INFLUENCE OF NITROGEN LEVEL AND PLANTING DENSITY ON GROWTH AND YIELD OF MUNGBEAN

SABIKUNNAHER SHOVA

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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By

SABIKUNNAHER SHOVA

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Approved by:

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

(Prof. Dr. H. M.M. Tariq Hossain)
Co-supervisor

(Prof. Dr. Md. Fazlul Karim)
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 9144270-79

CERTIFICATE

*This is to certify that the thesis entitled "**INFLUENCE OF NITROGEN LEVEL AND PLANTING DENSITY ON GROWTH AND YIELD OF MUNGBEAN**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **SABIKUNNAHER SHOVA,** Registration. No. **10-04031** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated:
Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)

Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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The author

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ABSTRACT

An experiment was carried out at Sher-e-Bangla Agricultural University farm, Dhaka to investigate the influence of nitrogen level and planting density on growth and yield of mungbean during the period from March to June, 2015. The trial comprised of three nitrogen levels such as N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40 kg N ha^{-1}; and four planting density, P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}. The experiment was laid out in split-plot design with three replications by assigning nitrogen level in the main plot and planting density in the sub plot. Seedling emergence, plant height, number of leaves plant^{-1}, dry matter production, number of branches plant^{-1}, nodulation, days required to first flowering, days required to 50% flowering, number of pods plant^{-1}, number of seeds pod^{-1},1000-seed weight, seed yield, stover yield, biological yield, harvest index and shelling percentage were compared for different treatments. Results revealed that, nitrogen level did not significantly influenced most of the growth and yield parameters except some yield parameters of mungbean. As a single factor effect, the maximum seed yield (1.52 t ha^{-1}) was recorded from no nitrogen (N_0) application, which was 13.43 % higher than that of 40 kg N ha^{-1} (N_2) (1.34 t ha^{-1}). In case of planting density, the maximum seed yield (1.58 t ha^{-1}) was obtained from 45 plants m^{-2} (P_3) and the minimum seed yield (1.25 t ha^{-1}) was obtained from 15 plants m^{-2} (P_1). The 45 plants m^{-2} gave 26.40% higher yield over 15 plants m^{-2}. However, the highest seed yield (1.68 t ha^{-1}) was obtained from 45 plants m^{-2} with 20 kg N ha^{-1} which was similar with the same nitrogen level with 30 plants m^{-2} and 30-60 plants m^{-2} having zero nitrogen fertilizer application. The lowest seed yield (1.19 t ha^{-1}) was obtained from 15 plants m^{-2} having 20 kg N ha^{-1} application which was statistically similar with 15-30 plants m^{-2} with 40 kg N ha^{-1} along with 15 plants m^{-2} having no nitrogen fertilizer application. The crop sown with 45 plants m^{-2} in combination with 20 kg N ha^{-1} gave 41.18% higher yield over 15 plants m^{-2} in combination with 20 kg N ha^{-1}. Application of 20 kg N ha^{-1} of 45 plants m^{-2} could be the best production package for cultivation of mungbean.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BADC	=	Bangladesh Agricultural Development Corporation
LAI	=	Leaf area index
ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
G	=	Gypsum
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
G	=	Gram (g)
kg	=	Kilogram
q	=	Quintal
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^0C	=	Degree Celsius
NS	=	Non significant
cm	=	Centimeter
mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Mungbean (*Vigna radiata* L.) is an ancient and well known legume crop in Asia, particularly in the Indian subcontinent. It is one of the important pulse crops of Bangladesh, as it is an excellent source of easily-digestible protein of low flatulence, which complements the staple rice diet in the country. It contains amino acid, lysine which is generally deficit in food grains (Elias *et al*., 1986). It holds the 3rd in protein content and 5th in acreage and production and first in market price (BBS, 2008). It is grown three times in a year covering 35,313 ha with an average yield of 0.70 t ha^{-1} (BBS, 2013). It is produced for both human consumption and as fodder. Its seed contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamin (Afzal *et al*., 2008). This legume is known to have high nutrient values with excellent source of vegetable protein (seeds and sprouts contain to 28% of proteins). Sprout is rich in vitamins, minerals and amino acids (especially lysine). Mungbean is considered as a substitute of animal protein and forms a balanced diet when used with cereals (Mansoor, 2007; Anjum *et al.*, 2006; Khan and Malik, 2001). Mungbean seeds can be replaced by meat in many dishes especially for vegetarian due to it's a fat-free and protein enrichment (Rachwa-Rosiak *et al.*, 2015). Other different uses of biomass yield in fresh or dry form as a good and valuable for animal feed (Zahera and Permana, 2015; Khatik *et al*., 2007; Robinson *et al*., 2001). According to FAO (1999), a minimum intake of pulse by human should be 80g/day/capita for a balance diet, whereas in Bangladesh per capita daily consumption of pulses is only 14.19g. It may play an important role to supplement protein in the cereal- based low-protein diet of the people of Bangladesh (BBS, 2005).

Mungbean is usually grown at low to medium elevations in the tropics as a rainfed crop. It ranks second to drought resistance after soybean (Ali *et al*., 2001). Mungbean can be grown as manure, hay, cover crop and forage or intercropped in cereals, sugarcane, sunflower or jute. Cultivation of mungbean increases symbiotic fixation of atmospheric N_2 by the nodules and the decomposition of crop result in restoration of soil fertility. On an average, it fixes atmospheric nitrogen @ 300 kg ha^{-1} annually (Sharar *et al*., 2001).

The agro ecological condition of Bangladesh is favorable for growing this crop. During kharif-1 season the crop fits well into the existing cropping system of many areas of Bangladesh.

Since it is a short duration legume (maturing in 55 to 70 days), it fits well into many cropping systems, including rice and sugarcane under both rainfed and irrigated conditions. It increases small farmer’s income and improves soil conditions. On an average in Bangladeshi diet only 8 to 10% of the protein intake originates from animal sources, the rest can be met from plant sources by increasing the consumption of pulses. Hence from the point of nutritional value, mungbean is perhaps the best of all other pulses.

However, Mungbean productivity in farmer level management during the last five years (2008- 2012) was 1.1 to 1.2 t ha^{-1} (MOA, 2012), even though potential yield of mungbean varieties released is 1.5-2.5 t ha^{-1} (ILETRI, 2012). This yield gap between potential and actual yield can be minimized through good management practices. But the poor yield may be attributed due to climatic condition, adaptation of varieties, disease and insect problems, poor crop management practices, judicious application of fertilizer especially nitrogenous fertilizers and optimum planting density are the most important for optimum crop production.

In Bangladesh, most of the soils are deficient in organic matter and nitrogen. To fulfill the demand of nitrogen, usually urea is being used. Nitrogen (N) is the most essential nutrient element and its adequate supply increases growth and yield of crop. Without an adequate underlying of the dry matter production and the underlying physiological process of crop growth, development and yield of mungbean under different N treatments, any attempt to improve the yield potential of mungbean may not be successful. It alters leaf area and net photosynthetic rate because its usage strongly affects plant growth and productivity; therefore, the application of N fertilizer is very important to obtain maximum potential of crops (Novoa and Loomis, 1981). Pulses although fix nitrogen from the atmosphere, there is evident that application of nitrogenous fertilizers becomes helpful in increasing the yield (Ardeshana *et al*., 1993). Nitrogen is most useful for pulse crops because it is the component of protein (BARC, 2005). High yielding variety with proper nitrogen management is inadequate in farmer's field which is burning cause for lower yield. The lower amount of nitrogen is to be given at proper time for increasing growth and yield of mungbean with maximum utilization of nutrient. The important role of nitrogenous fertilizer in increasing mungbean yield has been widely recognized (BINA, 2003). Mungbean yield may be increased by 30 to 60% by proper utilization of nitrogen fertilizer (Patel *et al.*, 2003). Undoubtedly, higher yield can be obtained by the application of chemical fertilizers as they are instant source of nutrients for crops.

Grain yield production is determined by genetic potential, planting density (Mansoor *et al*., 2010) and fertilizer management (Hussain *et al*., 2014). High potential yield of genotype is characterized by the large leaf area and high biomass accumulation (Mondal *et al*., 2011). However, plants require adequate space to grow in a population. In accordance with planting density, proper plant spacing management has an important role in maximizing yield (Ahamed *et al*., 2011) because it affects the degree of competition between individual plant to access potential capacity of land such as light, water and nutrient. Absorbed sunlight efficiency by crop needed to enough a leaf area to distributing equally, this aim done by changing row spacing and distributing plants over soil (Naseri *et al*., 2010). Goals such as improving absorbed sunlight by changing plant density and also changing row spacing pursued in agricultural plants planting (Naseri *et al*., 2012). High planting density increases competition between plant and reduce occupation of plant to get light, water and nutrient. Individual plant at low population produce more branch and pod, but number of pods per unit area become low so therefore reduced yield (Singh *et al*., 2003) as well as less efficient in land use (Sullivan, 2003).

Mungbean yield decreases as planting density density increases, while the number of pods per plant increases as population decreases. Yield per unit area generally increases as population density increase to certain level near upper limit. Optimum population of mungbean varies over location. The highest grain yield in Punjab, India attained at population of 40 plants per m^2 with a spacing of 25 × 10 cm (Singh *et al.*, 2011), at AVRDC, Taiwan obtained in a population of 20 plants per m^2 at a spacing of 50 × 10 cm, and 30 plants per m^2 in Bangladesh (Hossain *et al*., 2011), 25 plants per m^2 in Iran

(Rafiei, 2009). Mungbean in Pati, Central Java produces better growth parameters at spacing of 30 × 30 cm rather than 30 × 20 cm (Budiastuti, 2000). Sharma and Prasad (1990) showed that Fennel increased from 15 to 30 cm row spacing, grain yield increased significantly. Also Singh (1970) reported that row spacing of 30 cm had the best follow and essential yield. Datta and Singh (1964) reported that the highest yield was obtained in row spacing of 30 cm. Other researchers with different crops and in different planting densities also have shown the variations of crop yields (Aflatuni, 2005; De La Luz *et al*., 2002; Arabaci and Bayram, 2004). Keeping in view the above discussion, it is obligatory to search out innovative alternatives to improve crop productivity on sustainable basis. Considering the above facts the present work was conducted to evaluate the response of nitrogen and planting density on mungbean production with the following objectives:

- to know the influence of different nitrogen doses on growth and yield of mungbean
- to observe the performance of mungbean under different levels of planting density and
- to study the combined effect of N fertilizer and planting density on the growth and yield of mungbean.

CHAPTER II

REVIEW OF LITERATURE

In this chapter, an attempt has been made to review the available information regarding the influence of nitrogen and planting density on growth and yield of mungbean. The 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.

2.1 Effect of Nitrogen rate

2.1.1 Plant height

A pot experiment was conducted by Razzaque *et al.* (2015) at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season (August to November) of 2010 to find out the nitrogen acquisition and yield of mungbean genotypes affected by different levels of nitrogen fertilizer in low fertile soil. Ten mungbean genotypes viz. IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Binamoog- 5 and six nitrogen fertilizer levels viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results indicated that, the tallest plant (63.66 cm) of IPSA 12 was observed at 60 kg N ha^{-1} , GK 27 (43.00 cm) at 40 kg N ha^{-1}, IPSA 3 (65.33 cm) at 80 kg N ha^{-1}, IPSA 5 (78.33 cm) at 80 kg N ha^{-1}, ACC 12980053 (75.00 cm) at 40 kg N ha^{-1}, BU mug 4 (60.06 cm) at 40 kg N ha^{-1}, BARI Mung 6 (57.00 cm) at 60 kg N ha^{-1} and Binamoog 5 (68.33 cm) at 60 kg N ha^{-1}. The lowest plant height was obtained at 0 kg ha^{-1} irrespective of genotypes.

An experiment conducted by Achakzai *et al*. (2012) in the experimental field of Agricultural Research Institute (ARI), Quetta. The soil of the study area was basic in reaction, salt free, medium textured having low organic matter and total N contents. Four different cultivars of mungbean *viz*., NM-92, NM-98, M-1 and NCM-209 grown in kharif season for two consecutive years *i.e*. 2007 and 2008. Six different levels of N fertilizer applied @ zero, 20, 40, 60, 80 and 100 kg ha^{-1}. Urea fertilizer used as a source of N. The plot was arranged in a randomized complete block design (RCBD). Results pertaining to plant height showed that there was a significant difference among different doses of N fertilizer. The plants of T_2 (20 + 50 + 30 kg NPK ha^{-1}) gained maximum height (36.81 cm) followed by T_3 (40 + 50 + 30 kg NPK ha^{-1}) (35.95 cm) and T_5 (80 + 50 + 30 kg NPK ha^{-1}) (34.82 cm) whereas the short structure plant (29.64 cm) was obtained in plots receiving no fertilizer.

Asaduzzaman *et al.* (2008) found that plant height of mungbean was significantly increased by the application of nitrogen fertilizer at 30 kg ha^{-1}.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK level (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mung bean cv. AEM 96 in Tandojam, Pakistan. The different NPK level significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording plant height of 56.25 cm.

In a pot experiment at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Masud (2003) observed the highest plant height with the application of 30 kg N ha^{-1}

2.1.2 Number of leaves plant^{-1}

Mondal *et al.* (2014) conducted a field experiments with mungbean (*Vigna radiata* L. Wilczek) in the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India and found that leaf area plant^{-1} of mungbean was significantly increased by the split application of Nitrogen fertilizer at 21 DAS.

An experiment conducted by Achakzai *et al*. (2012) in the experimental field of Agricultural Research Institute (ARI), Quetta. The soil of the study area was basic in reaction, salt free, medium textured having low organic matter and total N contents. Four different cultivars of mungbean *viz.*, NM-92, NM-98, M-1 and NCM-209 grown in kharif season for two consecutive years *i.e.*, 2007 and 2008. Six different levels of N fertilizer applied @ zero, 20, 40, 60, 80 and 100 kg ha^{-1}. Urea fertilizer used as a source of N. The plot was arranged in a randomized complete block design (RCBD). They reported that, the maximum number of leaves plant^{-1} (5.71) recorded in treatment T_1 (No fertilizer), while the minimum (4.86) noted for T_4 (60 + 50 + 30 kg NPK ha^{-1}) dose of fertilizer.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher leaves plant^{-1}.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that leaves plant^{-1} was significantly affected by varying level of nitrogen.

2.1.3 Number of nodules plant^{-1}

Nursu'aidah *et al.* (2014) conducted an experiment on growth and photosynthetic responses of longbean (*Vigna unguiculata*) and mungbean (*Vigna radiata*) response to fertilization and found that mungbean grown without fertilizer produced the highest nodules per plant.

Khalilzadeh *et al.* (2012) conducted an experiment on growth characteristics of mungbean (*Vigna radiata* L.*)* and found that foliar application of urea and organic manure substantially improved number and dry weight of nodule.

Mozumder (1998) conducted a field trail at the Agronomy Field, Bangladesh Agricultural University, Mymensingh during the period from March 1994 to June 1994 to study the effects of five nitrogen level on two varieties of summer mungbean and reported that nitrogen produced negative effect on nodule production and starter dose of nitrogen (40 kg ha^{-1}) gave the maximum seed yield (1607 kg ha^{-1}).

Santos *et al.* (1993) observed on mungbean cv. Berken, grown in pots in podzolic soil using 7 level of N (0, 25, 50, 100, 200, 400 and 500 kg ha^{-1} as NH_4NO_3. They noted that nodule number increased strongly, between flowering and maturity; in plants grown at 100 kg N ha^{-1}, suggesting a delay in nodulation occurred. Poor nodulation and depletion of soil N as indicated by the low N concentration in the young mature leaves at the maturity stages. Plants grown at 400 and 500 kg N ha^{-1} failed to nodulation.

Hoque and Barrow (1993) conducted a field trail at various locations in Bangladesh and found that the, inoculants markedly increased nodule number and nodule dry weight of soybean, lentil and mungbean compared to uninoculated control and urea-N treatments.

Murakami *et al*. (1990) reported that without N fertilizer, N fixation started at 12 days after sowing (DAS) increased rapidly at 34 DAS (flowering) to reach a peak at 45 DAS had a secondary peak at 60 DAS and then decreased until the plant died (83 DAS). With N fertilizer, N fixation started at 14 DAS, increased slowly to reach a much lower peak at 50 DAS and then decreased. Nodulation was greatly decreased by applied N, but fixation per unit nodule weight was similar in both N treatments. The percentage N derived from the air of 78 mungbean cultivar was 0-100% at 33 DAS and 760% in all cultivars at 60 DAS. The author suggested that these cultivars might respond more to applied N than high fixing cultivars.

2.1.4 Dry matter weight plant^{-1}

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher dry matter production.

An experiment was conducted by Asaduzzaman *et al*. (2008) at the experiment field of the Department of Agronomy, Sher-e-Bangla Agricultural University; Dhaka, Bangladesh to evaluate the effect of nitrogen and irrigation managements on dry matter accumulation and yield of mungbean (*Vigna radiata* L.) cv. BARI mung-5 during the period from March to May, 2006. The trial comprised of ten treatments such as T_1 =No fertilizer and no irrigation (control), T_2=20 kg N ha^{-1} as basal, T_3=20 kg N ha^{-1} as basal +

one irrigation at flower initiation stage, T_4=30 kg N ha^{-1} as basal, T_5=30 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_6=40 kg N ha^{-1} as basal, T_7=40 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_8= 10 kg N ha^{-1} as basal and 10 kg N ha^{-1} as split +one irrigation at first flowering stage, T_9= 15 kg N ha^{-1} as basal and 15 kg N ha^{-1} as split +one irrigation at flower initiation stage and T_{10}= 20 kg N ha^{-1} as basal and 20 kg N ha^{-1} as split +one irrigation at flower initiation stage. They found that, treatment 30 kg N ha^{-1} as basal + one irrigation at flower initiation stage (T_5) was significantly superior to other treatments in these accumulations. The maximum above ground dry matter (23.36 g) was found at harvest (85 DAS). Significantly the lowest accumulation (15.63 g) was observed in control treatment (no fertilizer and no irrigation).

Yakadri *et al.* (2002) studied the effect of nitrogen on crop growth and yield of green gram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in dry matter content in above ground part.

2.1.5 Number of branches plant^{-1}

An experiment conducted by Achakzai *et al*. (2012) in the experimental field of Agricultural Research Institute (ARI), Quetta. The soil of the study area was basic in reaction, salt free, medium textured having low organic matter and total N contents. Four different cultivars of mungbean viz., NM-92, NM-98, M-1, and NCM-209 grown in kharif season for two consecutive year i.e., 2007 and 2008. Six different levels of N fertilizer applied @ zero, 20, 40, 60, 80 and 100 kg ha^{-1}. Urea fertilizer used as a source of N. The plot was arranged in a randomized complete block design (RCBD). Results regarding number of branches plant^{-1} exhibited that there was a significant difference among various treatments of N fertilizer when compared it with their control treatment (T_1). The plants of T_6 (100 + 50 + 30 kg NPK ha^{-1}) produced the maximum number of branches plant^{-1} (3.83), whereas minimum recorded for T_1 (No fertilizer (control)) (3.17).

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly more number of branches (1.67) plant^{-1}.

Malik *et al.* (2003) conducted a study to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that number of branches plant^{-1} was found to be significantly higher by 25 kg N ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer. The number of branches increased with increasing N rates.

2.1.6 Days required to 50% flowering

An experiment conducted by Achakzai *et al*. (2012) in the experimental field of Agricultural Research Institute (ARI), Quetta. The soil of the study area was basic in reaction, salt free, medium textured having low organic matter and total N contents. Four different cultivars of mungbean viz., NM-92, NM-98, M-1, and NCM-209 grown in kharif season for two consecutive years i.e., 2007 and 2008. Six different levels of N fertilizer applied @ zero, 20, 40, 60, 80 and 100 kg ha^{-1}. Urea fertilizer used as a source of N. The plot was arranged in a randomized complete block design (RCBD). The plants of T_5 treatment (80 + 50 + 30 kg NPK ha^{-1}) took minimum days to flowering (43.75), followed by T_2 (20 + 50 + 30 kg NPK ha^{-1}) (44.33). The maximum day to flowering (48.25) was recorded for highest dose of N fertilizer (100 kg ha^{-1}).

2.1.7 Number of pods plant^{-1}

An experiment was conducted by Hossen *et al*. (2015) at the research field of the Horticulture Research Center at Labukhali, Patuakhali during the period from January to March, 2014 to find out the most suitable BARI mungbean variety and optimum rates of N concerning higher seed yield under the regional condition of Patuakhali (AEZ–13). Two BARI mungbean varieties namely BARI Mung–5 (V_1) and BARI Mung–6 (V_2) and

five levels of N fertilizer including control *viz.* 0 kg N ha^{-1} (N_0), 30 kg N ha^{-1} (N_{30}), 45 kg N ha^{-1} (N_{45}), 60 kg N ha^{-1} (N_{60}), and 75 kg N ha^{-1} (N_{75}) were used for the study as level factor A and B, respectively. They found that, the maximum number of pods $plant^{-1}$ (10.45) was obtained in 45 kg N ha^{-1} followed by 30 kg N ha^{-1} (9.50 cm). On the other hand, the control treatment (without N) produced the minimum number of pods $plant^{-1}$ (7.55).

A pot experiment was conducted by Razzaque *et al.* (2015) at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season (August to November) of 2010 to find out the nitrogen acquisition and yield of mungbean genotypes affected by different levels of nitrogen fertilizer in low fertile soil. Ten mungbean genotypes viz. IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Binamoog- 5 and six nitrogen fertilizer levels viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results indicated that, the genotype IPSA 12 produced the highest pods $plant^{-1}$ (30.16) with 60 kg N ha^{-1} and it was statistically similar to IPSA 5 at same N level. The lowest number of pods $plant^{-1}$ (16.16) was recorded in genotype GK-63 which was identical with pods $plant^{-1}$ (16.83) with Binamoog-5 with 100 kg N ha^{-1}.

Nursu'aidah *et al.* (2014) conducted an experiment on growth and photosynthetic responses of longbean (*Vigna unguiculata*) and mungbean (*Vigna radiata*) response to fertilization and they found that mungbean grown without fertilizer produced the highest number of pods plant $^{-1}$.

In order to effect of nitrogen fertilizer and seed inoculation with growth stimulus bacteria on the yield and yield components of mungbean, a factorial experiment was conducted by Mahmoudi *et al.* (2013) in a randomized complete block design with three replications in the research farm located 15 km from the city of West Ivan in the 40 km northwest of Ilam in the 2012. Factors included the levels of nitrogen fertilizer at four levels of urea source (Zero, 25, 50 and 75 kg urea per ha) and seed inoculation with growth stimulus bacteria at four levels included (Non-inoculated of the seed as control, seed inoculation with *Pseudomonas, Putida* strain 186, *Azotobacter* strain 5 and *Azospirillum lipoferum* strain). The results showed that, the highest number of pods per plant was obtained (32.70) consumption of 75 kg N ha^{-1} that increased 34% than lack of nitrogen fertilizer application (22.60).

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher pods plant $^{-1}$.

An experiment was conducted by Asaduzzaman *et al*. (2008) at the experiment field of the Department of Agronomy, Sher-e-Bangla Agricultural University; Dhaka, Bangladesh to evaluate the effect of nitrogen and irrigation managements on dry matter accumulation and yield of mungbean (*Vigna radiata* L.) cv. BARI mung-5 during the period from March to May, 2006. The trial comprised of ten treatments such as T_1 =No fertilizer and irrigation (control), T_2=20 kg N ha^{-1} as basal, T_3=20 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_4=30 kg N ha^{-1} as basal, T_5=30 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_6=40 kg N ha^{-1} as basal, T_7=40 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_8= 10 kg N ha^{-1} as basal and 10 kg N ha^{-1} as split +one irrigation at first flowering stage, T_9= 15 kg N ha^{-1} as basal and 15 kg N ha^{-1} as split +one irrigation at flower initiation stage and T_{10}= 20 kg N ha^{-1} as basal and 20 kg N ha^{-1} as split +one irrigation at flower initiation stage. They found that, 30 kg N ha^{-1} as basal + one irrigation at flower initiation stage (T_5) gave significantly highest number of pods per plant (43.30) whereas control treatment (no fertilizer and irrigation) gave the lowest pods per plant (12.41).

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest values for number of pods plant $^{-1}$ (38.3).

Kulsum (2003) reported that different level of nitrogen showed significantly increased pods plant $^{-1}$ of blackgram up to 60 kg N ha^{-1}.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer and reported that the number of pods plant $^{-1}$ increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1}) and 0, 25, 50 and 60 kg P ha^{-1}) and observed that the number of pods plant $^{-1}$ was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N.

2.1.8 Number of seeds pod^{-1}

An experiment was conducted by Hossen *et al*. (2015) at the research field of the Horticulture Research Center at Labukhali, Patuakhali during the period from January to March, 2014 to find out the most suitable BARI mungbean variety and optimum rates of N concerning higher seed yield under the regional condition of Patuakhali (AEZ–13). Two BARI mungbean varieties namely BARI Mung–5 (V_1) and BARI Mung–6 (V_2) and five levels of N fertilizer including control *viz.* 0 kg N ha$^{–1}$ (N_0), 30 kg N ha$^{–1}$ (N_{30}), 45 kg N ha$^{–1}$ (N_{45}), 60 kg N ha$^{–1}$ (N_{60}), and 75 kg N ha$^{–1}$ (N_{75}) were used for the present study as level factor A and B, respectively. They found that, among the nitrogen doses, nitrogen at the rate of 45 kg ha$^{–1}$ produced significantly the more seeds pod$^{–1}$ (9.70) followed by 30 kg N ha$^{–1}$ (9.30) while the minimum number of seeds pod$^{–1}$ (8.70) was taken from the control or without nitrogen.

A pot experiment was conducted by Razzaque *et al.* (2015) at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season (August to November) of 2010 to find out the nitrogen acquisition and yield of mungbean genotypes affected by different levels of nitrogen fertilizer in low fertile soil. Ten mungbean genotypes viz. IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Binamoog- 5 and six nitrogen fertilizer levels viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results indicated that, the highest seed pod^{-1}(12.40) was obtained in IPSA 12 and the lowest seed pod^{-1} (10.20) was recorded in BUmug 4 at o kg N ha^{-1}.

In order to effect of nitrogen fertilizer and seed inoculation with growth stimulus bacteria on the yield and yield components of mungbean, a factorial experiment was conducted by Mahmoudi *et al.* (2013) in a randomized complete block design with three replications in the research farm in the 2012. Factors included the levels of nitrogen fertilizer at four levels of urea source (Zero, 25, 50 and 75 kg urea per ha) and seed inoculation with growth stimulus bacteria at four levels included (Non-inoculated of the seed as control, seed inoculation with *Pseudomonas, Putida* strain 186, *Azotobacter* strain 5 and *Azospirillum lipoferum* strain). The results showed that, the highest number of seeds per plant was obtained 222.2 number with the consumption of 50 kg N ha^{-1} that revealed 20% increase compared to the lack of nitrogen fertilizer (181.76).

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2 % foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest seeds pod^{-1} (7.67).

Malik *et al*. (2003) investigated the effect of varying level of nitrogen (0, 25 and 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98 during 2001. It was found that number seeds pod^{-1} was significantly affected by varying level of nitrogen and phosphorous.

2.1.9 Length of pod

An experiment was conducted by Hossen *et al*. (2015) at the research field of the Horticulture Research Center at Labukhali, Patuakhali during the period from January to March, 2014 to find out the most suitable BARI mungbean variety and optimum rates of N concerning higher seed yield under the regional condition of Patuakhali (AEZ–13). Two BARI mungbean varieties namely BARI Mung–5 (V_1) and BARI Mung–6 (V_2) and five levels of N fertilizer including control *viz.* 0 kg N ha$^{–1}$ (N_0), 30 kg N ha$^{–1}$ (N_{30}), 45 kg N ha$^{–1}$ (N_{45}), 60 kg N ha$^{–1}$ (N_{60}), and 75 kg N ha$^{–1}$ (N_{75}) were used for the present study as level factor A and B, respectively. They found that, the length of pod increased significantly due to increasing dose of nitrogen up to 45 kg N ha$^{–1}$ and thereafter it decreased. The longest pod of mungbean (7.93 cm) was found in 45 kg N ha^{-1} followed by both 30 and 60 kg N ha$^{–1}$ (7.56 and 7.53 cm, respectively) where both doses were statistically identical in respect of pod length. On the other hand, the shortest pod (6.54 cm) was observed from the control (0 kg N ha^{-1}).

Mondal *et al.* (2014) conducted a field experiments with mungbean (V*igna radiata* L. Wilczek) in the Crop Research and Seed Multiplication Farm, Burdwan University, West Bengal, India. They found that pod length of mungbean was significantly increased by the split application of Nitrogen fertilizer at 21 DAS.

Azadi *et al.* (2013) conducted an experiment on the effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad and they found that the highest pod length was obtained at 150 kg ha^{-1} urea.

2.1.10 Weight of 1000 seeds

An experiment was conducted by Hossen *et al*. (2015) at the research field of the Horticulture Research Center at Labukhali, Patuakhali during the period from January to March, 2014 to find out the most suitable BARI mungbean variety and optimum rates of N concerning higher seed yield under the regional condition of Patuakhali (AEZ–13). Two BARI mungbean varieties namely BARI Mung–5 (V_1) and BARI Mung–6 (V_2) and

five levels of N fertilizer including control *viz.* 0 kg N ha^{-1} (N_0), 30 kg N ha^{-1} (N_{30}), 45 kg N ha^{-1} (N_{45}), 60 kg N ha^{-1} (N_{60}), and 75 kg N ha^{-1} (N_{75}) were used for the present study as level factor A and B, respectively. They found that, among the N doses, N at the rate of 45 kg ha^{-1} recorded the highest weight of 100–seed (4.52 g) followed by 30 kg N ha^{-1} (4.35 g) while it was lowest (3.74 g) in control treatment (no nitrogen).

A pot experiment was conducted by Razzaque *et al.* (2015) at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season (August to November) of 2010 to find out the nitrogen acquisition and yield of mungbean genotypes affected by different levels of nitrogen fertilizer in low fertile soil. Ten mungbean genotypes viz. IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Binamoog- 5 and six nitrogen fertilizer levels viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results indicated that, thousand seeds weight was not significantly affected by N fertilizer application.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1} and 0, 25, 50 and 60 kg P ha^{-1} and observed 1000-seeds weight increased with increasing rates of N up to 40 kg ha^{-1}.

Mahboob and Asghar (2002) studied the effect of seed inoculum at different nitrogen level on the yield and yield components of mungbean at the agronomic research station, Farooqabad in Pakistan durin the year of 2000 and 2001. They revealed that with the application of NPK at the rate of 50-50-0 kg ha^{-1} significantly affected the 1000 grains weight.

2.1.11 Seed yield

An experiment was conducted by Hossen *et al*. (2015) at the research field of the Horticulture Research Center at Labukhali, Patuakhali during the period from January to March, 2014 to find out the most suitable BARI mungbean variety and optimum rates of N concerning higher seed yield under the regional condition of Patuakhali (AEZ–13). Two BARI mungbean varieties namely BARI Mung–5 (V_1) and BARI Mung–6 (V_2) and

five levels of N fertilizer including control *viz.* 0 kg N ha^{-1} (N_0), 30 kg N ha^{-1} (N_{30}), 45 kg N ha^{-1} (N_{45}), 60 kg N ha^{-1} (N_{60}), and 75 kg N ha^{-1} (N_{75}) were used for the present study as level factor A and B, respectively. They found that, the higher weight of seeds $plant^{-1}$ (5.73 kg) was obtained from 45 kg N ha^{-1} followed by 30 kg N ha^{-1} (4.49 g) while it was lowest (1.78 g) in control or without N. Among the various doses of nitrogen, the seed yield had higher (1.85 t ha^{-1}) in 45 kg N ha^{-1} followed by 30 kg N ha^{-1} (1.55 t ha^{-1}) and the minimum seed yield (0.99 t ha^{-1}) was obtained from the control treatment (no nitrogen).

A pot experiment was conducted by Razzaque *et al.* (2015) at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif- II season (August to November) of 2010 to find out the nitrogen acquisition and yield of mungbean genotypes affected by different levels of nitrogen fertilizer in low fertile soil. Ten mungbean genotypes viz. IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Binamoog- 5 and six nitrogen fertilizer levels viz. 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results indicated that, there was general trend of increase seed yield with the increase of N fertilizer up to 60 kg N ha^{-1} and thereafter decreased. Increase nitrogen fertilizer in low fertile soil gradually increased seed yield up to 60 kg N ha^{-1} due to increase pod $plant^{-1}$.

Azadi *et al.* (2013) conducted an experiment on the effect of different nitrogen level on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad and they found that the highest seed yield and pod length was obtained at 150 kg ha^{-1} urea.

Akbar *et al.* (2013) conducted an experiment on the interactive effect of cobalt and nitrogen on growth, nodulation, yield and protein content of field grown pea and observed that the highest seed yield in the treatment the 60 kg N ha^{-1} and 10 g Co ha^{-1}.

In order to effect of nitrogen fertilizer and seed inoculation with growth stimulus bacteria on the yield and yield components of mungbean, a factorial experiment was conducted by Mahmoudi *et al.* (2013) in a randomized complete block design with three replications in the research farm in the 2012. Factors included the levels of nitrogen fertilizer at four levels of urea source (Zero, 25, 50 and 75 kg urea per ha) and seed inoculation with growth stimulus bacteria at four levels included (Non-inoculated of the seed as control, seed inoculation with Pseudomonas, *Putida* strain 186, *Azotobacter* strain 5 and *Azospirillum lipoferum* strain). The results showed that, the highest seed yield (2483 kg ha^{-1}) was recorded with the consumption of 75 kg N ha^{-1} while the lowest seed yield (1795 kg ha^{-1}) was recorded with the lack of nitrogen fertilizer.

Sadeghipour *et al. (*2010) conducted an experiment on the production of mungbean (*Vigna radiata* L.) by nitrogen and phosphorus fertilizer application and they found that the maximum seed yield was obtained when 90 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} was applied.

Sultana *et al.* (2009) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of nitrogen and weed managements on mungbean (*Vigna radiata* L.). They found that application of 20 kg N ha^{-1} as basal + 20 kg N ha^{-1} with one weeding at vegetative stage showed significantly higher seed yield ha^{-1} (1982.05 kg).

An experiment was conducted by Asaduzzaman *et al*. (2008) at the experiment field of the Department of Agronomy, Sher-e-Bangla Agricultural University; Dhaka, Bangladesh to evaluate the effect of nitrogen and irrigation managements on dry matter accumulation and yield of mungbean (*Vigna radiata* L.) cv. BARI mung-5 during the period from March to May, 2006. The trial comprised of ten treatments such as T_1 =No fertilizer and irrigation (control), T_2=20 kg N ha^{-1} as basal, T_3=20 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_4=30 kg N ha^{-1} as basal, T_5=30 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_6=40 kg N ha^{-1} as basal, T_7=40 kg N ha^{-1} as basal + one irrigation at flower initiation stage, T_8= 10 kg N ha^{-1} as basal and 10 kg N ha^{-1} as split +one irrigation at first flowering stage, T_9= 15 kg N ha^{-1} as basal and 15 kg N ha^{-1} as split +one irrigation at flower initiation stage and T_{10}= 20 kg N ha^{-1} as basal and 20 kg N ha^{-1} as split +one irrigation at flower initiation stage. They found that, significantly highest seed yield per plant (5.538 g) was produced in T_5 (30 kg N ha^{-1} as basal + one irrigation at flower initiation stage) and followed by T_3 (5.11 g). T_5 also produced significantly highest seed yield per hectare (1.65 t) and followed by T_3 (1.52 t) and T_7 (1.47 t). The lowest yield per plant and per hectare was recorded from control and that was 3.64 g and 1.09 ton, respectively.

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India to evaluate the effect of N application time as basal urea spray and use of plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram cv. K-851. The recommended rate of N: P: K (20:50:20 kg ha^{-1}) as basal was used as a control. Treatments were as included: 1/2 basal N + foliar N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2% foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest grain yield (9.66 q ha^{-1}).

Tickoo *et al*. (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher grain yield (1.63 t ha^{-1}) compared to cv. Pusa 105.

A field study conducted by Sharma and Sharma (2006) for two years at the Indian Agricultural Research Institute, New Delhi on a sandy clay loam soil showed that the application of NP increased the total grain production of a rice-wheat-mungbean cropping system by 0.5-0.6 t ha^{-1}, NK by 0.3-0.5 t ha^{-1} and NPK by 0.8-0.9 t ha^{-1} compared to N alone, indicating that the balanced use of primary nutrients was more advantageous than their imbalanced application.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK level (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg ha^{-1}) on the growth and yield of mungbean in Tandojam, Pakistan. The different NPK level significantly affected the crop parameters. The 10-30-30 kg NPK ha^{-1} was the best treatment, recording the highest seed yield of 1205.2 kg ha^{-1}.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM-98 to seed inoculum and different level of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying level of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. They observed that a fertilizer combination of 25 kg N + 75 kg P ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer and reported that grain yield increased with increasing rates of up to 40 kg N ha^{-1} only.

Mahboob and Asghar (2002) studied the effect of seed inoculum at different nitrogen level on mungbean at the agronomic research station, Farooqabad in Pakistan. They revealed that seed inoculum + 50-50-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Kamal *et al.* (2001) conducted an experiment at the BARI farm during rainy season for 2000-2001 to determine the effect of various level of fertilizer and weeding of mungbean. Superior grain yield (1430 kg ha^{-1}) was found when fertilized @ 20-60-30 NPK kg ha^{-1} with two hand weeding at 20 and 30 DAE were used. This was followed by that obtained (1368 kg ha^{-1}) by using inoculum + 60-30 PK kg ha^{-1} with two hand weeding at 20 and 30 DAE. This result showed that application of fertilizer @ 20-60-30 kg ha^{-1} combine with two hand weeding at 20 and 30 DAE was economical for yield as well as quality seed production of mungbean.

2.1.12 Stover yield

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Stover yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

The effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al*. (2002) in Hisar, Haryana, India during the summer and reported that straw yield increased with increasing N rates.

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at 0, 25 and 60 kg N ha^{-1} and 0, 25, 50 and 60 kg P ha^{-1} and stated that the stover yield increased with increasing N up to 40 kg ha^{-1}.

2.1.13 Biological yield

In order to effect of nitrogen fertilizer and seed inoculation with growth stimulus bacteria on the yield and yield components of mungbean, a factorial experiment was conducted by Mahmoudi *et al.* (2013) in a randomized complete block design with three replications in the research farm in the 2012. Factors included the levels of nitrogen fertilizer at four levels of urea source (Zero, 25, 50 and 75 kg urea per ha) and seed inoculation with growth stimulus bacteria at four levels included (Non-inoculated of the seed as control, seed inoculation with *Pseudomonas, Putida* strain 186, *Azotobacter* strain 5 and *Azospirillum lipoferum* strain). The results showed that, the highest biological yield (6013 kg ha^{-1}) was recorded with the consumption of 50 kg N ha^{-1} while the lowest biological yield (5076.9 kg ha^{-1}) was recorded with the lack of nitrogen fertilizer.

Tickoo *et al*. (2006) carried out an experiment on mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment conducted in Delhi, India. Cultivar Pusa Vishal recorded higher biological (3.66 1.63 t ha^{-1}) compared to cv. Pusa 105.

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Biological yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect biological yield.

2.1.14 Harvest index

In order to effect of nitrogen fertilizer and seed inoculation with growth stimulus bacteria on the yield and yield components of mungbean, a factorial experiment was conducted by Mahmoudi *et al.* (2013) in a randomized complete block design with three replications in the research farm in the 2012. Factors included the levels of nitrogen fertilizer at four levels of urea source (Zero, 25, 50 and 75 kg urea per ha) and seed inoculation with growth stimulus bacteria at four levels included (Non-inoculated of the seed as control, seed inoculation with *Pseudomonas*, *Putida* strain 186, *Azotobacter strain* 5 and *Azospirillum lipoferum* strain). The results showed that, the highest harvest index (47.6%) was recorded with the consumption of 75 kg N ha^{-1} while the lowest harvest index (38.71%) was recorded with the lack of nitrogen fertilizer.

In a field experiment carried out by Mozumder (1998) at the Agronomy field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from March 1994 to June 1994 studied with five nitrogen level (0. 20, 40, 60 and 80 kg N ha^{-1}) and two varieties of summer munghean *viz*. Binamoog-2 and Kanti, results revealed that nitrogen produced negative effect of harvest index. Harvest index (%) was decreased by higher nitrogen level.

2.2 Effect of planting density

2.2.1 Plant height

The research was conducted Taufiq and Kristiono (2016) at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mungbean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. The results of the research revealed that, the tallest plant (82.70 cm) was produced by planting density 500,000 ha^{-1} where as the shortest plant (77.70cm) was produced by planting density 200,000 ha^{-1} and the intermediate result (81.10cm) was recorded from 333,333 plant ha^{-1}.

An experiment was conducted by Kebede *et al.* (2015) in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, plant height of common bean were not significantly ($p \leq 0.01$) affected by plant spacing.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, the plant height was significantly affected by inter-row spacing and maximum plant height was observed at a plant spacing of 45 cm (50.83 cm) while the average plant height at maturity of 30 and 60 cm inter-row spacing were 49.36cm and 47.72 cm, respectively.

An experiment was conducted by Rana *et al.* (2011) at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh from February to May 2004. The experimental area was characterized by non calcareous dark grey floodplain soil. The pH value of the soil was 6.7, low in organic matter and silty loam texture. Three sets of treatments were included in the experiment, which were (a) three planting densitys: 30, 45, and 60 plants/m2, (b) two inoculations: no inoculation and inoculation and (c) three summer mungbean cultivars: BARI Mung-2, BARI Mung-5, and Binamoog-5. The experiment was laid out in a randomized complete block design (RCBD) with three replications with inter plot spacing of 0.5 m and inter block spacing of 1.0 m. the result of the experiment revealed that, at harvest, significantly tallest plant was found with 30 plants m^{-2} (36.84 cm), followed by 45 plants m^{-2} (35.19 cm) and the shortest plant was noted with 60 plants m^{-2} (33.59 cm).

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the tallest plant (38.31 cm) was observed at a planting density of 40 cm × 30 cm and the shortest plant (34.69 cm) was observed at a planting density of 20 cm × 20 cm.

2.2.2 Number of leaves plant^{-1}

The research was conducted Taufiq and Kristiono (2016) at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mung-bean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. The results of the research revealed that, maximum number of leaves plant^{-1} (10.00) was recorded from 200,000 plant ha^{-1} whereas the minimum (6.00) number of leaves plant^{-1} was recorded from 500,000 plant ha^{-1}.

2.2.3 Number of branches plant^{-1}

Taufiq and Kristiono (2016) carried out a research at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mungbean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. They reported that, maximum number of branches plant^{1} (1.80) was given by planting density 200,000 ha^{-1} whereas the minimum one (0.10) was recorded from planting density 500,000 ha^{-1}.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, the inter-row spacing of 30 cm affected the plant to produce more number of branches (6.24) and was statistically at par with that of inter-row spacing of 45 cm which produced 6.20 numbers of branches. The lowest number of branches per plant (5.93) was produced at inter-row spacing of 60 cm.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest number of branches plant^{-1} (2.33) was observed at 30 cm × 10 cm spacing and the lowest number of branches plant^{-1} (1.57) was observed at plant spacing 20 cm × 20 cm.

2.2.4 Dry matter weight plant^{-1}

The research was conducted Taufiq and Kristiono (2016) at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mungbean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. They reported that, planting density 200,000 ha^{-1} produced maximum dry matter plant^{-1} (29.54 g) whereas the minimum one (14.95 g) was recorded from 500,000 plant ha^{-1}.

Rao *et al.* (2015) investigated the extent and physiological bases of yield variation due to row spacing and plant density configuration in the mungbean [*Vigna radiata* (L.) Wilczek] variety "Crystal" grown in different subtropical environments. Field trials were conducted in six production environments; one rain-fed and one irrigated trial each at Biloela and Emerald, and one rain-fed trial each at Hermitageand Kingaroy sites in Queensland, Australia. In each trial, six combinations of spatial arrangement of plants, achieved through two inter-row spacing of 1 m or 0.9 m (wide row), 0.5 m or 0.3 m (narrow row),with three plant densities, 20, 30 and 40 plants m^{-2}, were compared. They concluded that, the narrow row spacing resulted in 22% higher shoot dry matter compared to the wide rows.

An experiment was conducted by Kebede *et al.* (2015) in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, plant spacing had no significant influence on above ground dry weight.

An experiment was conducted by Rana *et al.* (2011) at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh from February to May 2004. The experimental area was characterized by non calcareous dark grey floodplain soil. The pH value of the soil was 6.7, low in organic matter and silty loam texture. Three sets of treatments were included in the experiment, which were (a) three planting densitys: 30, 45, and 60 plants/m2, (b) two inoculations: no inoculation and inoculation and (c) three summer mungbean cultivars: BARI Mung-2, BARI Mung-5 and Binamoog-5. The experiment was laid out in a randomized complete block design (RCBD) with three replications with inter plot spacing of 0.5 m and inter block spacing of 1.0 m. the result of the experiment revealed that, the highest dry matter weight (334.06 g m^{-2}) was achieved at 60 plants m^{-2} followed by 273.82 g m^{-2} at 45 plants m^{-2} and the lowest 216.37 g m^{-2} from 30 plants m^{-2}.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest dry matter $plant^{-1}$ (9.64 g) was produced at spacing of 30 cm × 10 cm, which was identical to that of 40 cm × 30 cm (9.44 g). The lowest dry matter $plant^{-1}$ (8.79 g) was produced in 20 cm × 20 cm spacing.

2.2.5 Number of nodules plant^{-1}

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, the inter-row spacing of plants did not significantly affect the nodulation process.

2.2.6 Days required to 50% flowering

An experiment was conducted by Kebede *et al.* (2015) in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, days to flowering of common bean were not significantly ($p \leq 0.01$) affected by plant spacing.

2.2.7 Number Pods plant^{-1}

The research was conducted Taufiq and Kristiono (2016) at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mung-bean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. They reported that, maximum number of pods plant^{1} (21) was given by planting density 200,000 ha^{-1} whereas the minimum one (11.00) was recorded from planting density 500,000 ha^{-1}.

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the highest number of pods plant^{-1} (22.08) was obtained 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.

An experiment was conducted by Kebede *et al.* (2015) in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, number of pods per plant was not significantly ($p \leq 0.01$) affected by plant spacing.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, the effect of inter-row spacing was non-significant on the number of pods per plant.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest number of pods plant^{-1} (13.13) was found at 30 cm × 10 cm spacing and the lowest one (11.67) was found at 40 cm × 30 cm. However, 20 cm × 20 cm spacing produced (12.00) similar pods plant^{-1} as that of 40 cm × 30 cm spacing.

2.2.8 Number of seeds pod^{-1}

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the maximum number of seeds pod^{-1} (15.47) was obtained from P_2 treatment, while the minimum (9.83) was observed from P_1 treatment.

Kebede *et al.* (2015) conducted an experiment in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, number of seeds per pod was not significantly ($p \leq 0.01$) affected by plant spacing.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, the data further show that inter-row spacing S_3 and S_2 were statistically similar and produced significantly more number of seeds per pod (10.55 and 10.37, respectively) than produced by S_1 (30 cm) (9.11) inter-row spacing treatment.

2.2.9 Length of pod

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the maximum pod length (10.18 cm) was obtained from 30 cm × 10 cm spacing whereas, the minimum (6.38 cm) was observed from 20 cm × 10 cm.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest pod length (6.97 cm) was observed at 30 cm × 10 cm spacing. The lowest pod length (6.86

cm) was observed at 20 cm × 20 cm spacing, which was statistically identical to 40 cm × 30 cm spacing (6.87 cm).

2.2.10 Weight of 1000 seeds

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the maximum 1000 seeds weight (44.26 g) was obtained from the 30 cm × 10 cm spacing (P_2) treatment whereas, the minimum 1000 seeds 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).

A field experiment was conducted by Kebede *et al.* (2015) in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, plant spacing had no significant influence on 1000 seed weight.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, among the inter-row spacing treatments, the maximum 1000-seed weight (49.30 g) was obtained at 60 cm inter-row spacing while the minimum one (46.31 g) was recorded from 30 cm inter-row spacing.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest 1000-seed weight (32.06 g) was observed at 40 cm × 30 cm spacing followed in order by 30 cm × 10 cm (31.93 g) and the lowest one (31.38 g) was from plant spacing 20 cm × 20 cm.

2.2.11 Seed yield

The research was conducted Taufiq and Kristiono (2016) at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mungbean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. The results of the research revealed that, maximum grain weight $plant^{-1}$ (10.50 g) was recorded from planting density 200,000 ha^{-1} whereas the minimum (7.30 g) grain weight $plant^{-1}$ was recorded from planting density 500,000 ha^{-1}.

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the highest grain yield (1.63 t ha^{-1}) was obtained 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.

Rao *et al.* (2015) investigated the extent and physiological bases of yield variation due to row spacing and plant density configuration in the mungbean [*Vigna radiata* (L.) Wilczek] variety “Crystal” grown in different subtropical environments. Field trials were conducted in six production environments; one rain-fed and one irrigated trial each at Biloela and Emerald, and one rain-fed trial each at Hermitageand Kingaroy sites in Queensland, Australia. In each trial, six combinations of spatial arrangement of plants, achieved through two inter-row spacing of 1 m or 0.9 m (wide row), 0.5 m or 0.3 m (narrow row),with three plant densities, 20, 30 and 40 plants m^{-2}, were compared. They concluded that, the narrow row spacing resulted in 14% more yield compared to the wide rows.

An experiment was conducted by Kebede *et al.* (2015) in 2012 main cropping season at Haramaya and Hirna research fields, eastern Ethiopia, to determine the effect of plant spacing and weeding frequency on weeds, yield components and yield of common bean. The experiment comprised 18 treatment combinations with three inter- and intra-row plant spacing, respectively, (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm) and six weeding frequencies (one weeding by hand hoeing two weeks after crop emergence, one weeding by hand-hoeing three weeks after crop emergence, one weeding by hand-hoeing four weeks after crop emergence, two weeding by hand hoeing two and five weeks after crop emergence, weed-free check, weedy check). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. It was observed that, plant spacing had no significant influence on seed yield.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, crop sown at inter-row spacing of 30 cm gave maximum seed yield (675.84 kg ha^{-1}) while lowest seed yield (595.29 kg ha^{-1}) was obtained at inter-row spacing of 60 cm.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest seed yield (1046.0 kg ha^{-1}) was obtained at 30 cm × 10 cm spacing and lowest seed yield (530.90 kg ha^{-1}) was observed at 40 cm × 30 cm spacing.

2.2.12 Stover yield

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the maximum stover yield (2.03 t ha^{-1}) was obtained from the P_1 treatment whereas, the minimum (1.31 t ha^{-1}) was found in the P_3 treatment.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest stover yield (2580 kg ha^{-1}) was observed at 30 cm × 10 cm spacing and the lowest one (1370 kg ha^{-1}) was observed at 40 cm × 30 cm spacing.

2.2.13 Biological yield

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the maximum biological yield (3.13 t ha^{-1}) was obtained 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.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, there were significant differences among the inter-row spacing that affected the biological yield. The inter-row spacing of 30 cm and 45 cm produced 4131 and 4003.5 kg ha^{-1} of biological yield, respectively and these were statistically at par. The inter-row spacing of 60 cm gave minimum biological yield (3328.9 kg ha^{-1}).

2.2.14 Harvest index

The research was conducted Taufiq and Kristiono (2016) at Muneng Experiment Farm in Probolinggo from March to May, 2013. Two factors consisted of five mung-bean genotypes (MMC679-2C-GT-2, MMC647d-GT-2, MMC554d-GT-2, MMC601f-GT-1 and Vima-1) and three levels of planting density (200,000, 333,333 and 500,000 plants ha^{-1}) were evaluated at two soil fertility managements (with and without fertilization). The treatments were arranged in split plot design and replicated three times. The results of the research revealed that, highest harvest index (37%) was recorded from both planting density 200,000 and 333,333 ha^{-1} whereas the minimum (35%) harvest index was recorded from planting density 500,000 ha^{-1}.

Foysalkabir *et al*. (2016) carried out a field experiment to find out the effect of plant growth regulator (NAA) and row spacing 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*., 20 cm × 10 cm, 30 cm × 10 cm and 40 cm × 10 cm. The results indicated that, the maximum harvest index (55.71 %) was obtained 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.

A field trial was conducted by Rasul *et al.* (2012) to establish the proper inter-row spacing and suitable variety evaluation in Faisalabad, Pakistan. Three mungbean varieties V_1, V_2, V_3 (NM-92, NM-98, and M-1) were grown at three inter-row spacing (S_1-30 cm, S_2- 60 cm and S_3- 90 cm) respectively. Experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement randomizing varieties in the main and inter-row spacing in the sub-plots. The results revealed that, the inter-row spacing of plants did not significantly affect the harvest index.

An experiment was carried out by Kabir and Sarkar (2008) to study the effect of variety and planting density on the yield of mungbean in *Kharif*-I season (February to June) of 2003. The experiment comprised five varieties viz. BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and Binamoog-2 and three spacing of planting viz. 30 cm × 10 cm, 20 cm × 20 cm and 40 cm × 30 cm. The experiment was laid out in a randomized complete block design with three replications. It was observed that, the highest harvest index (29.28%) was found at 20 cm × 20 cm spacing and the lowest harvest index (28.16%) was found at 40 cm × 30 cm spacing.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to investigate the influence of nitrogen levels and planting density on growth and yield of mungbean. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Site and soil

Geographically the experimental field was located at 23° 77' N latitude and 90° 33' E longitudes at an altitude of 9 m above the mean sea level. The soil belonged to the Agro-ecological Zone - Modhupur Tract (AEZ -28) (Appendix-I). The land topography was medium high and soil texture was silty clay with pH 6.1.

3.1.2 Climate and weather

The climate of the locality is subtropical, which is characterized by high temperature and heavy rainfall during kharif season (April-September) and scanty rainfall during rabi season (October-March) associated with moderately low temperature.

3.2 Plant materials

BARI Mung-6 was used as planting material. BARI Mung-6 was released and developed by Bangladesh Agricultural Research Institute (BARI) in 2003. Plant height of the cultivar ranges from 40 to 45 cm. It is resistant to *Cercospora* leaf spot and tolerant to yellow mosaic virus. Its life cycle is about 55 to 60 days after emergence. One of the main characteristics of this cultivar is synchronization of pod ripening. Average yield of this cultivar is about 1.5-1.6 t ha^{-1}. The seeds of BARI Mung-6 for the experiment were collected from BARI, Joydepur, Gazipur. The seeds were drum-shaped, dull and greenish and free from mixture of other seeds, weed seeds and extraneous materials.

3.3 Treatments under investigation

There were two factors in the experiment namely nitrogen level and planting density as mentioned below:

A. Factor-1: Nitrogen level (3):

a) N_0= 0 kg N ha^{-1}(Control)
b) N_1= 20 kg N ha^{-1}
c) N_2= 40 kg N ha^{-1}

B. Factor-2: Planting density (4):

a) P_1= 15 plants m^{-2}
b) P_2= 30 plants m^{-2}
c) P_3 = 45 plants m^{-2}
d) P_4= 60 plants m^{-2}

Treatment combination: Twelve treatment combinations

N_0P_1	N_1P_1	N_2P_1
N_0P_2	N_1P_2	N_2P_2
N_0P_3	N_1P_3	N_2P_3
N_0P_4	N_1P_4	N_2P_4

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. Nitrogen level placed in the main plot whereas planting density in the sub plot. There were 12 treatment combinations and 36 unit plots. The unit plot size was 10.5 m^2 (5 m × 2.1 m). The main plot and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.5 Land preparation

The experimental land was opened with a power tiller on 22 March, 2015. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on 28 March, 2015 and was ready for sowing seeds.

3.6 Fertilizer application

The recommended chemical fertilizer dose was 100, 55 and 1 kg ha^{-1} of TSP, MOP and BA respectively (Hussain *et al.,* 2006). All the fertilizers were applied by broadcasting and were mixed with soil thoroughly at the time of final land preparation after making plot.

3.7 Description of nitrogen management

The nitrogen fertilizer (urea) dose was as per treatment and applied as basal dose by broadcasting and mixed with soil thoroughly.

3.8 Sowing of seeds

Seeds were sown at the rate of 20, 40, 60 and 80 g seeds $plot^{-1}$ in the furrow on 29 March, 2015 for maintaining 15, 30, 45 and 60 plants m^{-2}, respectively and the furrows were covered with the soils soon after seeding. Row to row distance was 30 cm and in rows seed to seed distance was maintained as per treatment.

3.9 Intercultural operations

3.9.1 Mulching

A natural mulching was done with breaking down the top soil on 12 April, 2015 which was 15 days after sowing.

3.9.2 Thinning

Thinning was done maintaining 20, 15, 10 and 5 cm plant to plant distance in row for getting desired planting density for P_1, P_2, P_3 and P_4 treatment, respectively.

3.9.3 Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done on 17 April, 2015 which was 20 days after sowing followed by second weeding on 27 April, 2015, which was 30 days after sowing.

3.9.4 Application of irrigation water

Irrigation water was added to thrice each plot, first irrigation was done as pre sowing and other two were given at 30 DAS and 45 DAS, respectively.

3.9.5 Plant protection measures

The crop was infested by insects, which were effectively and timely controlled by applying insecticides Diazinon 50 EC @ 2 ml L^{-1} two times with one week interval.

3.10 Harvesting and sampling

The harvesting was done by picking pods from central three lines for avoiding the boarder effects. The pod was harvested plot wise two times when about 80% of the pods became mature at 60 DAS and 68 DAS. The collected pods were sun dried, threshed and weighted to a control moisture level. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.11 Threshing

The pod was sun dried for three days by placing them on the open threshing floor. Seeds were separated from the pods by beating with bamboo sticks.

3.12 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.13 Recording of data

The data were recorded on the following parameters during the experimentation.

A. Crop growth characters

a. Seedling emergence (no. m^{-2})
b. Plant height (cm)
c. Number of leaves plant $^{-1}$
d. Dry matter content $plant^{-1}$ (g)
e. Number of nodules $plant^{-1}$
f. Dry weight of nodules $plant^{-1}$ (mg)
g. Days required to 1^{st} flowering
h. Days required to 50% flowering

B. Yield and other crop characters

a. Number of branches $plant^{-1}$
b. Number of pods $plant^{-1}$ at 1^{st} harvest
c. Number of pods $plant^{-1}$ at last harvest
d. Number of total pods $plant^{-1}$
e. Number of seeds pod^{-1} at 1^{st} harvest
f. Number of seeds pod^{-1} at last harvest
g. Pod length at 1^{st} harvest (cm)
h. Pod length at last harvest (cm)
i. 1000-seed weight at 1^{st} harvest (g)
j. 1000-seed weight at last harvest (g)
k. Shelling percentage (%)
l. Seed yield (t ha^{-1})
m. Stover yield (t ha^{-1})
n. Biological yield (t ha^{-1})
o. Harvest index (%)

3.14 Procedure of recording data

3.14.1 Crop growth characters

i. Seedling emergence (no. m^{-2})

1 m^2 area was selected from each plot where emerged plants were counted at 8 DAS.

ii. Plant height (cm)

Plant height of five randomly selected plants from each plot was measured at15, 30, 45 days after sowing (DAS) and at harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf of main shoot.

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

Number of leaves of five selected plants from each plot was counted at 15, 30, 45 DAS and at harvest. The number of leaves $plant^{-1}$ was counted from five randomly sampled plants. It was done by counting total number of leaves of all sampled plants then the average data were recorded.

iv. Dry matter content $plant^{-1}$ (g)

Five plants beyond the harvest area were collected randomly from each plot at 15, 30, 45, DAS and at harvest. The sample plants were oven dried for 24 hours at 70°C and then dry matter content $plant^{-1}$ was determined.

v. Number of nodules $plant^{-1}$

The randomly selected 5 plants $plot^{-1}$ outside the harvest area was uprooted carefully using Nirani along with sufficient surrounding soils at 35 DAS and washed; the total number of nodules were counted and the mean value determined.

vi. Nodule dry weight $plant^{-1}$

The collected nodules from five randomly selected plants of each plot were oven dried for 24 hours at 70°C and then nodule dry weight $plant^{-1}$ was determined.

vii. Days required to 1st flowering

The days required to 1st flowering were recorded and calculated as the number of days required from sowing to 1st flower initiation of plants from each plot.

viii. Days required to 50% flowering

The days required to 50% flowering were recorded and calculated as the number of days required sowing to 50% flower initiation of plants from each plot.

3.14.2 Yield and other crop characters

i. Number of branches plant^{-1}

The number of branches was counted at 30, 45 DAS and at harvest. The branches plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants then the average data were recorded.

ii. Number of pods plant^{-1} at 1st and last harvest

The number of pods plant^{-1} at 1st harvest was counted from the 5 randomly selected plant sample and then the average pod number was calculated. Similar procedure was followed for counting number of pods plant^{-1} at last harvest.

iii. Number of total pods plant^{-1}

Summation of number of pods at 1st and last harvest was done and the data was recorded.

iv. Number of seeds pod^{-1} at 1st and last harvest

The number of seeds pod^{-1} at 1st harvest was counted from 10 randomly selected pods of each plot and then the average seed number was calculated. Similar procedure was followed for counting number of seeds pod^{-1} at last harvest.

v. Pod length at 1st and last harvest (cm)

The length of pod at 1st harvest was measured by meter scale from 10 randomly selected pods of each plot at 1st harvesting time and then the average seed number was calculated. Similar procedure was followed for measuring pod length at last harvest.

vi. 1000 seed weight at 1st and last harvest (g)

The 1000 seeds were counted, which were taken from the seeds sample of each plot separately during 1st harvest, then weighed in an electrical balance and data were recorded in gram. Similar procedure was followed for measuring 1000 seed weight at last harvest.

vii. Shelling percentage (%)

The pods of one m^{-2} area $plot^{-1}$ were taken and shelling percentage was calculated by using the following formula:

$$\text{Shelling percentage} = \frac{\text{Grain weight}}{\text{Pod weight}} \times 100$$

viii. Seed yield ($t\ ha^{-1}$)

Seed yield was recorded on the basis of total harvested seeds $plot^{-1}$ (at 1st harvest + last harvest) and was expressed in terms of yield ($t\ ha^{-1}$). Seed yield was adjusted to 12% moisture content.

ix. Stover yield ($t\ ha^{-1}$)

After separation of seeds from plant, the straw and shell of harvested area was sun dried and the weight was recorded and then converted into $t\ ha^{-1}$.

x. Biological yield ($t\ ha^{-1}$)

The summation of seed yield and above ground stover yield was the biological yield. Biological yield = Seed yield + Stover yield.

xi. Harvest index (%)

Harvest index was calculated on dry basis with the help of following formula:

Harvest index (HI %) $= \frac{Seed\ yield}{Biological\ yield} \times 100$

Here, Biological yield = Seed yield + stover yield

3.15 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjudged by Least Significance Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

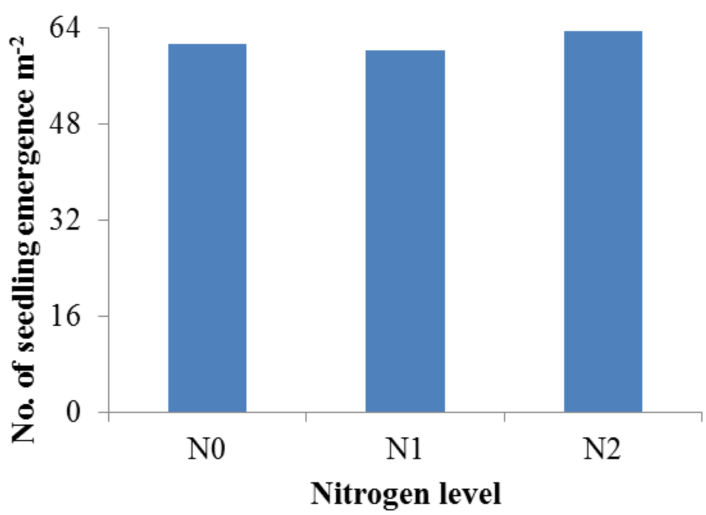
Results obtained from the present study regarding the effects of nitrogen level and planting density on the yield and yield components of mungbean have been presented, discussed and compared in this chapter. The analytical results have been presented in table 1 through table 9, figure 1 through figure 46.

4.1 Crop growth characters

4.1.1 Seedling emergence (No. m^{-2})

4.1.1.1 Effect of nitrogen levels

The seedling emergence of mungbean was not influenced by nitrogen level (Figure 1). The result revealed that, the N_2 gave the maximum number of seedling emergence (63.33) whereas N_1 gave the minimum number of seedling emergence (60.17).

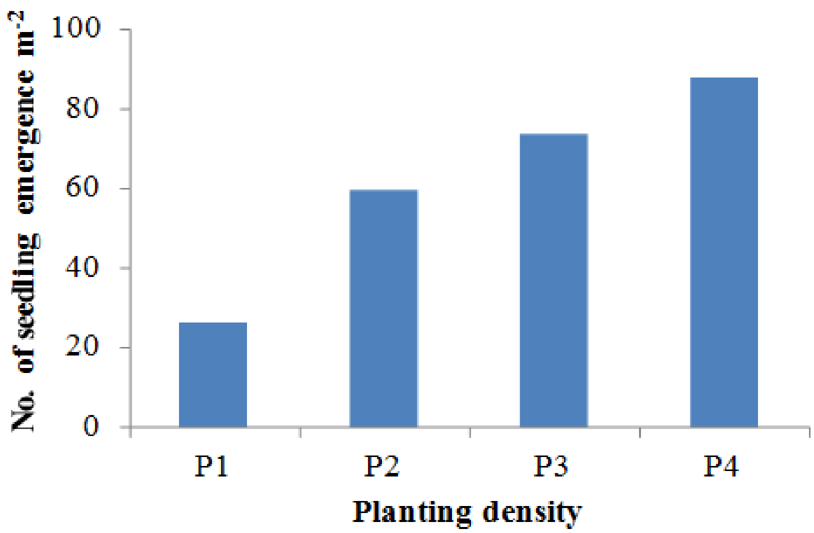


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 1. Effect of nitrogen levels on seedling emergence m^{-2} of mungbean (LSD $_{(0.05)}$ = NS)

4.1.1.2 Effect of planting density

Planting density had significant effect on seedling emergence (Figure 2). The highest number of seedling emergence (87.44) was obtained from treatment P_4 whereas the lowest seedling emergence (26.22) was obtained from P_1 treatment.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 2. Effect of planting density on seedling emergence m^{-2} of mungbean (LSD $_{(0.05)}$ = 5.70)

4.1.1.3 Interaction effect of nitrogen levels and planting density

Significant interaction effect between the nitrogen level and planting density was observed in seedling emergence (Table 1). The highest number of seedling emergence (96.33) was obtained from the N_0P_4 combination. The lowest number of seedling emergence (22.33) was given by treatment combination of N_1P_1 which was statistically similar with treatment combinations of N_0P_1 and N_2P_1. The emerged seedling number m^{-2} of N_0P_4 was 331.39% higher compared to that of N_1P_1 combination.

Table 1. Interaction effect of nitrogen levels and planting density on seedling emergence of mungbean

Treatment combination	Seedling emergence (No. m^{-2})
N_0P_1	27.67 e
N_0P_2	57.67 d
N_0P_3	63.67 d
N_0P_4	96.33 a
N_1P_1	22.33 e
N_1P_2	60.00 d
N_1P_3	73.00 c
N_1P_4	85.33 b
N_2P_1	28.67 e
N_2P_2	60.67 d
N_2P_3	83.33 b
N_2P_4	80.67 bc
LSD (0.05)	**9.87**
CV (%)	**9.34**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

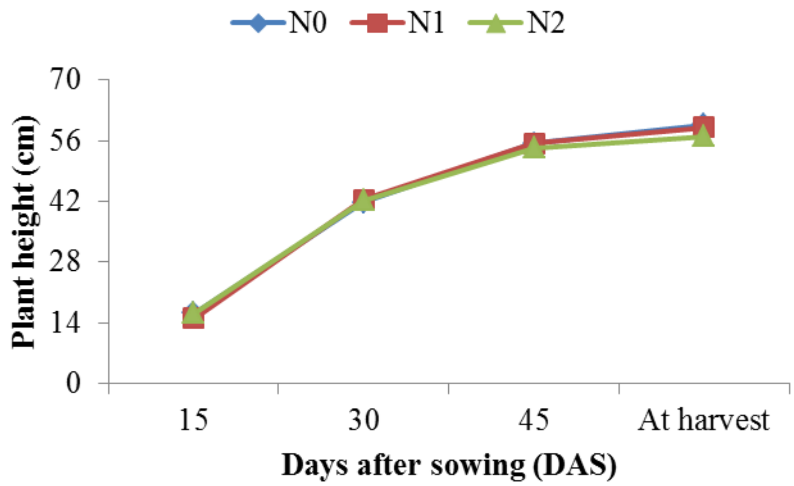
4.1.2 Plant height (cm)

4.1.2.1 Effect of nitrogen levels

The plant height of mungbean was significantly influenced by nitrogen levels only at 15 DAS and but it was insignificant at 30, 45 DAS and at harvest (Figure 3).

The result of the experiment revealed that at 15 DAS, the N_2 produced the taller plant (16.25 cm) which was statistically similar with N_0 and the N_1 gave the shorter plant (15.07 cm). At 30, 45 DAS and at harvest no significant variation of plant height observed for different nitrogen levels through numerically the tall plant height (42.30 cm, 55.35 cm and 59.61 cm at 30, 45 DAS and at harvest, respectively) was found from N_1,

N_1 and N_0 treatments, respectively and lower plant height (41.82, 54.26 and 57.03 cm at 30, 45 DAS and at harvest, respectively) was found from N_0, N_2 and N_2 treatments. The result might be due to enough nitrogen supply by symbiosis process. As mungbean is a legume crop, they have the capability to fix nitrogen with nodule through *Rhizobium* symbiosis process. So, supplementary nitrogen did not signify the plant height of mungbean plant. But this result is not similar with the results of Bozorgi *et al.* (2011); Law-Ogbomo and Egharevb (2009); Rahim *et al.* (2008); Sirohi and Kumar (2006) and Ashraf *et al.* (2003), who reported that plant height, being a genetically controlled character, varied in response to various doses of added nitrogen fertilizer. Sawwar *et al*. (1989) also reported that increase in plant height of mungbean at higher nitrogen levels may be ascribed to increase of N in chlorophyll which increased photosynthesis and enhanced meristimatic activity of plant. Besides, nitrogen is essential component of amino acids which are vital building blocks for development of tissues and consequently increased plant height. Similar results were also reported by Razzaque *et al.* (2015); Mainul *et al.* (2014); Bozorgi *et al.* (2011); Law-Ogbomo and Egharevb (2009); Sultana *et al*. (2009); Rahim *et al.* (2008); Sirohi and Kumar (2006); Ashraf *et al.* (2003) and Taj (1996) in mungbean; Rahman *et al*. (1992) in French bean at higher level of nitrogen (120 kg ha^{-1}).

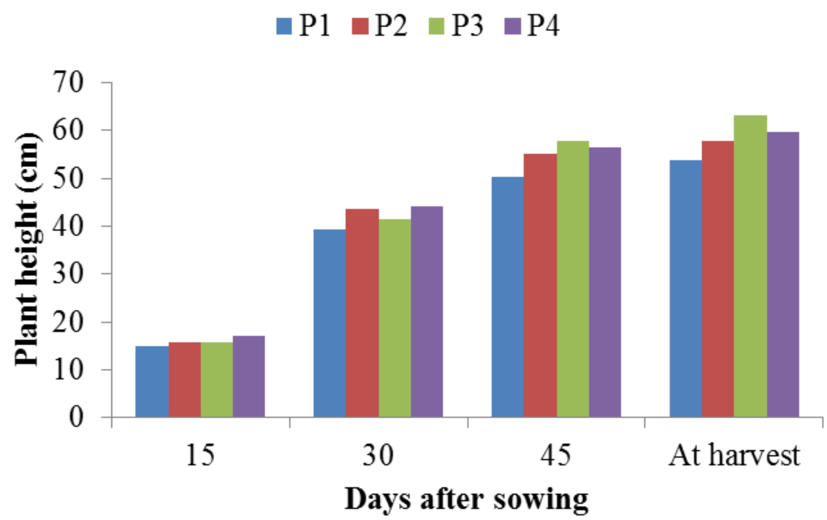


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 3. Effect of nitrogen levels on plant height of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.89, NS, NS and NS at 15, 30, 45 DAS and at harvest, respectively)

4.1.2.2 Effect of planting density

Planting density showed significant variation on plant height throughout the growing season (Figure 4). The tallest plant (17.18, 44.09 cm at 15, 30 DAS, respectively) was obtained from P_4 which was statistically similar with P_3 at 15 DAS, P_3 and P_2 at 45 DAS. At 45 DAS and at harvest, the tallest plant (57.94 and 63.08 cm) was obtained in P_3 treatment which was statistically similar with P_4 and P_2 at 45 DAS, P_4 at harvest and shortest plant height (14.80, 39.24, 50.43 and 53.85 cm at 15, 30, 45 DAS and at harvest, respectively) was consistently obtained from P_1 which was statistically similar with P_2 and P_3 at 15 DAS, P_3 at 30 DAS. Similar results with higher population densities was also reported by Taufiq and Kristino (2016). This result was dissimilar with the result of Rana *et al*. (2011) who reported that wider plant spacing gave the tallest plant than the narrower spacing. Rasul *et al.* (2012) also reported that inter row spacing affected the plant height significantly. Lower planting density produced maximum plant height because of plant enjoying of full benefit of available resources and sunlight as compared to dense population. Almost similar results were reported by Kabir and Sarkar (2008); Maqsood *et al.* (1999).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 4. Effect of planting density on plant height of mungbean at different days after sowing (LSD $_{(0.05)}$ = 1.55, 3.11, 3.17 and 3.67 at 15, 30, 45 DAS and at harvest, respectively)

4.1.2.3 Interaction effect of nitrogen levels and planting density

Significant interaction effect between the nitrogen level and planting density was observed at 15, 30, 45 DAS and at harvest in plant height (Table 2). At 15 DAS, the tallest plant was obtained from the N_2P_4 combination (18.60 cm) which was statistically similar with N_0P_4, N_0P_2, N_0P_3 and N_2P_3. The shortest plant height (13.86 cm) was found in N_1P_1 which was statistically similar with all the interactions except N_0P_4 and N_2P_4 treatment combinations. At 30 DAS, the tallest plant (46.23 cm) was obtained from the combination of N_2P_4 which was statistically similar with all the interaction except N_2P_3, N_2P_1, N_1P_1, N_0P_3 and N_0P_1. The shortest plant height (38.37, 49.48 and 51.94 cm at 30, 45 DAS and at harvest, respectively) was in N_2P_1 which was similar to N_0P_1, N_0P_3, N_1P_1, N_2P_3, N_2P_2, N_1P_4, N_1P_2 and N_0P_4 at 30 DAS, N_0P_1, N_2P_2 and N_1P_1 at 45 DAS, N_2P_2, N_1P_1, N_0P_1 and N_2P_4 at harvest, respectively. At 45 DAS, the tallest plant height was recorded from N_2P_3 interaction (60.52 cm) which was statistically similar with all the interactions except N_0P_1, N_1P_1, N_2P_1 and N_2P_2. At harvest, the tallest plant (64.44 cm) was obtained from the N_0P_3 interaction which was statistically similar with all the interactions except N_2P_1, N_2P_2, N_1P_1 and N_0P_1.

Table 2. Interaction effect of nitrogen level and planting density on plant height of mungbean at different days after sowing

Treatment combination	Days after sowing (DAS)			
	15	30	45	At harvest
N_0P_1	14.91 bc	39.93 bc	49.69 d	54.53 b-d
N_0P_2	16.44 a-c	43.85 ab	56.13 a-c	59.03 a-c
N_0P_3	16.00 a-c	39.75 bc	57.76 a	64.44 a
N_0P_4	17.49 ab	43.75 a-c	57.64 a	60.45 ab
N_1P_1	13.86 c	39.43 bc	52.11 b-d	55.07 b-d
N_1P_2	15.55 bc	43.50 a-c	57.54 ab	60.27 a-c
N_1P_3	15.45 bc	43.97 ab	55.54 a-c	60.83 ab
N_1P_4	15.43 bc	42.30 a-c	56.19 a-c	60.27 a-c
N_2P_1	15.62 bc	38.37 c	49.48 d	51.94 d
N_2P_2	14.83 bc	43.70 a-c	51.44 cd	54.05 cd
N_2P_3	15.94 a-c	40.37 bc	60.52 a	63.96 a
N_2P_4	18.60 a	46.23 a	55.59 a-c	58.17 a-d
$LSD_{(0.05)}$	**2.69**	**5.38**	**5.49**	**6.35**
CV (%)	**9.89**	**7.45**	**5.82**	**6.32**

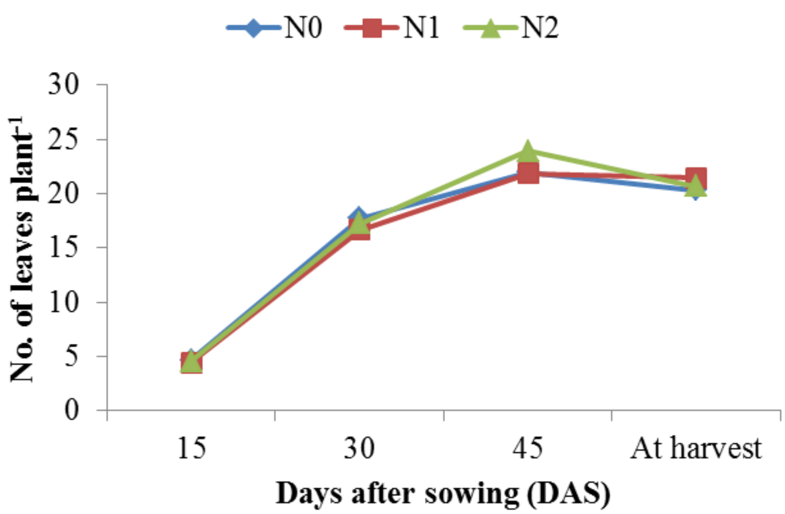
N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.1.3 Number of leaves plant^{-1} (No.)

4.1.3.1 Effect of nitrogen levels

The number of leaves plant^{-1} was not significantly influenced by the nitrogen levels throughout the growing period (Figure 5). Numerically the maximum number of leaves plant^{-1} (4.68, 17.70, 23.88 and 21.40 at 15, 30, 45 DAS and at harvest, respectively) were found in N_0, N_2 and N_1 treatments, respectively and the minimum number of leaves plant^{-}

[1] (4.45, 16.65 and 21.85 at 15, 30 and 45 DAS, respectively) was found in N_1 and 20.33 (at harvest) was found in N_0 treatment. This might be due to adequate nitrogen fixation by symbiosis process. Supplementary nitrogen did not affect the leaves number of mungbean plant. But this result was contradictory of the results of Mainul *et al.* (2014); Marti and Mills (1991) who explained that an adequate supply of N is associated with vigorous vegetative growth, thus plant produces maximum leaves.

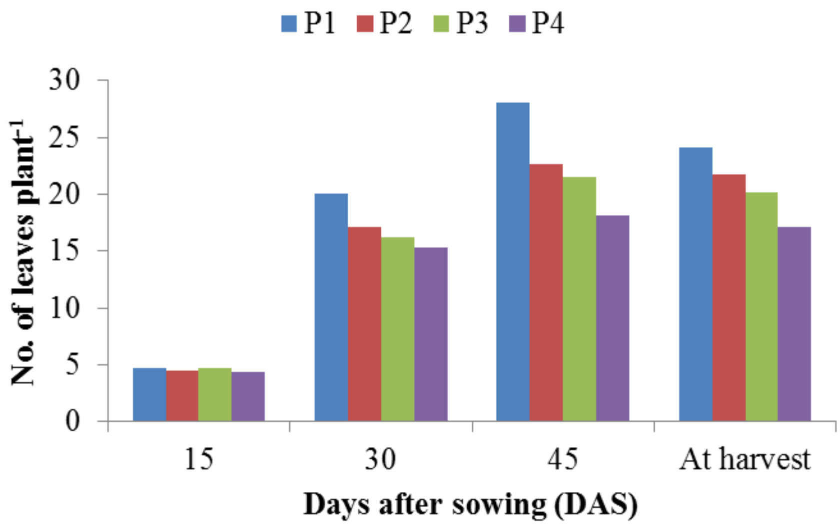


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 5. Effect of nitrogen levels on no. of leaves plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, NS, NS and NS at 15, 30, 45 DAS and at harvest, respectively**)**

4.1.3.2 Effect of planting density

The number of leaves plant^{-1} of mungbean was significantly influenced by the different planting density at 15, 30, 45 DAS and at harvest (Figure 6). At 15 DAS, the highest number of leaves plant^{-1} (4.71) was found in P_3 treatment which statistically similar with rest of the treatments except P_4 and P_4 produced the lowest number of leaves plant^{-1} (4.33) which was statistically similar with rest of the treatments except P_3. Treatment P_1 produced the highest number of leaves plant^{-1} (20.02, 28.02 and 24.11 at 30, 45 DAS and at harvest, respectively) and P_4 produced the lowest number of leaves plant^{-1} (15.33, 18.13 and 17.16 at 30, 45 DAS and at harvest, respectively). This result was coincided with the result of Rasul *et al.* (2012). The inter-row spacing also affected the leaves of mungbean which might be due to variable availability of light, nutrients, etc. in case of varying spacing. These results were in agreement with those of Khan (2000).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 6. Effect of planting density on no. of leaves plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.34, 0.95, 2.13 and 1.86 at 15, 30, 45 DAS and at harvest, respectively)

4.1.3.3 Interaction effect of nitrogen levels and planting density

Interaction effect of different levels of nitrogen and planting density had significant influence on leaves plant^{-1} at 15, 30 and 45 DAS and at harvest (Table 3). At 15 DAS, treatment combinations of N_0P_3 produced the highest number of leaves plant^{-1} (5.53) which was statistically similar with N_2P_1 and the lowest number of leaves plant^{-1} produced by N_1P_4 (4.00) which was statistically similar with N_2P_3, N_2P_2, N_0P_4, N_1P_3 and N_0P_1. At 30 DAS, N_0P_1 produced the highest number of leaves plant^{-1} (20.40) which was statistically similar with N_2P_1 and N_1P_1. At 45 DAS, N_2P_1 produced the highest number of leaves plant^{-1} (30.32) which was statistically similar with N_1P_1. At harvest, N_1P_1 produced the highest number of leaves plant^{-1} (26.60) which was statistically similar with N_2P_1. The N_0P_4 combination produced the lowest number of leaves plant^{-1} (15.00 and

16.67 at 30 DAS and at harvest, respectively) which was statistically similar with N_1P_4, N_2P_4, N_1P_2, N_2P_3 and N_1P_3 at 30 DAS, N_1P_4, N_2P_4 and N_2P_3 at harvest. At 45 DAS, the lowest number of leaves plant^{-1} (18.00) produced by N_2P_4 which was statistically similar with N_1P_4, N_0P_4, N_1P_3, N_1P_2 and N_0P_3.

Table 3. Interaction effect of nitrogen levels and planting density on number of leaves plant^{-1} of mungbean at different days after sowing

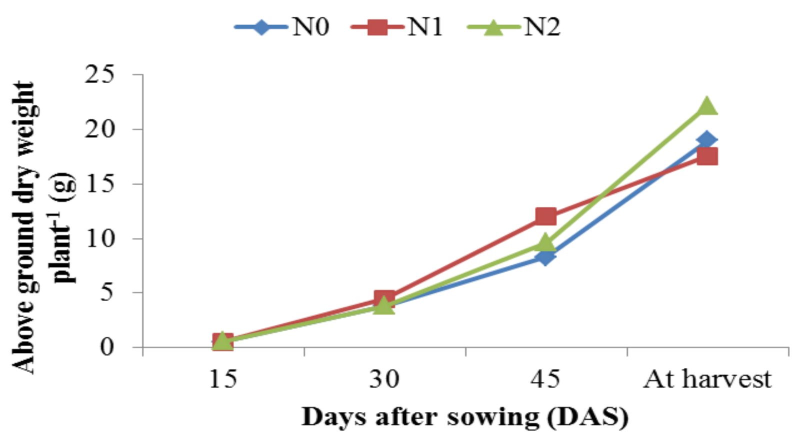
Treatment combination	Days after sowing (DAS)			
	15	30	45	At harvest
N_0P_1	4.40 c-e	20.40 a	25.73 bc	22.27 b-d
N_0P_2	4.60 b-d	18.40 bc	23.20 cd	21.33 b-d
N_0P_3	5.53 a	17.00 c-e	20.80 de	21.07 b-d
N_0P_4	4.20 de	15.00 f	18.20 e	16.67 f
N_1P_1	4.60 b-d	19.40 ab	28.00 ab	26.60 a
N_1P_2	4.80 bc	15.60 ef	20.80 de	21.07 b-d
N_1P_3	4.40 c-e	16.00 d-f	20.40 de	20.20 c-e
N_1P_4	4.00 e	15.60 ef	18.20 e	17.73 ef
N_2P_1	5.00 ab	20.25 a	30.32 a	23.47 ab
N_2P_2	4.20 de	17.40 cd	23.80 cd	22.80 bc
N_2P_3	4.20 de	15.80 d-f	23.40 cd	19.27 d-f
N_2P_4	4.80 bc	15.40 ef	18.00 e	17.07 ef
LSD $_{(0.05)}$	**0.58**	**1.65**	**3.69**	**3.21**
CV (%)	**7.48**	**5.59**	**9.53**	**9.01**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.1.4 Dry matter content plant^{-1} (g)

4.1.4.1 Effect of nitrogen levels

The nitrogen levels significantly influenced the total dry matter production at 30, 45 DAS and at harvest except 15 DAS (Figure 7). At 30 and 45 DAS, the highest dry weight plant^{-1} (4.48 and 12.02 g, respectively) was recorded from N_1. On the other hand, the lowest dry weight plant^{-1} (3.82 and 8.33 g at 30 and 45 DAS, respectively) was produced by N_2 and N_0, respectively. At harvest, the N_2 produced the highest dry weight plant^{-1} (22.17 g) which was 26.18% higher than the N_1 (17.57 g). Accumulation of higher dry weights for higher nitrogen treatment might be due to optimum N supply to the plant, which helps increased in both cell division and cell elongation and increased carbohydrate synthesis and hence the growth was excellent and produced more dry matter plant^{-1} (Mainul *et al.* 2014; Asaduzzaman *et al.*, 2008 and Karmer, 1988). This was in conformity with Sultana *et al.* (2009), who found that 20 kg N ha^{-1} significantly gave higher values for all growth parameters in mungbean that influenced the average dry weight of pulses.

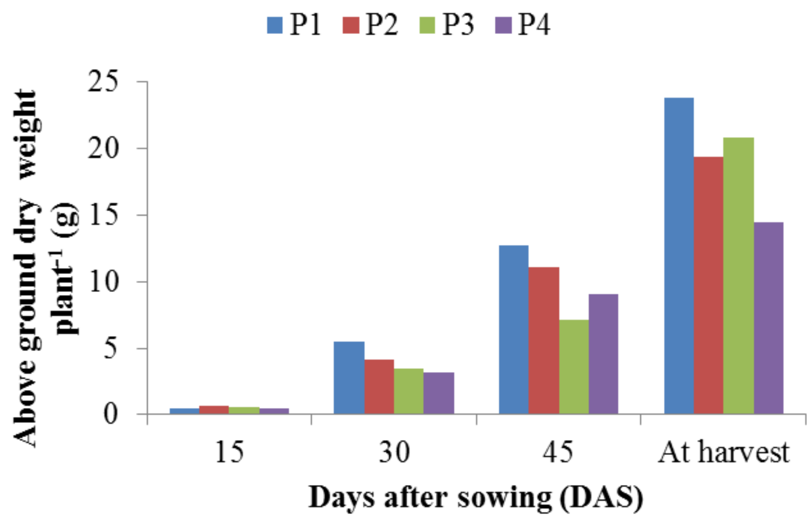


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 7. Effect of nitrogen levels on above ground dry weight plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, 0.39, 0.60 and 1.57at 15, 30, 45 DAS and at harvest, respectively)

4.1.4.2 Effect of planting density

The total dry weight of plant was significantly influenced by different levels of nitrogen at 15, 30, 45 DAS and at harvest (Figure 8). At 15 DAS, the highest dry weight plant^{-1} (0.62 g) was recorded in P_2 and the lowest dry weight plant^{-1} (0.51 g) was recorded in P_1 and P_4. At 30, 45 DAS and at harvest, the highest dry weight plant^{-1} (5.45, 12.74 and 23.78 g, respectively) was recorded in P_1 and the lowest dry weight plant^{-1} (3.13, 7.13 and 14.44 g, respectively) was recorded in P_4, P_3 and P_4, respectively which was statistically at par with P_3 at 30 DAS. Due to lower number of plants per unit area in lower population levels, there was less intra plant competition for nutrient, moisture, light and other resources, so they got chance to grow vigorously and accumulate more dry matter. This was in conformity with Rana *et al*. (2011); Kabir and Sarkar (2008); Trung and Yoshida (1985).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 8. Effect of planting density on above ground dry weight plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 39.54, 0.32, 0.73 and 1.73 at 15, 30, 45 DAS and at harvest, respectively)

4.1.4.3 Interaction effect of nitrogen levels and planting density

Interaction effect of nitrogen levels and planting density influenced the dry matter production plant^{-1} of mungbean at 15, 30, 45 DAS and at harvest (Table 4). At 15 DAS, the highest dry weight plant^{-1} (0.87 g) was observed in the N_0P_2 interaction and the lowest dry weight plant^{-1} (0.33 g) was observed in the N_0 with the interaction of P_1 which was statistically similar with N_0P_3. However, the highest dry weight plant^{-1} (6.40 and 14.80 g at 30 and 45 DAS, respectively) was obtained from the N_1P_1 interaction which was statistically similar with N_1P_2 and the lowest dry weight plant^{-1} (2.93 and 5.47 g at 30 and 45 DAS, respectively) was observed in the N_0P_3 interaction which was statistically similar with N_0P_2 and N_0P_4 at 30 DAS only. Again at harvest, the N_2 with the interaction of P_1 produced the highest dry weight plant^{-1} (28.67 g) whereas, the lowest dry weight plant^{-1} was produced by the N_0 with the interaction of P_4 (13.67 g) which was statistically similar with N_2P_4 and N_1P_4.

Table 4. Interaction effect of nitrogen levels and planting density on dry matter weight plant^{-1} of mungbean at different days after sowing

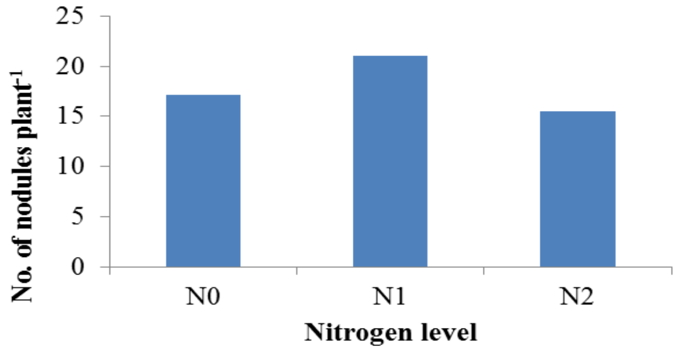
Treatment combination	Days after sowing (DAS)			
	15	**30**	**45**	**At harvest**
N_0P_1	0.33 f	5.80 b	10.33 c	24.00 b
N_0P_2	0.87 a	3.47 efg	9.00 de	17.33 ef
N_0P_3	0.40 ef	2.93 g	5.47 g	21.00 cd
N_0P_4	0.53 cd	3.13 fg	8.53 ef	13.67 g
N_1P_1	0.67 b	6.40 a	14.80 a	18.67 de
N_1P_2	0.47 de	4.97 c	14.40 a	18.00 ef
N_1P_3	0.60 bc	3.53 ef	8.27 ef	18.33 de
N_1P_4	0.47 de	3.00 fg	10.60 c	15.33 fg
N_2P_1	0.53 cd	4.15 d	13.10 b	28.67 a
N_2P_2	0.53 cd	4.00 de	9.80 cd	22.67 bc
N_2P_3	0.67 b	3.87 de	7.67 f	23.00 bc
N_2P_4	0.53 cd	3.27 fg	7.93 ef	14.33 g
LSD $_{(0.05)}$	**68.48**	**0.56**	**1.26**	**3.00**
CV (%)	**7.26**	**8.11**	**7.33**	**8.93**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.1.5 Number of nodules plant^{-1}

4.1.5.1 Effect of nitrogen levels

The number of nodules plant^{-1} was significantly influenced by nitrogen levels of mungbean (Figure 9). The N_1 produced the highest total number of nodules plant^{-1} (21.07) and the N_2 gave the lowest number of nodules plant^{-1} (15.53) which was statistically similar with N_0.

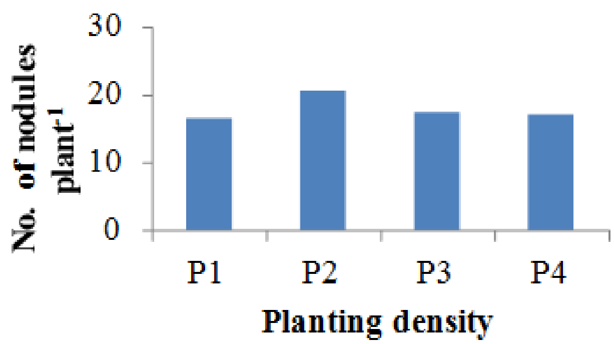


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 9. Effect of nitrogen levels on no. of nodules plant^{-1} of mungbean (LSD $_{(0.05)}$ = 2.41)

4.1.5.2 Effect of planting density

The different planting density had highly significant effect in formation of number of nodules plant^{-1} (Figure 10). The highest number of nodules plant^{-1} (20.53) was produced by P_2 and the lowest number of nodules plant^{-1} was produced by P_0 (16.53) which was statistically similar to all the treatments except P_2. This was disagreed with Rasul *et al.* (2012) who reported that planting density did not significantly affect the number of nodules plant^{-1}.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 10. Effect of planting density on no. of nodules plant^{-1} of mungbean (LSD $_{(0.05)}$ = 1.17)

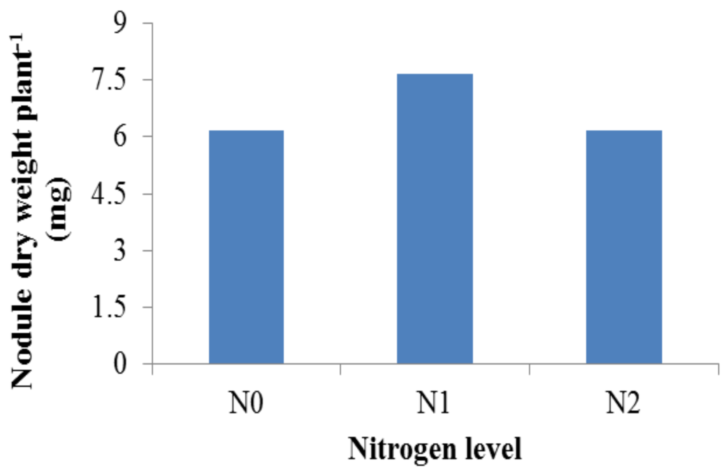
4.1.5.3 Interaction effect of nitrogen levels and planting density

Significant interaction effect between the nitrogen levels and planting density was observed on total number of nodules produced plant^{-1} (Table 5). The highest number of nodules was produced from the N_1 with P_4 (9.8 plant^{-1}) which was statistically similar with the interaction of N_2P_2 (22.80 plant^{-1}). The lowest number of nodule was produced in N_2P_4 (7.87 plant^{-1}).

4.1.6 Dry weight of nodules plant^{-1} (mg)

4.1.6.1 Effect of nitrogen levels

The dry weight of nodule plant^{-1} had significant effect for nitrogen levels (Figure 11). The N_2 produced the highest dry weight of nodules (7.67 mg plant^{-1}) and the N_0 and N_2 gave the lowest weight (6.17 mg plant^{-1}).

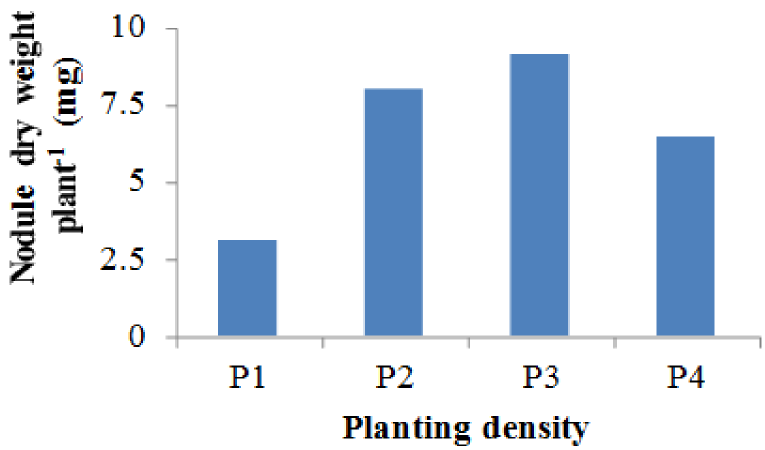


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 11. Effect of nitrogen levels on nodule dry weight plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.56)

4.1.6.2 Effect of planting density

Planting density had significant effect on dry weight of nodules plant^{-1} (Figure 12). The highest dry weight of nodules (9.11 mg plant^{-1}) was produced by P_3 and the lowest dry weight of nodules (3.11 mg plant^{-1}) was produced by P_1. Rest of the treatment gave the intermediate result.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 12. Effect of planting density on nodule dry weight plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.71)

4.1.6.3 Interaction effect of nitrogen levels and planting density

Significant interaction effect between the nitrogen levels and planting density was observed for dry weight of nodules produced plant^{-1} (Table 5). The highest dry weight of nodules (11.33 mg plant^{-1}) was obtained from the both N_2P_2 and N_1P_3 interactions which were statistically similar with the interaction of N_1P_4. The lowest dry weight of nodule was produced in both N_1P_1 and N_2P_4 (2.00 mg plant^{-1}).

Table 5. Interaction effect of nitrogen levels and planting density on number of nodules plant^{-1} and nodule wry weight plant^{-1} of mungbean

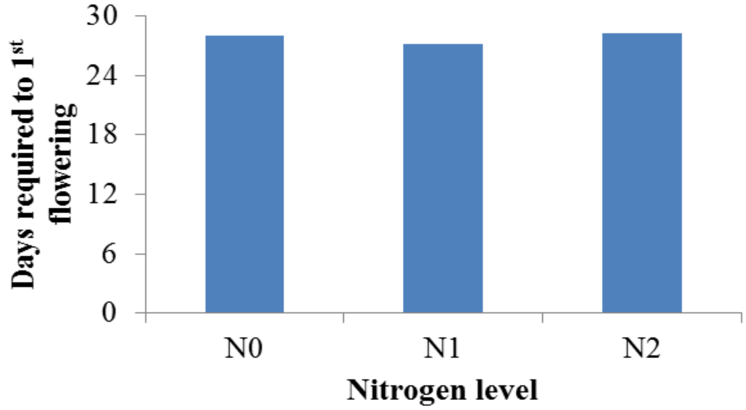
Treatment combination	Number of nodules plant^{-1}	Nodule dry weight plant^{-1} (mg)
N_0P_1	14.67 d	4.00 d
N_0P_2	17.00 c	6.00 c
N_0P_3	18.13 c	8.00 b
N_0P_4	18.60 c	6.67 c
N_1P_1	16.87 c	2.00 e
N_1P_2	21.80 b	6.67 c
N_1P_3	20.80 b	11.33 a
N_1P_4	24.80 a	10.67 a
N_2P_1	18.07 c	3.33 d
N_2P_2	22.80 ab	11.33 a
N_2P_3	13.40 d	8.00 b
N_2P_4	7.867 e	2.00 e
LSD $_{(0.05)}$	**2.03**	**1.22**
CV (%)	**6.62**	**10.69**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.1.7 Days to 1st flowering

4.1.7.1 Effect of nitrogen levels

Days to 1st flowering were not significantly influenced for nitrogen levels of mungbean (Figure 13). The maximum days required to 1st flowering (28.17) was in N_2 and the minimum days required to 1st flowering (27.08) in N_1.

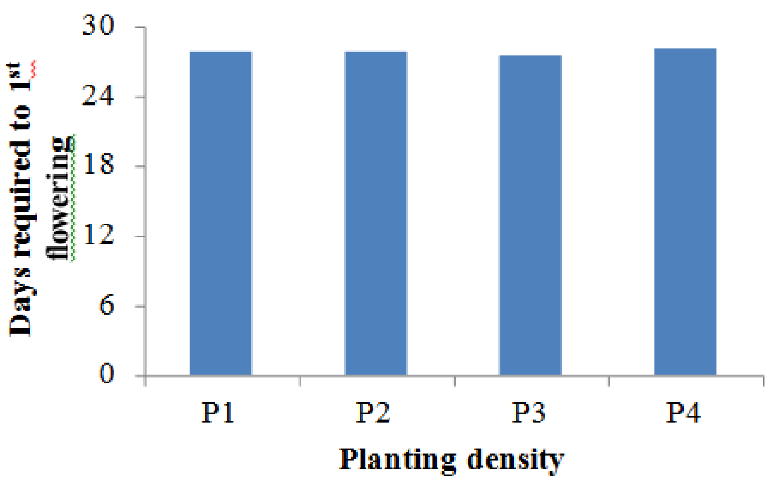


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 13. Effect of nitrogen levels on days required to 1st flowering of mungbean (LSD $_{(0.05)}$ = NS)

4.1.7.2 Effect of planting density

Planting density had no significant effect on days required to 1st flowering (Figure 14). The maximum days required to 1st flowering (28.00) was by P_4 and the minimum days required to 1st flowering (27.44) was in P_3.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 14. Effect of planting density on days required to 1st flowering of mungbean (LSD $_{(0.05)}$ = NS)

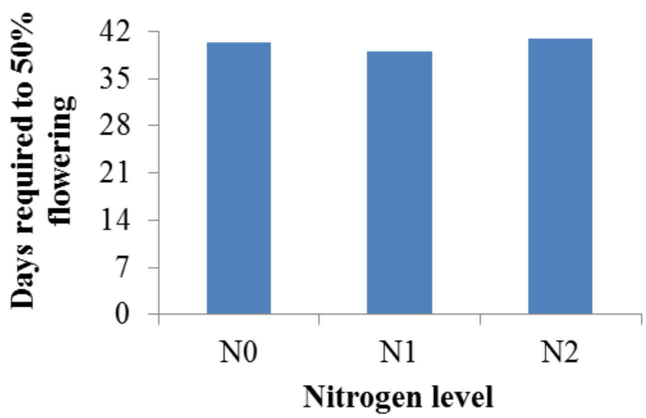
4.1.7.3 Interaction effect of nitrogen levels and planting density

Significant interaction effect between the nitrogen levels and planting density was observed on days required to 1st flowering (Table 7). The highest days required to 1st flowering (28.67) was obtained from the N_0P_1 and N_2P_2 interactions which were statistically similar with all the interactions except of N_0P_3, N_1P_1, N_1P_2 and N_1P_3. The lowest days required to 1st flowering (26.33) were in N_1P_2 which were statistically similar with N_1P_1, N_0P_3 and N_1P_3.

4.1.8 Days required to 50% flowering

4.1.8.1 Effect of nitrogen levels

Days required to 50% flowering were not significantly influenced for nitrogen levels of mungbean (Figure 15). The maximum days required to 50% flowering (40.83) was by N_2 and N_0 and the minimum days required to 50% flowering (39) was by N_1.

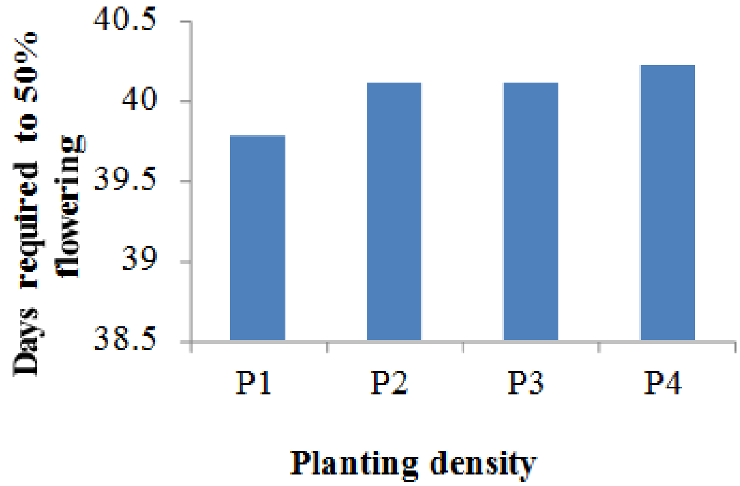


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 15. Effect of nitrogen levels on days required to 50% flowering of mungbean (LSD $_{(0.05)}$ = NS)

4.1.8.2 Effect of planting density

Planting density had no significant effect on days required to 50% flowering (Figure 16). The maximum days required to 50% flowering (40.22) was by P_4 and the minimum days required to 50% flowering (39.78) was in P_1. This result was in line with the observation of Kebede *et al*. (2015) who reported that plant spacing had no significant effect on days to 50% flowering in common bean. Similar result also reported by Blackshaw *et al*. (2000).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 16. Effect of planting density on days required to 50% flowering of mungbean (LSD $_{(0.05)}$ = NS)

4.1.8.3 Interaction effect of nitrogen levels and planting density

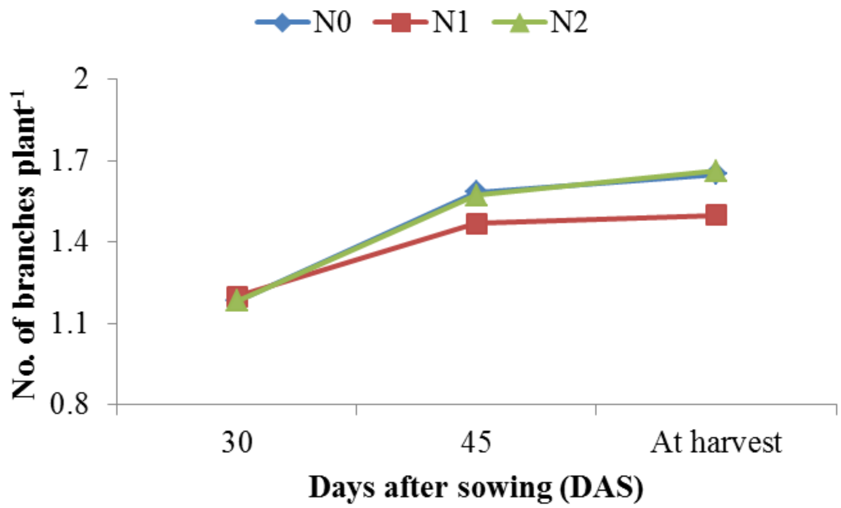
Significant interaction effect between the nitrogen levels and planting density was observed for days required to 50% flowering (Table 7). The maximum days required to 50% flowering (41.33) was obtained from the N_2P_4 interaction which was statistically similar with all the interactions except of N_1P_1, N_1P_2, N_1P_3 and N_1P_4. The minimum days required to 50% flowering (38.67) were in N_1P_1 which were statistically similar with N_1P_2, N_1P_4, N_1P_3, N_2P_1, N_0P_4, N_0P_3 and N_0P_1.

4.2 Yield and yield contributing characters

4.2.1 Number of branches plant^{-1}

4.2.1.1 Effect of nitrogen levels

The number of branches plant^{-1} was not significantly influenced by nitrogen levels (Figure 17). Results showed that, the N_1 produced maximum number of branches plant^{-1} (1.20) whereas the minimum branches plant^{-1} was obtained from N_0 and N_2 (1.18) at 30 DAS. At 45 DAS and at harvest, maximum number of branches plant^{-1} (1.58 and 1.66) produced by N_0 and N_2, respectively. The N_1 produced minimum number of branches plant^{-1} (1.47 and 1.50 at 45 DAS and at harvest, respectively). These findings were not in line with Ayub *et al.,* (2010) who stated that application of nitrogen significantly increased the forage yield of cluster bean varieties, and maximum yield of 63.70 kg ha^{-1} recorded at 50 kg N ha^{-1}. According to them, such an increase in yield was mainly attributed to greater number of branches, leaves, leaf area plant^{-1}, and plant height. Mainul *et al.* (2014) also reported that, number of branches plant^{-1} increased with the increasing rate of nitrogen fertilizer. Eman *et al.* (2013) and Sultana *et al*. (2009) found similar results while experimenting with mungbean. Nitrogenous fertilizers are the key factors for increasing the number of branches plant^{-1}. This can be justifies that increasing nitrogen can increase factors such as root growth, increased leaf area, increasing the number of leaves and at last vegetative growth and uses of environmental factors would be better.

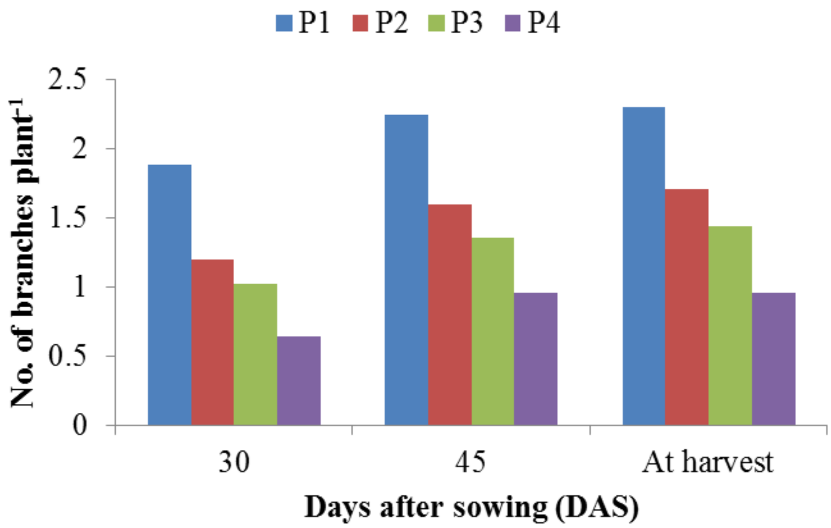


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 17. Effect of nitrogen levels on no. of branches plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = NS, NS and NS at 30, 45 DAS and at harvest, respectively)

4.2.1.2 Effect of planting density

Different planting density significantly influenced the number of branches plant^{-1} (Figure 18). The maximum number of branches plant^{-1} (1.89, 2.25 and 2.31 at 30, 45 DAS and at harvest, respectively) were obtained from the $P_{1.}$ On the other hand the lowest number of branches plant^{-1} (0.64, 0.96 and 0.96 at 30, 45 DAS and at harvest, respectively) were obtained from P_4. Wider plant spacing might be helpful for plant producing more branches as they get favorable condition for getting adequate light, water and nutrient for healthy growth. Similar result also found by Rasul *et al.* (2012); Khan (2000); Zaidi (1998) and Waheed (1996) who reported that the inter-row spacing also affected the fruit bearing branches, which might be due to variable availability of light, nutrients, etc. in case of varying spacing.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 18. Effect of planting density on no. of branches plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.11, 0.13 and 0.15 at 30, 45 DAS and at harvest, respectively)

4.2.1.3 Interaction effect of nitrogen levels and planting density

The number of branches plant^{-1} was significantly influenced by the interaction effect of nitrogen levels and planting density (Table 6). The highest number of branches plant^{-1} (2.00, 2.42 and 2.58 at 30, 45 DAS and at harvest, respectively) were obtained from the N_2 with the interaction of P_1 which was similar to the interaction of N_1P_1 at 30 DAS, N_0P_1 at 45 DAS. The lowest number of branches plant^{-1} (0.53) was obtained from N_1P_4 at 30 DAS which was statistically similar with N_2P_4. The N_2P_4 produced lowest number of branches plant^{-1} (0.67 and 0.67 at 45 DAS and a harvest, respectively).

Table 6. Interaction effect of nitrogen levels and planting density on number of branches plant^{-1} of mungbean at different days after sowing (DAS)

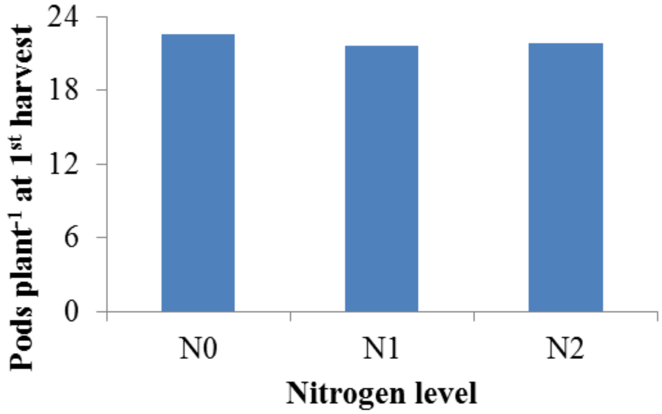
Treatment combination	Branches plant^{-1} (DAS)		
	30	**45**	**At harvest**
N_0P_1	1.73 b	2.27 ab	2.27 b
N_0P_2	1.27 c	1.73 c	1.73 de
N_0P_3	0.93 ef	1.27 d-f	1.53 ef
N_0P_4	0.80 f	1.07 f	1.07 h
N_1P_1	1.93 a	2.07 b	2.07 bc
N_1P_2	1.20 c	1.33 de	1.47 f
N_1P_3	1.13 cd	1.33 de	1.33 fg
N_1P_4	0.53 g	1.13 ef	1.13 gh
N_2P_1	2.00 a	2.42 a	2.58 a
N_2P_2	1.13 cd	1.73 c	1.93 cd
N_2P_3	1.00 de	1.47 d	1.47 f
N_2P_4	0.60 g	0.67 g	0.67 i
LSD $_{(0.05)}$	**0.19**	**0.22**	**0.26**
CV (%)	**9.13**	**8.17**	**9.49**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.2.2 Number of pods plant^{-1} at 1st harvest

4.2.2.1 Effect of nitrogen levels

The number of pods plant^{-1} at 1st harvest was not significantly influenced by nitrogen levels (Figure 19). Results showed that, the N_0 produced maximum number of pods plant^{-1} at 1st harvest (22.52) whereas the minimum number of pods plant^{-1} at 1st harvest was obtained from N_1 (21.63).

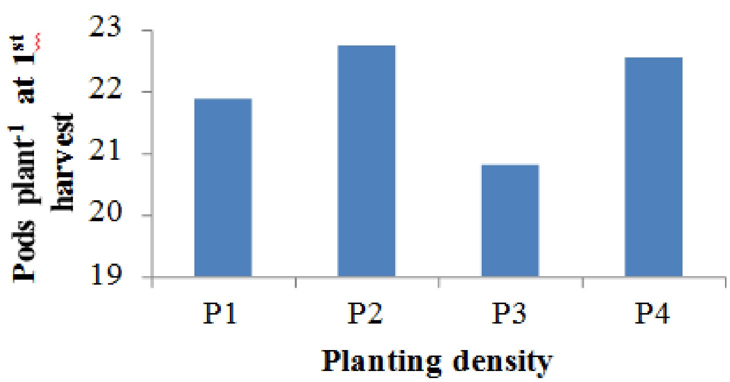


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 19. Effect of nitrogen levels on pods plant^{-1} at 1st harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.2.2 Effect of planting density

Planting density showed significant effect on the number of pods plant^{-1} at 1st harvest (Figure 20). Results revealed that, treatment P_2 and P_4 produced maximum number of pods plant^{-1} at 1st harvest (22.73) which was statistically at par with P_1 (21.87) and the minimum was obtained from P_3 (20.80) which was also statistically at par with P_1 (21.87).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 20. Effect of planting density on pods plant^{-1} at 1st harvest of mungbean (LSD $_{(0.05)}$ = 1.69)

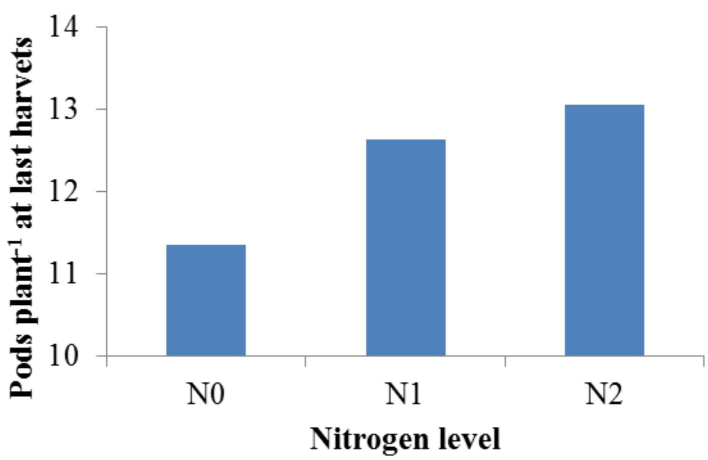
4.2.2.3 Interaction effect of nitrogen levels and planting density

The number of pods plant^{-1} at 1st harvest was significantly influenced by the interaction effect of nitrogen levels and planting density (Table 7). The highest number of pods plant^{-1} at 1st harvest (26.20) was obtained from the N_2P_4 which shown similarity with N_1P_2 and N_0P_2. The lowest number of pods plant^{-1} at 1st harvest (19.33) was obtained from N_2P_3 and N_2P_2 which shown similarity with the interaction of N_1P_1, N_0P_4, N_0P_3 and N_1P_3.

4.2.3 Number of pods plant^{-1} at last harvest

4.2.3.1 Effect of nitrogen levels

The number of pods plant^{-1} at last harvest was significantly influenced by nitrogen levels (Figure 21). Results revealed that, the N_2 produced maximum number of pods plant^{-1} at last harvest (13.05) which was statistically similar with N_1 whereas the minimum number of pods plant^{-1} at last harvest was obtained from N_0 (11.35) which was also statistically similar with N_1.

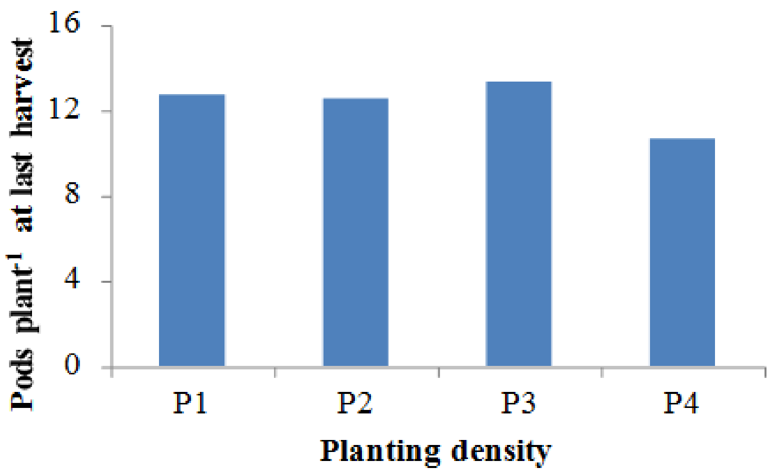


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 21. Effect of nitrogen levels on pods plant^{-1} at last harvest of mungbean (LSD $_{(0.05)}$ = 1.32)

4.2.3.2 Effect of planting density

Planting density had significant effect on the number of pods plant^{-1} at last harvest (Figure 22). Results of the experiment revealed that, treatment P_3 produced the highest number of pods plant^{-1} at last harvest (13.36) which was statistically at par with P_1 (12.76) and the lowest pods was obtained from P_4 (10.69).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 22. Effect of planting density on pods plant^{-1} at last harvest of mungbean (LSD $_{(0.05)}$ = 0.76)

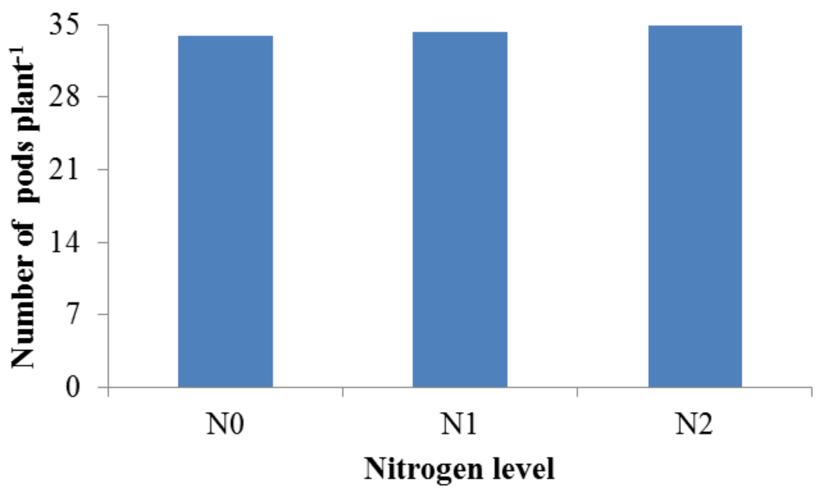
4.2.3.3 Interaction effect of nitrogen levels and planting density

The number of pods plant^{-1} at last harvest was significantly influenced by the interaction effect of nitrogen levels and planting density (Table 7). The highest number of pods plant^{-1} at last harvest (16.13) was obtained from the N_2P_2 which shown similarity with N_1P_3. The lowest number of pods plant^{-1} at last harvest (9.73) was obtained from N_0P_2 which shown similarity with the interaction of N_0P_4, N_1P_4 and N_2P_4.

4.2.4 Number of total pods plant^{-1}

4.2.4.1 Effect of nitrogen levels

The number of pods plant^{-1} was not significantly influenced by nitrogen levels (Figure 23). Results showed that, the N_2 produced maximum number of pods plant^{-1} (34.85) whereas the minimum number of pods plant^{-1} was obtained from N_0 (33.87). It might be due to adequate supply of nitrogen to develop pod bearing branches. This result was not agreement with Hossen *et al.* (2015); Razzaque *et al.* (2015); Ghasempour and Ashori (2014); Mainul *et al.* (2014); Mahmoudi *et al*. (2013); Anjum *et al*. (2006); Ashraf (2001). They reported that higher number of pods plant^{-1} was found in higher nitrogen application compared to no nitrogen application. Moniruzzaman *et al*. (2008) also reported that there was a significant effect of N fertilizers on pods production plant^{-1} whereas the maximum pods plant^{-1} was obtained with 120-120-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B. Parvez (2011) also found that high N dose (50 kg ha^{-1}) gave significantly higher number of pods and seeds pod^{-1}.

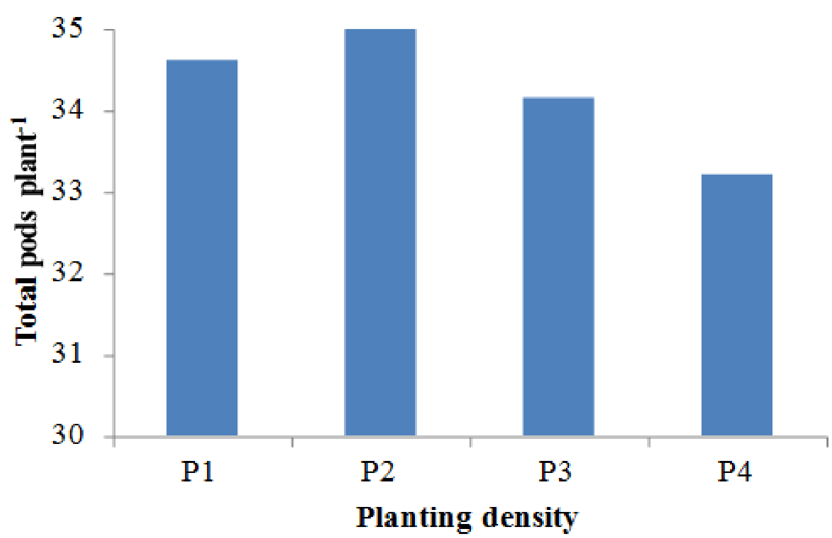


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 23. Effect of nitrogen levels on total number of pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = NS)

4.2.4.2 Effect of planting density

Planting density had significant effect on the number of pods plant^{-1} (Figure 24). Results of the experiment revealed that, treatment P_2 produced the highest number of pods plant^{-1} (35.31) which was statistically at par with P_1 and P_3 and the lowest pods was obtained from P_4 (33.22) which was statistically at par with all treatments except P_2 . Similar result also found by Rasul *et al.* (2012) who reported that number of pods plant^{-1} did not significantly differed due to different planting density. But number of pods per plant is a key factor for determining the yield performance in leguminous plants. Contradictory result also reported by Ghasempour and Ashori (2014) and Bakhsh *et al.* (2011) who reported that the increased plant density for beans may result in decreasing the number of pods per plant due to wider row spacing helps to get more sunlight and food for photosynthesis as a result pods plant^{-1} is higher.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 24. Effect of planting density on total pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = 2.05)

4.2.4.3 Interaction effect of nitrogen levels and planting density

The number of pods plant^{-1} was significantly influenced by the interaction effect of nitrogen levels and planting density (Table 7). The highest number of pods plant^{-1} (37.07) was obtained from the N_1P_2 and N_2P_4 which shown similarity with N_1P_3, N_2P_2, N_2P_1, N_0P_1 and N_0P_3. The lowest number of pods plant^{-1} (30.27) was obtained from N_1P_4 which shown similarity with the interaction of N_2P_3, N_0P_4, N_0P_2 and N_1P_1. This result was coincided with the result of Ghasempour and Ashori (2014) who reported that the interaction between planting density and nitrogen fertilizer on the number of pods per plant was significant.

Table 7. Interaction effect of nitrogen levels and planting density on yield contributing characters of mungbean

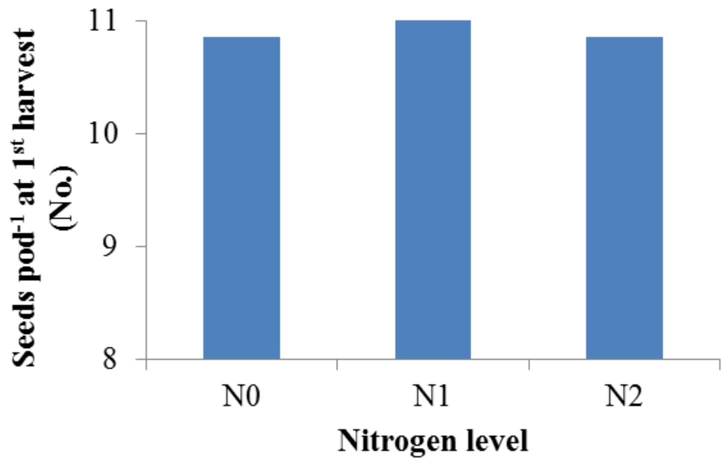
Treatment combination	Days required to 1st flowering	Days required to 50% flowering	Pods plant^{-1} at 1st harvest (No.)	Pods plant^{-1} at last harvest (No.)	Total pods plant^{-1} (No.)
N_0P_1	28.67 a	40.33 a-d	22.93 b-d	12.13 bc	35.07 a-c
N_0P_2	28.33 ab	40.67 a-c	23.67 a-c	9.733 e	33.40 b-e
N_0P_3	27.33 b-d	40.00 a-d	21.73 c-f	12.93 b	34.67 a-d
N_0P_4	27.67 a-c	40.33 a-d	21.73 c-f	10.60 de	32.33 c-e
N_1P_1	26.67 cd	38.67 d	20.33 d-f	13.07 b	33.40 b-e
N_1P_2	26.33 d	39.00 cd	25.20 ab	11.87 b-d	37.07 a
N_1P_3	27.33 b-d	39.33 b-d	21.33 c-f	15.00 a	36.33 ab
N_1P_4	28.00 ab	39.00 cd	19.67 ef	10.60 de	30.27 e
N_2P_1	28.00 ab	40.33 a-d	22.33 b-e	13.07 b	35.40 a-c
N_2P_2	28.67 a	40.67 a-c	19.33 f	16.13 a	35.47 a-c
N_2P_3	27.67 a-c	41.00 ab	19.33 f	12.13 bc	31.47 de
N_2P_4	28.33 ab	41.33 a	26.20 a	10.87 c-e	37.07 a
LSD $_{(0.05)}$	**1.27**	**1.90**	**2.93**	**1.31**	**3.55**
CV (%)	**2.66**	**2.76**	**7.76**	**6.20**	**6.03**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.2.5 Number of seeds pod^{-1} at 1st harvest

4.2.5.1 Effect of nitrogen levels

The number of seeds pod^{-1} at 1st harvest was not significantly influenced by the nitrogen levels (Figure 25). The N_1 produced higher number of seeds pod^{-1} at 1st harvest (11.15) and the N_2 produced lower number of seeds pod^{-1} at 1st harvest (10.85).

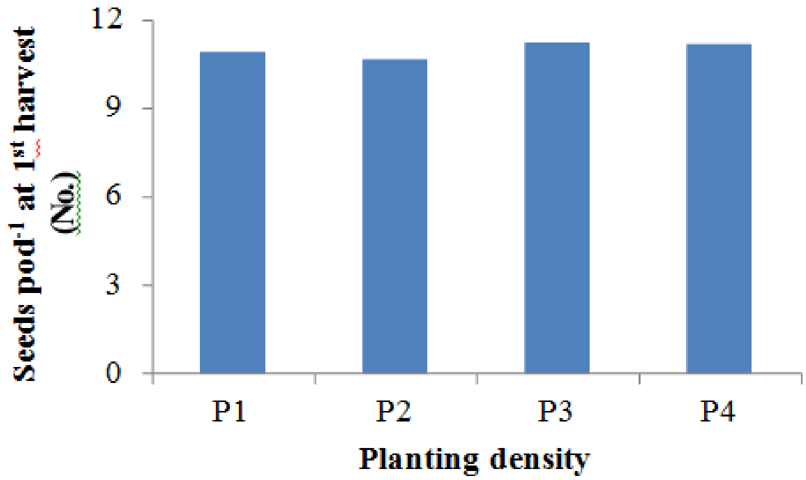


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 25. Effect of nitrogen levels on seeds pod^{-1} at 1st harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.5.2 Effect of planting density

Planting density had no significant effect on the number of seeds pod^{-1} at 1st harvest (Figure 26). The maximum number of seeds pod^{-1} at 1st harvest was recorded from the P_3 (11.18) and the minimum number of seeds pod^{-1} at 1st harvest was recorded from P_2 (10.62).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 26. Effect of planting density on seeds pod^{-1} at 1st harvest of mungbean (LSD $_{(0.05)}$ = NS)

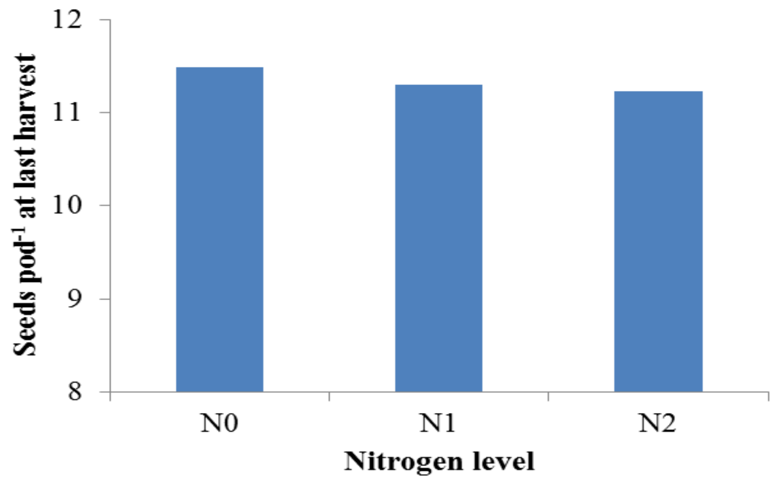
4.2.5.3 Interaction effect of nitrogen levels and planting density

The number of seeds pod^{-1} at 1st harvest was significantly influenced by the interaction effect of nitrogen level and planting density (Table 8). The highest number of seeds pod^{-1} at 1st harvest (11.73) was obtained from N_1 with the interaction of P_4, which was similar with all the interactions except N_0P_2, N_0P_4 and N_2P_2. The lowest number of seeds pod^{-1} at 1st harvest (10.33) was obtained from N_2 with the interaction of P_2 which was similar with all the interaction except N_1P_4.

4.2.6 Number of seeds pod^{-1} at last harvest

4.2.6.1 Effect of nitrogen levels

The number of seeds pod^{-1} at last harvest was not significantly influenced by the nitrogen levels (Figure 27). The N_0 produced higher number of seeds pod^{-1} at last harvest (11.49) and the N_2 produced lower number of seeds pod^{-1} (11.23). These findings were agreed with the findings of Razzaque *et al.* (2015) and Asaduzzaman *et al.* (2008) who reported that nitrogen had no significant effect on seeds pod^{-1} of mungbean. The number of seeds pod^{-1} is mostly genetically controlled but its number may be regulated by canopy photosynthesis during pod developing stage. Seed number also may be limited by the activity of the source (Akther, 2005). During seed filling, the ability of the individual seed to utilize assimilate determines number of seeds pod^{-1} and limitation of assimilate reduced the seeds pod^{-1} (Jenner *et al.* 1992). This results however contrasting with the findings of Hossen *et al.* (2015); Mainul *et al.* (2014), Mian and Hossain (2014); Parvez (2011), Rashid *et al.* (1999); Masih (1998) and Taj (1996) who reported that application of N fertilizer increases seeds pod^{-1} significantly. Cheraghi *et al.* (2011) stated that the effect of nitrogen on pod and seed number was positive and carbon metabolism can have a greater impact on the number and yield of grain.

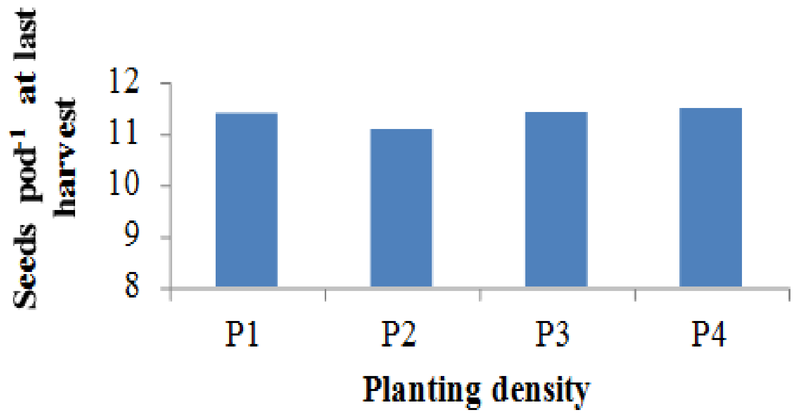


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 27. Effect of nitrogen levels on seeds pod^{-1} at last harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.6.2 Effect of planting density

Planting density had no significant effect on the number of seeds pod^{-1} at last harvest (Figure 28). The maximum number of seeds pod^{-1} at last harvest was recorded from the P_4 (11.49) and the minimum number of seeds pod^{-1} at last harvest was recorded from P_2 (11.08). This result was not similar with the findings of Foysalkabir *et al.* (2016); Rasul *et al.* (2012) and Hamid (1989) who reported that planting density significantly influenced the seeds pod^{-1}. They also reported that lower planting density gave the higher number of seeds pod^{-1}.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 28. Effect of planting density on seeds pod^{-1} at last harvest of mungbean (LSD $_{(0.05)}$ = NS)

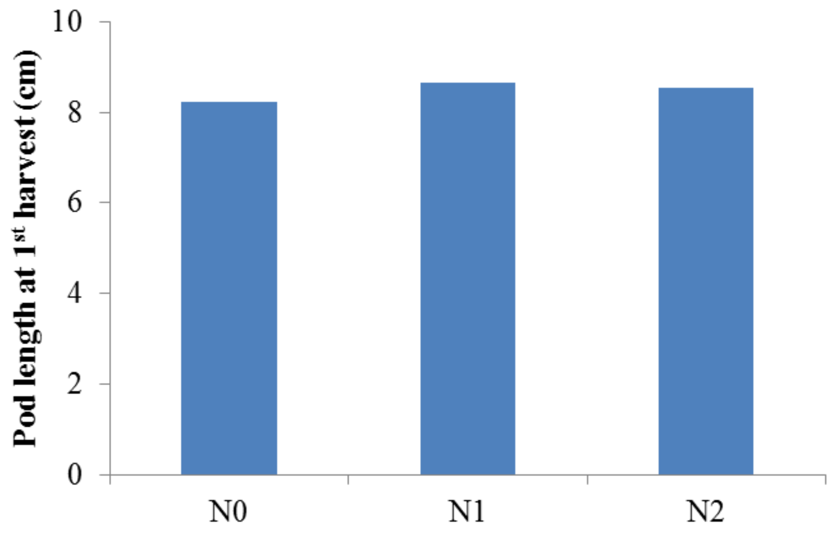
4.2.6.3 Interaction effect of nitrogen levels and planting density

The number of seeds pod^{-1} at last harvest was significantly influenced by the interaction effect of nitrogen level and planting density (Table 8). The highest number of seeds pod^{-1} at last harvest (12.07) was obtained from N_0 with the interaction of P_3, which was similar with the interactions of N_1P_4, N_2P_1, N_2P_4, N_1P_2 and N_0P_1. The lowest number of seeds pod^{-1} at last harvest (10.97) was obtained from N_1 with the interaction of P_1 which was similar with all the interaction except N_0P_3 and N_1P_4.

4.2.7 Pod length at 1st harvest (cm)

4.2.7.1 Effect of nitrogen levels

The pod length at 1st harvest was not significantly influenced by nitrogen levels (Figure 29). The maximum (8.66 cm) and minimum (8.22 cm) pod length at 1st harvest was obtained from N_1 and N_0, respectively. This result was not similar with the result of Hossen *et al.* (2015) and Moniruzzaman *et al.* (2009) who reported that pod length was significantly influenced by higher dose of nitrogen. Noor-e-Alam Siddiqui (2010); Hossain (2007) also found significant variation in pod length due to nitrogen application.

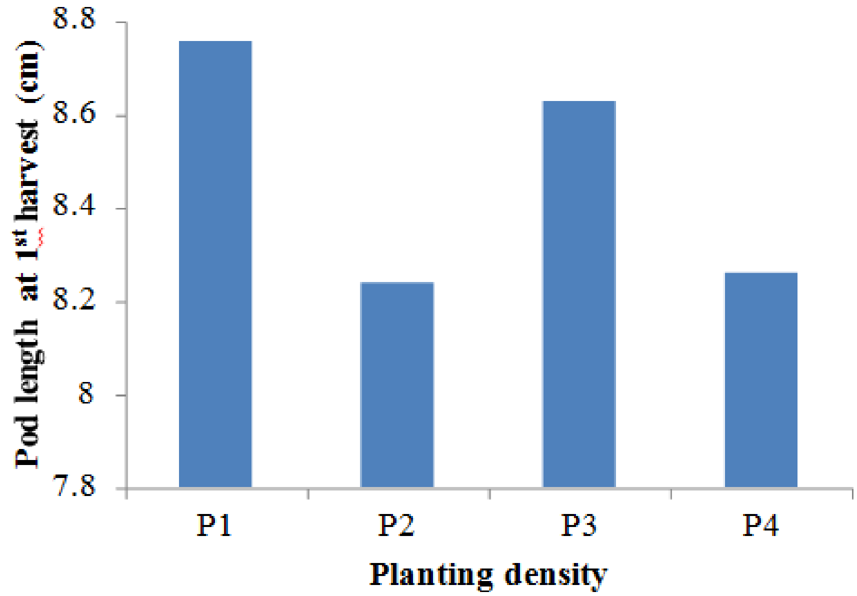


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 29. Effect of nitrogen levels on pod length at 1st harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.7.2 Effect of planting density

There was significant difference observed in pod length at 1st harvest due to different planting density (Figure 30). The higher pod length at 1st harvest (8.76 cm) was observed in P_1 which was statistically similar with P_3. The lower pod length at 1st harvest (8.24 cm) was observed in P_2 treatment which was statistically similar with P_4. The less planting density per unit area *i e*. higher plant spacing helps the plant to uptake more nutrient and water. They also get more sunlight which was useful for photosynthesis, consequently more dry matter partitioning to the reproductive unit of plant (pod), thus increased the pod length compared to the densely populated plot. The present finding consisted with the findings of Agasimani *et al.* (1984).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 30. Effect of planting density on pod length at 1st harvest of mungbean (LSD $_{(0.05)}$ = 0.38)

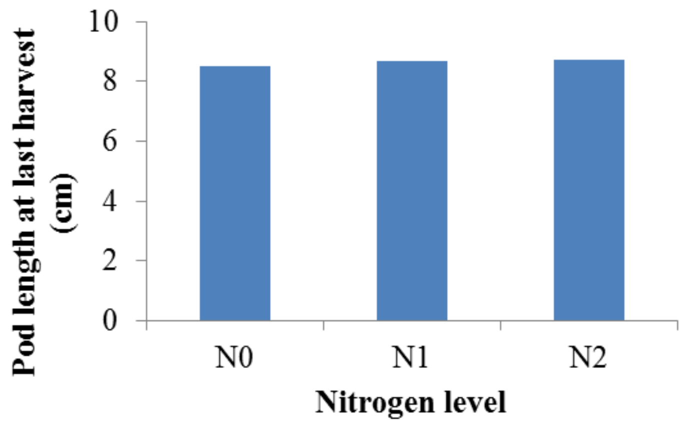
4.2.7.3 Interaction effect of nitrogen levels and planting density

The pod length at 1st harvest was significantly influenced by the interaction effect of nitrogen level and planting density (Table 8). The highest pod length at 1st harvest (9.02 cm) was recorded from the N_1P_1 which was statistically similar with N_2P_3, N_1P_3, N_2P_4, N_2P_1, N_0P_1 and N_1P_2. The lowest pod length at 1st harvest (8.05 cm) was obtained from the N_0P_3 which was statistically similar with all the interactions except N_1P_1, N_1P_3 and N_2P_3.

4.2.8 Pod length at last harvest (cm)

4.2.8.1 Effect of nitrogen levels

The pod length at last harvest was not significantly influenced by nitrogen levels (Figure 31). The higher (8.71cm) and lower (8.50 cm) pod length at last harvest was obtained from N_2 and N_0, respectively.

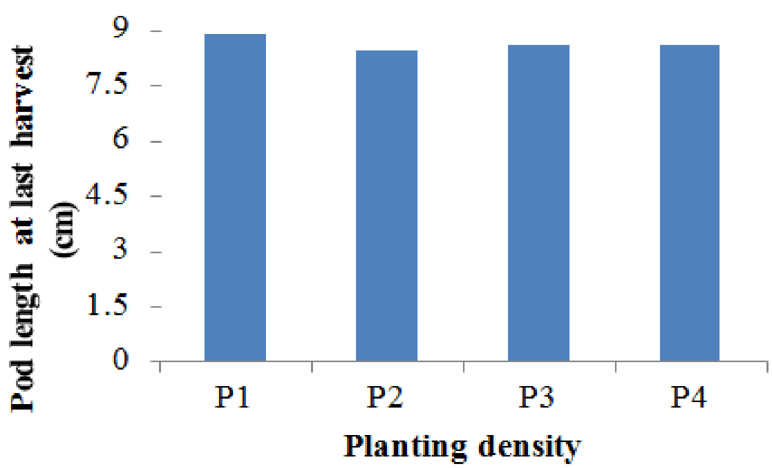


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 31. Effect of nitrogen levels on pod length at last harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.8.2 Effect of planting density

There was no significant difference observed in pod length at last harvest due to different planting density (Figure 32). The higher pod length at last harvest (8.89 cm) was observed in P_1. The lower pod length at last harvest (8.44 cm) was observed in P_2 treatment.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 32. Effect of planting density on harvest index of mungbean (LSD $_{(0.05)}$ = NS)

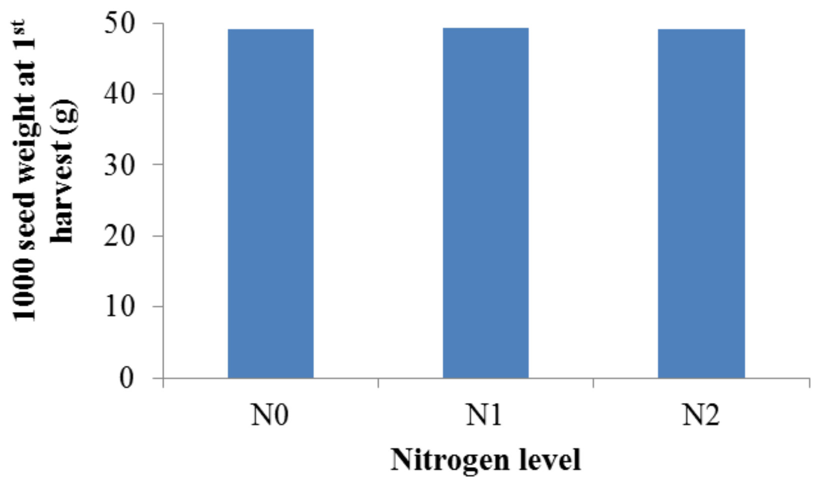
4.2.8.3 Interaction effect of nitrogen levels and planting density

The pod length at last harvest was not significantly influenced by the interaction effect of nitrogen level and planting density (Table 8). The maximum pod length at last harvest (9.14 cm) was recorded from the N_2P_1. The minimum pod length at last harvest (8.32 cm) was obtained from the N_0P_3.

4.2.9 1000 seed weight at 1st harvest (g)

4.2.9.1 Effect of nitrogen levels

The 1000-seed weight at 1st harvest was not significantly influenced by the nitrogen levels (Figure 33). The numerically maximum 1000-seed weight at 1st harvest (49.25 g) was obtained from $N_1$and the minimum 1000-seed weight at 1st harvest (49.08 g) was obtained from both N_0 and N_2.

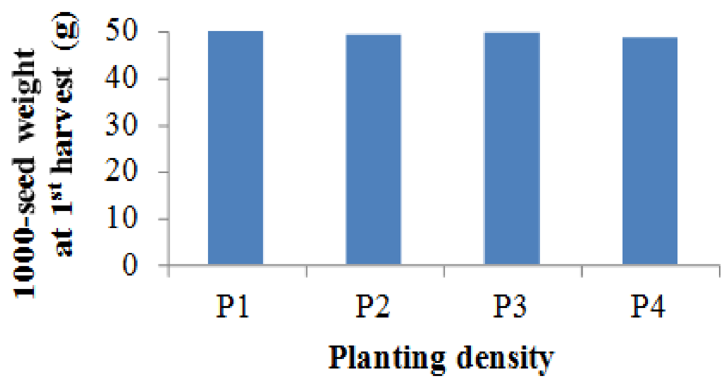


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 33. Effect of nitrogen levels on 1000-seed weight at 1st harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.9.2 Effect of planting density

There was no significant variation observed among the planting density in respect of 1000 seed weight of 1st harvest (Figure 34). The maximum 1000-seed weight at 1st harvest (49.67 g) was obtained from the P_1 and the minimum 1000-seed weight at 1st harvest (48.44 g) was obtained from the P_4.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 34. Effect of planting density on 1000-seed weight at 1st harvest of mungbean (LSD $_{(0.05)}$ = NS)

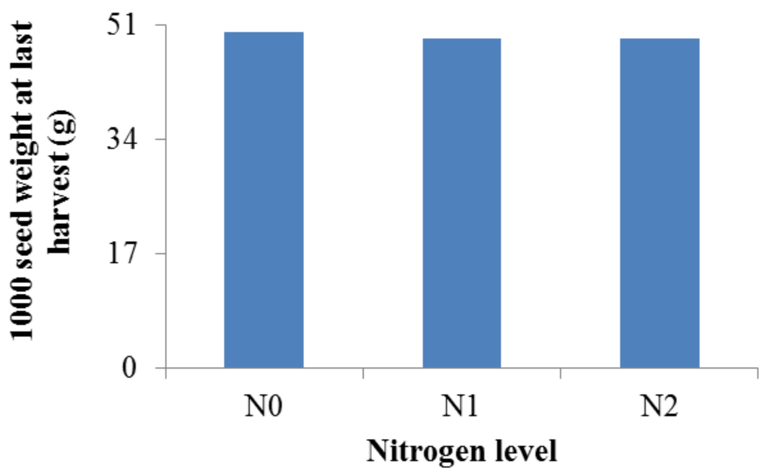
4.2.9.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen level and planting density was not found significant in respect of 1000-seed weight at 1st harvest (Table 8). The maximum 1000-seed weight at 1st harvest (50.33 g) was obtained from N_0P_3 and N_1P_2. The minimum 1000-seed weight at 1st harvest (48.00 g) was obtained from N_0P_4 and N_1P_4.

4.2.10 Thousand seed weight at last harvest (g)

4.2.10.1 Effect of nitrogen levels

The 1000-seed weight at last harvest was not significantly influenced by the nitrogen levels (Figure 35). The maximum 1000-seed weight at last harvest (50.00 g) was obtained from N_0 and the minimum 1000-seed weight at last harvest (48.92 g) was obtained from both N_1 and N_2. This findings was full agreement with Razzaque *et al.* (2015) and Mahmoudi *et al*. (2013) who reported that nitrogen level had no significant effect on 1000 seed weight, but was not coincide with the result of Hossen *et al*. (2015); Mian and Hossain (2014) who found significant variation where 1000-seed weight was higher in N 40 kg ha^{-1} compared to the control treatment. Similarly, Ayub *et al*. (1999) also found that the N at the rate of 40 kg ha^{-1} produced highest 1000-seed weight. In present study although, soil N fertilizer failed to enhance 1000-seed weight but it increased in faba bean (Elsheikh and Elzidany, 1997) and groundnut (Chetti *et al.*, 1995) due to soil N fertilizer application.

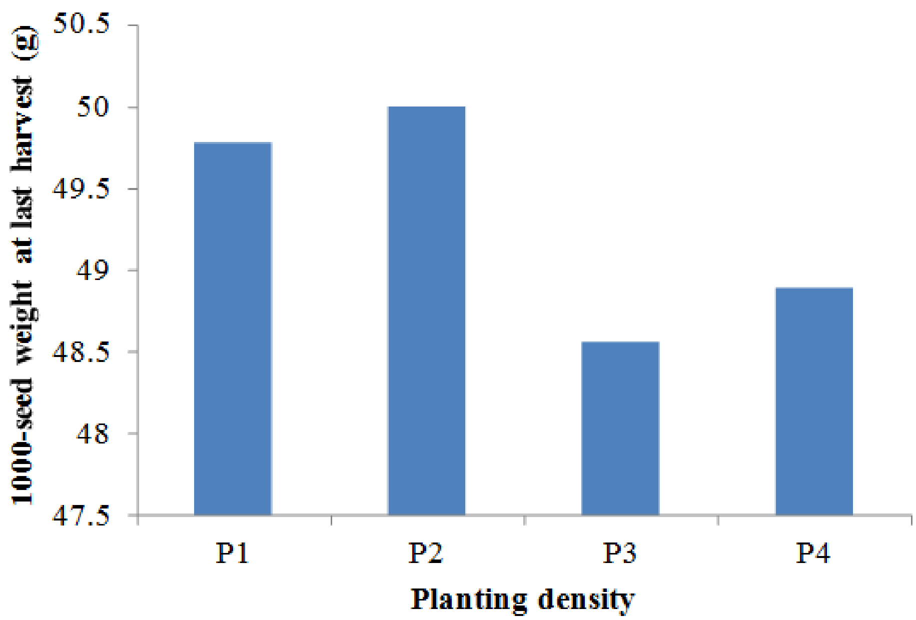


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 35. Effect of nitrogen levels on 1000-seed weight at last harvest of mungbean (LSD $_{(0.05)}$ = NS)

4.2.10.2 Effect of planting density

There was significant variation observed among the planting density in respect of 1000-seed weight at last harvest (Figure 36). The highest 1000-seed weight at last harvest (50.00 g) was obtained from the P_2 which shown similarity with P_1 and the minimum 1000-seed weight at last harvest (48.56 g) was obtained from the P_3 which shown similarity with P_4. Lower planting density per unit area get more natural resources which were beneficial for plant and partitioned more assimilates to the pod compared to the densely populated one and as a result they produced higher 1000-seed weight. Similar result also reported by Rasul *et al.* (2012) where wider row spacing help to get highest 1000-seeds weight of mungbean. Row spacing significantly affected the seed yield of legumes (Porwal *et al*., 1991).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 36. Effect of planting density on 1000-seed weight at last harvest of mungbean (LSD $_{(0.05)}$ = 0.93)

4.2.10.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen level and planting density was found significant in respect of 1000 seed weight at last harvest (Table 8). The highest 1000 seed weight at last harvest (51.33 g) was obtained from N_0P_2 which shown similarity with N_0P_1. The lowest 1000 seed weight at last harvest (48.33 g) was obtained from N_2P_3 which was statistically different with interaction of N_0P_1 and N_0P_2.

Table 8. Interaction effect of nitrogen levels and planting density on yield and yield contributing characters of mungbean

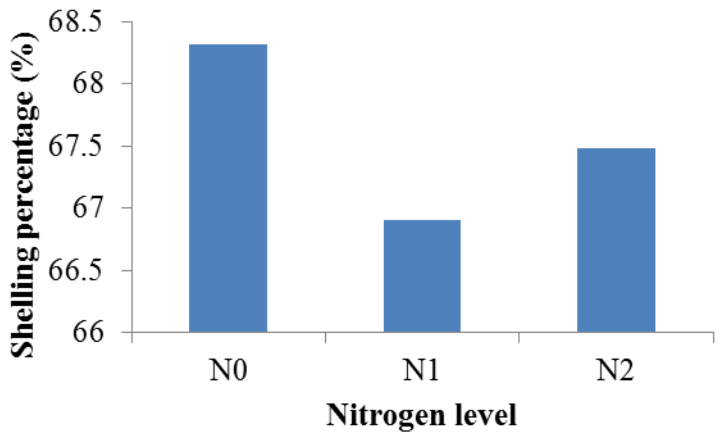
Treatment combination	Seeds pod^{-1} at 1st harvest (no.)	Seeds pod^{-1} at last harvest (No.)	Pod length at 1st harvest (cm)	Pod length at last harvest(cm)	1000 seed weight at 1st harvest (g)	1000 seed weight at last harvest (g)
N_0P_1	11.40 ab	11.73 a-c	8.67 a-c	8.71	49.67	50.67 ab
N_0P_2	10.47 b	11.07 bc	8.13 c	8.46	48.33	51.33 a
N_0P_3	11.07 ab	12.07 a	8.05 c	8.32	50.33	48.67 c
N_0P_4	10.50 b	11.10 bc	8.07 c	8.52	48.00	49.33 bc
N_1P_1	10.60 ab	10.97 c	9.02 a	8.83	50.00	49.33 bc
N_1P_2	11.07 ab	11.13 a-c	8.42 a-c	8.43	50.33	49.33 bc
N_1P_3	11.20 ab	11.10 bc	8.89 ab	8.73	48.67	48.67 c
N_1P_4	11.73 a	12.00 ab	8.31 bc	8.71	48.00	48.67 c
N_2P_1	10.60 ab	11.47 a-c	8.59 a-c	9.14	49.33	49.33 bc
N_2P_2	10.33 b	11.03 c	8.17 c	8.43	48.33	49.33 bc
N_2P_3	11.27 ab	11.07 bc	8.95 ab	8.70	49.33	48.33 c
N_2P_4	11.20 ab	11.37 a-c	8.41 a-c	8.60	49.33	48.67 c
LSD $_{(0.05)}$	**1.20**	**0.97**	**0.65**	**NS**	**NS**	**1.61**
CV (%)	**6.37**	**4.97**	**4.47**	**5.60**	**3.59**	**1.90**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

4.2.11 Shelling percentage (%)

4.2.11.1 Effect of nitrogen levels

The shelling percentage was significantly influenced by the nitrogen levels (Figure 37). The highest shelling percentage (68.32%) was obtained from the N_0 which was statistically at par with N_2 and the lowest shelling percentage (66.90%) obtained from N_1 which was statistically at par with N_2.

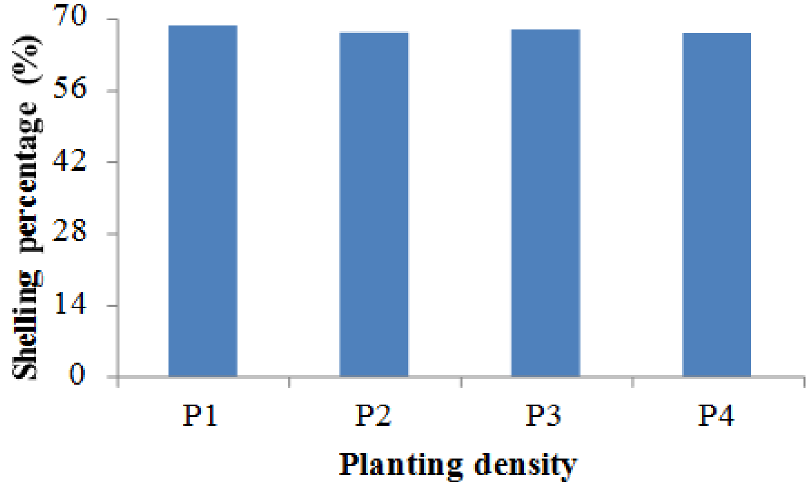


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 37. Effect of nitrogen levels on shelling percentage of mungbean (LSD $_{(0.05)}$ = 1.18)

4.2.11.2 Effect of planting density

Planting density had no significant effect on shelling percentage (Figure 38). The P_1 produced numerically maximum shelling percentage (68.39%) and the minimum shelling percentage (67.02) was obtained from P_4.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 38. Effect of planting density on shelling percentage of mungbean (LSD $_{(0.05)}$ = NS)

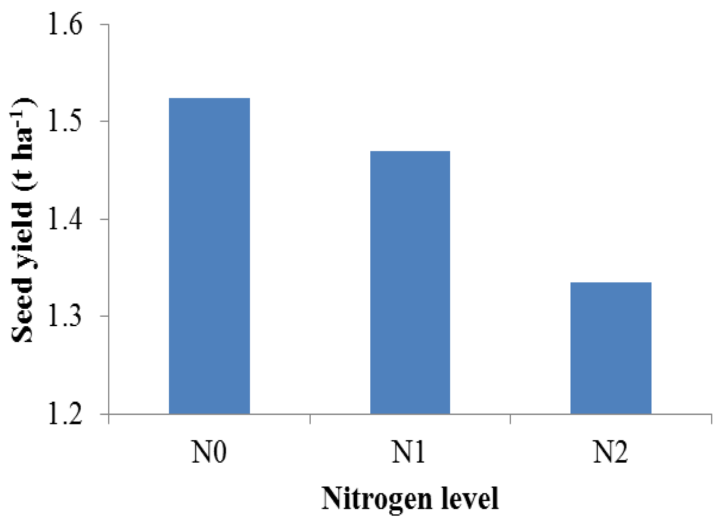
4.2.11.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen levels and planting density was found significant in respect of shelling percentage (Table 9). The highest shelling percentage (69.43%) was obtained from N_0P_2 which was similar with all the interactions except N_1P_2 and N_2P_2. The lowest shelling percentage (65.85%) was obtained from N_1P_2 which were similar with all the interactions except N_0P_2 and N_2P_1.

4.2.12 Seed yield (t ha^{-1})

4.2.12.1 Effect of nitrogen levels

Seed yield was significantly influenced by the nitrogen levels (Figure 39). The highest seed yield (1.52 t ha^{-1}) was obtained from the N_0 compared to the yield of N_2 (1.34 t ha^{-1}) which was 13.43% higher than N_2. This finding was not coincide with Gholinejad *et al.* (2009) who stated that investment of assimilates in higher levels of nitrogen has increased in leaf and stem segments and as a result concentrated material increases in the grain and consequently increased the yield. Razzaque *et al.* (2015); Biswas and Hamid (1989); Mitra and Ghildiyal (1988) also reported that, increase amount of nitrogen increase the amount of seed yield. Kamanu *et al*. (2012) reported that the inorganic fertilizer application 91 kg N ha^{-1} as DAP-CAN had the highest total yield. Simonne *et al*. (2012), Mondal *et al*. (2012), Ayub *et al*. (2010), Noor-e-Alam Siddiqui (2010) and Sen *et al*. (2010) and so many researchers were found significant variation in grain yield due to different levels of nitrogen application. Kamithi and Akuja (2009) also found that the highest grain yield was 2,574.4 and 2,353.7kg grain ha^{-1} under 20 and 40 kg N ha^{-1}, respectively. Mainul *et al.* (2014) and Sultana *et al*. (2009) found that application of 20 kg N ha^{-1} produced significantly more seed yield (1,982 kg ha^{-1}) in mungbean. Seed yield per plant were increased due to the application of nitrogenous fertilizers (Taj, 1996; Patel and Pramer, 1986).

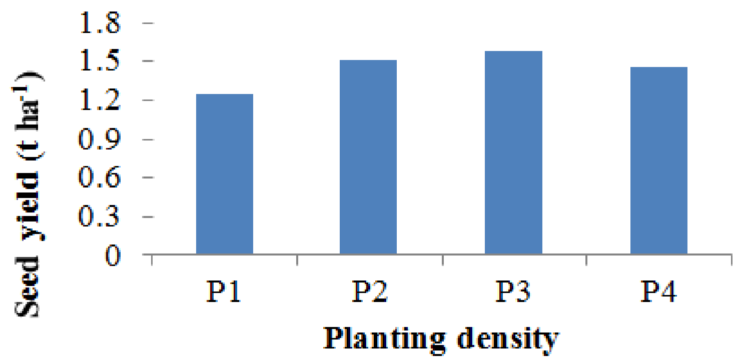


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 39. Effect of nitrogen levels on seed yield of mungbean (LSD $_{(0.05)}$ = 0.12)

4.2.12.2 Effect of planting density

Planting density had significant effect on seed yield (Figure 40). The P_3 produced significantly the highest seed yield (1.58 t ha^{-1}) which was similar with P_2 and the lowest seed yield (1.24 t ha^{-1}) was obtained from P_1. The P_3 produced 27.42% seed over P_1. Dry matter production and its transformation into economic yield was the ultimate outcome of various physiological, biochemicals, phenological and morphological events occurring in the plant system (Rasul *et al.*, 2012). The favorable density refers to a density in which all environmental factors (water, air, light and soil) are completely used and at the same time both intra-plant and extra-plant competitions are at minimum level in order to achieve the highest possible yield with the ideal quality. Most studies indicated that the yield of beans per unit area was decreased as the result of increasing the space between rows and between two plants in a single row and decreasing the density (Ghasempour and Ashori, 2014). Wider plant spacing helped the plant to produce more seed yield per plant but due to lower no. of plant per unit area it produced lower seed than the narrower spacing one. Again in over populated area plant produced less seed yield because there was huge intra plant competition between them for moisture, sunlight and soil nutrients. This result was also coincide with Rasul *et al.*, (2012); Ali *et al*. (2010); Panwar and Sirohi (1987) and Agarico (1985), who reported that, crop sown at inter-row spacing of 30 cm gave maximum seed yield while lowest seed yield was obtained at inter-row spacing of 60 cm.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 40. Effect of planting density on seed yield of mungbean (LSD $_{(0.05)}$ = 0.10)

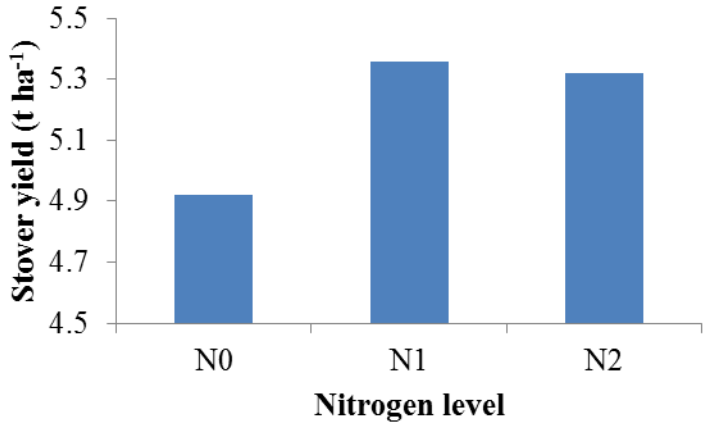
4.2.12.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen levels and planting density was found significant in respect of seed yield (Table 9). The highest seed yield (1.68 t ha^{-1}) was obtained from N_1P_3 which was similar with the interaction of N_0P_3, N_1P_2, N_0P_2 and N_0P_4. The lowest seed yield (1.19 t ha^{-1}) was obtained from N_1P_1which were similar with the interaction of N_2P_1, N_2P_2 and N_0P_1. Similar result also found by Ghasempour and Ashori (2014) in mungbean. Khoram and Farboudi (2008) reported that the interaction between planting space and nitrogen fertilizer on rice yield per unit area was significant (5%). Likewise, Khamoushi *et al.*, (2011) reported that the interaction between planting space and nitrogen fertilizer on seed was significant, as the density of 25x25cm plants per unit area with 40 kg nitrogen fertilizer was defined as the treatment in which the best yield was obtained.

4.2.13 Stover yield (t ha^{-1})

4.2.13.1 Effect of nitrogen levels

Stover yield was not significantly influenced by the variety (Figure 41). The numerically maximum stover yield (5.36 t ha^{-1}) was obtained from the N_1 which showed similarity with N_2 compared to the yield (4.92 t ha^{-1}) of N_0. The N_1 gave 8.94 % higher yield than the N_0.

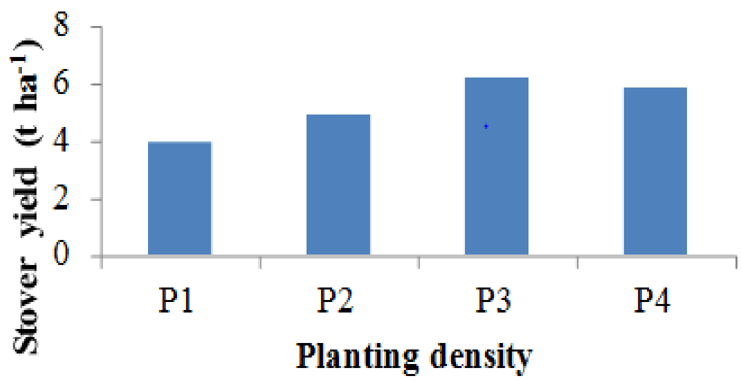


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 41. Effect of nitrogen levels on stover yield of mungbean (LSD $_{(0.05)}$ = 0.34)

4.2.13.2 Effect of planting density

Planting density had significant effect on stover yield (Figure 42). The P_3 produced significantly the highest stover yield (6.14 t ha^{-1}) which was similar to P_4. The lowest stover yield (3.94 t ha^{-1}) was obtained from P_1. Wider plant spacing might help more vigorous growth of plant but due to lower no. of plants per unit area produced comparably lower stover yield than the densely populated area. On the other hand due higher no. of plants per unit area it produced higher stover yield. Similar report was reported by Bullock and Kraijevic (1998) who stated that due to row spacing helped to get more stover yield.



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 42. Effect of planting density on stover yield of mungbean (LSD $_{(0.05)}$ = 0.37)

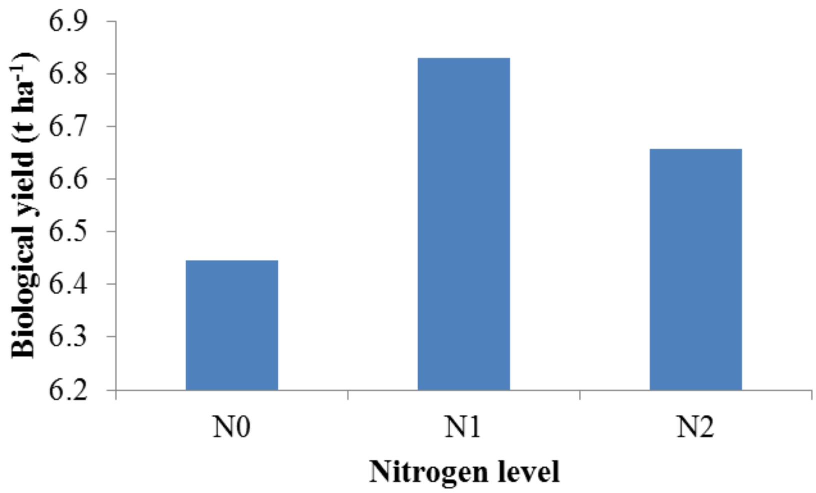
4.2.13.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen levels and planting density was found significant in respect of stover yield (Table 9). The highest stover yield (6.89 t ha^{-1}) was obtained from N_2P_3. The lowest stover yield (3.49 t ha^{-1}) was obtained from N_0P_1 which was similar to the interaction of N_2P_1.

4.2.14 Biological yield (t ha^{-1})

4.2.14.1 Effect of nitrogen levels

The biological yield was significantly influenced by the nitrogen levels (Figure 43). The highest biological yield (6.83 t ha^{-1}) was obtained from the N_1 which similar with N_2 whereas the lowest biological yield (4.92 t ha^{-1}) was obtained from N_0 which was also similar with N_2. This finding was also similar with the findings of Mahmoudi *et al.* (2013) who reported that nitrogen had significant effect on biological yield of mungbean. Ghorbanli *et al*. (2006) in their reviews about effect of nitrogen on the dry weight of rice plants also showed that nitrogen increase caused to increased total plant dry weight. In their experiments correlation between the nitrogen content and net exchange of the carbon dioxide in different rice genotypes confirms that nitrogen increase was essential for dry matter production. Gholinejad *et al.* (2009) stated that nitrogen deficiency due to reduced leaf size and durability; probably reduced the amount of received light, light use efficiency, crop photosynthetic and then began to decrease biomass.

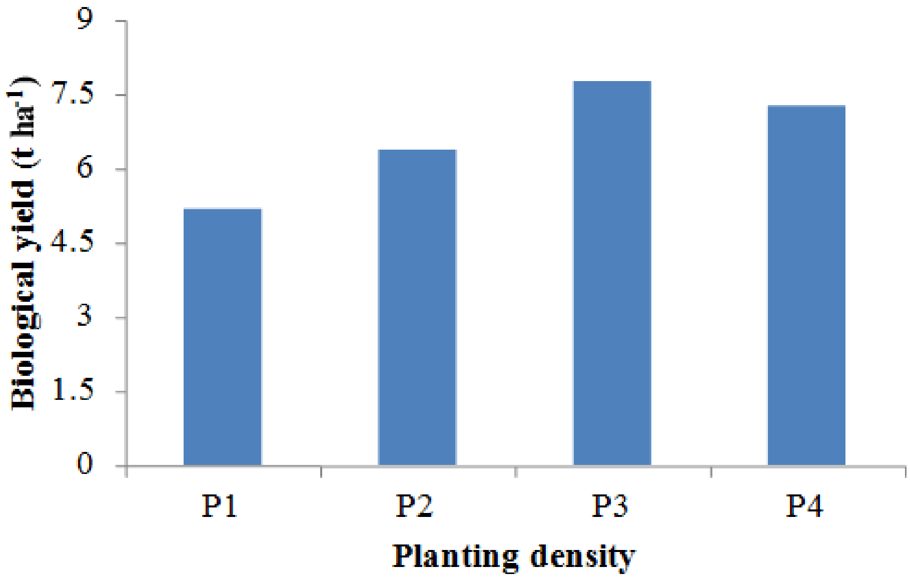


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 43. Effect of nitrogen levels on biological yield of mungbean (LSD $_{(0.05)}$ = 0.37)

4.2.14.2 Effect of planting density

Planting density had significant effect on biological yield (Figure 44). The P_3 produced significantly the highest biological yield (7.75 t ha^{-1}) over the treatment P_1 (5.18 t ha^{-1}). Similar result also found by Beheshti *et al.*, (2010) who studied grain Sorghum and Pinto Bean and reported that the effect of density on biomass yield was significant and the highest biomass yield was gained for both crops in a high-density planting situation. Rasul *et al.* (2012) also reported that the inter-row spacing of 30 cm and 45 cm produced 4131 and 4003.5 kg ha^{-1} of biological yield, respectively where the inter row spacing of 60 cm gave minimum biological yield (3328.9 kg ha^{-1}). The more biomass produced at narrower row spacing was due to more planting density contributing to the final biomass production. Same findings also reported by Ghasempour and Ashori (2014) and Khan *et al.* (2001).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 44. Effect of planting density on biological yield of mungbean (LSD $_{(0.05)}$ = 0.46)

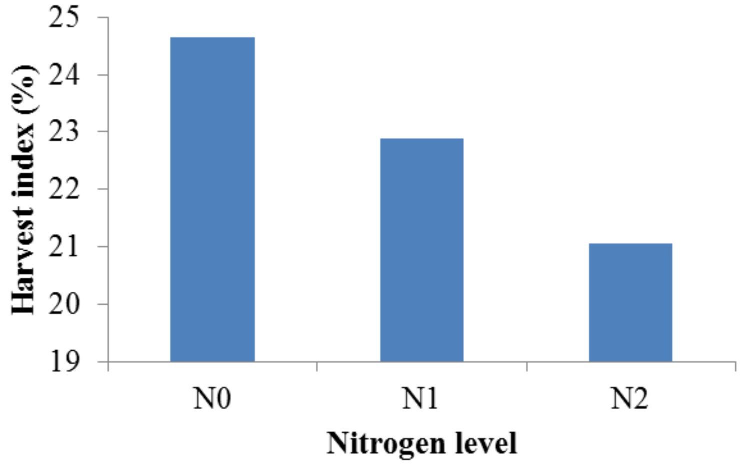
4.2.14.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen levels and planting density was found significant in respect of biological yield (Table 9). The highest biological yield (8.28 t ha^{-1}) was obtained from N_2P_3, which was similar to the interaction of N_0P_3 and N_1P_4. The lowest biological yield (4.83 t ha^{-1}) was obtained from N_0P_1 which was similar to the interaction of N_1P_1. This result was also coincided with Ghasempour and Ashori (2014) and Roshan *et al.*,(2007) who reported that the interactions between planting space and nitrogen fertilizer on straw beans became significant.

4.2.15 Harvest index (%)

4.2.15.1 Effect of nitrogen levels

Harvest index was significantly influenced by nitrogen levels (Figure 45). The highest harvest index (24.65 %) was found from the N_0 which was similar with N_1 and the lowest harvest index (21.06%) was found from the N_2 which was also similar with N_1. This finding was not coincide with the finding of Mahmoudi *et al.* (2013) who reported that nitrogen had significant effect on the mungbean harvest index.

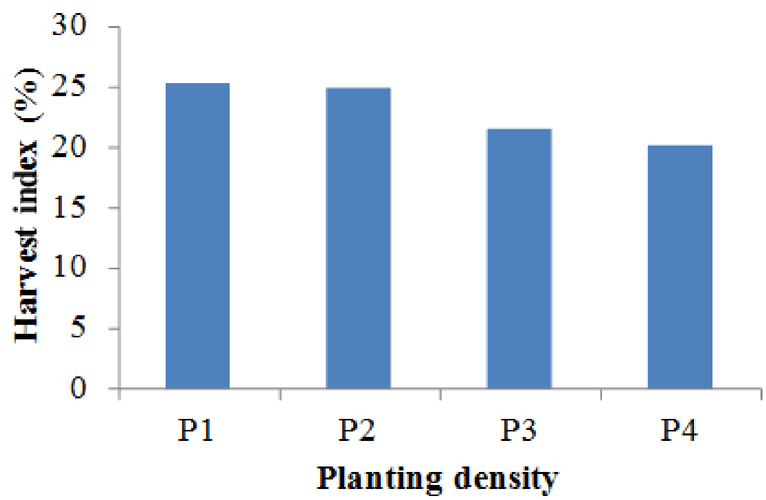


N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}

Figure 45. Effect of nitrogen levels on harvest index of mungbean (LSD $_{(0.05)}$ = 2.94)

4.2.15.2 Effect of planting density

Planting density had significant effect on harvest index (Figure 46). The highest harvest index (25.16%) was obtained from P_1 which was similar to P_2. The lowest harvest index (20.07%) was obtained from P_4 treatment which was similar to P_3. This might be due to because row spacing helped to get highest harvest index yield of mungbean as reported by Khan *et al.* (2001).



P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

Figure 46. Effect of planting density on harvest index of mungbean (LSD $_{(0.05)}$ = 1.75)

4.2.14.3 Interaction effect of nitrogen levels and planting density

Interaction effect between nitrogen levels and planting density was found significant in respect of harvest index (Table 9). The highest harvest index (27.99%) was obtained from N_0P_1 which was similar to the interaction of N_0P_2. The lowest harvest index (17.19%) was obtained from the N_2 with the interaction of $P_{3,}$ which was similar to the interaction of N_1P_4.

Table 9. Interaction effect of nitrogen levels and planting density on yield characters of mungbean

Treatment combination	Shelling percentage (%)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0P_1	69.04 a-c	1.34 d-f	3.49 f	4.83 e	27.99 a
N_0P_2	69.43 a	1.57 ab	4.24 e	5.81 d	27.48 ab
N_0P_3	66.89 a-c	1.66 a	6.20 b	7.85 ab	22.13 cd
N_0P_4	67.93 a-c	1.53 a-c	5.76 b-d	7.28 bc	20.99 de
N_1P_1	66.91 a-c	1.19 f	4.20 e	5.39 de	23.89 cd
N_1P_2	65.85 c	1.63 a	5.65 b-d	7.28 bc	24.35 c
N_1P_3	68.62 a-c	1.68 a	5.43 d	7.12 bc	24.92 bc
N_1P_4	66.21 a-c	1.38 c-e	6.15 bc	7.53 a-c	18.35 ef
N_2P_1	69.20 ab	1.20 ef	4.12 ef	5.32 de	23.60 cd
N_2P_2	66.00 bc	1.31 d-f	4.73 e	6.04 d	22.59 cd
N_2P_3	67.79 a-c	1.39 cd	6.89 a	8.28 a	17.19 f
N_2P_4	66.94 a-c	1.44 b-d	5.55 cd	6.99 c	20.86 de
LSD $_{(0.05)}$	**3.31**	**0.18**	**0.64**	**0.80**	**3.04**
CV (%)	**2.85**	**7.25**	**7.17**	**7.06**	**7.74**

N_0= 0 kg N ha^{-1}, N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}; P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was carried out at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from March to June, 2015 to find out the influence of nitrogen level and planting density on growth and yield of mungbean.

The experiment was laid out in a split-plot design with three replications. The size of the individual plot was 10.5 m^2 and total numbers of plots were 36. The experiment comprised with two factors viz. (i) nitrogen level & (ii) planting density. Three nitrogen levels (N_0= 0 kg N $ha^{-1,}$ N_1= 20 kg N ha^{-1} and N_2 = 40kg N ha^{-1}) and four planting density (P_1= 15 plants m^{-2}, P_2= 30 plants m^{-2}, P_3= 45 plants m^{-2} and P_4= 60 plants m^{-2}). There were 12 treatment combinations. Nitrogen level was placed in the main plot and planting density was placed in the sub plot. Data on different growth, yield contributing characters and yield were recorded from the experimental field and analyzed statistically.

The data on growth parameters viz. plant emergence was recorded at 8 DAS where plant height, number of leaves $plant^{-1}$, dry matter $plant^{-1}$, days to 1^{st} flowering, days required to 50% flowering were recorded during the period from 15 DAS to harvest. Number of nodules $plant^{-1}$ and dry weight of nodules $plant^{-1}$ were recorded once at maximum vegetative stage. Yield contributing characters and yield parameters like number of branches $plant^{-1}$, number of pods $plant^{-1}$ at 1^{st} harvest, number of pods $plant^{-1}$ at last harvest, number of total pods $plant^{-1}$, number of seeds pod^{-1} at 1^{st} harvest, number of seeds pod^{-1} at last harvest, pod length at 1^{st} harvest, pod length at last harvest, 1000 seed weight at 1^{st} harvest, 1000-seed weight at last harvest, shelling percentage, seed yield, stover yield, biological yield and harvest index were recorded.

Results of the experiment revealed that nitrogen level had no significant effect on most of the growth, yield contributing and yield parameters except plant height at 15 DAS, above ground dry weight $plant^{-1}$, number of nodules $plant^{-1}$, nodule dry weight $plant^{-1}$, number of pods $plant^{-1}$ at last harvest, shelling percentage, seed yield, stover yield, biological yield and harvest index. At 15 DAS, tallest plant (16.25 cm) was produced by N_2 (40kg N ha^{-1}) whereas the shortest one (15.07 cm) was recorded from N_1 (20 kg N ha^{-1}). At harvest maximum above ground dry matter plant^{-1} (22.17 g) was accumulated by N_2 (40kg N ha^{-1}) and the minimum (17.58 g) was accumulated by N_1 (20 kg N ha^{-1}) treatment. Maximum number of nodules plant^{-1} (21.07) was produced by N_1 (20 kg N ha^{-1}) and minimum number of nodules plant^{-1} (15.53) was produced by N_2 (40 kg N ha^{-1}). Same trend was observed for nodule dry weight plant^{-1}. Here, maximum nodule weight (7.67 mg) was recorded from N_1 (20 kg N ha^{-1}) and the minimum one (6.17 mg) was given by both N_0 (0 kg N ha^{-1}) and N_2 (40kg N ha^{-1}). The highest number of pods plant^{-1} at last harvest (13.05) was produced by N_2 (40kg N ha^{-1}) and the lowest number of pods plant^{-1} at last harvest (11.35) was recorded with no nitrogen application. The maximum shelling percentage (68.32%), seed yield (1.52 t ha^{-1}) and harvest index (24.65%) were recorded from no nitrogen application (N_0). The 20 kg N ha^{-1} (N_1) produced maximum stover yield (5.36 t ha^{-1}) and biological yield (6.83 t ha^{-1}). The minimum shelling percentage (66.90%), seed yield (1.34 t ha^{-1}), stover yield (4.92 t ha^{-1}), biological yield (6.45t ha^{-1}) and harvest index (21.06%) were recorded from N_1, N_2, N_0, N_0 and N_2 treatments, respectively.

Planting density significantly affected most of the growth, yield contributing and yield parameters except days required to 1st flowering, days required to 50% flowering, number of seeds pod^{-1} at 1st harvest, number of seeds pod^{-1} at last harvest, pod length at last harvest, 1000 seed weight at 1st harvest and shelling percentage but did not consistently gave the better performance . Among planting density, maximum seedling emergence (87. 44 m^{-2}) was recorded from planting density of P_4 (60 plants m^{-2}) and the lowest one (26.22 m^{-2}) was from P_1 (15 plants m^{-2}). The tallest plant (63.08 cm) was observed from P_3 (45 plants m^{-2}) whereas the shortest plant (53.85 cm) was recorded from P_1 (15 plants m^{-2}). The maximum number of leaves plant^{-1} (24.11) was produced by P_1 and the minimum (17.16) was from P_4 (60 plants m^{-2}). In case of number of branches plant^{-1} maximum value (2.31) was produced by P_1 and the minimum value (1.44) was produced by P_3 (45 plants m^{-2}). The maximum dry matter content plant^{-1} (23.78 g) was recorded from 15 plants m^{-2} while the minimum dry matter content plant^{-1} (14.44 g) was recorded from 60 plants m^{-2}. The maximum number of nodules plant^{-1} (20.53) was scored by 30 plants m^{-2} and the minimum one (16.53) was by 15 plants m^{-2}. Planting density of 45 plants m^{-2} produced maximum nodule dry weight $plant^{-1}$ (9.11 mg) and 15 plants m^{-2} produced minimum nodule dry weight $plant^{-1}$ (3.11 mg). The highest pods $plant^{-1}$ at 1^{st} harvest (22.73) was recorded in P_2 whereas the lowest pods $plant^{-1}$ at 1^{st} harvest (20.80) was recorded in P_3. The highest pods $plant^{-1}$ at last harvest (13.36) was recorded in P_3 whereas the lowest pods $plant^{-1}$ at last harvest (10.69) was recorded in P_4. The highest total pods $plant^{-1}$ (35.31) was recorded in P_2 whereas the lowest total pods $plant^{-1}$ (33.22) was recorded in P_4. The maximum pod length at 1^{st} harvest (8.76 cm) was given by P_1 while the minimum pod length at 1^{st} harvest (8.24 cm) was recorded from P_2. The maximum 1000 grain weight at last harvest (50.00 g) was recorded by 30 plants m^{-2} and the minimum 1000 grain weight at last harvest (48.56 g) was recorded by 45 plants m^{-2}. The maximum seed yield (1.58 t ha^{-1}) was obtained from treatment P_3 (45 plants m^{-2}) and the minimum seed yield (1.25 t ha^{-1}) was obtained from treatment P_1 (15 plants m^{-2}). The 45 plants m^{-2} gave 26.40% higher yield over 15 plants m^{-2}. The maximum stover yield (5.82 t ha^{-1}), biological yield (7.75 t ha^{-1}) and harvest index (25.16%) were recorded from P_4, P_3 and P_1, respectively. On the other hand the minimum stover yield stover yield (3.94 t ha^{-1}), biological yield (5.18 t ha^{-1}) and harvest index (20.07%) were recorded from P_1, P_1 and P_4, respectively.

In combination, it was observed that, different nitrogen level with planting density had significant effect on crop growth parameters except pod length at last harvest and 1000 seed weight at 1^{st} harvest. The maximum seedling emergence (96.33 m^{-2}) was recorded from no nitrogen (N_0) with planting density of 60 plants m^{-2} (P_4) and the lowest one (26.22 m^{-2}) was from 20 kg N ha^{-1} (N_1) with 15 plants m^{-2} (P_1). At harvest the tallest plant (64.44 cm) was observed from no nitrogen (N_0) in combination with 45 plants m^{-2} whereas the shortest plant (51.94 cm) was recorded from 40 kg ha^{-1} (N_2) with 15 plants m^{-2} (P_1). The maximum number of leaves $plant^{-1}$ (26.60) was produced by N_1P_1 treatment combination and the minimum (16.67) was from 60 plants m^{-2} where no nitrogen was applied. In case of number of branches $plant^{-1}$ maximum value (2.58) was produced by N_2P_1 and the minimum value (0.67) was produced by N_2P_4. The maximum dry matter content $plant^{-1}$ (28.67 g) was recorded from 15 plants m^{-2} with 40 kg ha^{-1} N was applied while the minimum dry matter content plant^{-1} (13.67 g) was recorded from 60 plants m^{-2} where no nitrogen was applied. The maximum number of nodules plant^{-1} (24.80) was scored by 20 kg ha^{-1} with 60 plants m^{-2} and the minimum one (7.87) was by 40 kg ha^{-1} with 60 plants m^{-2}. Planting density of 45 plants m^{-2} with 20 kg N ha^{-1} and planting density of 30 plants m^{-2} with 40 kg N ha^{-1} was applied produced maximum nodule dry weight plant^{-1} (11.33 mg) and 60 plants m^{-2} where 40 kg N ha^{-1} was applied produced minimum nodule dry weight plant^{-1} (2.00 mg). The maximum days required to 1st flowering (28.67) was recorded in both N_0P_1 and N_2P_2 whereas the minimum days required to 1st flowering (26.33) was recorded in N_1P_2. The maximum days required to 50% flowering (41.33) was recorded in N_2P_4 whereas the minimum days required to 50% flowering (38.67) was recorded in N_1P_1. The highest pods plant^{-1} at 1st harvest (26.20) was recorded in N_2P_4 whereas the lowest pods plant^{-1} at 1st harvest (19.33) was recorded in both N_2P_3 and N_2P_2. The highest pods plant^{-1} at last harvest (16.13) was recorded in N_2P_2 whereas the lowest pods plant^{-1} at last harvest (9.73) was recorded in N_0P_2. The highest pods plant^{-1} (37.07) was recorded in N_1P_2 whereas the lowest pods plant^{-1} (30.27) was recorded in N_1P_4. The highest seeds pod^{-1} at 1st harvest (11.73) was recorded in N_1P_4 whereas the lowest seeds pod^{-1} at 1st harvest (10.33) was recorded in N_2P_2. The highest seeds pod^{-1} at last harvest (12.07) was recorded in N_0P_3 whereas the lowest seeds pod^{-1} at last harvest (10.97) was recorded in N_1P_1. The maximum pod length at 1st harvest (9.02 cm) was given by N_1P_1 while the minimum pod length at 1st harvest (8.05 cm) was recorded from N_0P_3. The maximum 1000 grain weight at last harvest (51.33 g) was recorded in 30 plants m^{-2} where no nitrogen was applied and the minimum 1000 grain weight at last harvest (48.33 g) was recorded in 45 plants m^{-2} where 40 kg N ha^{-1} was applied. The maximum shelling percentage (69.43) was recorded in N_0P_2 whereas the minimum shelling percentage (38.67) was recorded in N_1P_2. The maximum seed yield (1.68 t ha^{-1}) was obtained from treatment 45 plants m^{-2} where 20 kg N ha^{-1} was applied and the minimum seed yield (1.19 t ha^{-1}) was obtained from treatment 15 plants m^{-2} where 20 kg N ha^{-1} was applied. The 45 plants m^{-2} with 20 kg N ha^{-1} was applied gave 41.18% higher yield over treatment 15 plants m^{-2} with 20 kg N ha^{-1} was applied. The maximum stover yield (6.89 t ha^{-1}) and biological yield (8.28 t ha^{-1}) were recorded from N_2P_3. On the other hand the minimum stover yield (3.49 t ha^{-1}) and biological yield (4.83

t ha^{-1}) were recorded from N_0P_1. The maximum harvest index (27.99%) and minimum harvest index (17.19%) were recorded from N_0P_1 and N_2P_3 treatment combinations, respectively.

It may be concluded that:

- For mungbean cultivation, application of 20 kg N ha^{-1} could be better nitrogen management practice
- Planting density with 45 plants m^{-2} could be optimum population for optimum growth and yield of mungbean
- The application of 20 kg N ha^{-1} with 45 plants m^{-2} could be the better production package for maximum growth and yield of mungbean.

RECOMMENDATION

This type of experiment with other varieties and of different nitrogen levels and plant densities could be conducted in different mungbean growing areas of Bangladesh for further testing and final recommendation.

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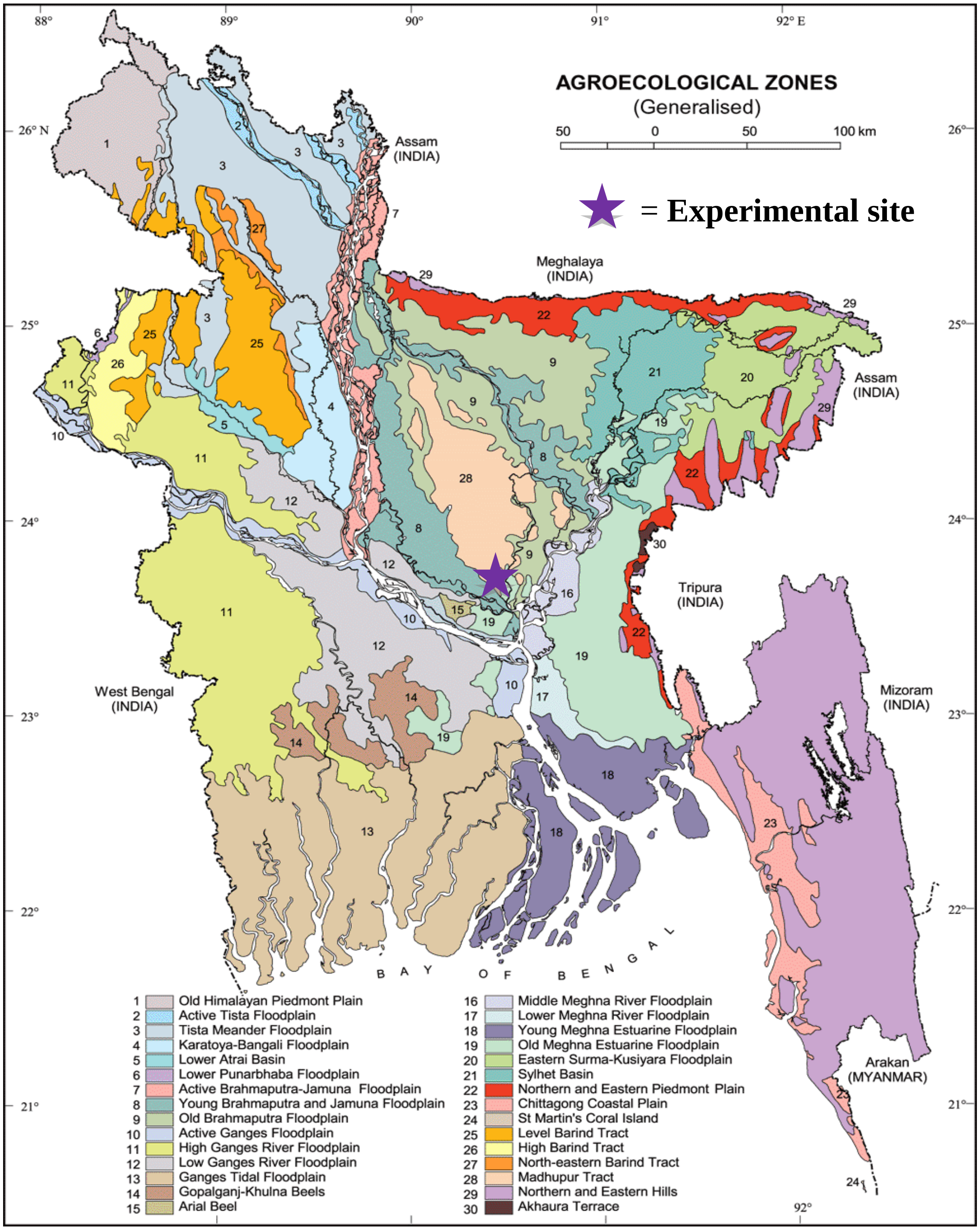
APPENDICES

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



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Analysis of variance of the data on plant height of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square value of	Mean square of plant height at different days after sowing (DAS)			
		Seedling emergence	15	30	45	At harvest
Replication	2	119.69	3.78	26.99	132.01	162.58
Nitrogen (A)	2	30.78^{NS}	5.37*	0.73^{NS}	4.56^{NS}	22.52^{NS}
Error	4	14.28	0.62	13.88	13.75	19.65
Planting density (B)	3	6185.52*	8.78*	45.55*	95.13*	133.02*
Nitrogen (A) X Planting density (B)	6	165.30*	2.32*	9.56*	18.16*	11.60*
Error	18	33.12	2.46	9.85	10.23	13.72

*Significant at 5% level of significance

^{NS} Non significant

Appendix IV. Analysis of variance of the data on number of leaves plant^{-1} of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square of number of leaves plant^{-1} at different days after sowing (DAS)			
		15	30	45	At harvest
Replication	2	0.15	9.95	0.42	1.31
Nitrogen (A)	2	0.16^{NS}	3.31^{NS}	15.46^{NS}	3.60^{NS}
Error	4	0.06	1.70	4.73	1.71
Planting density (B)	3	0.26*	36.88*	151.28*	76.51*
Nitrogen (A) X Planting density (B)	6	0.82*	1.71*	5.29*	5.78*
Error	18	0.12	0.93	4.63	3.51

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on number of branches plant^{-1} of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square of number of branches plant^{-1} at different days after sowing (DAS)		
		30	45	At harvest
Replication	2	0.003	0.05	0.02
Nitrogen (A)	2	0.001^{NS}	0.05^{NS}	0.10^{NS}
Error	4	0.003	0.02	0.03
Planting density (B)	3	2.44*	2.65*	2.85*
Nitrogen (A) X Planting density (B)	6	0.05*	0.14*	0.16*
Error	18	0.01	0.02	0.02

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on above ground dry weight plant^{-1} of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square of above ground dry weight plant^{-1} at different days after sowing (DAS)			
		15	30	45	At harvest
Replication	2	0.12	0.08	0.17	2.33
Nitrogen (A)	2	0.33^{NS}	1.68*	41.91*	66.08*
Error	4	0.18	0.12	0.28	1.92
Planting density (B)	3	2.48*	9.53*	53.53*	136.47*
Nitrogen (A) X Planting density (B)	6	9.37*	1.62*	3.74*	17.64*
Error	18	0.16	0.11	0.54	3.06

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on No. of nodule plant^{-1}, nodule dry weight plant^{-1}, days to 1st flowering and Days to 50% flowering of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square value			
		No. of nodule plant^{-1}	Nodule dry weight plant^{-1}	Days to 1st flowering	Days to 50% flowering
Replication	2	0.64	0.07	1.08	0.03
Nitrogen (A)	2	97.61*	9.00*	4.08^{NS}	10.78^{NS}
Error	4	4.50	0.25	8.67	8.32
Planting density (B)	3	29.00*	61.33*	0.47^{NS}	0.33^{NS}
Nitrogen (A) X Planting density (B)	6	67.49*	29.00*	1.42*	0.33*
Error	18	1.41	0.51	0.55	1.22

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on pods plant^{-1} at 1st harvest, pods plant^{-1} at last harvest, total pods plant^{-1}, seeds pod^{-1} at 1st harvest and seeds pod^{-1} at last harvest of mungbean as influenced nitrogen levels, planting density and their interaction

Source of variation	df	Mean square value				
		Pods plant^{-1} at 1st harvest	Pods plant^{-1} at last harvest	Total pods plant^{-1}	Seeds pod^{-1} at 1st harvest	Seeds pod^{-1} at last harvest
Replication	2	3.64	1.98	2.67	0.44	0.01
Nitrogen (A)	2	2.64^{NS}	9.42*	2.93^{NS}	0.35^{NS}	0.22^{NS}
Error	4	3.10	1.35	13.40	0.30	0.09
Planting density (B)	3	6.84*	11.96*	6.92*	0.61^{NS}	0.30^{NS}
Nitrogen (A) X Planting density (B)	6	23.03*	9.98*	21.82*	0.64*	0.62*
Error	18	2.91	0.59	4.29	0.49	0.32

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on pod length at 1st harvest, pod length at last harvest, 1000-seed weight at 1st harvest, 1000-seed weight at last harvest and shelling percentage of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square value				
		Pod length at 1st harvest	Pod length at last harvest	1000 seed weight at 1st harvest	1000 seed weight at last harvest	Shelling percentage
Replication	2	0.43	0.14	0.36	3.03	1.24
Nitrogen (A)	2	0.58NS	0.15NS	0.11NS	4.36NS	6.15*
Error	4	0.17	0.06	0.28	2.03	1.09
Planting density (B)	3	0.62*	0.33NS	2.62NS	4.32*	3.69NS
Nitrogen (A) X Planting density (B)	6	0.16*	0.06NS	2.70NS	0.66*	5.17*
Error	18	0.14	0.23	3.12	0.88	3.72

*Significant at 5% level of significance

NS Non significant

Appendix X. Analysis of variance of the data on seed yield, stover yield, biological yield and harvest index of mungbean as influenced by nitrogen levels, planting density and their interaction

Source of variation	df	Mean square value			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.02	0.06	0.11	0.20
Nitrogen (A)	2	0.11*	0.71*	0.45*	38.58*
Error	4	0.01	0.09	0.11	6.71
Planting density (B)	3	0.18*	9.11*	11.47*	56.94*
Nitrogen (A) X Planting density (B)	6	0.03*	1.06*	0.99*	16.83*
Error	18	0.01	0.14	0.22	3.14

*Significant at 5% level of significance

NS Non significant