EFFECT OF INDOLE-3-ACETIC ACID AND ROW SPACING ON NODULATION, SOIL NITROGEN AND YIELD OF MUNGBEAN

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF INDOLE-3-ACETIC ACID AND ROW SPACING ON NODULATION, SOIL NITROGEN AND YIELD OF MUNGBEAN**" submitted to the Faculty of Agriculture, Sher-e-BanglaAgricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) IN AGRONOMY, embodies the result of a piece of bona-fide research work carried out by MD. HASIB ABDULLAH, Registration no. 09-03392 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.

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ABSTRACT

An experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka, during March to June, 2014 to study the effect of IAA and row spacing on growth, nodulation, soil nitrogen and yield of mungbean. The experiment was consisted of four levels of IAA applications viz. i) control (No IAA spray) ii) Foliar spray of Indole-3-acetic acid (IAA) @ 50 ppm at 25 DAS iii) Foliar spray of Indole-3-acetic acid (IAA) @ 100 ppm at 25 DAS and iv) Foliar spray of Indole-3-acetic acid (IAA) @ 150 ppm at 25 DAS and three spacings viz. i) 20cm x 10 cm, ii) 30cm x 10 cm and iii) 40cm x10cm. The experiment was laid out in randomized complete block design (RCBD) (factorial) with three replications.The results showed that nodulation, soil N, yield and yield attributes of mungbean were significantly influenced by the different levels of IAA application, spacing and their interactions. The highest nodules dry weight, SPAD value (52.47 %), soil N change and seed yield ha^{-1} (2.15 ton) was observed in 100 ppm of IAA application. Spacing also had significant effect on different growth and yield parameters. The plant with 30cm x 10 cm spacing gave the highest SPAD value (49.99 %) and seed yield ha^{-1} (2.17 ton). The interaction of 100 ppm IAA application and 30 cm row to row distance showed maximum SPAD value (55.00 %), soil N change and grain yield ha^{-1}(2.21 ton) as well as other 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
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	Editors
et al.	et alii (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 1

INTRODUCTION

Mungbean (*Vigna radiata L.*) is an important pulse crop of Bangladesh, which contains high graded vegetable proteins and satisfactory level of minerals and vitamins. This pulse plays a significant role as supplement of low protein diet of poor people in Bangladesh but its production and acreage is declining day by day with an average yield of 0.69 ton ha^{-1} (BBS, 2008). After 1970s, the production area of pulses is in decreasing trend in Asia due to increasing cultivation of cereals and vegetable crops (FAO, 2011; Munir *et al.,* 2012). Among the pulse area, only 8.10 % lands are used for the cultivation of mungbean (Kabir, 2001). According to World Health Organization (WHO), per capita per day requirement of pulse is 45 g. However, in Bangladesh, only 12g pulse is available per capita per day. About 6.01 million tons of pulse is required to meet the present per capita requirement of our country.

Auxin is known as a plant hormone and is synthesised by all higher plants (Ljung *et al.,* 2002). The most abundant form of auxin in plants is indole-3-acetic acid (IAA). Auxin appears to be a pattern-determining global regulator, as well as a player in cell division, cell elongation and vascular tissue differentiation (Woodward and Bartel 2005; Teale *et al.,* 2006, Heisler *et al.,* 2005). Auxin is the major regulator of lateral root initiation, differentiation and meristem specification (Casimiro *et al.,* 2003; Fukaki *et al.,* 2007). The correct auxin localisation and subsequent auxin response are crucial for lateral root development (Casimiro *et al.,* 2003; De Smet *et al.,* 2006; Fukaki *et al.,* 2007). Auxin is directly involved in activating the cell cycle during lateral root initiation (Himanen *et al.,* 2004) and the expression of downstream genes (Himanen *et al.,* 2004; Vanneste *et al.,* 2005). Mutants which overproduce auxin, like the *Arabidopsis superroot* mutant, have increased numbers of lateral roots (Boerjan *et al.,* 1995) and similarly exogenous application of auxin increases lateral root numbers (Wightman *et al.,* 1980; Laskowski *et al.,* 1995). In contrast, mutants resistant to auxin show reduced numbers of lateral roots (De Smet *et al.,* 2006).

It has been suggested that auxin may be a regulator of nodule development (Thimann 1936; Hirsch 1992; Hirsch and Fang 1994). However, many plant-associated soil bacteria are also known to synthesise auxin, in particular IAA, and this could be part of a strategy to manipulate the growth of host plants (Spaepen *et al.,* 2007). There is evidence that auxin synthesis by bacteria alters root architecture in non-nodulating plants (Clark *et al.,* 1993). In *Casuarina glauca* Sieber, the auxin import protein AUX1 is specifically induced in root cells colonised by *Frankia* (Peret *et al.,* 2007). Flavonoids, which are exuded in particular from legume roots to stimulate Nod factor synthesis, have been shown to stimulate IAA synthesis in *Rhizobium* sp. (Theunis *et al.,* 2004). Studies with *Rhizobium* mutants deficient in IAA synthesis have shown that nitrogen fixation can be impaired by a lack of rhizobial auxin, whereas increased nodulation efficiency can be reached with IAA overproducing strains, although this might differ between determinate and indeterminate legumes (Pii *et al.,* 2007). It has been noted that non-legumes can also be stimulated to form nodule-like structures after application of auxin and the resulting structures can be colonised by diazotrophs, including *Azospirillum* and *Rhizobium* sp. which appear to infect via crack entry (Christiansen-Weniger 1998). It was also observed in several legumes that synthetic auxin transport inhibitors can induce nodules spontaneously in the absence of rhizobia (Allen *et al.,* 1953; Wu *et al.,* 1996). The developmental mechanisms of lateral root formation have been studied in great detail, and auxin has emerged as a central regulator of lateral root development (Fukaki *et al.,* 2007). Each root nodule is packed with thousands of living *Rhizobium* bacteria and these nodule structures, known as symbiosomes, which may contain several bacteroids or just one, are where the nitrogen fixation takes place (Society of Microbiology). Root nodule symbioses with nitrogen-fixing bacteria provide many plants with a source of nitrogen (PLoS Biology) by converting atmospheric nitrogen into a form that is directly available for plant growth (Brewin *et al.*, 2010). IAA and 4-Cl-IAA improved the growth and nitrogen fixation in mung bean (Boustar *et al.*, 2008). So, if nodule development has been recruited from lateral root formation, it could be expected that similar developmental signals regulate both processes. Therefore, artificial application of auxin is likely to accelerate nodule developmental process and increase nitrogen fixation.

IAA (indol-3-acetic acid), a naturally synthesized growth hormone, plays a very important role to enhance crop growth and development, which could increase the availability of food to the growing plant when required. With increasing plant density, competition between plants increases which could result lower food production of individual plant that could hamper nodule production. Artificial applied auxin could increase root and shoot growth which could help to harvest more light, water, nutrients etc. to produce more food by individual plant. Therefore, artificially applied auxin might have a positive effect on nodulation process and increasing yield quality under different plant density.

Taking the above mentioned points in view, the present study was undertaken with the following objectives:

- To study the role of different level of IAA on nodulation and N fixation of mungbean in Kharif-I season under different plant density.
- To study the yield pattern of BARI Mung 6 under different level of IAA and different plant density.
- To findout the proper dose of IAA for higher yield of mungbean under different plant density.
- To findeout the interaction effect of IAA and row spacing on BARI Mung 6.

CHAPTER 2

REVIEW OF LITERATURE

The growth and development of mungbean are influenced due to different level of IAA foliar application and row spacing. Experimental results are available from home and abroad to reveal that IAA and row spacing may influence growth and yield to a great extent. Relevant reviews on the above aspects have been presented and discussed in this chapter.

2.1. Role of IAA

2.1.1. Chlorophyll

Muthulakshmi and Pandiyarajan (2015) conducted an experiment to study the different concentration of IAA (50, 100, 150, and 200ppm) foliar spray on vegetative growth, physiological and biochemical constituents of *Chataranthus roseus* (L). G.Don. The application of IAA led to 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, NRA and peroxidase activity. On unit fresh weight basis, the total chlorophyll content was found to increase at all concentrations.

2.1.2. Photosynthetic pigment

Muthulakshmi and Pandiyarajan (2015) reported the application of IAA led to significant increase photosynthetic pigment, non-photosynthetic pigment composition and total soluble protein.

2.1.3. Nodulation

A role for IAA in nodule development was first postulated in 1936 by K. V. Thimann, supported by the observation that root nodules have a higher IAA content than uninfected root tissue. Studies on nodule development performed with natural (flavonoids) and artificial (e.g. NPA) inhibitors of auxin transport, as well as direct and indirect measurements of IAA, have indicated that auxin accumulates at the site of nodule initiation during nodule formation (Boot *et al.*, 1999; Mathesius *et al.*, 1998; Pacios *et al.*, 2003) . In general, root nodules contain more auxin than non-nodulated roots (Badenochjones *et al.*,1983).

Since IAA is involved in multiple processes including cell division, differentiation and vascular bundle formation, these three processes are also essential for nodule formation. Hence, it seems likely that auxin levels in the host legume plants are necessary for nodule formation (Glick, 2012; Spaepen *et al.*, 2007).

Many scientists suggested that auxin may be a regulator of nodule development (Thimann, 1936; Hirsch, 1992; Hirsch and Fang 1994). However, some suggested that nodule organogenesis and lateral root formation display some similarities. Both organs require auxin at development of the primordia and for the differentiation of the vasculature (Billy *et al.*, 2001 and Mathesius *et al.*, 2000).

Clark *et al.* (1993) found some evidence that auxin synthesis by bacteria alters root architecture in non-nodulating plants. Theunis *et al.* (2004) also found that Flavonoids, which are exuded in particular from legume roots to stimulate Nod factor synthesis, have been shown to stimulate IAA synthesis in *Rhizobium* sp.

Camerini *et al.* (2008) found that expression of the IAM biosynthetic pathway resulted in *Vicia hirsuta* root nodules containing up to 60-fold more IAA than nodules invoked by the wild-type strain.

Free-living rhizobia synthesize IAA (Badenoch *et al.*, 1982) and most likely they retain a similar capacity to synthesize IAA during nodulation, because a positive correlation between IAA production in liquid culture and IAA content of the nodules has been demonstrated by using *Brady rhizobium japonicum* mutants with different IAA synthesising capacities (Hunter, 1987)

Pii *et al.* (2007) found that in *Casuarina glauca*, the auxin import protein AUX1 is specifically induced in root cells colonised by *Frankia* which is regulator of nodule development and increased nodulation efficiency can be reached with IAA overproducing strains, although this might differ between determinate and indeterminate legumes.

Fukuhara, *et al.* (1994) found a promoting effect of IAA on determinate nodule formation was also suggested by the observation that IAA-deficient *B. japonicum* mutants produced significantly less nodules than wild type strains.

Christiansen-Weniger (1998) noted that non-legumes can also be stimulated to form nodule-like structures after application of auxin and the resulting structures can be colonised by diazotrophs, including *Azospirillum* and *Rhizobium* sp. which appear to infect via crack entry.

It was also observed in several legumes that synthetic auxin transport inhibitors can induce nodules spontaneously in the absence of rhizobia (Allen *et al.,* 1953; Wu *et al.,* 1996).

Boustar *et al.* (2008) concluded there research that both IAA and 4-Cl-IAA improved the growth and nitrogen fixation in mung bean.

Remans *et al.* (2008) conducted an experiment to know the role of IAA in nodulation and N fixation using an Azospirillum ipdC mutant, producing 10% of IAA produced by the wild-type strain. Increase in nodulation and nitrogen fixation was not observed, indicating that bacterial IAA production is important in symbiosis.

Hunter (1987) found that excess IAA is not good for nodule formation. In his experiment he found that 5-methyl tryptophan resistant mutants of *B. japonicum* that overproduce IAA caused, in comparison with wild type rhizobia, a lower nodule mass and a lower number of nodules in soybean.

Mathesius (2008) suggested that Auxin is involved in many processes of nodule formation by *rhizobia* in legume plants, such as founder cell specification (auxin transport inhibition mainly by flavonoids), nodule initiation and differentiation (auxin accumulation), vascular bundle formation, and nodule numbers (long distance auxin transport). Because many rhizobia are capable of producing IAA via different pathways, it is assumed that bacterially produced auxin can alter the auxin balance inside the plant. In addition, rhizobia can also indirectly influence the auxin homeostasis by interfering with plant auxin transport.

Sudadi and Suryono (2015) conducted a greenhouse experiment on soybean to investigate the effect of IAA on soybean. They found that exogenous application of amino acid tryptophan and IAA in increasing root nodules and soybean yield. The results showed that both exogenous amino acid tryptophan and IAA increased number of root nodules, nodule weight, shoot and root dry weight and soybean yield.

2.1.4. Pod length

Saha *et al*. (1996) reported that 300, 600 and 900 ppm IAA applied at the beginning of the tillering stage in wheat increased ear, spikelet and grain length. Sanyal *et al*. (1995) mentioned that IAA had profound effect on fruit length of tomato.

2.1.5. Number of pods plant^{-1}

The regulatory effect of IAA on number of pods per chickpea plant was reported by Arora *et al*. (1998). Lee (1990) reported that soaking groundnut seeds in 500, 100 and 200 ppm IAA solution prior to sowing produced plants with greater number of pods plant^{-1}. Application of 10^{-5}M IAA significantly increased the number of capsules per flax plant (Abdel *et al*., 1996) and application of 50 ppm IAA on grasspea increased number of pods per plant (Rahman *et al*., 1989). Chellappa and Karivaratharaju (1973) found that soaking groundnut seeds before sowing in 5 ppm IAA for 12 hours gave the highest number of pods plant^{-1}.

Manikandan and Hakin (1998) reported increased number of pod when IAA at 30 ppm was applied in groundnut (arachis hypogaea cv. Co-02)

2.1.6. Seeds pod^{-1}

Arora *et al*. (1998) conducted an experiment on chickpea and found that IAA applied at the 50% flowering stage to chickpeas increased the number of seeds per pod. Abdel *et al*. (1996) observed similar kind of results in case of flax seeds with IAA at 10^{-5}M.

2.1.7. 1000- seed weight

Foliar application of 50 ppm IAA increased seed weight in grass pea (Rahman *et al.*, 1989). Saha *et al.*, (1996) reported that 300, 600 and 900 ppm IAA applied at the beginning of the tillering stage in wheat increased 1000 grain weight. Similar results were also reported by Yan *et al.* (1995) and Gurdev and Saxena (1991). Rahman *et al.* (1989) found 50 ppm of IAA increased seed weight in grasspea. Higher seed weight also reported by Lee (1990) in case of IAA treated groundnut seeds.

2.1.8. Seed yield

Rastogi *et al.* (2013) conducted a pot experiment to know the effect of auxin and gibberellic acid on linseed and concluded that plant growth regulators can be successfully employed to enhance the yield in this economically important oil seed crop.

Jong *et al.* (2009) reported that auxin and gibberellin play major role in the development of fruit and expression of genes in tomato.

Arora *et al.* (1998) reported that IAA applied at 50% flowering stage to chickeas grown in Indian Panjab increased seed yield per plant compared to control. Rahman *et al.*, (1989) found foliar application of IAA on grasspea increased seed yield.

Application of IAA to rice plants at panicle emergence stage significantly increased grain yield (Awan and Alizai, 1989; Singh *et al.*, 1984; Thakre, 1985). Saha *et al.* (1996) also reported similar result in case of wheat.

Sanyal *et al.* (1995) mentioned that IAA had profound effect on fruit length of tomato.

Abdel *et al.* (1996) observed that treatment of flax seeds with IAA at 10^{-5} M increased the number of seeds per capsule.

The regulatory effect of IAA on number of pods per chickpea plant was reported by Arora *et al.* (1998). Lee (1990) reported that soaking groundnut seeds in 500, 100 and 200 ppm IAA solution prior to sowing produced plants with greater number of pods per plant. Application of 10^{-5}M IAA significantly increased the number of capsules per flax plant (Abdel *et al.*, 1996) and application of 50 ppm IAA on grasspea increased number of pods per plant (Rahman *et al.*, 1989). Chellappa and Karivaratharaju (1973) found that soaking groundnut seeds before sowing in 5 ppm IAA for 12 hours gave the highest number of pods per plant.

Manikandan and Hakin (1998) reported increased number of pod when IAA at 30 ppm was applied in groundnut (*Arachis hypogaea* cv. Co-02)

2.2. Role of spacing

2.2.1. Chlorophyll

Moreira *et al.* (2015) conducted an experiment to evaluate the interaction between N fertilization, row spacing, and plant density on photosynthetic index, yield components, yield, and nutritional status of soybean–wheat (*Triticum aestivum* L.) intercropping. plant height, chlorophyll content (CC), and transpiration rate (Trmmol) decreased with increasing spacing of soybean

2.2.2. Photosynthetic pigment

Denmead *et al.* (1962) estimated that 60 cm inter row spacing might increase the energy available for photosynthesis 15-20%, compared with 100cm spaced row in corn.

2.2.3. Nodulation

Herbert and Litchfield, (1984); Ethredge *et al.* (1989) and Kapustka and Wilson, (1990) reported significantly higher seed yield and masses and numbers of nodules on soybean plants grown in narrow row spacings (25, 30, 50 and 51 cm) than in row spacings greater than 51 cm. Thalji (2006) found higher number of nodule in higher plant spacing. Worku and Astatkie (2015) and Ndor *et al.* (2012) also mention about the role of spacing on nodulation of soybean and cowpea respectively.

Thalji (2006) conducted an experiment to investigate the effect of row spacing on *faba bean (L).* The results showed that higher row spacing (50-70 cm) resulted in the greatest yield with a reduction at the narrow spacing. The increase in the characters studied was: (50 %) for grain, (53-100%) for nodule dry weight, (77%) for nodule number and (34%) for root dry weight. Jamro *et al.* (1990) found that nodule weight per plant was higher at a RS of 60 cm compared to ones of the 30 and 45 cm, and in southern Quebec, Canada, high plant densities increased fresh nodule mass per unit area, but had little effect on individual plant nodulation (Chen *et al.*, 1992).

2.2.4. Pod length

Islam *et al.* (2011) conducted a field experiment at the Horticultural farm of the BangladeshAgricultural Research Institute (BARI), Joydebpur, Gazipur, and found that number of fruits per plant, fruit length were significantly increased with the increasing of plant density

Ahmed *et al.* (2005) conducted a field experiment in 2000 to investigate the effect of P fertilizer and plant density on the yield and yield components of mungbean cm. NM-92 in Faisalabad, Punjab, Pakistan. They found highest seed yield at 30 cm row spacing while pod length, pods plant^{-1}, seeds pod^{-1} and 1000 seed weight were highest with 45 cm row spacing.

Pookpakdi and Pataradilok (1993) reported about decreased yield of Mungbean and Black Gram with decreasing plant density, while pod length, pods plant^{-1} increased with decreasing density.

2.2.5. Number of pods plant^{-1}

Pookpakdi and Pataradilok (1993) conducted an experiment in 1989 & 1990 on Mungbean and Black Gram and found that, yield of both crops generally decreased with decreasing plant density, while pod number/plant increased with decreasing density.

Ahmed *et al.* (2005) reported that, at 45 cm row spacing pods plant^{-1} were highest. Pookpakdi and Pataradilok (1993) also reported about higher pods plant^{-1} of Mungbean and Black Gram with decreasing plant density.

2.2.6. Seeds pod^{-1}

Baloch (2004) found that crop sown in closer row spacing resulted in significantly maximum seed yield, but the yield components depicted better performance under wider row plant density.

Ahmed *et al.* (2005) conducted a field experiment in Faisalabad, Punjab, Pakistan and found that seed pod^{-1} were higher at 45 cm row spacing compared to other narowar row spacing.

2.2.7. 1000-seed weight

Mozumder *et al.* (2012). conducted an experiment at the Horticulture Field Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University during December 2007 to July 2008 of *Eryngium foetidum* at different spacing. They found that thousand seed weight were higher in wider spacing but marketable fresh yield and seed yield per unit area was better in medium (10 cm×10 cm) spacing.

Islam *et al.* (2011) conducted a field experiment at the Horticultural farm of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, and found that number of fruits per plant, fruit length, individual fruit weight, yield plant^{-1} were significantly increased with the increasing of plant spacing.

2.2.8. Seed yield

Baloch (2004) worked on three row are 30 cm, 45 cm, and 60 cm. He found that crop sown in closer row spicing of 30 cm resulted in significantly maximum seed yield, but the yield components depicted better performance under wider row spacing of 60 cm, due to more space for spreading and higher chances in taking moisture and nutrients from the soil.

Sarkar *et al.*, (2004) reported that, in Bangladesh, planting density of 30x10 cm gave higher yield of mungbean than 20x20 cm or 40x30 cm planting density. Row and plant spacings influence plant yield, yield attributes and yields of mungbean (Ihsanullah *et al.*, 2002).

Singh and Singh (1990) reported that plant population did not affect seed yield.

Kumar and Sharma (1989) who reported higher biological yield at narrow row spacing, but don’t confirmed by Soni *et al.* (1991), who reported non-significant effect of row spacing on biological yield.

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 per hectare in a field experiment which was conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 ton per hectare, respectively) compared to cv. Pusa 105.

Ahmed *et al.* (2005) conducted a field experiment in Faisalabad, Punjab, Pakistan, during 2000 to study the effect of P fertilizer f(0, 30, 60 and 90 kg per hectare) and row spacing (30 and 45 cm) on the yield and yield components (pods per plant, seeds per pod and 1000 seed weight) of mungbean cm. 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.

Raghuwanshi (2009) conducted a field trial at Tikamagarh, Madhya Pradesh in 2008 kharif (monsoon) season, sesame cv. TKG-9, tkg-21, JLSC-8 and JT-7 produced mean seed yields of 2.53, 2.80, 2.92 and 1.86 tha^{-1}, respectively. Yield averaged 2.05 and 3.00 t with spacings of 30x15 and 10x10cm, and 3.99, 1.85 and 1.75 t when sownat the onset of monsson (1 July) or 10 or 20 d after this date. Asghar *et al.* (2009) and Krishna *et al.* (2008) also reported about similar kind of result for sesame.

CHAPTER 3

MATERIALS AND METHODS

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

3.1. Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University research farm, Dhaka, during the period from March 2014 to June 2014. The experimental site was located at 23°77′ N latitude and 90°37′ E longitudes with an altitude of 9 m.

3.2. Agro-ecological region

The experimental site belongs to 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, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). For better understanding, the experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.3. Climate and weather

The geographical location of the experimental site was under the sub-tropical climate characterized by three distinct seasons. 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 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 site was collected from Bangladesh Meteorological Department, Agargaon, Dhaka and is presented in Appendix II.

3.4. Soil

The experiment was carried out in a typical rice growing soil belonging to the Madhupur Tract. Top soil was silty clay in texture, red brown terrace soil type, olive–gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The land was well drained with good irrigation facilities. The experimental site was a medium high land. It was above flood level and sufficient sunshine was available during the experimental period. The morphological characters of soil of the experimental plots are as following - Soil series: Tejgaon, General soil: Non-calcareous dark grey (Appendix III). The physicochemical properties of the soil are presented in Appendix III.

3.5. Crop / Planting materials

BARI Mung-6 was used as planting material. The seeds of BARI Mung 6 was collected from Bangladesh Agricultural Research Inistitute, Joydepur, Gazipur. This variety is suitable for summer season. 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^{-1}

3.6. Treatments under Investigation

Factor A: Indole-3-acetic acid (4 levesls)

A_1 = Control (Foliar spraying of water at 25 DAS)

A_2 = Foliar spraying of Indol-3-Acetic Acid (IAA) @ 50 ppm at 25 DAS

A_3 = Foliar spraying of Indol-3-Acetic Acid (IAA) @ 100 ppm at 25 DAS

A_4 = Foliar spraying of Indol-3-Acetic Acid (IAA) @ 150 ppm at 25 DAS

Factor B: Row spacing (3 levels)

S_1 = 20cm x 10cm

S_2 = 30cm x 10cm

S_3 = 40cm x 10cm

3.7. Details of the Experiment

3.7.1. Experimental treatments

Two factor experiments were conducted to evaluate the effect of IAA on growth, nodulation pattern and soil nitrogen after mungbean cultivation and yield of mungbean under different row spacing.

3.7.2. Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatments. The experimental field was divided into 3 blocks. Each block was again divided into 12 plots. The total numbers of unit plots of the experiment were 36 (12 × 3). The size of the unit plot was 3.75 m × 1.78 m (6.675 m^2). There were 0.50 m width and 10 cm depth for drains between the blocks. Each treatment was again separated by drainage channel of 0.4 m width and 10 cm depth. The treatments were randomly distributed to each block following the experimental design (Figure 1).

3.8. Growing of crops

3.8.1. Seed collection

The seeds of the test crops were collected from BARI.

3.8.2. Land preparation

The land was irrigated before ploughing. After having field capacity, land was conditioned and firstly opened with disc plough. The first ploughing was done on 08 March, 2014 and final land ploughing was done on 10 March, 2014. The experimental field was divided and arranged according to experimental layout. The basal fertilizer doses were applied on 10 March, 2014. The experimental layout is presented in Figure 1.

3.8.3. Fertilizer Application

Urea, Triple Super Phosphate (TSP) and Murate of Potash (MP) were used as sources of nitrogen, phosphorus and potash. BARI recommended dose were applied. All the fertilizers were applied as a basal dose during final land preparation.

Nutrient	**Source**	**Dose (kg ha^{-1})**
N (Nitrogen)	Urea (46% N)	30
P (phosphorus)	TSP (48% P_2O_5)	48
K (potassium)	MoP (60% K_2O)	30

3.8.4. Seed Sowing

Seeds were sown on 11 March, 2014. The seed rate was maintained at 30 kg ha^{-1}. Seeds were treated with fungicide provex to protect them from seed borne diseases. Seeds were placed in rows having different distance of 20 cm, 30 cm, 40 cm and depth of 2-3 cm.

Emergences of seedling: Seed germination occurred on 14 March, 2014 and 50% seed germination was recorded on 16 March, 2014.

3.9. Intercultural operation

3.9.1. Weeding and thinning

Weeding was done as per requirement. Thinning was done to maintain plant to plant distance 10 cm. The first thinning was done at 8 DAS and second one was done at 15 DAS.

3.9.2. Irrigation and drainage

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

3.9.3. Insect control

The insecticide Malathion 57EC was sprayed @ 1.5 1 ha^{-1} at the time of 50% pod formation stage to control pod borer.

3.10. General observation

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

3.11. Determination of maturity

At the time when 80% of the pods turned blackish in color, the crop was assessed to attain maturity.

3.12. Harvesting and sampling

The crops were harvested from central 1.0 m^2 area of each plot for yield data on different dates as they attained maturity. Five randomly selected plants from each plot were marked for recording data on plant height, pods $plant^{-1}$, pod length and seed weight $plant^{-1}$. Pods were collected thrice throughout the growing period.

3.13. Threshing

The crop bundles were sundried for two days by placing them on threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks.

3.14. Drying, cleaning and weighing:

The collected seeds were dried in the sun for reducing the moisture to about nearly14% level. The dried seeds and stover were cleaned and weight of seeds $plot^{-1}$ was recorded.

3.15. Recording of data

Data were recorded on the following characters

i. Number of nodule $plant^{-1}$
ii. Dry weight of nodule $plant^{-1}$
iii. Chlorophyll content
iv. Soil N
v. Pod length
vi. Number of pod $plant^{-1}$
vii. Seeds pod^{-1}
viii. 1000-seed weight
ix. Seed yield ha^{-1}

3.16. Outline of data recording

A brief outline of data recording procedure is given below:

3.16.1. Days to seedling emergence

It was taken by an overview to measure first germination of crops took places.

3.16.2. Days to 50% seedling emergence

It was observed on 17 March, 2014 when 50% seed were germinated.

3.16.3. Number of nodules plant^{-1}

Three randomly selected plants from each plot were selected to count nodule. Nodule numbers were counted at 30, 40, 50 and 60 DAS from randomly selected plants. Selected plants were first watered a little to lose the soil of root area. After that, plants were uprooted with soil surrounded it by a Nerani. Then it was soaked in a boll full of water. After 5-10 minutes when soil was fallen, plants were removed from the ball. Drying few minutes in air under shed nodule was counted.

3.16.4. Dry weight of nodule plant^{-1}

Nodules were separated from the roots after counting and kept in a paper bag separately according to the different treatment. Nodules were oven dried at 72 °C temperature for 24 hours and weight was recorded.

3.16.5. Chlorophyll content of leaf

Leaf chlorophyll was measured by SPAD Meter at the 80% flowering stage of BARI Mung 6. Newly full matured leave was used to count the leaf chlorophyll percent.

3.16.6. Soil N change

Cultivation of mungbean fixes atmospheric N to soil. Soil N percent was measured before the cultivation of BARI Mung 6. After harvest, soil was taken from 36 plots and soil N percent was analyzed. Subtracting the initial result from the final soil N change was calculated.

3.16.7. Days to harvesting

Days to harvesting was considered when the 80% pod of the plants within a plot becomes blackish in color. The number of days to maturity was recorded from the date of sowing.

3.16.8. Pod length (cm)

Pod length was calculated from ten randomly selected pods of five selected plants and then the average pod length was calculated.

3.16.9. Number of pods plant^{-1}

Pods from 5 selected plants were counted and recorded as the average of pod^{-1}.

3.16.10. Number of seeds pod $^{-1}$

Number of seeds pod^{-1}was counted from ten randomly selected pods of 5 selected plants and then the average seed number was calculated.

3.16.11. Weight of 1000-seeds

One thousand cleaned dried seeds were counted randomly from the total cleaned harvested grains of each individual plot and then weighed with a digital electric balance at the stage the seed retained 14% moisture and the mean weight were expressed in gram.

3.16.12. Seed yield

The crop was harvested and threshed respective plots wise. Seeds were separated, cleaned and dried in the sun. Then seed yield plot^{-1} was recorded at 12% moisture level. The yield plot^{-1}was converted to hectare basis.

3.18. Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques to obtain the level of significance by using MSTAT-C computer package program (Fred, 1986). The significant differences among the treatment means were compared by Least Significant Difference (LSD) test at 5% level of probability.

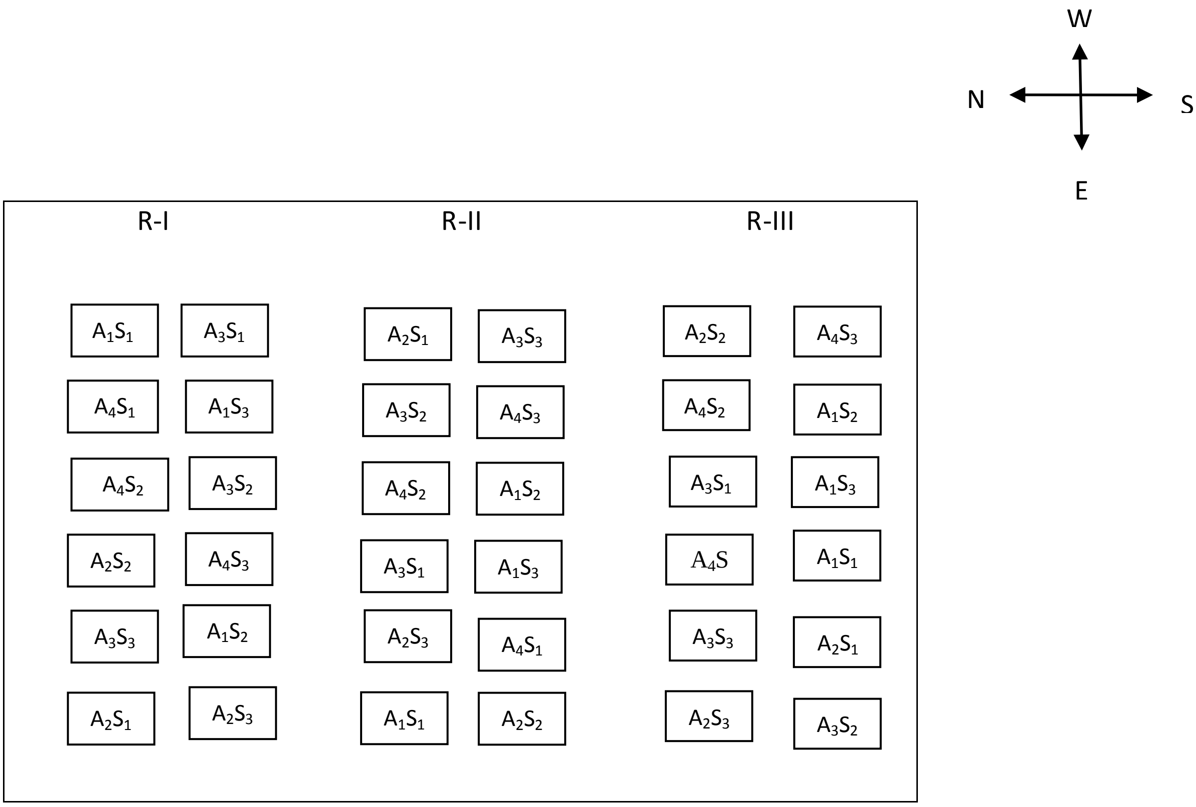


Figure 1: Experimental layout

Here,

S_1 = 20cm x 10cm row spacing

S_2 = 30cm x 10cm row spacing

S_3= 40cm x 10cm row spacing

A_1 = Control (Foliar spraying of water at 25 DAS)

A_2 = Foliar spraying of Indol-3-Acetic Acid (IAA) @ 50 ppm at 25 DAS

A_3 = Foliar spraying of Indol-3-Acetic Acid (IAA) @ 100 ppm at 25 DAS

A_4 = Foliar spraying of Indol-3-Acetic Acid (IAA) @ 150 ppm at 25 DAS

Number of treatments: 12

Plot to plot: 0.4 m

Block to block: 0.5 m

Total plot Area: 3.75 x 1.8= 6.75 m^2

CHAPTER 4
RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained from the present study. The results have been presented, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

4.1. Nodule parameter

4.1.1. Nodule number plant^{-1}

4.1.1.1. Effect of IAA

The influence of IAA on nodule number was found significant throughout the life period of BARI Mung 6 (Appendix-IV). At 30 DAS all treatment showed statistically identically identical results (Fig. 2a). However as plant went to maturity, nodule number was found to have influenced by IAA as A_4 (150 ppm IAA application) gave maximum nodule number per plant (71.89 at 40DAS, 79.15 at 50 DAS and 66.85 at 60 DAS) (Fig. 2a). At harvesting stage, the nodule number per plant of all IAA treatment was found statistically similar. On the other hand, minimum number of nodule was recorded in A_1 (No IAA treated) treatment throughout the growth period of BARI Mung 6.

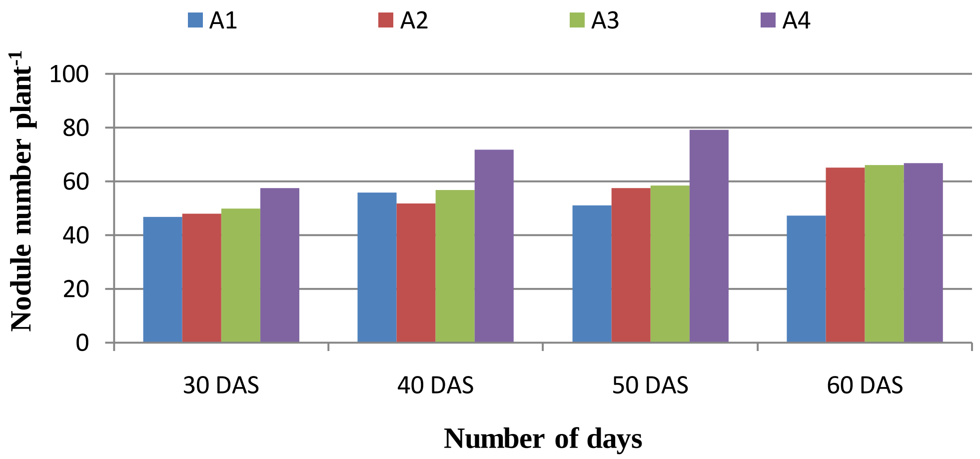
In general, root nodules contain more auxin than non-nodulated roots (Badenochjones *et al.,* 1983). Glick (2012) and Spaepen *et al.* (2007) mentioned that auxin levels in the host legume plants are necessary for nodule formation. Similar results were reported by Boot *et al.* (1999); Mathesius *et al.* (1998) and Pacios-Bras *et al.* (2003).

4.1.1.2. Effect of spacing

It was found that nodule number was influenced by the different spacing provided in this experiment (Appendix-IV). Nodule number of BARI Mung 6 was found maximum at S_2 (30 cm row to row distances) treatment throughout the life period (54.28, 63.5, 71.08 and 72.61 at 30, 40, 50 and 60 DAS respectively) (Fig. 2b). However, at 30 DAS all the spacing treatment showed statistically identical results. S_3 (40 cm row to row distances) also showed statistically identical result at 40 DAS (58.33) and statistically similar result at 50 DAS (59.94) with S_2 (30 cm row to row distances) (Fig. 2b). However, S_1 (20 cm row to row distance) showed lowest nodule number at 40, 50 and 60 DAS, where both narrow S_1 (20 cm row to row distance) and wider spacing S_3 (40 cm row to row distance) showed lower nodule production, which was statistically identical, at 50 and 60 DAS.

Herbert and Litchfield (1984); Ethredge *et al.* (1989) and Kapustka and Wilson (1990) reported significantly higher numbers of nodules on soybean plants grown in narrow row spacings (25, 30, 50 and 51 cm) than in row spacings greater than 51 cm. Worku and Astatkie (2015) and Ndor *et al.* (2012) also mention about the role of spacing on nodulation of soybean and cowpea respectively.

(a)

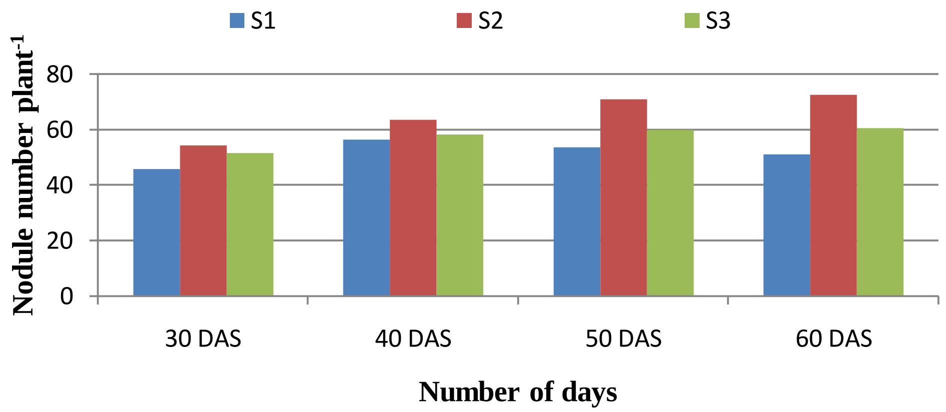


Note: A_1 : No IAA A_3 : 100 ppm IAA

A_2 : 50 ppm IAA A_4 : 150 ppm IAA

LSD values were12.63, 19.62, 14.65 and 12.97at 30, 40, 50 and 60 DAS respectively

(b)



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm

S_3 : 40 cm ×10 cm

LSD values were10.94, 6.99, 12.69 and 11.23 at 30, 40, 50 and 60 DAS respectively

Figure 2. Effect of IAA (a) and row spacing (b) on the number of nodule plant^{-1} of BARI Mung 6.

4.1.1.3. Interaction effect of IAA and row spacing

Interaction effect of IAA and spacing was found to play significant role to the number of nodule per plant in this experiment (Appendix-IV). The highest nodule number was recorded in A_4S_2 (150 ppm IAA application + 30 cm row to row distance) treatment that was 77.67 at 30 DAS, 97.67 at 40 DAS, 94.00 at 50 DAS and 89.00 at 60 DAS (Table 1). A_3S_1 (100 ppm IAA application + 20 cm row to row distance)and A_4S_3 (150 ppm IAA application + 40 cm row to row distance) showed statistically similar result to A_4S_2 (150 ppm IAA application + 30 cm row to row distance) at 30 DAS. At 40 DAS A_1S_3 (No IAA application + 40 cm row to row distance), A_3S_1 (100 ppm IAA application + 20 cm row to row distance), A_4S_1(150 ppm IAA application + 20 cm row to row distance) and A_4S_2 (150 ppm IAA application + 30 cm row to row distance) showed statistically similar nodule number per plant. A_4S_2 (150 ppm IAA application + 30 cm row to row distance) and A_4S_3 (150 ppm IAA application + 40 cm row to row distance) showed statistically similar nodule number per plant at 50 DAS. On the other hand, control treatment combination (A_1S_1) (No IAA application + 20 cm row to row distance) always showed lower nodule number throughout the life period of BARI Mung 6.

Table 1. Interaction effects of IAA and row spacing on number of nodule plant^{-1} of BARI Mung 6

Treatments	Number of nodule plant^{-1}			
	30 DAS	**40 DAS**	**50 DAS**	**60 DAS**
A_1S_1	32.56 d	37.78 c	40.44 d	39.89 e
A_1S_2	53.78 bcd	51.33 bc	55.22 bcd	48.00 de
A_1S_3	53.67bcd	78.67 ab	57.22 bcd	54.22 cde
A_2S_1	50.11 bcd	54.67 bc	48.33 cd	53.78 cde
A_2S_2	42.67 bcd	48.78 bc	67.00 bc	76.11 abc
A_2S_3	51.44 bcd	51.78 bc	57.33 bcd	65.78 bcd
A_3S_1	61.78 ab	64.78 abc	61.00 bcd	63.67 bcd
A_3S_2	43.00 bcd	52.22 bc	68.11 bc	77.33 ab
A_3S_3	44.67 bcd	53.22 bc	46.66 cd	57.67 bcde
A_4S_1	38.44 cd	68.33 abc	64.89 bcd	46.67 de
A_4S_2	77.67 a	97.67 a	94.00 a	89.00 a
A_4S_3	56.22 abc	49.67 bc	78.56 ab	64.89 bcd
LSD $_{(0.05)}$	**21.88**	**33.98**	**25.37**	**22.46**
CV (%)	**15.58**	**13.97**	**14.34**	**15.24**

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

S_1 : 20 cm x 10 cm
S_2 : 30 cm x 10 cm
S_3 : 40 cm x 10 cm

A_1 : Control (No IAA)
A_2 : 50 ppm IAA
A_3 : 100 ppm IAA
A_4 : 150 ppm IAA

4.1.2. Nodule weight plant^{-1}

4.1.2.1. Effect of IAA

The role of IAA on the dry weight of nodule was found significant (Appendix-V). Dry weight of nodule was increased after IAA application compared to the control treatment. It was found highest in A_3 (100 ppm IAA application) at 40 and 60 DAS (0.2914 g and 0.2011 g respectively) (Fig. 3a). At 50 DAS, highest nodule dry weight was recorded in A_4 (150 ppm IAA application) (0.1828 g). However, at 60 DAS A_3 (100 ppm IAA application) showed higher nodule dry weight (0.2011 g) which was statistically similar with A_4 (150 ppm IAA application) (0.1647 g). On the other hand, control treatment (A_1) (No IAA application) showed lower nodule dry weight then IAA treated plants.

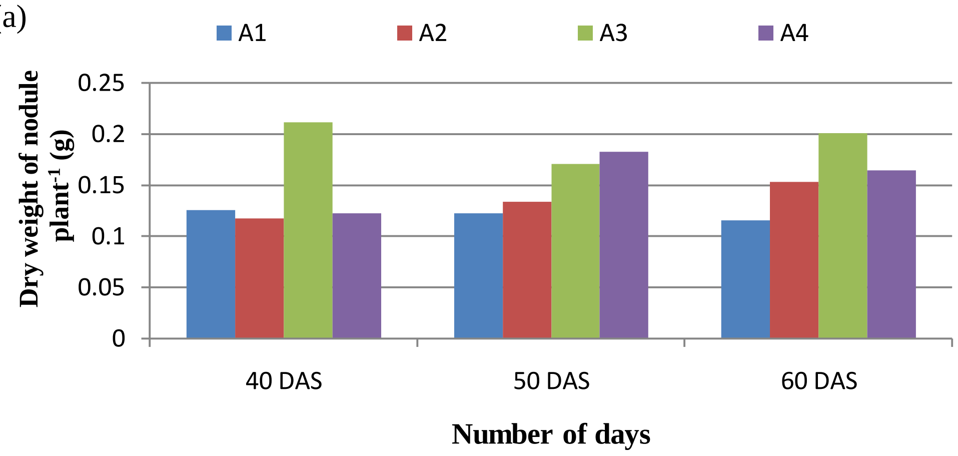
Sudadi and Suryono (2015) found that exogenous application of amino acid tryptophan and IAA is increasing root nodules, nodule weight, shoot and root dry weight of soybean.

4.1.2.2. Effect of row spacing

In this experiment significant role of different planting density was found for nodule dry weight (Appendix-V). Dry weight of nodule was found highest in higher spacing (S_3: 40 cm row to row distance) at 40, 50 and 60 DAS which was 0.2308 g, 0.1803 g and 0.1839 g respectively (Fig. 3b). At 50 DAS nodule weight of (S_2:30 cm row to row distance) treatment (0.1740 g) was found statistically similar to S_3 (40 cm row to row distance). However, lowest nodule dry weight was recorded in closer spacing (S_1) (20 cm row to row distance) at 40, 50 and 60 DAS which was 0.1082 g, 0.1027 g and 0.1311 g respectively (Fig. 3b).

Thalji (2006) found 53-100% increased nodule dry weight at higher plant spacing. Jamro *et al.* (1990) and Chen *et al.* (1992) also mentioned about similar type of results.

(a)

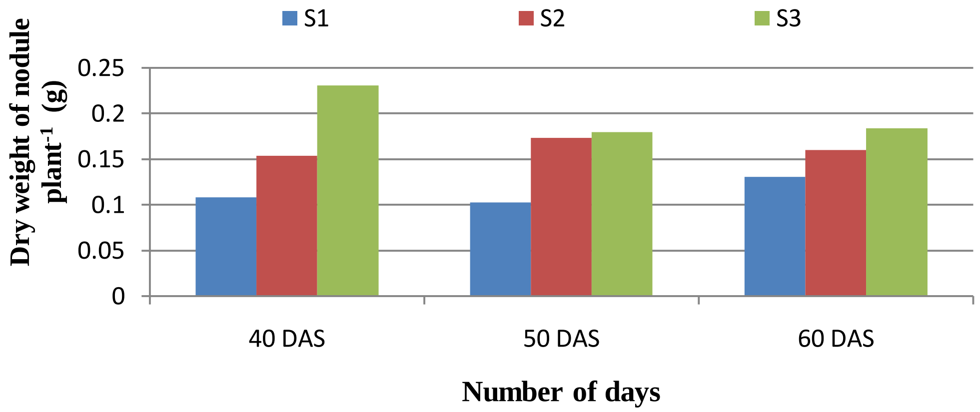


Note: A_1 : No IAA A_3 : 100 ppm IAA

A_2 : 50 ppm IAA A_4 : 150 ppm IAA

LSD values were 0.1348, 0.05355 and 0.04372 at 40, 50 and 60 DAS respectively

(b)



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm

S_3 : 40 cm ×10 cm

LSD values were 0.1167, 0.04637 and 0.03786 at 40, 50 and 60 DAS respectively

Figure 3. Effect of IAA (a) and row spacing (b) on dry weight of nodule plant^{-1} of BARI Mung 6.

4.1.2.3 Interaction effect of IAA and row spacing:

Plants were found to show better response when both IAA and spacing effect together. Interaction effect of IAA and spacing was found significant on dry weight of nodule in this experiment (Appendix- V). It was found that, nodule weight was highest in A_3S_3 at 40, 50 and 60DAS (0.4847 g, 0.2507 g, 0.2527 g respectively) (Table 2). On the other hand, lowest nodule dry weight was recorded in A_1S_1 at 40, 50 and 60DAS (0.04733 g, 0.05200 g, 0.09467 g respectively) (Table 2).

Table 2. Interaction effects of IAA and row spacing on dry weight of nodule plant^{-1} BARI Mung 6

Treatments	Dry weight of nodule (g) plant^{-1}		
	40 DAS	**50 DAS**	**60 DAS**
A_1S_1	0.04733 b	0.05200 d	0.09467 d
A_1S_2	0.1293 b	0.1650 abc	0.1100 d
A_1S_3	0.2003 b	0.1497 bc	0.1417 bcd
A_2S_1	0.1273 b	0.1013 bcd	0.1193 cd
A_2S_2	0.08467 b	0.1907 ab	0.1867 abc
A_2S_3	0.1410 b	0.1087 bcd	0.1530 bcd
A_3S_1	0.1383 b	0.08700 cd	0.1517 bcd
A_3S_2	0.2513 ab	0.1747 abc	0.1990 ab
A_3S_3	0.4847 a	0.2507 a	0.2527 a
A_4S_1	0.1197 b	0.1703 abc	0.1587 bcd
A_4S_2	0.1500 b	0.1910 ab	0.1470 bcd
A_4S_3	0.09733 b	0.1870 ab	0.1883 abc
LSD $_{(0.05)}$	**0.2334**	**0.0927**	**0.0757**
CV (%)	**12.94**	**14.70**	**13.33**

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

S_1 : 20 cm x 10 cm
S_2 : 30 cm x 10 cm
S_3 : 40 cm x 10 cm

A_1 : Control (No IAA)
A_2 : 50 ppm IAA
A_3 : 100 ppm IAA
A_4 : 150 ppm IAA

4.2. SPAD value

4.2.1. Effect of IAA

SPAD value was measured to compare chlorophyll content of leaves. The influence of IAA on the SPAD value of leaf was found significant of BARI Mung 6 (Appendix- VI). The highest SPAD value was found in A_3 (100 ppm IAA application) (52.47) (Fig. 4a). However, statistically similar chlorophyll percent was recorded in A_4 (150 ppm IAA application) (51.25) (Fig. 4a). On the contrary, lowest SPAD value was recorded in control treatment (A_1) (No IAA application) (45.89) (Fig. 4a).

Muthulakshmi and Pandiyarajan (2015) said that application of IAA led to significant increase photosynthetic pigment, non-photosynthetic pigment composition leaf nitrate, chlorophyll content

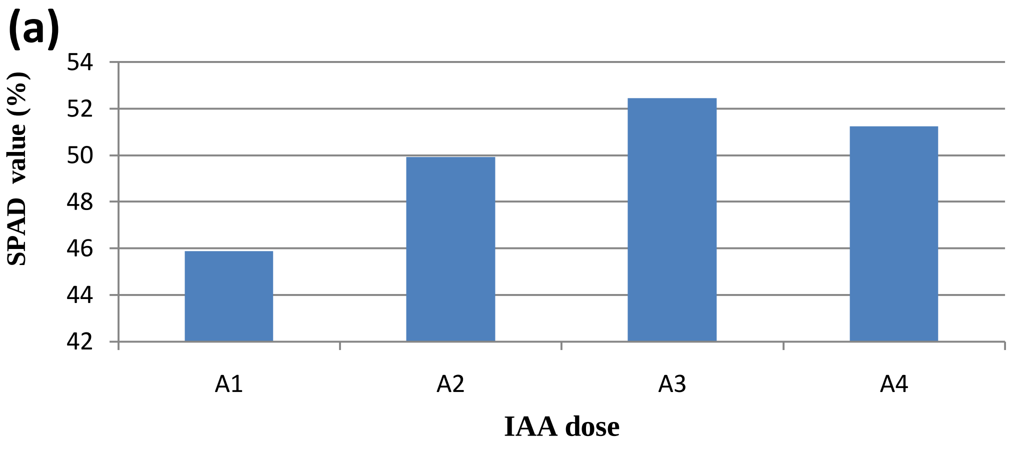
4.2.2. Effect of row spacing

SPAD value was found non-significant due to spacing effect in this experiment (Appendix- VI). However, highest SPAD value was found in wider spacing S_2 (30 cm row to row distance) (49.99) where lowest in closer spacing S_1 (20 cm row to row distance) (49.54) (Fig. 4b).

Denmead *et al.* (1962) mentioned the role of spacing on the photosynthesis capabilities of plants. Moreira *et al.* (2015) mentioned about the effect of spacing on chlorophyll content of soybean.

4.2.3 Interaction effect of IAA and row spacing

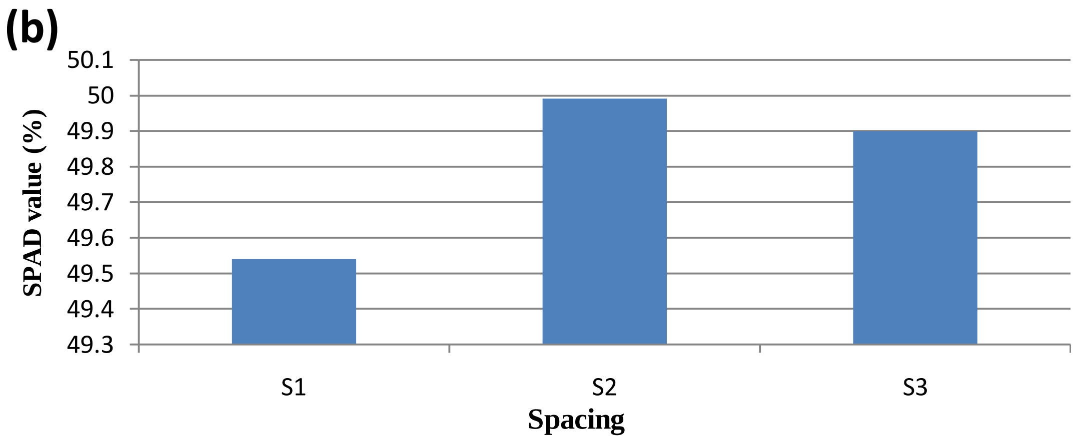
Interaction effect of IAA and spacing was found non-significant on the SPAD value of leaves in this experiment (Appendix- VI).The highest SPAD value was recorded in A_3S_2 (100 ppm IAA application + 30 cm row to row distance) treatment that was 55.00 (Table 3). On the other hand, lowest chlorophyll content of plants was recorded in combination of control treatments A_1S_1 (No IAA application + 20 cm row to row distance) (43.33). Higher SPAD value indicated the higher chlorophyll conten.



Note: A_1 : No IAA A_3 : 100 ppm IAA

A_2 : 50 ppm IAA A_4 : 150 ppm IAA

LSD = 1.70



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm

S_3 : 40 cm ×10 cm

LSD = 1.47

Figure 4. Effect of IAA (a) and row spacing (b) on the SPAD value of BARI mung 6.

4.3. Soil nitrogen

4.3.1. Effect of IAA

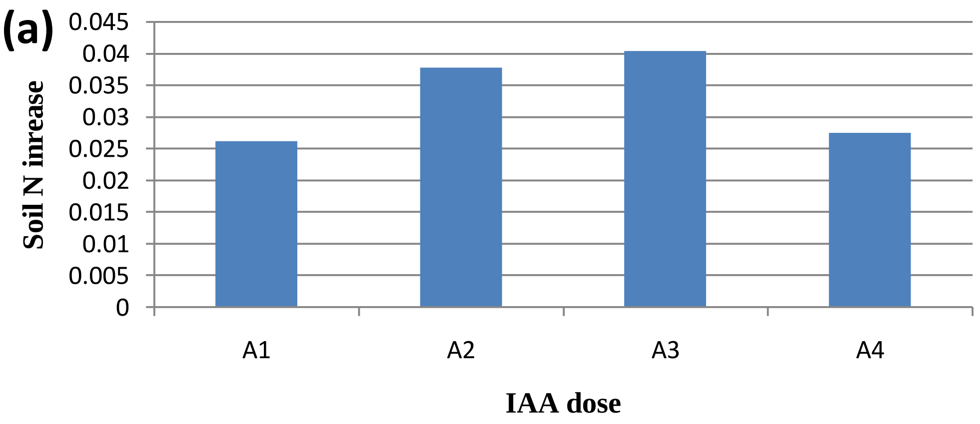
The influence of IAA on soil nitrogen increase after BARI Mung 6 cultivation was found significant (Appendix-VI). The highest soil nitrogen increase was found in A_3 (100 ppm IAA application) (0.0404 %) (Fig. 5a). However, statistically similar results were recorded in all IAA treated plots: 0.0378 % in A_2 (50 ppm IAA application) and 0.0275 % in A_4 (150 ppm IAA application) (Fig. 5a). On the contrary, lowest soil nitrogen increase was recorded in control treatment (A_1) (No IAA application) (0.0262 %) (Fig. 5a).

4.3.2. Effect of row spacing

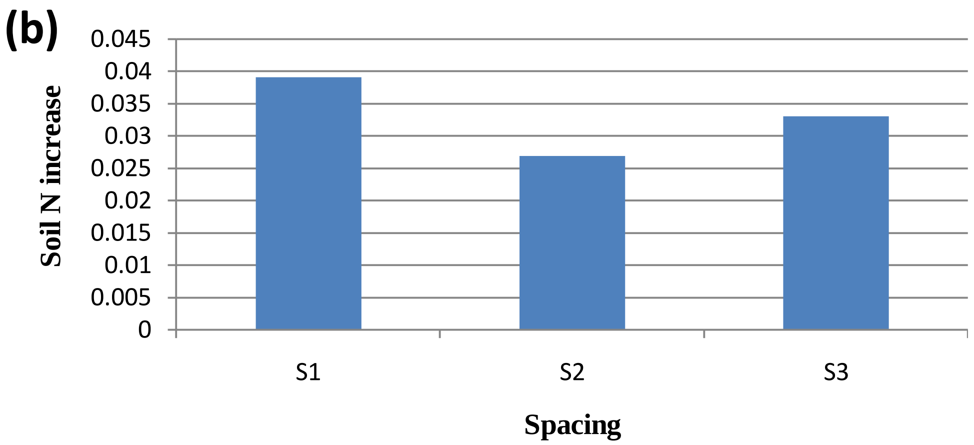
Soil nitrogen increase after BARI Mung 6 cultivation was found significant due to spacing effect in this experiment (Appendix-VI). However, highest soil nitrogen increase was recorded in closest spacing S_1 (20 cm row to row distance) (0.0391 %) where lowest soil nitrogen increase (0.0269%) was recorded in S_2 (30 cm row to row distance) (Fig. 5b).

4.3.3. Interaction effect of row spacing and IAA

Interaction effect of IAA and spacing was found non-significant to the N level increase of soil after BARI Mung 6 cultivation in this experiment (Appendix-VI). The highest soil nitrogen increase was recorded in A_3S_2 (100 ppm IAA application + 30 cm row to row distance) treatment that was 0.0516 % (Table 3). However, A_2S_2 (50 ppm IAA application + 30 cm row to row distance), A_2S_3 (50 ppm IAA application + 40 cm row to row distance) and A_3S_3 (150 ppm IAA application + 40 cm row to row distance) showed statistically similar results to A_3S_2 (100 ppm IAA application + 30 cm row to row distance). On the other hand, lowest soil nitrogen increase was recorded in combination of control treatments A_1S_1 (No IAA application + 20 cm row to row distance) (0.0230 %).



Note: A_1 : No IAA A_3 : 100 ppm IAA
A_2 : 50 ppm IAA A_4 : 150 ppm IAA
LSD = 0.011



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm
S_3 : 40 cm ×10 cm
LSD = 0.009

Figure 5. Effect of IAA (a) and row spacing (b) on soil N increase after BARI Mung 6 cultivation.

Table 3. Interaction effect of IAA and row spacing on SPAD value and soil N increase by BARI Mung 6

Treatments	SPAD value (%)	Soil Nitrogen increase (%)
A_1S_1	43.33 f	0.0230 d
A_1S_2	46.69 e	0.0290 bcd
A_1S_3	47.65 de	0.0267 bcd
A_2S_1	51.43 b	0.0313 bcd
A_2S_2	48.12 cde	0.0423 ab
A_2S_3	50.27 bcd	0.0400abcd
A_3S_1	51.48 b	0.0290bcd
A_3S_2	55.00 a	0.0516 a
A_3S_3	50.94 bc	0.0406abc
A_4S_1	51.92 b	0.0243 cd
A_4S_2	50.15 bcd	0.0336bcd
A_4S_3	51.69 b	0.0246 cd
LSD $_{(0.05)}$	**2.95**	**0.017**
CV (%)	**3.49**	**14.66**

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

S_1 : 20 cm x 10 cm
S_2 : 30 cm x 10 cm
S_3 : 40 cm x 10 cm

A_1 : Control (No IAA)
A_2 : 50 ppm IAA
A_3 : 100 ppm IAA
A_4 : 150 ppm IAA

4.4. Yield parameters

4.4.1. Pod length

4.4.1.1. Effect of IAA

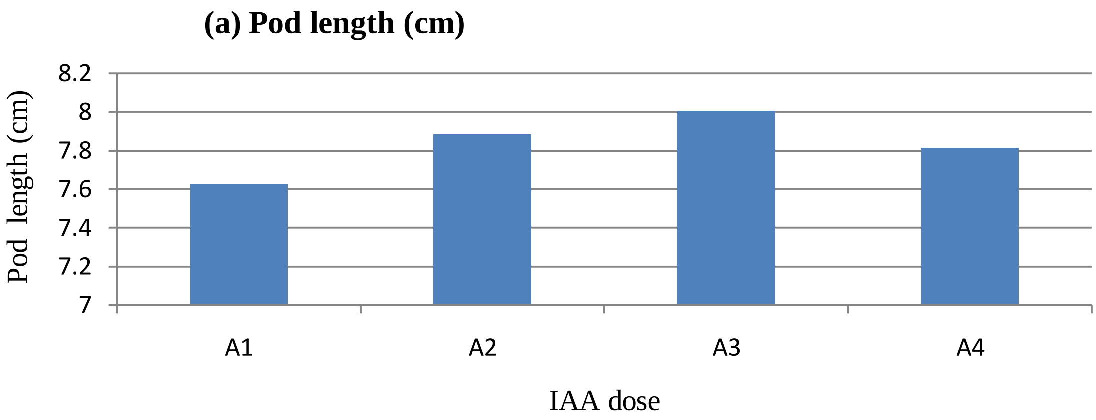
The role of IAA on pod length of BARI Mung 6 was found significant in this experiment (Appendix- VII). Pod length was increased due to the foliar application of IAA. The highest pod length was recorded in A_3 (100 ppm IAA application) (8.007 cm). However, statistically identical result were found in A_2 (50 ppm IAA application) (7.882 cm) and statically similar result in A_4 (150 ppm IAA application) (7.814 cm) (Fig. 6a). On the other hand, plants without the application of IAA (control treatment A_1) gave lowest pod length (7.626 cm) (Fig. 6a).

Saha *et al.* (1996) reported that 300, 600 and 900 ppm IAA applied at the beginning of the tillering stage in wheat increased ear, spikelet and grain length. Sanyal *et al*. (1995) mentioned similar results for tomato.

4.4.1.2. Effect of row spacing

The influence of row spacing on pod length of BARI Mung 6 was found significant (Appendix- VII) in this experiment. Pod length increased after incrising row spacing. However, at maximum row spacing (S_3: 40 cm row to row distance) pod length was decreased a bit. The highest pod length was recorded in S_2 (30 cm row to row distance) (7.963 cm) which was statistically identical to S_3 (40 cm row to row distance) (7.914 cm) (Fig. 6b). On the other hand, lowest pod length was recorded at shortest row spacing S_1 (20 cm row to row distance) (7.619 cm) (Fig. 6b)

Baloch (2004) found yield components depicted better performance under wider row spacing. Islam *et al.* (2011) reported that fruit length was significantly increased with the increasing row spacing of sweet pepper (*Capsicum annuum* L.).



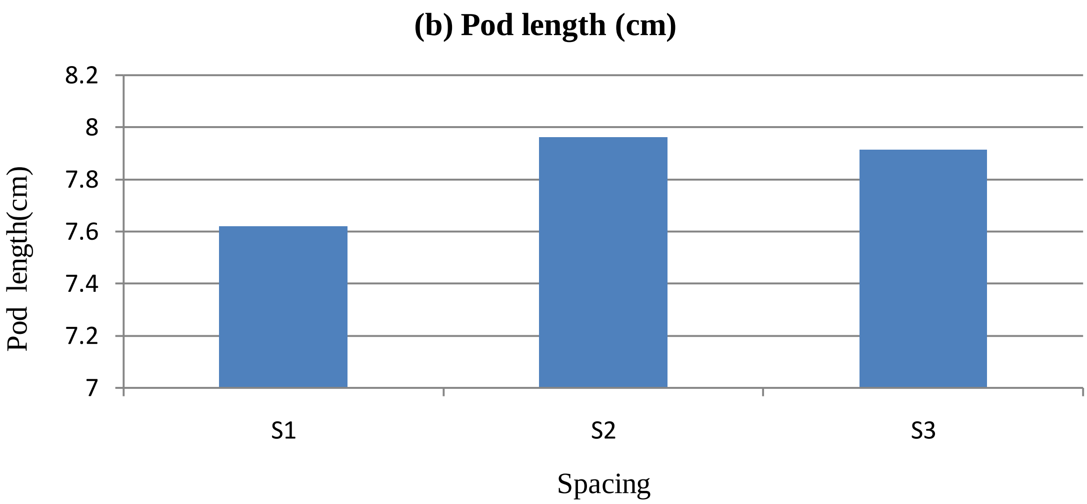
Note: A_1 : No IAA

A_2 : 50 ppm IAA

A_3 : 100 ppm IAA

A_4 : 150 ppm IAA

LSD value was 0.24.



Note: S_1 : 20 cm ×10 cm ,

S_2 : 30 cm ×10 cm

S_3 : 40 cm ×10 cm

LSD value was 0.215.

Figure 6. Effect of IAA (a) and row spacing (b) on pod length of BARI Mung 6

4.4.1.3. Interaction effect of IAA and row spacing on pod length of BARI Mung 6

It was found that pod length of BARI Mung 6 was influenced by interaction effect of IAA foliar application and row spacing (Appendix- VII). Highest pod length was recorded at A_3S_2 (100 ppm IAA application + 30 cm row to row distance) (8.34 cm) and lowest at A_1S_1(No IAA application + 20 cm row to row distance) (7.24 cm) (Table. 4). However, A_4S_3 (150 ppm IAA application + 40 cm row to row distance) (8.13 cm), A_3S_3 (100 ppm IAA application + 40 cm row to row distance) (8.00 cm) and A_2S_1 (50 ppm IAA application + 20 cm row to row distance) (8.03 cm) showed statistically similar results to A_3S_2 (100 ppm IAA application + 30 cm row to row distance) (8.34 cm) (Table 4).

4.4.2. Pods plant^{-1}

4.4.2.1. Effect of IAA

In this experiment, effect of IAA on pods plant^{-1} of BARI Mung 6 was found significant (Appendix- VII). Pods plant^{-1} was increased due to the foliar IAA application to a certain limit. With highest IAA concentration (A_4) (150 ppm IAA application), pods plant^{-1} were found to decrease a bit. Highest pods plant^{-1} was recorded at A_3 (100 ppm IAA application) (20.34) (Fig. 7a). However, statistically similar result was observed in A_4 (150 ppm IAA application) (18.8). On the other hand, lowest pods plant^{-1} was recorded in control treatment A_1 (No IAA application) (14.18).

Arora *et al*. (1998) reported the regulatory effect of IAA on number of pods per chickpea plant. Application of 10^{-5}M IAA significantly increased the number of capsules per flax plant (Abdel *et al*., 1996) and application of 50 ppm IAA on grasspea increased number of pods per plant (Rahman *et al*., 1989). Similar results were found by Lee (1990), Chellappa and Karivaratharaju (1973) and Manikandan and Hakin (1998) for groundnut.

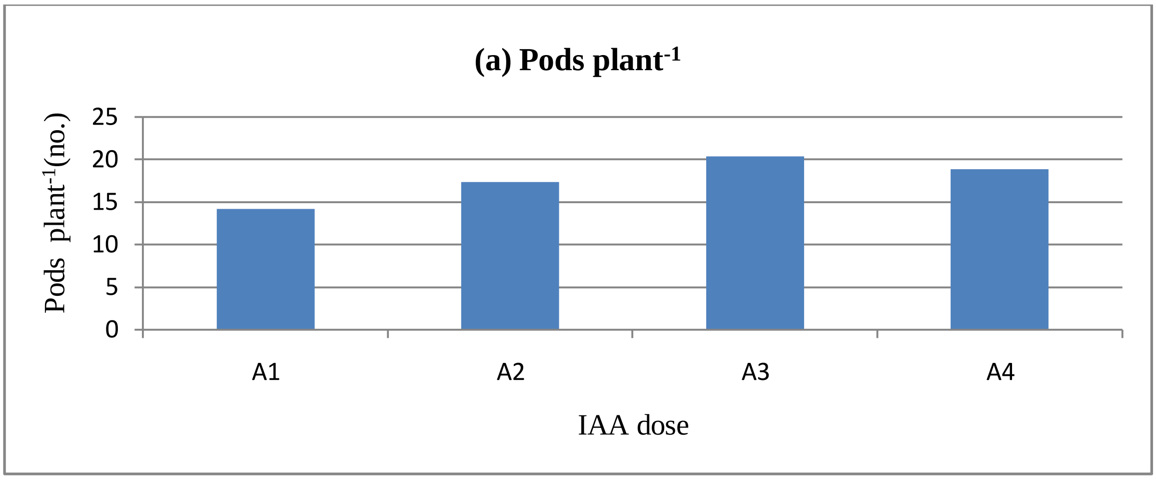
4.4.2.2. Effect of row spacing

The number of pods plant^{-1} was found to be significantly influenced by the different row spacing (Appendix-VII). Pods plant^{-1} was increased with increasing row spacing (Fig. 7b) to a certain limit. The highest pods number in a plant were recorded in S_2 (30 cm row to row distance) (20.7) treatment and the lowest in S_1 (20 cm row to row distance) (13.55) (Fig. 7b). However, statistically similar results were found in S_2 (30 cm row to row distance) and S_3 (30 cm row to row distance) (18.75) although it was a bit lower.

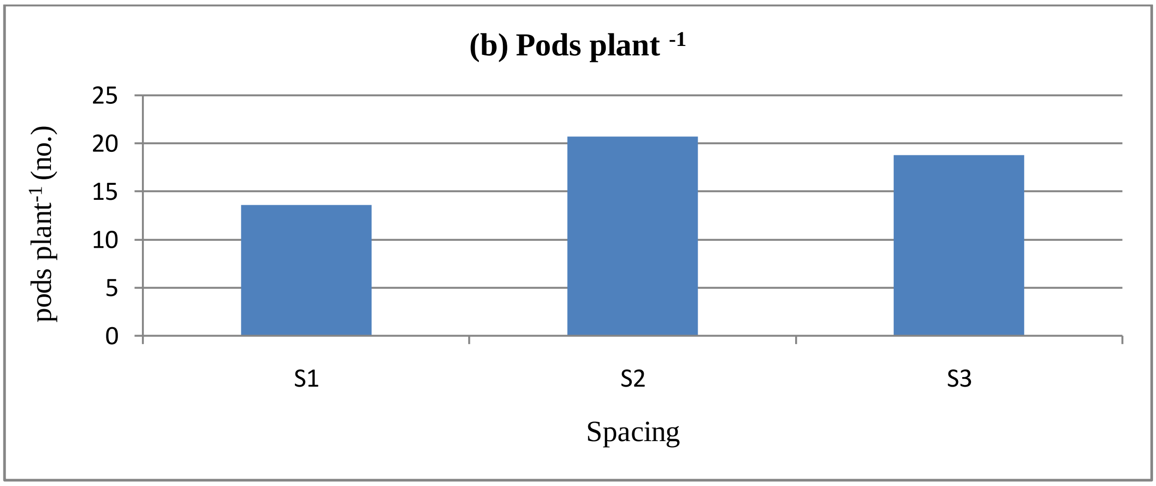
Pookpakdi and Pataradilok (1993) found that pod number plant^{-1} was increased with increasing row spacing. Islam *et al.* (2011) reported similar results for sweet pepper (*Capsicum annuum* L.).

4.4.2.3. Interaction effect of IAA and row spacing

There was found a significant interaction effect of IAA and row spacing on the number of pods plant^{-1} (Appendix-VII). The highest pod number plant^{-1} was recorded in A_3S_2 (100 ppm IAA application + 30 cm plant to plant distance) (25.6) and the lowest in A_1S_1 (No IAA application + 20 cm plant to plant distance) (10.4) (Table. 4). However, statistically similar results were shown in A_3S_2 (100 ppm IAA application + 30 cm plant to plant distance) and was found in A_2S_2 (50 ppm IAA application + 30 cm plant to plant distance) (21.6) (Table 4).



Note: A_1 : No IAA A_3 : 100 ppm IAA
A_2 : 50 ppm IAA A_4 : 150 ppm IAA
LSD value was 2.73.



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm
S_3 : 40 cm ×10 cm
LSD value was 2.36.

Figure 7. Effect of IAA (a) and row spacing (b) on the pods plant^{-1} of BARI Mung 6

4.4.3. Seeds pod^{-1}

4.4.3.1. Effect of IAA

The role of IAA on seeds pod^{-1} of BARI Mung 6 was found significant (Appendix-VII). Seeds pod^{-1} was increased due to the foliar IAA application to a certain limit and decreased after that. With highest IAA concentration (A_4) (150 ppm IAA application), number of seeds pod^{-1} was found statistically identical to control treatment A_1 (No IAA application) which indicates that A_4 (150 ppm IAA application) is a super optimal concentration. Highest number of seeds pod^{-1}was recorded at A_3 (100 ppm IAA application) (9.22) (Fig. 8a). However, statistically similar result was observed in A_2 (50 ppm IAA application) (8.711) (Fig. 8a). On the other hand, the lowest number of pod plant^{-1} was recorded in control treatment A_1 (No IAA application) (8.456) (Fig. 8a).

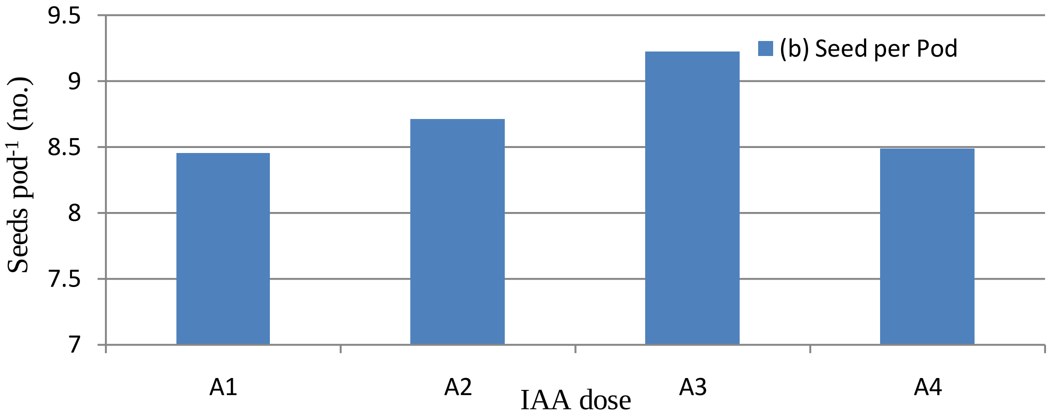
Arora *et al*. (1998) reported that IAA applied at the 50% flowering stage to chickpeas increased the number of seeds per pod. Abdel *et al*. (1996) observed similar kind of results in case of flax seeds with IAA at 10^{-5}M.

4.4.3.2. Effect of row spacing

Row spacing had significant effect on the number of seeds pod^{-1} of BARI Mung 6 (Appendix-VII) Closer row spacing produced lower number of seeds pod^{-1} compared to the wider row spacing. The highest seed number pod^{-1} was observed in S_2 (30 cm row to row distance) (9.192) although S_3 (40 cm row to row distance) (8.833) produced statistically identical results (Fig. 8b). On the other hand, the lowest number of seeds pod^{-1} was observed in S_1 (20 cm row to row distance) (8.133) (Fig. 8b).

Baloch (2004) found that crop sown in closer row spacing resulted in significantly maximum seed yield, but the yield components depicted better performance under wider row plant density.

(a) Seeds pod^{-1}

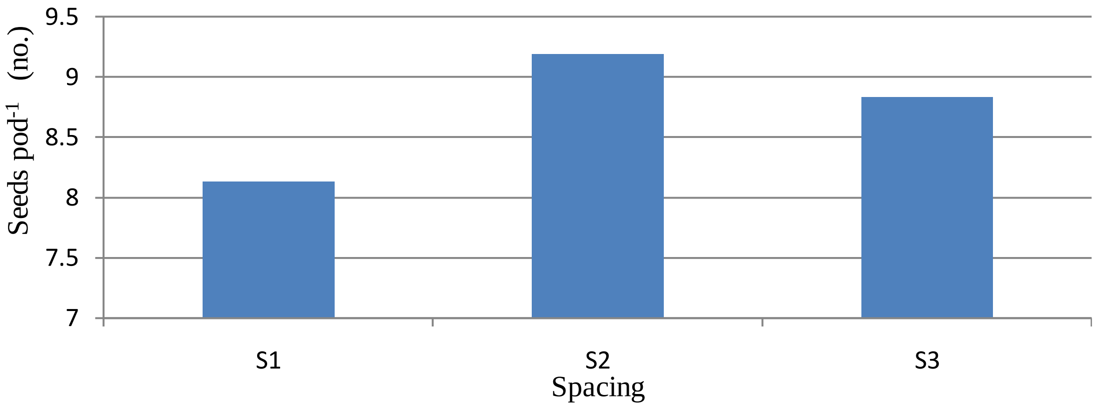


Note: A_1 : No IAA A_3 : 100 ppm IAA

A_2 : 50 ppm IAA A_4 : 150 ppm IAA

LSD value was 0.57.

(b) Seeds pod^{-1}



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm

S_3 : 40 cm ×10 cm

LSD value was 0.49.

Figure 8. Effect of IAA (a) and row spacing (b) on seeds pod^{-1} of BARI Mung 6

4.4.3.3. Interaction effect of IAA and row spacing

It was found that interaction effect of row spacing and IAA had significant influence on seeds pod^{-1} of BARI Mung 6 (Appendix-VII). Seeds pod^{-1} of BARI Mung 6 increased with IAA foliar application and increasing row spacing. However, the highest seeds pod^{-1} of BARI Mung 6 was recorded at A_3S_2 (100 ppm IAA application + 30 cm row to row distance) (10.53) and the lowest at A_1S_1 (No IAA application + 20 cm row to row distance) (7.50) (Table. 4).

4.4.4. 1000-seed weight

4.4.4.1. Effect of IAA

Effect of IAA on 1000-seed weight of BARI Mung 6 was found significant (Appendix- VII) in this experiment. 1000 seed weight of BARI Mung 6 was increased due to the foliar IAA application. However, with highest IAA concentration (A_4) (150 ppm IAA application), 1000 seed weight of BARI Mung 6 was found to decrease a bit. The highest 1000-seed weight of BARI Mung 6 was recorded at A_3 (100 ppm IAA application) (60.49 g) (Fig. 9a). However, A_4 (50 ppm IAA application) (59.88 g) (Fig. 9a) showed statistically similar results. On the contrary, lowest 1000 seed weight of BARI Mung 6 was recorded in control treatment (A_1: No IAA application) (57.01 g) (Fig. 9a).

Saha *et al.* (1996) reported that 300, 600 and 900 ppm IAA applied at the beginning of the tillering stage in wheat increased 1000 grain weight. Similar results were also reported by Yan *et al.* (1995); Gurdev and Saxena (1991) and Rahman *et al.* (1989).

4.4.4.2. Effect of row spacing

In this experiment, the influence of spacing on 1000-seed weight of BARI Mung 6 was found significant (Appendix- VII). 1000 seed weight of BARI

Mung 6 increased by decreasing plant density to a certain limit. At maximum spacing (S_3: 40 cm row to row distance) 1000 seed weight of BARI Mung 6 was decreased a little. The highest weight of 1000 seed was recorded in S_2 (30 cm row to row distance) (59.40 g) (Fig. 9b). However, statistically similar result was found in S_3 (40 cm row to row distance) (59.29 g). On the other hand, lowest 1000 seed weight of BARI Mung 6 was recorded in closer spacing S_1 (20 cm row to row distance) (58.84) (Fig. 9b).

Mozumder *et al.* (2012) found that thousand seed weight were higher in wider spacing. Islam *et al.* (2011) also reported about higher individual fruit weight with the increasing of plant spacing.

4.4.4.3. Interaction effect to IAA and row spacing

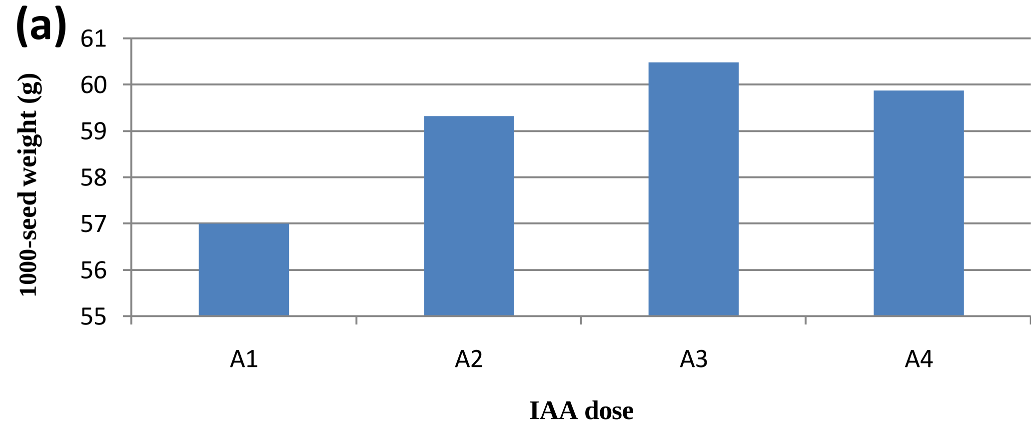
It was found that 1000 seed weight of BARI Mung 6 was influenced by the interaction of IAA foliar application and plant density (Appendix- VII). Highest 1000 seed weight of BARI Mung 6 was recorded at A_3S_2 (100 ppm IAA application + 30 cm row to row distance) (61.13 g). On the other hand, lowest 1000 seed weight of BARI Mung 6 was recorded at A_1S_1 (No IAA application + 20 cm row to row distance) (56.77) (Table. 4).

4.4.5. Seed yield ha^{-1}

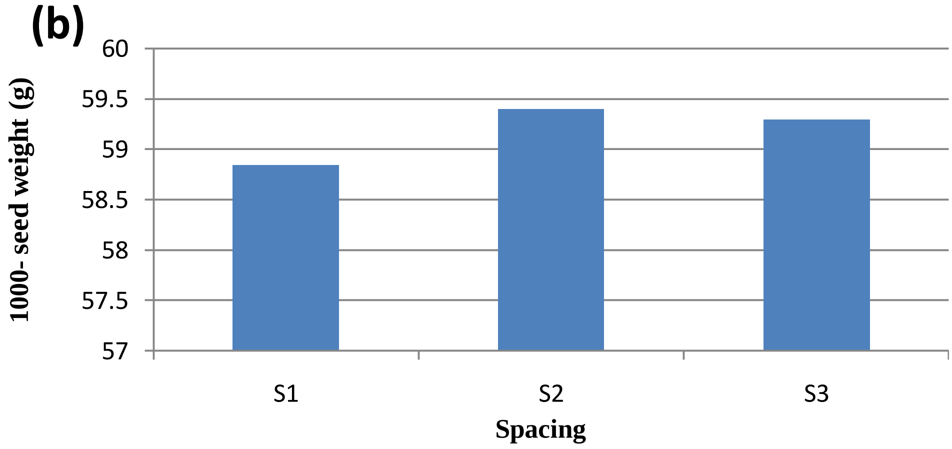
4.4.5.1. Effect of IAA

Effect of IAA on seed yield ha^{-1} of BARI Mung 6 was found significant (Appendix - VII) in this experiment. Seed yield ha^{-1} was increased due to the foliar IAA application. However, with highest IAA concentration (A_4) (150 ppm IAA application), seed yield ha^{-1} was found to decrease a bit. Highest seed yield ha^{-1} was recorded at A_3 (100 ppm IAA application) (2.15 t) (Fig. 10a). However, A_2 (50 ppm IAA application) (2.06 t) (Fig. 10a) showed statistically similar results. On the contrary, lowest seed yield was recorded in control treatment (A_1: No IAA application) (1.90 t) (Fig. 10a).

Jong *et al.* (2009) reported that auxin and gibberellin play major role in the development of fruit and expression of genes in tomato. Rastogi *et al.* (2013) also found increased yield of linseed after auxin treatment.



Note: A_1 : No IAA | A_3 : 100 ppm IAA
A_2 : 50 ppm IAA | A_4 : 150 ppm IAA
LSD = 0.74



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm
S_3 : 40 cm ×10 cm
LSD = 0.39

Figure 9. Effect of IAA (a) and row spacing (b) on 1000-seed weight of BARI Mung 6.

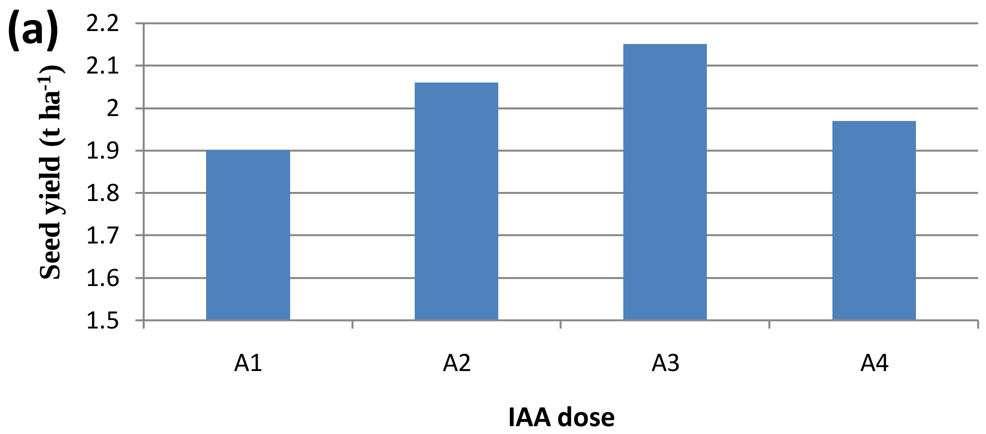
4.4.5.2. Effect of row spacing

In this experiment, the influence of spacing on seed yield ha^{-1} of BARI Mung 6 was found significant (Appendix- VII). Seed yield ha^{-1} increased by decreasing plant density to a certain limit. However, at maximum spacing (S_3: 40 cm row to row distance) seed yield ha^{-1} was decreased and became statistically identical to closest spacing S_1 (20 cm row to row distance). The highest seed yield ha^{-1} was recorded in S_2 (30 cm row to row distance) (2.17 t) and lowest in closer spacing S_1 (20 cm row to row distance) (1.79 t) (Fig. 10b).

Baloch (2004) mentioned that closer row spicing significantly increase seed yield, but the yield components depicted better performance under wider row spacing. Sarkar *et al.* (2004) said that planting density of 30 × 10 cm gave higher yield of mungbean than 20 × 20 cm or 40 × 30 cm planting density in Bangladesh. Ihsanullah *et al.* (2002) found influence of row spacing on plant yield, yield attributes and yields of mungbean.

4.4.5.3. Interaction effect to IAA and row spacing

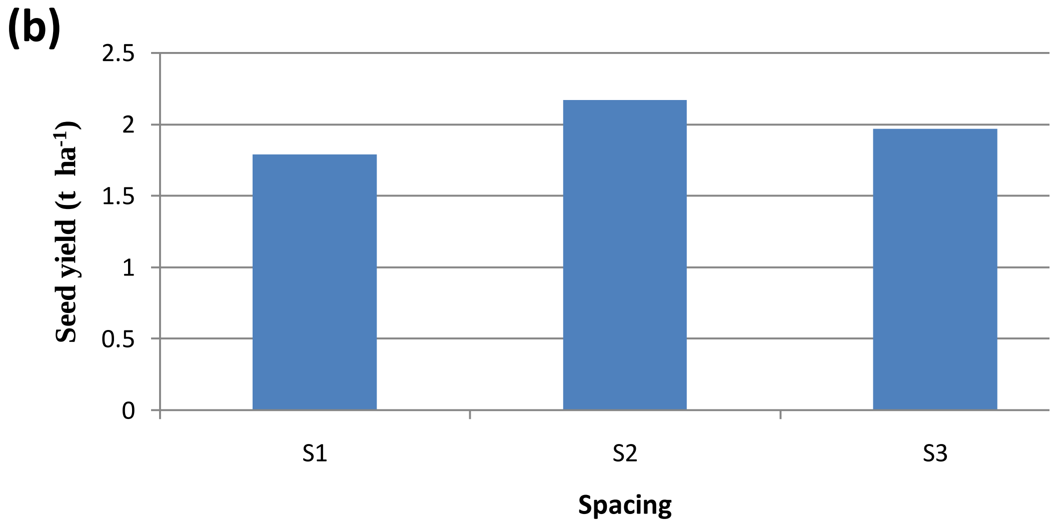
It was found that seed yield ha^{-1} of BARI Mung 6 was influenced by the interaction of IAA foliar application and plant density (Appendix - VII). Highest seed yield ha^{-1} was recorded at A_3S_2 (100 ppm IAA application + 30 cm row to row distance) (2.21 tha^{-1}). On the other hand, lowest seed yield ha^{-1} was recorded at A_1S_1 (No IAA application + 20 cm row to row distance) (1.66 t/ha) (Table. 4).



Note: A_1 : No IAA A_3 : 100 ppm IAA

A_2 : 50 ppm IAA A_4 : 150 ppm IAA

LSD = 0.171



Note: S_1 : 20 cm ×10 cm , S_2 : 30 cm ×10 cm

S_3 : 40 cm ×10 cm

LSD value = 0.189

Figure 10. Effect of IAA (a) and row spacing (b) on seed yield ha^{-1} of BARI Mung 6 .

Table 4. Interaction effects of IAA and spacing on yield characteristics and yield of BARI Mung 6

Treatments	Pod length (cm)	Pod plant^{-1} (no.)	Seed pod^{-1} (no.)	1000-seed weight (g)	Seed Yield (t ha^{-1})
A_1S_1	7.24 e	10.4 e	7.50 c	56.77 f	1.66 e
A_1S_2	7.95abcd	15.334 d	8.83 b	56.90 ef	1.72 de
A_1S_3	7.68 cd	16.8 cd	9.03 b	57.37 e	1.71 de
A_2S_1	8.03abc	16.77 cd	8.30bc	58.97 d	1.86 bcd
A_2S_2	7.77bcd	21.6 ab	9.00 b	59.80 bc	2.05 ab
A_2S_3	7.83bcd	17.4 bcd	8.83 b	59.23 cd	1.78 cde
A_3S_1	7.67 cd	14.67 de	8.46bc	59.63 bc	1.76 cde
A_3S_2	8.34 a	25.6 a	10.53 a	61.13 a	2.21 a
A_3S_3	8.00abc	20.74 bc	8.66 b	60.30 b	2.01 b
A_4S_1	7.52de	16.07 cd	8.26bc	60.00 b	1.96 bc
A_4S_2	7.78bcd	20.26 bc	8.40bc	59.77 bc	1.89 bcd
A_4S_3	8.13ab	20.06 bc	8.80 b	59.87 b	1.80 cde
LSD $_{(0.05)}$	**0.43**	**4.722**	**0.99**	**0.58**	**0.198**
CV (%)	**3.25**	**15.78**	**6.73**	**5.73**	**17.70**

S_1 : 20 cm × 10 cm
S_2 : 30 cm × 10 cm
S_3 : 40 cm × 10 cm

A_1 : Control (No IAA)
A_2 : 50 ppm IAA
A_3 : 100 ppm IAA
A_4 : 150 ppm IAA

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.

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from March 2014 to June 2014 study the effect of Indole-3-acetic acid (IAA) on nodulation, soil nitrogen, growth yield of mungbean under differcent plant density.

The experiment was consisted of four levels of IAA application viz. i) A_1= control (No IAA application) ii) A_2 = Foliar spray of Indole-3-acetic acid (IAA) @ 50 ppm at 25 DAS iii) A_3 = Foliar spray of Indole-3-acetic acid (IAA) @ 100 ppm at 25 DAS and iv) A_4 = Foliar spray of Indole-3-acetic acid (IAA) @ 150 ppm at 25 DAS and three spacing viz. i) S_1= 20cm x 10 cm, ii) S_2= 30cm x 10 cm and iii) S_3=40cm x10cm.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatments. The experimental field was divided into 3 blocks. Each block was again divided into 12 plots. The total numbers of unit plots of the experiment were 36 (12 × 3). The size of the unit plot was 3.75 m × 1.78 m (6.675 m^2). There were 0.50 m width and 10 cm depth for drains between the blocks. Each treatment was again separated by drainage channel of 0.4 m width and 10 cm depth. The treatments were randomly distributed to each block following the experimental design.

Significant variation was recorded for data on growth, nodulation, soil N change, yield and yield contributing parameters of experimental materials of whole plot. The analysis was performed using the MSTAT–C (Version 2.10) computer package program. The mean differences among the treatments were compared by least significant difference test (LSD) at 5 % level of significance.

Records showed that number of nodule and nodule dry weight $plant^{-1}$ on BARI Mung 6 were influenced significantly by the row spacing. The highest nodule number $plant^{-1}$ (72.61) and nodule dry weight $plant^{-1}$(0.2308 g) was observed in S_2 at 60 DAS and S_3 at 40 DAS respectively. Number of nodule and nodule dry weight $plant^{-1}$ were influenced significantly by the IAA foliar application. The highest nodule number $plant^{-1}$ (79.15) and nodule dry weight $plant^{-1}$ (0.2114g) was observed in A_4 at 50 DAS and A_3 at 40 DAS respectively. Among the interaction treatments A_4S_2 gave the highest nodule number $plant^{-1}$ (97.67) at 40 DAS and A_3S_3 gave highest nodule dry weight $plant^{-1}$ (0.2527 g) than the other treatments.

Chlorophyll percent of leaf and soil N change was influenced significantly by IAA foliar application where spacing has no significant influence on chlorophyll percent of leaf. However, the highest chlorophyll percent of leaf was recorded in S_2 (49.99%) where lowest in S_1 (49.54%). Soil N change was highest in S_1 (0.0391%) and lowers change was observed in S_2 (0.0269%). In case of IAA foliar application, A_3 gave the highest chlorophyll percent (52.47%) and soil N change (0.0404 %) where no IAA treated plots showed the lowest chlorophyll percent (45.89%) and soil N change (0.0262 %). However, highest chlorophyll percent (55.00%) and soil N change (0.0516 %) were found in A_3S_2 interaction treatment.

Yield parameters showed to by influenced by IAA foliar application and row spacing. In case of IAA foliar application, A_3 showed highest pod length (8.007 cm), pods $palnt^{-1}$ (20.34), seeds pod^{-1} (9.22), 1000-seed weight (60.49 g), and seed yield ha^{-1}(2.15 t ha^{-1}) where control treatment (A_1) gave lowest pod length (7.626 cm), pods $palnt^{-1}$ (14.18), seeds pod^{-1} (8.45), 1000-seed weight (57.01 g), seed yield ha^{-1}(1.90 t ha^{-1}). On the other hand, the highest pod length (7.96 cm), pods $palnt^{-1}$ (20.7), seeds pod^{-1} (9.19), 1000-seed weight (59.4 g), seed yield ha^{-1} (2.17 t ha^{-1}), were recorded in S_2 treatment where S_1 gave the lowest pod length (7.91 cm), pods $palnt^{-1}$ (18.71), seeds pod^{-1} (8.13), 1000-seed weight (58.84 g), seed yield ha^{-1}(1.79 t ha^{-1}). In case of interaction effect, A_3S_2 gave highest pod length (8.34 cm), pods palnt^{-1} (25.61), seeds pod^{-1} (10.53), 1000-seed weight (61.13 g) and seed yield ha^{-1}(2.21 t ha^{-1}).

From the results of the experiment, it may be concluded that the performance of BARI Mung-6 was better in 30 cm spacing and 100 ppm IAA foliar application.

For determination of effectiveness of IAA foliar application, further trail should be performed in different locations for more conformation.

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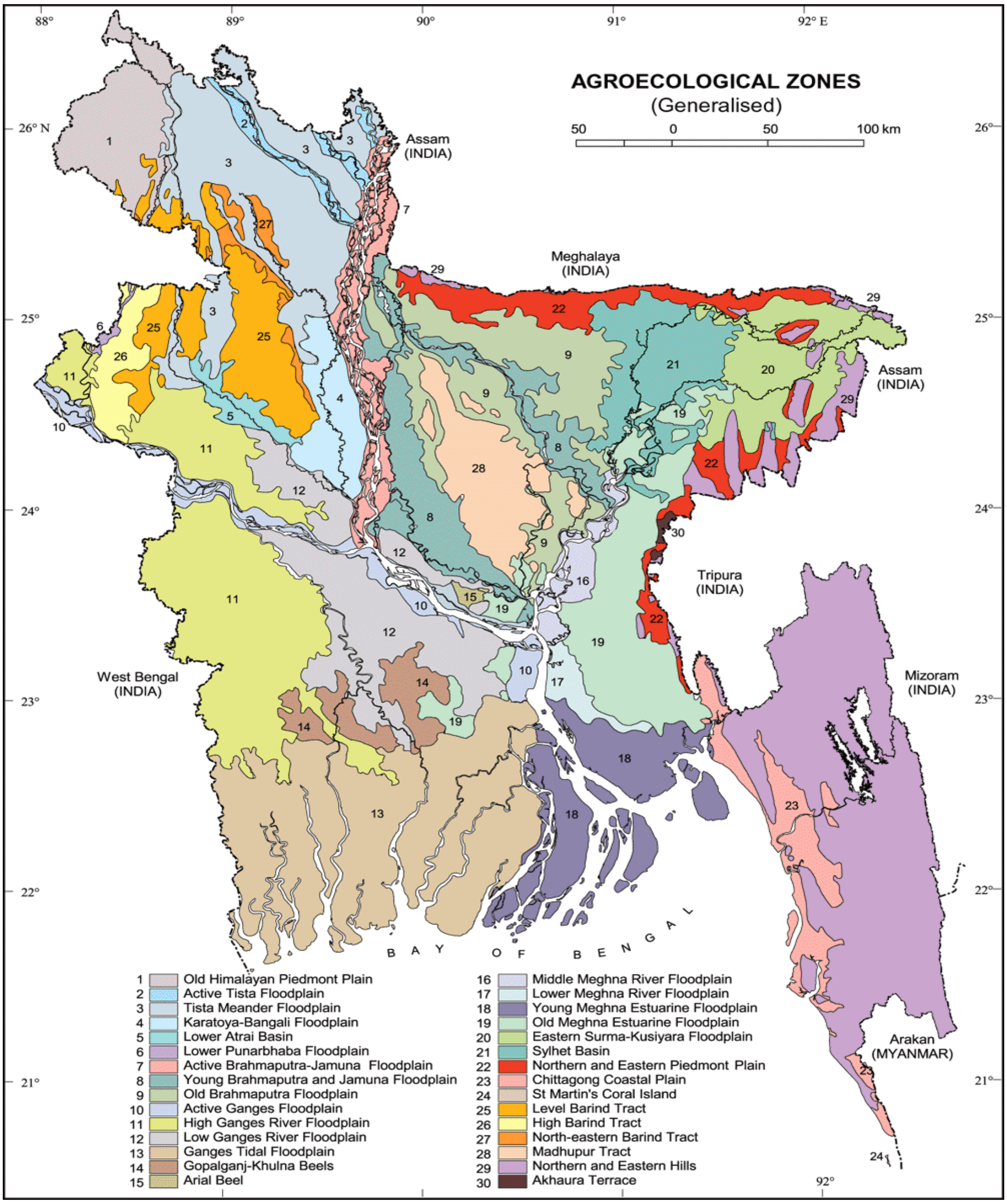
APPENDICES

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 2014 to July 2014

Month	Air temperature (^0C)		R. H. (%)		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	Horticulture Farm, SAU, Dhaka
AEZ	Madhupur 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: Analysis of variance of data on nodule plant^{-1} of BARI Mung 6

Sources of variation	Degrees of freedom (df)	Mean square of nodule per plant of mungbean			
		30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	2801.004	317.572	176.911	1506.292
Factor A (Indole-3-acetic acid)	3	207.764*	700.123*	1339.595**	793.196**
Factor B (Spacing)	2	228.640*	116.925*	933.673**	1406.637**
Interaction (A X B)	6	589.256**	1037.790*	191.359*	260.249*
Error	22	166.899	402.733	224.490	175.934

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

Appendix-V. Analysis of variance of data on nodule weight plant^{-1} of BARI Mung 6

Sources of variation	Degrees of freedom (df)	Mean square of nodule weight		
		40 DAS	50 DAS	60 DAS
Replication	2	0.029	0.003	0.029
Factor A (Indole-3- acetic acid)	3	0.065**	0.008*	0.011**
Factor B (Spacing)	2	0.046*	0.022**	0.008**
Interaction (A X B)	6	0.028*	0.006*	0.002
Error	22	0.019	0.003	0.002

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

Appendix- VI. Analysis of variance of data on chlorophyll content and soil N change of BARI Mung 6

Sources of variation	Degrees of freedom (df)	Mean square of	
		Chlorophyll content	Soil Nitrogen Change
Replication	2	0.750	48.111
Factor A (Indole-3- acetic acid)	3	73.632**	860.778**
Factor B (Spacing)	2	1.153	945.444**
Interaction (A X B)	6	13.353**	98.778
Error	22	3.036	186.869
** : Significant at 1% level of probability; * : Significant at 5% level of probability			

Appendix- VII. Analysis of variance of data on yield characteristics of BARI Mung 6

Source of variation	Degrees of freedom (df)	Mean square of				
		Pod length	Pod plant^{-1}	Seed pod^{-1}	1000 seed weight	Seed Yield (t/ha)
Replication	2	0.347	1255.583	0.605	1.087	7.282
Factor A (Indole acetic acid)	3	0.228**	1549.852**	1.127**	20.783**	8.256**
Factor B (Spacing)	2	0.416**	4098.250**	3.477**	1.052*	6.071**
Interaction (A X B)	6	0.215**	260.546**	1.046**	0.539*	2.621**
Error	22	0.065	194.341	0.344	0.575	0.868
** : Significant at 1% level of probability; * : Significant at 5% level of probability						