EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF BARI Mashkalai-1 (*Vigna mungo* L.)

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECT OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF BARI Mashkalai-1 (Vigna mungo L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **SOIL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **MIR RASHEDUZZAMAN, Registration No. 08-03105** 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, as has been availed of during the course of this investigation has duly been acknowledged by him.

Dated:

Dhaka, Bangladesh

Professor Mst. Afrose Jahan
Department of Soil Science
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was carried out at Sher-e-Bangla Agricultural University research farm, Dhaka to investigate the growth and yield response of blackgram (*Vigna mungo* L.) as affected by nitrogen and phosphorus management during the period from August to October, 2014. The experiment consisted of two factors. Factor A: Nitrogen fertilizer (4 levels); N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}, and factor B: Phosphorus fertilizer (3 levels); P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}. The variety, BARI mash-1 was used in this experiment as the test crop. The experiment was laid out in a Randomized complete block design with three replications (RCBD). Plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, weight of 1000-seeds, seed yield and stover yield were compared for different treatments. Results revealed that, N_3, P_2 treatment and their interaction influenced significantly on most of the growth, yield parameters and yield of blackgram. N_3 gave the higher yield (1.54 t ha^{-1}) which was 57.14% higher than N_0 (0.98 t ha^{-1}). Application of P_2 greatly influenced the seed yield and P_2 produced (1.38 t ha^{-1}) which was 50% higher than P_0 (0.92 t ha^{-1}). The highest seed yield (1.62 t ha^{-1}) was recorded from the treatment combination of N_3P_2 which was 88.37% higher than N_0P_0 (0.86 t ha^{-1}). The maximum yield might be attributed to higher pods $plant^{-1}$, seed pod^{-1}, 1000-seeds weight considering the higher production of blackgram. The maximum NPK concentration in seeds and stover was found from N_3, P_2 and their interaction N_3P_2 whereas the minimum was found from N_0, P_0 and N_0P_0, respectively. Application of 30 Kg N ha^{-1} and 20 Kg P ha^{-1} could be the best fertilizer management practices for cultivation of blackgram.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

%	= Percent
^0C	= Degree Celsius
AEZ	= Agro-Ecological Zone
BARI	= Bangladesh Agricultural Research Institute
BAU	= Bangladesh Agricultural University
BBS	= Bangladesh Bureau of Statistics
Co	= Cobalt
CV%	= Percentage of coefficient of variance
cv.	= Cultivar
DAE	= Department of Agricultural Extension
DAS	= Days after sowing
et al.	=And others
FAO	= Food and Agriculture Organization
g	= gram(s)
ha^{-1}	= Per hectare
HI	= Harvest Index
kg	= Kilogram
LSD	= Least Significant Difference
Max	= Maximum
mg	= milligram
Min	= Minimum
MoP	= Muriate of Potash
N	= Nitrogen
No.	= Number
NPK	= Nitrogen, Phosphorus and Potassium
NS	= Not significant
P	= Phosphorus
SAU	= Sher-e-Bangla Agricultural University
SRDI	= Soil Resources and Development Institute
TSP	= Triple Super Phosphate
Wt.	= Weight

CHAPTER 1

INTRODUCTION

Pulses or grain legumes which are a vital source of protein, calories, minerals and some vitamins. Pulses occupy about 4% of the total cropped area and contribute about 2% to the total grain production of Bangladesh (BBS, 2010). About a dozen pulse crops are grown in the winter and summer seasons. Among these, khesari, lentil, chickpea, blackgram, mungbean, field pea, cowpea, and fava bean are grown during the winter season (November–March). Collectively, they occupy 82% of the total pulse-cultivation area and contribute 84% of the total pulse production. Blackgram and mungbean can also be grown in late winter in southern areas such as the Bhola, Barisal, and Chittagong districts (Shahjahan, 2002).

Pulse protein is rich in amino acids like isoleucine, leucine, lysine, valine etc. FAO (1999) recommends a minimum pulse intake of 80 g $head^{-1}day^{-1}$ whereas; it is only 14.19 g in Bangladesh (BBS, 2006). This is because of the fact that production of the pulses is not adequate to meet the national demand.

Among the pulse crops, blackgram (*Vigna mungo*) is one of the main edible pulse crops of Bangladesh. It ranks fourth among the pulses with an area of about 82000 ha (BBS, 2006). As an excellent source of plant protein it is cultivated extensively in the tropics and subtropics. Blackgram grain contains 59% carbohydrates, 24% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981; Kaul, 1982). The green plants can also be used as animal feed and its residues have manual value. The crop is potentially useful in improving cropping pattern. The yield of blackgram is very poor as compared to many other legume crops (Wahab *et al*., 1981). It can also fix atmospheric nitrogen through the symbiotic relationship between the host blackgram roots and soil bacteria and thus improves soil fertility. Slow rate of dry matter accumulation during pre-flowering phase, leaf senescence during the period of pod development and low partitioning efficiency of assimilates to grain are identified as the main physiological constraints for increasing yield. That is why blackgram is highly responsive to nitrogen. It plays an important role to supplement protein in the cereal-based low-protein diet of the people of Bangladesh, but the acreage and production of blackgram is steadily declining (BBS, 2006).

The average yield of Blackgram is 0.7 t ha^{-1} (BBS, 2006). There are many reasons of lower yield of blackgram. Fertilizer management in kharif-1 season is one of them. For the pulse crops, nitrogen is most useful because it is the main component of protein. The management of fertilizer greatly affects the growth, development and yield of this crop. Pulses although fix nitrogen from the atmosphere, there is evident that application of nitrogenous fertilizers at flowering stage becomes helpful in increasing the yield (Patel *et al.*, 1984, Ardeshana *et al.*, 1993).

Phosphorus is second most critical plant nutrient but for pulse it assumes primary importance owing to its important role in root proliferation and there by atmospheric nitrogen fixation or phosphorus play a very vital role in crop production in pulses . Phosphorus is a constituent of proteins, nucleic acids, phospholipids and enzymes and then it control all metabolic activities of the plant. Phosphorus is a costly input in crop production but legume response well to phosphorus for the increase of its productivity.

Since the process of nodulation and nitrogen fixation is inhibited at higher levels of fertilizer nitrogen in the soil (Lawn and Brun, 1974) but there is a demand of nitrogen of the crop at post flowering period. Application of N along with adequate amount of P improves the grain yield (Tomar and Kumar, 2013).

In Bangladesh some studies have been conducted to find out the seed yield of blackgram with optimum nitrogen and phosphorus dose. More studies are needed in respect of nitrogen and phosphorus management for blackgram.

Considering the above facts, the present study was undertaken with following objectives:

1) To investigate the effect of different levels of nitrogen and phosphorus on the growth and yield of BARI mash-1.

2) To find out the suitable combination of nitrogen and phosphorus on the growth and yield of BARI mash-1.

CHAPTER 2

REVIEW OF LITERATURE

In recent years, many scientists are engaged to change the pattern of growth and development of plants for long time to achieve higher yield benefit. In Bangladesh, pulse crops are generally grown without fertilizer or manures. However, there is evidence that the yield of pulse can be increased substantially by using fertilizers. Pulses, although fix nitrogen from atmosphere, it is evident that extra nitrogen application become helpful to increase the yield. Furthermore, literature revealed that nitrogen and phosphorus interface each other to increase pulse yield. Available literatures have been reviewed in this regard and presented below.

2.1 Effect of nitrogen on growth, yield and yield contributing characters

Tomar and Kumar (2013) conducted a field experiment with the treatments compared were three plant density (500 × 103, 400 × 103 and 333 × 103 plants ha^{-1}), two levels of nitrogen (0 and 20 kg N ha^{-1}) and four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) to study the effect of plant densities, nitrogen and phosphorus on black gram. The growth and yield attributes increased with the decrease in plant density and with the increase in the levels of nitrogen and phosphorus while plant height was positively increased with the increase in plant density and levels of nitrogen and phosphorus. Interaction effect revealed that decreasing plant density and increasing levels of nitrogen and phosphorus increased dry matter accumulation and grain yield significantly. The maximum dry matter (34.4 g plant^{-1}) and grain yield (2.07 t ha^{-1}) were recorded in 333 × 103 plants ha^{-1} plant density with 20 kg N and 60 kg P_2O_5 ha^{-1}.

Asaduzzaman (2006) found that plant height and number of leaves per plant of mungbean was significantly increased by the application of nitrogen fertilizer at 30 kg ha^{-1}.

Mozumdar *et al*. (2003) conducted an experiment to study the effect of different nitrogen levels viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on two varieties of summer mungbean viz., Binamoog-2 and Kanti. The results revealed that increase of nitrogen fertilizer increased seed yield up to 40 kg N ha^{-1} and that was 1607 kg ha^{-1}.

They also found that nitrogen application had negative effect on the harvest index in both the varieties.

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

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

Srinivas *et al.* (2002) examined the effect of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and P (0, 25, 50 and 75 kg ha^{-1}) on the growth and seed yield of mungbean. They observed that the number of pods per plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N.

Yakadri *et al.* (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of greengram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in leaf area ratios indicating better partitioning of leaf dry matter.

Biswas (2001) reported that irrigation frequency exerted a remarkable impact on yield of fieldbean. Application of 3 irrigations increased pod yield about 19% and 13% and seed yield about 53% and 30% over 1 and 2 irrigations respectively. He also reported higher number of pods/plant, seeds/pod and pod length with higher frequency of irrigation.

Akhtaruzzaman (1998) conducted a field experiment on mungbean where plant height increased almost linearly up to 40 kg N ha^{-1} although response of 30 and 40 kg N ha^{-1} was identical.

Saini and Thakur (1996) stated that nitrogen at 30 and 40 kg ha^{-1} significantly increased the plant height and grain yield per plant of blackgram compared with no N.

In a field experiment conducted by Satyanarayanamma *et al.* (1996), five mungbean cultivars were sprayed with 2% urea at pre-flowering, flowering, pod development or at all the combinations or at combination of two of three growth stages. They reported that spraying urea at flowering and pod development stages produced the highest seed yield.

Kaneria and Patel (1995) conducted a field experiment on a Vartisol in Gujarat, India with mungbean cv. K 581 using 0 or 20 kg N ha^{-1} levels. They found that application of 20 kg N ha^{-1} significantly increased the seed yield.

Bachchhav *et al.* (1994) conducted a field experiment during the summer season with greengram cv. Phule-M. They observed that among nitrogen fertilizers rates (0-45 kg N ha^{-1}) seed yield increased with 30 kg N ha^{-1}.

Quah and Jafar (1994) noted that 1000 seed weight of mungbean increased significantly with 40 kg N ha^{-1}.

Chowdhury and Rosario (1992) studied the effect of 0, 30, 60 or 90 kg N ha^{-1} levels on the rate of growth and yield performance of mungbean at los Banos, Philippines in 1988. They observed that N above the rate of 30 kg N ha^{-1} reduced the dry matter yield.

Agbenin *et al.* (1991) carried out a field experiment under glass house condition and found that nitrogen application significantly increased the dry matter yield of mungbean.

Leelavathi *et al* (1991) reported that different levels of nitrogen showed significant difference in dry matter production of blackgram up to a certain level of 60 kg N ha^{-1}.

A field experiment was conducted by Sarkar and Banik (1991) to evaluate the effect of varying rates of N on mungbean. Results revealed that application of 10 kg N ha^{-1} resulted in the appreciable improvement in different yield attributes along with number of pods per plant and 1000 seed weight over control.

Upadhayay *et al*. (1991) reported that N application markedly increased the seed yield of blackgram in nitrogen deficient sandy loam soil.

Jamro *et al*. (1990) observed that application of 90 kg N ha^{-1} is significantly increased the plant height and number of pods per plant of blackgram.

Hamid (1988) conducted a field experiment to investigate the effect of nitrogen and carbon on the growth and yield performance of mungbean (*Vigna radiate* L. wilczek). He found that the plant height of mungbean cv. Mubarik was found to be increased with nitrogen at 40 kg ha^{-1}.

Pongkao and Inthong (1988) applied N at the rate of 0-60 kg ha^{-1} on mungbean and reported that application of 15 kg N ha^{-1} was found to be superior giving 23% higher seed yield over the control.

Patel and Parmar (1986) conducted an experiment to evaluate the response of greengram with varying levels of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of pods per plant.

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.

Patil *et al*. (1984) showed that increased in the dose of nitrogen from 20 to 40 kg ha^{-1} at flowering improved grain yield from 39 to 89 percent over control. It is interesting to note that half dose of 20 kg ha^{-1} of nitrogen applied at sowing and remaining at the time of flowering gave higher yield than the application of 40 kg N ha^{-1} as basal in mungbean.

Raju and Verma (1984) carried out a field experiment during summer season of 1979 and 1980 to study the response of mungbean var. Pusa baishaki to varying levels of nitrogen (15, 30, 45 and 60 kg N ha^{-1}) in the presence and absence of seed inoculation with *Rhizobium.* They found that maximum dry matter weight per plant was obtained by the application of 60 kg N ha^{-1} inoculated with *Rhizobium.They also* reported that application of 15-60 kg N ha^{-1} significantly increased seed yields of mungbean.

Trung and Yoshida (1983) conducted a field trial on mungbean in nutrient-rich soil, involving 0-100 ppm N as treatments. They observed that maximum plant height at all the stages of plant growth were obtained by the application of 25 ppm N.

Srivastava and Verma (1982) showed that N application at the rate of 15kg ha^{-1} increased the number of green leaves in greengram plants.

In an experiment, Yein *et al.* (1981) applied nitrogen and phosphorus fertilizers to mungbean and reported that combined application of nitrogen and phosphorus fertilizers increased the number of pods per plant. The rate of nitrogen and phosphorus was 50 kg and 75 kg per hectare, respectively.

2.2 Effect of phosphorus on growth, yield and yield contributing characters

Nigamananda and Elamathi (2007) conducted an experiment during 2005-06 to evaluate the effect of N application time as basal and as DAP (diammonium phosphate) or urea spray and plant growth regulator (NAA at 40 ppm) on the yield and yield components of greengram. Results showed that 2% foliar spray as DAP and NAA, applied at 35 DAS resulted in the highest values for number of pods $plant^{-1}$ (38.3), seeds pod^{-1}, test weight, flower number, fertility coefficient, grain yield (9.66 q ha^{-1}).

Malik *et al.* (2006) conducted a field experiment in Faisalabad, Pakistan in 2000 and 2001 to evaluate the interactive effects of irrigation and phosphorus on green gram *(Vigna radiata*, cv. NM-54). Five phosphorus doses (0, 20, 40, 60 and 80 kg P ha^{-1}) were arranged in a split plot design with four replications. Phosphorus application at 40 kg P_2O_5 ha^{-1} affected the crop positively, while below and above this rate resulted in no significant effects. Interactive effects of two irrigations and 40 kg P_2O_5 ha^{-1} were the most effective. The rest of the combinations remained statistically non-significant to each other. It may be concluded that green gram can be successfully grown with phosphorus at 40 kg P_2O_5 ha^{-1}. kgP/ha.

A field experiment was conducted by Edwin *et al.* (2005) during 1995 and 1996 pre-kharif seasons in Imphal. Manipur, India to study the effect of sources (Single superphosphate (SSP), diammonium phosphate (DAP). Mussoorie rock phosphate (MRP). phosphate solubilizing organism (PSO) and farmyard manure) and levels (10, 15, 30 and 60 kg P_2O_5 ha^{-1}) of P on the growth and yield of green gram cv. AAU-34. The highest number of branches/plant (3.23) was obtained with 30 kg MRP + 30 kg SSP/ha. Single super phosphate at 60 kg/ha gave the highest number of clusters/plant (4.36). Pod length (7.34 cm), seeds/pod (10.5). 1000-seed weight (34.9 g) and seed yield (15.1 q/ha). Maximum plant height (31.2 cm), dry matter/plant (36.1 g) and number of pods/plant (l 7.4) was obtained with 60 kg DAP/ha.

Khan *et al.* (2004) conducted a study to determine the effect of different levels of phosphorus on the yield components of mungbean cv. NM-98 in D.I. Khan. Pakistan in 2000. Treatments comprised: 0, 20, 40, 60, 80, and 100 kg P/ha. The increase in phosphorus levels decreased the days to flowering and increased the branches/plant, number of pods/ plant, 1000-grain weight and grain yield. The highest yield of 1022 kg/ha was obtained at the phosphorus level of 100 kg/ha compared to a 774-kg/ha yield in the control. However, the most economical phosphorus level was 40 kg/ha, because it produced a grain yield statistically comparable to 100 kg P/ha.

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

Umar *et al.* (2001) observed that plant height and numbers of branches per plant were significantly increased by phosphorus application. Number of pods per plant, number of seeds per pod, 1000-seed weight and grain yields were also increased significantly by application of phosphorus along with nitrogen.

Teotia *et al.* (2001) conducted a greenhouse experiment to study the effect of P and S interaction on yield and nutrient composition of mungbean cv. *Pant Moong-2* and revealed that P and S applied individually or in combination increased the N and K content of the grain and straw and the yield of the plant.

Mastan *et al.* (1999) stated that the number of pods $plants^{-1}$ of summer mungbean cv. LOG 127 increased with increasing P rates.

Mitra *et al.* (1999) reported that mungbean grown in acid soils of Tripura, The maximum number of pods/plants were recorded with application of 50 kg P_2O_5 ha^{-1}.

Raundal *et al.* (1999) also reported that application of phosphorus 60 kg ha^{-1} to mungbean grown in *Kharif* season significantly increase the dry matter yield.

Singh and Ahlawat (1998) reported that application of phosphorus to mungbean cv. PS 16 increased the number of branches $plant^{-1}$ up to 12.9 kg ha^{-1} when grown in a sandy loam soil, low in organic carbon and N, and medium in P and K and with a pH of 7.8.

Sharma and Singh (1997) carried out a field experiment during 1989 and 1990 to study the effect of various levels of phosphorus (0, 25, 50 and 75 kg ha^{-1}) on the growth and yield of greengram. Results of their study revealed that application of phosphorus at 30 kg ha^{-1} enhanced the plant height significantly.

Thakur *et al.* (1996) conducted an experiment with greengram *(Vigna radiata)* grown in kharif [monsoon] 1995 at Akola, Maharashtra, India which was given 0. 25. 50 or 75 kg P_2O_5 ha^{-1} as single superphosphate or diammonium phosphate. Seed and straw yields were not significantly affected by P source, and seed yield averaged 0.91, 1.00, 1.24 and 1.13 ha^{-1} at the 4 P rates, respectively. Phosphorus uptake was also highest with 50.

Reddy *et al.* (1990) set up an experiment with three cultivars of mungbean in 1987, applying 0 or 50 kg P_2O_5 ha^{-1} as a basal dressing or 50 kg P_2O_5 ha^{-1} in two equal split dressing at the sowing and flowering stages. They found that application of phosphorus increased the dry matter accumulation in mungbean.

Thakuria and Saharia (1990) observed that phosphorus levels significantly influenced the grain yield of green gram. The highest plant height, pods $plant^{-1}$ and the grain yield were recorded with 20kg P_2O_5 ha^{-1}, which was of equal value with 40 and 60 kg P_2O_5 ha^{-1}.

Kalita (1989) conducted an experiment with applying 30 kg P_2O_5 ha^{-1} to mungbean and observed that application of phosphorus increased the number of pods $plants^{-1}$. In another trial, Reddy *et al.* (1990) found similar result.

Anwar *et al.* (1981) reported beneficial effect of P application on greengram in respect to number of pods $plant^{-1}$, number of seed $plant^{-1}$, weight of 1000 seeds at low doses of P but higher doses of P showed depressing effect. The maximum grain yield of 1446.6 kg ha^{-1} was recorded at 60kg P_2O_5 ha^{-1} compared to only 886.6 kg ha^{-1} in control.

2.3 Interaction effect of nitrogen and phosphorus on growth, yield and yield contributing characters

Athokpam *et al.* (2009) was carried out an experiment to assess the effect of N, P and K application on seed yield and nutrient uptake by blackgram during *kharif* seasons of 2004-05. Three nutrients applied in combination did increase the seed yield significantly over control. The highest seed yield was recorded with the application of 15:60:20 kg $N:P_2O_5:K_2O$ ha^{-1}. Application of 30 kg N ha^{-1} alone reduced the seed yield than 15 kg N ha^{-1} alone indicating inefficiency of higher N level to legume. The increase in seed yield seems to be due to the effect of P as revealed by the relative higher yields with the treatments having P than those without P or lower P treatments.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 50, 75, and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Rajander *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85- 111 and T44. They observed grain yield increased with increasing N rates up to 20 kg ha^{-1}.

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer mungbean. They reported that mungbean produced higher seed yield with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Bhalu *et al.* (1995) observed that seed yield of blackgram increased with up to 20 kg N and 40 kg P_2O_5.

Yadav *et al*. (1994) reported that higher seed yield of blackgram with 20 kg N ha^{-1}, 40 kg P ha^{-1} and 40 kg K ha^{-1}.

Ardeshana *et al.* (1993) conducted a field experiment on clay soil during the rainy season of 1990 to study the response of mungbean to nitrogen. They observed that seed yield increased with the application of nitrogen fertilizer up to 20 kg N ha^{-1} in combination with phosphorus fertilizer up to 40 kg P_2O_5 ha^{-1}.

Singh *et al*. (1993) reported increased pod and seed yield of blackgram with N 20 kg ha^{-1} and P 40 kg ha^{-1}.

Tank *et al.* (1992) reported that mungbean fertilized with 20 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant.

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

Suhartatik (1991) in a study observed that increased application of NPK fertilizers significantly increased the plant height of mungbean.

A field experiment conducted by Sarkar and Banik (1991) to study the effect of N in combination with P on the yield of mungbean. Results showed that application of N along with P significantly increased the seed yield of mungbean. The maximum seed yield was obtained with the combination of 20 kg N and 60 kg P_2O_5 ha^{-1}.

Yadav (1990). observed that application of 40 kg P_2O_5 ha^{-1} along with 20 kg N ha^{-1} significantly increased the 1000 seed weight of mungbean.

Dhage *et al.* (1984) carried out an experiment to study the effect of N and P fertilization on yield and composition of black gram. Fertilization of black gram with nitrogen (10 kg N ha^{-1}) in the form of urea produced a 32% increase in yield over control, and significantly improved nutritional quality of seeds. The highest yield of black gram was obtained when plants were supplied with phosphorus at a rate of 40kg P_2O_5 ha^{-1}. Fertilization with N and P in a 1:2 ratio at 20kg N ha^{-1} and 40kg P_2O_5 ha^{-1} produced a 32% seed yield increase and improved the nutritional value of blackgram seeds.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N levels (0, 10, 20 and 30 kg N ha^{-1}) and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. It was found that application of 30 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant.

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

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka, during the period of August to October, 2014 in the kharif-II season to study the efficacy of nitrogen and phosphorus fertilizer managements on the yield attributes and yield of blackgram (cv. BARI mash-1). Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental site

The present research work conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka. The experimental area is located at 23˚77′ N and 90˚33′ E latitude and at an altitude of 8.6 m above

from the sea level (Appendix-I).

3.2 Soil

The soil belongs to the Agro-Ecological Zone – Modhupur Tract (AEZ 28) and the General Soil Type is Deep Red Brown Terrace Soils. The land topography is medium high and soil texture is silty clay with pH 5.6. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-II.

3.3 Climate

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October. The rainfall was heavy during Kharif season and low rainfall in Rabi season. The atmospheric temperatures were higher in Kharif season. The weather conditions during experimentation such as monthly total rainfall (mm), mean temperature (^{0}C), sunshine hours and humidity (%) collected from the Bangladesh Meteorological Department, Agargoan, Dhaka are presented in Appendix III.

3.4 Crop/planting material

The variety of blackgram used for the present study was BARI mash-1. The required seeds for the experiment were collected from the Pulse Research Centre of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The seeds were healthy, well matured and free from mixture of other seeds, weed seeds and extraneous materials. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%. The important characteristic of this variety is mentioned below:

BARI mash-1 is a medium statured (45-50cm), semi erect cultivar with basal primary branches. Stem pigmentation is absent at the seedling stage, but it becomes light green at the late vegetative stage. Leaves are dark green with slightly pubescence. Leave size is medium with dark green color, short petiole and rachis that form no tendrils. Its flowers are white, and the pods and leaves turn to straw. Its seed coat is ash and testa pattern is dotted with smooth seed surface, and cotyledon is yellow. The variety is resistant to *Cercospora* leaf spot and yellow mosaic virus. The life cycle of this variety is 65-70 days. It has a 1000 seed weight of 39.2 g compared to 21.5 g or less for the local cultivars. Maximum seed yield is 1.4-1.5 t ha^{-1}. Seeds contain 25.5% protein and 47.3% carbohydrate.

3.5 Treatments of the experiment

The treatments were tested as follows**:**

Doses of nitrogen	**Doses of phosphorus**
1. N_0 = No nitrogen (Control)	1. P_0 = No phosphorus (Control)
2. N_1 = 10 kg ha^{-1}	2. P_1 = 10 kg ha^{-1}
3. N_2 = 20 kg ha^{-1}	3. P_2 = 20 kg ha^{-1}
4. N_3 = 30 kg ha^{-1}	

The treatment combinations were as follows:

N_0P_0, N_0P_1, N_0P_2, N_1P_0, N_1P_1, N_1P_2, N_2P_0, N_2P_1, N_2P_2, N_3P_0, N_3P_1, N_3P_2

3.6 Experimental design and lay out

The experiment was laid out in a Randomized complete block design with three replications (RCBD). Each replication had 12 unit plots in which the treatment combination were assigned at random. The total number of plot was 36. The size of each plot was 2m × 2m = 4m^2. The blocks and unit plots were separated by 1m and 0.5m, respectively. The intra block and plot spaces were used as irrigation and drainage channels. A layout of the experiment has been shown in below.

Replication 1	Replication 2	Replication 3
N_0P_0	N_3P_2	N_1P_1
N_0P_1	N_3P_1	N_1P_2
N_0P_2	N_3P_0	N_2P_0
N_1P_0	N_2P_2	N_2P_1
N_1P_1	N_2P_1	N_2P_2
N_1P_2	N_2P_0	N_3P_0
N_2P_0	N_1P_2	N_3P_1
N_2P_1	N_1P_1	N_3P_2
N_2P_2	N_1P_0	N_0P_0

N_3P_0	**N_0P_2**	**N_0P_1**
N_3P_1	**N_0P_1**	**N_1P_0**
N_3P_2	**N_0P_0**	**N_0P_2**

Plate 1. Layout of experimental field

3.7 Land preparation

The land was irrigated and first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 07 August and 14 August 2014, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly.

3.8 Fertilizers application

Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP) and Gypsum were used as a source of nitrogen, phosphorous, potassium and sulphur, respectively. Nitrogen and phosphorous was applied in the experiment as per treatment. Half amount of urea was applied during the final land preparation and rest of the urea was applied as top dressing at 25 DAS. TSP was applied during the final land preparation. MoP and gypsum were applied during the final land preparation at the rate of 20g and 27g per plot, respectively following BARI recommendation.

3.9 Germination test

Three layers of filter paper were placed on Petridishes. Each petridish contained 100 seeds. Germination percentage was calculated by using the following formula.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{} \times 100$$

Number of seeds taken for germination

3.10 Sowing of seeds in the field

Seeds were sown on the furrow on 20 August, 2014 and the furrows were covered by soils soon after seeding. Seeds were treated with Bavistin before sowing the seeds to control the seed borne disease. The seeds were sown continuously in 30cm apart rows at about 2-3 cm depth in afternoon and covered with soil.

3.11 Germination of seeds

Seed germination occurred from 6th days after sowing. On the 7th day the percentage of germination was more than 85% and on the 9th day nearly all baby plants came out of the soil.

3.12 Intercultural operations

3.12.1 Thinning and weeding

Thinning and weeding were done at 20 days after sowing (DAS) when the plant attained at a height of about 10 cm. Plant to plant distance was maintained at 6-7 cm. Second weeding was done at 35 DAS when the plants attained about 15-20 cm height.

3.12.2 Irrigation

The field was irrigated twice- one at 15 days and the other one at 30 days after sowing.

3.12.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) and virus vectors (jassid) attacked the young plants and at latter stage of growth pod borer (*Maruca testulalis*) attacked the plant. Dimacron 50EC was sprayed at the rate of 1litre ha^{-1} to control these insects.

3.13 Crop sampling and data collection

Ten plants were selected randomly from each plot and were uprooted for data recording. The data of plant height, number of branches, number of flowers, and leaves per plant were recorded from sampled plants at an interval of fifteen days which was started from 25 DAS.

3.14 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown to black in color. The matured pods were collected by hand picking from a pre demarcated area of 1 m^2 at the center of each plot.

3.15 Data collection

The following data were recorded

1. Plant height (cm)
2. Number of leaves $plant^{-1}$
3. Number of branches $plant^{-1}$
4. Number of pods $plant^{-1}$
5. Pod length (cm)
6. Number of seeds pod^{-1}
7. Weight of 1000 seeds (g)
8. Seed yield (t /ha)
9. Stover yield (t/ ha)
10. Biological yield (t/ ha)
11. Harvest index (%)

3.15.1 Plant height

The plant height was measured from the ground level to the top. Height of 10 plants randomly from each plot was measured. It was done at the ripening stage of the crop.

3.15.2 No. of leaves $plant^{-1}$

The leaves were counted from selected plants. The average number of leaves was determined. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot during harvest.

3.15.3 No. of branches plant^{-1}

Branches were counted at the ripening stage. Branches of 10 plants randomly from each plot were counted and averaged.

3.15.4 No. of pods plant^{-1}

Pods were counted at the ripening stage. Pods of 10 plants randomly from each plot were counted and averaged.

3.15.5 Pod length

Length of 10 pods from each plot were measured randomly and averaged after harvesting.

3.15.6 No. of seeds pod^{-1}

It was done after harvesting. At first, number of seeds pod^{-1} was counted. Seeds of 10 pods randomly from each plot were counted and averaged.

3.15.7 Thousand seed weight

Thousand seed of blackgram were counted randomly and then weighed plot wise.

3.15.8 Grain yield

Grains obtained from 1 m^2 area from the center of each unit plot was dried, weighted carefully and then converted into t ha^{-1}.

3.15.9 Stover yield

Stover obtained from each individual plot was dried, weighed carefully and the yield expressed in t ha^{-1}.

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

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

3.15.11 Harvest index (%)

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

Harvest index (HI %) = (Seed yield/ Biological yield) × 100

Here, Biological yield = Grain yield + stover yield

3.16 Analyses of Soil Samples

Soil samples were analyzed for both physical and chemical properties such as texture, pH, organic carbon, total nitrogen, available P and exchangeable K. These results have been presented in Appendix II.

The soil samples were analyzed following standard methods as follows:

3.16.1 Textural class

Particle size analysis of soil was done by hydrometer method and the textural class was determined by plotting of values for %sand, %silt and %clay to the Marshall's Triangular Coordinate following the USDA system.

3.16.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil: water ratio of 1: 2.5 .

3.16.3 Organic matter content

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (van Bemmelen factor) and the results were expressed in percentage .

3.16.4 Total nitrogen

One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se=100: 10: 1), 2 mL 30% H_2O_2 and 5 mL H_2SO_4 were added. The flasks were swirled and allowed to stand for about 10 minutes. Then heating was continued until the digest was clear and colorless. After cooling, the content was taken into 100 mL volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digest was used for nitrogen determination. After completion of digestion, 40% NaOH was added with the digest for distillation. The evolved ammonia was trapped into 4% H_3BO_3 solution and 5 drops of mixed indicator of bromocressol green ($C_{21}H_{14}O_5Br_4S$) and methyl red ($C_{10}H_{10}N_3O_3$) solution. Finally the distillate was titrated with standard 0.01 NH_2SO_4 until the color changed from green to pink (Bremner and Mulvaney, 1982).

The amount of N was calculated using the following formula.

$$\% \text{ N } = \frac{(\text{T} - \text{B}) \times \text{N} \times 0.014 \times 100}{\text{S}}$$

Where, T = Sample titration value (mL) of standard H_2SO_4

B = Blank titration value (mL) of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.16.5 Available phosphorus

Available phosphorus was extracted from the soil samples by shaking with 0.5 M $NaHCO_3$ solution at pH 8.5 following Olsen method (Olsen *et al.*, 1954). The extracted phosphorus was determined by developing blue color by $SnCl_2$ reduction of phosphomolybdate complex and measuring the intensity of color colorimetrically at 660 nm wavelength and the readings were calibrated to the standard P curve.

3.16.6 Exchangeable potassium

Exchangeable potassium was extracted from the soil samples with 1.0 N NH_4OAc (pH 7) and K was determined from the extract by flame photometer and calibrated with a standard curve.

3.17 Chemical Analyses of Plant Samples

3.17.1 Preparation of plant samples

The representative seed and stover samples were dried in an oven at 65°C for about 24 hours before they were ground by a grinding machine. Then the ground samples were passed through a 10-mesh sieve and stored in paper bags and finally they were kept in desiccators. The seed and stover samples were analyzed for determination of N, P and K.

3.17.2 Digestion of plant samples for total nitrogen determination

For the determination of nitrogen 0.1 g of oven dry ground plant sample (both seed and stover separately) was taken in a micro-kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 100: 10: 1), 2 mL 30% H_2O_2 and 5 mL H_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 10 minutes. Then heating was continued until the digest was clear and colorless. After cooling, the content was taken in to a 100mL volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner (Bremner and Mulvaney, 1982).

3.18 Determination of N, P and K from Plant Samples

3.18.1 Nitrogen content (%)

The N concentration was determined by Semi–micro Kjeldahl method as described in section 3.16.4.

3.18.2 Phosphorus content (%)

Phosphorus concentration is digested seed and stover was determined from the extract by adding ammonium molybdate and $SnCl_2$ solution and measuring the colour with the help of spectrophotometer at 660 nm wavelength .

3.18.3 Potassium content (%)

Potassium concentration in digested seed and stover were determined directly with the help of flame photometer.

3.19 Statistical Analysis

The collected data were statistically analyzed by using the ANOVA technique. The test of significance of all parameters was done. The Duncan's Multiple Range Test (DMRT) with Least Significant Difference value was determined with appropriate levels of significance and the means were tabulated. The mean comparison was carried out by DMRT technique . The statistical package MSTAT-C was used for this purpose.

CHAPTER 4

RESULTS AND DISCUSSION

The study was conducted to determine the effect of nitrogen (N) and phosphorus (P) on the growth and yield of blackgram. Data on different yield contributing characters and yield were recorded to find out the optimum levels of nitrogen and phosphorus on blackgram. The results have been presented and discussed and possible interpretations have been given under the following headings:

4.1 Plant height (cm)

4.1.1 Effect of nitrogen on the plant height of blackgram

Plant height of blackgram varied significantly due to the application of different level of nitrogen (Table 1). The longest plant (53.38 cm) was recorded under N_3 (30 kg N ha^{-1}) treatment which was followed (51.94 cm) by N_2 (20 kg N ha^{-1}) treatment. While the shortest plant (49.27 cm) was recorded in N_0 (control) treated plot (Table 1). This might be due to higher availability of nitrogenous fertilizer that progressively enhanced the vegetative growth of the plant. Nitrogen promoted cell division or cell elongation of blackgram plants thus increased plant height. Saini and Thakur (1996) found similar results and Yein *et al.* (1981) found increased plant height of blackgram with nitrogen application.

4.1.2 Effect of phosphorus on the plant height of blackgram

The effects of phosphorus on the plant height of blackgram are presented in Table 2. Significant variation was observed on the plant height of blackgram when the field was fertilized with different doses of phosphorus. Among the different doses of phosphorus, P_2 (20 kg P ha^{-1}) showed the highest plant height (51.49 cm) which was followed by the fertilizer dose of P_1 (10 kg P ha^{-1}). On the other hand, the lowest plant height (48.76 cm) was observed in the P_0 treatment where phosphorus was not applied. It was observed that plant height increased gradually with the increment of phosphorus doses. This might be due to higher availability of N P and their uptake that progressively enhanced the vegetative growth of the plant. This result is similar with the findings of Sharma and Singh (1997) found significant increase in plant height of greengram due to the application of 40 kg P ha^{-1}.

Table 1. Effect of nitrogen on the growth and yield parameters of blackgram

Level of Nitrogen	Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}	No. of pods plant^{-1}	Pod length (cm)
N_0	49.27 c	18.26 c	8.91 c	15.83 c	6.72 c
N_1	50.63 bc	19.32 c	9.97 bc	18.01 b	7.14 bc
N_2	51.94 ab	21.64 b	11.22 ab	18.97 ab	7.75 ab
N_3	53.38 a	23.65 a	12.36 a	19.76 a	8.01 a
LSD (0.05)	**2.197**	**1.311**	**1.339**	**1.291**	**0.664**
CV (%)	**7.95**	**5.53**	**7.97**	**7.66**	**7.61**

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

Here, N_0: No nitrogen (Control),

N_1: 10 Kg N ha^{-1},

N_2: 20 Kg N ha^{-1}, and

N_3: 30 Kg N ha^{-1}

Table 2. Effect of phosphorus on the growth and yield parameters of black gram

Level of Phosphorus	Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}	No. of pods plant^{-1}	Pod length (cm)
P_0	48.76 b	17.45 b	8.63 b	15.43 b	6.61 b
P_1	50.09 ab	18.24 b	9.41 b	16.17 b	7.08 ab
P_2	51.49 a	21.86 a	10.98 a	18.06 a	7.67 a
LSD (0.05)	**2.197**	**1.311**	**1.339**	**1.291**	**0.664**
CV (%)	**7.95**	**5.53**	**7.97**	**7.66**	**7.61**

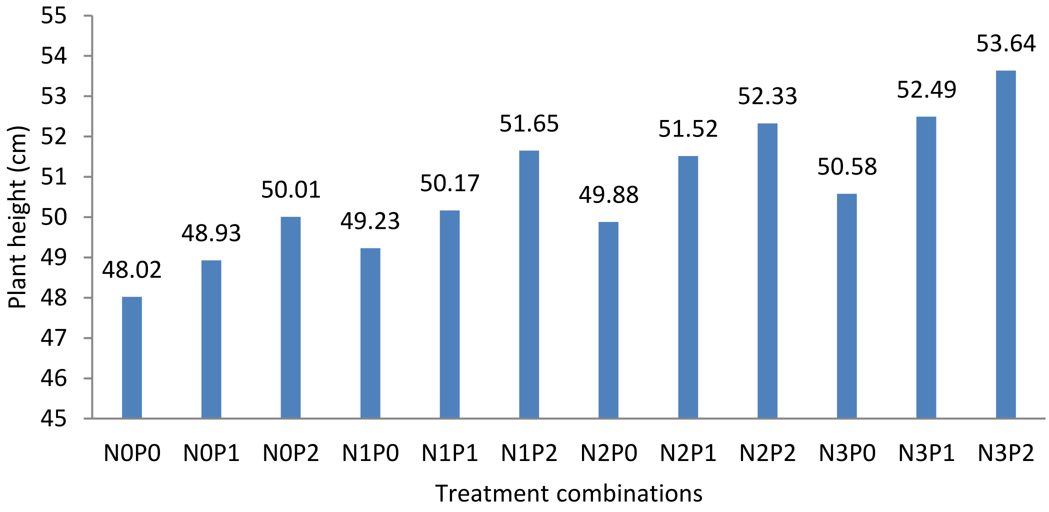
In a column, means having similar letters are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Here, P_0: No phosphorus (Control),

P_1: 10 Kg P ha^{-1}, and P_2: 20 Kg P ha^{-1}

4.1.3 Interaction effect of nitrogen and phosphorus on the plant height of blackgram

Combined application of different doses of nitrogen and phosphorus fertilizers had significant effect on the plant height of blackgram (Figure 1). The lowest plant height (48.02 cm) was observed in the treatment combination of N_0P_0 (control). On the other hand, the highest plant height (53.64 cm) was recorded with N_3P_2 (30 kg N ha^{-1} + 20 kg P ha^{-1}) treatment. Suhartatik (1991) found similar results and Yein *et al.* (1981) found increased plant height of blackgram with nitrogen application.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 1. Interaction effect of nitrogen and phosphorus on the plant height of blackgram (LSD $_{(0.05)}$ = 1.493)

4.2 Number of leaves plant^{-1}

4.2.1 Effect of nitrogen on the number of leaves plant^{-1} of blackgram

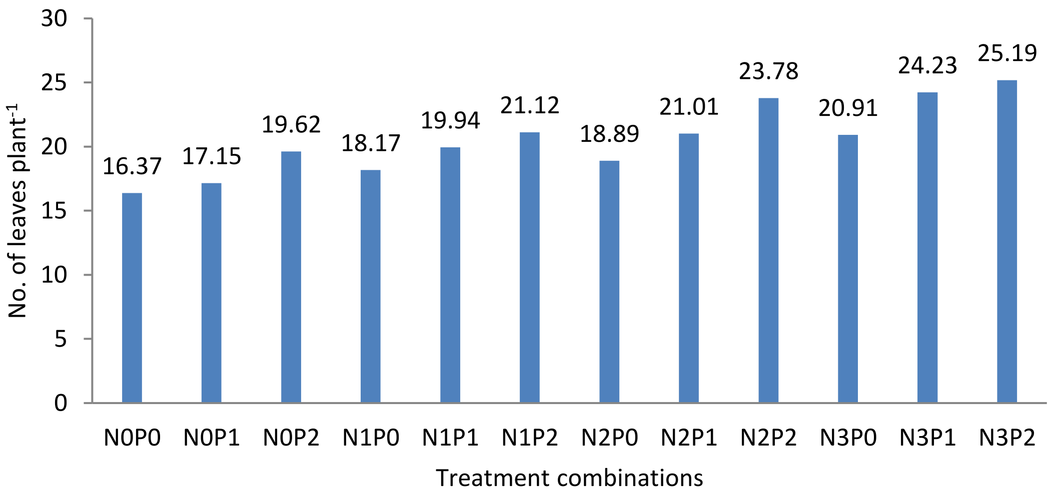
Number of leaves plant^{-1} of blackgram differed significantly due to the application of different level of nitrogen. The maximum number of leaves plant^{-1} (23.65) was recorded in N_3 treatment which was statistically different from all other treatments, while the minimum number of leaves plant^{-1} (18.26) was recorded in N_0 (control) treatment (Table 1). This might be due to higher availability of N P and their uptake that progressively enhanced the vegetative growth of the plant. Srivastava and Verma (1982) showed that N application at a rate of 15 kg ha^{-1} increased the number of green leaves, in mungbean plant.

4.2.2 Effect of phosphorus on the number of leaves $plant^{-1}$ of blackgram

Number of leaves per plant of blackgram differed significantly due to the application of different level of phosphorus. The maximum number of leaves per plant (21.86) was recorded in P_2 which was statistically different from all other treatments, while the minimum number of leaves per plant (17.45) was recorded in P_0 (control) treatment (Table 2). Probably, phosphorus ensured the availability of other essential nutrients as a result maximum growth was occurred and the ultimate results is the maximum number of leaves per plant.

4.2.3 Interaction effect of nitrogen and phosphorus on the number of leaves $plant^{-1}$ of blackgram

Combined effect of nitrogen and phosphorus showed statistically significant variation for number of leaves per plant. The maximum number of leaves $plant^{-1}$ (25.19) was recorded in N_3P_2 which was statistically similar with N_3P_1 and N_2P_2 interaction. The minimum number of leaves per plant (16.37) was recorded in N_0P_0 (Figure 2).



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 2. Interaction effect of nitrogen and phosphorus on the number of leaves plant^{-1} of blackgram (LSD $_{(0.05)}$ = 1.986)

4.3 Number of branches plant^{-1}

4.3.1 Effect of nitrogen on the number of branches plant^{-1} of blackgram

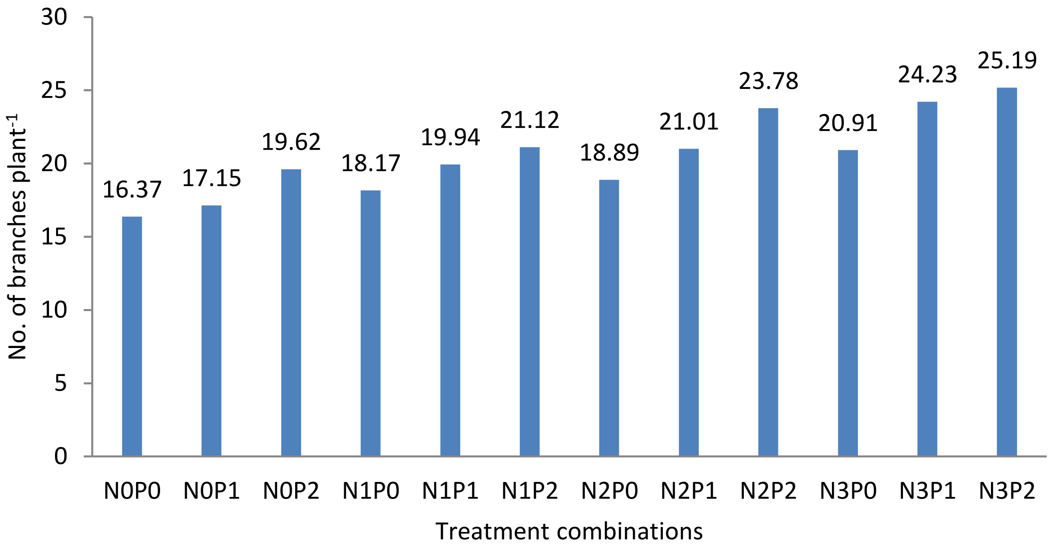
Significant variation was observed in the number of branches plant^{-1} of blackgram when different doses of nitrogen were applied (Table 1). The highest number of branches plant^{-1} (12.36) was recorded in N_3 which was followed by N_2 treatment. The lowest number of branches plant^{-1} (8.91) was recorded in N_0 treatment where no nitrogen was applied.

4.3.2 Effect of phosphorus on the number of branches plant^{-1} of blackgram

Significant variation was observed in the number of branches plant^{-1} of blackgram when different doses of phosphorus were applied (Table 2). The highest number of branches plant^{-1} (10.98) was recorded in P_2 which was statistically different from all other treatments. The lowest number of branches plant^{-1} (8.63) was recorded in the P_0 treatment where no phosphorus was applied. Singh *et al.* (1993) also found similar results with increasing rate of P and they noted that the no, of branches plant^{-1} generally increased with the application of P.

4.3.3 Interaction effect of nitrogen and phosphorus on the number of branches plant^{-1} of blackgram

The combined effect of different doses of N and P fertilizers on the number of branches plant^{-1} of blackgram was significant (Figure 3). The highest number of branches plant^{-1} (13.52) was recorded with the treatment combination of N_3P_2 (30 kg N ha$^{\cdot 1}$ + 20 kg P ha^{-1}). On the other hand, the lowest number of branches plant^{-1} (8.67) was found in N_0P_0 (control) treatment.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 3. Interaction effect of nitrogen and phosphorus on the number of branches plant^{-1} of blackgram (LSD $_{(0.05)}$ = 2.003)

4.4 Number of pods plant^{-1}

4.4.1 Effect of nitrogen on the number of pods plant^{-1} of blackgram

Significant variation was observed in number of pods plant^{-1} of blackgram when different doses of nitrogen were applied (Table 1). The highest number of pods plant^{-1} (19.76) was recorded in N_3 (30 kg N ha-^{1}) which was statistically similar with N_2 (20 kg N ha-^{1}) but different from other treatment. The lowest number of pods plant^{-1} (15.83) was recorded in the N_0 treatment where no nitrogen was applied. Probably optimum nitrogen restricted flower and pod dropping, which might have contributed to more pods per plant as reported by Biswas (2001) in fieldbean.

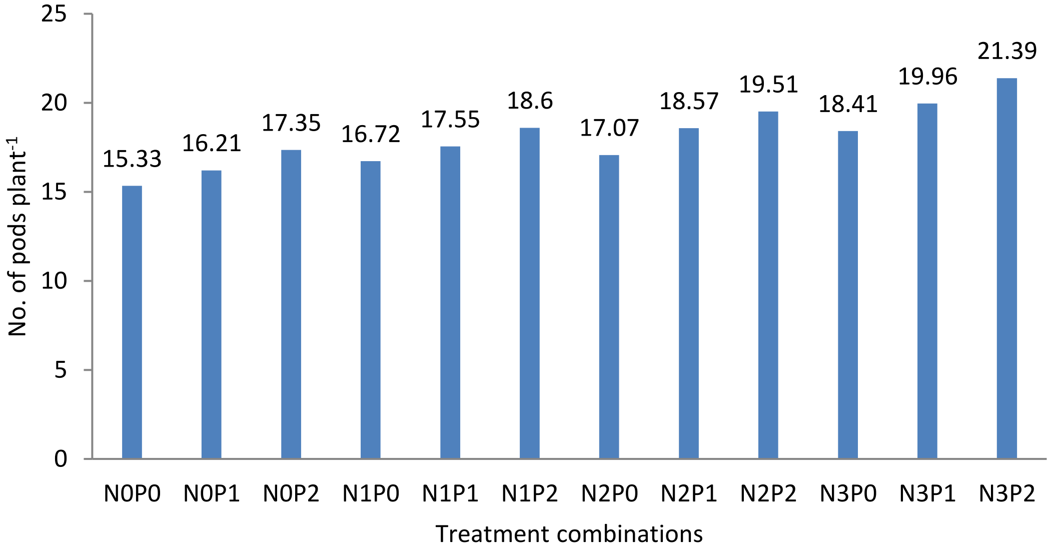
4.4.2 Effect of phosphorus on the number of pods plant^{-1} of blackgram

Different doses of phosphorus fertilizers showed significant variations in respect of number of pods plant^{-1} (Table 2). Among the different doses of fertilizers, P_2 (20 Kg P ha-^{1}) showed the highest number of pods plant^{-1} (18.06) which was statistically different from other treatment. On the contrary, the lowest number of pods plant^{-1}

(15.43) was observed with P_0. Mastan *et al.* (1999), Kalita (1989) and Reddy *et al.* (1990) also found similar results.

4.4.3 Interaction effect of nitrogen and phosphorus on the number of pods plant^{-1} of blackgram

The combined effect of different doses of N and P fertilizers on number of pods plant^{-1} of blackgram was significant (Figure 4). The highest number of pods plant^{-1} (21.39) was recorded with the treatment combination of N_3P_2 (30 kg N ha^{-1} + 20 kg P ha^{-1}) which were statistically different from the rest of the treatments. On the other hand, the lowest number of pods plant^{-1} (15.33) was found in N_0P_0 treatment. Patel *et al.* (1984) found that application of 30 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant of mungbean.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 4. Interaction effect of nitrogen and phosphorus on the number of pods plant^{-1} of blackgram (LSD $_{(0.05)}$ = 1.378)

4.5 Pod length (cm)

4.5.1 Effect of nitrogen on pod length of blackgram

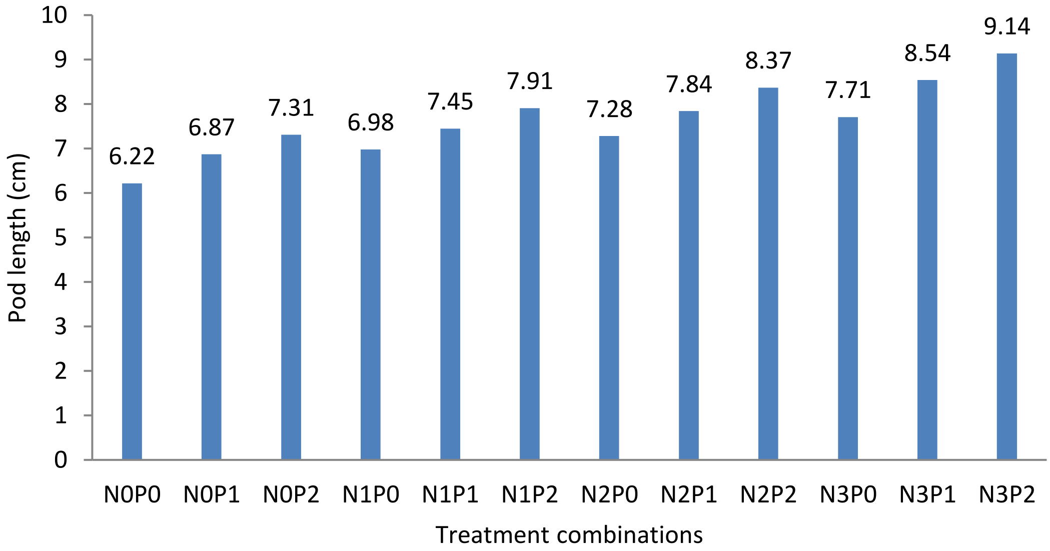
The pod length as affected by different doses of nitrogen showed statistically significant variation (Table 1). Among the different doses of N the highest pod length (8.01 cm) was observed in N_3 (30 kg N ha^{-1}) which was statistically similar with N_2 (20 kg N ha-^{1}) but different from other treatment. The lowest pod length (6.72 cm) was recorded in the N_0 treatment where no nitrogen was applied.

4.5.2 Effect of phosphorus on pod length of blackgram

Application of P fertilizers at different doses showed significant variation on the pod length of blackgram (Table 2). Among the different P fertilizer doses, P_2 (20 kg P ha^{-1}) showed the highest pod length (7.67 cm), which was statistically similar with P_1 (10 kg P ha^{-1}) treatment. The lowest pod length (6.61 cm) was recorded in the P_0 treatment where no phosphorus was applied.

4.5.3 Interaction effect of nitrogen and phosphorus on pod length of blackgram

Combined effect of different doses of N and P fertilizers on pod length showed a statistically significant variation (Figure 5). The highest pod length (9.14 cm) was recorded in the treatment combination of N_3P_2 (30 kg N ha^{-1}+ 20 kg P ha^{-1}) which was statistically identical with the treatment combinations of N_3P_1 (30 kg N ha^{-1}+ 10 kg P ha^{-1}) and N_2P_2 (20 kg N ha^{-1}+ 20 kg P ha^{-1}) treatment. On the other hand, the lowest pod length (6.22 cm) was found in N_0P_0.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 5. Interaction effect of nitrogen and phosphorus on pod length of blackgram (LSD $_{(0.05)}$ = 0.916)

4.6 Number of seeds pod^{-1}

4.6.1 Effect of nitrogen on the number of seeds pod^{-1} of blackgram

Significant variation was observed in number of seeds pod^{-1} of blackgram when different doses of nitrogen were applied (Table 3). The highest number of seeds pod^{-1} (9.44) was recorded in N_3 (30 kg N ha^{-1}). The lowest number of seeds pod^{-1} (7.11) was recorded in the N_0 treatment where no nitrogen was applied. This finding was partly supported by Singh *et al.* (1993) who stated that application of nitrogen increased the number of seeds per pod.

Table 3. Effect of nitrogen on the yield and yield contributing characters of blackgram

Level of Nitrogen	Number of seeds pod^{-1}	1000-seed wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
N_0	7.11 d	40.21 c	0.98 d	1.79 d	2.77 d	35.38
N_1	8.01 c	41.02 c	1.19 c	2.28 c	3.47 c	34.29
N_2	8.67 b	42.35 b	1.42 ab	2.74 b	4.16 b	34.13
N_3	9.44 a	43.80 a	1.54 a	2.95 a	4.49 a	34.30
LSD (0.05)	**0.512**	**1.218**	**0.176**	**0.158**	**0.193**	**NS**
CV (%)	**5.73**	**8.81**	**6.85**	**7.53**	**4.61**	**8.31**

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

Here, N_0: No nitrogen (Control),

N_1: 10 Kg N ha^{-1},

N_2: 20 Kg N ha^{-1}, and

N_3: 30 Kg N ha^{-1}

4.6.2 Effect of phosphorus on the number of seeds pod^{-1} of blackgram

Different doses of phosphorus fertilizers showed significant variations in respect of number of seeds pod^{-1} (Table 4). Among the different doses of fertilizer, P_2 (20 kg P ha^{-1}) showed the highest number of seeds pod^{-1} (8.51) which was statistically different from other treatment. On the contrary, the lowest number of seeds pod^{-1} (7.02) was observed with P_0, where no phosphorus fertilizer was applied. Umar *et al.* (2001) was found that number of seeds per pod was significantly increased by phosphorus application.

Table 4. Effect of phosphorus on the yield and yield contributing characters of blackgram

Level of Phosphorus	Number of seeds pod^{-1}	1000-seed wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
P_0	7.02 c	40.77 b	0.92 c	1.66 c	2.58 c	35.66
P_1	7.92 b	41.45 ab	1.17 b	2.12 b	3.29 b	35.56
P_2	8.51 a	42.11 a	1.38 a	2.63 a	4.01 a	34.41
LSD (0.05)	**0.512**	**1.218**	**0.176**	**0.158**	**0.193**	**NS**
CV (%)	**5.73**	**8.81**	**6.85**	**7.53**	**4.61**	**8.31**

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

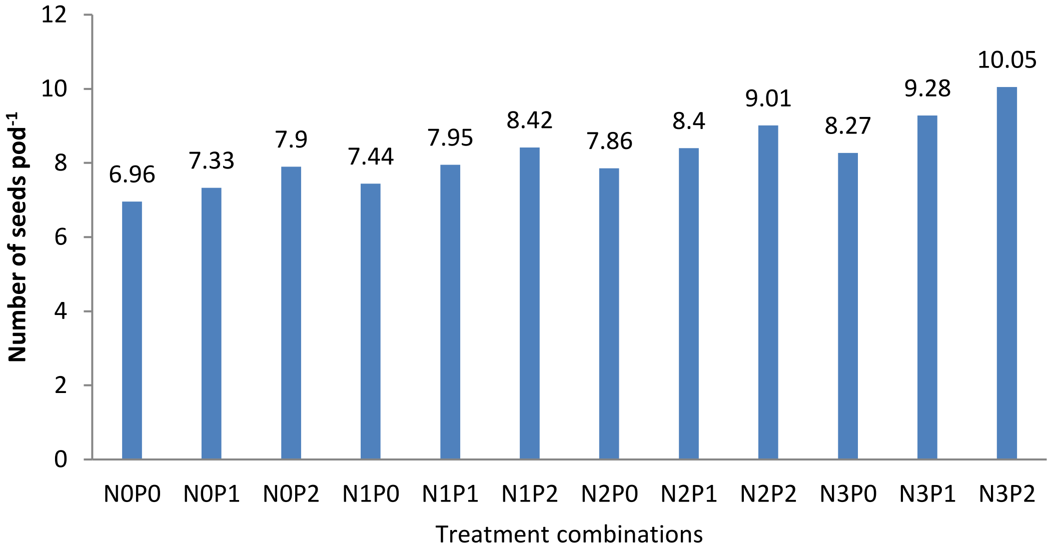
Here, P_0: No phosphorus (Control),

P_1: 10 Kg P ha^{-1}, and

P_2: 20 Kg P ha^{-1}

4.6.3 Interaction effect of nitrogen and phosphorus on the number of seeds pod^{-1} of blackgram

The combined effect of different doses of N and P fertilizer on number of seeds pod^{-1} of blackgram was significant (Figure 6). The highest number of seeds pod^{-1} (10.05) was recorded with the treatment combination of N_3P_2 (30 kg N ha^{-1} + 20 kg P ha^{-1}) which was statistically similar with N_3P_1 (30 kg N ha^{-1} + 10 kg P ha^{-1}) treatment. On the other hand, the lowest number of seeds pod^{-1} (6.96) was found in N_0P_0 treatment (control). Malik *et al.* (2003) was found that number of seeds per pod was significantly affected by varying levels of nitrogen and phosphorus.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 6. Interaction effect of nitrogen and phosphorus on the number of seeds pod^{-1} of blackgram (LSD $_{(0.05)}$ = 0.974)

4.7 Weight of 1000 seed (g)

4.7.1 Effect of nitrogen on weight of 1000-seed of blackgram

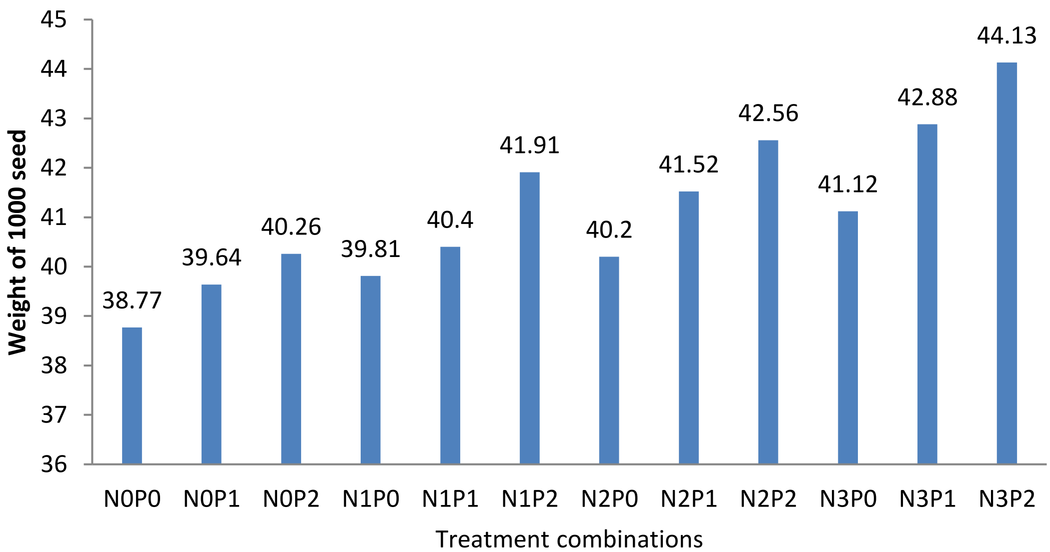
A significant variation was observed on the weight of 1000 seed of blackgram when different doses of nitrogen were applied (Table 3). The highest weight of 1000 seed (43.8 g) was recorded in N_3 (30 kg N ha^{-1}), which was statistically different from other treatment. The lowest weight of 1000 seed (40.21 g) was recorded in the N_0 treatment where no nitrogen was applied. Mahboob and Asghar (2002) revealed that the application of nitrogen fertilizer was significantly affected the 1000 seed weight of mungbean.

4.7.2 Effect of phosphorus on weight of 1000 seed of blackgram

Different doses of phosphorus fertilizers showed significant variations in respect of the weight of 1000 seed (Table 4). Among the different doses of P fertilizers, P_2 (20 kg P ha^{-1}) showed the highest weight of 1000 seed (42.11 g) and it was identical with P_1 (10 kg P ha^{-1}) treatment. On the contrary, the lowest weight of 1000 seed (40.77 g) was observed with P_0 where no phosphorus fertilizer was applied. Khan *et al.* (2004) found that the increase in phosphorus levels was significantly increasing the weight of 1000 seed of mungbean.

4.7.3 Interaction effect of nitrogen and phosphorus on weight of 1000 seed of blackgram

The combined effect of different doses of N and P fertilizers on the weight of 1000 seed of blackgram was significant (Figure 7). The highest weight of 1000 seed (44.13 g) was recorded with the treatment combination of N_3P_2 which was statistically similar with N_3P_1 (42.88 g) and N_2P_2 (42.56 g) treatments. On the other hand, the lowest weight of 1000 seed (38.77 g) was found in N_0P_0 treatment (control).



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 7. Interaction effect of nitrogen and phosphorus on weight of 1000 seed of blackgram (LSD $_{(0.05)}$ = 2.097)

4.8 Grain yield (t ha^{-1})

4.8.1 Effect of nitrogen on the grain yield of blackgram

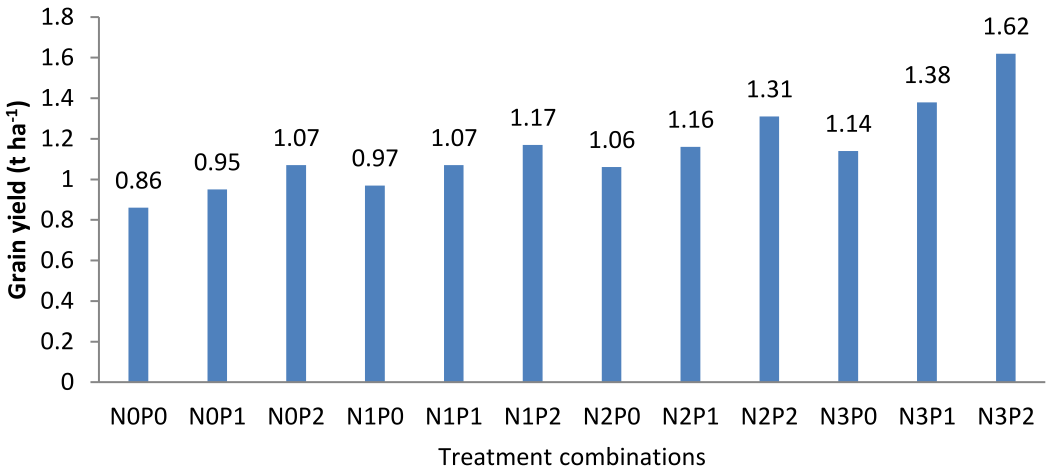
Significant variation was observed on the grain yield of blackgram when different doses of nitrogen were applied (Table 3). The highest grain yield of blackgram (1.54 t ha^{-1}) was recorded in N_3 (30 kg N ha^{-1}) which was statistically similar with N_2 (20 kg N ha-^{1}) but different from other treatments. The lowest grain yield of blackgram (0.98 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied. N_3 produced the highest yield due to maximum production of crop characters like plant height, branches plant^{-1}, leaves plant^{-1}, pods plant^{-1} and seeds pod^{-1}.

4.8.2 Effect of phosphorus on the grain yield of blackgram

Different doses of phosphorus fertilizers showed significant effect of grain yield of blackgram (Table 4). Among the different doses of P fertilizers, P_2 (20 kg P ha^{-1}) showed the highest grain yield of blackgram (1.38 t ha^{-1}). On the contrary, the lowest grain yield of blackgram (0.92 t ha^{-1}) was observed with P_0 where no phosphorus fertilizer was applied. Umar *et al.* (2001) found that grain yields were also increased significantly by application of phosphorus fertilizer.

4.8.3 Interaction effect of nitrogen and phosphorus fertilizers on grain yield of blackgram

The combined effect of different doses of N and P fertilizers on the grain yield of blackgram was significant (Figure 8). The highest grain yield of blackgram (1.62 t ha^{-1}) was recorded with the treatment combination of N_3P_2 which was statistically different from all other treatments. On the other hand, the lowest grain yield of blackgram (0.86 t ha^{-1}) was found in N_0P_0 treatment (no nitrogen and phosphorus). Bhalu *et al.* (1995) and Yadav *et al*. (1994) were also found the similar result in blackgram.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 8. Interaction effect of nitrogen and phosphorus on grain yield of blackgram (LSD $_{(0.05)}$ = 0.134)

4.9 Stover yield

4.9.1 Effect of nitrogen on the stover yield of blackgram

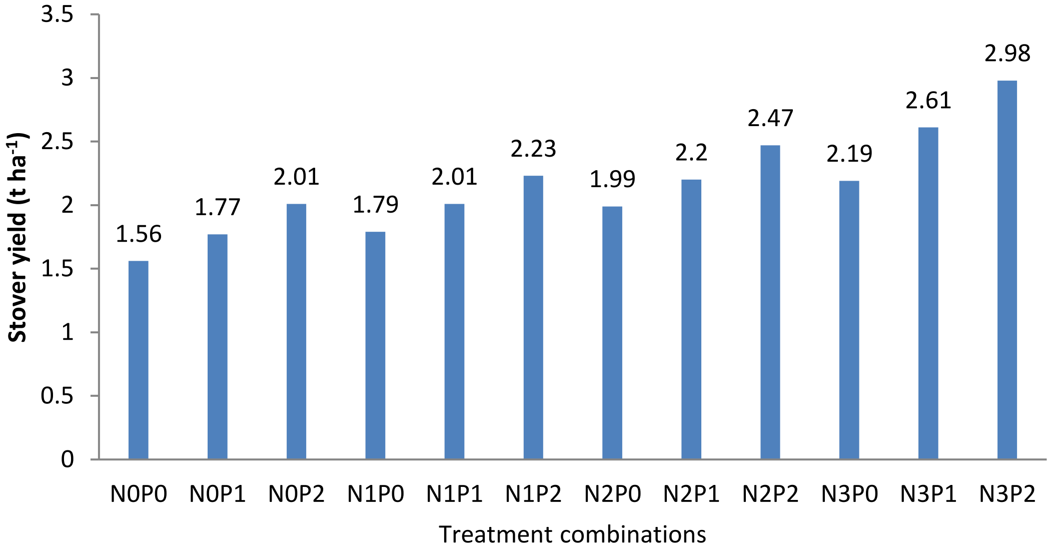
Significant variation was observed on the stover yield of blackgram when different doses of nitrogen were applied (Table 3). The highest stover yield of blackgram (2.95 t ha^{-1}) was recorded in N_3 (30 kg N ha^{-1}), which was statistically different from other treatments. The lowest stover yield (1.79 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied.

4.9.2 Effect of phosphorus on the stover yield of blackgram

Different doses of phosphorus fertilizers showed significant variations in respect of stover yield of blackgram (Table 4). Among the different doses of P fertilizers, P_2 (20 kg P ha^{-1}) showed the highest stover yield (2.63 t ha^{-1}), which was statistically different from other treatments. On the contrary, the lowest stover yield (1.66 t ha^{-1}) was observed with P_0 treatment.

4.9.3 Interaction effect of nitrogen and phosphorus on stover yield of blackgram

The combined effect of different doses of N and P fertilizers on the stover yield was significant (Figure 9). The highest stover yield (2.98 t ha^{-1}) was recorded with the treatment combination of N_3P_2 (30 kg N ha^{-1} + 20 kg P ha^{-1}). On the other hand, the lowest stover yield (1.56 t ha^{-1}) was found in N_0P_0 treatment (no nitrogen and phosphorus).



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 9. Interaction effect of nitrogen and phosphorus on stover yield of blackgram (LSD $_{(0.05)}$ = 0.288)

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

4.10.1 Effect of nitrogen on the biological yield of blackgram

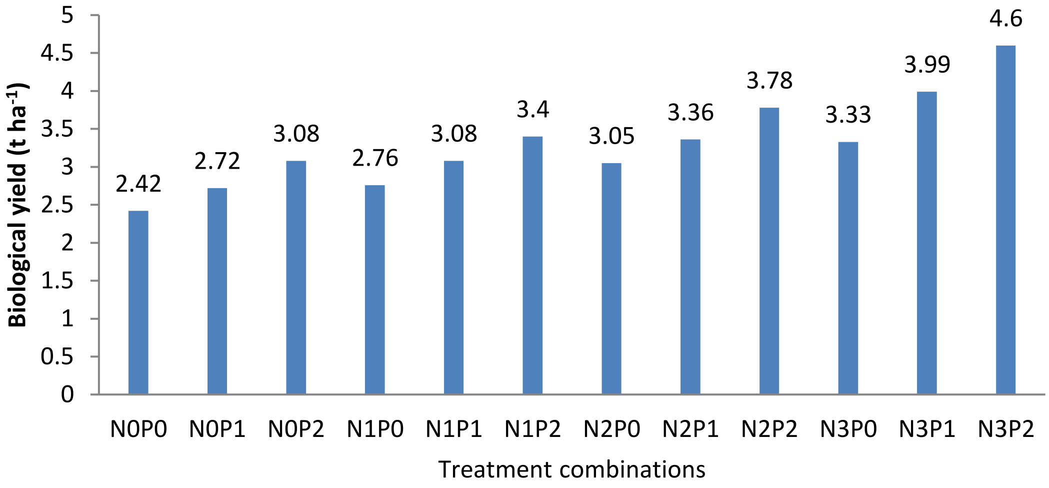
Significant variation was observed on the biological yield of blackgram when different doses of nitrogen were applied (Table 3). The highest biological yield of blackgram (4.49 t ha^{-1}) was recorded in N_3 (30 kg N ha^{-1}), which was statistically different from other treatments. The lowest biological yield (2.77 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied.

4.10.2 Effect of phosphorus on the biological yield of blackgram

Different doses of phosphorus fertilizers showed significant variations in respect of biological yield of blackgram (Table 4). Among the different doses of P fertilizers, P_2 (20 kg P ha^{-1}) showed the highest biological yield (4.01 t ha^{-1}), which was statistically different from other treatments. On the contrary, the lowest biological yield (2.58 t ha^{-1}) was observed with P_0 treatment.

4.10.3 Interaction effect of nitrogen and phosphorus on biological yield of blackgram

The combined effect of different doses of N and P fertilizers on the biological yield was significant (Figure 10). The highest biological yield (4.60 t ha^{-1}) was recorded with the treatment combination of N_3P_2 (30 kg N ha^{-1} + 20 kg P ha^{-1}). On the other hand, the lowest biological yield (2.42 t ha^{-1}) was found in N_0P_0 treatment (no nitrogen and phosphorus).



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 10. Interaction effect of nitrogen and phosphorus on biological yield of blackgram (LSD $_{(0.05)}$ = 0.323)

4.11 Harvest index (%)

4.11.1 Effect of nitrogen on the harvest index of blackgram

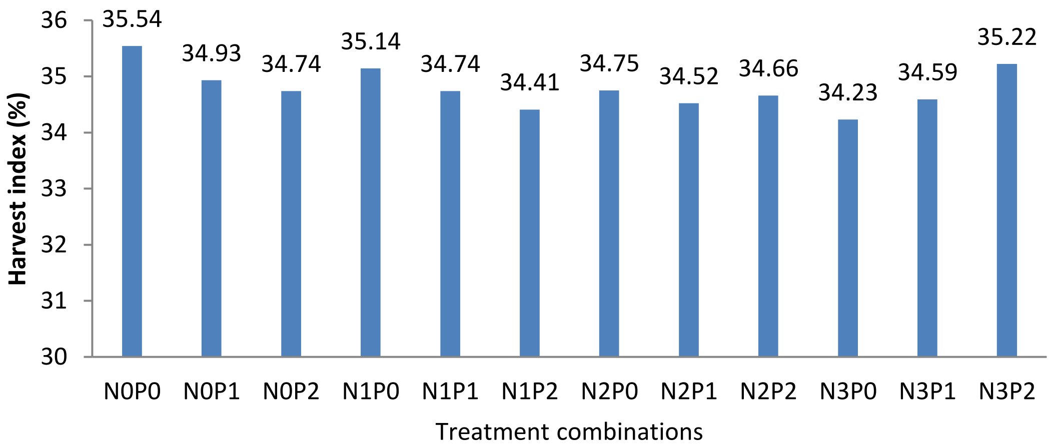
Non-significant variation was observed on the harvest index of blackgram when different doses of nitrogen were applied (Table 3). The highest harvest index of blackgram (35.38%) was recorded in N_0 while the lowest harvest index (34.13%) was recorded in the N_2 treatment.

4.11.2 Effect of phosphorus on the harvest index of blackgram

Different doses of phosphorus fertilizers showed non-significant variations in respect of harvest index of blackgram (Table 4). The highest harvest index (35.66%) was recorded in P_0 while the lowest harvest index (34.41%) was observed with P_2 treatment.

4.11.3 Interaction effect of nitrogen and phosphorus on harvest index of blackgram

The combined effect of different doses of N and P fertilizers on the harvest index was non-significant (Figure 11). The highest harvest index (35.54%) was recorded with the treatment combination of N_0P_0 whereas the lowest harvest index (34.23%) was found in N_3P_0 treatment combination.



N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}

P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}

Figure 11. Interaction effect of nitrogen and phosphorus on harvest index of blackgram (LSD $_{(0.05)}$ = NS)

4.12 N, P and K concentration in seeds

4.12.1 Effect of nitrogen on N, P and K concentration in seeds

Significant variation was found on N, P and K concentration in seeds due to different levels of nitrogen (Table 5). The maximum concentration in seeds for N (3.80%), P (0.507%) and K (0.674%) was found from N_3, while the minimum N (2.67%), P (0.450%) and K (0.547%) was found from N_0 treatment.

Table 5. Effect of nitrogen on N, P and K concentration in seeds of blackgram

Level of Nitrogen	Concentration (%) in seeds		
	N	P	K

N_0	2.67 d	0.450 c	0.547 d
N_1	3.46 c	0.473 bc	0.615 c
N_2	3.68 ab	0.492 ab	0.660 ab
N_3	3.80 a	0.507 a	0.674 a
LSD (0.05)	**0.143**	**0.032**	**0.034**
CV (%)	**5.71**	**6.34**	**6.23**

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

Here, N_0: No nitrogen (Control),
N_1: 10 Kg N ha^{-1},
N_2: 20 Kg N ha^{-1}, and
N_3: 30 Kg N ha^{-1}

4.12.2 Effect of phosphorus on N, P and K concentration in seeds

N, P and K concentration in seeds showed statistically significant variation due to different levels of phosphorus (Table 6). The maximum concentration in seeds for N (3.61%), P (0.502%) and K (0.650%) was observed from P_2 and the minimum concentration in seeds for N (3.18%), P (0.449%) and K (0.585%) was recorded from P_0 treatment.

Table 6. Effect of phosphorus on N, P and K concentration in seeds of blackgram

Level of Phosphorus	Concentration (%) in seeds		
	N	P	K
P_0	3.18 c	0.449 c	0.585 c
P_1	3.41 b	0.491 ab	0.636 ab
P_2	3.61 a	0.502 a	0.650 a
LSD(0.05)	**0.143**	**0.032**	**0.034**
CV (%)	**5.71**	**6.34**	**6.23**

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

Here, P_0: No phosphorus (Control),
P_1: 10 Kg P ha^{-1}, and
P_2: 20 Kg P ha^{-1}

4.12.3 Interaction effect of nitrogen and phosphorus on N, P and K concentration in seeds

Statistically significant variation was recorded due to the interaction effect of nitrogen and phosphorus in terms of N, P and K concentration in seeds (Table 7). The maximum concentration in seeds for N (4.06%), P (0.550%) and K (0.728%) was observed from N_3P_2, whereas the minimum concentration in seeds for N (2.52%), P (0.434%) and K (0.533%) from N_0P_0 treatment combination.

Table 7. Interaction effect of nitrogen and phosphorus on N, P and K concentration in seeds of blackgram

Nitrogen × Phosphorus	Concentration (%) in seeds		
	N	P	K
N_0P_0	2.52 h	0.434 e	0.533 e
N_0P_1	2.67 gh	0.453 de	0.547 e
N_0P_2	2.81 g	0.463 c-e	0.562 e
N_1P_0	3.23 f	0.464 c-e	0.585 de
N_1P_1	3.44 ef	0.466 c-e	0.621 cd
N_1P_2	3.65 b-e	0.508 a-c	0.664 bc
N_2P_0	3.45 ef	0.437 e	0.581 de
N_2P_1	3.69 b-d	0.489 b-d	0.638 cd
N_2P_2	3.87 a-c	0.507 a-c	0.672 a-c
N_3P_0	3.52 de	0.462 c-e	0.643 c
N_3P_1	3.88 ab	0.535 ab	0.713 ab
N_3P_2	4.06 a	0.550 a	0.728 a
LSD (0.05)	**0.231**	**0.052**	**0.054**
CV (%)	**5.71**	**6.34**	**6.23**

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

Here, N_0: No nitrogen (Control), P_0: No phosphorus (Control),

N_1: 10 Kg N ha^{-1}, P_1: 10 Kg P ha^{-1}, and

N_2: 20 Kg N ha^{-1}, and P_2: 20 Kg P ha^{-1}

N_3: 30 Kg N ha^{-1}

4.13 N, P and K concentration in stover

4.13.1 Effect of nitrogen on N, P and K concentration in stover

Significant variation was found on N, P and K concentration in stover due to different levels of nitrogen (Table 8). The maximum concentration in stover for N (1.93%), P (0.255%) and K (1.67%) was found from N_3, while the minimum N (1.63%), P (0.179%) and K (1.23%) was found from N_0 treatment.

Table 8. Effect of nitrogen on N, P, and K concentration in stover of blackgram

Level of Nitrogen	Concentration (%) in stover		
	N	**P**	**K**
N_0	1.63 d	0.179 c	1.23 d
N_1	1.74 c	0.220 b	1.59 a-c
N_2	1.88 ab	0.247 ab	1.61 ab
N_3	1.93 a	0.255 a	1.67 a
LSD (0.05)	**0.082**	**0.031**	**0.093**
CV (%)	**4.76**	**9.92**	**7.23**

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

Here, N_0: No nitrogen (Control),
N_1: 10 Kg N ha^{-1},
N_2: 20 Kg N ha^{-1}, and
N_3: 30 Kg N ha^{-1}

4.13.2 Effect of phosphorus on N, P and K concentration in stover

N, P and K concentration in stover showed statistically significant variation due to different levels of phosphorus (Table 9). The maximum concentration in stover for N (1.91%), P (0.251%) and K (1.67%) was observed from P_2 and the minimum concentration in stover for N (1.64%), P (0.179%) and K (1.31%) was recorded from P_0 treatment.

Table 9. Effect of phosphorus on N, P and K concentration in stover of blackgram

Level of Phosphorus	Concentration (%) in stover		
	N	**P**	**K**
P_0	1.64 c	0.179 c	1.31 c
P_1	1.84 ab	0.247 ab	1.59 ab

P_2	1.91 a	0.251 a	1.67 a
LSD(0.05)	**0.082**	**0.031**	**0.093**
CV (%)	**4.76**	**9.92**	**7.23**

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

Here, P_0: No phosphorus (Control),
P_1: 10 Kg P ha^{-1}, and
P_2: 20 Kg P ha^{-1}

4.13.3 Interaction effect of nitrogen and phosphorus on N, P and K concentration in stover

Statistically significant variation was recorded due to the interaction effect of nitrogen and phosphorus in terms of N, P and K concentration in stover (Table 10). The maximum concentration in stover for N (2.14%), P (0.328%) and K (2.03%) was observed from N_3P_2, whereas the minimum concentration in stover for N (1.57%), P (0.140%) and K (1.12%) from N_0P_0 treatment combination.

Table 10. Interaction effect of nitrogen and phosphorus on N, P and K concentration in stover of blackgram

Nitrogen × Phosphorus	Concentration (%) in stover		
	N	**P**	**K**
N_0P_0	1.57 f	0.140 f	1.12 g
N_0P_1	1.62 ef	0.198 de	1.22 g
N_0P_2	1.70 ef	0.194 de	1.27 fg
N_1P_0	1.64 ef	0.214 d	1.42 ef
N_1P_1	1.74 de	0.214 d	1.63 cd
N_1P_2	1.85 cd	0.232 cd	1.73 bc
N_2P_0	1.58 f	0.144 ef	1.19 g
N_2P_1	1.92 c	0.277 a-c	1.68 b-d
N_2P_2	1.95 bc	0.249 b-d	1.64 cd
N_3P_0	1.76 de	0.216 d	1.52 de
N_3P_1	2.07 ab	0.298 ab	1.85 ab

N_3P_2	2.14 a	0.328 a	2.03 a
LSD (0.05)	**0.141**	**0.053**	**0.185**
CV (%)	**4.76**	**9.92**	**7.23**

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

Here, N_0: No nitrogen (Control), P_0: No phosphorus (Control),

N_1: 10 Kg N ha^{-1}, P_1: 10 Kg P ha^{-1}, and

N_2: 20 Kg N ha^{-1}, and P_2: 20 Kg P ha^{-1}

N_3: 30 Kg N ha^{-1}

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during August to October, 2014 to study the effect of nitrogen and phosphorus on the growth and yield of blackgram. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Nitrogen fertilizer (4 levels); N_0: No nitrogen (Control), N_1: 10 Kg N ha^{-1}, N_2: 20 Kg N ha^{-1} and N_3: 30 Kg N ha^{-1}, and factor B: Phosphorus fertilizer (3 levels); P_0: No phosphorus (Control), P_1: 10 Kg P ha^{-1} and P_2: 20 Kg P ha^{-1}. The variety, BARI mash-1 was used in this experiment as the test crop. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 4 m^2 (2 m × 2 m). MoP and gypsum were applied during the final land preparation at the rate of 20g and 27g per plot, respectively following BARI recommendation. Data on different yield contributing characters & yield were recorded to find out the optimum levels of N and P for higher yield of blackgram.

Different plant and yield parameters were significantly influenced by different levels of nitrogen. The highest plant height (53.38 cm), number of leaves $plant^{-1}$ (23.65), number of branches $plant^{-1}$ (12.36), number of pods $plant^{-1}$ (19.76), pod length (8.01 cm), number of seeds pod^{-1} (9.44), weight of 1000-seeds (43.80 g), seed yield (1.54 t ha^{-1}), stover yield (2.95 t ha^{-1}) and biological yield (4.49 t ha^{-1}) produced by N_3 (30 Kg N ha^{-1}) treatment. The lowest plant height (49.27 cm), number of leaves $plant^{-1}$ (18.26), number of branches $plant^{-1}$ (8.91), number of pods $plant^{-1}$ (15.83), pod length (6.72 cm), number of seeds pod^{-1} (7.11), weight of 1000-seeds (40.21 g), seed yield (0.98 t ha^{-1}), stover yield (1.79 t ha^{-1}) and biological yield (2.77 t ha^{-1}) produced by N_0 (control) treatment. The highest (35.38%) and lowest (34.13%) harvest index was recorded in N_0 and N_2, respectively.

Different plant and yield parameters were significantly influenced by different levels of phosphorus. The highest plant height (51.49 cm), number of leaves $plant^{-1}$ (21.86), number of branches $plant^{-1}$ (10.98), number of pods $plant^{-1}$ (18.06), pod length (7.67

cm), number of seeds pod^{-1} (8.51), weight of 1000-seeds (42.11 g), seed yield (1.38 t ha^{-1}), stover yield (2.63 t ha^{-1}) and biological yield (4.01 t ha^{-1}) produced by P_2 (20 Kg P ha^{-1}) treatment. The lowest plant height (48.76 cm), number of leaves plant^{-1} (17.45), number of branches plant^{-1} (8.63), number of pods plant^{-1} (15.43), pod length (6.61 cm), number of seeds pod^{-1} (7.02), weight of 1000-seeds (40.77 g), seed yield (0.92 t ha^{-1}), stover yield (1.66 t ha^{-1}) and biological yield (2.58 t ha^{-1}) produced by P_0 (control) treatment. The highest (35.66%) and lowest (34.41%) harvest index was recorded in P_0 and P_2, respectively.

Seed yield of blackgram responded significantly to the combined application of nitrogen and phosphorus. The highest seed yield (1.62 t ha^{-1}) was recorded in N_3P_2 treatment. The lowest seed yield (0.86 t ha^{-1}) was recorded in the control viz. N_0P_0 treatment which received neither nitrogen nor phosphorus. Like seed yield the highest stover yield (2.98 t ha^{-1}) was recorded in N_3P_2 treatment and the lowest stover yield (1.56 t ha^{-1}) was recorded in the control viz. N_0P_0 treatment. Tallest plant (53.64 cm) and shortest plant (48.02 cm) were produced in N_3P_2 and N_0P_0 treatments, respectively. The treatment combination N_3P_2 produced highest number of leaves plant^{-1} (25.19), number of branches plant^{-1} (13.52), number of pods plant^{-1} (21.39), pod length (9.14 cm), number of seeds pod^{-1} (10.05), weight of 1000-seeds (44.13 g) and biological yield (4.60 t ha^{-1}). The control treatment N_0P_0 produced lowest number of leaves plant^{-1} (16.37), number of branches plant^{-1} (8.67), number of pods plant^{-1} (15.33), pod length (6.22 cm), number of seeds pod^{-1} (6.96), weight of 1000-seeds (38.77 g) and biological yield (2.42 t ha^{-1}). The highest (35.54%) and lowest (34.23%) harvest index was recorded in N_0P_0 and N_3P_0, respectively.

Significant variation was found on N, P and K concentration in seeds and stover due to different levels of nitrogen, phosphorus and their interactions. The maximum concentration in seeds and stover for N (3.80 and 1.93%, respectively), P (0.507 and 0.255%, respectively) and K (0.674 and 1.67%, respectively) was found from N_3, while the minimum N (2.67 and 1.63%, respectively), P (0.450 and 0.179%, respectively) and K (0.547 and 1.23%, respectively) were found from N_0 treatment.

The maximum concentration in seeds and stover for N (3.61 and 1.91%, respectively), P (0.502 and 0.251%, respectively) and K (0.650 and 1.67%, respectively) was observed from P_2 and the minimum concentration in seeds for N (3.18 and 1.64%, respectively), P (0.449 and 0.179%, respectively) and K (0.585 and 1.31%, respectively) was recorded from P_0 treatment.

The maximum concentration in seeds and stover for N (4.06 and 2.14%, respectively), P (0.550 and 0.328%, respectively) and K (0.728 and 2.03%, respectively) was observed from N_3P_2, whereas the minimum concentration in seeds for N (2.52 and 1.57%, respectively), P (0.434 and 0.140%, respectively) and K (0.533 and 1.12%, respectively) from N_0P_0 treatment combination.

The results in this study indicated that the plants performed better in respect of seed yield in N_3P_2 treatment than the control treatment (N_0P_0) showed the least performance. It can be therefore, concluded from the above study that the treatment (application of 30 Kg N ha^{-1} and 20 Kg P ha^{-1}) was found to the most suitable combination for the highest yield of blackgram in Deep Red Brown Terrace Soils of Bangladesh.

Based on the results of the present study, the following recommendation may be drawn:-

1. The individual and combined effects of N and P on yield and yield attributes of blackgram were found positive and significant.

2. Application of 30 Kg N ha^{-1} and 20 Kg P ha^{-1} was the most suitable combination for higher yield of blackgram in Deep Red Brown Terrace Soils of Bangladesh.

This experiment was an individual one conducted in this soil type. For proper fertilizer recommendation, further regional trials should be conducted.

However, to reach a specific conclusion and recommendation, more research work on blackgram should be done in different Agro-ecological zones of Bangladesh.

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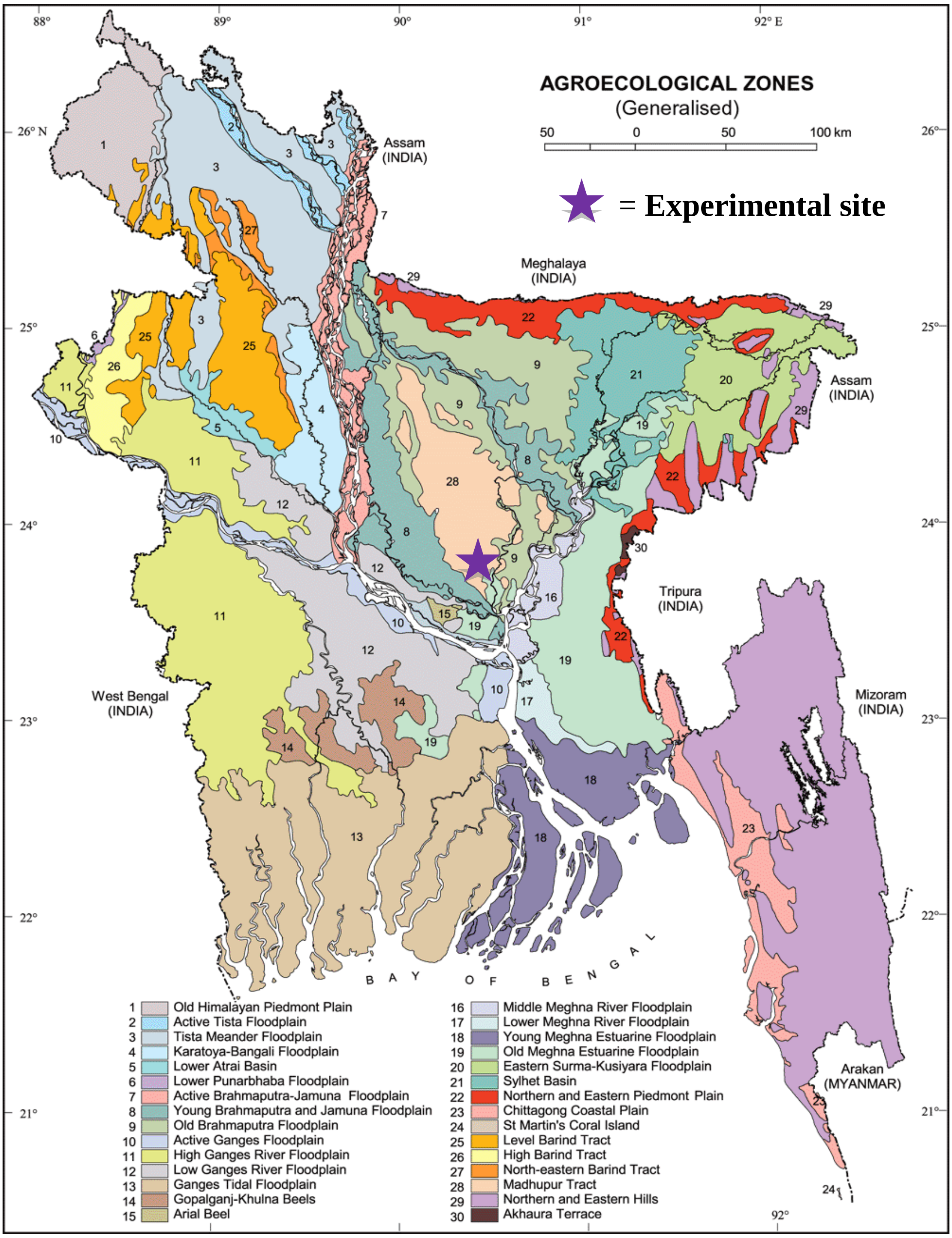
APPENDICES

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



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

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

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

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

Appendix III. Monthly meteorological information during the period from July to November, 2014

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2014	July	32.10	23.20	76.08	241
	August	31.02	15.27	74.41	158
	September	31.46	14.82	73.20	161
	October	30.18	14.85	67.82	137

	November	28.10	11.83	58.18	47

Source: Meteorological centre, Agargaon, Dhaka (Climate Division)