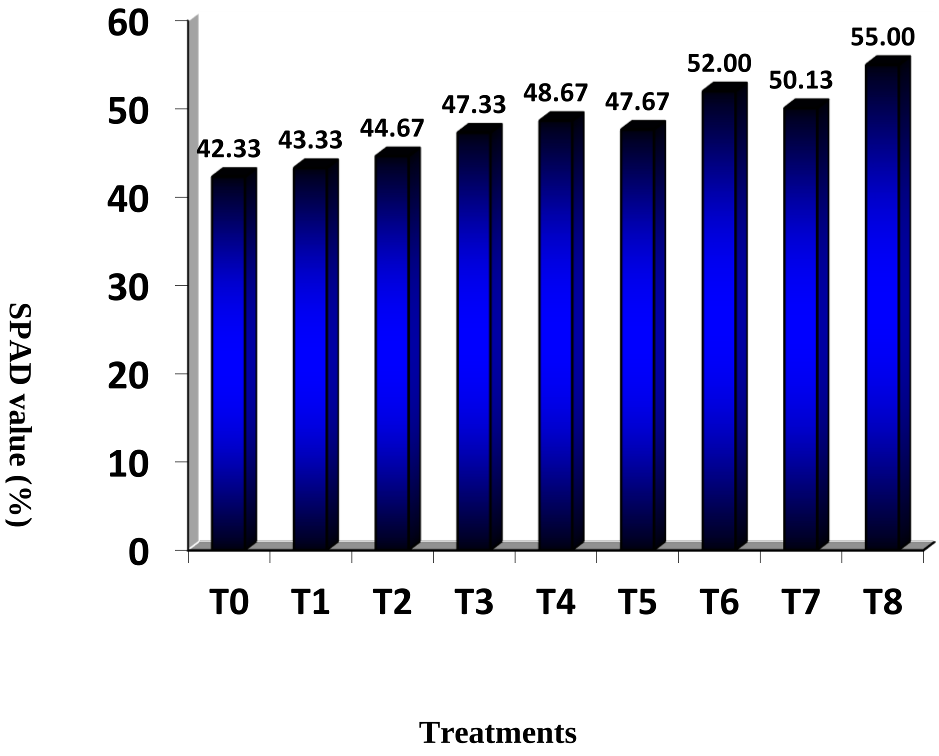


Fig.1: Effect of plant growth regulators with BARI mung-6 on SPAD value (%).

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3)

4.2.2 Days to flowering

The effect of IAA and GA_3 on days to flowering plant^{-1} of BARI Mung-6 was found significant (Appendix VIII). Number of days to flowering was decreased, which means early flowering occurred due to the foliar application of IAA and GA_3. The lowest value was recorded at (T_0: No IAA and GA_3 foliar application) (31.66) and the highest in T_8 (50 ppm IAA and 50 ppm GA_3 application) (27.33). However, statistically similar result was detected for T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) (28.33) (Table 4). As the concentration of Gibberellin is higher in both T_8 and $T_{6,}$ which causes early flowering in plants.

Lim *et al.* (2003) mentioned that plant growth hormones like auxin, cytokinin and gibberellins play a role in suppressing flower and pod dropping.

4.2.3 Days to maturity

The effect of IAA and GA_3 on the number of days to maturity plant^{-1} of BARI Mung-6 was found significant (Appendix XI). Number of days to maturity was decreased, which means early maturity occurred due to the foliar application of IAA and GA_3. The highest value was recorded at (T_0: No IAA and GA_3 foliar application) (61.66) and the lowest in T_8 (50 ppm IAA and 50 ppm GA_3 application) (55.33). However, statistically similar result was detected for T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) (56.33) (Table 4). As the concentration of Gibberellin (GA_3) is higher in both of the treatments T_8 and $T_{6,}$ which causes early maturity in plants.

Chakrabarti and Mukherji (2003) experimented that Gibberellic acid (GA_3) is known to be importantly concerned in the regulation of plant responses to external environment.

Table 4. Effect of IAA and GA_3 on Days to Flowering and Days to Maturity of BARI Mung-6.

Treatment	Days to Flowering	Days to Maturity
T_0	41.66 a	61.66 a
T_1	40.83 a	60.33 b
T_2	40.10 a	59.66 b
T_3	39.91 b	58.33 c
T_4	39.70 bc	56.33 e
T_5	39.66 c	57.66 cd
T_6	37.13 cd	56.33 e
T_7	38.33 c	57.33 d
T_8	35.33 d	55.33 f
LSD $_{(0.05)}$	**1.75**	**1.91**
CV (%)	**13.20**	**10.90**

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3).

4.3 Yield contributing parameters

4.3.1. Number of Pods plant^{-1}

Pods plant^{-1} showed significant variation due to the effects of different growth regulators (Table 5). The highest number of pods plant^{-1} (37.66) was obtained from the T_8 (50 ppm IAA and 50 ppm GA_3) treatment. The lowest number of pods plant^{-1} (27.33) was found when the plants were raised without growth regulators (T_0: 0 ppm of IAA and 0 ppm of GA_3). However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results (35.66) to T_8 ((50 ppm IAA and 50 ppm GA_3 application)) treatment.

This result is supported with the findings of Foysal (2014) who found the no. of pods plant^{-1} of mungbean differed significantly due to the application of plant growth regulators.

Genotypic variations in effective pod per plant was observed by Mondal *et al.* (2004) in mungbean. Similar result was found by Aslam *et al. (*2004) and he experimented significant differences between mungbean varieties for no. of pods plant^{-1}. Similar result was also found by Parvez *et al.* (2013), Kumar *et al.* (2018) and Raj and Tripathi, (2005). They found that different varieties had significant effects on number of pods plant^{-1} of mungbean.

4.3.2. Pod length

Pod length showed significant variation due to the application of different growth regulators (Table. 5). T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest pod length (14.99cm). The lowest pod length (8.60 cm) was obtained by T_0 (0 ppm of IAA and 0 ppm of GA_3). However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results (13.98cm) to T_8 ((50 ppm IAA and 50 ppm GA_3 application) treatment.

Foysal (2014) also found the similar result. Sarkar *et al.* (2014) reported that pod length differed from varieties to varieties. The probable reason of this difference could be the genetic makeup of the varieties. Similar result was found by Aslam *et al.* (2004) and he observed significant differences between mungbean varieties for pod length.

4.3.3. Number of Seeds pod^{-1}

Application of growth regulators at different levels showed significant variation on number of seeds pod^{-1} (Table. 5). Among the different growth regulators T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest number of seeds pod^{-1} (13.78). The lowest number of seeds per pod (9.29) was recorded with T_0 (0 ppm of IAA and 0 ppm of GA_3) treatment where no growth regulators were applied. Foysal (2014) found that number of seeds per pod significantly increased by growth regulator.

Table 5. Effects of IAA and GA_3 on Number of Pods plant^{-1}, Pod Length (cm) and Number of seeds per pod of BARI Mung-6.

Treatments	Number of Pods per plant	Pod Length (cm)	Number of seed per pod
T_0	27.33 g	8.60 g	9.29 g
T_1	28.66 f	10.33 f	10.09 f
T_2	30.33 e	11.39 e	11.03 e
T_3	31.66 d	12.30 d	11.66 d
T_4	33.66 c	13.29 bc	11.96 c
T_5	33.33 c	12.76 cd	11.85 cd
T_6	35.66 b	13.98 b	12.89 b
T_7	35.33 b	13.88 b	13.03 b
T_8	37.66 a	14.99 a	13.78 a
LSD $_{(0.05)}$	**1.01**	**1.72**	**1.28**
CV (%)	**11.79**	**13.34**	**12.38**

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3).

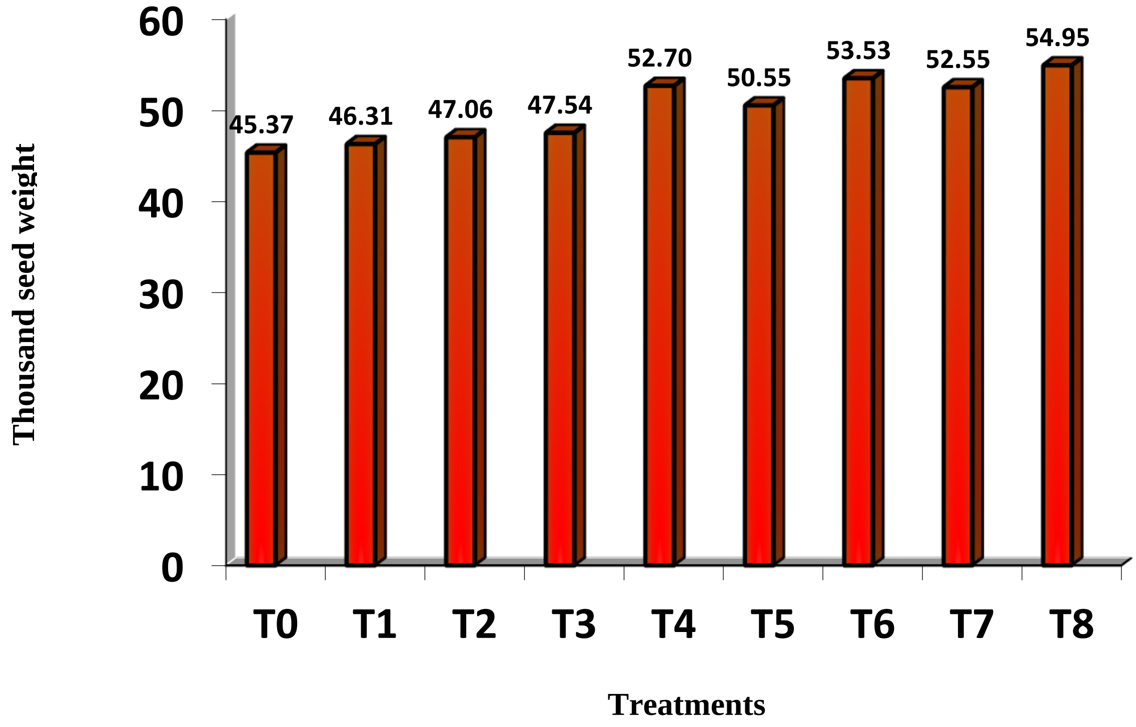
4.4. Weight of 1000 seeds

Application of growth regulators at different levels showed significant variation on thousand seeds weight (Fig. 2). Among the different growth regulators levels T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest thousand seed weight (54.95 g). The lowest thousand seeds weight (45.37 g) was recorded with T_0 (0 ppm of IAA and 0 ppm of GA_3) treatment where no growth regulators were applied.

However, at harvest, T_6 and T_4 treatment showed statistically similar results (53.43 g and 52.70 g, respectively) to T_8 (50 ppm IAA and 50 ppm GA_3 application) treatment. It proves that effect of GA_3 is more in increasing thousand seed weight than the effect of auxin.

This result was consistent with the findings of Foysal (2014) who found 1000 grains weight of mungbean differed significantly due to PGRs. The highest 1000 grains weight (44.50 g) was recorded from the 40 ppm NAA treatment and the lowest (37.14 g) was found in the 0 ppm NAA treatment.

Thousand seeds weight were increased with the increasing rate of GA_3 in grasspea (Rahman *et al.* 1989), in sesame (Sontakey *et al.* 1991) and in soybean (Reena *et al.*, 1999).



In a column, means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

Fig.2: Effect of plant growth hormones with BARI mung-6 on the number of thousand seeds weight.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3)

4.5. Seed yield

There was a significant variation in the seed yield of mungbean plants due to the application of plant growth regulators (Table 6). From the table it was observed that T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest seed yield (1.62 t/ ha). The lowest seed yield (1.20 t/ ha) was observed from T_0 (0 ppm of IAA and 0 ppm of GA_3) treatment where no growth regulators were applied. However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results (1.57 t/ ha) to T_8 ((50 ppm IAA and 50 ppm GA_3 application) treatment.

This result was consistent with the findings of Foysal (2014) where Grain yield of mungbean varied significantly due to the application of plant growth regulators. The highest grain yield was recorded from the 40 ppm NAA treatment whereas, the lowest was found in the 0 ppm NAA treatment in his experiment.

Sinha *et al.* (1989), Poehlman (1991) and Miah *et al.,* (2009) reported that mungbean being a warm season plant produced higher yield at the optimum mean temperature range of 25-30°C. The highest seed yield obtained due to suitable temperature prevailing accompanied by higher soil moisture content due to sufficient rainfall, which enhanced the vegetative as well as reproductive growth of the crop and the lowest yields of low quality seeds are produced in late sowing of rnungbean. Late sown crop could not attain proper growth which resulted in drastic reduction in yield. Rahman *et al.* (1989) proved that seed yield was increased by applying foliar spray of IAA and GA_3 in grasspea.

4.6. Stover yield

Different levels of growth regulators showed significant variations in terms of stover yield of mungbean (Table 6). Among the different levels of growth regulators, T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest stover yield (1.78 t/ ha). On the contrary, the lowest stover yield (1.34 t/ ha) was observed from T_0 (0 ppm of IAA and 0 ppm of GA_3) treatment where no growth regulators were applied. However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results to T_8 ((50 ppm IAA and 50 ppm GA_3 application) treatment.

Varietal performance showed significant variation on stover yield which was supported by the findings of Parvez *et al.* (2013) and Hossain and Solaiman, (2004).

4.7. Biological yield

Different levels of growth regulators showed significant variations in respect of biological yield of mungbean (Table 6). Among the different levels of growth regulators, T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest biological yield (3.74 t/ ha). The lowest biological yield (1.54 t/ ha) was observed from T_0 (0 ppm of IAA and 0 ppm of GA_3) treatment where no growth regulators were applied. However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results to T_8 ((50 ppm IAA and 50 ppm GA_3 application) treatment.

This result was not similar with the findings of Foysal (2014) where the highest biological yield (3.24 t/ ha) was observed from 0 ppm NAA (G_0) treatment and the lowest (2.98 t/ ha) was found in 40 ppm NAA (G_{40}) treatment.

4.8. Harvest Index

Different levels of growth regulators showed significant variations in respect of harvest index of mungbean (Table 6). Among the different levels of growth regulators, T_8 (50 ppm IAA and 50 ppm GA_3) treatment showed the highest harvest index (47.64 %). The lowest harvest index (%) was observed from T_0 (0 ppm of IAA and 0 ppm of GA_3) (32.64 %) treatment where no growth regulators were applied.

However, at harvest, T_6 (25 ppm IAA and 50 ppm GA_3 foliar application) treatment showed statistically similar results to T_8 (50 ppm IAA and 50 ppm GA_3 application) treatment.

The similar result was reported by Quaderi *et al.* (2006) that shows seed treatment with 200 ppm IAA resulted the highest harvest index (38.48) of mungbean.

Table 6. Effect of IAA and GA_3 on Number of Seed yield (t/ha), Stover Yield (t/ha), Biological Yield (ton/ha) and Harvest Index (%) of BARI Mung 6.

Treatments	Seed yield (t/ ha)	Stover Yield (t /ha)	Biological Yield (t /ha)	Harvest Index (%)
T_0	1.20 f	1.34 b	1.54 d	32.64 c
T_1	1.27 ef	1.46 b	1.73 cd	37.33 bc
T_2	1.36 de	1.58 b	1.82 cd	37.78 bc
T_3	1.41 d	1.67 b	1.90 c	38.00 bc
T_4	1.47 c	1.88 a	2.09 b	39.81 bc
T_5	1.49 b	2.00 a	2.36 ab	41.02 ab
T_6	1.57 a	2.17 a	3.63 a	42.43 ab
T_7	1.54 a	2.10 a	3.40 ab	42.24 ab
T_8	1.62 a	1.78 a	3.74 a	43.64 a
LSD $_{(0.05)}$	**0.10**	**0.49**	**0.50**	**1.65**
CV (%)	**5.86**	**21.22**	**12.63**	**11.08**

In a column having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

CV= Coefficient of variation, LSD = Least significant difference.

(T_0= 0 ppm IAA+ 0ppm GA_3, T_1 = 25 ppm IAA, T_2= 50 ppm IAA, T_3= 25 ppm GA_3, T_4=50 ppm GA_3, T_5= 25 ppm IAA + 25 ppm GA_3, T_6= 50 ppm IAA +25 ppm GA_3, T_7= 25 ppm IAA+ 50ppm GA_3, T_8= 50 ppm IAA + 50 ppm GA_3).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the central research field of Sher-e-Bangla Agricultural University, Dhaka, during the period of March to June, 2020 to study the effect of plant growth regulators on growth and yield of BARI Mung-6.

The experiment was consisted of nine levels of treatments viz. i) T_0 = Untreated Control (IAA 0.0 mg/L , GA_3 0.0 mg/L); ii) T_1 = Foliar spray of IAA 25 mg/L at 30 DAS ; iii) T_2 = Foliar spray of IAA 50mg/L at 30 DAS; iv) T_3 = Foliar spray of GA_3 25 mg/L at 30 DAS; v) T_4 = Foliar spray of GA_3 50 mg/L at 30 DAS; vi) T_5 = Foliar spray of IAA 25 mg/L + GA_3 25 mg/L at 30 DAS; vii) T_6 = Foliar spray of IAA 25 mg/L + GA_3 50 mg/L at 30 DAS; viii) T_7 = Foliar spray of IAA 50 mg/L + GA_3 25 mg/L at 30 DAS; ix) T_8 = Foliar spray of IAA 50 mg/L + GA_3 50 mg/L at 30 DAS.

The experiment was carried out in randomized complete block design (RCBD) with three replications. The layout of the experiment was prepared carefully for distributing the treatments properly. Total area of the experiment was 300 m^2. The experimental field was divided into 3 blocks. Each block was again divided into 9 plots. The total numbers of unit plots of the experiment were (9 × 3) =27. The size of the unit plot was 3 m × 2 m (6 m^2). The distances between plot to plot and replication to replication were 0.50 m and 1.00 m, respectively. The treatments were randomly distributed to each block following the experimental design.

On 17th March 2020, the first ploughing was given and final land ploughing was given on 19th March, 2020. The experimental field was divided and arranged according to experimental layout. On 19 March, 2020, the basal fertilizer doses were applied. Before sowing seeds, the land was prepared well by two plowing followed by laddering respectively on 8th and 10th March.

Urea, TSP and MOP were applied as basal to supply 46% N, 48% P_2O_5 and 60% K_2O @ 30, 80 and 30 kg/ ha, respectively.

Data was recorded on growth, SPAD value, days to flowering, days to maturity, stover yield, biological yield, thousand seeds weight, seed yield and harvest index of experimental materials of whole plot. The analysis was performed by using the MSTAT–C (Version 2.10) computer package program. The mean differences among all the treatments were compared by least significant difference test (LSD) at 5 % level of significance.

Results also showed that growth regulators had significant effect on crop growth characters. Application of IAA and GA_3 alone and together with different concentrations showed significant influence on the SPAD values of BARI Mung-6 (Fig. 1). SPAD values was increased with the increasing concentration of IAA, GA_3 and both of them. The significant result was found in T_8 treatment and it was 55% (Fig. 1). However, T_6 and T_7 treatment showed statistically almost similar SPAD values of BARI Mung -6 (51% and 52%, respectively). On the other hand, control treatment showed the lowest SPAD values of BARI Mung-6 at different growth stage (42.33%). The combination of IAA and Gibberellin is higher concentration in $T_{8,}$ T_7 and $T_{6,}$ causes higher amount of SPAD values (%) in BARI Mung -6. In the contrast, Number of days to flowering was decreased due to the foliar application of IAA and GA_3 alone and together. The highest value was recorded at (T_0: No IAA and GA_3 foliar application) (36.66) and the lowest in T_8 (27.33). However, statistically similar result was detected for T_6 (28.33) (Table 4). As the concentration of Gibberellin is higher in both T_8 and T_6 that causes early flowering in plants. Similarly, Number of days to maturity was decreased, which means early maturity occurred due to the foliar application of IAA and GA_3. The highest value was recorded at T_0 (61.66) and the lowest in T_8 (55.33). However, statistically similar result was detected for (56.33) (Table 4). As the concentration of

Gibberellin (GA_3) is higher in both of the treatments T_8 and T_6 that causes early maturity in plants.

Yield and yield contributing parameters showed to be influenced by the foliar application of IAA and GA_3 alone and together with different concentrations. The highest number of pods plant^{-1} (37.66) was obtained from the T_8. The lowest number of pods plant^{-1} (27.33) was found when the plants were raised without growth regulators. Similarly, T_8 treatment showed the highest pod length (14.99cm) and the lowest pod length (8.60 cm) was obtained by T_0. . Among the different growth regulators levels T_8 treatment showed the highest number of seeds pod^{-1} (13.78). The lowest number of seeds pod^{-1} (9.29) was recorded with T_0. Again, T_8 treatment showed the highest seed yield (1.62 t/ ha). The lowest seed yield (1.20 t/ ha) was observed from T_0. Among the different growth regulators levels T_8 treatment showed the highest thousand seed weight (54.95 g) and the lowest thousand seeds weight (45.37 g) was recorded with T_0. Then, T_8 treatment showed the highest stover yield (1.78 t/ ha). On the contrary, the lowest stover yield (1.34 t/ ha) was observed from T_0. Among the different levels of growth regulators, T_8 treatment showed the highest biological yield (3.74 t/ ha) and the lowest biological yield (1.50 t/ ha) was observed from T_0. In case of Harvest Index (%), T_8 treatment showed the highest harvest index (47.64 %). The lowest harvest index (%) was observed from T_0 (32.64 %).

From the results of the experiment, it might be concluded that the performance of BARI Mung-6 was better in T_8 (50 ppm IAA and 50 ppm GA_3) foliar application. T_6 showed statistically similar result as the concentration of GA_3 was higher in those treatments, which is responsible mainly for the higher growth, maturity and yield of mungbean. For determination of effectiveness of IAA, GA_3, and both of their foliar application, further trail should be performed in different locations for more conformation.

Conclusions

Based on the above results of the present study, the following conclusions may be drawn-

1. Combined effect of IAA @ 50 mg/L and GA_3 @ 50 mg/L at 30 DAS (T_8) showed the highest seed yield of BARI Mung-6 (1.62 t/ ha) than the others.
2. However, T_6 showed statistically similar result as the concentration of GA_3 was higher in those treatments, which is responsible mainly for the higher growth, maturity and yield of mungbean.
3. The growth regulators remarkably increased yield % over control compared to that of untreated plants.

Recommendations

The following recommendations may be suggested for further study:

1. Combined effect of IAA and GA_3 @ 50 mg/L at 30 DAS (T_8) showed the highest seed yield of BARI Mung-6 than the others. Further study may be needed to ensure better result.
2. The national extension services should be encouraged to organize demonstration plots using PGRs to popularize it among farmers.
3. Government should emphasize on lowering the cost of PGRs the increase the usages of PGRs on mungbean and other crops production.
4. Plant growth regulators should be used as substitute over normal fertilizers.

CHAPTER VI

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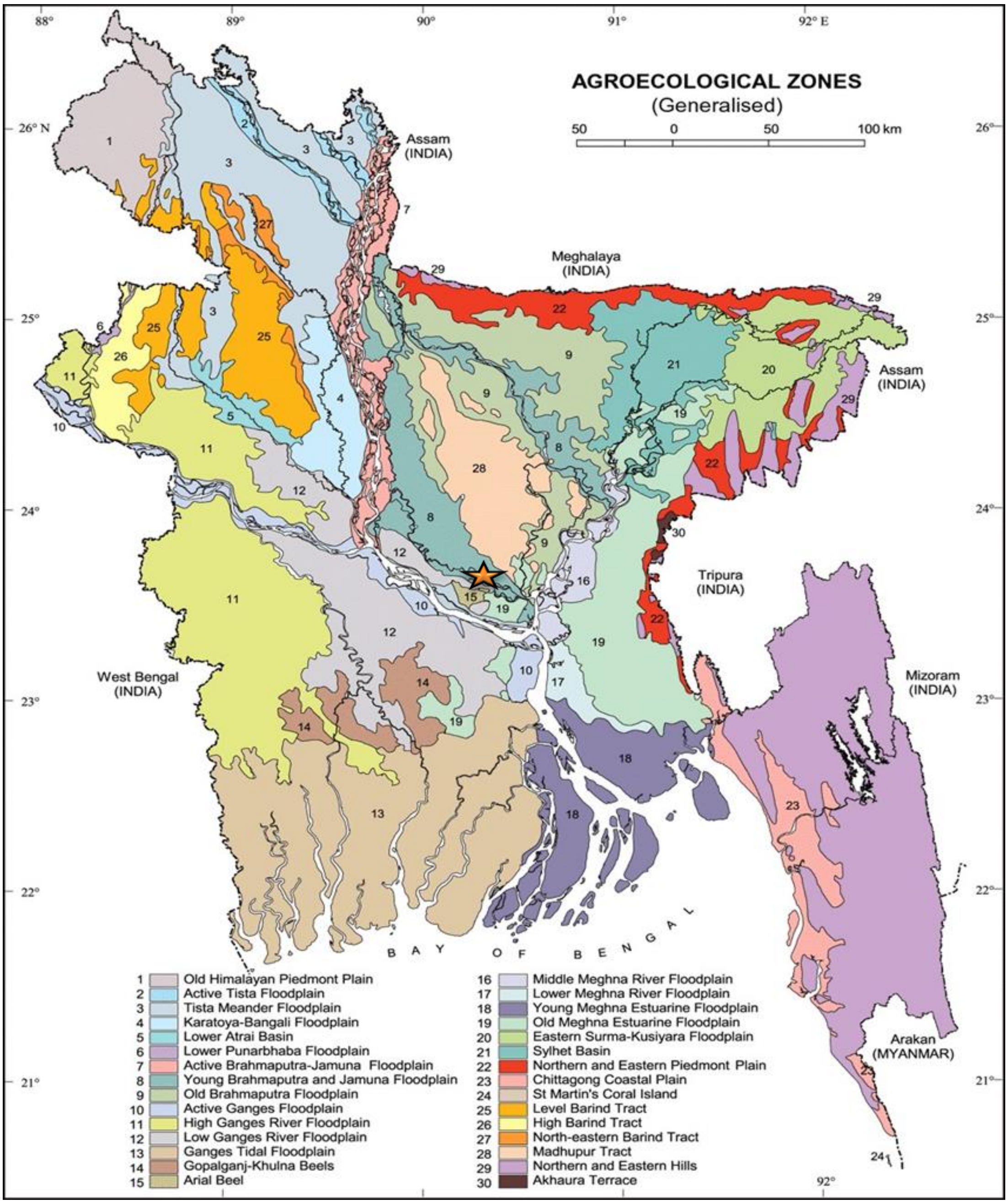
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from March 2020 to July 2020.

Month	Air temperature (^{0}C)		Relative Humidity (%)		Total rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
March	37.4	20.2	80.2	32.4	3.80
April	39.4	19.4	80.2	39.2	65.60
May	38.2	19.3	89.2	40	96.23
June	37.2	17.4	88.4	46.3	282.7
July	35.6	18.2	88.2	55.4	107.8

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka

Appendix III. Results of morphological, mechanical and chemical analysis of soil of the experimental plot.

A. Morphological Characteristics

Morphological features	Characteristics
Location	Central Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red-brown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

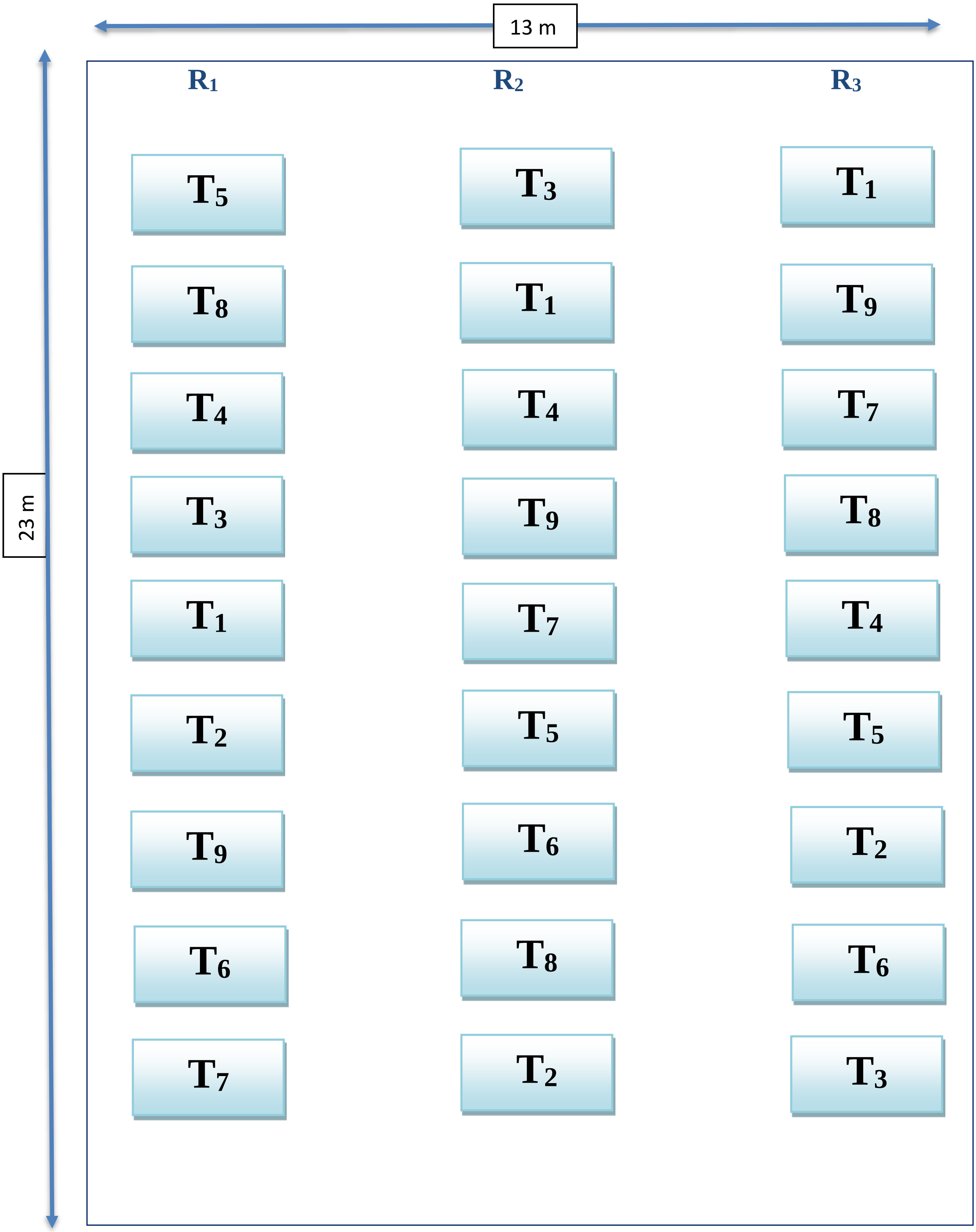
Constituents	Percentage (%)
Sand	27
Silt	43
Clay	30

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experimental field



Appendix V. Analysis of variance of data on plant height of BARI Mung-6.

Sources of variation	Degrees of freedom (d.f)	Mean square of plant height at	
		30 DAS	HARVEST
Replication	2	0.25	3.03**
Treatments	8	1.94	103.90 ***
Error	16	2.28	0.486

*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix-VI. Analysis of variance of data on leaves plant^{-1} BARI Mung-6.

Sources of variation	Degrees of freedom (df)	Mean square of leaves plant^{-1} at	
		30 DAS	HARVEST
Replication	2	0.78	1.44*
Treatments	8	1.58	21.00***
Error	16	1.36	0.36

*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VII. Analysis of variance of data on number of branch plant^{-1} of BARI Mung-6.

Sources of variation	Degrees of freedom (df)	Mean square of number of branch plant^{-1} at	
		30 DAS	HARVEST
Replication	2	0.04	1.37***
Treatments	8	0.56	6.62***
Error	16	0.70	0.12

*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VIII. Analysis of variance of SPAD value (%), Days to Flowering and Days to Maturity of BARI Mung-6.

Sources of variation	**Degrees of freedom (df)**	**Mean square of**		
		SPAD value (%)	**Days to Flowering**	**Days to Maturity**
Replication	2	1.44	1.15	0.78.
Treatments	8	52.50***	38.20***	13.08***
Error	16	0.44	1.02	0.28

*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix IX. Analysis of variance on Number of Pods plant^{-1}, Pod Length (cm) and Number of seed pod^{-1} of BARI Mung-6.

Sources of variation	Degrees of freedom (df)	Mean square of		
		Number of Pods per plant	Pod Length (cm)	Number of seed per pod
Replication	2	0.26	0.07	0.05
Treatments	8	35.04***	12.0356 ***	6.16***
Error	16	0.34	0.17	0.03
*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability				

Appendix X. Analysis of variance on Number of Weight of 1000 seeds, Seed yield (t /ha) and Stover Yield(t/ha) of BARI Mung-6.

Sources of variation	Degrees of freedom (df)	Mean square of		
		Weight of 1000 seeds	Seed yield (ton/ha)	Stover Yield (ton/ha)
Replication	2	5.84	0.02*	0.19
Treatments	8	37.56***	1.15***	1.87***
Error	16	3.85	0.03	0.08
*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability				

Appendix-XI. Analysis of variance on Number Biological Yield (t /ha) and Harvest Index (%) of BARI Mung-6.

Sources of variation	Degrees of freedom (d.f)	Mean square of	
		Biological Yield (t /ha)	Harvest Index (%)
Replication	2	0.29	37.02
Treatments	8	5.88 ***	52.70 *
Error	16	0.08	19.52
*** :Significant at 1% level of probability; ** : Significant at 1% level of probability; * : Significant at 5% level of probability			

Some Pictorial View During Experimental Period

Plate 1. Photograph during land pre--paration and seed sowing.

Plate 2. Photograph during data collection.

Plate 3. Photograph during collecting data of growth parameters.

Plate 4. Photograph of seed yield of BARI mung-6.