INFLUENCE OF NITROGEN FERTILIZER AND PLANT DENSITY ON THE PERFORMANCE OF BLACKGRAM

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CERTIFICATE

This is to certify that the thesis entitled 'Influence of Nitrogen Fertilizer and Plant Density on the Performance of Blackgram' **submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of** MASTER OF SCIENCE in AGRONOMY, **embodies the results of a piece of bonafide research work carried out by** MUNMUN DAS, **Registration No.** 10-04046 **under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.**

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated:
Dhaka, Bangladesh

Prof. Dr. Parimal Kanti Biswas
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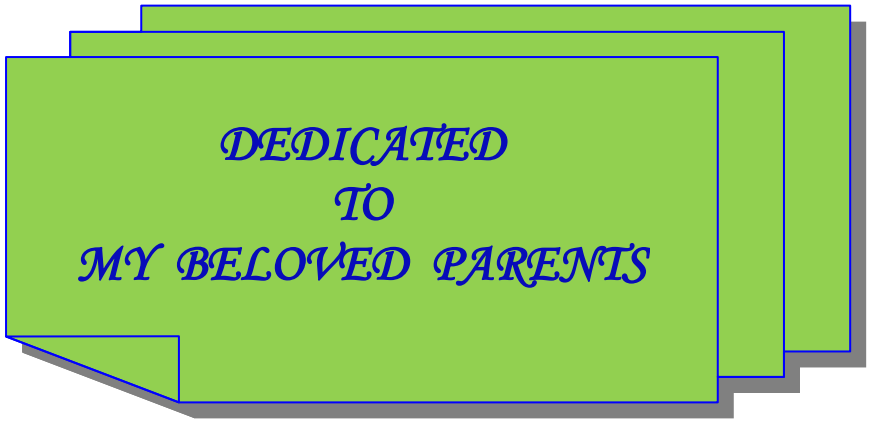
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TO
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INFLUENCE OF NITROGEN FERTILIZER AND PLANT DENSITY ON THE PERFORMANCE OF BLACKGRAM

ABSTRACT

The experiment was conducted during the period from March to June, 2015 at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka to find out the influence of nitrogen fertilizer and plant density on the performance of blackgram. Blackgram variety BARI Mash-3 (Hemantoo) was used as planting material for the study. The experiment comprised of two factors; Factor A: Levels of nitrogen (3 levels)- N_0: 0 kg N ha^{-1} (control), N_1: 20 kg N ha^{-1}, N_2: 40 kg N ha^{-1} and Factor B: Plant density (4 levels)- D_1: 15 plants m^{-2}, D_2: 30 plants m^{-2}, D_3: 45 plants m^{-2}, D_4: 60 plants m^{-2}. The experiment was laid out in a split-plot design with three replications. Nitrogen level were assigned to main plots and plant densities to sub plots. Data on different yield parameters and yield of blackgram were recorded and statistically significant variation was observed for different treatments. In case of nitrogen fertilizer, at harvest the tallest plant (61.91 cm), the longest pod (5.59 cm), the highest weight of 1000-seeds (40.83 g) and the highest seed yield (1.23 t ha^{-1}) were found from N_2(40 kg N ha^{-1}), while the shortest plant (56.20 cm), the shortest pod (5.14 cm), the lowest weight of 1000-seeds (36.88 g) and the lowest seed yield (0.89 t ha^{-1}) were recorded from N_0(0 kg N ha^{-1}). For plant density, at harvest, the tallest plant (62.97 cm), the longest pod (5.70 cm), the highest weight of 1000-seeds (40.83 g) and the highest seed yield (1.19 t ha^{-1}) were recorded from D_3 (45 plants m^{-2}) and the shortest plant (57.62 cm) was found from D_1 (15 plants m^{-2}), while the shortest pod (5.07 cm), the lowest weight of 1000-seeds (37.83 g) and the lowest seed yield (0.93 t ha^{-1}) were recorded from D_4 (60 plants m^{-2}). Due to the interaction effect of nitrogen fertilizer and plant density, at harvest the tallest plant (68.29 cm), the longest pod (5.98 cm), the highest weight of 1000-seeds (42.34 g) and the highest seed yield (1.49 t ha^{-1}) were recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the shortest plant (51.18 cm) recorded from N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}) but the shortest pod (4.82 cm), the lowest weight of 1000-seeds (34.33 g) and the lowest seed yield (0.73 t ha^{-1}) were found from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). From the above results it was appeared that 40 kg N ha^{-1} with 45 plants m^{-2} provided the best yield attributes and yield of blackgram cv. BARI Mash-3.

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SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
and others	*et al.*
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Co-efficient of variation	cv
Days After Sowing	DAS
Degree Celsius	^{0}C
Duncan Multiple Range Test	DMRT
Etcetera	etc
Food and Agriculture Organization	FAO
gram	g
Millimeter	mm
Muriate of Potash	MoP
Parts per million	ppm
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Square meter	m^2
ton per hectare	t ha^{-1}
Triple Super Phosphate	TSP

CHAPTER I

INTRODUCTION

Blackgram (*Vigna mungo* L.) locally known as maskalai belongs to the family Fabaceae and it is a self pollinating and widely cultivated grain legume (Naga *et al*., 2006). It is a deep rooted drought hardy crop, source of fodder, green mannuring, pluses and lavish iron and zinc rich minerals (Singh *et al*., 2013). Blackgram is originated in south and southeast Asia but widely grown in India, Pakistan, Bangladesh, Myanmar, Thailand, Philippines, China and Indonesia (Poehlman, 1991). It is an important pulse crop of Bangladesh and ranks the fourth position considering both acreage and production (MoA, 2014). This crop is grown in Bangladesh in cropping systems as a mixed crop, cash crop, sequential crop besides growing as sole crop under residual moisture conditions after the harvest of rice and also before and after the harvest of other summer crops under semi irrigated and dry land conditions (Parveen *et al*., 2011). The crop is resistant to adverse climatic conditions and improves the soil fertility by fixing atmospheric nitrogen in the soil.

As an excellent source of plant protein blackgram is cultivated extensively in the tropics and subtropics. It's grain contains 59% carbohydrates, 24% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981 and Kaul, 1982). According to FAO (2013) recommendation, a minimum intake of pulse by a human should be 80 g day^{-1}, whereas it is 7.92 g in Bangladesh (BBS, 2012). Bangladesh needs more than 2299 thousand tons of pulses to meet the demand of a population of millions at present situation (FAO, 2012; BBS, 2012). However, the country produced only 474 thousand tons which was only *29.53%* of the total demand. In 2011-2012, the country produced only 18,000 tons of blackgram which was less than 5.26% of the immediate previous year (BBS, 2012). In Bangladesh, it can be grown both in summer and winter seasons.

Blackgram plays an important role to supplement protein in the cereal-based low-protein diet of the people of Bangladesh, but the average production of blackgram is gradually declining day by day (BBS, 2012). The average yield of blackgram is 0.7 t ha^{-1} which is incomparable with the average yield of developed countries of the world (BBS, 2013). Basically it is cultivated with minimum tillage, local varieties with no or minimum fertilizers, no pesticides, no weed management and very early or very late sowing, no practicing of irrigation and drainage facilities etc., which are responsible for low yield of blackgram. The low yield of blackgram besides other factors may partially be due to lack of knowledge regards to suitable production technology of this crop (Hossain *et al*., 2008). Application of judicious levels of nitrogen and suitable plant density is prerequisite for increasing the production of blackgram in Bangladesh.

Among the fertilizers, the optimum doses of nitrogenous fertilizer plays vital role for the growth and development of plant and its growth is seriously hampered when lower dose of nitrogen is applied, which drastically reduced yield; further, excessive nitrogen fertilization encourages excessive vegetative growth which make the plant susceptible to insect pests and diseases which ultimately reduces yield. Being leguminous in nature, blackgram needs low but optimum nitrogen during onset of flowering and podding. Pulses although fix nitrogen from the atmosphere; there is evident that the application of supplemental nitrogenous fertilizers becomes helpful is increasing the yield of blackgram (Patel *et al.*, 1984; Ardeshana *et al.*, 1993). It was revealed that pulse crop stop to nourish *Rhizobia* rather translocate energy towards development of flowers and pods. Thus, nitrogen fixation is totally ceased during reproductive stage which eventually hampers the development of reproductive traits due to shortage of energy. Many research works revealed a significant response of blackgram to nitrogen fertilizer and the results revealed that the application of nitrogen showed a significant increment in the yield attributes and yield of blackgram (Tomar *et al*., 2013; Sharma and Abraham, 2010; Kulsum *et al*., 2007).

Yield components and seed yield of blackgram are markedly influenced by planting density. The farmers of our country usually grow blackgram without maintaining proper planting density. Plant density may vary with genotype, time of sowing, growing condition, management practices and also other factors (Sekhon *et al*., 2002). Generally, wider plant spacing, which intercepted more photosynthetically active radiation owing to better geometric situation, results in vigorous plant growth and more number of branches and leaves as compared to narrow spacing (Murade *et al*., 2014). Vigorous development of the growth attributes (branches and leaves plant^{-1}) ultimately increases the dry matter accumulation plant^{-1}. On the other hand, higher plant density produces taller and lesser branched plants and their lower leaves can not receive sufficient solar radiation to accelerate photosynthetic activities. Thus lower leaves become parasitic due to high rate of respiration in which larger quantities of stored photosynthates are consumed than produced in photosynthesis (Tomar *et al*., 2013). Higher rate of photosynthesis results more production of food materials that is accumulated as dry matter in plants and shows the vigorous growth and development.

Under the above mention context and situation, the present experiment was conducted to find out the performance of blackgram in response of nitrogen fertilizer and plant density with the following objectives:

- to study the effect of basal nitrogen dose on the growth and yield of blackgram;
- to determine the optimum plant population for maximum yield of blackgram and
- to find out the interaction effect of nitrogen and plant population on the performance of blackgram.

CHAPTER II

REVIEW OF LITERATURE

Blackgran is an important pulse crop in Bangladesh as well as in many countries of the world although the crop has conventional less attention by the researchers on various aspects. Basically it grows in fallow land or as intercropped without or minimum care or management practices. Although nitrogen fertilizer and plant density of blackgram play an important role in improving yield but research works related to nitrogen fertilizer and plant density on blackgram are limited and not conclusive in the context of Bangladesh. However, some of the important and informative works and research findings related to nitrogen fertilizer and plant density on blackgram so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Performance of Blackgram in Response to Nitrogen Fertilizer

2.1.1 Plant height

A field experiment was carried out by Mishra (2016) to find out the effect of growth regulator, organic and inorganic foliar nutrition on yield and yield attributes of blackgram in the department of crop physiology at Vindhya Science & Agricultural Research Institute, Raushar, Rewa. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values in growth attributes like plant height.

Tomar *et al*. (2013) conducted an experiment at Janta Vedic College, Ch. Charan Singh University, Baraut, Baghpat-250 611 (Uttar Pradesh) and reported that plant height positively increased with the increase in levels of nitrogen.

Ekanayake *et al*. (2011) conducted a field experiment to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed

rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that the plant height varied with nitrogenous fertilizer rates and application of 30 kg of N ha^{-1} produced tallest plant.

An experiment was conducted by Sharma and Abraham (2010) during the *kharif* season at Allahabad (U.P.) to study the effect of zinc with and without organic and inorganic fertilizer on blackgram. There were eight treatment combinations with two levels of nitrogen (N_0- 0 kg N ha^{-1}, N_1-20 kg N ha^{-1}), zinc (Z_0- 0 kg Zn ha^{-1}, Z_1-15 kg Zn ha^{-1}) and farmyard manure (F_0- 0 t FYM ha^{-1}, F_1-10 t FYM ha^{-1}). The results revealed that the application of nitrogen @ 20 kg ha^{-1} showed a significant increment in the plant height of blackgram over the control.

Kulsum *et al*. (2007) conducted an experiment to evaluate the performance of blackgram under various levels of nitrogen at the Agronomy research site of Bangabandhu Sheikh Mujibur Rahman Agricultural University. Two varieties of blackgram BARI mash 3 and Bina mash 1 and six level of nitrogen i.e., 0, 20, 40, 60, 80 and 100 kg ha^{-1} N ha^{-1} were the treatment variables. Data revealed that different morphological characters were affected significantly by the nitrogen level and the longest plant was measured with 100 kg N ha^{-1}.

Saini and Thakur (1996) carried out an experiment and stated that nitrogen @ 30 and 40 kg ha^{-1} significantly increased the plant height of blackgram compared with no application of N.

Jamro *et al*. (1990) observed from a study that application of nitrogen significantly increased the plant height of blackgram and the tallest plant was recorded from the application of 90 kg N ha^{-1}.

Yein *et al.* (1981) conducted a field experiment on nitrogen in combination with phosphorus fertilizer to blackgram and revealed that application of 40 kg N ha^{-1} increased plant height.

2.1.2 Leaves and branches plant^{-1}(no.)

Tomar *et al*. (2013) conducted a field experiment in Uttar pradesh during summer seasons to study the effect of plant densities, nitrogen and phosphorus on blackgram. The treatments were compared three plant density (500 × 103, 400 × 103 and 333 × 103 plants ha^{-1}), two levels of nitrogen and four levels of phosphorus and found that the number of branches plant^{-1} increased with the increase in the levels of nitrogen.

A field experiment was conducted by Ekanayake *et al*. (2011) at the Field Crops Research and Development Institute, Mahailluppllama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that number of leaves plant^{-1} significantly varied with fertilizer rates.

Kulsum *et al*. (2007) conducted an experiment to evaluate the performance of blackgram under various levels of nitrogen at the Agronomy research site of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. Two varieties of blackgram BARI mash 3 and Bina mash 1 and six level of nitrogen i.e., 0, 20, 40, 60, 80 and 100 kg ha^{-1} N ha^{-1} were the treatment variables. Data revealed that different morphological characters and the largest leaf was obtained with 80 kg N ha^{-1}.

2.1.3 Total dry matter production

Surendar *et al*. (2013) carried out a field experiment in the department of crop physiology at TNAU to study the effect of basal application of nitrogen in combination with foliar spray of urea and plant growth regulators. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values of total dry matter production.

Sharma and Abraham (2010) carried out an experiment during the kharif season at Allahabad (U.P.) to study the effect of zinc with and without organic and inorganic fertilizer on blackgram. There were eight treatment combinations with two levels of nitrogen (N_0- 0 kg N ha^{-1}, N_1-20 kg N ha^{-1}), zinc (Z_0- 0 kg Zn ha^{-1}, Z_1-15 kg Zn ha^{-1}) and farmyard manure (F_0- 0 t FYM ha^{-1}, F_1-10 t FYM ha^{-1}). The results of the study revealed that the application of nitrogen @ 20 kg ha^{-1} showed a significant increment of dry matter content of blackgram over the control.

Yakadri *et al.* (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of blackgram and reported that application of nitrogen at 20 kg ha^{-1} resulted in the significant increase of leaf dry matter.

Leelavathi *et al*. (1991) reported that different levels of nitrogen fertilizer significantly increased dry matter production of blackgram and the highest total dry matter was observed in 60 kg N ha^{-1}.

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

Surendar *et al*. (2013) carried out a field experiment in the department of crop physiology at TNAU to study the effect of basal application of nitrogen in combination with foliar spray of urea and plant growth regulators. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values in number of pods plant^{-1}.

An experiment was carried out by Kulsum (2003) and reported that different levels of nitrogen showed significantly increased number of pods plant^{-1} of blackgram and the maximum number of pods plant^{-1} was recorded from the application of N @ 60 kg ha^{-1}.

Application of 90 kg N ha^{-1} to blackgram resulted in appreciable improvement in the number of pods plant^{-1} reported by Jamro *et al*., (1990).

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

A field experiment conducted by Ekanayake *et al*. (2011) at the Field Crops Research and Development Institute, Mahailluppllama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that the maximum number of seeds pod^{-1} was obtained when N is supplied at the rate of 30 kg ha^{-1}.

Kulsum *et al*. (2007) conducted an experiment to evaluate the performance of blackgram under various levels of nitrogen at the Agronomy research site of Bangabandhu Sheikh Mujibur Rahman Agricultural University. Two varieties of blackgram BARI mash 3 and BINA mash 1 and six level of nitrogen i.e., 0, 20, 40, 60, 80 and 100 kg ha^{-1} N ha^{-1} were the treatment variables. Data revealed that different morphological characters and the maximum number of seeds plant^{-1} was recorded with 80 kg N ha^{-1}.

Yakadri *et al.* (2002) carried out an experiment to find out the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of blackgram and reported that application of nitrogen at 20 kg ha^{-1} resulted in the significant increase number of seeds plant^{-1}.

2.1.6 Pod length

Mishra (2016) carried out a field experiment to find out the effect of growth regulator, organic and inorganic foliar nutrition on yield and yield attributes of blackgram in the department of crop physiology at Vindhya Science & Agricultural Research Institute, Raushar, Rewa. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide was found to be the most effective treatment in improving pod length of blackgram.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that the longest pod of blackgram was obtained when N is supplied at the rate of 30 kg ha^{-1}.

A field experiment carried out by Surendar *et al*. (2013) in the department of crop physiology at TNAU to study the effect of basal application of nitrogen in combination with foliar spray of urea and plant growth regulators. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values of pod length of blackgram.

Kulsum *et al*. (2007) conducted an experiment to evaluate the performance of blackgram under various levels of nitrogen at the Agronomy research site of Bangabandhu Sheikh Mujibur Rahman Agricultural University. Two varieties of blackgram BARI mash 3 and Bina mash 1 and six level of nitrogen i.e., 0, 20, 40, 60, 80 and 100 kg ha^{-1} N ha^{-1} were the treatment variables. Data revealed that the longest pod was recorded with 80 kg N ha^{-1}.

2.1.7 1000-seed weight

Surendar *et al*. (2013) carried out a field experiment in the department of crop physiology at TNAU to study the effect of basal application of nitrogen in combination with foliar spray of urea and plant growth regulators. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values in growth attributes viz., 1000-seed weight.

A field experiment was conducted by Ekanayake *et al*. (2011) at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that 1000 seed weight varied with the fertilizer level.

Patel and Patel (1991) found that application of nitrogen, phosphorus and potassium fertilizers resulted in significant increases in 1000 seed weight of blackgram.

2.1.8 Seed yield

Mishra (2016) carried out a field experiment to find out the effect of growth regulator, organic and inorganic foliar nutrition on yield and yield attributes of blackgram in the department of crop physiology at Vindhya Science & Agricultural Research Institute, Raushar, Rewa. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide was found to be the most effective treatment in improving the grain yield by 27 percent over control.

Surendar *et al*. (2013) carried out a field experiment in the department of crop physiology at TNAU to study the effect of basal application of nitrogen in combination with foliar spray of urea and plant growth regulators. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values in growth attributes viz., leaf area index, crop growth rate, net assimilation rate and specific leaf weight by showing higher accumulation of total dry matter production with increased yield.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum

seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that the maximum yield was recorded when N is supplied @ 30 kg ha^{-1}.

An experiment was conducted by Sharma and Abraham (2010) during the kharif season at Allahabad (U.P.) to study the effect of zinc with and without organic and inorganic fertilizer on blackgram. There were eight treatment combinations with two levels of nitrogen (N_0- 0 kg N ha^{-1}, N_1-20 kg N ha^{-1}), zinc (Z_0- 0 kg Zn ha^{-1}, Z_1-15 kg Zn ha^{-1}) and farmyard manure (F_0- 0 t FYM ha^{-1}, F_1-10 t FYM ha^{-1}). The results of the study revealed that the application of nitrogen @ 20 kg ha^{-1} showed a significant increment in the yield, and yield attributes of blackgram over the control.

Kulsum *et al*. (2007) conducted an experiment to evaluate the performance of blackgram under various levels of nitrogen at the Agronomy research site of Bangabandhu Sheikh Mujibur Rahman Agricultural University. Two varieties of blackgram BARI mash 3 and Bina mash 1 and six level of nitrogen i.e., 0, 20, 40, 60, 80 and 100 kg ha^{-1} N ha^{-1} were the treatment variables. Data revealed that yield were affected significantly by the nitrogen levels. Application of 60 kg N ha^{-1} favored most of the yield contributing characters that contributed the maximum grain yield of blackgram.

Saini and Thakur (1996) stated that application of nitrogen significantly increased the grain yield $plant^{-1}$ of blackgram and the application of 30 kg N ha^{-1} produced the highest seed yield.

Bhalu *et al.* (1995) observed that seed yield and biological yield of blackgram increased with the application of up to 20 kg N ha^{-1}. Yadav *et al*. (1994) reported that higher seed yield of blackgram was observed with 20 kg N ha^{-1}. Singh *et al*. (1993) reported increased seed yield of blackgram with N 20 kg ha^{-1}.

Vidhate *et al.* (1986) explored the response of blackgram to nitrogen fertilization. They observed that an increase in the dose of N fertilizer increased the grain yield. Higher percent of grain yield increased when equal dose of 25 kg N ha^{-1} applied at sowing and at flowering.

2.1.9 Harvest Index

Surendar *et al*. (2013) carried out a field experiment in the department of crop physiology at TNAU to study the effect of basal application of nitrogen in combination with foliar spray of urea and plant growth regulators. Among the treatments, the basal application of nitrogen 25kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed the higher values in harvest index with highest grain yield.

An experiment was conducted by Sharma and Abraham (2010) during the kharif season at Allahabad (U.P.) to study the effect of zinc with and without organic and inorganic fertilizer on blackgram. There were eight treatment combinations with two levels of nitrogen (N_0- 0 kg N ha^{-1}, N_1-20 kg N ha^{-1}), zinc (Z_0- 0 kg Zn ha^{-1}, Z_1-15 kg Zn ha^{-1}) and farmyard manure (F_0- 0 t FYM ha^{-1}, F_1-10 t FYM ha^{-1}). The results of the study revealed that the application of nitrogen @ 20 kg ha^{-1} showed a significant increment in harvest index of blackgram.

Kulsum *et al*. (2007) conducted an experiment to evaluate the performance of blackgram under various levels of nitrogen at the Agronomy research site of Bangabandhu Sheikh Mujibur Rahman Agricultural University. Two varieties of blackgram BARI mash 3 and BINA mash 1 and six level of nitrogen i.e., 0, 20, 40, 60, 80 and 100 kg ha^{-1} N ha^{-1} were the treatment variables. Data revealed that harvest index were affected significantly by the nitrogen levels.

Saini and Thakur (1996) stated that application of nitrogen significantly increased the grain yield $plant^{-1}$ blackgram and the application of 30 kg N ha^{-1} produced the highest harvest index.

2.2 Performance of Blackgram in Response to Plant Density/Spacing

2.2.1 Plant height

Tanya *et al*. (2015) conducted an experiment at experimentation centre and research field of School of Forestry & Environment, SHIATS, Allahabad, to study the effect of spacing on the growth and yield of different varieties of blackgram and they found the maximum plant height (36.73 cm) from 30 cm × 15 cm row to row and plant to plant spacing.

Kumar *et al*. (2013) conducted several field experiment in Chhattisgarh, India, to determine the effect of plant density on the growth, nodulation and yield of black gram cultivars. The treatments comprised 2 row spacing (30 × 10 cm and 45 × 10 cm), 3 cultivars and 3 seed treatments. Results showed that the increase in row spacing decreased the plant height, with Indira Urd-1 being the tallest.

A field experiment was carried out by Tomar *et al*. (2013) at Janta Vedic College, Ch. Charan Singh University, Baraut, Baghpat-250 611 (Uttar Pradesh) and reported that plant height was positively increased with the increase in plant density.

Ihsanullah *et al*. (2012) carried out an experiment in Malakandher Research Farm, under irrigated condition of Peshawar valley during summer to observe the influence of various inter-row spacing on blackgram. They observed the highest plant height of 47.50 cm in 43 cm row spacing where plants were spaced 7 cm within rows.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahailluppllama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that the plant height did not vary with the seed rate.

A field experiment was carried out by Kabir *et al*. (2002) to investigate the effects of six different seed rates viz., 15, 17.5, 20, 22.5, 25 and 27.5 kg ha^{-1} on the growth, yield and yield attributes of mash bean (*Vigna mungo*) in two consecutive years and their results revealed that 20 kg^{-1} seed gave the highest plant height.

2.2.2 Leaves and branches $plant^{-1}$(no.)

Tanya *et al.* (2015) carried out an investigation to study the effect of spacing on the growth and yield of different varieties of black gram at experimentation centre and research field of School of Forestry & Environment, SHIATS, Allahabad and reported the maximum number of branches $plant^{-1}$ (7.26) in 40 cm ×15 cm spacing.

A field experiment was conmducted by Murade *et al*. (2014) at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during Kharif season on Blackgram genotype AKU-07-04 and concluded that the numbers of branches and leaves $plant^{-1}$ were significantly higher with the spacing of 45 × 10 cm (S_2) as compared to the spacing of 30 × 10 cm (S_1) at harvest. They reported that wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth and more number of branches and leaves as compared to narrow spacing.

Tomar *et al*. (2013) conducted a field experiment in uttara pradesh during summer seasons to study the effect of plant densities, nitrogen and phosphorus on blackgram. The treatments were compared three plant density (500 × 103, 400 × 103 and 333 × 103 plants ha^{-1}), two levels of nitrogen and four levels of phosphorus were and found that the branches increased with the decrease in plant density.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on

rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that number of leaf $plant^{-1}$ did not vary with the seed rate.

2.2.3 Total dry matter production

A field trial was carried out by Murade *et al*. (2014) and stated that total dry matter of blackgram were significantly influenced by appropriate row spacing. They found that the row spacing of 30 cm proved as best row spacing in terms of total dry matter production.

Tomar *et al*. (2013) conducted a field experiment in uttara Pradesh and reported that the vigorous development of their growth attributes (branches and leaves $plant^{-1}$) ultimately increased the dry matter accumulation $plant^{-1}$. Higher plant density (500 × 103 plants ha^{-1}) produced taller and lesser branched plants and their lower leaves had not received sufficient solar radiation to accelerate photosynthetic activities, thus become lower leaves parasitic due to high rate of respiration in which larger quantities of stored photosynthates were consumed than produced in photosynthesis.

Singh *et al.* (1994) reported significantly positive linear trends of dry matter production in three varieties of blackgram with increasing density.

2.2.4 Pods $plant^{-1}$(no.)

Murade *et al*. (2014) conducted an experiment in Maharashtra, INDIA to study the effect of P fertilizer (0, 30, 60 and 90 kg ha^{-1}) and row spacing (30 and 45 cm) on the yield and yield components of blackgram and reported that pods $plant^{-1}$ was highest with 45 cm row spacing.

An experiment was conducted by Tomar *et al.* (2013) in Uttar pradesh and reported that number of pods $plant^{-1}$ is the key yield component in leguminous crops. Number of pods $plant^{-1}$ was maximum (28.25) for 20 cm row spacing. Minimum pods $plant^{-1}$ (22) were for 43 cm row spacing. As in the case of 20 cm

row spacing plants were spaced 15 cm within rows while in 43 cm row spacing plants were spaced 7 cm within rows. The result shows that plants needs uniform distribution for maximum pods plant^{-1} and inter or intra row spacing less than optimum results in competition for nutrients light and space.

A study was conducted by Rasul *et al*. (2012) in Pakistan with the interaction of varieties and inter-row spacing. They noticed that the number of pods plant^{-1} was significantly affected by plant density and while the highest number of pods plant^{-1} was found at 30 cm × 10 cm spacing and the lowest one was found at 40 cm × 30 cm. However, 20 cm × 20 cm spacing produced similar pods plant^{-1} as that of 40 cm × 30 cm spacing.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that number of pods plant^{-1} did not vary with the seed rate.

Nadeem *et al*. (2004) carried out a field experiment to study the effect of two planting patterns on different legumes in Faisalabad-Pakistan and found that the number of pods plant^{-1} was affected significantly by different planting patterns. The 60 cm apart double row produced more number of pods plant^{-1} than 40 cm apart single row strips in all legume crops. The results are in similarity with that of Rajput *et al*. (1984), who reported that increasing row or plant spacing increased the number of pods plant^{-1}.

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

Murade *et al*. (2014) conducted an experiment in Maharashtra, INDIA to study the effect of P fertilizer (0, 30, 60 and 90 kg ha^{-1}) and row spacing (30 and 45

cm) on the yield and yield of blackgram and reported that seeds pod^{-1} was highest with 45 cm row spacing.

An experiment was conducted by Tomar *et al.* (2013) in Uttar Pradesh and reported that number of seeds pod^{-1} is an important parameter that directly affects yield potential of legumes. Significant higher number of 10.25 seeds was recorded for 20 cm row spacing where plants were spaced 15 cm within rows.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out as a two factor factorial experiment with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that number of seeds pod^{-1} did not vary with the seed rate.

The non-significant effect of row spacing on the number of seeds plant^{-1} has also been reported by Ali *et al*. (2001). These results do not confirm the findings of Shahidullah and Hossain (1981), who reported that row spacing had non-significant effect on number of seeds pod^{-1}.

2.2.6 Pod length

Murade *et al*. (2014) conducted an experiment in Maharashtra, INDIA to study the effect of P fertilizer (0, 30, 60 and 90 kg ha^{-1}) and row spacing (30 and 45 cm) on the yield and yield of blackgram and reported that pod length was highest with 45 cm row spacing.

Tomar *et al.* (2011) reported that effect of row spacing was non significant for the pod length. It has values of 7.57, 7.50 and 7.75 cm pod length in 20, 30 and 43 cm spaced rows respectively. It could be concluded that pod length is a genetically controlled parameter and is less affected by the changes in the micro environment.

Achakzai and Panizai (2007) reported from their experiment that different level of row spacing does not significantly influenced pod length. However, numerically a longest pod 6.76 cm was noted in row spacing of 45 cm.

2.2.7 1000-Seeds weight

Agarwal *et al.* (2015) reported that 1000 seeds weight was affected significantly by different planting patterns. Crops sown in 40 cm apart rows produced significantly higher 1000 seeds weight than 60 cm apart double row strips.

Murade *et al*. (2014) conducted an experiment in Maharashtra, INDIA to study the effect of P fertilizer (0, 30, 60 and 90 kg ha^{-1}) and row spacing (30 and 45 cm) on the yield and yield components of blackgram and reported that 1000-seeds weight were highest with 45 cm row spacing.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahailluppllama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The results revealed that 1000 seed weight did not vary with the seed rate.

2.2.8 Seed yield

Prasad *et al.* (2014) carried out an experiment and they reported that different spacing significantly influenced the grain yield and biological yield. The spacing of 30 cm × 10 cm recorded significantly higher grain yield (1035.36 kg ha^{-1}) than the yield produced (971.39 kg ha^{-1}) by the spacing of 45 × 10 cm. Significantly higher biological yield 2951.25 kg ha^{-1} was also recorded with spacing 30 cm × 10 cm than spacing 45 cm ×10 cm.

Murade *et al*. (2014) conducted a field experiment on spacing and fertilizer level on promising urad bean genotype AKU-07-04 was at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during kharif season. Treatment

combinations were comprised of two level of spacing viz. 30 cm ×10 cm (S_1), 45 cm × 10 cm (S_2) and four levels of fertilizer and reported the highest grain yield from S_2.

Ekanayake *et al*. (2011) conducted a field experiment at the Field Crops Research and Development Institute, Mahaillupplama to identify an optimum seed rate and the respective nitrogen level for broadcast blackgram grown on rainfed uplands with the variety MI-1. The study was carried out as a two factor factorial experiment with six seed rates (25 kg ha^{-1}, 37.5 kg ha^{-1}, 50 kg ha^{-1}, 62.5 kg ha^{-1}, 75 kg ha^{-1}, 87.5 kg ha^{-1}) with two rates of nitrogen (30 kg of N ha^{-1} and 0 kg of N ha^{-1}). The maximum yield was recorded at a seed rate of 64 kg ha^{-1}. The maximum yield was obtained was estimated as 93 plants m^{-2} which is also comparable to this seed rate. It can be concluded that the optimum seed rate for broadcast crop of black gram under rain-fed conditions is 62.5 kg ha^{-1}.

Tomar *et al.* (2011) reported that yield attributes (number of pods, pod length, number of grains pod^{-1} and 1000 grains weight) were increased with the decrease plant density from 500 × 10 to 333 × 10 plants ha^{-1} due to better growth attributes and ultimately the grain and straw yield ha^{-1} due to translocation of larger synthesized food material from leaves (source) to the site of yield attributes. The larger translocation of photosynthates towards yield attributes resulted the higher grain yield ha^{-1}.

A field experiment was carried out by Kabir and Sarkar (2008) and reported the highest seed yield (1046.0 kg ha^{-1}) was obtained at 30 cm × 10 cm spacing followed in order by 20 cm × 20 cm and 40 cm × 30 cm spacing. This highest seed yield resulted mainly due to higher number of branches $plant^{-1}$ and number of pods $plant^{-1}$.

Achakzai and Panizai (2007) conducted a field experiment at Agricultural Research Institute, Quetta to study the influence of six different row spacing i.e., 20, 25, 30, 35, 40 and 45 cm on the growth, yield and yield attributes of mash

bean grown under semi-arid climate. Results revealed that yield plant^{-1} and yield ha^{-1} responded insignificantly in response to various levels of row spacing. However, numerically a maximum grain yield plant^{-1} (12.73 g) and yield ha^{-1} (2516 kg) were obtained from 35 cm row spacing. Though data are statistically not significant, but there is a trend that as row spacing increases, grain yield also increases.

Kabir *et al.* (2002) carried out field experiment for two consecutive years at the Agriculture Research Institute (ARI) under the existing semi-arid climatic, edaphic and water conditions of Quetta, Baluchistan to investigate the effects of six different seed rates viz., 15, 17.5, 20, 22.5, 25 and 27.5 kg ha^{-1} on the growth, yield and yield attributes of mash bean (*Vigna mungo*). The findings of the study revealed that grain yield plant^{-1} and grain yield ha^{-1} were significantly influenced by varying seed rates. However, other mentioned growth and yield attributes did not respond significantly. Statistically and numerically a maximum yield plant^{-1} (20.98 g) and yield ha^{-1} (3120 kg) were obtained in applied seed @ 20 kg ha^{-1}.

Kumaran and Subramanian (2001) conducted a field experiments in Vallanadu, Tamil Nadu, India, to study the effects of plant population and method of nutrient application on yield and economics of blackgram. The treatments in the main plots were plant densities of 33, 40 and 50 plants m^{-2}. The treatments in the subplots comprised control (S_1), spray of 2% DAP [diammonium phosphate] + 40 ppm NAA at 50% flowering stage (S_2), seed treatment with 25 ppm ammonium molybdate + 100 ppm $ZnSO_4$ + 100 ppm $FeSO_4$ (S_3), 1% DAP + 0.5% urea + 0.5% $MgSO_4$ + 0.25% $ZnSO_4$ spray at 50% flowering stage (S_4), S_2 + S_3 (S_5), and S_3 + S_4 (S_6). Adoption of 40 plants m^{-2} (25 × 10 cm) resulted in a higher grain yield.

Ahmed (2001) reported increased grain yield with 30 cm row spacing. The lowest yield 1041 kg ha^{-1} was recorded in 40 cm row spacing treatment, in which plant spacing was less.

Singh *et al.* (1994) got seed yields of 1.13, 1.37 and 1.36 t ha^{-1} of blackgram with 15, 22.5 and 30 cm row spacing. In this respect present results to some extent are in conformity with the results obtained by some workers (Borah, 1994 and Mishra and Mishra, 1995) but are in contradictory with the achievements observed by other research workers (Rajput *et al*., 1984). Based on climatic conditions, researchers obtained differential response of mash bean in relation to row spacing.

2.2.9 Harvest Index

Agarwal *et al.* (2015) reported that 1000 seeds weight was affected significantly by different planting patterns. Crops sown in 40 cm apart rows produced significantly higher harvest index than 60 cm apart double row strips.

Murade *et al*. (2014) conducted an experiment in Maharashtra, INDIA to study the effect of P fertilizer and row spacing (30 and 45 cm) on the yield and yield of blackgram and reported that harvest index was highest with 45 cm row spacing.

Achakzai and Panizai (2007) reported from their experiment that different level of row spacing does not significantly influenced pod length. However, numerically a maximum harvest index of balckgram 44.23% was noted in row spacing of 45 cm.

From the above cited reviews, it may be concluded that application of optimum doses of nitrogen fertilizer and suitable plant density are the prerequisite for attaining optimum growth and highest yield of blackgram. The literature revealed that the influence of nitrogen fertilizer and plant density have not been studied well and have no definite conclusion for the production of blackgram under the agro climatic condition of Bangladesh.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the performance of blackgram in response of nitrogen fertilizer and plant density. The materials and methods for this experiment includes a short description of the location of experimental site, soil and climatic condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The details description of the materials and methods for this experiment have been presented below under the following headings-

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from March to June, 2015.

3.1.2 Experimental location

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka and it was located in 24.09^0N latitude and 90.26^0E longitudes. As per the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level.

3.1.3 Characteristics of soil

The general soil type of the experimental field is Shallow Red Brown Terrace soil and the soil belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28). A composite sample of the experimental field was made by collecting soil from several spots of the field at a depth of 0-15 cm before initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 5.7 and 1.13%, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, details have been presented in Appendix I.

3.1.4 Climatic condition

The climatic condition of experimental site is subtropical and characterized by three distinct seasons, the *Rabi* from November to February and the *Kharif-I*, pre-monsoon period or hot season from March to April and the *Kharif-II* monsoon period from May to October. The monthly average temperature, relative humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II. During the experimental period the maximum temperature (35.4^0C), highest relative humidity (80%) and highest rainfall (227 mm) was recorded in the month of June 2015, whereas the minimum temperature (19.5^0C), minimum relative humidity (65%) and no rainfall was recorded for the month of March 2015.

3.2 Experimental details

3.2.1 Treatments of the experiment

The experiment comprised of two factors

Factor A: Levels of nitrogen (3 levels)

i) N_0: 0 kg N ha^{-1} (control)

ii) N_1: 20 kg N ha^{-1}

iii) N_2: 40 kg N ha^{-1}

Factor B: Plant density (4 levels)

i) D_1: 15 plants m^{-2}

ii) D_2: 30 plants m^{-2}

iii) D_3: 45 plants m^{-2}

iv) D_4: 60 plants m^{-2}

There were total 12 (3×4) treatment combinations as, N_0D_1, N_0D_2, N_0D_3, N_0D_4, N_1D_1, N_1D_2, N_1D_3, N_1D_4, N_2D_1, N_2D_2, N_2D_3 and N_2D_4.

3.2.2 Planting material

Blackgram variety BARI Mash-3 (Hemantoo) was used as planting material for the study. The seeds of BARI mash-3 were collected from the Pulse Seed Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The yellow mosaic virus resistant BARI mash-3 variety was released by BARI in 1996 in farmers' level and it was developed through hybridization between line BMA-2140 and BMA-2038.

3.2.3 Land preparation

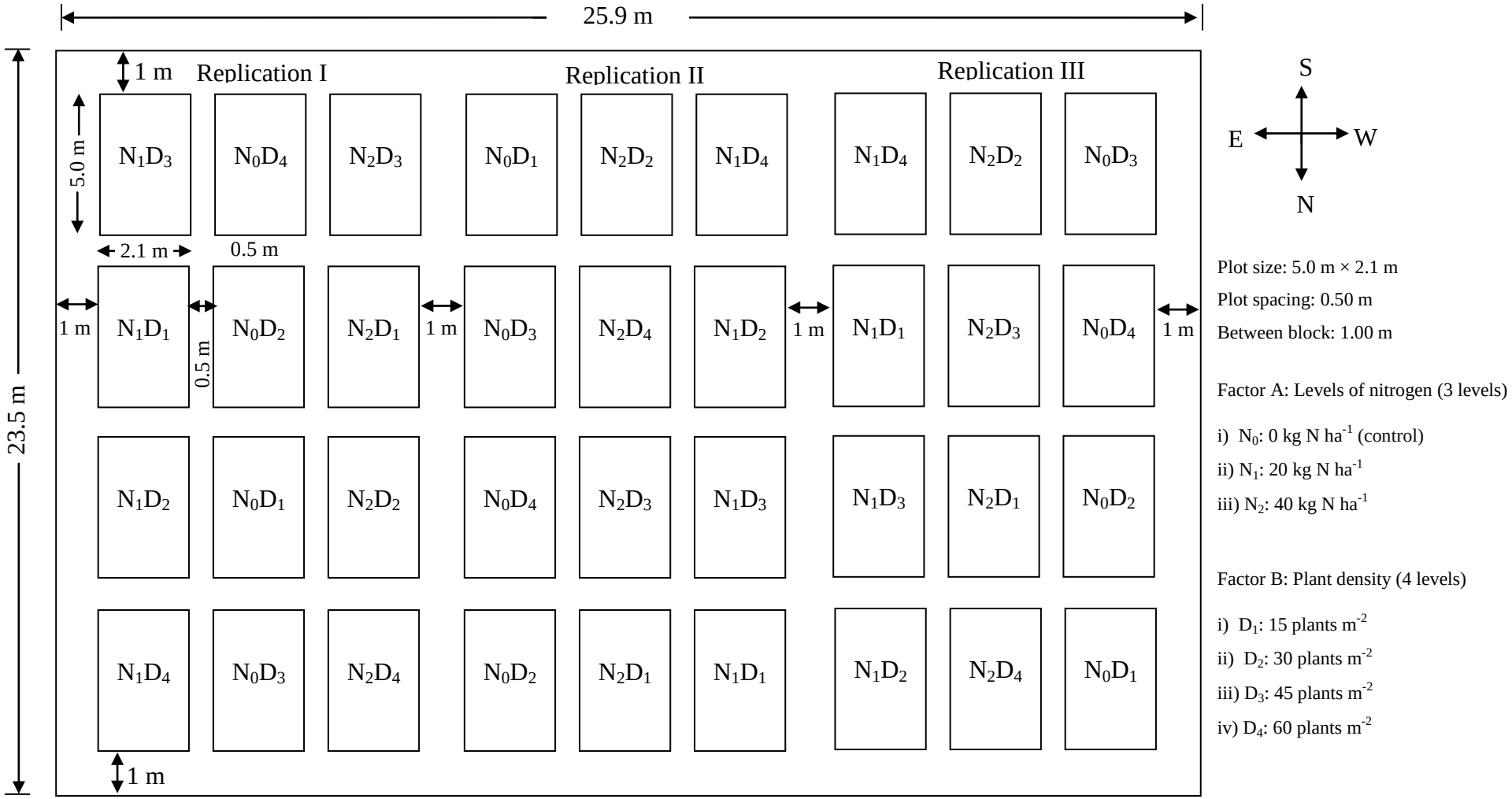
The land where the experiment was conducted it was opened on the 16th March, 2015 with the tractor drawn disc plough. Ploughed soil again and again to brought into desirable tilth by cross-ploughing, harrowing and laddering. The stubble and weeds were removed from the tilth soil. The first ploughing and the final land preparation were done on the 23th and 29nd March, 2015, respectively. Experimental land was divided into unit plots following the experimental design of this experiment.

3.2.4 Fertilizer application

Urea, Triple super phosphate (TSP) and Muriate of potash (MoP) were used in the experimental soil as a source of nitrogen (N), phosphorous (P) and potassium (K), respectively. Urea was applied 0, 20 and 40 kg N ha^{-1} in the soil as per treatment of the experiment. TSP and MoP were applied at the rate of 85 and 35 kg ha^{-1}, respectively. All of the fertilizers were applied during final land preparation.

3.2.5 Experimental design and layout

The two factors experiment was laid out in a split-plot design with three replications. An area of 25.9 m × 23.5 m was divided into three blocks. Different levels of nitrogen were assigned in the main plot and plant densities in sub-plot. The size of the each unit plot was 5.0 m × 2.1 m. The space between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experimental plot is shown in Figure 1.



Plot size: 5.0 m × 2.1 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Levels of nitrogen (3 levels)

i) N_0: 0 kg N ha^{-1} (control)

ii) N_1: 20 kg N ha^{-1}

iii) N_2: 40 kg N ha^{-1}

Factor B: Plant density (4 levels)

i) D_1: 15 plants m^{-2}

ii) D_2: 30 plants m^{-2}

iii) D_3: 45 plants m^{-2}

iv) D_4: 60 plants m^{-2}

Fig 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Sowing of seeds in the field

The seeds of blackgram were sown on March 29, 2015 in solid rows in the furrows having a depth of 2-3 cm with 20, 40, 60 and 80 g seeds for 15, 30, 45 and 60 plants m^{-2}, respectively as per plant density treatments.

3.3.2 Intercultural operations

3.3.2.1 Thinning

Seeds started germination on 4 Days after sowing (DAS). Thinning was done two times; first thinning was done at 10 DAS and second at 17 DAS to maintain optimum plant population in each plot as per plant density treatment and during 2^{nd} thinning 15, 30, 45 and 60 plants m^{-2} were adjusted by thinning.

3.3.2.2 Irrigation, drainage and weeding

Irrigation was provided before 15 and 30 DAS for optimizing the vegetative growth of blackgram for the all experimental plots equally. Proper drain also made for drained out excess water from irrigation and also rainfall from the experimental plot. The field was weeded at 15 and 30 DAS by hand weeding.

3.3.2.3 Plant protection measures

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 ml with 1 litre water to 5 decimal lands for two times at 15 days interval after seedlings germination to control the insects. Before sowing seeds were treated with Bavistin 50 WP to protect seed borne disease.

3.4 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height, number of branches $plant^{-1}$, number of leaves $plant^{1}$, dry matter content $plant^{-1}$ and number of nodules $plant^{-1}$ were recorded at different DAS and at harvest. All of the yield parameters were recorded in 2 times and total or average was estimated as per the nature of yield parameters.

3.5 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown to black in color and it was carried out for two times namely 1st harvest at 15 June, 2015 and last harvest at 22 June, 2015 **.** The matured pods were collected by hand picking from each plot.

3.6 Data collection

The following data were recorded

i. Plant height at 15, 30, 45 days after sowing (DAS) and harvest
ii. Leaves plant^{-1}(no.) at 15, 30, 45 DAS and harvest
iii. Branches plant^{-1}(no.) at 30, 45 DAS and harvest
iv. Dry matter content plant^{-1} at 15, 30, 45 DAS and harvest
v. Nodules plant^{-1}(no.) at 30 and 45 DAS
vi. Days to flowering
vii. Days to harvest
viii. Pods plant^{-1}(no.) at 1st, last harvest and total
ix. Seeds pod^{-1}(no.) at 1st, last harvest and average
x. Pod length at 1st, last harvest and average
xi. Weight of 1000-seeds at 1st, last harvest and average
xii. Shelling percentage (%)
xiii. Seed yield ha^{-1} at 1st, last harvest and total
xiv. Stover yield ha^{-1}
xv. Biological yield ha^{-1}
xvi. Harvest index

3.7 Procedure of data collection

3.7.1 Plant height

The height of plant was recorded in centimeter (cm) at 15, 30, 45 DAS and harvest. Data were recorded from randomly selected 5 plants from each plot and average plant height plant^{-1} was recorded as per treatment. The height was measured from the ground level to the tip of the plant by a meter scale.

3.7.2 Leaves plant^{-1}(no.)

The number of leaves plant^{-1} was counted at 15, 30, 45 DAS and harvest. Data were recorded from randomly selected 5 plants from each plot and average number of leaves plant^{-1} was recorded as per treatment.

3.7.3 Branches plant^{-1}(no.)

The number of branches plant^{-1} was counted at 30, 45 DAS and harvest. Data were recorded from randomly selected 5 plants from each plot and average number of branches plant^{-1} was recorded as per treatment.

3.7.4 Dry matter content plant^{-1}

Five randomly selected plants were collected randomly from each plot at 15, 30, 45 DAS and harvest. Fresh plant samples from each plot were put into envelop and placed in oven maintained at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final dry weight of the sample was taken and recorded in gram.

3.7.5 Nodules plant^{-1}(no.)

Five randomly selected plants from each plot was uprooted carefully with soil at 30 and 45 DAS then washed out with water and made clean. The number of nodules plant^{-1} was observed and counted from each plot and average number of nodules plant^{-1} was recorded as per treatment.

3.7.6 Days to flowering

Days to 1st flowering were recorded by counting the number of days required to start flower initiation of blackgram plant in each plot.

3.7.7 Days to maturity

Days to maturity were recorded by counting the number of days required to maturity of blackgram plant in each plot.

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

Numbers of total pods of 10 randomly selected plants from each plot were counted at 1st and last harvest and the total was calculated by adding them and the mean numbers were expressed as plant^{-1} basis.

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

The number of seeds pod^{-1} was recorded randomly from selected pods at 1st and last harvest and average was calculated. Data were recorded as the average of 10 pods from each plot.

3.7.10 Pod length

Pod length was taken from randomly selected 10 pods at 1st, last harvest and average was calculated and the mean pod length was expressed on pod^{-1} basis.

3.7.11 Weight of 1000-seeds

One thousand cleaned, dried seeds were counted randomly at 1st, last harvest and average was calculated from each harvest sample and weighed by using a digital electric balance and expressed in gram (g).

3.7.12 Seed yield

The pods were collected from central 3 lines at each plot at 1st and last harvest and sun dried properly. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.7.13 Shelling percentage (%)

The mass of seeds obtained from the pods that were randomly drawn from a bulk sample and calculated the shelling percentage by using following formula:

$$\text{Shelling percentage} = \frac{\text{Seed mass}}{\text{Pod mass}} \times 100$$

3.7.14 Stover yield

The stover yield was determined from central 3 lines of each plot. After separation of seeds, the sub-sample were oven dried to a constant weight and converted the yield in t ha^{-1}.

3.7.15 Biological yield

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

Biological yield (t ha^{-1}) = Grain yield + Stover yield

3.7.16 Harvest index

Harvest index was calculated from the seed and stover yield of blackgram expressed in percentage.

$$HI\ (\%) = \frac{\text{Economic yield (seed weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.8 Statistical analysis

The data obtained for different parameters were analyzed to find out the performance of blackgram in response of nitrogen fertilizer and plant density. The mean values of all the characters were calculated and the analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the response of nitrogen fertilizer and plant density on the performance of blackgram. The analyses of variance (ANOVA) of the data on different yield contributing characters and yield of blackgram are presented in Appendix III-XIII. The results have been presented with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

4.1.1 Effect of nitrogen fertilizer

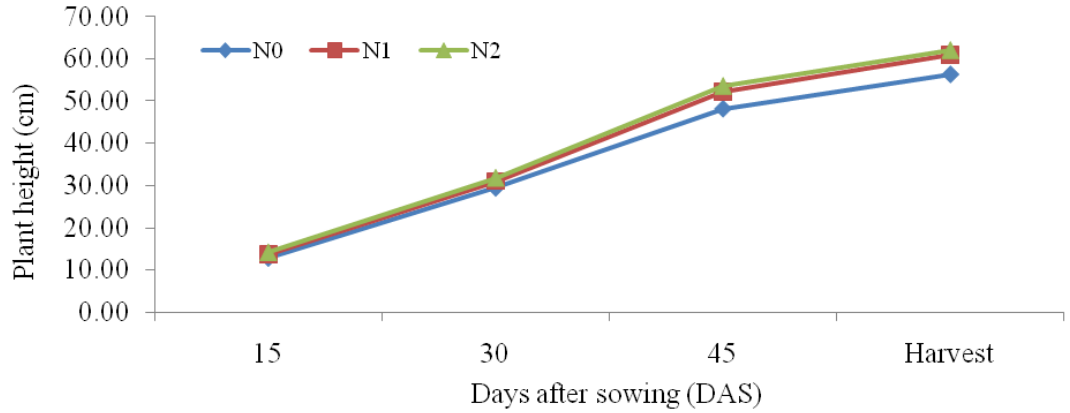
Plant height of blackgram showed statistically significant variation due to different levels of nitrogen at 15, 30, 45 DAS and harvest (Fig 2). At 15, 30, 45 DAS and harvest, the tallest plants (14.10, 31.71, 53.43 and 61.91 cm, respectively) were found from N_2 (40 kg N ha^{-1}) which was statistically similar (13.66, 31.02, 52.15 and 61.00 cm, respectively) to N_1 (20 kg N ha^{-1}), while the shortest plants (12.91, 29.44, 48.10 and 56.20 cm, respectively) were recorded from N_0 (0 kg N ha^{-1} i.e., control condition). Generally plant height is a genetical character and it is controlled by the genetic make up of the varieties and different varieties produces different size of plant. It was revealed that nitrogenous fertilizer increased plant height of blackgram compared to control and plant growth was seriously hampered when lower dose of nitrogen was applied. Data reveled that 40 kg N ha^{-1} produced the tallest plant at 15, 30, 45 DAS and harvest. Saini and Thakur (1996) carried out an experiment and stated that nitrogen @ 30 and 40 kg ha^{-1} significantly increased the plant height of blackgram compared with no application of N. Tomar *et al*. (2013) earlier reported that plant height positively increased with the increase in levels of nitrogenous fertilizer. Ekanayake *et al*. (2011) revealed that the plant height varied with nitrogenous fertilizer rates and application of 30 kg of N ha^{-1} produced the tallest plant. But Kulsum *et al*. (2007) recorded the longest plant with the application of 100 kg N ha^{-1}.

4.1.2 Effect of plant density

Statistically significant variation was observed in terms of plant height of blackgram at 15, 30, 45 DAS and harvest for different plant density (Fig 3). At 15, 30, 45 DAS and harvest, the tallest plants (14.94, 33.61, 54.12 and 62.97 cm, respectively) were recorded from D_3 (45 plants m^{-2}), which was statistically similar (14.58, 31.82, 52.17 and 59.00 cm, respectively) to D_4 (60 plants m^{-2}). On the other hand, the shortest plants (12.34, 28.27, 48.92 and 57.62 cm, respectively) were found from D_1 (15 plants m^{-2}) which was statistically similar (12.35, 29.20, 49.70 and 59.23 cm, respectively) to D_2 (30 plants m^{-2}). Generally, wider plant spacing intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth (Murade *et al*., 2014).

4.1.3 Interaction effect

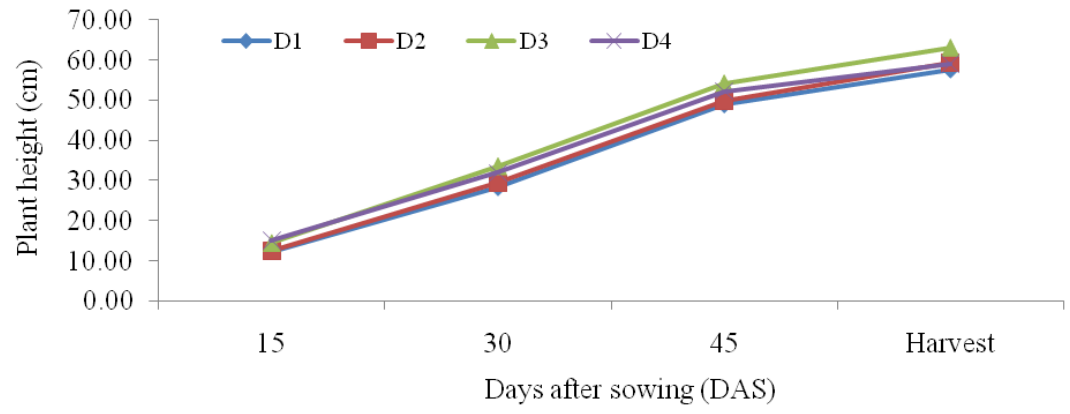
Interaction effect of different levels of nitrogen fertilizer and plant density varied significantly on plant height of blackgram at 15, 30, 45 DAS and harvest (Table 1). At 15, 30, 45 DAS and at harvest, the tallest plants (16.75, 36.06, 58.97 and 68.29 cm, respectively) were recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the shortest plant (10.44, 25.57, 44.56 and 51.18 cm, respectively) from N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}). The highest plant height of N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) at harvest was similar with that of N_1D_2 (20 kg N ha^{-1} + 30 plants m^{-2}), whereas the lowest height of N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}) was similar to N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}).



N_0: 0 kg urea ha^{-1} (control); N_1: 20 kg urea ha^{-1}

N_2: 40 kg urea ha^{-1}

Figure 2. Effect of differnt levels of nitrogen fertilizer on plant height of blackgram (SE = 0.190, 0.345, 0.853 and 0.963 at 15, 30, 45 DAS and harvest)



D_1: 15 plants m^{-2}; D_2: 30 plants m^{-2}

D_3: 45 plants m^{-2}; D_4: 60 plants m^{-2}

Figure 3. Effect of differnt plant density on plant height of blackgram (SE = 0.281, 0.808, 0.765 and 1.158 at 15, 30, 45 DAS and harvest)

Table 1. Interaction effect of different levels of nitrogen fertilizer and plant density on plant height of blackgram

Treatments	Plant height (cm) at			
	15 DAS	30 DAS	45 DAS	Harvest
N_0D_1	10.44 f	25.57 e	44.56 d	51.18 d
N_0D_2	12.63 de	26.13 de	45.40 cd	54.45 cd
N_0D_3	15.29 b	34.48 ab	52.25 b	59.01 bc
N_0D_4	13.26 cd	31.60 a-c	50.22 b	60.17 bc
N_1D_1	13.12 d	30.74 bc	53.03 b	61.61 b
N_1D_2	13.27 cd	30.79 bc	51.55 b	62.85 ab
N_1D_3	13.44 cd	30.30 b-d	51.13 b	61.61 b
N_1D_4	14.82 bc	32.25 a-c	52.87 b	57.94 bc
N_2D_1	11.27 ef	28.50 c-e	49.16 bc	60.07 bc
N_2D_2	13.35 cd	30.68 bc	52.15 b	60.38 bc
N_2D_3	16.75 a	36.06 a	58.97 a	68.29 a
N_2D_4	15.01 b	31.61 a-c	53.42 b	58.89 bc
SE	0.486	1.399	1.325	2.005
CV(%)	6.21	7.89	4.48	5.82

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

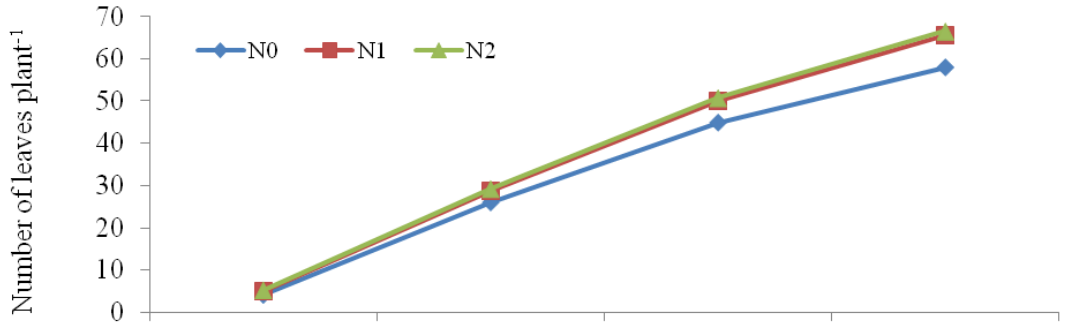
N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.2 Leaves plant^{-1}(no.)

4.2.1 Effect of nitrogen fertilizer

Statistically significant variation was recorded in terms of number of leaves plant^{-1} of blackgram due to different levels of nitrogen at 15, 30, 45 DAS and harvest (Fig 4). At 15, 30, 45 DAS and at harvest, the highest number of leaves plant^{-1} (5.13, 29.13, 50.70 and 66.50, respectively) were observed from N_2 (40 kg N ha^{-1})which was statistically similar (4.92, 28.68, 50.05 and 65.60, respectively) to N_1(20 kg N ha^{-1}), whereas the lowest number (4.13, 25.98, 44.83 and 57.88, respectively) were found from N_0 (0 kg N ha^{-1}). Murade *et al*. (2014) reported that wider plant spacing which intercepted more photosynthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth and more number of leaves as compared to narrow spacing. Ekanayake *et al*. (2011) reported that that number of leaves plant^{-1} significantly varied with fertilizer rates. Kulsum *et al*. (2007) found largest leaf was obtained with 80 kg N ha^{-1}.



N_0: 0 kg urea ha^{-1} (control); N_1: 20 kg urea ha^{-1}
N_2: 40 kg urea ha^{-1}

Figure 4. Effect of differnt levels of nitrogen fertilizer on number of leaves plant^{-1} of blackgram (SE = 0.164, 0.569, 0.801 and 0.789 at 15, 30, 45 DAS and harvest)

4.2.2 Effect of plant density

Number of leaves plant^{-1} of blackgram at 15, 30, 45 DAS and at harvest varied significantly for different plant density (Fig 5). At 15, 30, 45 DAS and harvest, the highest number of leaves plant^{-1} (5.16, 29.89, 50.99 and 65.64, respectively) was found from D_3 (45 plants m^{-2}), which was followed (5.02, 27.70, 47.68 and 63.42, respectively) by D_4 (60 plants m^{-2}), while the lowest number (4.60, 26.47, 46.74 and 60.31, respectively) was recorded from D_1 (15plants m^{-2}) which was followed (4.13, 27.68, 48.70 and 63.93, respectively) by D_2 (30plants m^{-2}). Ekanayake *et al*. (2011) revealed that number of leaf plant^{-1} did not vary with the seed rate.

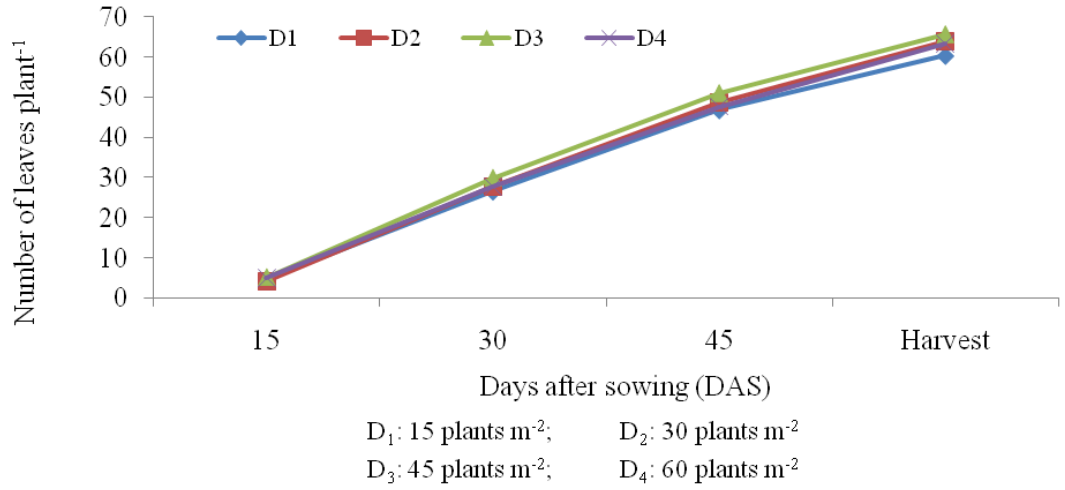


Figure 5. Effect of differnt plant density on number of leaves plant^{-1} of blackgram (SE = 0.116, 0.635, 0.956 and 0.871 at 15, 30, 45 DAS and harvest)

4.2.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly in terms of number of leaves plant^{-1} of blackgram at 15, 30, 45 DAS and harvest for their interaction effect (Table 2). At 15 DAS, the highest number of leaves plant^{-1} (5.87) was observed from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) that similar to N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}), whereas the lowest number (2.80) was recorded from N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}). At 30 DAS, the highest number of leaves plant^{-1} (31.00) was found in N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) that similar with all other treatment combinations except N_0D_1 (0 kg N ha^{-1} +15 plants m^{-2}), N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}) and N_0D_4 (0 kg N ha^{-1} + 60

plants m^{-2}). The highest number of leaves $plant^{-1}$ (55.60) of N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2})was also observed at 45 DAS that similar to N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2}), N_1D_1 (20 kg N ha^{-1} + 15 plants m^{-2}) and N_1D_3 (20 kg N ha^{-1} + 30 plants m^{-2}). Similar the highest number of leaves $plant^{-1}$ at harvest (70.87) was also revealed in N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) that similar to N_1D_3 (20 kg N ha^{-1} + 30 plants m^{-2}) and N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2}) whereas the lowest number of leaves $plant^{-1}$ was in N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}) that similar to N_0D_3 (0 kg N ha^{-1} + 45 plants m^{-2}).

Table 2. Interaction effect of different levels of nitrogen fertilizer and plant density on number of leaves $plant^{-1}$ of blackgram

Treatments	Number of leaves $plant^{-1}$ at			
	15 DAS	30 DAS	45 DAS	Harvest
N_0D_1	4.40 de	23.13 d	42.10 e	53.87 f
N_0D_2	2.80 f	25.83 cd	44.50 de	58.60 e
N_0D_3	5.00 b-d	28.40 a-c	45.77 de	57.53 ef
N_0D_4	4.33 de	26.57 bc	46.97 b-e	61.53 de
N_1D_1	5.20 bc	28.07 a-c	51.73 a-c	62.07 de
N_1D_2	4.60 c-e	27.80 a-c	49.20 b-d	66.00 b-d
N_1D_3	4.60 c-e	30.27 ab	51.60 a-c	68.53 ab
N_1D_4	5.27 ab	28.60 a-c	47.67 b-d	63.47 cd
N_2D_1	4.20 e	28.20 a-c	46.40 c-e	65.00 b-d
N_2D_2	5.00 b-d	29.40 a-c	52.40 ab	67.20 a-c
N_2D_3	5.87 a	31.00 a	55.60 a	70.87 a
N_2D_4	5.47 ab	27.93 a-c	48.40 b-d	65.27 b-d
SE	0.201	1.099	1.656	1.508
CV(%)	7.37	6.82	5.91	4.12

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.3 Branches plant^{-1}(no.)

4.3.1 Effect of nitrogen fertilizer

Different levels of nitrogen varied significantly in terms of number of branches plant^{-1} of blackgram at 30, 45 DAS and at harvest (Table 3). At 30, 45 DAS and harvest, the highest number of branches plant^{-1} (3.75, 4.80 and 8.37, respectively) were found from N_2 (40 kg N ha^{-1}) which was statistically similar (3.62, 4.65 and 8.20, respectively) to N_1 (20 kg N ha^{-1}), whereas the lowest number (3.05, 4.02 and 7.65, respectively) were recorded from N_0 (0 kg N ha^{-1}).

4.3.2 Effect of plant density

Number of branches plant^{-1} of blackgram at 30, 45 DAS and at harvest varied significantly for different plant density (Table 3). At 30, 45 DAS and harvest, the highest number of branches plant^{-1} (3.69, 4.71 and 8.31, respectively) was observed from D_3 (45 plants m^{-2}), which was statistically similar (3.51, 4.51 and 8.09, respectively) to D_2 (30 plants m^{-2}), while the lowest number of branches plant^{-1} (3.27, 4.20 and 7.76, respectively) was found from D_4 (60 plants m^{-2}) which was followed (3.42, 4.53 and 8.13, respectively) by D_1 (15plants m^{-2}). Tomar *et al*. (2013) and reported that the branches increased with the decrease in plant density.

4.3.3 Interaction effect

Statistically significant variation was recorded in terms of number of branches plant^{-1} of blackgram at 30, 45 DAS and harvest due to the interaction effect of different levels of nitrogen fertilizer and plant density (Table 4). At 30 DAS, the highest number of branches plant^{-1} (4.20) was observed in N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) that similar to N_1D_1 (20 kg N ha^{-1} + 15 plants m^{-2}), N_1D_3(20 kg N ha^{-1} + 30 plants m^{-2}) and N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2}). The highest number of branches plant^{-1} (5.33) of N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) was also observed at 45 DAS that similar to N_1D_1 (20 kg N ha^{-1} + 15 plants m^{-2}).Similarly the highest number of branches plant^{-1} at harvest (8.60) was also revealed in N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) that similar with all other treatment combinations except N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}), N_0D_2 (0 kg N

ha^{-1} + 30 plants m^{-2}), N_0D_3 (0 kg N ha^{-1} + 45 plants m^{-2}), N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}), N_1D_4 (20 kg N ha^{-1} + 60 plants m^{-2}) and N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}), whereas the lowest number of branches plant^{-1} was in N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}) that similar to N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}), N_0D_3 (0 kg N ha^{-1} + 45 plants m^{-2}), N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}), N_1D_4 (20 kg N ha^{-1} + 60 plants m^{-2}) and N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}).

Table 3. Effect of different levels of nitrogen fertilizer and plant density on number of branches plant^{-1} of blackgram

Treatments	Number of branches plant^{-1} at		
	30 DAS	45 DAS	Harvest
Levels of nitrogen fertilizer			
N_0	3.05 b	4.02 b	7.65 b
N_1	3.62 a	4.65 a	8.20 a
N_2	3.75 a	4.80 a	8.37 a
SE	0.065	0.119	0.123
CV(%)	6.50	9.21	5.27
Plant density			
D_1	3.42 b	4.53 a	8.13 ab
D_2	3.51 ab	4.51 a	8.09 ab
D_3	3.69 a	4.71 a	8.31 a
D_4	3.27 b	4.20 b	7.76 b
SE	0.083	0.093	0.124
CV(%)	7.16	6.18	4.59

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 4. Interaction effect of different levels of nitrogen fertilizer and plant density on number of branches plant^{-1} of blackgram

Treatments	Number of branches plant^{-1} at		
	30 DAS	45 DAS	Harvest
N_0D_1	2.93 d	3.90 d	7.20 e
N_0D_2	3.13 cd	3.93 d	7.80 c-e
N_0D_3	3.07 cd	4.07 d	7.80 c-e
N_0D_4	3.07 cd	4.13 d	7.80 c-e
N_1D_1	3.93 a	5.00 ab	8.60 a
N_1D_2	3.27 cd	4.80 bc	8.07 a-d
N_1D_3	3.80 ab	4.73 bc	8.53 ab
N_1D_4	3.47 bc	4.07 d	7.60 de
N_2D_1	3.40 b-d	4.67 bc	8.60 a
N_2D_2	4.13 a	4.80 bc	8.40 a-c
N_2D_3	4.20 a	5.33 a	8.60 a
N_2D_4	3.27 cd	4.40 cd	7.87 b-e
SE	0.144	0.160	0.214
CV(%)	7.16	6.18	4.59

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.4 Dry matter content plant^{-1}

4.4.1 Effect of nitrogen fertilizer

Dry matter content plant^{-1} of blackgram differed significantly due to different levels of nitrogen at 15, 30, 45 DAS and harvest (Table 5). At 15, 30, 45 DAS and harvest, the highest dry matter content plant^{-1} (0.76, 3.05, 6.07 and 7.81 g, respectively) were recorded from N_2 (40 kg N ha^{-1}) which was statistically similar (0.70, 2.92, 5.85 and 7.57 g, respectively) to N_1 (20 kg N ha^{-1}), whereas the lowest dry matter content plant^{-1} (0.63, 2.58, 5.13 and 6.88 g, respectively) were observed from N_0 (0 kg N ha^{-1}). Sharma and Abraham (2010) reported that nitrogen @ 20 kg ha^{-1} showed a significant increment of dry matter content of blackgram over the control.

4.4.2 Effect of plant density

Statistically significant variation was recorded in terms of dry matter content plant^{-1} of blackgram for different plant density at 15, 30, 45 DAS and harvest (Table 5). At 15, 30, 45 DAS and harvest, the highest dry matter content plant^{-1} (0.76, 3.05, 6.05 and 7.67 g, respectively) was found from D_3 (45 plants m^{-2}), which was followed (0.75, 2.85, 5.92 and 7.58 g, respectively) by D_2 (30 plants m^{-2}), while the lowest dry matter content plant^{-1} (0.59, 2.69, 5.36 and 6.73 g, respectively) was observed from D_4 (60 plants m^{-2}) which was followed (0.68, 2.81, 5.38 and 6.89 g, respectively) by D_1 (15 plants m^{-2}). Singh *et al.* (1994) reported significantly positive linear trends of dry matter production in three varieties of blackgram with increasing density.

4.4.3 Interaction effect

Dry matter content plant^{-1} of blackgram at 15, 30, 45 DAS and at harvest varied significantly for the interaction effect of different levels of nitrogen fertilizer and plant density (Table 6). At 15 DAS, the highest dry matter content plant^{-1} (0.81 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with all other combinations except N_0D_1 (0 kg N ha^{-1} + 15plants m^{-2}), N_0D_4 (0 kg N ha^{-1} + 60plants m^{-2}) and N_1D_1 (20 kg N ha^{-1} + 15plants m^{-2}). At 30 DAS, the highest dry matter content plant^{-1} (3.42 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45plants m^{-2})which was statistically similar with N_0D_3 (0 kg N ha^{-1} + 45plants m^{-2}), N_1D_2 (20 kg N ha^{-1} + 45plants m^{-2}), N_2D_1 (40 kg N ha^{-1} + 15plants m^{-2}) and N_2D_4 (40 kg N ha^{-1} + 60plants m^{-2}). At 45 DAS, the highest dry

matter content plant^{-1} (6.87 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45plants m^{-2}) which was statistically similar with N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}), N_0D_3 (0 kg N ha^{-1} + 45 plants m^{-2}), N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}), N_1D_4 (20 kg N ha^{-1} + 60plants m^{-2}) and N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}). At harvest the highest dry matter content plant^{-1} (8.03 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with all other combination except N_0D_1 (0 kg N ha^{-1} +15 plants m^{-2}) and N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}), whereas the lowest dry matter content plant^{-1} (0.48, 2.32, 3.87 and 5.83 g, respectively) were found from N_0D_1 (0 kg N ha^{-1} +15 plants m^{-2}).

Table 5. Effect of different levels of nitrogen fertilizer and plant density on dry matter content plant^{-1} of blackgram

Treatments	Dry matter content plant^{-1} (g) at			
	15 DAS	30 DAS	45 DAS	Harvest
Levels of nitrogen fertilizer				
N_0	0.63 b	2.58 b	5.13 b	6.88 b
N_1	0.70 a	2.92 a	5.85 a	7.57 a
N_2	0.76 a	3.05 a	6.07 a	7.81 a
SE	0.015	0.069	0.163	0.139
CV(%)	7.86	8.38	9.94	6.46
Plant density				
D_1	0.68 b	2.81 ab	5.38 b	6.89 b
D_2	0.75 a	2.85 ab	5.92 a	7.58 a
D_3	0.76 a	3.05 a	6.05 a	7.67 a
D_4	0.59 c	2.69 b	5.36 b	6.73 b
SE	0.024	0.081	0.153	0.169
CV(%)	10.09	8.52	8.06	6.85

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 6. Interaction effect of different levels of nitrogen fertilizer and plant density on dry matter content plant^{-1} of blackgram

Treatments	Dry matter content plant^{-1} (g) at			
	15 DAS	30 DAS	45 DAS	Harvest
N_0D_1	0.48 d	2.32 e	3.87 d	5.83 c
N_0D_2	0.68 ab	2.40 e	6.00 a-c	6.93 b
N_0D_3	0.74 ab	3.27 ab	6.07 a-c	7.23 ab
N_0D_4	0.63 bc	2.33 e	4.60 d	7.50 ab
N_1D_1	0.52 cd	2.75 c-e	5.48 c	7.53 ab
N_1D_2	0.78 a	3.00 a-d	5.41 c	7.87 ab
N_1D_3	0.80 a	2.88 b-d	6.41 ab	7.80 ab
N_1D_4	0.71 ab	2.62 de	6.08 a-c	7.07 ab
N_2D_1	0.77 a	3.33 ab	6.27 a-c	7.30 ab
N_2D_2	0.74 ab	2.73 c-e	5.67 bc	7.93 a
N_2D_3	0.81 a	3.42 a	6.87 a	8.03 a
N_2D_4	0.71 ab	3.13 a-c	5.47 c	7.97 a
SE	0.041	0140	0.264	0.293
CV(%)	10.09	8.52	8.06	6.85

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.5 Nodules plant^{-1}(no.)

4.5.1 Effect of nitrogen fertilizer

Statistically significant variation was recorded in terms of number of nodules plant^{-1} of blackgram due to different levels of nitrogen at 30 and 45 DAS (Table 7). At 30 and 45 DAS, the highest number of nodules plant^{-1} (29.04 and 25.42, respectively) were recorded from N_1 (20 kg N ha^{-1})which was followed (28.59 and 23.28, respectively) by N_2 40 kg N ha^{-1}), whereas the lowest number of nodules plant^{-1} (24.05 and 20.88, respectively) were observed from N_0 (0 kg N ha^{-}).

4.5.2 Effect of plant density

Number of nodules plant^{-1} of blackgram at 30 and 45 DAS varied significantly for different plant density (Table 7). At 30 and 45 DAS, the highest number of nodules plant^{-1} (31.31 and 26.30, respectively) was found from D_3(45 plants m^{-2}), while the lowest number of nodules plant^{-1} (25.00 and 22.00, respectively) was observed from D_1(15plants m^{-2}) which was statistically similar to D_4(60plants m^{-2}) (26.27 and 21.66, respectively) and D_2(30plants m^{-2}) (26.33 and 22.81, respectively).

4.5.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly due to their interaction effect in terms of number of nodules plant^{-1} of blackgram at 30 and 45 DAS (Table 8). At 30, the highest number of nodules plant^{-1} (34.40) was found from N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_1D_4 (20 kg N ha^{-1} + 60 plants m^{-2}), N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) and N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}). At 45 DAS, the highest number of nodules plant^{-1} (30.77) was found from N_1D_3 (20kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_1D_4 (20 kg N ha^{-1} + 60 plants m^{-2}), N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2}) and N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest number of nodules plant^{-1} (18.73 and 14.33, respectively) were recorded from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

4.6 Days to flowering

4.6.1 Effect of nitrogen fertilizer

Days to flowering of blackgram showed statistically significant variation due to different levels of nitrogen (Table 7). The maximum days to flowering (31.00) was recorded from N_2 (40 kg N ha^{-1}) which was followed (29.42) by N_0 (0 kg N ha^{-1}), whereas the minimum days to flowering (28.17) was found from N_1 (20kg N ha^{-1}).

4.6.2 Effect of plant density

Plant density varied significantly in terms of days to flowering of blackgram (Table 7). The highest days to flowering (30.22) was observed from D_4 (60plants m^{-2}) which was statistically similar (30.11 and 29.67) to D_1 (15 plants m^{-2}) and D_2 (30 plants m^{-2}), while the lowest of days to flowering (28.11) was found from D_3 (45 plants m^{-2}). Tanys *et al.* (2015) reported that optimum plant density induced early flowering compared to closely and wider density of plant.

4.6.3 Interaction effect

Statistically significant variation was recorded due to the interaction effect of different levels of nitrogen fertilizer and plant density in terms of days to flowering of blackgram (Table 8). The maximum days to flowering (32.00) was recorded from N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}) which was statistically similar with N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}) and N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2}), whereas the minimum days to flowering (27.00) were found from N_1D_3 (20 kg N ha^{-1} + 60 plants m^{-2}) which was statistically similar with N_0D_3 (0 kg N ha^{-1} + 45 plants m^{-2}) and N_1D_2 (20 kg N ha^{-1} + 30 plants m^{-2}).

4.7 Days to harvest

4.7.1 Effect of nitrogen fertilizer

Statistically significant variation was recorded in terms of days to harvest of blackgram due to different levels of nitrogen (Table 7). The maximum days to harvest (64.75) was found from N_2 (40 kg N ha^{-1}), whereas the minimum days (61.42) was recorded from N_1 (20 kg N ha^{-1}) which was statistically similar (62.25) to N_0 (0 kg N ha^{-1}). Kulsum (2003) found the maximum days to harvest for wider spacing in earlier experiment.

Table 7. Effect of different levels of nitrogen fertilizer and plant density on number of nodules plant^{-1}, days to flowering and harvest of blackgram

Treatments	Number of nodules plant^{-1} at		Days to flowering	Days to harvest
	30 DAS	45 DAS		
Levels of nitrogen fertilizer				
N_0	24.05 b	20.88 c	29.42 b	62.25 b
N_1	29.04 a	25.42 a	28.17 c	61.42 b
N_2	28.59 a	23.28 b	31.00 a	64.75 a
SE	0.764	0.536	0.255	0.492
CV(%)	9.73	8.00	2.99	2.71
Plant density				
D_1	25.00 b	22.00 b	30.11 a	62.78
D_2	26.33 b	22.81 b	29.67 a	62.44
D_3	31.31 a	26.30 a	28.11 b	62.89
D_4	26.27 b	21.66 b	30.22 a	63.11
SE	0.906	1.071	0.222	0.268
CV(%)	9.98	13.85	2.26	1.28

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 8. Interaction effect of different levels of nitrogen fertilizer and plant density on number of nodules plant^{-1}, days to flowering and harvest of blackgram

Treatments	Number of nodules plant^{-1} at		Days to flowering	Days to harvest
	30 DAS	45 DAS		
N_0D_1	26.55 bc	24.53 b-d	30.33 bc	62.00 bc
N_0D_2	24.42 c	21.60 c-e	30.00 c	62.00 bc
N_0D_3	26.50 bc	23.07 b-d	28.00 ef	62.67 b
N_0D_4	18.73 d	14.33 f	29.33 cd	62.33 bc
N_1D_1	24.36 c	24.53 b-d	28.67 de	61.33 bc
N_1D_2	27.60 bc	18.53 d-f	27.67 ef	61.00 c
N_1D_3	34.40 a	30.77 a	27.00 f	61.67 bc
N_1D_4	29.80 ab	27.83 ab	29.33 cd	61.67 bc
N_2D_1	24.09 c	16.93 ef	31.33 ab	65.00 a
N_2D_2	26.80 bc	28.30 ab	31.33 ab	64.33 a
N_2D_3	33.02 a	25.07 a-c	29.33 cd	64.33 a
N_2D_4	30.45 ab	22.82 b-e	32.00 a	65.33 a
SE	1.569	1.855	0.385	0.465
CV(%)	9.98	13.85	2.26	1.28

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.7.2 Effect of plant density

Days to harvest of blackgram varied non-significantly for different plant density (Table 7). The maximum days to harvest (63.11) was observed from D_4 (60 plants m^{-2}), while the minimum number of days to harvest (62.44) was recorded from D_2 (30 plants m^{-2}). Similar results also reported by Tanys *et al.* (2015).

4.7.3 Interaction effect

Interaction effect of different levels of nitrogen fertilizer and plant density varied significantly in terms of days to harvest of blackgram (Table 8). The maximum days to harvest (65.33) was observed from N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}), whereas the minimum days to harvest (61.00) were recorded from N_1D_2 (20kg N ha^{-1} + 30 plants m^{-2}).

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

4.8.1 Effect of nitrogen fertilizer

Number of pods plant^{-1} of blackgram varied significantly due to different levels of nitrogen at 1st harvest and last harvest (Table 9). At 1st harvest and last harvest, the highest number of pods plant^{-1} (42.00 and 15.75, respectively) were observed from N_1 (20kg N ha^{-1}) which was statistically similar (40.17 and 15.42, respectively) to N_2 (40kg N ha^{-1}), whereas the lowest number of pods plant^{-1} at 1st and last harvest (33.83 and 11.83, respectively) were found from N_0 (0kg N ha^{-1}). The highest total number of pods plant^{-1} (57.75) was found in N_1 (20kg N ha^{-1}) (Fig 6) which was statistically similar to N_2 (40kg N ha^{-1}) (55.59) but the lowest number (45.66) was recorded in N_0 (0kg N ha^{-1}) treatment. Kulsum (2003) found the maximum number of pods plant^{-1} from N @ 60 kg ha^{-1}.

4.8.2 Effect of plant density

Plant density varied significantly in terms of number of pods plant^{-1} of blackgram at 1st harvest and last harvest (Table 9). At 1st harvest and last harvest, the highest number of pods plant^{-1} (40.44 and 15.78) was found from D_3 (45 plants m^{-2}), which was statistically similar (39.78 and 15.11) to D_2 (30 plants m^{-2}),), while the lowest number of pods plant^{-1} (36.56 and 12.44) was recorded from D_1 (15plants m^{-2}) which was statistically similar (37.89 and 14.00) to D_4

(60plants m^{-2}). The highest total number of pods $plant^{-1}$ (56.22) was found in D_3 (45plants m^{-2}) (Fig 7) which was statistically similar to D_2 (60plants m^{-2}) (54.89) but the lowest number of total pods $plant^{-1}$ (49.00) was recorded in D_1 (15plants m^{-2}) treatment which was statistically similar to D_4 (60plants m^{-2}) (51.89). Tomar *et al.* (2013) reported that plants needs uniform distribution for maximum pods $plant^{-1}$.

4.8.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly due to their interaction effect in terms of number of pods $plant^{-1}$ of blackgram at 1^{st} harvest and last harvest (Table 10). At 1^{st} harvest and last harvest, the highest number of pods $plant^{-1}$ (44.67 and 18.67, respectively) was observed from N_1D_2 (20kg N ha^{-1} + 30 plants m^{-2}), whereas the lowest number of pods $plant^{-1}$ (29.67, 10.33 and 40.00, respectively) were recorded from N_0D_1 (0kg N ha^{-1} + 15plants m^{-2}). The highest total number of pods $plant^{-1}$ (61.67) was observed from N_1D_2 (20kg N ha^{-1} + 30 plants m^{-2}), whereas the lowest total number of pods $plant^{-1}$ (40.00) was recorded from N_0D_1 (0kg N ha^{-1} + 15plants m^{-2}) (Fig 8).

Table 9. Effect of different levels of nitrogen fertilizer and plant density on number of pods plant^{-1} and number of seeds pod^{-1} of blackgram

Treatments	Number of pods plant^{-1} at		Number of seeds pod^{-1} at	
	1st harvest	Last harvest	1st harvest	Last harvest
Levels of nitrogen fertilizer				
N_0	33.83 b	11.83 b	5.10 c	6.18 c
N_1	42.00 a	15.75 a	5.58 b	6.47 b
N_2	40.17 a	15.42 a	5.87 a	6.87 a
SE	0.702	0.413	0.112	0.066
CV(%)	6.29	9.97	7.07	3.54
Plant density				
D_1	36.56 c	12.44 c	5.60 a	6.31 bc
D_2	39.78 ab	15.11 ab	5.47 ab	6.53 b
D_3	40.44 a	15.78 a	5.69 a	7.04 a
D_4	37.89 bc	14.00 bc	5.31 b	6.13 c
SE	0.801	0.563	0.091	0.120
CV(%)	6.21	11.78	4.96	5.52

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 10. Interaction effect of different levels of nitrogen fertilizer and plant density on number of pods plant^{-1} and number of seeds pod^{-1} of blackgram

Treatments	Number of pods plant^{-1} at		Number of seeds pod^{-1} at	
	1st harvest	Last harvest	1st harvest	Last harvest
N_0D_1	29.67 e	10.33 f	5.13 cd	5.67 d
N_0D_2	34.33 cd	11.67 ef	5.20 b-d	6.53 bc
N_0D_3	38.00 bc	13.67 c-e	5.27 b-d	7.07 ab
N_0D_4	33.33 de	11.67 ef	4.80 d	5.47 d
N_1D_1	39.33 b	15.00 b-d	5.67 ab	6.33 c
N_1D_2	44.67 a	18.67 a	5.87 a	6.47 bc
N_1D_3	42.67 ab	15.00 b-d	5.87 a	6.67 bc
N_1D_4	41.33 ab	16.00 a-c	5.93 a	6.40 bc
N_2D_1	40.67 ab	12.00 d-f	6.00 a	6.93 a-c
N_2D_2	40.33 ab	16.67 a-c	5.33 bc	6.60 bc
N_2D_3	40.67 ab	17.00 ab	6.07 a	7.40 a
N_2D_4	39.00 b	14.33 b-e	5.07 cd	6.53 bc
SE	1.387	0.975	0.158	0.207
CV(%)	6.21	11.78	4.96	5.52

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

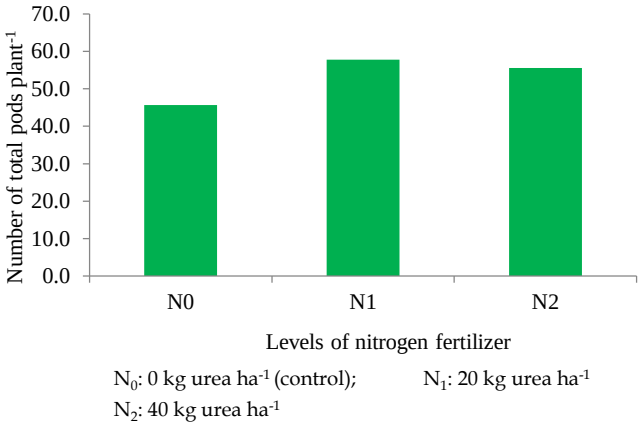


Figure 6. Effect of different levels of nitrogen fertilizer on number of total pods plant^{-1} of blackgram (Sx = 0.768)

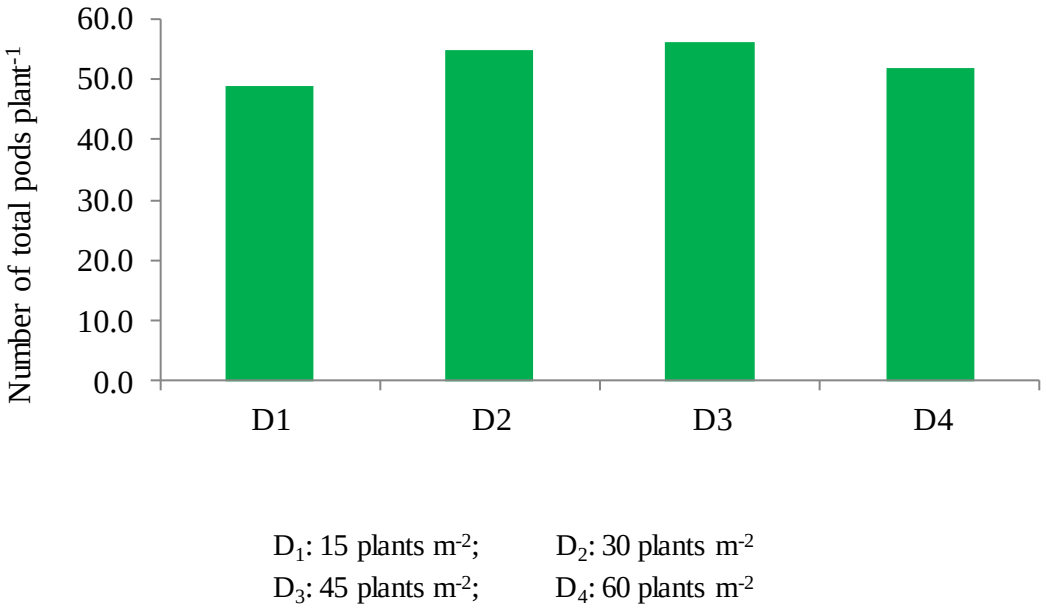


Figure 7. Effect of different plant density on number of total pods plant^{-1} of blackgram (Sx = 1.172)

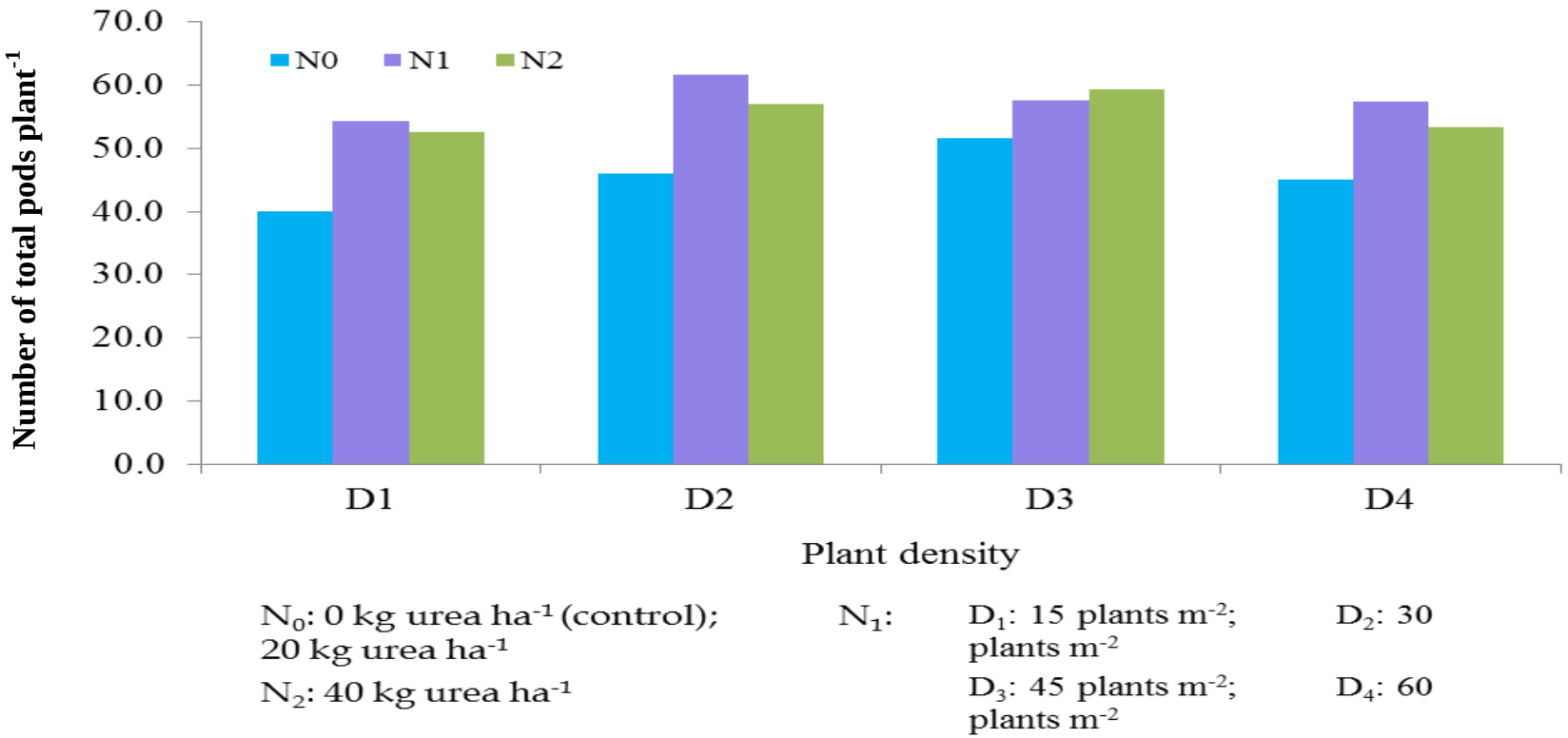


Figure 8. Interaction effect of differnt levels of nitrogen fertilizer and plant density on number of total pods plant^{-1} of blackgram (Sx = 2.030)

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

4.9.1 Effect of nitrogen fertilizer

Different levels of nitrogen showed statistically significant variation in terms of number of seeds pod^{-1} of blackgram at 1st harvest and last harvest (Table 9). At 1st harvest and last harvest, the highest number of seeds pod^{-1} (5.87 and 6.87, respectively) were found from N_2 (40 kg N ha^{-1}) which was closely followed (5.58 and 6.47, respectively) by N_1 (20kg N ha^{-1}), whereas the lowest number of seeds pod^{-1} (5.10, 6.18 and 5.64, respectively) were recorded from N_0 (0kg N ha^{-1}). In an average, the highest number of seeds pod^{-1} (6.37) was found from N_2 (40 kg N ha^{-1})which was closely followed (6.03) by N_1 (20kg N ha^{-1}), whereas the lowest number of seeds pod^{-1} (5.64) from N_0 (0kg N ha^{-1}) (Fig 9). Kulsum *et al*. (2007) recorded the maximum number of seeds plant^{-1} with 80 kg N ha^{-1}.

4.9.2 Effect of plant density

Statistically significant variation was recorded in terms of number of seeds pod^{-1} of blackgram at 1st harvest and last harvest for different plant density (Table 9). At 1st harvest and last harvest, the highest number of seeds pod^{-1} (5.69 and 7.04, respectively) was observed from D_3 (45plants m^{-2}), which was followed (5.47 and 6.53, respectively) by D_2 (30plants m^{-2}), while the lowest number of seeds pod^{-1} (5.31 and 6.13, respectively) was found from D_4 (60plants m^{-2}) which was followed (5.60 and 6.31, respectively) by D_1 (15plants m^{-2}). In an average, the highest number of seeds pod^{-1} (6.37) was observed from D_3 (45plants m^{-2}), which was followed (6.00) by D_2 (30plants m^{-2}), while the lowest number of seeds pod^{-1} (5.72) was found from D_4 (60plants m^{-2}) which was followed (5.96) by D_1 (15plants m^{-2}) (Fig 10). The non-significant effect of row spacing on the number of seeds plant^{-1} has also been reported by Ali *et al*. (2001).

4.9.3 Interaction effect

Number of seeds pod^{-1} of blackgram at 1st harvest and last harvest varied significantly due to the interaction effect of different levels of nitrogen fertilizer and plant density (Table 10). At 1st harvest and last harvest, the highest number of seeds pod^{-1} (6.07 and 7.40, respectively) was recorded from N_2D_3 (40kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest number of seeds pod^{-1} (4.80 and 5.47,

respectively) were observed from N_0D_4 (0kg N ha^{-1} + 60 plants m^{-2}). In an average, the highest number of seeds pod^{-1} (6.67) was recorded from N_2D_3 (40kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest number (5.13) was found from N_0D_4 (0kg N ha^{-1} + 60 plants m^{-2})(Fig 11).

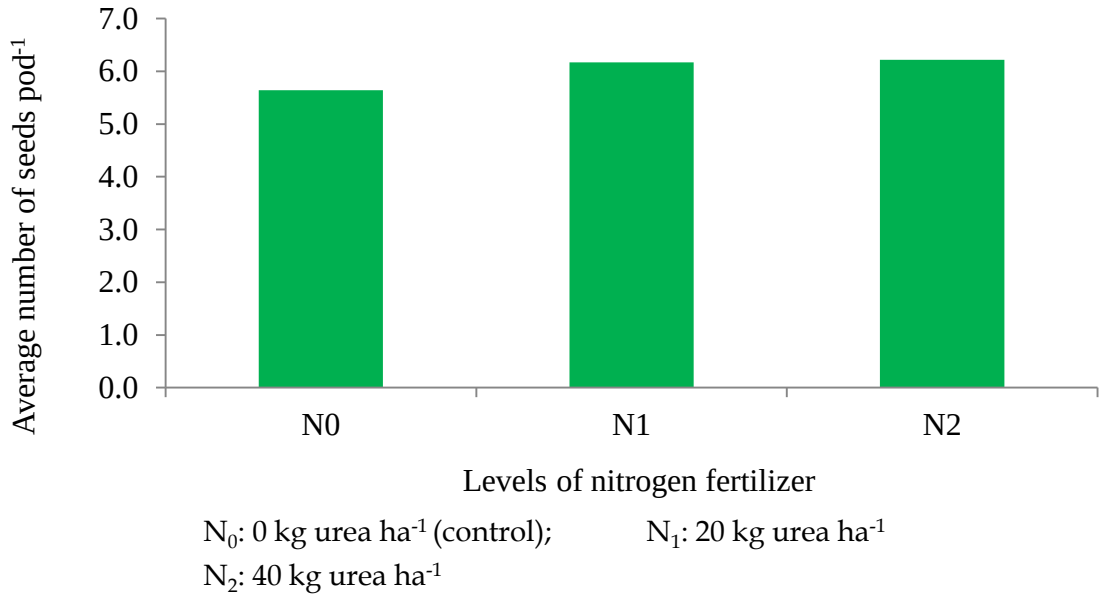


Figure 9. Effect of different levels of nitrogen fertilizer on average number of seeds pod^{-1} of blackgram (Sx = 0.072)

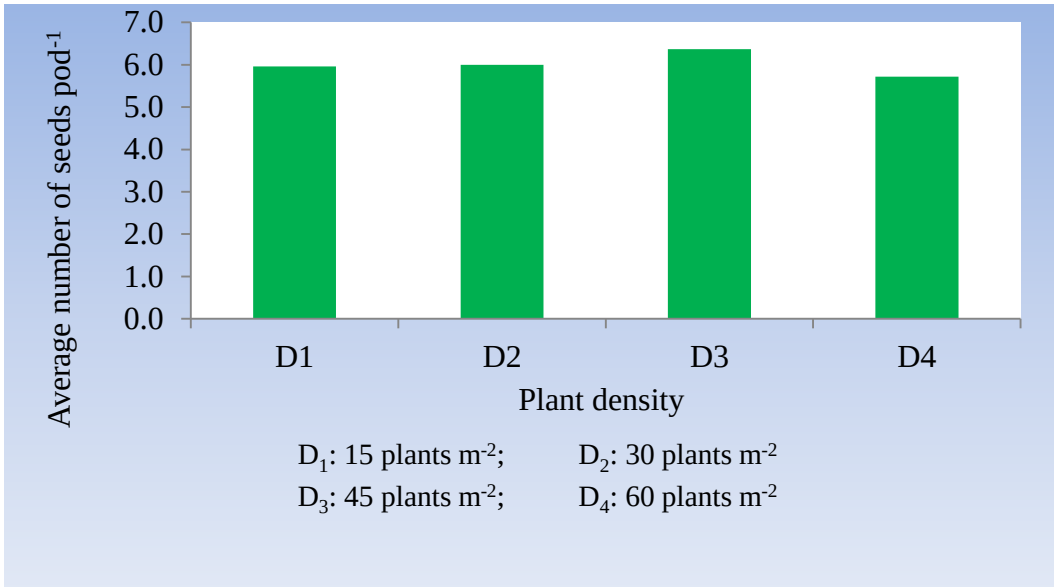
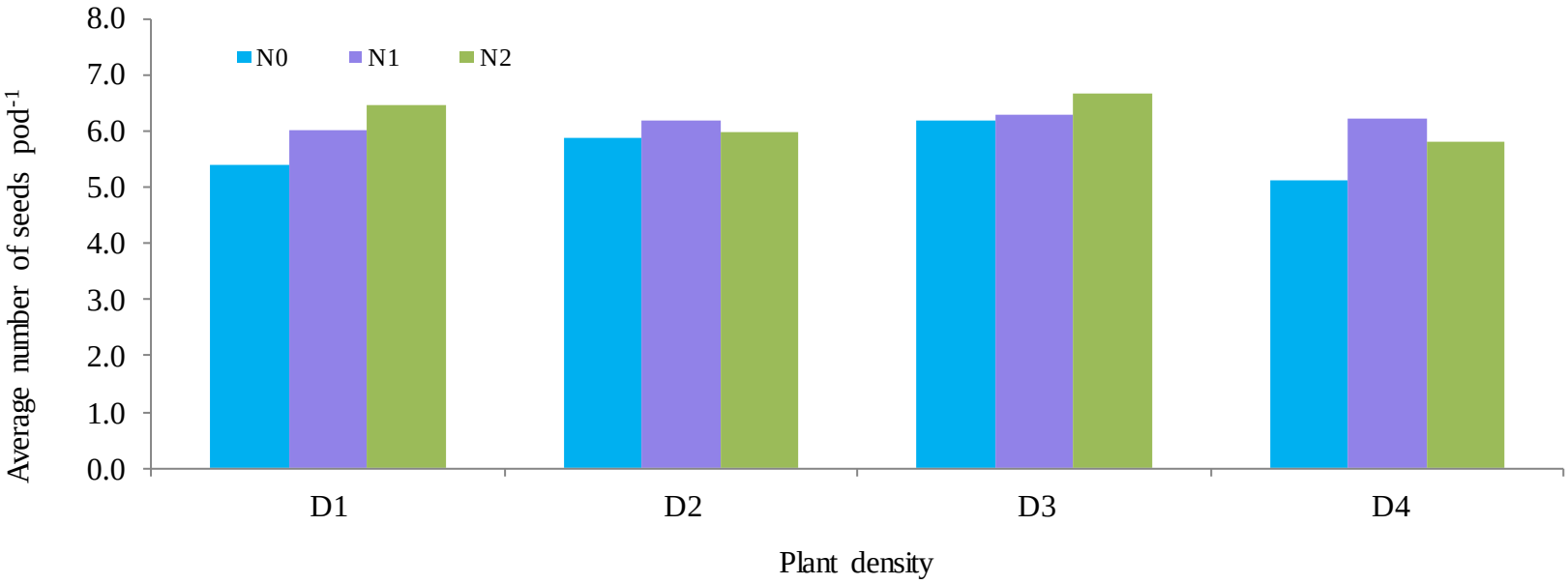


Figure 10. Effect of different plant density on average number of seeds pod^{-1} of blackgram (Sx = 0.069



N_0: 0 kg urea ha^{-1} (control); N_1: 20 kg urea ha^{-1} D_1: 15 plants m^{-2}; D_2: 30 plants m^{-2}

N_2: 40 kg urea ha^{-1} D_3: 45 plants m^{-2}; D_4: 60 plants m^{-2}

Figure 11. Interaction effect of differnt levels of nitrogen fertilizer and plant density on average number of tseeds pod $^{-1}$ of blackgram (Sx = 2.030)

4.10 Pod length

4.10.1 Effect of nitrogen fertilizer

Statistically significant variation was recorded in terms of pod length of blackgram due to different levels of nitrogen at 1st harvest, last harvest and average (Table 11). At 1st harvest, last harvest and average, the longest pod (5.50, 5.69 and 5.59 cm, respectively) were observed from N_2 (40kg N ha^{-1}) which was statistically similar (5.32, 5.44 and 5.38 cm, respectively) to N_1 (20kg N ha^{-1}), whereas the shortest pod (5.12, 5.15 and 5.14 cm, respectively) were found from N_0 (0kg N ha^{-1}). Ekanayake *et al*. (2011) recorded the longest pod of blackgram when N is supplied at the rate of 30 kg ha^{-1} but Kulsum *et al*. (2007) obtained the longest pod with 80 kg N ha^{-1}. Murade *et al*. (2014) reported that pod length was highest with 45 cm row spacing.

4.10.2 Effect of plant density

Pod length of blackgram at 1st harvest, last harvest and average varied significantly for different plant density (Table 11). At 1st harvest, last harvest and average, the longest pod (5.79, 5.62 and 5.70 cm, respectively) was found from D_3 (45plants m^{-2}), which was followed (5.32, 5.39 and 5.36 cm, respectively) by D_1 (15plants m^{-2}), while the shortest pod (4.99, 5.15 and 5.07 cm, respectively) was recorded from D_4 (60plants m^{-2}) which was followed (5.15, 5.54 and 5.34 cm, respectively) by D_2 (30plants m^{-2}).

4.10.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly due to their interaction effect in terms of pod length of blackgram at 1st harvest, last harvest and average (Table 12). At 1st harvest, the longest pod (5.95 cm) was observed from N_2D_3 (40kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_0D_1 (0kg N ha^{-1} + 15 plants m^{-2}), N_0D_3(0kg N ha^{-1} + 45 plants m^{-2}), N_1D_3 (20kg N ha^{-1} + 45 plants m^{-2}), N_2D_1 (40kg N ha^{-1} + 15 plants m^{-2}) and N_2D_2 (40kg N ha^{-1} + 30 plants m^{-2}). Similarly at last harvest, the longest pod (6.00 cm) was observed in N_2D_3 (40kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_0D_3 (0kg N ha^{-1} + 45 plants m^{-2}), N_1D_1 (20kg N ha^{-1} + 15 plants m^{-2}), N_1D_2 (20kg N ha^{-1} + 30 plants m^{-2}), N_1D_3 (20kg N ha^{-1} + 45 plants m^{-2}), N_2D_1

(40kg N ha^{-1} + 15 plants m^{-2}) and N_2D_2 (40kg N ha^{-1} + 30 plants m^{-2}). In an average, the longest pod (5.98 cm) was observed in N_2D_3 (40kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_0D_3 (0kg N ha^{-1} + 45 plants m^{-2}), N_2D_1 (40kg N ha^{-1} + 15 plants m^{-2}) and N_2D_2 (40kg N ha^{-1} + 30 plants m^{-2}), whereas the shortest pod (4.70, 4.94 and 4.82 cm, respectively) were recorded from N_0D_4 (0kg N ha^{-1} + 60 plants m^{-2}).

Table 11. Effect of different levels of nitrogen fertilizer and plant density on pod length of blackgram

Treatments	Pod length (cm) at		
	1st harvest	Last harvest	Average
Levels of nitrogen fertilizer			
N_0	5.12 b	5.15 b	5.14 c
N_1	5.32 ab	5.44 ab	5.38 b
N_2	5.50 a	5.69 a	5.59 a
SE	0.057	0.079	0.051
CV(%)	3.72	5.01	3.28
Plant density			
D_1	5.32 b	5.39 ab	5.36 b
D_2	5.15 b	5.54 a	5.34 b
D_3	5.79 a	5.62 a	5.70 a
D_4	4.99 b	5.15 b	5.07 c
SE	0.114	0.106	0.069
CV(%)	6.43	5.85	3.85

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 12. Interaction effect of different levels of nitrogen fertilizer and plant density on pod length of blackgram

Treatments	Pod length (cm) at		
	1st harvest	Last harvest	Average
N_0D_1	5.49 a-c	5.02 de	5.26 b-d
N_0D_2	4.88 cd	5.09 c-e	4.99 d
N_0D_3	5.41 a-c	5.55 a-e	5.48 a-c
N_0D_4	4.70 d	4.94 e	4.82 d
N_1D_1	5.11 b-d	5.41 a-e	5.26 b-d
N_1D_2	4.99 b-d	5.51 a-e	5.25 b-d
N_1D_3	6.01 a	5.63 a-d	5.82 a
N_1D_4	5.16 b-d	5.21 b-e	5.18 cd
N_2D_1	5.36 a-d	5.83 ab	5.59 ab
N_2D_2	5.58 ab	5.69 a-c	5.64 ab
N_2D_3	5.95 a	6.00 a	5.98 a
N_2D_4	5.12 b-d	5.23 b-e	5.18 cd
SE	0.197	0.183	0.119
CV(%)	6.43	5.85	3.85

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.11 Weight of 1000-seeds

4.11.1 Effect of nitrogen fertilizer

Weight of 1000-seeds of blackgram showed statistically significant variation due to different levels of nitrogen at 1st harvest, last harvest and average (Table 13). At 1st harvest, last harvest and average, the highest weight of 1000-seeds (40.08, 41.58 and 40.83 g, respectively) were recorded from N_2 (40kg N ha^{-1}) which was statistically similar (39.67, 40.75 and 40.21 g, respectively) to N_1 (20kg N ha^{-1}), whereas the lowest weight of 1000-seeds (36.25, 37.50 and 36.88 g, respectively) were observed from N_0 (0kg N ha^{-1}). Patel and Patel (1991) found that application of nitrogen in significant increases in 1000 seed weight of blackgram.

4.11.2 Effect of plant density

Statistically significant variation was recorded in terms of weight of 1000-seeds of blackgram at 1st harvest, last harvest and average due to different plant density (Table 13). At 1st harvest, last harvest and average, the highest weight of 1000-seeds (40.11, 41.56 and 40.83 g, respectively) was observed from D_3 (45 plants m^{-2}), which was statistically similar (38.89, 40.89 and 39.89 g, respectively) to D_1 (15 plants m^{-2}), while the lowest weight of 1000-seeds (37.67, 38.00 and 37.83 g, respectively) was found from D_4 (60 plants m^{-2}) which was followed (38.00, 39.33 and 38.67 g, respectively) by D_2 (30 plants m^{-2}). Agarwal *et al.* (2015) reported that crops sown in 40 cm apart rows produced significantly higher 1000 seeds weight than 60 cm apart double row strips.

4.11.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly due to their interaction effect in terms of weight of 1000-seeds of blackgram at 1st harvest, last harvest and average (Table 14). At 1st harvest, the highest weight of 1000-seeds (41.67 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with all other combinations except N_0D_1 (0kg N ha^{-1} + 15 plants m^{-2}), N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}), N_0D_3 (0 kg N ha^{-1} + 45 plants m^{-2}) and N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). At last harvest, the highest weight of 1000-seeds (43.00 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with all other combinations except

N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}), N_0D_2 (0 kg N ha^{-1} + 30 plants m^{-2}) and N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). In an average, the highest weight of 1000-seeds (42.34 g) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}), N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}), N_1D_4 (20 kg N ha^{-1} + 60 plants m^{-2}), N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}), N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2})·and N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}), whereas the lowest weight of 1000-seeds (34.00, 34.67 and 34.33 g, respectively) were found from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

Table 13. Effect of different levels of nitrogen fertilizer and plant density on weight of 1000-seeds of blackgram

Treatments	Weight of 1000-seeds (g) at		
	1st harvest	Last harvest	Average
Levels of nitrogen fertilizer			
N_0	36.25 b	37.50 b	36.88 b
N_1	39.67 a	40.75 a	40.21 a
N_2	40.08 a	41.58 a	40.83 a
SE	0.648	0.488	0.537
CV(%)	5.81	4.23	4.73
Plant density			
D_1	38.89 ab	40.89 a	39.89 ab
D_2	38.00 b	39.33 ab	38.67 bc
D_3	40.11 a	41.56 a	40.83 a
D_4	37.67 b	38.00 b	37.83 c
SE	0.565	0.745	0.459
CV(%)	4.38	5.59	3.50

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 14. Interaction effect of different levels of nitrogen fertilizer and plant density on weight of 1000-seeds of blackgram

Treatments	Weight of 1000-seeds (g) at		
	1st harvest	Last harvest	Average
N_0D_1	38.00 b-d	38.00 b-d	38.00 cd
N_0D_2	35.33 de	37.33 cd	36.33 de
N_0D_3	37.67 cd	40.00 a-c	38.83 bc
N_0D_4	34.00 e	34.67 d	34.33 e
N_1D_1	38.67 a-c	42.67 a	40.67 ab
N_1D_2	39.33 a-c	38.67 a-d	39.00 bc
N_1D_3	41.00 ab	41.67 ab	41.34 ab
N_1D_4	39.00 a-c	40.00 a-c	39.50 a-c
N_2D_1	40.00 a-c	42.00 ab	41.00 ab
N_2D_2	39.33 a-c	42.00 ab	40.67 ab
N_2D_3	41.67 a	43.00 a	42.34 a
N_2D_4	40.00 a-c	39.33 a-c	39.67 a-c
SE	0.978	1.290	0.795
CV(%)	4.38	5.59	3.50

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.12 Seed yield

4.12.1 Effect of nitrogen fertilizer

Seed yield of blackgram showed statistically significant variation in due to different levels of nitrogen at 1st harvest, last harvest and total (Table 15). At 1st harvest, last harvest and total, the highest seed yield (0.92, 0.32 and 1.23 t ha^{-1}, respectively) were recorded from N_2 (40 kg N ha^{-1}) which was statistically similar (0.85, 0.29 and 1.14 t ha^{-1}, respectively) to N_1 (20 kg N ha^{-1}), whereas the lowest seed yield (0.63, 0.25 and 0.89 t ha^{-1}, respectively) were observed from N_0 (0 kg N ha^{-1}). Ekanayake *et al*. (2011) obtained the maximum yield when N is supplied @ 30 kg ha^{-1}. Kulsum *et al*. (2007) reported that application of 60 kg N ha^{-1} favored most of the yield contributing characters that contributed the maximum grain yield of blackgram. Saini and Thakur (1996) stated that application of nitrogen significantly increased the grain yield of blackgram and the application of 30 kg N ha^{-1} produced the highest seed yield.

4.12.2 Effect of plant density

Plant density varied significantly in terms of seed yield of blackgram at 1st harvest, last harvest and total (Table 15). At 1st harvest, last harvest and total, the highest seed yield (0.86, 0.33 and 1.19 t ha^{-1}, respectively) was observed from D_3 (45 plants m^{-2}), which was statistically similar (0.83, 0.33 and 1.16 t ha^{-1}, respectively) to D_1 (15 plants m^{-2}), while the lowest seed yield (0.71, 0.22 and 0.93 t ha^{-1}, respectively) was recorded from D_4 (45 plants m^{-2}) which was closely followed (0.79, 0.27 and 1.06 t ha^{-1}, respectively) by D_2 (30 plants m^{-2}). Ekanayake *et al*. (2011) reported that the maximum yield at a seed rate of 64 kg ha^{-1}, and the maximum yield was estimated as 93 plants m^{-2} which was also comparable to this seed rate. Kabir *et al.* (2002) recorded numerically yield ha^{-1} (3120 kg) from seeds @ 20 kg ha^{-1}.

4.12.3 Interaction effect

Interaction effect of different levels of nitrogen fertilizer and plant density varied significantly in terms of seed yield per of blackgram at 1st harvest, last harvest and total (Table 16). At 1st harvest, last harvest and total, the highest seed yield (1.03, 0.46 and 1.49 t ha^{-1}, respectively) was observed from N_2D_3 (40 kg N ha^{-1} +

45 plants m^{-2}), whereas the lowest (0.50, 0.23 and 0.73 t ha^{-1}, respectively) were recorded from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

Table 15. Effect of different levels of nitrogen fertilizer and plant density on seed yield of blackgram

Treatments	Seed yield (t ha^{-1}) at		
	1st harvest	Last harvest	Total
Levels of nitrogen fertilizer			
N_0	0.63 b	0.25 b	0.89 c
N_1	0.85 a	0.29 ab	1.14 b
N_2	0.92 a	0.32 a	1.23 a
SE	0.032	0.009	0.025
CV(%)	13.69	11.03	7.70
Plant density			
D_1	0.83 ab	0.33 a	1.16 a
D_2	0.79 b	0.27 b	1.06 b
D_3	0.86 a	0.33 a	1.19 a
D_4	0.71 c	0.22 c	0.93 c
SE	0.019	0.010	0.023
CV(%)	7.06	10.58	6.33

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 16. Interaction effect of different levels of nitrogen fertilizer and plant density on seed yield of blackgram

Treatments	Seed yield (t ha^{-1}) at		
	1st harvest	Last harvest	Total
N_0D_1	0.58 e	0.22 e	0.79 g
N_0D_2	0.71 d	0.28 cd	0.99 ef
N_0D_3	0.75 d	0.29 c	1.04 d-f
N_0D_4	0.50 e	0.23 de	0.73 g
N_1D_1	0.90 bc	0.31 bc	1.20 bc
N_1D_2	0.85 bc	0.30 bc	1.16 b-d
N_1D_3	0.89 bc	0.36 b	1.25 bc
N_1D_4	0.75 d	0.19 e	0.93 f
N_2D_1	0.93 b	0.36 b	1.29 b
N_2D_2	0.81 cd	0.23 de	1.04 d-f
N_2D_3	1.03 a	0.46 a	1.49 a
N_2D_4	0.89 bc	0.23 de	1.12 c-e
SE	0.033	0.018	0.040
CV(%)	7.06	10.58	6.33

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.13 Shelling percentage

4.13.1 Effect of nitrogen fertilizer

Statistically significant variation was recorded in terms of shelling percentage of blackgram due to different levels of nitrogen (Table 17). The highest shelling percentage (97.14%) was found from N_2 (40 kg N ha^{-1}) which was statistically similar (96.89%) to N_1 (20 kg N ha^{-1}), whereas the lowest shelling percentage (93.53%) was observed from N_0 (0 kg N ha^{-1}).

4.13.2 Effect of plant density

Shelling percentage of blackgram varied significantly for different plant density (Table 17). The highest shelling percentage (96.80%) was recorded from D_2 (30 plants m^{-2}) and D_3 (45 plants m^{-2}), which was statically similar (96.47%) to D_1 (15 plants m^{-2}), while the lowest shelling percentage (93.34%) was found from D_4 (60 plants m^{-2}).

4.13.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly due to their interaction effect in terms of shelling percentage of blackgram (Table 18). The highest shelling percentage (68. 21%) was found from N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}) which was statistically similar with N_1D_1 (20 kg N ha^{-1} + 15 plants m^{-2}), N_1D_2 (20 kg N ha^{-1} + 30 plants m^{-2}), N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}), N_2D_2 (40 kg N ha^{-1} + 30 plants m^{-2}) and N_2D_3 (40 kg N ha^{-1} + 30 plants m^{-2}), whereas the lowest shelling percentage (61.96%) was observed from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

4.14 Stover yield

4.14.1 Effect of nitrogen fertilizer

Different levels of nitrogen showed statistically significant variation in terms of stover yield of blackgram (Table 17). The highest stover yield (2.74 t ha^{-1}) was observed from N_2(40kg N ha^{-1}) which was closely followed (2.60 t ha^{-1}) by N_1 (20 kg N ha^{-}), whereas the lowest (2.44 t ha^{-1}) was recorded from N_0 (0 kg N ha^{-1}). Yadav *et al*. (1994) reported that higher stover yield of blackgram was observed with 20 kg N ha^{-1}.

4.14.2 Effect of plant density

Stover yield of blackgram varied significantly due to different plant density (Table 17). The highest stover yield (2.79 t ha^{-1}) was observed from D_3 (45 plants m^{-2}), which was closely followed (2.59 t ha^{-1} and 2.57 t ha^{-1}, respectively) by D_2 (30 plants m^{-2})and D_1 (15plants m^{-2}) and they were statistically similar, while the lowest stover yield (2.43 t ha^{-1}) was observed from D_4 (60plants m^{-2}).

4.14.3 Interaction effect

Statistically significant variation was recorded due to the interaction effect of different levels of nitrogen fertilizer and plant density in terms of stover yield of blackgram (Table 18). The highest stover yield (2.90 t ha^{-1}) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}) which was closely followed by N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}), whereas the lowest stover yield (2.21 t ha^{-1}) was observed from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

Table 17. Effect of different levels of nitrogen fertilizer and plant density on shelling percentage, stover yield, biological yield and harvest index of blackgram

Treatments	Shelling percentage (%)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Levels of nitrogen fertilizer				
N_0	93.53 b	2.44 c	3.33 c	36.28 b
N_1	96.89 a	2.60 b	3.73 b	43.72 a
N_2	97.14 a	2.74 a	3.97 a	44.92 a
SE	0.091	0.022	0.033	1.002
CV(%)	3.33	2.99	3.10	8.33
Plant density				
D_1	96.47 a	2.57 b	3.73 b	44.70 a
D_2	96.80 a	2.59 b	3.65 b	41.11 bc
D_3	96.80 a	2.79 a	3.98 a	42.69 ab
D_4	93.34 b	2.43 c	3.36 c	38.06 c
SE	0.167	0.028	0.036	1.044
CV(%)	4.52	3.22	2.91	7.52

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

Table 18. Interaction effect of different levels of nitrogen fertilizer and plant density on shelling percentage, stover yield, biological yield and harvest index of blackgram

Treatments	Shelling percentage (%)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0D_1	64.05 b	2.34 e	3.13 e	33.96 fg
N_0D_2	64.10 b	2.50 d	3.50 d	39.77 c-f
N_0D_3	64.02 b	2.72 bc	3.75 c	38.21 e-g
N_0D_4	61.96 c	2.21 e	2.95 f	33.20 g
N_1D_1	67.60 a	2.56 cd	3.76 c	47.05 b
N_1D_2	68.13 a	2.57 cd	3.73 c	44.96 bc
N_1D_3	68.21 a	2.75 b	4.00 b	45.50 bc
N_1D_4	63.62 b	2.50 d	3.44 d	37.35 fg
N_2D_1	67.76 a	2.80 ab	4.29 a	53.09 a
N_2D_2	68.16 a	2.69 bc	3.72 c	38.60 d-g
N_2D_3	68.17 a	2.90 a	4.19 a	44.36 b-d
N_2D_4	64.45 b	2.57 cd	3.69 c	43.63 b-e
SE	0.289	0.048	0.062	1.808
CV(%)	4.52	3.22	2.91	7.52

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

N_0: 0 kg N ha^{-1} (control)
N_1: 20 kg N ha^{-1}
N_2: 40 kg N ha^{-1}

D_1: 15 plants m^{-2}
D_2: 30 plants m^{-2}
D_3: 45 plants m^{-2}
D_4: 60 plants m^{-2}

4.15 Biological yield

4.15.1 Effect of nitrogen fertilizer

Biological yield of blackgram showed statistically significant variation due to different levels of nitrogen (Table 17). The highest biological yield (3.97 t ha^{-1}) was observed from N_2 (40 kg N ha^{-1}) which was closely followed (3.73 t ha^{-1}) by N_1 (20 kg N ha^{-1}), whereas the lowest biological yield (3.33 t ha^{-1}) was found from N_0 (20 kg N ha^{-1}). Bhalu *et al.* (1995) observed from their experiment that biological yield of blackgram increased with the application of up to 20 kg N ha^{-1}.

4.15.2 Effect of plant density

Plant density varied significantly in terms of biological yield of blackgram (Table 17). The highest biological yield (3.98 t ha^{-1}) was found from D_3 (45 plants m^{-2}), which was closely followed (3.73 t ha^{-1} and 3.65 t ha^{-1}, respectively) by D_1 (15 plants m^{-2}) and D_2 (30 plants m^{-2})and they were statistically similar, while the lowest biological yield (3.36 t ha^{-1}) was recorded from D_4 (60 plants m^{-2}). Prasad *et al.* (2014) reported significantly higher biological yield of 2951.25 kg ha^{-1} with spacing of 30 cm × 10 cm than spacing of 45 cm ×10 cm.

4.15.3 Interaction effect

Different levels of nitrogen fertilizer and plant density varied significantly due to their interaction effect in terms of biological yield of blackgram (Table 18). The highest biological yield (4.29 t ha^{-1}) was observed from N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}), whereas the lowest biological yield (2.95 t ha^{-1}) was recorded from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

4.16 Harvest index

4.16.1 Effect of nitrogen fertilizer

Statistically significant variation was recorded in terms of harvest index of blackgram due to different levels of nitrogen (Table 17). The highest harvest index (44.92%) was found from N_2 (40 kg N ha^{-1}) which was statistically similar (43.72%) to N_1 (20 kg N ha^{-1}), whereas the lowest harvest index (36.28%) was observed from N_0 (0 kg N ha^{-1}). Sharma and Abraham (2010) revealed that the application of nitrogen @ 20 kg ha^{-1} showed a significant increment in harvest index of blackgram. Saini and Thakur (1996) stated that the application of 30 kg N ha^{-1} produced the highest harvest index.

4.16.2 Effect of plant density

Harvest index of blackgram varied significantly due to different plant density (Table 17). The highest harvest index (44.70%) was recorded from D_1 (15 plants m^{-2}), which was statistically similar (42.69%) to D_3 (45 plants m^{-2}), while the lowest harvest index (38.06%) was found from D_4 (60 plants m^{-2}) which was statistically similar (41.11%) to D_2 (30 plants m^{-2}). Murade *et al*. (2014) reported that harvest index was highest with 45 cm row spacing.

4.16.3 Interaction effect

Interaction effect of different levels of nitrogen fertilizer and plant density varied significantly in terms of harvest index of blackgram (Table 18). The highest harvest index (53.09%) was recorded from N_2D_1 (40 kg N ha^{-1} + 15 plants m^{-2}) which was statistically similar with N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest harvest index (33.20%) was found from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from March to June, 2015 at the Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka to find out the response of nitrogen fertilizer and plant density on the performance of blackgram. Blackgram variety BARI Mash-3 (Hemantoo) was used as planting material for the study. The experiment comprised of two factors; Factor A: Levels of nitrogen (3 levels)- N_0: 0 kg N ha^{-1} (control), N_1: 20 kg N ha^{-1}, N_2: 40 kg N ha^{-1} and Factor B: Plant density (4 levels)- D_1: 15 plants m^{-2}, D_2: 30 plants m^{-2}, D_3: 45 plants m^{-2}, D_4: 60 plants m^{-2}. The two factors experiment was laid out in a split-plot design with three replications. Data on different parameters were recorded and statistically significant variation was observed for different treatment.

In case of nitrogen fertilizer, at 15, 30, 45 DAS and harvest, the tallest plant (14.10, 31.71, 53.43 and 61.91 cm, respectively), the highest number of leaves $plant^{-1}$ (5.13, 29.13, 50.70 and 66.50, respectively), the highest number of branches $plant^{-1}$ (3.75, 4.80 and 8.37, respectively) and the highest dry matter content $plant^{-1}$ (0.76, 3.05, 6.07 and 7.81 g, respectively) were found from N_2 (40 kg N ha^{-1}), while the shortest plant (12.91, 29.44, 48.10 and 56.20 cm, respectively), the lowest number of leaves $plant^{-1}$ (4.13, 25.98, 44.83 and 57.88, respectively), the lowest number of branches $plant^{-1}$ (3.05, 4.02 and 7.65, respectively) and the lowest dry matter content $plant^{-1}$ (0.63, 2.58, 5.13 and 6.88 g, respectively) were observed from N_0 (0 kg N ha^{-1}). At 30 and 45 DAS, the maximum number of nodules $plant^{-1}$ (29.04 and 25.42, respectively) was recorded from N_1(20 kg N ha^{-1}), whereas the minimum number (24.05 and 20.88, respectively) was observed from N_0 (0 kg N ha^{-1}). The maximum days to flowering (31.00) and the maximum days to harvest (64.75) was recorded from N_2 (40 kg N ha^{-1}), whereas the minimum days to flowering (28.17) and the minimum days to maturity (61.42) was recorded from N_1 (20 kg N ha^{-1}).

At 1st harvest, last harvest and total, the maximum number of pods plant^{-1} (42.00, 15.75 and 57.75, respectively) were observed from N_1 (20 kg N ha^{-1}), whereas the minimum number of pods plant^{-1} (33.83, 11.83 and 45.66, respectively) were found from N_0 (0 kg N ha^{-1}). At 1st harvest, last harvest and average, the maximum number of seeds pod^{-1} (5.87, 6.87 and 6.37, respectively), the longest pod (5.50, 5.69 and 5.59 cm, respectively), the highest weight of 1000-seeds (40.08, 41.58 and 40.83 g, respectively) and the highest seed yield (0.92, 0.32 and 1.23 t ha^{-1}, respectively) were found from N_2 (40 kg N ha^{-1}), whereas the minimum number of seeds pod^{-1} (5.10, 6.18 and 5.64, respectively), the shortest pod (5.12, 5.15 and 5.14cm, respectively), the lowest weight of 1000-seeds (36.25, 37.50 and 36.88 g, respectively), the lowest seed yield (0.63, 0.25 and 0.89 t ha^{-1}, respectively) were found from N_0 (0 kg N ha^{-1}). The highest shelling percentage (97.14%), the highest stover yield (2.74 t ha^{-1}) the highest biological yield (3.97 t ha^{-1}) and the highest harvest index (44.92%) were found from N_2 (40 kg N ha^{-1}), whereas the lowest shelling percentage (93.53%), the lowest stover yield (2.44 t ha^{-1}), the lowest biological yield (3.33 t ha^{-1}) and the lowest harvest index (36.28%) were observed from N_0 (0 kg N ha^{-1}).

For plant density, at 15, 30, 45 DAS and harvest, the tallest plant (14.94, 33.61, 54.12 and 62.97 cm, respectively), the maximum number of leaves plant^{-1} (5.16, 29.89, 50.99 and 65.64, respectively) and the maximum number of branches plant^{-1} (3.69, 4.71 and 8.31, respectively) was recorded from D_3 (45 plants m^{-2}), whereas the shortest plant (12.34, 28.27, 48.92 and 57.62 cm, respectively), the minimum number of leaves plant^{-1} (4.60, 26.47, 46.74 and 60.31, respectively) and the minimum number of branches plant^{-1} (3.27, 4.20 and 7.76, respectively) was found from D_1 (15 plants m^{-2}). At 15, 30, 45 DAS and at harvest, the highest dry matter content plant^{-1} (0.76, 3.05, 6.05 and 7.67 g, respectively) was found from D_3 (45 plants m^{-2}), while the lowest (0.59, 2.69, 5.36 and 6.73 g, respectively) from D_4 (60 plants m^{-2}). At 30 and 45 DAS, the maximum number of nodules plant^{-1} (31.31 and 26.30, respectively) was found from D_3 (45 plants m^{-2}), while the minimum number (25.00 and 22.00, respectively) from D_1 (15 plants m^{-2}). The maximum days to flowering (30.22) were observed from D_4 (60 plants m^{-2}), while the minimum number (28.11) from D_3 (45 plants m^{-2}). The

maximum days to harvest (63.11) were observed from D_4 (60 plants m^{-2}), while the minimum number (62.44) from D_2 (30 plants m^{-2}).

At 1st harvest, last harvest and total, the maximum number of pods $plant^{-1}$ (40.44, 15.78 and 56.22, respectively) was found from D_3 (45 plants m^{-2}), while the minimum number (36.56, 12.44 and 49.00, respectively) from D_1 (15 plants m^{-2}). At 1st harvest, last harvest and average, the maximum number of seeds pod^{-1} (5.69, 7.04 and 6.37, respectively), the longest pod (5.79, 5.62 and 5.70 cm, respectively) and the highest weight of 1000-seeds (40.11, 41.56 and 40.83 g, respectively) was observed from D_3 (45 plants m^{-2}), while the minimum number of seeds pod^{-1} (5.31, 6.13 and 5.72, respectively), the shortest pod (4.99, 5.15 and 5.07 cm, respectively) and the lowest weight of 1000-seeds (37.67, 38.00 and 37.83 g, respectively) was found from D_4 (60 plants m^{-2}). At 1st harvest, last harvest and total, the highest seed yield (0.86, 0.33 and 1.19 t ha^{-1}, respectively) was observed from D_3 (45 plants m^{-2}), while the lowest seed yield (0.71, 0.22 and 0.93 t ha^{-1}, respectively) from D_4 (60 plants m^{-2}). The highest shelling percentage (96.80%) and was recorded from D_2 (30 plants m^{-2}) and D_3 (45plants m^{-2}), while the lowest shelling percentage (93.34%) from D_4 (60 plants m^{-2}). The highest stover yield (2.79 t ha^{-1}) and the highest biological yield (3.98 t ha^{-1}) was observed from D_3 (45 plants m^{-2}), while the lowest stover yield (2.43 t ha^{-1}) and the lowest biological yield (3.36 t ha^{-1}) was found from D_4 (60 plants m^{-2}). The highest harvest index (44.70%) was recorded from D_1 (15 plants m^{-2}), while the lowest (38.06%) from D_4 (60 plants m^{-2}).

Due to the interaction effect of nitrogen fertilizer and plant density, at 15, 30, 45 DAS and harvest, the tallest plant (16.75, 36.06, 58.97 and 68.29 cm, respectively), the highest number of leaves $plant^{-1}$ (5.87, 31.00, 55.60 and 70.87, respectively), the highest number of branches $plant^{-1}$ (4.20, 5.33 and 8.60, respectively) and the highest dry matter content $plant^{-1}$ (0.81, 3.42, 6.87 and 8.03 g, respectively) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the shortest plant (10.44, 25.57, 44.56 and 51.18 cm, respectively), the lowest number (2.80, 23.13, 42.10 and 53.87, respectively), the lowest number of branches $plant^{-1}$ (2.93, 3.90 and 7.20, respectively) and the lowest dry matter content $plant^{-1}$ (20.48, 2.32, 3.87 and 5.83 g, respectively) were found from N_0D_1

(0 kg N ha^{-1} + 15 plants m^{-2}). At 30 and 45 DAS, the maximum number of nodules $plant^{-1}$ (34.40 and 30.77, respectively) was found from N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}), whereas the minimum number (18.73 and 14.33, respectively) from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). The maximum days to flowering (32.00) was recorded from N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}), whereas the minimum days (27.00) from N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}). The maximum days to harvest (65.33) were found from N_2D_4 (40 kg N ha^{-1} + 60 plants m^{-2}), whereas the minimum days (61.00) from N_1D_2 (20 kg N ha^{-1} + 30 plants m^{-2}).

At 1st harvest, last harvest and total, the maximum number of pods $plant^{-1}$ (44.67, 18.67 and 61.67, respectively) was observed from N_1D_2 (20 kg N ha^{-1} + 30 plants m^{-2}), whereas the minimum number of pods $plant^{-1}$ (29.67, 10.33 and 40.00, respectively) were recorded from N_0D_1 (0 kg N ha^{-1} + 15 plants m^{-2}).

At 1st harvest, last harvest and average, the maximum number of seeds pod^{-1} (6.07, 7.40 and 6.67, respectively), the longest pod (5.95, 6.00 and 5.98 cm, respectively) and the highest weight of 1000-seeds (41.67, 43.00 and 42.34 g, respectively) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the minimum number of seeds pod^{-1} (4.80, 5.47 and 5.13, respectively), the shortest pod (4.70, 4.94 and 4.82 cm, respectively) and the lowest weight of 1000-seeds (34.00, 34.67 and 34.33 g, respectively) were observed from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). At 1st harvest, last harvest and total, the highest seed yield (1.03, 0.46 and 1.49 t ha^{-1}, respectively) was observed from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest seed yield (0.50, 0.23 and 0.73 t ha^{-1}, respectively) from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). The highest shelling percentage (68.21%) was found from N_1D_3 (20 kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest shelling percentage (61.96%) from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). The highest stover yield (2.90 t ha^{-1}) was recorded from N_2D_3 (40 kg N ha^{-1} + 45 plants m^{-2}), whereas the lowest stover yield (2.21 t ha^{-1}) from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}). The highest biological yield (4.29 t ha^{-1}) and the highest harvest index (53.09%) were observed from N_2D_1 (40 kg N ha^{-1} + 15

plants m^{-2}), whereas the lowest biological yield (2.95 t ha^{-1}) and the lowest harvest index (33.20%) from N_0D_4 (0 kg N ha^{-1} + 60 plants m^{-2}).

Considering the findings of the present experiment, following conclusions may be drawn:

1. Maintaining 45 plants m^{-2} with applying 40 kg N ha^{-1} revealed maximum yield contributing characters and yield compared to the others.

2. Before recommendation of nitrogenous fertilizer and plant density to optimize blackgram production further study is needed in different agro-ecological zones of Bangladesh for regional adaptability.

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APPENDICES

Appendix I. Characteristics of the soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Research Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.7
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from March to June, 2015

Month (2015)	*Air temperature (^{o}C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
March	31.7	19.5	65	00
April	33.4	23.2	67	78
May	34.7	25.9	70	185
June	35.4	22.5	80	277

* Monthly average

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

Appendix III. Mean square values of plant height of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square			
		Plant height at			
		15 DAS	30 DAS	45 DAS	Harvest
Replication	2	0.243	0.120	4.087	0.868
Nitrogen fertilizer (A)	2	4.340*	16.194*	92.543*	112.856*
Error	4	0.431	1.427	8.728	11.138
Plant density (B)	3	17.732**	53.646**	50.704**	47.249*
Interaction (A×B)	6	6.275**	17.393*	22.032**	36.897*
Error	18	0.708	5.872	5.266	12.059

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Mean square values of number of leaves plant^{-1} of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square			
		Number of leaves plant^{-1} at			
		15 DAS	30 DAS	45 DAS	Harvest
Replication	2	0.314	0.253	3.541	5.098
Nitrogen fertilizer (A)	2	3.321*	34.830*	124.11**	269.21**
Error	4	0.323	3.888	7.691	7.633
Plant density (B)	3	1.918**	18.285**	29.969*	44.529**
Interaction (A×B)	6	1.331**	12.791*	22.677*	19.446*
Error	18	0.121	3.626	8.228	6.820

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix V. Mean square values of number of branches plant^{-1} of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square		
		Number of branches plant^{-1} at		
		30 DAS	45 DAS	Harvest
Replication	2	0.021	0.071	0.041
Nitrogen fertilizer (A)	2	1.658**	2.074*	1.688*
Error	4	0.051	0.171	0.181
Plant density (B)	3	0.280**	0.406**	0.484*
Interaction (A×B)	6	0.363**	0.289**	0.397*
Error	18	0.062	0.077	0.137

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VI. Mean square values of dry matter content plant^{-1} of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square			
		Dry matter content plant^{-1} at			
		15 DAS	30 DAS	45 DAS	Harvest
Replication	2	0.001	0.028	0.141	0.116
Nitrogen fertilizer (A)	2	0.048**	0.693*	2.857*	2.816*
Error	4	0.003	0.057	0.319	0.230
Plant density (B)	3	0.060**	0.199*	1.107**	1.142*
Interaction (A×B)	6	0.017*	0.493**	2.151**	0.605*
Error	18	0.005	0.059	0.210	0.258

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VII. Mean square values of nodules plant^{-1}, days to flowering and harvest of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square			
		Number of nodules plant^{-1} at		Days to flowering	Days to harvest
		30 DAS	45 DAS		
Replication	2	1.547	1.978	0.111	8.028
Nitrogen fertilizer (A)	2	91.360*	61.720**	24.194**	36.111*
Error	4	7.011	3.447	0.778	2.903
Plant density (B)	3	70.000**	40.708*	8.546**	0.694
Interaction (A×B)	6	35.271**	86.154**	0.935*	0.333*
Error	18	7.388	10.321	0.444	0.648

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VIII. Mean square values of number of pods plant^{-1} of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square		
		Number of pods plant^{-1} at		
		1st harvest	Last harvest	Total
Replication	2	3.583	1.583	5.250
Nitrogen fertilizer (A)	2	220.333**	56.583**	498.083**
Error	4	5.917	2.042	7.083
Plant density (B)	3	28.370**	19.111**	93.556**
Interaction (A×B)	6	11.926*	7.139*	32.639*
Error	18	5.769	2.852	12.361

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IX. Mean square values of number of seeds pod^{-1} of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square		
		Number of seeds pod^{-1} at		
		1st harvest	Last harvest	Average
Replication	2	0.063	0.014	0.025
Nitrogen fertilizer (A)	2	1.803*	1.414**	1.239**
Error	4	0.152	0.053	0.062
Plant density (B)	3	0.244*	1.403**	0.639**
Interaction (A×B)	6	0.295**	0.407*	0.273**
Error	18	0.075	0.129	0.042

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix X. Mean square values of pod length of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square		
		Pod length at		
		1st harvest	Last harvest	Average
Replication	2	0.013	0.042	0.007
Nitrogen fertilizer (A)	2	0.437*	0.866*	0.633**
Error	4	0.039	0.074	0.031
Plant density (B)	3	1.065**	0.378*	0.604**
Interaction (A×B)	6	0.211*	0.465*	0.156*
Error	18	0.117	0.101	0.043

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix XI. Mean square values of weight of 1000-seeds of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square		
		Weight of 1000-seeds at		
		1st harvest	Last harvest	Average
Replication	2	1.083	0.361	0.632
Nitrogen fertilizer (A)	2	53.083*	55.861**	54.340**
Error	4	5.042	2.861	3.455
Plant density (B)	3	10.741*	22.926**	15.750**
Interaction (A×B)	6	11.935*	4.231	1.590
Error	18	2.870	4.991	1.894

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix XII. Mean square values of seed yield hecatre^{-1} of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square		
		Seed yield at		
		1st harvest	Last harvest	Total
Replication	2	0.0001	0.001	0.002
Nitrogen fertilizer (A)	2	0.256**	0.012*	0.376**
Error	4	0.012	0.001	0.007
Plant density (B)	3	0.036**	0.028**	0.126**
Interaction (A×B)	6	0.022**	0.014**	0.059**
Error	18	0.003	0.001	0.005

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix XIII. Mean square values of shelling percentage, stover yield, biological yield and harvest index of blackgram as influenced by different levels of nitrogen fertilizer and plant density

Source of variation	Degrees of freedom	Mean square			
		Shelling percentage	Stover yield	Biological yield	Harvest index
Replication	2	0.005	0.001	0.004	4.286
Nitrogen fertilizer (A)	2	48.658**	0.265**	1.257**	262.541**
Error	4	0.099	0.006	0.013	12.039
Plant density (B)	3	25.454**	0.199**	0.593**	70.690**
Interaction (A×B)	6	1.051**	0.020*	0.126**	62.559**
Error	18	0.250	0.007	0.011	9.801

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability