EFFECT OF ROW SPACING AND GROWTHREGULATOR (NAA) ON GROWTH AND YIELD OF MUNGBEAN

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EFFECT OF ROW SPACING AND GROWTH REGULATOR (NAA) ON GROWTH AND YIELD OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled,**"Effect of row spacing and growth regulator (NAA) on growth and yield of mungbean"**submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of**MASTER OF SCIENCE (MS) IN AGRONOMY,**embodies the result of a piece of *bonafide* research work carried out by**A. K. M. Foysalkabir,** Registration No.**08-03048** 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 during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

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The Author

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ABSTRACT

A field experiment was conducted at the Research Field, SAU, Dhaka, in the *Kharif-II* season during the period from August 2013 to November 2013 to study the effect of row spacing and growth regulator (NAA) on growth and yield of mungbean**.** The experiment consists of four levels of NAA viz. 0, 20, 40 and 60 ppm and three different spacing viz. 20cm × 10cm, 30cm × 10cm and 40cm × 10cm. The experiment was laid out in randomized complete block design with three replications.The result indicated significant variations in plant height, number of branches plant^{-1}, leaf dry weight, stem dry weight, root dry weight, number of pod plant^{-1}, pod length,number of seed plant^{-1}, weight of 1000 seeds, grain yield,stover yield, biological yield and harvest index due to row spacing and/or plant growth regulator (NAA). The treatment combinations,the maximum plant height,number of branches plant^{-1}, leaf dry weight, stem dry weight, root dry weight and leaf area index were recorded with 30cm × 10cm when treated with 40 ppm NAA irrespective of growing period. This combination also exhibited maximum number of pods plant^{-1}, longest pod length and maximum number of seed pod^{-1}. The maximum weight of 1000 seeds, highest grain yield and harvest index were found when mungbean was sown with row spacing in30cm × 10cm when treated with 40 ppm NAA.

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ABBREVIATIONS AND ACRONYMS

%	:	Percentage
@	:	At the Rate of
Abstr.	:	Abstract
AEZ	:	Agro-Ecological Zone
Agric.	:	Agriculture
AVRDC	:	Asian Vegetables Research and Development
BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit Cost Ratio
cm.	:	Centimeter
cv.	:	Cultivar
DAS	:	Day After Sowing
et al.	:	et alii (and others)
FAO	:	Food and Agriculture Organization
Fig.	:	Figure
FW	:	Fresh weight
FYM	:	Farm Yard Manure
G	:	Gram
Hort.	:	Horticulture
i.e.	:	That is
J.	:	Journal

K	:	Potassium
Kg	:	Kilogram
LSD	:	Least Significant Difference
M	:	Meter
MP	:	Muriate of Potash
N	:	Nitrogen
NS	:	Non-significant
^{O}C	:	Degree Celsius
P	:	Phosphorus
RCBD	:	Randomized Complete Block Design
Sci.	:	Science
Soc.	:	Society
T	:	Tonne
ton/ha	:	Ton per hectare
Tk.	:	Taka
TSP	:	Triple Super Phosphate
UK	:	United Kingdom
UNDP	:	United Nations Development Program
Viz.	:	Namely

CHAPTER 1

INTRODUCTION

Pulse crops belong to grain legume. Bangladesh grows various types pulse crops. Among them lentil, cowpea, blackgram, mungbean, field pea and grass pea are important. Pulses constitute the main source of protein for the people, particularly the poor sections of Bangladesh. These are also the best source of protein for domestic animals. Besides, the crops have the capability to enrich soils through nitrogen fixation. Pulse protein is rich in lysine that is deficient in rice. According to FAO (2013) recommendation, a minimum intake of pulse by a human should be 80 gm/day, whereas it is 7.92 g in Bangladesh (BBS, 2011). This is because of fact that national production of the pulses is not adequate to meet our national demand. Both the acreage and production of the pulses are decreasing in Bangladesh day by day due to the inception of wheat and born rice in our cropping pattern with irrigation facilities.In Bangladesh, total production of pulses is only 0.65 million ton against 2.7 million tons requirement. This means the shortage is almost 80% of the total requirement (Rahman and Ali, 2007). This is mostly due to low yield (MoA, 2013). At present, the area under pulse crop is 0.406 million hectare with a production of 0.322 million tons (BBS, 2013). Where mungbean is cultivated in the area of 0.108 million ha with production of 0.03 million tons (BBS, 2014).

Mungbean [*Vignaradiata* L. Wilczek] is one of the most important pulse crops in Bangladesh. This commonly grown pulse crop belongs to the family Fabaceae. Its edible grain is characterized by good digestibility, flavor, high protein content and absence of any flatulence effects (Ahmad *et al.*, 2008). It holds the 3rd in protein content and 4th in both acreage and production in Bangladesh(BBS, 2012). The agro-ecological condition of Bangladesh is favorable for growing this crop. Mungbean grain contains 51% carbohydrate, 26% protein. 10% moisture. 4%

mineral and 3% vitamins (Khan, 1981; Kaul, 1982). On the nutritional point of view, mungbean is one of the best among pulses (Khan, 1981). It is widely used as "Dal" in the country like other pulses.

Among the pulse crops, mungbean has a special importance inintensive crop production system of the counts for its short growing period (Ahmad *et al*, 1978). In Bangladesh, it can be grown in late winter and summer season. Summer mungbean can tolerate a high temperature exceeding 40°C and grows well inthe temperature range of 30-35 °C. Mungbean gives higher yield under summer planting than late winter season (Singh and Yadav, 1978). This crop is also reported to be drought tolerant and can also be cultivated inareas of low rainfall, but also grows well inareas with 750-900 mm rainfall (Kay, 1979). So, cultivation of mungbean in the summer season could be an effective effort to increase pulse production in Bangladesh. The green plants can also be used as animal feed and the residues as manure. The crop is potentially useful in improving cropping system as it can be grown as a catch crop due to its rapid growth and early maturing characteristics. It can also fix atmospheric nitrogen through the symbiotic relationship between the host mungbean roots and soil bacteria and thus improves soil fertility. Such effort may also help to save the foreign exchange for importing mungbean grain from abroad (Gowda and Kaul, 1982).

In Bangladesh, althoughmungbean ranks 4^{th} in acreage and production but ranks 1st in market price. Mungbean covers an area of 22,267 hectare and production was about 17000 metric tons. The average production of mungbean in the country is about 763 kg ha^{-1} (BBS, 2014). About 3 t ha^{-1} of seed yield have been reported in a trial in Taiwan (Lawn, 1978). But in Bangladesh the average yield is very low. The average yield of mungbean is 0.69 t ha^{-1} (BBS, 2014). The yield difference indicates the wide scope for increasing yield of mungbean.

The reasons for low yield are manifold; some are varietals and some are agronomic management practices. Various experiments and work on spacing of mungbean have been carried out in Bangladesh, as well as in other countries to find out the suitable plant population to get maximum yield (Mondal, 2007). Narrower spacing reduces the yield of mungbean up to 20 to 40% due to competition for light, space, water and nutrition, whereas wider spacing reduces yield by reducing plant population (AVRDC, 1976).The optimum spacing favors the plants to grow in their both aerial and underground parts through efficient utilization of solar radiation and nutrients (Miah *et al.*, 1990). Plant spacing directly affects the physiological activities through intra-specific competition. Narrowing of plant spacing by increasing seed rate generally means a more uniform distribution of plants over a given area, thus matching the plant canopy effective in intercepting radiant energy and shading weeds. Though wider space allows individual plants to produce more branches and pods, but it provides smaller number of pods per unit area due to fewer plants per unit area.

Plant growth regulators (PGRs) are being used as aids to enhance yield of different crops (Nickell, 1982; Sarkar *et al*., 2002; Sarkar *et al*., 2009; Bakhsh*et al*., 2011). Naphthalene acetic acid is the growth promoting substance, which may play a significant role to change growth characters and yield of mungbean. Foliar application of growth regulator-NAA produces more fertile grain. NAA has a positive effect on growth and higher dry matter production (Nickell, 1982). Foliar spray of NAA (15 ppm) at 15, 30 and 45 days after sowing increased fruit set and productivity (Resmi andGopalakrishnan, 2004). Lee (1990) examined the foliar application of NAA and also found to increase plant height, number of leaves plant^{-1}, fruit size with consequent enhancement in seed yield in different crops and are being advised to use PGRs to get higher production. Therefore, NAA might have positive effect on higher yield under various plant spacing. Although, there are various findings on spacing and fewer on NAA separately, there are no research findings on NAA under different spacing.

Considering the above background, this research program is initiated with the following objectives:

1. To observe the effect of row spacing on the growth, yield attributes and yield of mungbean;

2. To evaluate the effect of naphthalene acetic acid (NAA) on growth, yield attributes and yield of summer mungbean;

3. To find out the interaction effect of row spacing and naphthalene acetic acid (NAA) on the growth, yield attributes and yield of mungbean.

CHAPTER 2

REVIEW OF LITERATURE

The growth and yield of mungbean are influenced by row spacing and Naphthalene Acetic Acid (NAA). Following review of literature includes reports as studied by several investigators who were engaged in understanding the problems that may help in the explanation and interpretation of results of the present investigation. In this chapter, an attempt has been made to review the available information in home and abroad regarding the effect of row spacing and naphthalene acetic acid on the yield of mungbean.

2.1. Effect of row spacing

One approachof elevating the seed yield of mungbean by Asian Vegetables Research and Development Center (AVRDC) is to increase yield by increasing plant density. The yield of mungbean does not increase linearly with increase in density as it does in soybean. The number of pods per plant of mungbean decreases as density increases unlike soybean (Mackenzie *et al.*, 1975).

Grain yield generally increases with raising plant population but this relationship is parabolic (Hamblin, 1976). In general, yield of edible podded pea decreased with increase in plant spacing and vegetable pea yield decreased with increase in line to line spacing.

Narrow row spacing with high plant density increased the grain yield of pea significantly (Singh and Yadav, 1978). However, Singh *et al*. (1981) obtained high grain yield of peas at 15 cm × 15 cm spacing and the grain yield decreased when the spacing was increased to 50 cm from 25 cm (Yadav*etal*., 1992). Singh *et al.*, (1993) reported that, pea genotypes do not respond significantly to plant density in terms of seed yield and attributes.

Per plant dry matter yield decreased progressively with increasing density. Grain yield plant^{-1} decreased with increasing density but the yield density function constructed based on grain yield/unit area followed a quadratic relationship. Increased plant density resulted in plants bearing less pod and seed in *Vicia fava*L. (Zahab*et al.,* 1981).

In Arkansas, Betty and Aulakh (1982) adjusted plant population with row spacing and that April plantings in 18-cm rows with 60 seeds m^{-2} and 48-cm rows with 46 seeds m^{-2} yielded more than May or June plantings at any row spacing.

High yield of good quality pod can be obtained from increased plant density and weed free environment in *Vignaunguiculata*(Braithwaite, 1982).

Muchow and Edwards (1982) reported significantly positive linear trends of dry matter production in three varieties of mungbean to increasing density.

Narrow spacing significantly increased dry matter production in pigeon pea (Madhavan*et al.,* 1986). Narrow spacing increased plant height and reduced the number of branches plant^{-1} in crops (Narayanan and Narayanan, 1987; Chimanshette and Dhoble, 1992; Hossain and Salahuddin, 1994).

Yield per hectare and number of seeds per podincreased with increasing plant density whereas yield plant^{-1} and number of pods plant^{-1} decreased with increasing plant density in mungbean (Panwar and Sirohi, 1987).

Plant density has considerable effect on the suppression of weeds. Plant density, species proportion, and spatial arrangements are important considerations, which mediate the influence of environmental and biological factors (Radosevich, 1987).

Agasimani*et al.* (1984) reported that 20 cm × 15 cm spacinggave higheryield in groundnut.

It was stated that plant density is the most important non-momentary input which can be maintained through plant and row spacing to obtain higher yield per unit land area (Lain and Chauhan, 1988).

Miah (1988) recorded higher crop growth rate with higher planting density in cowpea and mungbean.

Seeds per plant was higher under 30 cm row spacing in dwarf pea because of more pods plant^{-1} and seeds pod^{-1} (Saharia and Thakuria, 1988).

Plant density is the most important yield contributing character, which can maximize yield (BabuandMitra, 1989).

Variable plant densities were achieved by varying the row spacing. Seed yield of soybean was significantlyhigher with higher population in narrower rows than in the wider rows (Ethredge*etal.*, 1989).

Hamid (1989) found that mungbean grown at very high density failed to produce yield because of high rate of mortality.

In another study, inter row spacing of 22.5 cm produced highest grain yield of the pulses followed by 15 cm spacing (Tripurari and Yadav, 1990). Rajput *et al.* (1991) reported that significantly higher grain and straw yields were recorded under narrower row spacing (30 cm) than under wider row spacing (45 cm) in soybean.

Porwal*et al.* (1991) found that row spacing significantly affected seed yield and the seed index. Closer row spacing (30 cm) gave 11.90% higher seed yield over wider spacing (40 cm)in soybean.

Higher grain yield was recorded with 25 cm row spacing in pea and then was significant reduction in yield when the spacing was increased to 50 cm (Yadav*et al.*, 1990).

Narrow spacing was significantly affected by population density. The crop growth rate increased from 20 - 50 days after emergence and then declined in sesame (Hossain and Salahuddin, 1994). The maximum crop growth rate value was recorded at 40-50 days after emergence irrespective of population densities.

The closer spacing was suitable for higher vegetable pod and grain yield (Anonymous, 1996).

Boquet (1998) found that planting date and cultivars selection were the most important factors for increasing yields in Louisiana while row spacing was less significant.

Research under different conditions and locations throughout the USA has investigated adjusting plant populations and row spacing to achieve suitable vegetative growth and increase yield (Bullock and Kraijevic, 1998).

Researchers in Arkansas, Louisiana, and Texas summarized 21 field experiments conducted over 14 years to determine the effect of row spacing on seed yield in soybean (Bowers *et. al.,* 2000). For all environments tested, narrow rows (< 40 cm) yielded equal to or greater than that of wider rows. These researchers concluded that narrow rows should be used to optimize yields in soybean in the mid-southern USA.

GriepentrogandTomar(2000) also found that increasing wheat seed rates from 200-660 m^{-2} greatly increased weed suppression. However, sowing in a cross pattern at 12-8 cm comparedwith a normal row pattern at the same width, suppressed weed by a further 30%. Yield also increased by 60% over normal row pattern at 400 seeds m^{-2}.

Provisional Scottish results indicated that row width of about 16cm gives better weed suppression than narrower or wider row widths, but these trials are being repeated over two further seasons (Davies and Hoad, 2000).

Khan*et al.* (2001) conducted anexperiment with mungbean duringthe summer season of 2000, in Peshawar, Pakistan. The row spacing treatments were 25 and 50 cm, while plant spacing were 5, 7.5 and 10 cm. Emergence of seedlings m^{-2},daysto flowering, days to maturity, number of grains pod^{-1}, number of branches $plant^{-1}$, plant height (cm), 1000 grain weight (g), percent hard grain (%), biological yield (kg)and grain yield (kg ha^{-1}) were significantly affected by row and plant spacing,pods number $plant^{-1}$ and harvest index were not significantly affected at 5% level of significance with row and plant spacing. The results revealed that a spacing of 50 cm between rows and 10 cm within rows produced the maximum number ofpods/plant, grains/pod, 1000 grain weight, low percent hard grain and high biological yield, harvest index and grain yield (kg ha^{-1}).

Ahmed *et al.* (2005) conducted an experiment in Faisalabad, Punjab, Pakistan, during 2000 to study the effect of P fertilizer (0, 30, 60, and 90 kg ha^{-1}) and row spacing (30 and 45cm) on the yield and yield components (pods $plant^{-1}$, seeds pod^{-1} and 1000 seed weight) of mungbean cv. NM-92. Seed yield was the highest with 30 cm row spacing while pods per plant, seeds per pod and 1000 seed weight were highest with 45 cm row spacing.

Bhatti *et al.*, (2005) conducted a field experiment on a sandy-clay loam soil in Faisalabad, Pakistan for two consecutive years (2001 and 2002) to evaluate the effect of intercrops and planting patterns on the agronomic traits of sesame. The planting patterns comprised 40 cm spaced single rows, 60 cm spaced 2-row strips and 100 cm spaced 4-row strips, while the cropping systems were sesame + mungbean, sesame + mashbean*(Vignaaconitifolia)*,sesame + soybean, sesame + cowpea and sesame alone. Among the intercropping patters, sesame intercropped with mungbean, mashbean, soybean and cowpea in pattern of 100 cm spaced 4-row strips (mungbean25 cm apart) proved to be feasible,easily workable and more productive than sesame mono-cropping.

Mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 cm spacing and supplied with 36-46 and 58-46 kg N-P ha^{-1} in a field experiment which was conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishalrecorded higher biological and grain yield (3.66 and 1.63 t ha^{-1} respectively) compared to cv. Pusa 105. Row spacing at 22.5 cm resulted in higher grain yields in both crops (Tickoo*et al.*, 2006).

2.2. Effect of Naphthalene Acetic Acid (NAA)

Chellappa and Karicaratharaju (1973) studied the effect of soaking groundnuts seed in 5 or 10 ppm solution of NAA for 12 or 24 hours. They found that seeds treated with 5 ppm NAA for 12 hours resulted in the highest number of flowers.

Studies have showed that external application of planofix (NAA) reduced the premature abscissions of flowers, young pods and thus increased the number of pods and consequently the yield of groundnut (Mani and Raja, 1976).

A foliar application of 40 ppm NAA on groundnut increased the number of pods perplant and eventually the pod yield (Gupta and Singh, 1982).

Singh *et al.* (1982) conducted an experiment on groundnut to determine the effect of NAA. They observed that two foliar spray of 100-ppm planofix (NAA) to groundnut at 40 and 50 days after sowing increased the number of leaves per plant.

Subbian and Chamy (1982)mentioned that two foliar sprays of 40-ppm planofix (NAA) when applied to summer mungbean at the flower initiation stage and 15 days later significantly increased the seed yield.

Reddy and Shah (1984) reported that application of planofix (NAA) at the rate of 50 ppm significantly produced the higher number of leaves in groundnut.

Subbian and Chamy (1984) carried out a field trial in summer with 2 foliar applications of 0, 20 or 40 ppm NAA to greengram. They found increased number of flowers and pods per plant with increasing NAA rate. They also reported that seed yield was increased from 0.8 to 1.2 t ha^{-1} with increasing NAA concentrations.

Venkaten*et al.* (1984) pointed out that both in rabi and in kharif seasons application of NAA at various concentrations sprayed at 30 and 50 days after sowing increased the number of pods per plant and 1000 seed weight in groundnut.

Bai*et al.* (1987) investigated the effect of growth regulators (NAA and GA) on the yield performance of mungbean. They found that 25 ppm of NAA and 50 ppm of GA increased the yield of mungbean when compared with control.

Gurpreet*et al*. (1988)mentioned that grain yield was increased from 0.71 t $ha^{-1}$to 0.78 t $ha^{-1}$with applications ofNAA in mungbean.

Jaiswal and Bhambil (1989) conducted a field experiment to determine the effect of growth regulators on mungbean. It was observed that GA_3 and NAA resulted in the reduction of yield and yield components.

Kalita (1989) reported that applying a foliar spray at the rate of 50 ppm of in NAA mungbean increased seed yield from 0.64 to 0.88 t ha^{-1}.

Rahman *et al.* (1989) in a pot experiment on grasspea showed that foliar application of 50 ml/liter of GA_3 increased seed yield.

Sharma *et al.* (1989) reported from the result of a field trial with foliar applications of NAA at anthesis and 10 days later on mungbean. It was found that the NAA treated plants gave higher seed yield of 795 - 849 kg ha^{-1} compared with 611-694 kg ha^{-1} of without NAA. Results revealed that the NAA application increased the number of pods per plant, number of seeds per pod and 1000 seed weight.

Subbian*et al.* (1989) performed two foliar sprays with 20 or 40-ppm planofix (NAA) in blackgram at the flower initiation stage and 15 days later in summer season found that seed yield of 1.46 t ha^{-1} was obtained by using 40 ppm NAA, compared 0.95 t ha^{-1} when no growth regulator was used.

Kandagal*et al.* (1990) observed that a foliar application of 50 ppm of NAA at flowering stage of mungbean gave seed yields of 0.66 t/ha compared with 0.55 t/ha with the untreated control.

Lee (1990) found 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.

Kelaiya*et al.* (1991) conducted an experiment with four growth regulators, such as CCC (chlormequat), NAA, GA_3, and triacontanol and sprayed at 25, 50 and 75 days after sowing (DAS) on groundnut. In that experiment, they observed that where NAA was found to be most effective one in increasing the plant height. They also reported that groundnuts when sprayed with 40 ppm of NAA at 25 and 50 DAS increased plant dry weight.

Kelaiya*et al.*(1991) also stated that spraying with 40 ppm of NAA ongroundnut cv. GG2 increased 1000 seed weight.

Application of 10 or 20 ppm planofix (NAA) on groundnut cv. DH3-30 increased the dry matter production when compared to the untreated control (Nawalagatti*et al.* 1991).

Chaplot*et al.* (1992) reported that increasers in seed yield of mungbean due to NAA application by 5.7 – 21%.

Kalita and Dey (1994) observed that greengram when sprayed with different concentrations of phosphorus alone or in combination with 50 or 100 ppm of NAA improved yields and yield components. Kalita*et al.* (1995) also reported the regulatory effect of NAA on number of pod of mungbean.

Baghel and Yadav (1994) revealed that blackgram when sprayed with 0 - 30 ppm of NAA; seed yield was generally increased and was highest with 30 ppm concentration.

Upadhyay (1994) conducted a field experiment at Faizabad, Uttar Pradesh. Chickpea cv. K-850 was treated with 10, 20 or 30 ppm of NAA at bud initiation and pod formation stages. It was reported that growth regulator increased the number of flowers. Seed yield was generally increased by the growth regulator and it was highest with 20 ppm.

Lakshrnamma and Rao (1996a) conducted a field experiment during the rabi season at Rajendranagar, Andhra Pradesh. Blackgram was sprayed with 0, 5, 10 or 20 ppm NAA at 50% flowering stage. They found that application of NAA increased plant height of blackgram.

Lakshmamma and Rao (1996b) conducted a field experiment at Rajendranagar in Andhra Pradesh during rabi season. They found that blackgram when sprayed with 20 ppm of NAA at 50 % flowering stage decreased flower drop and increased seed yield.

Arora *et al.* (1998) reported that NAA applied at 50% flowering stage to chickpea increased the number of flowers as compared with the untreated ones. Flowering and fruiting were also reported to be increased by foliar spraying with NAA on groundnut (Manikandan and Hakim, 1999).

Mahla*et al.* (1999) reported that spraying 20 ppm NAA on blackgram had greater effect in increasing the number of branches.

Das and Prasad (2003) conducted a study on sandy clay loam soil in New Delhi, India, during summer 1999. The treatments comprised of three summer mungbean cultivars and two levels of NAA (20 and 40 ppm). NAA sprayed at 30 days after sowing and at flowering stages. Both the concentrations of NAA significantly increased the total dry matter production, number of leaves, number of flowers and number of pods per plant, pod length, number of seeds per pod, 1000 grain weight and grain yield of summer mungbean.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural UniversityFarm Dhaka, Bangladesh during the period from August 2013 to November 2013 to studythe effect of row spacing and growth regulator (NAA) on growth and yield of mungbean**.** The details of the materials and methods have been presented below:

3.1. Description of the experimental site

3.1.1. Location

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

3.1.2. Soil

The soil belongs to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix II.

3.1.3. Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October.Details of the metrological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.2. Test crop and its characteristics

BARI Mung-6 was the test crop. Seeds of BARI Mung-6 was collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. After multilocation trials BARI released this variety for general cultivation with a popular name BARI Mung-6 in the year 2003. The plant attains a height of 35-40 cm, the leaves look light green and its life duration is about 75-80 days. Seeds are larger than local variety and light brown yellow in color. Seed contains 20-25 % protein. Thousand seed weight is 35-40 g.Under proper management practices it may give 1.6-2.0 t ha^{-1} grain yields.

3.3. Experimental details

3.3.1. Treatments

The experiment comprised as two factors.

Factor A: **Doses of Naphthalene acetic acid (NAA)**

i. G_0= Control (0 level of NAA)
ii. G_1= 20 ppm
iii. G_2= 40 ppm
iv. G_3= 60 ppm

Factor B: **Spacing**

i. P_1= 20cm×10cm
ii. P_2 = 30cm×10cm
iii. P_3= 40cm×10cm

There were 12 (4 × 3) treatment combinations viz., G_0P_1, G_0P_2, G_0P_3, G_1P_1, G_1P_2, G_1P_3, G_2P_1, G_2P_2, G_2P_3, G_3P_1, $G_3P_2$and G_3P_3.

3.3.2. Experimental design and layout

The experiment was laid out in randomized complete block design with three replications. The layout of the experiment was prepared for distributing the combination ofdoses of naphthalene acetic acid (NAA) and spacing. The 12 treatment combinations of the experiment were assigned at random into 12 plots of each replication. The size of each unit plot 3.0 × 2.5 m. The spacing between blocks and plots were 1.0 m and 0.5 m, respectively.

3.4. Growing of crops

3.4.1. Raising seedlings

3.4.1.1. Seed collection

The seeds of the test crop i.e., BARI Mung-6 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur**.**

3.4.1.2. Preparation of Naphthalene acetic acid (NAA) and Control solution

NAAin different concentrations viz. 0, 20, 40 and 60 ppm were prepared following the procedure mentioned below. 20 ppm solution of NAA was prepared by dissolving 20 mg of it with distilled water. Then distilled water was added to make the volume 1 liter 20 ppm solution. In a similar way, 40 and 60 ppm concentrations were made. An adhesive Tween-20 @ 0.1% was added to each solution. Control plots were treated with distilled water along with tween-20.

3.4.1.3. Seed sprouting

Healthy seeds were selected by specific gravity method and then seeds wereprimed.

3.4.2. Preparation of the main field

The plot selected for the experiment was opened in the first week of September, 2013 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.4.3. Fertilizers and manure application

The fertilizers N, P, K, S and B in the form of urea, TSP, MoP, Gypsum and borax, respectively were applied @ 50, 90, 40, 10 and 10 kg ha^{-1}. The urea and TSP, MoP, Gypsum, Zinc sulphate and borax were applied during the final preparation of land (BARI, 2012).

3.4.4. Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mungbean.

3.4.4.1. Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening up to 10 DAS to establish seedlings properly. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rains.

3.4.4.2. Gap filling

First gap filling was done for all of the plots at 10 days after sowing (DAS) by planting same aged and same sources seedlings.

3.4.4.3. Weeding

Threeweeding were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 20 days after sowing (DAS), 2^{nd} and 3^{rd} weeding was done at 35 and 50 DAS.

3.4.4.4. Plant protection

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

3.5. Harvesting, threshing and cleaning

The crop was harvested at full maturity on 5 November 2013 and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mungbeanseed. Fresh weight of grain and stover were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The stover was sun dried and the yields of grain and stover $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.6. Data recording

3.6.1. Plant height

The height of plant was recorded in centimeter (cm) at the time of 10, 20, 30, 40, 50 and 60 DAS (days after sowing) and at harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.6.2. Number of leaves $plant^{-1}$

Number of leaves $plant^{-1}$ was counted at an interval of 10 days starting from 10 DAS till 60 DAS. Leaves number $plant^{-1}$ were recorded by counting all leaves from each plant of each plot and mean was calculated.

3.6.3. Leaf, stem and root dry weight $plant^{-1}$

Leaf, stem and root dry weight $plant^{-1}$were measured at an interval of 10 days starting from 10 DAS till 60 DAS. First the fresh weight was taken. Then the samples of stem were dried in oven at 72^0C for 72 hours. From which the dry matter percentage of above ground harvestwas calculated with the following formula (Elfinesh*et al.*, 2011)-

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.6.4. Number of pods plant^{-1}

Number of total pods of ten plants from each plot was noted and the mean number was expressed per plant basis.

3.6.5. Pod length plant^{-1}

Ten pods were randomly selected from all the pods collected from 10 sample plants. The length of selected 10 pods were measured and was averaged.

3.6.6. Number of seeds pod^{-1}

Ten randomly selected pods from ten sample plants were considered plot wise to measure seed number per pod. Total number of seeds from 10 selected pods was counted and was average. The seeds collected from 10 plants.

3.6.7. 1000 seeds weight

One thousand cleaned and dried seeds were counted randomly form sample and weight by using a digital electric balance and expressed in gram.

3.6.8. Grain yield

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}.

3.6.9. Stover yield

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

3.6.10. Biological yield

Grain yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Stover yield.

3.6.11. Harvest index (%)

Harvest index was calculated from the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula.

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

3.7. Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the least significant differenttest at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of row spacing and naphthalene acetic acid (NAA) on growth and yield of mungbean. The results obtained from the study have been presented, discussed and compared in this chapter through tables, figures and appendices. The analyses of variance of data in respect of all the parameters have been shown in Appendix IV-X. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings.

4.1.Crop growth characters

4.1.1. Plant height

4.1.1.1. Effect of row spacing

The plant height of mungbean was measured at 10, 20, 30, 40, 50 and 60 DAS. It was evident from Figure 1 and Appendix IV that the height of plant was significantly influenced by row spacing at all the sampling dates. Figure 1 showed that plant height increased with advancing growing period irrespective of row spacing, the mungbean height increased rapidly at the early stages of growth and rate of progression in height was slow at the later stages except control treatment. At 10 DAS, 30 cm × 10 cm spacing treatment showed the longest plant (22.37 cm) whereas, the shortest plant (17.85 cm) was found from 20 cm × 10 cm spacing treatment. At 20, 30, 40, 50 and 60 DAS, 30 cm × 10 cm spacinggave the highest plant height (39.72, 49.47, 60.01, 56.96 and 54.96 cm, respectively) which was statistically similar with 40 cm × 10 cm spacing (34.22, 43.97, 55.11, 53.52 and 51.52 cm, respectively) whereas, the lowest height was recorded from 20 cm × 10 cm spacing (42.94, 57.59, 55.67 cm, respectively). Plant height of a crop depends on the plant vigor, cultural practices, growing environment and agronomic management. In the present experiment since mungbean was grown in the same environment and were given same cultural practices except row spacing. So, the variation of plant height might be due to the effect different level of row spacing.

4.1.1.2. Effect of plant growth regulator

Significant variation of plant height was found due to plant growth regulator in all the studied durations except 10 DAS (Appendix IV and Figure 2). At 10 DAS, numerically highest plant (20.93 cm) was found in 40 ppm NAA treatment and lowest plant (19.19 cm) was 0 ppm NAA treatment. At 20 and 30 DAS, the tallest plant (39.76 and 47.76 cm, respectively) was obtained from 40 ppm NAA (G_{40}) treatment which was statistically similar (35.21 and 45.21 cm, respectively) with 60 ppm NAA (G_{60}) treatment whereas, the shortest plant (31.23 and 38.23 cm, respectively) was obtained from the 0 ppm NAA (G_0) treatment. At 40, 50 and 60 DAS, the tallest plant (58, 57.67 and 56.00 cm, respectively) was obtained from G_{40} treatment which was statistically similar (55.33, 52.99 and 51.32 cm, respectively) with G_{20} treatment and (55.23, 52.83 and 51.17 cm, respectively) with G_{60} treatment whereas, the shortest plant (45.60, 43.32 and 42.66 cm, respectively) was obtained from G_0 treatment.

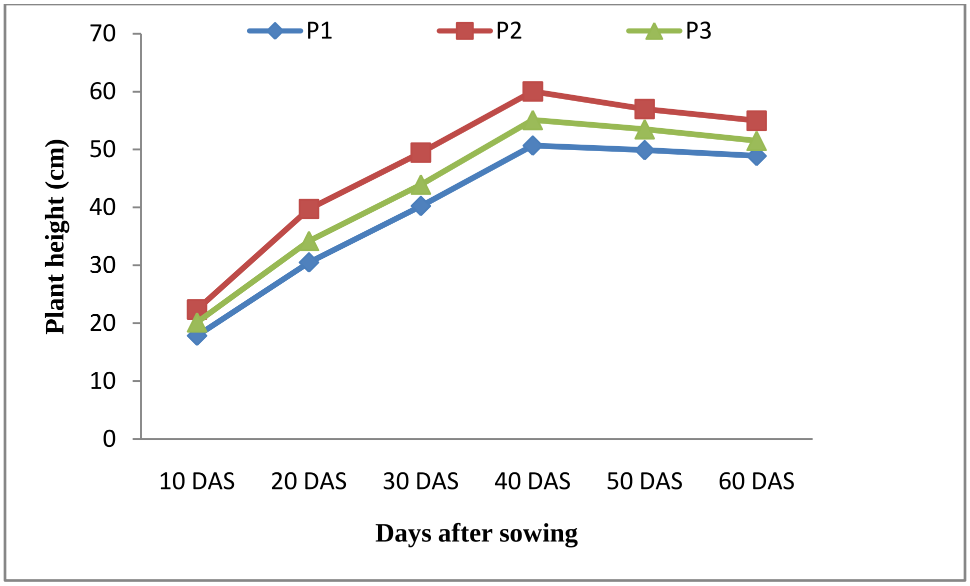

Figure 1. Effect of row spacing on plant height of mungbean(LED value = 2.04, 5.69, 5.64, 8.88, 5.06 and 5.06 at10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

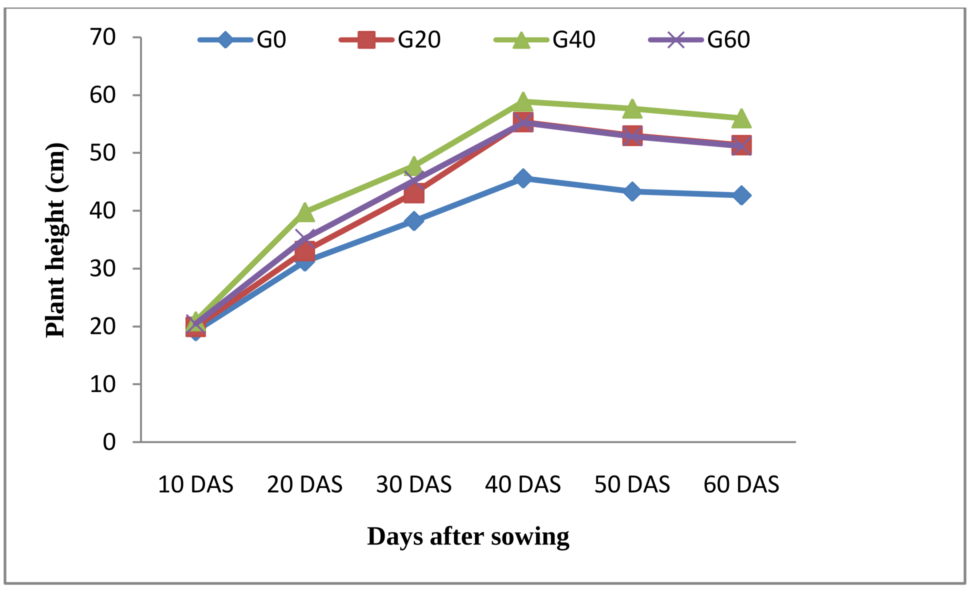

Figure 2. Effect of plant growth regulator on plant height of mungbean(LED value = NS, 6.56, 4.57, 5.67, 5.85 and 5.58 at 10, 20 , 30, 40, 50 and 60 DAS, respectively)

Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

4.1.1.3.Interaction effects of row spacing and plant growth regulator

Significant Interaction effects of row spacing and plant growth regulator on plant height was observed at 10, 20, 30, 40, 50 and 60 days after sowing(DAS) (Appendix IV and Table 1). Plant height increased with advancing growing period irrespective of row spacing and plant growth regulator (Table 2). At 10, 20 and 30 DAS, the tallest plant (23.30, 45.87 and 53.87 cm, respectively) was obtained from P_2G_{40} treatment, which was statistically similar with P_2G_{60} (23.20, 40.50 and 50.50 cm, respectively) and the shortest plant (17.07, 25.53 and 36.53 cm, respectively) was obtained from P_1G_0 treatment which was statistically similar with P_1G_{20} (17.83, 30.07 and 40.07 cm, respectively), P_1G_{40} (18.30 cm at 10 DAS and 42.87 cm at 30 DAS), P_1G_{60} (18.20, 31.53 and 41.53 cm, respectively), P_3G_0 (19.07 cm), P_3G_{20} (32.00 and 42.00 cm at 20 and 30 DAS). At 40, 50 and 60 DAS, the highest plant height (63.60, 62.73 and 60.73cm, respectively) was observed from P_2G_{40} treatment which was statistically similar with P_1G_{40} (54.30 cm), P_2G_0 (57.30 cm), P_2G_{20} (60.60 cm), P_2G_{60} (58.53 cm), P_3G_{20} (55.87 cm), P_3G_{40} (58.73 cm), P_3G_{60} (55.30 cm) at 40 DAS, with P_2G_{20} (57.00 cm), P_3G_{40} (57.40 cm) at 50 DAS, with P_2G_{20} (55.00 cm), P_3G_{40} (54.40 cm) at 60 DAS whereas, the lowest plant height (46.97, 47.20 and 46.20 cm, respectively) was recorded from P_1G_0 treatment which was statistically similar with P_1G_{20} (49.53 cm), P_1G_{60} (51.87 cm), P_3G_0 (50.53 cm) at 40 DAS, with P_1G_{20} (50.00 cm),P_1G_{40} (52.87 cm), P_1G_{60} (49.43 cm), P_2G_0 (52.00 cm), P_3G_0 (51.77 cm), P_3G_{20} (51.97 cm), P_3G_{60} (52.97 cm) at 50 DAP, with P_1G_{20} (49.00 cm),P_1G_{40} (51.87 cm), P_1G_{60} (48.43 cm), P_2G_0 (50.00 cm), P_3G_0 (49.77 cm), P_3G_{20} (49.97 cm), P_3G_{60} (50.97 cm) at 60 DAS.

Table 1. Interaction effect of row spacing and plant growth regulator on plant height of mungbean at different days after sowing (DAS)

Treatments	Plant height (cm) at					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
P_1G_0	17.07 f	25.53 f	36.53 e	46.97 d	47.20 c	46.20 d
P_1G_{20}	17.83 ef	30.07 ef	40.07 de	49.53 cd	50.00 c	49.00 cd
P_1G_{40}	18.30 d-f	34.87 b-e	42.87 c-e	54.30 a-d	52.87 bc	51.87 b-d
P_1G_{60}	18.20 d-f	31.53 d-f	41.53 c-e	51.87 b-d	49.43 c	48.43 cd
P_2G_0	21.43 ab	35.43 b-e	46.43 b-d	57.30 a-c	52.00 bc	50.00 b-d
P_2G_{20}	21.53 ab	37.07 b-d	47.07 bc	60.60 ab	57.00 ab	55.00 ab
P_2G_{40}	23.30 a	45.87 a	53.87 a	63.60 a	62.73 a	60.73 a
P_2G_{60}	23.20 a	40.50 ab	50.50 ab	58.53 a-c	56.10 b	54.10 bc
P_3G_0	19.07 c-f	32.73 c-e	43.73 cd	50.53 b-d	51.77 bc	49.77 b-d
P_3G_{20}	20.43 b-d	32.00 c-f	42.00 c-e	55.87 a-d	51.97 bc	49.97 cd
P_3G_{40}	21.20 a-b	38.53 bc	46.53 b-d	58.73 a-c	57.40 ab	55.40 ab
P_3G_{60}	19.97 b-e	33.60 c-e	43.60 cd	55.30 a-d	52.97 bc	50.97 b-d
$LSD_{(0.05)}$	2.36	6.57	6.55	7.26	5.85	5.08
CV (%)	6.94	11.15	8.75	10.12	6.64	6.67

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability
Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm
G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

4.1.2. Number of leaves plant^{-1}

4.1.2.1. Effect of row spacing

The effect of row spacing on number of leaves plant^{-1} was insignificant. Results revealed that, the number of leaves plant^{-1} of mungbean increased gradually with increased the row spacing upto 30 cm × 10 cm(P_2) at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix V and Figure 3). At 10, 20, 30, 40, 50 and 60 DAS, the numerically maximum leaves number plant^{-1} (3.21, 6.46, 7.67, 8.65, 8.78 and 7.56, respectively) was observed from P_2 treatment and the minimum number (3.03, 6.40, 7.21, 8.09, 8.53 and 7.02, respectively) was observed from P_1 treatment. The present study referred that 30 cm × 10 cmproduced maximum number of leaves.

4.1.2.2. Effect of plant growth regulator

The number of leaves plant^{-1} was significantly influenced by different plant growth regulator at 10, 20, 30, 40, 50 and 60 days after sowing(DAS) (Appendix V and Figure 4). The number of leaves plant^{-1} gradually increased with the advancement of plant age up to 40 DAP and thereafter more/less remain static with advancing growing period, irrespective of different plant growth regulator. At 10, 20, 30, 40, 50 and 60 DAS, the maximum leaves number plant^{-1} (3.30, 6.76, 8.41, 8.90, 8.35 and 7.47, respectively) was observed from the 40 ppm NAA (G_{40}) treatment and the minimum number (3.01, 5.80, 6.46, 6.71, 6.38 and 5.92, respectively) was observed from the 0 ppm NAA (G_0) treatment.

4.1.2.3. Interaction effect of row spacing and plant growth regulator

There was significant variation among the interaction of row spacing and plant growth regulator on the total numbers of leaves plant^{-1}at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix V and Table 2). Number of leaves plant^{-1} increased with advancing growing period up to 40 DAS irrespective of row spacing and plant growth regulator and thereafter decreased (Table 2). At 10, 20, 30, 40, 50 and 60 DAS, the maximum number of leaves plant^{-1} (3.50, 6.60, 9.04, 9.67, 9.35 and 8.67, respectively) was recorded with the combination of 30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment whereas, the minimum (3.00, 5.20, 6.20, 5.67, 5.39 and 4.89, respectively) was recorded from the combination of 20 cm × 10 cm spacing and 0 ppm NAA (P_1G_0) treatment. Present study showed that 30 cm × 10 cm spacing and 40 ppm NAA produced maximum number of leaves.

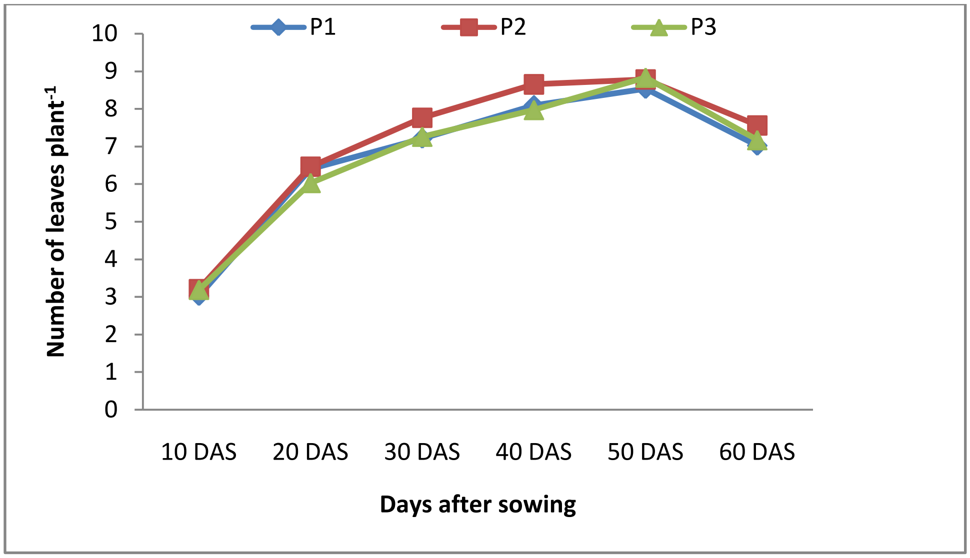

Figure 3. Effect of row spacing on number of leaves plant^{-1} of mungbean(LSD value = NS at 20, 40, 60, 80 and 100 DAS, respectively)

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

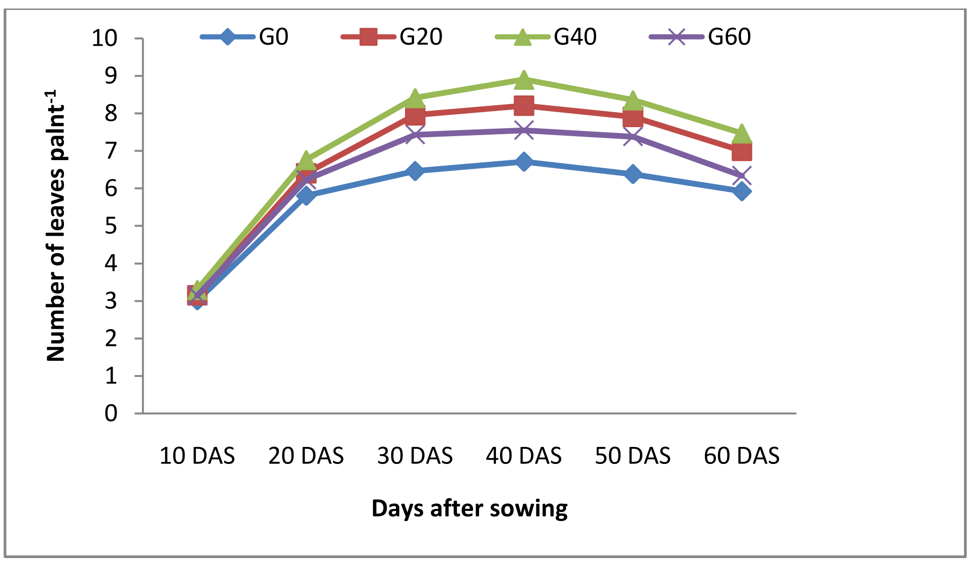

Figure 4. Effect of plant growth regulator on number of leaves plant^{-1} of mungbean(LSD value = 0.13, 0.34, 0.44, 0.62, 0.39 and 0.47 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

Table 2. Interaction effect of row spacing and plant growth regulator on number of leaves plant^{-1} of mungbeanat different days after sowing (DAS)

Treatments	Number of leaves plant^{-1} at					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
P_1G_0	3.00 f	5.20 f	6.20 g	5.67 h	5.39 h	4.89 f
P_1G_{20}	3.10 e	6.13 cd	8.50 b	9.07 b	8.78 b	7.34 b
P_1G_{40}	3.13 d	6.40 b	7.64 d	7.53 e	7.34 e	6.85 c
P_1G_{60}	3.31 c	6.20 c	8.19 bc	8.68 c	8.17 cd	7.49 b
P_2G_0	3.13 d	6.00 d	6.68 f	7.17 f	6.97 f	6.29 de
P_2G_{20}	3.13 d	6.13 cd	8.00 c	6.87 g	6.56 fg	6.04 e
P_2G_{40}	3.50 a	6.60 a	9.04 a	9.67 a	9.35 a	8.67 a
P_2G_{60}	3.41 b	6.40 b	7.92 c	8.60 c	8.04 d	7.69 b
P_3G_0	3.29 c	5.60 e	7.19 e	8.93 b	8.49 c	7.56 b
P_3G_{20}	3.18 d	6.33 bc	7.33 e	7.37 e	7.09 ef	6.49 d
P_3G_{40}	3.12 d	5.53 e	6.65 f	8.40 c	7.98 d	7.46 b
P_3G_{60}	3.18 d	6.33 bc	7.42 d	7.88 d	7.37 e	6.97 c
$LSD_{(0.05)}$	0.07	0.17	0.40	0.30	0.52	0.34
CV (%)	7.62	7.62	9.26	7.47	5.49	6.35

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability
Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm
G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

4.1.3.Leaf dry weight plant^{-1}

4.1.3.1. Effect of row spacing

Leaf dry weight plant^{-1} significantly influenced by row spacing at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix VI and Figure 5). At 10, 20, 30, 40, 50 and 60 DAS, 30 cm × 10 cm spacing produced higher leaf dry weight (0.81, 2.58, 5.91, 6.85, 7.18 and 7.56 g, respectively) whereas, the lowest (0.71, 2.24, 4.53, 5.55, 5.97 and 6.29 g, respectively) was recorded from 20 cm × 10 cm spacing.This might be due to the affect of row spacing.

4.1.3.2. Effect of plant growth regulator

Leaf dry weight plant^{-1} varied significantly with different levels of plant growth regulator at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix VI and Figure 6). At 10, 20, 30, 40, 50 and 60 DAS, the maximum leaf dry weight (0.84, 2.60, 5.45, 6.79, 7.39 and 8.40 g, respectively) was produced from 40 ppm NAA (G_{40})treatment while, the minimum (0.24, 1.80, 4.60, 5.83, 6.57 and 6.97 g, respectively) was found from 0 ppm NAA (G_0) treatment. Present study showed that leaf dry weight of mungbean was significantly increased with increasing NAA concentration up to 40 ppm NAA thereafter declined.

4.1.3.3.Interaction effect of row spacing and plant growth regulator

Interaction effect of row spacing and plant growth regulatoron leaf dry weight at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) were significant (Appendix VI and Table 3). At 10, 20, 30, 40, 50 and 60 DAS, it was observed that the maximum (0.96, 2.90, 6.38, 7.23, 7.89 and 8.17 g, respectively) was obtained from the combination of30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment whereas, the minimum (0.52, 2.07, 3.68, 4.97, 5.37 and 5.53 g, respectively) was recorded from the P_1G_0 (20 cm × 10 cm spacing with 0 ppm NAA).

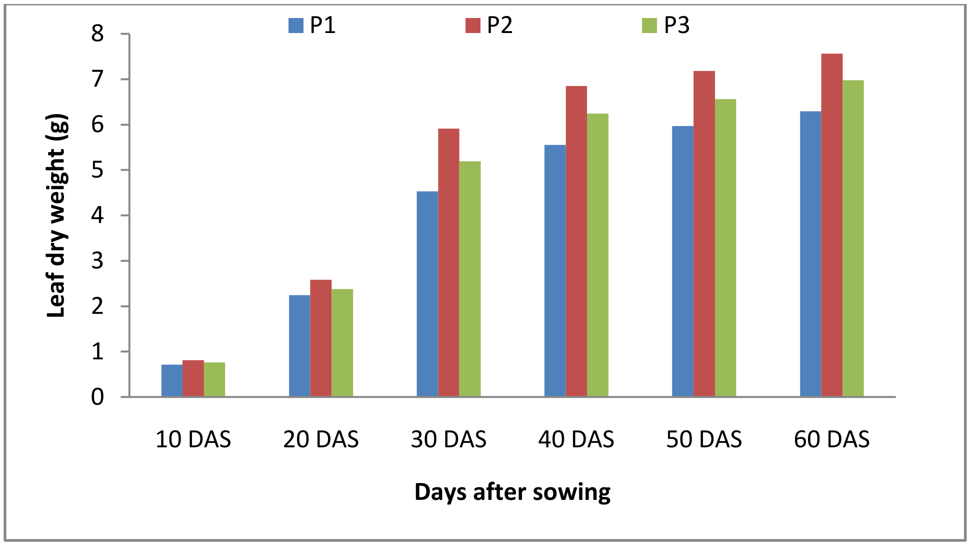

Figure 5. Effect of row spacing on leaf dry weight plant^{-1} of mungbean(LSD value = 0.04, 0.18, 0.49, 0.51, 0.39 and 0.61 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

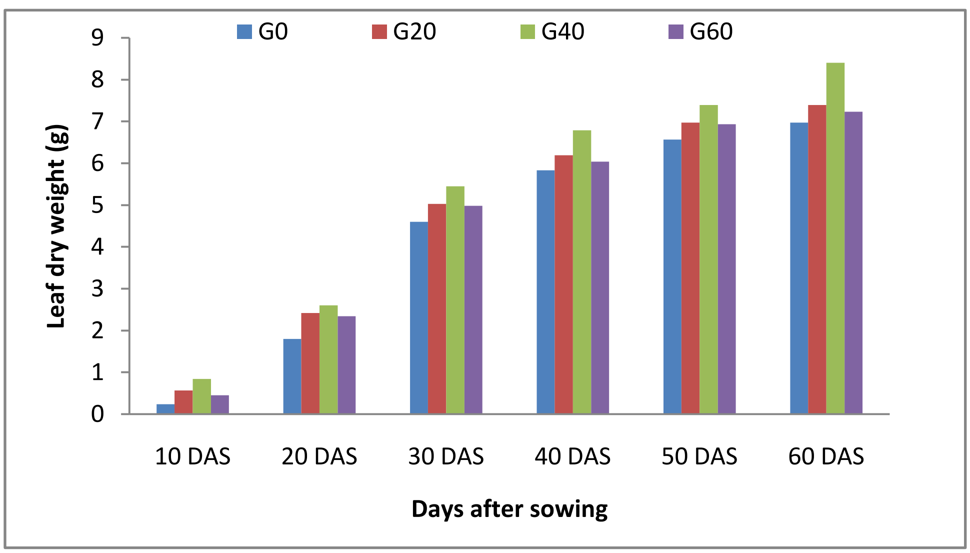

Figure 6. Effect of plant growth regulator on leaf dry weight plant^{-1} of mungbean(LSD value = 0.18, 0.14, 0.34, 0.53, 0.29 and 0.65 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

Table 3. Interaction effect of row spacing and plant growth regulator on leaf dry weight of mungbeanat different days after sowing (DAS)

Treatments	Leaf dry weight plant^{-1} (g) at					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
P_1G_0	0.52 d	2.07 d	3.68 g	4.97 f	5.37 e	5.53 d
P_1G_{20}	0.62 c	2.33 c	5.98 b	6.88 b	7.19 b	7.34 b
P_1G_{40}	0.67 c	2.36 c	4.73 d	5.63 c	6.03 c	6.39 c
P_1G_{60}	0.73 b	2.48 b	5.63 c	6.73 b	7.03 b	7.48 b
P_2G_0	0.72 b	2.34 c	4.12 f	5.43 d	5.99 d	6.27 c
P_2G_{20}	0.71 b	2.58 b	5.82 b	6.68 b	6.90 b	7.42 b
P_2G_{40}	0.96 a	2.90 a	6.38 a	7.23 a	7.89 a	8.17 a
P_2G_{60}	0.82 b	2.60 b	5.63 c	6.85 b	7.28 b	7.56 b
P_3G_0	0.80 b	2.38 c	4.80 d	5.35 e	5.98 d	6.37 c
P_3G_{20}	0.77 b	2.62 b	4.45 e	5.58 c	6.11 c	6.79 c
P_3G_{40}	0.80 b	2.44 c	4.46 e	5.78 c	6.38 c	6.46 c
P_3G_{60}	0.82 b	2.38 c	5.72 b	6.68 b	7.29 b	7.68 b
$LSD_{(0.05)}$	0.10	0.25	0.31	0.30	0.36	0.48
CV (%)	9.36	11.02	8.19	5.82	8.49	6.39

In a column means having similar letter (s) are statistically similar and those having dissimilar letter differ significantly by LSD at 0.05 level of probability
Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm
G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

4.1.4.Stem dry weight plant^{-1}

4.1.4.1. Effect of row spacing

Stem dry weight plant^{-1} significantly influenced by row spacing at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix VII and Figure 7). At 10, 20, 30, 40, 50 and 60 DAS, 30 cm × 10 cm spacing produced maximum stem dry weight (0.45, 1.12, 2.92, 3.85, 3.90 and 3.97 g, respectively) whereas, the minimum (0.35, 0.87, 1.54, 2.55, 2.69 and 2.70 g, respectively) was recorded from 20 cm × 10 cm spacing.

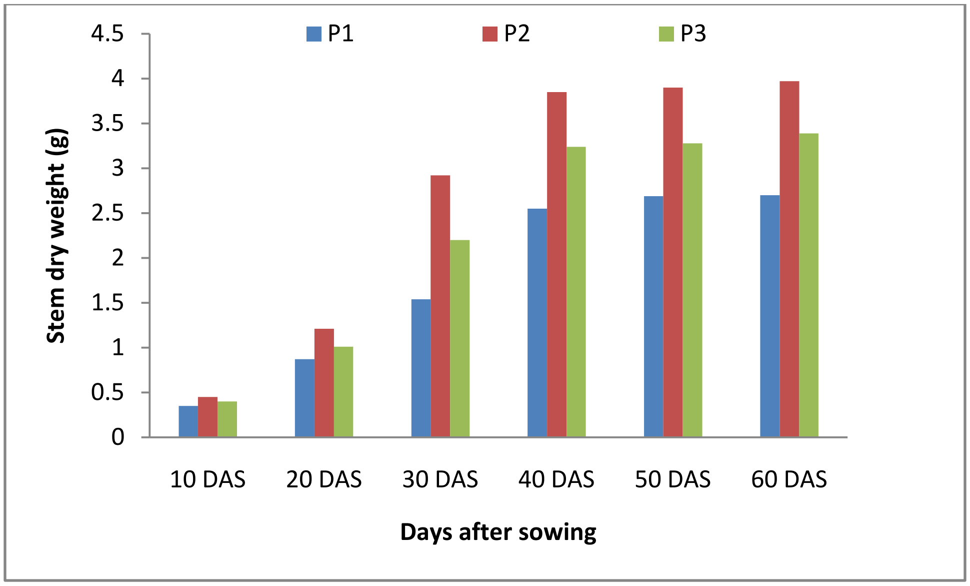

Figure 7. Effect of row spacing on stem dry weight plant^{-1} of mungbean(LSD value = 0.03, 0.14, 0.27, 0.23, 0.45 and 0.38 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: P_1=20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

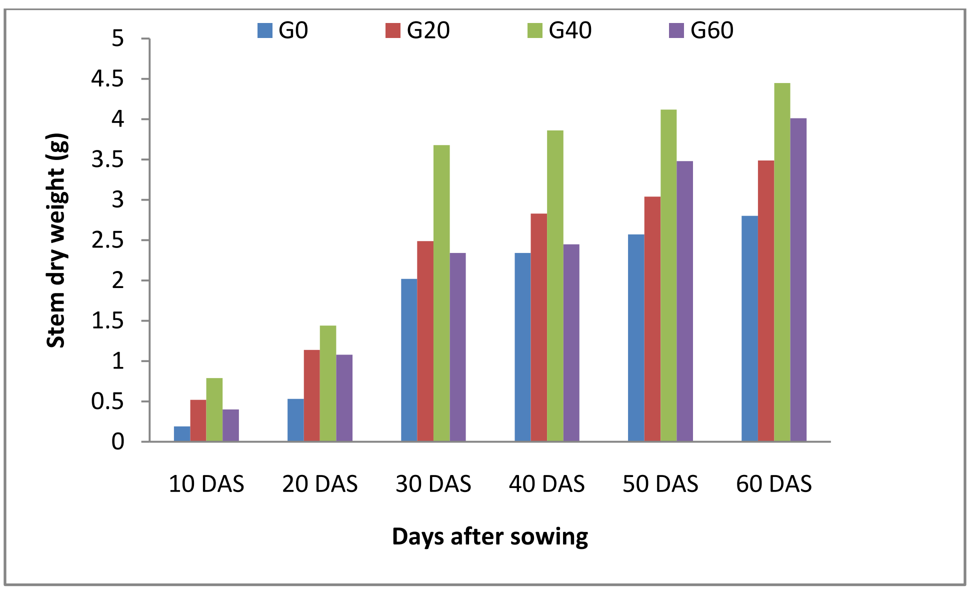

Figure 8. Effect of plant growth regulator on stem dry weight plant^{-1} of mungbean(LSD value = 0.23, 0.08, 0.37, 0.48, 0.18 and 0.28 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

4.1.4.2. Effect of plant growth regulator

Stem dry weight plant^{-1} varied significantly with different levels of plant growth regulator at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix VII and Figure 8). At 10, 20, 30, 40, 50 and 60 DAS, the highest stem dry weight (0.79, 1.44, 3.68, 3.86, 4.12 and 4.45 g, respectively) was produced from 40 ppm NAA (G_{40})treatment while, the lowest (0.19, 0.53, 2.02, 2.34, 2.57 and 2.80 g, respectively) was found from 0 ppm NAA (G_0) treatment.

Table 4. Interaction effect of row spacing and plant growth regulator on stem dry weight of mungbeanat different days after sowing (DAS)

Treatments	Stem dry weight plant^{-1} (g) at					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
P_1G_0	0.22 c	0.58 e	1.47 f	2.97 h	3.39 g	3.63 k
P_1G_{20}	0.53 b	0.83 d	2.33 e	3.02 g	3.72 f	3.84 j
P_1G_{40}	0.54 b	0.85 d	2.75 d	3.48 e	3.98 e	5.35 d
P_1G_{60}	0.54 b	0.81 d	2.49 e	3.26 f	3.83 e	5.02 e
P_2G_0	0.61 b	1.59 c	2.32 e	3.09 g	3.84 e	3.85 j
P_2G_{20}	0.64 b	1.72 b	2.78 d	3.15 g	3.87 e	4.04 i
P_2G_{40}	0.89 a	1.91 a	3.75 a	4.62 a	5.56 a	6.12 a
P_2G_{60}	0.64 b	1.75 b	3.43 b	3.49 e	4.37 d	5.93 b
P_3G_0	0.60 b	1.73 b	3.47 b	3.89 d	4.98 c	5.71 c
P_3G_{20}	0.60 b	1.72 b	3.12 c	4.33 b	5.25 b	4.78 f
P_3G_{40}	0.59 b	1.76 b	3.42 b	4.04 c	5.01 c	4.53 g
P_3G_{60}	0.59 b	1.73	3.12 c	3.89 d	4.60 d	4.26 h
$LSD_{(0.05)}$	0.24	0.13	0.25	0.19	0.20	0.17
CV (%)	8.65	10.57	9.88	2.70	4.39	8.37

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: P_1=20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

4.1.4.3.Interaction effect of row spacing and plant growth regulator

Interaction effect of row spacing and plant growth regulatoron stem dry weight at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) were significant (Appendix VII and Table 4). At 10, 20, 30, 40, 50 and 60 DAS, it was observed that the maximum (0.89, 1.19, 3.75, 4.62, 5.56 and 6.12 g, respectively) was obtained from the combination of30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment whereas, the minimum (0.22, 0.58, 1.47, 2.97, 3.39 and 3.63 g, respectively) was recorded from the P_1G_0 (20 cm × 10 cm spacing with 0 ppm NAA).

4.1.5.Root dry weight plant^{-1}

4.1.5.1 Effect of row spacing

Root dry weight plant^{-1} significantly influenced by row spacing at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix VIII and Figure 9). At 10, 20, 30, 40, 50 and 60 DAS, 30 cm × 10 cm spacing (P_2) treatment produced highest root dry weight (0.05, 0.34, 0.97, 1.80, 2.34 and 2.57 g, respectively) whereas, the lowest (0.03, 0.26, 0.74, 1.41, 1.73 and 2.10 g, respectively) was found from 20 cm × 10 cm spacing (P_1) treatment.

4.1.5.2. Effect of plant growth regulator

Root dry weight plant^{-1} varied significantly with different levels of plant growth (NAA) regulator at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) (Appendix VIII and Figure 10). At 10, 20, 30, 40, 50 and 60 DAS, the maximum root dry weight (0.06, 0.37, 1.34, 1.90, 2.56 and 2.80 g, respectively) was produced from G_{40}treatmentwhereas, the minimum (0.03, 0.25, 0.71, 1.31, 1.78 and 2.12 g, respectively) was found from G_0 treatment.

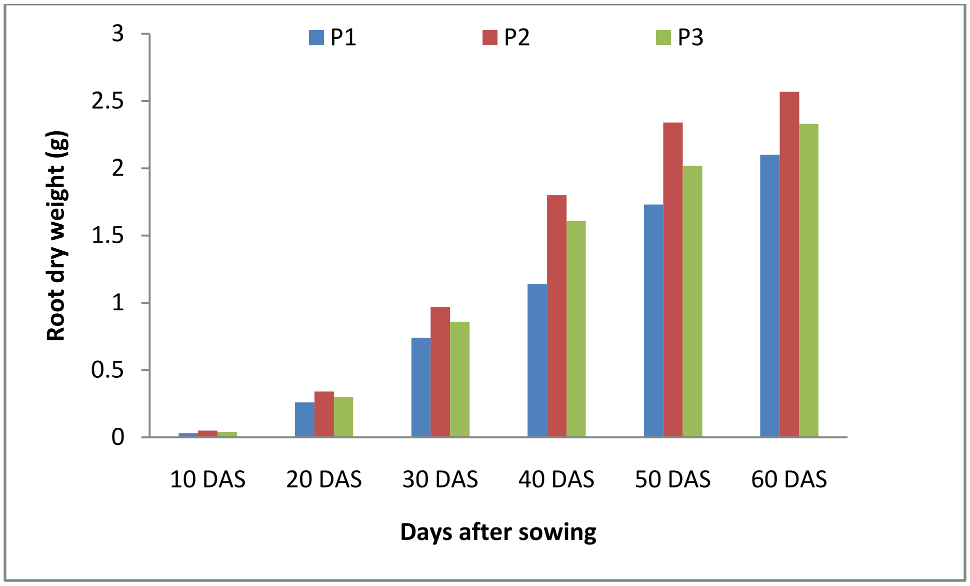

Figure 9. Effect of row spacing on root dry weight plant^{-1} of mungbean(LSD value = 0.01, 0.03, 0.10, 0.18, 0.27 and 0.19 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: P_1= 20 cm × 10 cm, P_2 -=30 cm × 10 cm andP_3=40 cm × 10 cm

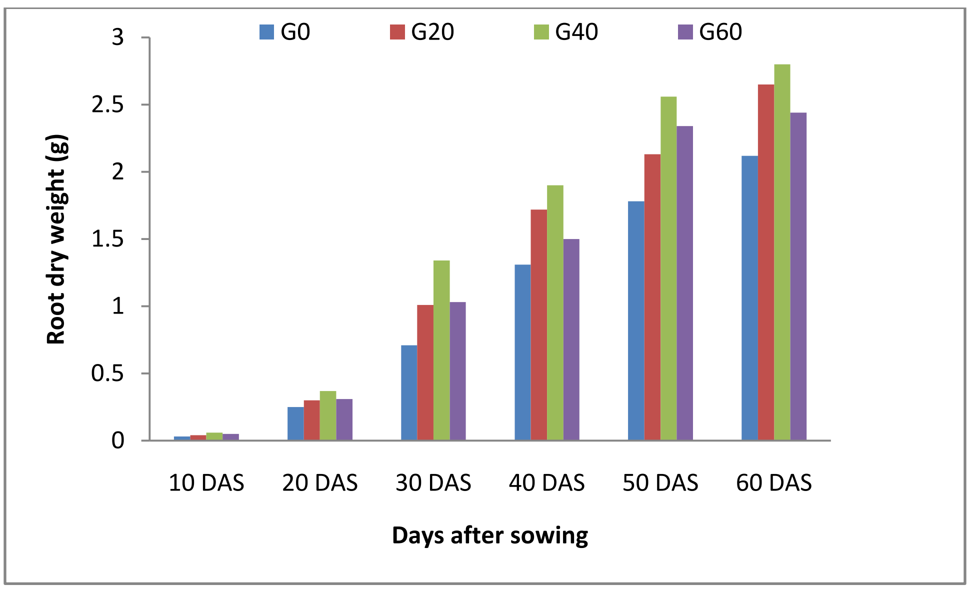

Figure 10. Effect of plant growth regulator on root dry weight plant^{-1} of mungbean(LSD value = 0.01, 0.04, 0.29, 0.17, 0.15, 0.11 at 10, 20, 30, 40, 50 and 60 DAS, respectively)

Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

4.1.5.3.Interaction effect of row spacing and plant growth regulator

Interaction effect of row spacing and plant growth regulatoron root dry weight at 10, 20, 30, 40, 50 and 60 days after sowing (DAS) were significant (Appendix VIII and Table 5). At 10, 20, 30, 40, 50 and 60 DAS, it was observed that the highest root dry weight (0.06, 0.37, 0.98, 1.56, 2.49 and 2.80 g, respectively) was obtained from the combination of30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment while, the lowest root dry weight (0.02, 0.16, 0.54, 1.04, 1.38 and 1.53 g, respectively) was recorded from the P_1G_0 (20 cm × 10 cm spacing with 0 ppm NAA). Present study showed that root dry weight of mungbean was the highest with the combination of30 cm × 10 cm spacing and 40 ppm NAA.

Table 5. Interaction effect of row spacing and plant growth regulator on root dry weight of mungbeanat different days after sowing (DAS)

Treatments	Dry weight of root plant^{-1} (g) at					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
P_1G_0	0.02 e	0.16 e	0.54 e	1.04 e	1.38 e	1.53 e
P_1G_{20}	0.03 d	0.20 d	0.64 d	1.19 d	1.88 b	2.04 d
P_1G_{40}	0.04 c	0.32 b	0.67 d	1.34 b	1.95 b	2.37 c
P_1G_{60}	0.03 d	0.24 c	0.78 c	1.28 c	1.67 c	2.38 c
P_2G_0	0.05 b	0.30 b	0.82 b	1.30 c	1.68 c	2.60 b
P_2G_{20}	0.05 b	0.30 b	0.87 b	1.32 c	1.59 d	2.41 c
P_2G_{40}	0.06 a	0.37 a	0.98 a	1.56 a	2.49 a	2.80 a
P_2G_{60}	0.04 c	0.31 b	0.85 b	1.40 b	1.85 b	2.41 c
P_3G_0	0.04 c	0.24 c	0.77 c	1.34 b	1.83 b	2.67 b
P_3G_{20}	0.04 c	0.24 c	0.64 d	1.32 c	1.63 c	2.56 b
P_3G_{40}	0.04 c	0.29 b	0.62 d	1.29 c	1.89 b	2.64 b
P_3G_{60}	0.04 c	0.25 c	0.73 c	1.20 d	1.36	2.62 b
$LSD_{(0.05)}$	0.01	0.03	0.10	0.08	0.17	0.09
CV (%)	12.54	5.80	2.71	3.40	5.93	6.38

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

4.2. Yield contributing characters

4.2.1. Number of pod plant^{-1}

4.2.1.1. Effect of row spacing

Statistically significant differences were found for number of pod plant^{-1} of mungbean due to row spacing (Appendix IX and Table 6). The highest number of pod plant^{-1} (22.08) was recorded from 30 cm × 10 cm spacing(P_2) treatment, which was statistically similar to that of P_3 (20.58) treatment whereas, the lowest (18.83) was observed from 20 cm × 10 cm spacing(P_1) treatment.

4.2.1.2. Effect of plant growth regulator

Number of pods plant^{-1} of mungbean differed significantly due to plant growth regulator (Appendix IX and Table 7). The height number of pod plant^{-1} (24.89) was recorded from 40 ppm NAA (G_{40}) treatment whereas, the lowest (16.56) was found 0 ppm NAA (G_0)treatment.

Table 6. Effect of row spacing on yield contributing characters of mungbean

Spacing	Number of pods plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	1000 seeds weight (g)
P_1	18.83 b	6.38 c	9.83 c	37.72 b
P_2	22.08 a	10.18 a	15.47 a	44.26 a
P_3	20.58 a	8.47 b	12.75 b	40.00 b
$LSD_{(0.05)}$	1.713	0.3562	0.04637	2.540
CV (%)	5.70	2.90	0.23	4.26

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3=40 cm × 10 cm

Table 7. Effect of plant growth regulator on yield contributing characters of mungbean

Growth regulator	Number of pods plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	1000 seeds weight (g)
G_0	16.56 c	7.09 c	10.67 d	37.14 c
G_{20}	21.00 b	8.42 b	12.67 c	40.92 b
G_{40}	24.89 a	9.68 a	14.67 a	44.50 a
G_{60}	19.56 b	8.21 b	12.73 b	40.07 bc
$LSD_{(0.05)}$	1.978	0.4113	0.05355	2.933
CV (%)	5.70	2.90	0.23	4.26

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability
Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

4.2.1.3. Interaction effect of row spacing and plant growth regulator

Interaction effectrow spacing and plant growth regulatorshowed significant variation in number of pod plant^{-1} (Appendix IX and Table 8). The highest number of pod plant^{-1} (26.33) was recorded from the combination of 30 cm × 10 cm spacing and 40 ppm NAA(P_2G_{40}) treatmentwhereas, the lowest (15.00) was observed from thecombination of 20 cm × 10 cm spacing and 0 ppm NAA(P_1G_0) treatment, which was statistically similar in P_1G_{60} (15.67) treatment.

4.2.2.Length of pod

4.2.2.1. Effect of row spacing

Statistically significant differences were found for length of pod of mungbean due to row spacing (Appendix IX and Table 6). The maximum length of pod (10.18 cm) was recorded from 30 cm × 10 cm spacing whereas, the minimum (6.38 cm) was observed from 20 cm × 10 cm spacing.

4.2.2.2. Effect of plant growth regulator

Length of pod of mungbean differed significantly due to plant growth regulator (Appendix IX and Table 7). The maximum length pod (9.68 cm) was recorded from 40 ppm NAA treatment and the minimum (7.09 cm) was found in0 ppm NAA treatment.

4.2.2.3. Interaction effect of row spacing and plant growth regulator

Interaction effectofrow spacing and plant growth regulatorshowed significant variation in length ofpod (Appendix IX and Table 8). The maximum length of pod (11.53 cm) was recorded from thecombination of 30 cm × 10 cm spacing and 40 ppm NAAtreatment and the minimum (5.20 cm) was observed from thecombination of 20 cm × 10 cm spacing and 0 ppm NAAtreatment.

4.2.3. Number of seeds pod^{-1}

4.2.3.1. Effect of row spacing

Statistically significant differences were found for number of seeds pod^{-1} of mungbean due to row spacing (Appendix IX and Table 6). The maximum number of seeds pod^{-1} (15.47) was recorded from P_2 treatmentand the minimum (9.83) was observed from P_1treatment.

4.2.3.2. Effect of plant growth regulator

Number of seeds pod^{-1} of mungbean differed significantly due to plant growth regulator (Appendix IX and Table 7). The height number of seeds pod^{-1} (14.67) was recorded from G_{40} treatment.The lowest number of seeds pod^{-1} (01.67) was found G_0treatment.

4.2.3.3. Interaction effect of row spacing and plant growth regulator

The number of seeds pod^{-1} was significantly influenced by the interaction ofrow spacing and plant growth regulator (Appendix IX and Table 8). The maximum number of seeds pod^{-1} (17.80) was recorded from the combination of P_2G_{40} treatmentwhereas, the minimum (8.50) was observed from the combination ofP_1G_0treatment.

4.2.4. 1000 grains weight

4.2.4.1. Effect of row spacing

Statistically significant differences were found for 1000 grains weight of mungbean due to row spacing (Appendix IX and Table 6). The maximum 1000 grains weight(44.26 g) was recorded from the 30 cm × 10 cm spacing (P_2) treatment whereas, the minimum 1000 grains weight (37.72 g) was observed from the 20 cm × 10 cm spacing (P_1) treatment, which was statistically similar in the 40 cm × 10 cm spacing i.e., P_3 treatment (40.00 g).

4.2.4.2. Effect of plant growth regulator

1000 grains weight of mungbean differed significantly due to plant growth regulator (Appendix IX and Table 7). 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,which was statistically similar to that of the 60 ppm NAA (40.07 g) treatment.

Table 8. Interaction effect of row spacing and plant growth regulator on yield contributing characters of mungbean

Treatments	Number of pods plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	1000 seeds weight (g)
P_1G_0	15.00 h	5.20 i	8.50 l	34.50 f
P_1G_{20}	19.67 ef	6.39 h	9.60 k	37.70 de
P_1G_{40}	25.00 ab	7.80 f	11.20 h	41.00 c
P_1G_{60}	15.67 h	6.20 h	10.00 j	37.67 de
P_2G_0	18.00 fg	8.87 d	13.20 e	40.10 cd
P_2G_{20}	21.67 cd	10.21 b	15.50 b	44.70 b
P_2G_{40}	26.33 a	11.53 a	17.80 a	49.70 a
P_2G_{60}	22.33 cd	10.10 bc	15.40 c	42.53 bc
P_3G_0	16.67 gh	7.20 g	10.30 i	36.83 ef
P_3G_{20}	21.67 cd	8.65 de	12.90 f	40.35 cd
P_3G_{40}	23.33 bc	9.70 c	15.00 d	42.80 bc
P_3G_{60}	20.67 de	8.34 e	12.80 g	40.02 cd
$LSD_{(0.05)}$	1.978	0.4113	0.05355	2.933
CV (%)	5.70	2.90	0.23	4.26

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: P_1= 20 cm × 10 cm, P_2= 30 cm × 10 cm andP_3=40 cm × 10 cm

G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

4.2.4.3. Interaction effect of row spacing and plant growth regulator

Interaction effectofrow spacing and plant growth regulatorshowed significant variation in 1000 grains weight of mungbean (Appendix IX and Table 8). The highest 1000 grains weight (49.70 g) was recorded from the combination of P_2G_{40} treatmentand the lowest (34.50 g) was recorded from the combination of P_1G_0 treatment which,was statistically similar to P_3G_0 (36.83 g) treatment.

4.2.5. Grain yield

4.2.5.1. Effect of row spacing

Grain yield varied significantlydue torow spacing (Appendix X and Table 9). The highest grain yield (1.63 t ha^{-1}) was recorded from the 30 cm × 10 cm spacing treatment whereas, the lowest (1.10 t ha^{-1}) was found in the 20 cm × 10 cm spacing treatment.

4.2.5.2. Effect of plant growth regulator

Grain yield of mungbean varied significantly due to plant growth regulator (Appendix X and Table 10). The highest grain yield (1.68 t ha^{-1}) was recorded from the 40 ppm NAA treatmentwhereas, the lowest (1.11 t ha^{-1}) was found in the 0 ppm NAA treatment.

4.2.5.3. Interaction effect of row spacing and plant growth regulator

Statistically significant differences in grain yield of mungbean were recorded for the interaction of row spacing and plant growth regulator (Appendix X and Table 11). The maximum grain yield (2.00 t ha^{-1}) was recorded from the combination of30 cm × 10 cm spacing with 40 ppm NAA treatment and the minimum (0.93 t ha^{-1}) was found in the combination of20 cm × 10 cm spacing with 0 ppm NAA treatment.

Table 9. Effect of row spacing on yieldsand harvest index of mungbean

Spacing	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
P_1	1.10 c	2.03 a	3.13 a	35.39 c
P_2	1.63 a	1.75 b	2.93 b	55.71 a
P_3	1.38 b	1.31 c	3.12 ab	44.65 b
$LSD_{(0.05)}$	0.09275	0.2272	0.1912	4.928
CV (%)	4.54	9.12	4.24	7.43

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3 = 40 cm × 10 cm

4.6. Stover yield

4.2.6.1. Effect of row spacing

Stover yield of mungbean were significantly influenced by row spacing (Appendix X and Table 9). The maximumstover yield (2.03 t ha^{-1}) was recorded from theP_1 treatment whereas, the minimum (1.31 t ha^{-1}) was found in theP_3treatment.

4.2.6.2. Effect of plant growth regulator

Stover yield of mungbean were significantly influenced by plant growth regulator (Appendix X and Table 10). The maximumstover yield (2.13 t ha^{-1}) was recorded from the G_0 treatment whereas, the minimum (1.30 ha^{-1}) was found in theG_{40}treatment.

4.2.6.3. Interaction effect of row spacing and plant growth regulator

The interaction effect of row spacing and plant growth regulator on stover yield of mungbean was significant (Appendix X and Table 11). The height stover yield (2.40 t ha^{-1}) was recordved from the combination ofP_1G_0 treatment and the lowest (.90 t ha^{-1}) was found in the combination ofP_2G_{40} treatment.

Table 10. Effect of plant growth regulator on yieldsand harvest index of mungbean

Growth regulator	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
G_0	1.11 c	2.13 a	3.24 a	34.64 c
G_{20}	1.30 b	1.70 b	3.00 b	43.59 b
G_{40}	1.68 a	1.30 c	2.98 c	56.42 a
G_{60}	1.38 b	1.64 b	3.02 b	46.35 b
$LSD_{(0.05)}$	0.1071	0.2623	0.2208	5.690
CV (%)	4.54	9.12	4.24	7.34

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Note: G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA

4.7. Biological yield

4.2.7.1. Effect of row spacing

Row spacing differed a significantly in producing biological yield (Appendix X and Table 9). The maximum biological yield (3.13 t ha^{-1}) was observed from P_1 treatment which was statistically similar (3.12 t ha^{-1}) to P_3 treatment whereas, the minimum (2.93 t ha^{-1}) was found in P_2 treatment.

4.2.7.2. Effect of plant growth regulator

Plant growth regulatora significant in producing biological yield (Appendix X and Table 10). The highest biological yield (3.24 t ha^{-1}) was observed from G_0 treatment and the lowest (2.98 t ha^{-1}) was found in G_{40} treatment.

4.2.7.3. Interaction effect of row spacing and plant growth regulator

Interaction effect of row spacing and plant growth regulator showed significant variation in biological yield (Appendix X and Table 11). The maximum biological yield (3.39 t ha^{-1}) was recorded from the combination of P_3G_0 treatment which was statistically similar (3.33 t ha^{-1}) to P_1G_0 treatment whereas, the lowest (2.88 t ha^{-1}) was observed from the combination of P_2G_{60} treatment which was statistically similar (3.06, 2.99, 3.01, 2.95, 2.90, 3.00, 3.05 and 3.06 t ha^{-1}, respectively) to P_1G_{20}, P_1G_{40}, P_2G_0, P_2G_{20}, P_2G_{40}, P_3G_{20}, P_3G_{40} and P_3G_{60}.

4. 8. Harvest Index

4.2.8.1. Effect of row spacing

A significant difference was found in harvest index due to row spacing (Appendix X and

Table 9). The maximum harvest index (55.71 %) was recorded from 30 cm × 10 cm spacing (P_2) treatment whereas, the minimum (35.39 %) was found in 20 cm × 10 cm spacing (P_1) treatment.

4.2.8.2. Effect of plant growth regulator

A significant difference was found in harvest index due to plant growth regulator (Appendix X and Table 10). The maximum harvest index (56.42 %) was recorded from 40 ppm NAA (G_{40}) treatment whereas, the minimum (34.64 %) was found from 0 ppm NAA (G_0) treatment.

4.2.8.3. Interaction effect of row spacing and plant growth regulator

The interaction effect of row spacing and plant growth regulator was significant on harvest index of mungbean (Appendix X and Table 11). The height harvest index (68.97 %) was recorded from the combination of 30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment whereas, the lowest (27.93 %) were found in the combination of 20 cm × 10 cm spacing and 0 ppm NAA (P_1G_0) treatment which, was statistically similar (32.49 %) to the combination of 40 cm × 10 cm spacing and 0 ppm NAA (P_3G_0) treatment. Present study revealed that 30 cm × 10 cm spacing and 40 ppm NAA produced best harvest index (%).

Table 11. Interaction effect of row spacing and plant growth regulator on yields and harvest index of mungbean

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
P_1G_0	0.93 f	2.40 a	3.33 ab	27.93 e
P_1G_{20}	1.06 e	2.00 b	3.06 cd	34.64 d
P_1G_{40}	1.29 d	1.70 c	2.99 cd	43.11 c
P_1G_{60}	1.12 e	2.00 b	3.12 bc	35.87 d
P_2G_0	1.31 d	1.70 c	3.01 cd	43.50 c
P_2G_{20}	1.55 c	1.40 d	2.95 cd	52.81 b
P_2G_{40}	2.00 a	0.90 e	2.90 d	68.97 a
P_2G_{60}	1.65 bc	1.23 d	2.88 d	57.57 b
P_3G_0	1.10 e	2.29 a	3.39 a	32.49 de
P_3G_{20}	1.30 d	1.70 c	3.00 cd	43.33 c
P_3G_{40}	1.74 b	1.30 d	3.05 cd	57.18 b
P_3G_{60}	1.37 d	1.69 c	3.06 cd	45.60 c
$LSD_{(0.05)}$	0.1071	0.2623	0.2204	5.690
CV (%)	4.54	9.12	4.24	7.43

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability

Note: P_1= 20 cm × 10 cm, P_2=30 cm × 10 cm andP_3 -=40 cm × 10 cm

G_0=0 ppm NAA, G_{20}=20 ppm NAA, G_{40}=40 ppm NAA and G_{60}=60 ppm NAA.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University Dhaka farm, in the *kharif-II* season during the period from August 2013 to November 2013 to study the effect of row spacing and growth regulator (NAA) on growth and yield of mungbean**.** The experiment was consisted of four levels of NAA viz. 0, 20, 40 and 60 ppm and three different row spacing viz. 20cm × 10cm, 30cm × 10cm and 40cm × 10cm. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 4.0 m × 2.5 m. Chemical fertilizers were applied as per its recommended dose.

Results showed that plant height wassignificantly influenced by row spacing. At 60 DAS, 30 cm × 10 cm spacinggave the highest plant height (54.96 cm). The number of leaves plant^{-1} of mungbean increased gradually with increasing the row spacing up to 30 cm × 10 cm(P_2) at 10, 20, 30, 40, 50 and 60 DAS. At 60 DAS, the numerically maximum leaves number plant^{-1} (7.56) was observed from P_2 treatment.Leaf dry weight plant^{-1} was significantly influenced by row spacing at different DAS. At 60 DAS, 30 cm × 10 cm spacing produced higher leaf dry weight (7.56 g). Stem dry weight plant^{-1}was significantly influenced by row spacing. At 60 DAS, 30 cm × 10 cm spacing produced maximum stem dry weight (3.97 g). Root dry weight plant^{-1}was also significantly influenced by row spacing. At 60 DAS, 30 cm × 10 cm spacing (P_2) treatment produced highest root dry weight (2.57 g).Row spacing significantly influenced leaf area index (%) of mungbean. The highest leaf area index (4.85 %) was found in 30 cm × 10 cm spacing (P_2) treatment.Statistically significant differences were found for number of pod plant^{-1} of mungbean due to row spacing. The highest number of pod plant^{-1} (22.08) was recorded from 30 cm × 10 cm spacing (P_2) treatment which was statistically similar to P_3 (20.58) treatment. Statistically significant differences were found for length of pod of mungbean due to row spacing. The maximum length of pod (10.18 cm) was recorded from 30 cm × 10 cm spacing. Statistically significant differences were found for number of seeds pod^{-1} of mungbean due to row spacing. The maximum number of seeds pod^{-1} (15.47) was recorded from P_2 treatment. Statistically significant differences were found for 1000 pod weight of mungbean due to row spacing. The maximum 1000 pod weight (44.26 g) was recorded from the 30 cm × 10 cm spacing (P_2) treatment. Grain yield exerted significant differences among different row spacing's. The highest grain yield (1.63 t ha^{-1}) was observed from the 30 cm × 10 cm spacing treatment. Stover yield of mungbean was significantly influenced by row spacing. The maximum stover yield (2.03 t ha^{-1}) was observed from the P_1 treatment (20cm × 10cm). Row spacing differed significantly in producing biological yield. The maximum biological yield (3.13 t ha^{-1}) was observed from P_1 treatment(20cm × 10cm) which was statistically similar (3.12 t ha^{-1}) to P_3 treatment. A significant difference was observed for harvest index due to row spacing. The maximum harvest index (55.71 %) was observed from 30 cm × 10 cm spacing (P_2) treatment.

Significant variation of plant height was found due to plant growth regulator in all the studied durations except 10 DAS. At 60 DAS, the tallest plant (56.00 cm) was obtained from G_{40} treatment. The number of leaves plant^{-1} was significantly influenced by different plant growth regulator at different DAS. At 60 DAS, the maximum leaves number plant^{-1} (7.47) was observed from the 40 ppm NAA (G_{40}) treatment. Leaf dry weight plant^{-1} varied significantly with different levels of plant growth regulator at 10, 20, 30, 40, 50 and 60 DAS. At 10, 20, 30, 40, 50 and 60

DAS, the maximum leaf dry weight (8.40 g) was produced from 40 ppm NAA (G_{40}) treatment. Present study showed that leaf dry weight of mungbean was statistically affected up to 40 ppm NAA to control treatment.Plant growth regulator had significant effect on Stem dry weight plant^{-1}. At 60 DAS, the highest stem dry weight (4.45 g) was produced from 40 ppm NAA (G_{40}) treatment. Root dry weight plant^{-1} varied significantly with different levels of plant growth regulator. At 60 DAS, the maximum root dry weight (2.80 g) was produced from G_{40} treatment. Different levels of plant growth regulator significantly influenced leaf area index (%) of mungbean.The highest leaf area index (4.57 %) was recorded from 40 ppm NAA (G_{40}) treatment.Number of pod plant^{-1}of mungbean differed significantly due to plant growth regulator. The highest number of pod plant^{-1} (24.89) was recorded from 40 ppm NAA (G_{40}) treatment. Length of pod of mungbean differed significantly due to plant growth regulator. The maximum length of pod (9.68 cm) was recorded from 40 ppm NAA treatment. Number of seeds pod^{-1} of mungbean differed significantly due to plant growth regulator. The highest number of seeds pod^{-1} (14.67) was recorded from G_{40} treatment. 1000-seed weight of mungbean differed significantly due to plant growth regulator .The highest 1000 seed weight (44.50 g) was recorded from the 40 ppm NAA treatment. Grain yield of mungbean varied significantly due to plant growth regulator. The highest grain yield (1.68 t ha^{-1}) was observed from the 40 ppm NAA treatment. Stover yield of mungbean were significantly influenced by plant growth regulator. The maximum stover yield (2.13 t ha^{-1}) was observed from the G_0(control) treatment. Plant growth regulatorhad significant effect in producing biological yield. The highest biological yield (3.24 t ha^{-1}) was observed from G_0 treatment. A significant difference was observed for harvest index due to plant growth regulator. The maximum harvest index (56.42 %) was observed from 40 ppm NAA (G_{40}) treatment.

Significant interaction effects of row spacing and plant growth regulator on plant height was observed at 10, 20, 30, 40, 50 and 60 DAS. At 60 DAS, the highest plant height (60.73cm) was observed from P_2G_{40} treatment. There was significant variation among the interaction of row spacing and plant growth regulator on the total numbers of leaves plant^{-1}. At 60 DAS, the maximum number of leaves plant^{-1} (8.67) was recorded with the combination of 30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment. Present study showed that 30 cm × 10 cm spacing and 40 ppm NAA produced maximum number of leaves.Interaction effect of row spacing and plant growth regulator influenced the leaf dry weight. At 60 DAS, it was observed that the maximum (8.17 g) leaf dry weight was obtained from the combination of30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment. Interaction effect of row spacing and plant growth regulator influenced the stem dry weight at different DAS. It was observed that the maximum stem dry weight (6.12 g) was obtained from the combination of30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment.Interaction effect of row spacing and plant growth regulator influenced the root dry weight. At 60 DAS, it was observed that the highest root dry weight (2.80 g) was obtained from the combination of30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment. Leaf area index (%) of mungbean was significantly influenced by the interaction effect of row spacing and plant growth. The maximum leaf area index (5.25 %) was recorded from the combination of 30 cm × 10 cm spacing with 40 ppm NAA (P_2G_{40}) treatment. The study indicated that 30 cm × 10 cm spacing with 40 ppm NAA showed better performance in terms of leaf area index.Interaction between row spacing and plant growth regulatorshowed significant variation in number of pod plant^{-1}. The highest number of pod plant^{-1} (26.33) was recorded from the combination of 30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment. Interaction effect between row spacing and plant growth regulatorshowed significant variation in length of pod.The maximum length of pod (11.53 cm) was recorded from the combination of 30 cm × 10 cm spacing and 40 ppm NAA treatment. Interaction effect between row spacing and plant growth regulatorshowed significant variation in number of seeds pod^{-1}. The maximum number of seeds pod^{-1} (17.80) was recorded from the combination of P_2G_{40} treatment. Interaction effect between row spacing and plant growth regulatorshowed significant variation in 1000 seed weight of mungbean. The highest 1000 seed weight (49.70 g) was recorded from the combination of P_2G_{40} treatment. Statistically significant differences were recorded for the interaction effect of row spacing and plant growth regulatoron grain yield of mungbean. The maximum grain yield (2.00 t ha^{-1}) was observed from the combination of 30 cm × 10 cm spacing with 40 ppm NAA treatment. Row spacing and plant growth regulatorinteraction had significant differences on stover yield of mungbean. The highest stover yield (2.40 t ha^{-1}) was observed from the combination of P_1G_0 treatment. Interaction between row spacing and plant growth regulator showed significant variation in biological yield. The maximum biological yield (3.39 t ha^{-1}) was recorded from the combination of P_3G_0 treatment which was statistically similar (3.33 t ha^{-1}) to P_1G_0 treatment. Row spacing and plant growth regulatorinteraction had significant differences on harvest index of mungbean. The highest harvest index (68.97%) were observed from the combination of 30 cm × 10 cm spacing and 40 ppm NAA (P_2G_{40}) treatment. Present study reveled that 30 cm × 10 cm spacing and 40 ppm NAA produced best harvest index (%).

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

i) The effect of growth regulator naphthalene acetic acid (NAA) and row spacing had positive effect on morphological and growth characters, yield and yield attributes in mungbean.

ii) Application of 40 ppm NAA with 30 cm × 10 cm combination seemed to be more suitable for getting higher yield in mungbean.

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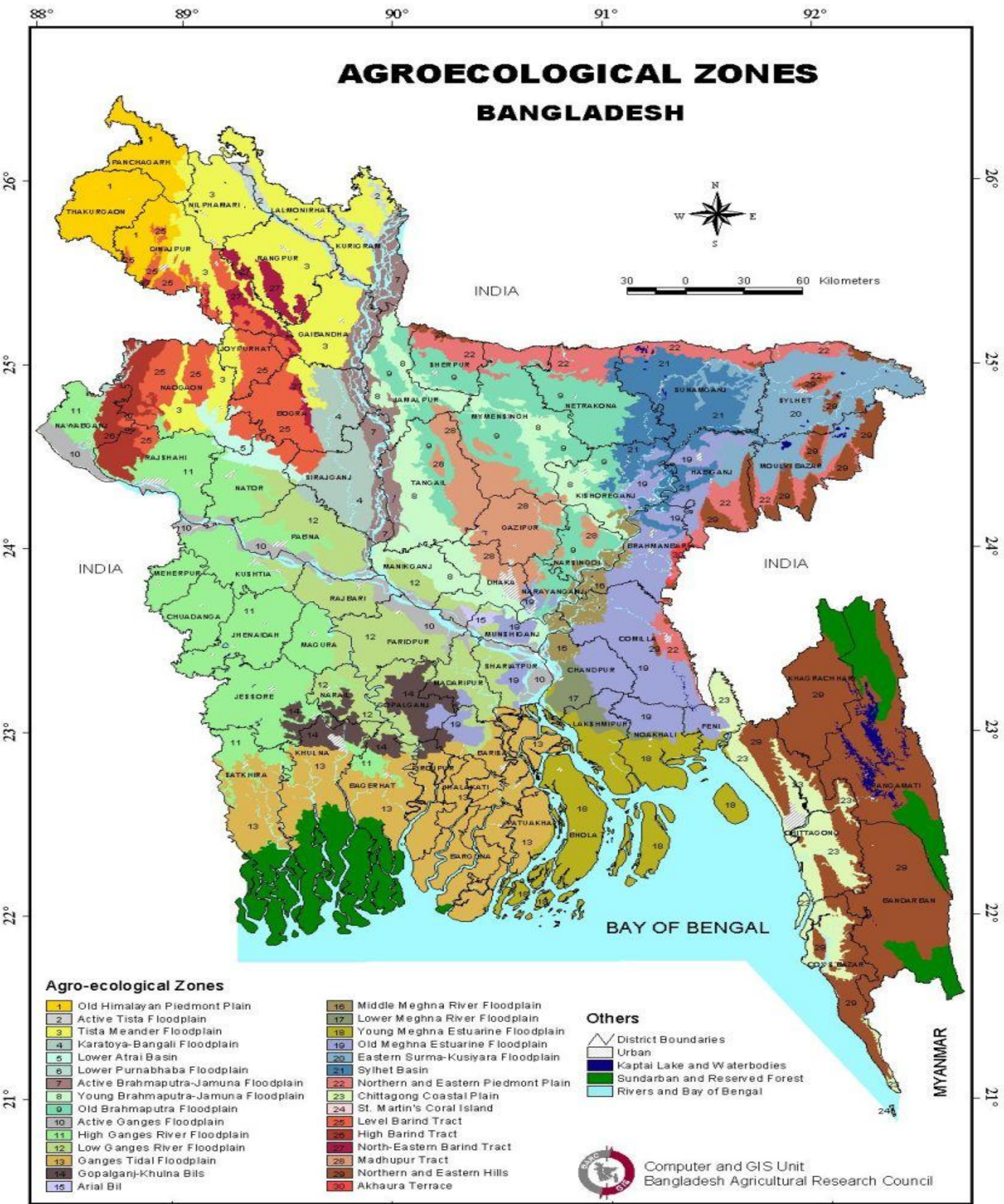
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Characteristics of Agronomic Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur 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	Fallow- Mungbean

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty-clay
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel/100 g soil)	0.10
Available S (ppm)	45

Source : SRDI, 2013

Appendix III. Monthly record of air temperature, rainfall, relativehumidity, soil temperature and sunshine of the experimentalsite during the period from August 2013 to November 2013

Months	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
August, 2013	36.0	23.6	29.8	81	319	4.0
September,2013	34.8	24.4	29.6	81	279	4.4
October, 2013	34.8	18.0	26.4	77	227	5.8
November, 2013	29.7	20.1	24.9	65	5	6.4

Source: Bangladesh Meteorological Department (Climate & weather division),Agargoan. Dhaka – 1212

Appendix IV: Mean square values for plant height of mungbean at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Plant height					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.512	6.929	6.929	70.355	146.980	146.980
Row spacing (A)	2	61.214*	258.021*	258.021*	262.010*	150.568*	111.634*
Plant Growth regulation (B)	3	5.027*	121.587*	55.037**	79.470*	84.468*	84.468**
A × B	6	0.716**	6.669**	6.669*	3.795*	5.685**	5.685*
Error	22	1.949	15.077	15.077	36.725	11.934	11.934

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V: Mean square values for number of leaves plant^{-1}of mungbean at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Number of leaves plant^{-1}					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.008	0.612	0.401	0.737	0.136	0.138
Row spacing (A)	2	3.909**	8.810*	12.801*	6.418**	8.048**	3.923**
Plant Growth regulation (B)	3	0.268*	13.934**	9.808*	7.435*	10.310*	0.328**
A × B	6	0.087*	0.679*	0.368**	0.081*	0.252**	1.247*
Error	22	0.185	0.350	0.481	0.522	0.591	0.245

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VI: Mean square values for leafdry weight plant^{-1} of mungbean at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Leaf dry weight plant^{-1}					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.020	0.433	0.001	0.001	0.07	0.084
Row spacing (A)	2	0.305*	0.135*	0.082*	0.041*	0.012*	0.583*
Plant Growth regulation (B)	3	0.081*	0.395*	0.034*	0.026*	0.33*	0.527*
A × B	6	0.003*	0.641*	0.008*	0.007*	0.103*	0.441*
Error	22	0.006	2.839	0.003	0.002	6.720	5.913

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VII: Mean square values for stemdry weight plant^{-1} of mungbean at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Stem dry weight plant^{-1}					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	1.863	2.164	4.224	0.302	0.264	1.863
Row spacing (A)	2	3.346*	6.761**	5.643**	5.362*	2.794*	3.346*
Plant Growth regulation (B)	3	4.086**	1.107**	8.127**	1.901*	3.655*	4.086**
A × B	6	3.407**	1.26**	5.03**	1.60*	3.660*	3.407**
Error	22	0.452	1.61	3.35	4.23	2.752	0.452

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VIII: Mean square values for rootdry weight plant^{-1} of mungbean at different days after sowing (DAS)

Sources of variation	Degrees of freedom	Root dry weight plant^{-1}					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.934	0.042	0.147	0.0001	0.000	0.143
Row spacing (A)	2	0.883**	0.491*	0.952*	0.017**	0.054*	0.398**
Plant Growth regulation (B)	3	0.933*	0.832*	0.892*	0.001*	0.880*	0.212**
A × B	6	0.518**	0.981*	0.50**	0.001*	0.515*	0.758*
Error	22	8.306	5.173	5.38	0.001	3.412	2.421

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

Appendix IX: Mean square values fornumber of pods plant^{-1}, pod length, number of seeds pod^{-1} and 1000 grain weight of mungbean

Sources of variation	Degrees of freedom	Number of pods plant^{-1}	Pod length	Number of seeds pod^{-1}	1000 grains weight
Replication	2	4.000	0.096	0.001	0.186
Row spacing (A)	2	31.750*	43.002**	95.807**	132.281**
Plant Growth regulation (B)	3	107.889*	10.131**	24.101*	82.548*
A × B	6	7.306**	0.024*	0.697**	3.323*
Error	22	1.364	0.059	0.001	3.000

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

Appendix X: Mean square values for grain yield, stover yield, biological yield and harvest index of mungbean

Sources of variation	Degrees of freedom	Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.009	0.068	0.058	29.538
Row spacing (A)	2	0.833*	1.577**	0.147*	1242.871*
Growth regulation (B)	3	0.494**	1.040*	0.134*	723.641*
A × B	6	0.017*	0.018*	0.017*	18.225**
Error	22	0.004	0.024	0.017	11.292

*Significant at 5% level of probability

** Significant at 1% level of probability