PERFORMANCE OF CHICKPEA UNDER DIFFERENT LEVELS OF NITROGEN AND PHOSPHORUS WITH *RHIZOBIUM* INOCULA

BY

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CERTIFICATE

This is to certify that the thesis entitled, "*Performance of Chickpea Under Different Levels of Nitrogen and Phosphorous With Rhizobium Inocula.*" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY, embodies the result of a piece of bona fide research work carried out by MD. SHAHIN UDDIN, Registration No. 03-01208 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 16.10.2011

Place: Dhaka, Bangladesh

Prof. Md. Sadrul Anam Sardar

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Dedicated

To

My Respected Parents

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Abstract

The experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka from November 2008 to March 2009 to evaluate the 'Performance of chickpea under different levels of nitrogen and phosphorus with *Rhizobium* inocula'. The experiment comprised of 11 treatments, $T_1 = N_0P_0R_h$, $T_2 = N_0P_0R_0$, $T_3 = N_1P_1R_h$, $T_4 = N_1P_2R_h$, $T_5 = N_1P_3R_h$, $T_6 = N_2P_1R_h$, $T_7 = N_2P_2R_h$, $T_8 = N_2P_3R_h$, $T_9 = N_3P_1R_h$, $T_{10} = N_3P_2R_h$ and $T_{11} = N_3P_3R_h$ where R_h = Recommended dose of *Rhizobium* (6 kg R_h ha^{-1}), N_0 = No application (0 kg N ha^{-1}), N_1 = 50% less than recommended dose (10 kg N ha^{-1}), N_2 = Recommended dose (20 kg N ha^{-1}), N_3 = 50% higher than recommended dose (30 kg N ha^{-1}), P_0 = No application (0 kg P_2O_5 ha^{-1}), P_1 = 50% less than recommended dose (20 kg P_2O_5 ha^{-1}), P_2 = Recommended dose (40 kg P_2O_5 ha^{-1}) and P_3 = 50% higher than recommended dose (60 kg P_2O_5 ha^{-1}). The experiment was set up in Randomized Complete Block Design with three replications. Results revealed that the treatment $N_2P_2R_h$ (20 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} with 6 kg mesorhizobium ha^{-1}) obtained the highest values in all the growth, yield and yield contributing parameters except plant height, the highest value of which was obtained by the treatment $N_3P_2R_h$ (30 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} with 6 kg mesorhizobium). The corresponding lowest values in all the growth, yield and yield contributing parameters were obtained by the control treatment ($N_0P_0R_0$). Whereas the only application of mesorhizobium inocula at the rate of 6 kg ha^{-1} under the treatment R_h obtained higher values than that of control but lower than each of other treatments. The treatments $N_2P_3R_h$, $N_3P_2R_h$, obtained much higher values than that of control and R_h treatment but lower than that of $N_2P_2R_h$ in all the parameters studied. Again, the treatments $N_1P_2R_h$, $N_2P_1R_h$ and $N_3P_1R_h$ obtained a bit higher values than that of control and R_h treatments. The highest number of nodules $plant^{-1}$ obtained by the treatment $N_2P_2R_h$ at 50 DAS was 26.28 and the lowest of the same obtained by the treatment $N_0P_0R_0$ was 16.13 whereas the R_h obtained the same as 21.88, 23.67, 24.25 and 22.74 were the number of nodules $plant^{-1}$ obtained by the treatments $N_2P_3R_h$, $N_3P_2R_h$ and $N_3P_3R_h$ respectively. The highest 1000 seed weight (118.15 g) was also achieved by $N_2P_2R_h$ where the lowest (108.65 g) was from $N_1P_1R_h$. Accordingly the highest seed yield ha^{-1} was 1.28 t obtained by the treatments $N_2P_2R_h$, the lowest seed yield ha^{-1} was 0.29 t, obtained by the control and the seed yield ha^{-1} eg. 1.03 t ha^{-1}, 1.11 t ha^{-1} and .97 t ha^{-1} were obtained by the treatments $N_3P_2R_h$, $N_3P_2R_h$ and $N_3P_3R_h$ respectively. Here the treatments, $N_1P_2R_h$, $N_2P_1R_h$ and $N_3P_1R_h$ obtained the seed yield ha^{-1} was 0.85 t, 0.73 t and 0.61 t respectively.

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SOME COMMONLY USED ABBREVIATIONS

Abbreviations	Full words
AEZ	Agro- Ecological Zone
Anon.	Anonymous
Atm.	Atmospheric
BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
cv.	Cultivar (s)
DAS	Days After Sowing
et al.	And others
FAO	Food and Agriculture Organization
g	Gram (s)
HI	Harvest Index
kg ha^{-1}	Kilogram per hectare
kg	Kilogram (s)
K	Potassium
m^2	Meter squares

Abbreviations	Full words
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P	Phosphorus
R_h	Rhizobium
S	Sulpher
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources and Development Institute
SE	Standard Error
TSP	Triple Super Phosphate
var.	Variety
Wt.	Weight
t ha^{-1}	Ton per hectare
^{0}C	Degree Centigrade
%	Percentage

Chapter 1
Introduction

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Chapter 1

Introduction

Chickpea (*Cicer arietinum* L) is a grain legume crop grown for its nutritional value because of high protein contents. It is considered as an economical source of quality vegetable protein in human diet. Farmers have a wrong notion that chickpea being a legume crop, does not need any nutrition and usually they grow it on the marginal land, without applying any fertilizer. The yield gap of chickpea may be attributed to improper agro-technology used by the farmers. Yield gap can be abridged, by adopting the advanced production technology accompanying with the use of inoculums, balanced nutrition, weed management and high yielding varieties. Application of phosphorus to the legumes also improves the seed yield considerably (Hussain, 1983). Further, Raut and Kohire (1991) reported that seed yield of chickpea was increased significantly with *Rhizobium* and phosphorus application. Patel and Patel (1991) also observed that nitrogen application as a starter dose along with phosphorus and seed inoculation has beneficial effect on yield of chickpea crop. Tippannavar and Desai (1992) studied that seed inoculation with *Rhizobium* increased the nodule number, seed yield and plant dry weight. Shah *et al*. (1994) found that increase in number of nodules, and seed yield due to was seed inoculation.

Roy *et al*. (1995) reported that seed inoculation increased the nodule number per plant and gave the highest harvest index and 1000-seed weight. Konde and Deshmukh (1996) and Saraf *et al*. (1997) concluded that plant dry weight and other yield components were generally increased by inoculation. Pawar *et al*. (1998) investigated that seed inoculation increased the number of nodules per plant, nodules dry weight per plant as compared to non-inoculated seed (control) in a trail on chickpea. Takankhar *et al*. (1998) reported similar findings that application of 75 kg P_20_5 ha^{-1} produced the highest seed yield of 1.25 tons ha^{-1}. El-Hadi and El-Sheik (1999) calculated an increase of 70-72% in seed yield due to inoculation over non-inoculated (control).

Chickpea is an important cool season legume of the semi tropics, and is considered to sustain cropping system productivity due to its ability to fix atmospheric nitrogen. This crop possess nodules on its roots where bacteria of the genus *Rhizobium* lives with a specific function of converting the atmospheric nitrogen into plant available form called biological nitrogen fixation (BNF). In this way an appreciable amount of free of cost nitrogen is deposited in the soil which can be used by the same crop and the subsequent one. The efficiency of such crop in fixing maximum nitrogen depends upon the cultivar, nodules number and the efficient strain of the bacteria existing in their root nodules. Chickpea has the capacity to fix sufficient atmospheric nitrogen to replace the nitrogen removed in harvested grains (FAO, 1984). The average yield (746 kg ha^{-1}) of chickpea is very low than its potential yield. The unavailability of good quality seed, absence of effective rhizobial inoculation and serious damage by blight and pod borer attack were reported responsible for low yields. Artificial seed inoculation of chickpea in those soils lacking native effective Rhizobia is a very useful practice for improving root nodulation and yield of the crop (Rupela and Dart, 1979; Patil and Sbinde, 1980: Hernandez and Hill, 1984; Shamim and Ali, 1987; Shah *et al*., 1994). Chickpea also responded positively to artificial rhizobial inoculation when grown in soils that contain its native rhizobia (Sharma *et al*., 1983). Our soils are generally deficient in nitrogen: the most important element in the metabolism of plants and protein synthesis. Its deficiency in soil usually results in low crop yield. A starter dose of fertilizer nitrogen is often used to stimulate early growth of leguminous crops and to induce the activity of nitrogen fixing bacteria in most legumes (Ali *et al*., 1998).

Chickpea is a major pulse crop in Bangladesh. It stands 5^{th} in respect of area (13915 ha) and production (10380 tons), and 2nd in consumption priority (BBS, 2004). The average yield of chickpea is low (746 kg/ha) which can he attributed to lack of high yielding varieties and suitable rhizobial strains capable of fixing high atmospheric nitrogen. The Bangladesh Agricultural Research Institute (BARI) has developed a good number of varieties of chickpea. There is a good possibility to increase its production by exploiting better colonization of the roots and rhizospheres through application of effective nitrogen fixing bacteria to the seed or to the soil. This can minimize uses of nitrogenous fertilizer, which is very costly in this country. Using high yielding varieties of chickpea along with use of effective rhizohial strains can enhance the yield. Keeping in view the above-mentioned importance of chickpea seed inoculation and phosphorus application, the present study was designed to select the best-suited combinations of seed inoculation, nitrogen and phosphorus level for chickpea production.

Hence, the objectives of the study are:

- To observe the effectiveness of Mesorhizobium inoculant on nodulation, growth and yield of chickpea.
- To study the effect of nitrogen and phosphorus level for chickpea production.
- To select the best-suited combinations of seed inoculation, nitrogen and phosphorus level for chickpea production.

Chapter 2

Review of literature

Chapter 2

Review of literature

Considerable work regarding Performance of Chickpea (*Cicer arietinum* L.) under different levels of Nitrogen and Phosphorus with *Rhizobium* inocula is available throughout the world, but very little work has been reported. Research work related to nitrogen and phosphorus application, and rhizobium inoculation in chickpea is briefly reviewed below.

2.1 Nutrient Requirement

Being a legume, chickpea obtains its nitrogen through nitrogen fixation. It requires optimum amounts of phosphorus, potash, sulfur, and other nutrients. The response to nutrient application in chickpea depends on the nutrient status of the soil, agroclimatic conditions, and the genotype. Both organic and inorganic sources of nutrients and *Rhizobium* inoculation have been found to be useful for chickpea growth and yield.

2.1.1 Nitrogen (N)

An application of 15-25 kg N ha^{-1} has been found to be optimum for stimulating growth and yield of chickpea in sandy and loam soils (Saxena and Yadav, 1975). However, when an active symbiotic nitrogen-fixing system was present, there was no response to nitrogen application up to 100 kg N/ha (Saxena and Sheldrake, 1980). In the alluvial soils of India, an application of 30-40 kg N ha^{-1} was found to be profitable under rainfed cultivation (Rajendran *et al.*, 1982).

Application of 20 kg N ha^{-1} increased chickpea yield in sandy loam soils. A high yield was obtained with 20 kg N ha^{-1} and *Rhizobium* inoculation in Gujarat, India (Patel and Patel, 1991).

Increase in yield was reported with nitrogen application as basal dose and at post flowering stage. Nitrogen application during the post flowering stage enhanced nitrate reductase activity and yield (Sekhon *et al.*, 1988). Saxena and Yadav (1975) indicated that N uptake by chickpea may range from 60 to 200 kg N ha^{-1}. Foliar application of 2% urea increased yield at some locations of India (Ali, 1989).

2.1.2 Phosphorus (P)

The response to phosphate application in chickpea depends on the available soil P and other edaphic factors (Saxena and Yadav, 1975). On Vertisols which are low in P content, there was no response to broadcast or deep-placed P application (Saxena and Sheldrake 1980). On terrarosa soils in Syria, with an available soil P level of less than 2.5 mg kg^{-1}, application of 22 kg P ha^{-1} as triple superphosphate has been quite effective (Saxena, 1984). On alluvial soils in India with low available soil P, a 78% increase was observed in seed yield with an application of 32 kg P ha^{-1} under rainfed conditions (Singh *et al.*, 1981).

The effect of phosphorus application was more pronounced when it was in conjunction with starter N, *Rhizobium* (Pal, 1986), and irrigation (Daftardar *et al.*, 1988). Phosphorus application gave a yield increase of 30% under non-irrigated conditions and about 40% under supplemental irrigation in chickpea. Supplemental irrigation increased consumptive water use as well as water-use efficiency (Prabhakar and Saraf, 1989). Application of 17.48 kg P ha^{-1} as single superphosphate with two irrigations gave maximum seed yield. Phosphorus application significantly increased dry matter production and resulted in greater diversion of dry matter to pods. Further, more dry matter was produced with one or two irrigations at 0.4 IW: CPE, indicating greater dry-matter production with irrigation during the vegetative phase of chickpea (Prabhakar and Saraf ,1991). Utilization of P was better when it was applied as a basal dose than as topdressing or foliar application (Singh and Kamath, 1989).

Saxena *et al.* (1988) reported no response to P application in Vertisols where the available soil P level was 2 to 5 mg kg^{-1} at ICRISAT Asia Center, India. The P concentration in shoots of 30-day-old plants in the absence of P fertilizer was greater than the critical (0.6%) level reported for chickpea growth. This declined rapidly with the advancement of growth and at maturity, it was only 0.2%. In Vertisols, chickpea produced 400 kg of shoot mass and 200 kg of seed yield for each kg of P uptake.

Varughese and Pathak (1987) reported that application of diammonium phosphate at 50 kg ha^{-1} as basal dose and 50 kg $^{ha-1}$ split equally at branching and flowering stages produced the highest chickpea yield (2470 kg ha^{-1}) and a cost:benefit ratio of 1:2.69. Idris and Mahmood (1989) reported a 59% yield increase at 26 kg P ha^{-1} and 54% at 35 kg P ha^{-1}.

Borgohain and Agrawal (1986) reported that the source of P (single super-phosphate, triple superphosphate, or phospho-composite) had no significant effect on chickpea yield. The highest yield was at 35 kg P ha^{-1} with two irrigations at Hisar, India. Tomar *et al.* (1987) reported that superphosphate was a better source of P than monoammonium phosphate. In a comparison of P application methods under irrigation, mixing in soil (15 cm depth) proved superior to banding at 5 cm depth (Arihara and Ae, 1988). Pala and Matar (1988) reported that in Syria band application of P did not differ significantly from broadcasting and incorporating in plow layer before sowing. Arihara *et al.* (1991) reported that incorporating P in the topsoil layer was more effective than its placement in shallow bands but was less effective compared to placement in deep bands at 15 cm depth, under rainfed conditions. This may be due to the higher and stable soil moisture levels at 15 cm depth.

2.1.3 Balanced fertilizer application

Singh and Sharma (1983) suggested a procedure for calculating the specific requirement of N, P and K for a targeted seed yield of chickpea. This was 4.48 kg N, 0.34 kg P, and 3.15 kg K for 100 kg of chickpea seed yield. Kar *et al.* (1989) reported the highest seed yield at 40 kg N + 35 kg P + 40 kg K ha^{-1} in acidic sandy loam soil in Orissa, India. Khokar and Warsi (1987) reported the highest yield (2600 kg ha^{-1}) at 18 kg N + 20 kg P + 40 kg K + 25 kg ZnSO4 ha^{-1} at Faizabad, Uttar Pradesh, India.

Tomar *et al.* (1987) reviewed the work done on fertilizer management in chickpea and reported significant economic returns from N and P application. In low-fertility soil, P application was more profitable. A balanced.application of N and P resulted in higher yields and net returns than the application of either nutrient alone. From this review, they concluded that balanced application of fertilizer should be based on a soil test and the targeted yield.

2.1.4 *Rhizobium* inoculation

Chickpea is generally inoculated with *Bradyrhizobium* sp *cicer*. The effect of *Rhizobium* inoculation on chickpea yield depends on the native rhizobial status. Fields in which well nodulated chickpea was grown previously do not require *Rhizobium* inoculation. However, where chickpea is being grown after paddy or chickpea is being introduced for the first time, *Rhizobium* inoculation is necessary (ICRISAT, 1987). A yield increase of 12% was recorded with *Rhizobium* inoculation alone. *Rhizobium* inoculation along with the recommended fertilizer application increased yield by 40% in the Sabour and Bhagalpur areas of Bihar, India (Singh *et al.* 1989).

In alluvial soils (Udic Ustochrepts), inoculation of composite strains of Rhizobium with phosphorus and molybdenum gave a better yield than inoculation of a single strain of *Rhizobium*. When *Rhizobium*, *Bacillus polymyxa*, and *Glomus fasciculatum* were applied separately in pot experiments, inoculation with *Rhizobium* alone markedly increased N uptake by the plant. In the other treatment in which all the three test organisms were applied, it resulted in significantly higher dry-matter production and phosphate uptake as compared with single or double inoculation of the test organisms. The trial also suggested that *Glomus fasciculatum* and phosphobacteria can greatly assist symbiotic N fixation as well as phosphate uptake in chickpea, particularly when the crop is grown in a soil containing soluble phosphates (Tiwari *et al.* 1989).

Singh and Tilak (1989) reported that chickpea already inoculated with Rhizobium leguminosarum, when inoculated with *Glomus versiformes* also under field conditions, showed a 12% increase in shoot dry weight and 25% in seed yield. When P was applied in addition to inoculation, the yield increase was 33% and 60% for these strains respectively.

Pala and Mazid (1992) summarized the results of 30 on-farm trials conducted over four seasons in northwestern Syria. They concluded that the effects of *Rhizobium* inoculations on chickpea were very small and inconsistent.

2.2 Nodulation

To utilize atmospheric nitrogen, proper nodule forming bacteria must be present in the soil, and, if the nodulated crop has not been sown recently or is to be grown for the first time, the seed should be inoculated before sowing. Further, to avoid uncertainty about natural inoculation, the seed should be inoculated every time. Seed inoculation with different strains of bacteria significantly improved stalk, root, and pod yield, N content of the plant, and average nitrogen recovery (Idris and Mahmood, 1989).

Soil N increased by 18 and 26 percent by inoculation and inoculation + P, respectively. Inoculation also increased the root and shoot N content and seed inoculation with rhizobium increased plant dry weight, number of branches, leaf area, seed protein and P content(Srivastava and Verma, 2004).

Ram *et al.* (2000) stated that Rhizobium inoculation significantly increased growth, yield, and quality of chickpea. They also stated that plant height, nodule number, nodule dry weight and seed yield were higher after treatment with Rhizobium.

Tippannavar and Desai (2001) reported that seed inoculation with Rhizobium increased the number of nodules, seed yield and plant dry weight and also found an increase in the number of nodules and seed yield due to seed inoculation.

Roy *et al.* (2000) reported that seed inoculation increased the nodule number per plant and gave the highest harvest index and grain weight. They also observed that plant dry weight and other field components were generally increased by inoculation.

2.2.1 Effect of inoculation on nodulation

Chickpea seeds inoculated with Rhizobium strains increased nodulation (Batra and Rao, 1985). These results were confirmed by Idris and Mahmood (1989). They observed that inoculation significantly increased number and weight of nodules. Roy *et al.* (2000) reported that number of nodules per plant was highest in inoculated seed.

Tiwari and Pathak (1988) found that inoculation resulted in more nodules and greater nodule fresh weight. Inoculation increased the number of nodules (Tippannavar and Desai, 2001). Hamidullah *et al.* (1989) claimed that chickpea seed inoculated with Rhizobium resulted in increase number of nodules per plant as compared to uninoculated (control). The increase in number of nodules per plant due to seed inoculation with Rhizobium has been reviewed by Shah *et al.* (2002) and Roy *et al.* (2000). Pawar *et al.* (1997) saw that seed inoculation increased the number of nodules per plant, nodules dry weight per plant as compared to uninoculated seed (control). Variation in nodule formation due to an environmental effect was also reported by them.

2.2.2 Effect of inoculation on seed yield of chickpea

Tiwari and Pathak (1988) reported an increase of 110 percent in seed yield of chickpea due to inoculation over uninoculated (control).

Seed inoculation with *Rhizobium* increased significantly the seed yield over the control (uninoculated) and similar beneficial effects of inoculation on seed yield were recorded in later years (Tippannavar and Desai, 2001).

Saraf *et al.* (1997) recorded an increase in seed yield by 17 percent due to inoculation over uninoculated seed (control). They also reported 1701.3 kg/ha and 1.03 t/ha increase in yield, respectively, over the control due to inoculation. El-Hadi and El-Sheik (1999) reported an increase of 70-72 percent in seed yield due to inoculation over the uninoculated control.

2.3 Effect of phosphorus on plant growth

Dixit *et al.* (1983) reported that phosphorus increased plant growth of Bengal gram, compared with treatments given no phosphorus. These results were confirmed by Hamidullah *et al.* (1989), in a study on pea and also reported that significant increase in number, dry weight and N content of nodules due to phosphorus application.

Patel and Patel (2003) observed that phosphorus application increased photo synthetic efficiency, leaf area, shoot dry weight and the rate of acetylene (C_2H_2) reduction, Phosphorus concentration of shoots and roots, soluble sugar contents of nodules, and nitrogen accumulation were also significantly increased in chickpea. Similar findings were reported by Idris and Mahmood (1989) in an experiment on chickpea.

2.4 Effect of phosphorus on yield components of chickpea

In a field experiment, Dixit *et al.* (1983) found that application of phosphorus gave the highest number of branches per plant, pods per plant, seeds per pod and 1000-seed weight, compared with a treatment without phosphorus fertilizer.

Increasing phosphorus levels before sowing increased the 1000-seed weight in peas (Patel and Patel,2003)). Kar *et al.* (1989) stated that phosphorus increased number of pods bearing branches, number of pods per plant, and 1000-seed weight.

2.5 Effect of phosphorus on seed yield

Balanced use of nitrogen and phosphorus increased yield by 15-30 percent compared with nitrogen alone (National Fertilizer Development Center, 1990). Dixit *et al.* (1983) found that application of phosphorus gave a higher yield compared with no fertilizer. Borgohain and Agarwal (1986) reported that seed yield of chickpea increased with increasing levels of phosphorus. 80 kg P_2O_5/ha gave the highest yield of 1.33 t/ha compared with 0.79 t/ha (control). Similar observation was recorded by Tomar *et al.* (1987). They reported that chickpea yields with 25, 50 and 75 kg P_2O_5/ha were 2.07, 2.26 and 2.18 t/ha compared with 1.89 t/ha without phosphorus (control).

Dry matter yield was also increased significantly by an increased level of phosphorus (Parihar, 1990). Hamidullah *et al.* (1989) reported that phosphorus application increased photosynthetic efficiency and seed yield in chickpea. Phosphorus application increased the seed yield in red chickpea (Tomar *et al.*, 1987).

2.6 Effect of phosphorus and inoculation on number of nodules, N and P-uptake, and seed yield

Phosphorus deficiency caused reduced plant growth, and nodules were not produced in the absence of *Rhizobium* inoculation. The yield of lucerne, and soybean treated with inoculum and P_2O_5 was 15 and 12 percent, respectively, higher than untreated control. Increase in seed yield of chickpea with phosphorus in inoculation has been confirmed by other scientists (Azad *et al.* 1991). Increase in number of nodules per plant and dry weight of nodules per plant was found in chickpea plots treated with phosphorus and inoculation (Singh and Ram, 1990).

Chandra (1991) reported that inoculation increased number of nodules per plant and dry weight, while phosphorus application increased number of nodules. Ral and Prasad (2002) stated that inoculation and phosphorus application increased chickpea growth rate, relative growth rate, net assimilation rate, leaf area index, leaf area ratio and leaf area duration as compared with the control.

Patel and Patel (2003) reported that chickpea seed yield and net return were increased by phosphorus application, with 30 kg P_2O_5/ha giving the best yield. *Rhizobium* inoculation and application of 20 kg N/ha both single and in combination, increased the seed yield and net returns compared with the control. Gupta (1998) found that N and P uptake and seed crude protein was increased with phosphorus and inoculum as compared to the control. Increase in nodulation, nodule weight, shoot weight, stover yield and seed yields of chickpea due to the application of Rhizobium and phosphorus has been reported by Bhuiyan *et al.* (1999). Sharar *et al.* (2000) reported that seed yield was increased with increase in NP levels and seed treatment with inoculum.

Chapter 3

Materials and Methods

Chapter 3

Materials and methods

The experiment was undertaken during rabi season (November 2008 to March, 2009) determine 'Performance of Chickpea under different levels of Nitrogen and Phosphorus with *Rhizobium* inocula'.

3.1 Site selection

The present experiment was conducted in the Agronomy farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^{/}$N latitude and $90^0 35^{/}$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989).

3.2 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 (Edris *et al*., 1979). The present experiment was conducted in rabi season. Cold temperature and minimum rainfall is the main feature of the rabi season. The monthly total rainfall, average sunshine hour, temperature during the study period (October to March) collected from the Bangladesh Meteorological Department, Agargoan, Dhaka are presented in Appendix I.

3.3 Characteristics of Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. It had shallow red brown terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and details of the recorded of soil characteristics were presented in Appendix II.

3.4 Details of the experiment

3.4.1 Seed

A high yielding variety of chickpea named 'BARI chola-5' developed by Bangladesh Agricultural Research Institute (BARI); Joydebpur, Gazipur was used in the experiment as a plant material. This variety bears good phenotypic characters; such as light green leaf, bushy type plant,30-45 cm height, whitish color flower, seed is smaller in size & deep brown in color, life cycle is 105-125 days and seed yield of 600-1800 kg/ha.

3.4.2 Fertilizers

Recommended dose of nutrients in chickpea are as follows:

$N = 20$ kg ha^{-1}

$P_2O_5 = 40$ kg ha^{-1}

$K_2O = 18$ kg ha^{-1}

Boric Acid = 10 kg ha^{-1}

Mesorhizobium = 6 kg ha^{-1}

But under the present experiment Urea (as nitrogen) and TSP (as phosphorus) were applied as per treatment and Muriate of Potash, Boric acid as per recommended dose along with mesorhizobium at 6 kg ha^{-1}.

3.5 Methods

3.5.1 Treatments

Four levels of nitrogen, four levels of phosphorus and mesorihzobium were used and eleven (11) treatments were set up for the present experiment.

4 levels of nitrogen

- N_0 = No application
- N_1 = 50% lower than recommended dose; 10 kg N ha^{-1}
- N_2 = Recommended dose, 20 kg N ha^{-1}
- N_3 = 50% higher than recommended dose; 30 kg N ha^{-1}

4 levels of phosphorus

- P_0 = No application
- P_1 = 50% lower than recommended dose; 20 kg P_2O_5 ha^{-1}
- P_2 = Recommended dose; 40 kg P_2O_5 ha^{-1}
- P_3 = 50% higher than recommended dose; 60 kg P_2O_5 ha^{-1}

Biofertilizer

- R_h = Mesorhizobium inoculam; 6 kg R_h

The following 11 treatment levels were used for the present experiment:

- $N_0P_0R_h$ kg ha^{-1}
- $N_0P_0R_0$ kg ha^{-1}
- $N_{1O}P_{20}R_{h6}$ kg ha^{-1}
- $N_{10}P_{40}$ R_{h6} kg ha^{-1}
- $N_{10}P_{30}$ $R_{h\ 6}$ kg ha^{-1}
- $N_{20}P_{20}$ $R_{h\ 6}$ kg ha^{-1}
- $N_{20}P_{40}$ R_{h6} kg ha^{-1}
- $N_{20}P$ $_{60}R_{h6}$ kg ha^{-1}
- $N_{30}P_{20}$ R_{h6} kg ha^{-1}
- $N_{30}P_{40}$ R_{h6} kg ha^{-1}
- $N_{30}P_{60}$ R_{h6} kg ha^{-1}

3.5.2 Land Preparation

The experiment plot was irrigated to remove its hard dryness before ploughing. Then it was first opened with tractor drawn disc plough after having 'zoe' condition. Ploughed soil was then brought into desirable 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 12 November and 22 November 2008, respectively. Experimental land was divided into unit plots following the design of experiment. The plots wee spaded one day before planting and the basal dose of fertilizers were incorporated thoroughly.

3.5.3 Fertilization

The amounts of fertilizer as per treatment in the forms of urea, Triple Super Phosphate and recommended dose of Muriate of Potash required per plot were calculated. Half of urea and total amount of all other fertilizers of each plot were applied and incorporated into soil. Rest of the urea was top dressed after 30 days of sowing (DAS).

3.5.4 Design and layout

The experiment was laid out in a Randomized Complete Block Design with three replications. The total plot number was $11 \times 3 = 33$. The unit plot size was $3 \text{ m} \times 2 \text{ m} = 6 \text{ m}^2$. The replications were separated from one another by 1.5 m. The distance between plots was 0.75 m.

3.5.5 Sowing of seeds

Sowing was done on 23 November, 2008 in rows 30 cm apart. Seeds were sown contentiously in rows. The seeds were sown at a rate of 45 kg ha^{-1}. Seeds were treated with Bavistin before sowing the seeds to control the seed borne disease. The treated seeds were then mixed with mesorhizobium inoculant at the rate of 6 kg ha^{-1}. After sowing, the seeds were covered with the soil, and slightly pressed by hand.

3.5.6 Thinning

The optimum plant population was maintained by thinning excess plant. Seeds were germinated 6 days after sowing (DAS). First and second thinning was done at 15 and 30 DAS respectively to maintain plant to plant distance as 10 cm.

3.5.7 Weeding

Weeding was done twice; first weeding was done at 20 DAS and second weeding was done at 45 DAS.

3.5.8 Irrigation

Three irrigations were given as plants required. First irrigation was given immediate after topdressing and second and third irrigations were applied at 45 and 70 DAS. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture.

3.5.9 Crop protection

At vegetative stage, aphid (*Aphis craccivora*) attacked the young plants and at latter stage of growth, pod borer (*Maruca testulalis*) attacked the plant. For aphid control, Ripcord 2 ml/l water and for pod borer Dimacron 50 EC at the rate of 1 l/ha were sprayed.

3.6 Crop sampling and data collection

Selected ten plants from each treatment were randomly sampled and marked with tag for recording plant characters. The data of plant height, number of branches, dry weight, 1000 seed weight, yield etc. were recorded 20 DAS to harvest.

3.7 Harvesting and threshing

Crops were harvested when 90% of the pod became brown to black in color. The matured crops were harvested on 24 March, 2009 and the harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.8 Drying and weighing

The seeds and stovers thus collected were dried in the sun for couple of days. Dried seeds and stovers of each plot was weighed and subsequently converted into kg ha^{-1}.

3.9 Data collection

The following data were collected for the present study

A. Nodulation and growth parameters

- Plant height (cm)
- No. of branches $plant^{-1}$
- Number of nodules $plant^{-1}$
- Dry matter weight $plant^{-1}$

B. Yield and yield contributing characters

- Number of pods $plant^{-1}$
- Number of seeds pod^{-1}
- Weight of 1000 seeds (g)
- Seed yield (t ha^{-1})
- Stover yield (t ha^{-1})
- Harvest index (%)

3.10 Procedure of recording data

3.10.1 Plant height (cm)

The height of ten plants were measured 20 DAS, 35 DAS, 50 DAS and at harvest from ground level (stem base) to the tip of the plant. Mean plant height was calculated and expressed in cm.

3.10.2 Number of branches plant^{-1}

The number of branches of ten randomly selected plants were counted at 20 DAS, 35 DAS, 50 DAS, at harvest and recorded. Average value of ten plants was recorded as number of branches plant^{-1}.

3.10.3 Number of nodules plant^{-1}.

Total number of nodules was counted from five plants and then average data was recorded as number of nodules plant^{-1}.

3.10.4 Dry weight plant^{-1}

Randomly selected 10 plants from each plot were oven dried and weighed. The average value was recorded in g plant^{-1}.

3.10.5 Number of pods plant^{-1}

Total number of pods were collected from 10 randomly selected plants and then averaged to express in number of pods plant^{-1}.

3.10.6 Number of seeds pod^{-1}

Total number of pods was collected from 10 randomly selected plants and total number of seeds was counted and then number of seeds/pod was measured by the following formula:

$$\text{Number of seeds pod}^{-1} = \frac{\text{Total number of seed}}{\text{Total number of pod}}$$

3.10.7 Weight of 1000-seeds

A composite sample was taken from the yield of ten plants. The 1000-seeds of each plot were counted and weighed with a digital electric balance. The 1000-seed weight was recorded in gram.

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

After threshing, cleaning and drying, total seed from harvested area (3.24 m^2) taken from the middle portion of the plot were recorded and was converted to t ha^{-1}.

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

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

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

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

3.10.11 Harvest index (%)

Harvest index was calculated by dividing the economic (seed) yield from the net plot by the total biological yield (seed + stover) from the same area (Donald, 1963) and multiplying by 100.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.11 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference between the results of different levels of nitrogen and phosphorus application on growth, yield and yield contributing characters of chickpea. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4

Results and Discussion

The experiment was conducted on 'Performance of chickpea under different levels of Nitrogen and Phosphorus with Rhizobium inocula' and the results on effectiveness of various treatments including untreated (control) for achieving growth and higher yield have been described and discussed below in detail under the following heading:

4.1 Growth parameters

The response of growth parameters like plant height (cm), number of branches plant^{-1}, number of nodules plant^{-1} and dry weight plant^{-1} of chickpea under different nitrogen and phosphorus levels with *Rhizobium* inocula were found statistically significant.

4.1.1 Plant height

Table 1 showed that nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) had significant effect on plant height at different growth stages of chickpea. There was no significant effect observed at 20 and 35 DAS on plant height but at 50 DAS and at harvest plant height of chickpea was significantly varied from different treatments. Nitrogen at the rate of 30 kg ha^{-1} along with 40 kg P_2O_5 ha^{-1} and with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_3P_2R_h$), gave the tallest plant; 35.48 and 35.59 cm at 50 DAS and at harvest respectively which was closely followed by $N_2P_2R_h$ at harvest (34.85 cm). The treatments of $N_3P_3R_h$, $N_3P_1R_h$, $N_2P_3R_h$ and $N_2P_1R_h$ also gave higher plant height compared to control and rhizobium inocula treatment but each of them was significantly lower then $N_3P_2R_h$. The treatment of $N_1P_3R_h$ (31.08 cm), $N_1P_2R_h$ (31.55 cm), $N_1P_1R_h$ (30.69 cm) showed similar response but each of them was significantly higher than the control and inocula treatments. Control treatment (N_0P_0) gave the lowest plant height at 50 DAS and at harvest (28.08 and 28.12 cm respectively) which were significantly different from all other treatments. Only *Rhizobium* treated plot gave lower plant height (29.10 and 29.17 cm at 50 DAS and at harvest respectively) which were also significantly different from all other treatments. Ram *et al.* (2000) stated that *Rhizobium* inoculation significantly increased plant height.

Table 1. Performance of chickpea on plant height under different levels of nitrogen and phosphorus with rhizobium inocula

Treatments	Plant height (cm)			
	20 DAS	35 DAS	50 DAS	At harvest
T_1 ($N_0P_0R_h$)	10.10	13.64	29.10 f	29.17 g
T_2 ($N_0P_0R_0$)	10.07	12.17	28.08 g	28.12 h
T_3 ($N_1P_1R_h$)	10.09	13.91	30.69 e	30.76 f
T_4 ($N_1P_2R_h$)	9.71	13.62	31.55 e	31.63 e
T_5 ($N_1P_3R_h$)	10.01	12.80	31.08 e	31.15 ef
T_6 ($N_2P_1R_h$)	10.35	13.53	32.78 d	32.84 d
T_7 ($N_2P_2R_h$)	10.29	13.22	34.59 b	34.85 ab
T_8 ($N_2P_3R_h$)	10.01	13.20	32.46 d	32.54 d
T_9 ($N_3P_1R_h$)	10.80	13.05	33.68 c	33.76 c
T_{10} ($N_3P_2R_h$)	10.22	12.56	35.48 a	35.59 a
T_{11} ($N_3P_3R_h$)	9.84	13.92	33.98 bc	34.09 bc
SE	0.5302	0.8629	0.0070	0.0124
CV (%)	3.56	4.12	6.58	7.39

R_h = Recommended dose of Rhizobium (6 kg ha^{-1})
N_0 = 0 kg N ha^{-1} P_0 = 0 kg P_2O_5 ha^{-1}
N_1 = 10 kg N ha^{-1} P_1 = 20 kg P_2O_5 ha^{-1}
N_2 = 20 kg N ha^{-1} P_2 = 40 kg P_2O_5 ha^{-1}
N_3 = 30 k3g N ha^{-1} P_3 = 60 kg P_2O_5 ha^{-1}

4.1.2 Number of branches plant^{-1}

Different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) had significant effect on number of branches plant^{-1} at different growth stages of chickpea (Table 2). Results showed that there was no significant effect on number of branches plant^{-1} at 20 DAS but at 35, 50 DAS and at harvest number of branches plant^{-1} showed significant results. Nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest number of branches plant^{-1}; 9.14, 22.40 and 22.48 at 35, 50 DAS and at harvest respectively which was significantly different from the other treatments. The treatments of $N_1P_2R_h$, $N_2P_1R_h$, $N_2P_3R_h$, $N_3P_2R_h$ and $N_3P_3R_h$ also gave higher number of branches plant^{-1} compared to control and Rhizobium inocula but was significantly different from $N_2P_2R_h$. Control treatment ($N_0P_0R_0$) gave the lowest number of branches plant^{-1} at 35, 50 DAS and at harvest (5.22, 13.12 and 13.15 respectively) which was significantly different from all other treatments. Only rhizobium treated plot gave lower number of branches plant^{-1} (6.50, 16.14 and 16.20 at 35, 50 DAS and at harvest respectively) which was also significantly higher than control treatments.

Soil N increased by 18 and 26 percent by inoculation and inoculation + P, respectively, inoculation also increased number of branches (Srivastava and Verma, 2004). Dixit *et al.* (1983) found that application of phosphorus gave the highest number of branchesplant^{-1}. Kar *et al.* (1989) stated that phosphorus increased number of pods bearing branches.

Table 2. Performance of chickpea on number of branches plant^{-1} under different levels of nitrogen, phosphorus with rhizobium inocula

Treatments	Number of branches plant^{-1}			
	20 DAS	35 DAS	50 DAS	At harvest
T_1 ($N_0P_0R_h$)	2.08	6.50 f	16.14 ef	16.20 ef
T_2 ($N_0P_0R_0$)	1.61	5.22 g	13.12 g	13.15 g
T_3 ($N_1P_1R_h$)	1.93	6.59 f	15.78 f	15.80 f
T_4 ($N_1P_2R_h$)	2.45	8.25 b	21.18 b	21.22 b
T_5 ($N_1P_3R_h$)	2.02	6.78 ef	16.35 ef	16.41 ef
T_6 ($N_2P_1R_h$)	2.27	7.34 c-e	19.94 c	20.00 c
T_7 ($N_2P_2R_h$)	2.61	9.14 a	22.40 a	22.48 a
T_8 ($N_2P_3R_h$)	2.31	7.46 cd	20.30 bc	20.33 bc
T_9 ($N_3P_1R_h$)	2.11	7.02 d-f	16.95 e	16.98 e
T_{10} ($N_3P_2R_h$)	2.39	7.90 bc	20.78 bc	20.84 bc
T_{11} ($N_3P_3R_h$)	2.19	7.26 de	18.08 d	18.05 d
SE	0.026	0.034	0.022	0.0426
CV (%)	3.87	5.34	8.19	8.86

Rh = Recommended dose of Rhizobium (6 kg ha^{-1})

N_0 = No application (0 kg N ha^{-1})
N_1 = 50% less than recommended dose (10 kg N ha^{-1})
N_2 = Recommended dose (20 kg N ha^{-1})
N_3 = 50% higher than recommended dose (30 kg N ha^{-1})

P_0 = No application (0 kg P_2O_5 ha^{-1})
P_1 = 50% less than recommended dose (20 kg P_2O_5 ha^{-1})
P_2 = Recommended dose(40 kg P_2O_5 ha^{-1})
P_3 = 50% higher than recommended dose (60 kg P_2O_5 ha^{-1})

4.1.3 Number of nodules plant^{-1}

Number of nodules plant^{-1} was significantly affected by different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) at different growth stages of chickpea (Table 3). Results indicated that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest number of nodules plant^{-1}; 14.16, 20.41 and 26.28 at 20, 35 and 50 DAS respectively which was significantly different from the other treatments. Higher number of nodules plant^{-1} was also obtained from the treatments of $N_1P_2R_h$, $N_2P_3R_h$, $N_3P_2R_h$ and $N_3P_3R_h$ but was significantly different from $N_2P_2R_h$. Control treatment ($N_0P_0R_0$)gave the lowest number of nodules plant^{-1} at 20, 35 and 50 DAS (8.04, 12.95 and 16.13 respectively) which was significantly was significantly different from all other treatments. Only Rhizobium treated plot also gave lower number of nodules $plant^{-1}$ (11.68, 16.17 and 21.88 at 20, 35 and 50 DAS respectively) which was significantly higher than $N_1P_1R_0$ and control treatment. Ram *et al.* (2000) stated that Rhizobium inoculation significantly increased nodule number and nodule dry weight. Tippannavar and Desai (2001) reported that seed inoculation with Rhizobium increased the number of nodules $plant^{-1}$. Chickpea seeds inoculated with Rhizobium strains increased nodulation (Batra and Rao, 1985). Idris and Mahmood (1989) observed that inoculation significantly increased number and weight of nodules.

Hamidullah *et al.* (1989) reported that significant increase in number, dry weight and N content of nodules was observed due to phosphorus application. Phosphorus deficiency caused reduced plant growth, and nodules were not produced in the absence of Rhizobium inoculation. Increase in number of nodules per plant and dry weight of nodules per plant was found in chickpea plots treated with phosphorus and inoculation (Singh and Ram, 1990).

Table 3. Performance of chickpea on number of nodules plant^{-1} under different levels of nitrogen and phosphorus with rhizobium inocula

Treatments	Number of nodules plant^{-1}		
	20 DAS	35 DAS	50 DAS
T_1 ($N_0P_0R_h$)	11.68 d	16.17 e	21.88 c-e
T_2 ($N_0P_0R_0$)	8.04 g	12.95 i	16.13 h
T_3 ($N_1P_1R_h$)	9.18 f	14.03 h	18.77 g
T_4 ($N_1P_2R_h$)	12.84 c	16.86 de	22.02 cd
T_5 ($N_1P_3R_h$)	10.26 e	15.01 g	20.04 f
T_6 ($N_2P_1R_h$)	11.58 d	16.05 ef	21.76 de
T_7 ($N_2P_2R_h$)	14.16 a	20.41 a	26.28 a
T_8 ($N_2P_3R_h$)	13.30 bc	17.85 bc	23.67 b
T_9 ($N_3P_1R_h$)	11.16 d	15.33 fg	21.08 e
T_{10} ($N_3P_2R_h$)	13.86 ab	18.17 b	24.25 b
T_{11} ($N_3P_3R_h$)	13.09 c	17.23 cd	22.74 c
SE	0.0452	0.0245	0.0562
CV (%)	6.58	7.28	9.24

Rh = Recommended dose of Rhizobium (6 kg ha^{-1})

N_0 = No application (0 kg N ha^{-1})

N_1 = 50% less than recommended dose (10 kg N ha^{-1})

N_2 = Recommended dose (20 kg N ha^{-1})

N_3 = 50% higher than recommended dose (30 kg N ha^{-1})

P_0 = No application (0 kg P_2O_5 ha^{-1})

P_1 = 50% less than recommended dose (20 kg P_2O_5 ha^{-1})

P_2 = Recommended dose(40 kg P_2O_5 ha^{-1})

P_3 = 50% higher than recommended dose (60 kg P_2O_5 ha^{-1})

4.1.4 Dry weight plant^{-1}

Significant variation was observed in terms of dry weight plant^{-1} with different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) at different growth stages of chickpea (Table 4). Results obtained from Table 4 pointed to that of nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest dry weight plant^{-1}; 0.94, 3.21, 13.34 and 20.26 g at 20, 35, 50 DAS and at harvest respectively which was significantly different from other treatments. Higher dry weight plant^{-1} was also obtained from the treatments of $N_1P_2R_h$, $N_2P_1R_h$, $N_2P_3R_h$, $N_3P_2R_h$ and $N_3P_3R_h$ but significantly lower than $N_2P_2R_h$. Rhizobium treated plot gave intermediate level of dry weight plant^{-1} (0.68, 2.81, 11.05 and 16.21 g at 20, 35, 50 DAS and at harvest respectively) which was significantly different from all other treatments. Control treatment (N_0P_0) gave the lowest number of dry weight plant^{-1} at 20, 35, 50 DAS and at harvest (0.42, 2.45, 7.11 and 13.01 g respectively) which was also significantly different from all other treatments. Patel and Patel (2003) observed that phosphorus application increased photo synthetic efficiency, leaf area, shoot dry weight. Similar findings were reported by Idris *et al.*, (1989) in an experiment on chickpea. Dry matter yield was also increased significantly by an increased level of phosphorus (Parihar, 1990). Application of 17.48 kg P_2O_5 ha^{-1} significantly increased dry matter production and resulted in greater diversion of dry matter to pods (Prabhakar and Saraf, 1991). When Rhizobium, *Bacillus polymyxa*, and *Glomus fasciculatum* were applied separately in pot experiments, inoculation with Rhizobium alone markedly increased N uptake by the plant. It resulted in significantly higher dry-matter production and phosphate uptake as compared with single or double inoculation of the test organisms (Tiwari *et al.*, 1989). Seed inoculation with rhizobium increased plant dry weight (Srivastava and Verma, 2004).

Table 4. Performance of chickpea on dry weight plant^{-1} under different levels of nitrogen and phosphorus with Rhizobium inocula

Treatments	Dry weight plant^{-1} (g)			
	20 DAS	35 DAS	50 DAS	At harvest
T_1 ($N_0P_0R_h$)	0.68 e	2.81 ef	11.05 c	16.21 d
T_2 ($N_0P_0R_0$)	0.42 g	2.45 h	7.11 f	13.01 g
T_3 ($N_1P_1R_h$)	0.54 f	2.69 g	8.23 e	14.33 f
T_4 ($N_1P_2R_h$)	0.74 de	2.93 cd	10.81 c	16.15 d
T_5 ($N_1P_3R_h$)	0.60 f	2.77 fg	9.39 d	15.01 e
T_6 ($N_2P_1R_h$)	0.70 de	2.89 de	10.72 c	16.01 d
T_7 ($N_2P_2R_h$)	0.94 a	3.21 a	13.34 a	20.26 a
T_8 ($N_2P_3R_h$)	0.83 bc	3.01 bc	11.19 c	18.05 c
T_9 ($N_3P_1R_h$)	0.70 de	2.86 d-f	10.63 c	15.67 d
T_{10} ($N_3P_2R_h$)	0.88 ab	3.07 b	12.11 b	18.86 b
T_{11} ($N_3P_3R_h$)	0.77 cd	2.95 cd	10.96 c	17.79 c
SE	0.024	0.0428	0.0126	0.0342
CV (%)	8.74	7.45	8.59	8.52

Rh = Recommended dose of Rhizobium (6 kg ha^{-1})

N_0	=	No application (0 kg N ha^{-1})	P_0	=	No application (0 kg P_2O_5 ha^{-1})
N_1	=	50% less than recommended dose (10 kg N ha^{-1})	P_1	=	50% less than recommended dose (20 kg P_2O_5 ha^{-1})
N_2	=	Recommended dose (20 kg N ha^{-1})	P_2	=	Recommended dose(40 kg P_2O_5 ha^{-1})
N_3	=	50% higher than recommended dose (30 kg N ha^{-1})	P_3	=	50% higher than recommended dose (60 kg P_2O_5 ha^{-1})

4.2 Yield contributing parameters

The response of yield contributing parameters like number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight (g) of chickpea to different nitrogen and phosphorus levels with Rhizobium inocula were found statistically significant.

4.2.1 Number of pods plant^{-1}

Number of pods plant^{-1} was found to be significantly varied due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) for chickpea yield (Table 5). Results obtained from Table 5 pointed to that of nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1})($N_2P_2R_h$), gave the highest number of pods plant^{-1} (38.21) which was significantly different from all other treatments. Higher number of pods plant^{-1} was also obtained from the treatments of $N_1P_2R_h$ (32.27), $N_2P_1R_h$ (31.81), $N_2P_3R_h$ (35.43), $N_3P_2R_h$ (36.31) and $N_3P_3R_h$ (33.17) but significantly different from $N_2P_2R_h$. The treatment of Rhizobium (R_h), $N_1P_3R_h$ and $N_3P_1R_h$ gave intermediate level of number of pods plant^{-1} (27.37, 27.14 and 29.74 respectively) which was significantly different from all other treatments. Control treatment ($N_0P_0R_0$) gave the lowest number of pods plant^{-1} (22.38) which was also significantly different from all other treatments. Application of 17.48 kg ha^{-1} significantly increased dry matter production and resulted in greater diversion of dry matter to pods (Prabhakar and Saraf, 1991). In a field experiment, Dixit *et al.* (1983) found that application of phosphorus gave the highest number of pods per plant compared with a treatment without phosphorus fertilizer.Kar *et al.* (1989) stated that phosphorus increased number of pods bearing branches and number of pods per plant.

4.2.2 Number of seeds pod^{-1}

Significant variation was measured for number of seeds pod^{-1} of chickpea due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) (Table 5). Results specified that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}), ($N_2P_2R_h$) gave the highest number of seeds pod^{-1} (1.833) where the lowest (1.013) was obtained from control treatment ($N_0P_0R_0$). Higher number of seeds pod^{-1} was also obtained from the treatments of $N_2P_3R_h$ (1.633), $N_3P_2R_h$ (1.703) and $N_3P_3R_h$ (1.58) which are significantly different from $N_2P_2R_h$. The treatment of $N_1P_2R_h$ (1.493) and $N_2P_1R_h$ (1.413) gave intermediate level of number of seeds pod^{-1} which was significantly different from all other treatments where Rhizobium (R_h) treatment showed lower number of seeds pod^{-1} (1.25) but significantly different from control treatment. Dixit *et al*. (1983) found that application of phosphorus gave the highest number of seeds per pod compared with a treatment without phosphorus fertilizer.

4.2.3 Weight of 1000 seeds

Significant variation was observed in terms of 1000 seed weight of chickpea due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) (Table 5). Results specified that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1})**($N_2P_2R_h$), gave the highest 1000 seed weight (118.15 g)** which was significantly different from all other treatments. Higher 1000 seed weight was also obtained from the treatments of $N_2P_3R_h$ (114.90 g) and $N_3P_2R_h$ (115.80 g) but significantly different from $N_2P_2R_h$. The treatments; $N_1P_2R_h$ (113.20 g), $N_2P_1R_h$ (111.65 g) and $N_3P_3R_h$ (114.05 g) gave intermediate level of 1000 seed weight which was significantly different from all other treatments where Rhizobium (R_h) treatment showed lower 1000 seed weight (109.65 g) compared to all the treatments regarding 1000 seed weight. On the other hand, the lowest 1000 seed weight (108.65 g) was obtained from treatment ($N_1P_1R_h$) which was statistically similar with R_h (109.65 g). Control treatment obtained higher 1000 seed weight (110.20 g) **than R_h treatment**. Dixit *et al*., (1983) found that application of phosphorus gave the highest 1000-seed weight, compared with a treatment without phosphorus fertilizer. Increasing phosphorus levels before sowing increased the 1000-seed weight in peas (Patel and Patel, 2003). Kar *et al.* (1989) stated that phosphorus increased 1000-seed weight.

Table 5. Performance of chickpea on yield contributing characters under different levels of nitrogen and phosphorus with *Rhizobium* inocula

Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of 1000 seeds (g)
T_1 ($N_0P_0R_h$)	27.37 e	1.25 f	109.65 fg
T_2 ($N_0P_0R_0$)	22.38 g	1.01 h	110.20 f
T_3 ($N_1P_1R_h$)	25.25 f	1.134 g	108.65 g
T_4 ($N_1P_2R_h$)	32.27 c	1.49 de	113.20 d
T_5 ($N_1P_3R_h$)	27.14 e	1.17 fg	110.15 f
T_6 ($N_2P_1R_h$)	31.81 c	1.42 e	111.65 e
T_7 ($N_2P_2R_h$)	38.21 a	1.83 a	118.15 a
T_8 ($N_2P_3R_h$)	35.43 b	1.64 bc	114.90 bc
T_9 ($N_3P_1R_h$)	29.74 d	1.28 f	110.60 ef
T_{10} ($N_3P_2R_h$)	36.31 b	1.70 b	115.80 b
T_{11} ($N_3P_3R_h$)	33.17 c	1.58 cd	114.05 cd
SE	0.0212	0.0652	0.0416
CV (%)	7.56	7.18	8.44

R_h = Recommended dose (6 kg R_h ha^{-1})
N_0 = No application (0 kg N ha^{-1})
N_1 = 50% less than recommended dose (10 kg N ha^{-1})
N_2 = Recommended dose(20 kg N ha^{-1})
N_3 = 50% higher than recommended dose (30 kg N ha^{-1})
P_0 = No application (0 kg P_2O_5 ha^{-1})
P_1 = 50% less than recommended dose (20 kg P_2O_5 ha^{-1})
P_2 = Recommended dose (40 kg P_2O_5 ha^{-1})
P_3 = 50% higher than recommended dose (60 kg P_2O_5 ha^{-1})

4.3 Yield

The response of yield parameters like seed yield plant^{-1} (g), seed yield ha^{-1} (ton), stover yield ha^{-1} (ton) and harvest index (%) of chickpea to treatment of different nitrogen and phosphorus levels with Rhizobium inocula were found statistically significant.

4.3.1 Seed yield plant^{-1}

Significant variation was observed in terms of seed yield plant^{-1} of chickpea due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) (Table 6). Results specified that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest seed yield plant^{-1} (16.10 g) which was significantly different from all other treatments. The results obtained from other treatment of $N_2P_3R_h$ (13.20 g), $N_3P_2R_h$ (14.17 g) and $N_3P_3R_h$ (11.40 g) showed higher seed yield plant^{-1} but significantly different from $N_2P_2R_h$. The treatments; $N_1P_2R_h$ (9.87 g) and $N_2P_1R_h$ (9.04 g) gave intermediate level of seed yield plant^{-1} which were statistically similar but was significantly different from all other treatments where Rhizobium (R_h) treatment showed lower seed yield plant^{-1} (7.113 g) compared to all the treatments regarding seed yield plant^{-1} except the treatment of $N_1P_1R_h$ (5.75 g) and $N_0P_0R_0$ where the later found the lowest seed yield plant^{-1} (5.13 g).

4.3.2 Seed yield t ha^{-1}

Significant variation was observed in terms of seed yield ha^{-1} of chickpea due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) (Table 6). Results specified that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest seed yield ha^{-1} (1.28 t ha^{-1}) which was significantly different from all other treatments. The results obtained from the other treatments; $N_2P_3R_h$ (1.03 t ha^{-1}), $N_3P_2R_h$ (1.11 t ha^{-1}) and $N_3P_3R_h$ (0.97 t ha^{-1}) showed higher seed yield ha^{-1} but significantly lower from $N_2P_2R_h$. The treatments; $N_1P_2R_h$ (0.85 t ha^{-1}) and $N_2P_1R_h$ (0.73 t ha^{-1}) which were statistically similar to each other gave intermediate level of seed yield ha^{-1} and was significantly different from all other treatments. Rhizobium (R_h) treatment showed lower seed yield ha^{-1} (0.47 t ha^{-1}) compared to all the treatments regarding seed yield ha^{-1} except $N_1P_1R_h$ (0.41 t ha^{-1}) and $N_0P_0R_0$ (0.29 t ha^{-1}) where the later treatment (control) produced the lowest seed yield ha^{-1} (0.29 t ha^{-1}) but it was statistically similar with $N_1P_1R_h$. Application of 20 kg N ha^{-1} increased chickpea yield in sandy loam soils. A high yield was obtained with

20 kg N ha^{-1} and Rhizobium inoculation in Gujarat, India (Patel and Patel 1991).Increase in yield was reported with nitrogen application as basal dose and at post flowering stage. Nitrogen application during the post flowering stage enhanced nitrate reductase activity and yield (Sekhon et al., 1988).Borgohain and Agarwal (1986) reported that seed yield of chickpea increased with increasing levels of phosphorus. 80 kg P_2O_5 ha^{-1} gave the highest yield of 1.33 t ha^{-1} compared with 0.79 t ha^{-1} (control). Similar observations were recorded by Tomar *et al.* (1987). They reported that chickpea yields with 25, 50 and 75 kg P_2O_5 ha^{-1} were 2.07, 2.26 and 2.18 t ha^{-1} compared with 1.89 t ha^{-1} without phosphorus (control). Hamidullah, *et al.* (1989) reported that phosphorus application increased photosynthetic efficiency and seed yield in chickpea. Phosphorus application increased the seed yield in red chickpea (Tomar *et al.*, 1987). Phosphorus application gave a yield increase of 30% under non-irrigated conditions and about 40% under supplemental irrigation (Prabhakar and Saraf, 1989). On alluvial soils low available soil P, a 78% increase was observed in seed yield with an application of 32 kg P/ha under rainfed conditions (Singh *et al.*, 1981). Varughese and Pathak (1987) reported that application of diammonium phosphate at 50 kg/ha as basal dose and 50 kg/ha split equally at branching and flowering stages produced the highest chickpea yield (2470 kg/ha). An yield increase of 12% was recorded with Rhizobium inoculation alone. Rhizobium inoculation along with the recommended fertilizer application increased yield by 40% (Singh *et al.* 1989). Singh and Tilak (1989) reported that chickpea already inoculated with Rhizobium leguminosarum, when inoculated with Glomus versiformes showed increase 25% in seed yield. When P was applied in addition to inoculation, the yield increase was 33% and 60% for these strains respectively.

4.3.3 Stover yield t ha^{-1}

Significant variation was observed in terms of stover yield ha^{-1} of chickpea due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) (Table 6). Results specified that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest stover yield ha^{-1} (3.32 t ha^{-1}) which was closely followed by $N_2P_3R_h$ (3.15 t ha^{-1}) and $N_3P_2R_h$ (3.20 t ha^{-1}). The results obtained from other treatments; $N_1P_2R_h$ (2.94 t ha^{-1}), $N_2P_1R_h$ (2.87 t ha^{-1}) and $N_3P_3R_h$ (3.06 t ha^{-1}) showed higher stover yield ha^{-1} but significantly different from $N_2P_2R_h$. Rhizobium (R_h) treatment showed lower stover yield (2.57 t ha^{-1}) compared to all the treatments regarding stover yield ha^{-1} but it was statistically similar with $N_1P_3R_h$ (2.62 t ha^{-1}) and N_0P_0 (2.53 t ha^{-1}) where the later control treatment produced the lowest seed yield ha^{-1}. Increase in stover yield of chickpea due to the application of Rhizobium and phosphorus has been reported by Bhuiyan *et al.*, (1999).

4.3.4 Harvest index

Harvest index was significantly varied due to different nitrogen and phosphorus levels with Mesorhizobium inoculam (R_h) (Table 6). Results showed that nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}), ($N_2P_2R_h$) gave the highest harvest index (27.84%) which was significantly different from all other treatments. On the other hand, the lowest harvest index (10.05%) was achieved by control treatment ($N_0P_0R_0$). Rhizobium (R_h) treatment showed lower harvest index (15.48%) compared to all the treatments. The results obtained from other treatments; $N_2P_3R_h$ (24.66%), $N_3P_2R_h$ (25.77%) and $N_3P_3R_h$ (24.09%) showed higher harvest index but significantly different from $N_2P_2R_h$. The treatments; $N_1P_2R_h$ (22.45 %), $N_2P_1R_h$ (20.29 %) and $N_3P_1R_h$ (18.28 %) showed intermediate results compared to highest and lowest harvest index under the present study. Roy *et al.* (2000) reported that seed inoculation gave the highest harvest index and grain weight.

Table 6. Performance of chickpea on yield parameters under different levels of nitrogen and phosphorus with rhizobium inocula

Treatments	Seed yield $plant^{-1}$ (g)	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Harvest index (%)
T_1 ($N_0P_0R_h$)	7.11 fg	0.47 fg	2.57 e	15.48 e
T_2 ($N_0P_0R_0$)	5.14 h	0.29 h	2.60 e	10.05 f
T_3 ($N_1P_1R_h$)	5.75 gh	0.41 gh	2.53 e	13.96 e
T_4 ($N_1P_2R_h$)	9.87 cd	0.85 cd	2.94 c	22.45 c
T_5 ($N_1P_3R_h$)	6.28 fh	0.50 fg	2.62 e	16.04 e
T_6 ($N_2P_1R_h$)	9.04 de	0.73 de	2.87 cd	20.29 d
T_7 ($N_2P_2R_h$)	16.10 a	1.28 a	3.32 a	27.84 a
T_8 ($N_2P_3R_h$)	13.20 b	1.03 b	3.15 ab	24.66 b
T_9 ($N_3P_1R_h$)	7.89 ef	0.61 ef	2.73 de	18.28 d
T_{10} ($N_3P_2R_h$)	14.17 b	1.11 b	3.20 ab	25.77 b
T_{11} ($N_3P_3R_h$)	11.40 c	0.97 bc	3.06 bc	24.09 b
SE	0.0241	0.0622	0.0384	0.0486
CV (%)	5.46	6.24	8.34	7.33

R_h = Recommended dose (6 kg R_h ha^{-1})

N_0 = No application (0 kg N ha^{-1})

N_1 = 50% less than recommended dose (10 kg N ha^{-1})

N_2 = Recommended dose(20 kg N ha^{-1})

N_3 = 50% higher than recommended dose (30 kg N ha^{-1})

P_0 = No application (0 kg P_2O_5 ha^{-1})

P_1 = 50% less than recommended dose (20 kg P_2O_5 ha^{-1})

P_2 = Recommended dose (40 kg P_2O_5 ha^{-1})

P_3 = 50% higher than recommended dose (60 kg P_2O_5 ha^{-1})

Chapter 5
Summary and Conclusion

CHAPTER 5

Summary and Conclusion

The experiment was conducted on 'Performance of Chickpea (*Cicer arietinum* L.) under different levels of Nitrogen and Phosphorus with *Rhizobium* inocula' at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka.

There are eleven (11) treatments comprised for the present study. The treatments of the experiment were $T_1 = R_h$, $T_2 = N_0P_0$, $T_3 = N_1P_1R_h$, $T_4 = N_1P_2R_h$, $T_5 = N_1P_3R_h$, $T_6 = N_2P_1R_h$, $T_7 = N_2P_2R_h$, $T_8 = N_2P_3R_h$, $T_9 = N_3P_1R_h$, $T_{10} = N_3P_2R_h$ and $T_{11} = N_3P_3R_h$ where R_h = Recommended dose (6 kg R_h ha^{-1}), N_0 = No application (0 kg N ha^{-1}), N_1 = 50% less than recommended dose (10 kg N ha^{-1}), N_2 = Recommended dose (20 kg N ha^{-1}), N_3 = 50% higher than recommended dose (30 kg N ha^{-1}), P_0 = No application (0 kg P_2O_5 ha^{-1}), P_1 = 50% less than recommended dose (20 kg P_2O_5 ha^{-1}), P_2 = Recommended dose (40 kg P_2O_5 ha^{-1}) and P_3 = 50% higher than recommended dose (60 kg P_2O_5 ha^{-1}).

The experiment was set up in Randomized Complete Block Design with three replications. The experimental plot was fertilized as per treatment with nitrogen and phosphorus fertilizer with *Rhizobium* inocula and with other fertilizer as per recommended dose. Data on different growth and yield parameters were recorded and analyzed statistically.

Data on growth parameters were plant height, number of branches $plant^{-1}$, number of nodules $plant^{-1}$ and dry weight $plant^{-1}$ and yield and yield contributing parameters were number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000 seed weight, yield $plant^{-1}$, yield ha^{-1}, stover yield ha^{-1} and harvest index.

In terms of growth parameters; there was no significant effect on plant height at 20 and 35 DAS. Nitrogen at the rate of 30 kg ha^{-1} along with 60 kg P $ha^{-1}$and with recommended dose of mesorhizobium (6 kg ha^{-1}), ($N_3P_3R_h$) gave the tallest plant

(35.48 and 35.59 cm at 50 DAS and at harvest respectively). Control treatment (N_0P_0) gave the lowest plant height (28.08 and 28.12 cm at 50 DAS and at harvest respectively). *Rhizobium* treated plot also gave lower plant height (29.10 and 29.17 cm at 50 DAS and at harvest respectively).

There was no significant effect on number of branches plant^{-1} at 20 DAS. But nitrogen rate (40 kg ha^{-1}) and phosphorus rate (80 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}),($N_2P_2R_h$) gave the highest number of branches plant^{-1} (9.14, 22.40 and 22.48 at 35, 50 DAS and at harvest respectively). Control treatment ($N_0P_0R_0$) gave the lowest number of branches plant^{-1} (5.22, 13.12 and 13.15 at 35, 50 DAS and at harvest respectively). *Rhizobium* treated plot gave lower number of branches plant^{-1} (6.497, 16.14 and 16.20 at 35, 50 DAS and at harvest respectively).

The $N_2P_2R_h$ also gave the highest number of nodules plant^{-1} (14.16, 20.41 and 26.28 at 20, 35 and 50 DAS respectively) and highest dry weight plant^{-1} (0.94, 3.21, 13.34 and 20.26 g at 20, 35, 50 DAS and at harvest respectively) where control treatment ($N_0P_0R_0$) gave the lowest number of nodules plant^{-1} (8.04, 12.95 and 16.13 at 20, 35, and 50 DAS respectively) and dry weight plant^{-1} (0.42, 2.45, 7.11 and 13.01 g at 20, 35, 50 DAS and at harvest respectively). *Rhizobium* treated plot gave lower number of nodules plant^{-1} (11.68, 16.17 and 21.88 at 20, 35, and 50 DAS respectively) and dry weight plant^{-1} (0.68, 2.81, 11.05 and 16.21 g at 20, 35, 50 DAS and at harvest respectively).

In terms of yield and yield contributing characters; nitrogen rate (20 kg ha^{-1}) and phosphorus rate (40 kg ha^{-1}) with recommended dose of mesorhizobium (6 kg ha^{-1}) ($N_2P_2R_h$), gave the highest number of pods plant^{-1} (38.21), number of seeds pod^{-1} (1.83), 1000 seed weight (118.15 g), seed yield plant^{-1} (16.10 g), seed yield ha^{-1} (1.28 t ha^{-1}), stover yield (3.317 t ha^{-1}) and harvest index (27.84%) where control treatment ($N_0P_0R_0$) gave the lowest number of pods plant^{-1} (22.38), number of seeds pod^{-1} (1.01), seed yield plant^{-1} (5.13 g), seed yield (0.29 t ha^{-1}) and harvest index (10.05%) but $N_1P_1R_h$ gave lowest 1000 seed weight (108.65 g). The lowest stover yield (2.527 t ha^{-1}) was obtained from $N_1P_1R_h$ which was statistically similar with R_h (2.57 t ha^{-1}), $N_0P_0R_0$ (2.53 t ha^{-1}). The treatment of *Rhizobium* (R_h) gave lower level of number of pods $plant^{-1}$ (29.74), number of seeds pod^{-1} (1.25), 1000 seed weight (109.65 g), seed yield $plant^{-1}$ (7.11 g), seed yield ha^{-1} (0.47 t/ha), stover yield (2.567 t ha^{-1}) and harvest index (15.48%).

It may be concluded from the results that nitrogen and phosphorus application with *Rhizobium* inocula is very much promising for higher chickpea yield. Comparing control treatment, nitrogen (10-30 kg ha^{-1}) and phosphorus application (20-60 kg ha^{-1}) at any rate showed better performance for chickpea yield. However, the best nitrogen dose was 20 kg $ha^{-1}$and phosphorus dose was 40 kg $ha^{-1}$with recommended dose of mesorhizobium inocula under the present study. The combination of $N_2P_2R_h$ (20 kg kg $ha^{-1}$and 40 kg P $ha^{-1}$with *Rhizobium* 6 kg ha-1 performed best in producing higher yield than other treatments comprised with other nitrogen and phosphorus levels with rhizobium under the present study. On the other hand, nitrogen at 20 kg ha^{-1} and phosphorus at 40 kg ha^{-1} with 6 kg ha^{-1} *Rhizobium* inocula showed its superiority in producing higher chickpea yield.

The present research work was carried out at the Sher-e-Bangla Agricultural University and in one season only. Further trial of this work in different locations of the country is needed to justify the result for higher return of yield.

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Appendices

Appendix I. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from October 2008 to March 2009

Month	RH (%)	Max. Temp. (°C)	Min. Temp. (°C)	Total Rain fall (mm)
October	73.36	29.46	19.19	Trace
November	71.15	26.98	14.88	Trace
December	68.30	25.78	14.21	Trace
January	69.53	25.00	13.46	0
February	50.31	29.50	18.49	0
March	44.95	33.80	20.28	0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II: Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

- Morphological characteristics of the experimental field

Morphological features	***Characteristics***
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

- **Physical and chemical properties of the initial soil**

Characteristics	*Value*
Partical size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III: Performance of chickpea on plant height under different levels of nitrogen and phosphorus with rhizobium inocula

Source of variation	Degrees of freedom	Mean square Plant height (cm)			
		20 DAT	35 DAT	50 DAT	At harvest
Replication	2	1.894	27.119	0.051	0.456
Treatment	10	0.249 ^{NS}	15.818^{NS}	15.818*	6.310*
Error	20	0.000	0.000	0.236	0.218

* = Significant at 5% level of significance
NS = Non significant

Appendix IV: Performance of chickpea on number of branches plant^{-1} under different levels of nitrogen, phosphorus with rhizobium inocula

Source of variation	Degrees of freedom	Mean square Number of branches/plant			
		20 DAT	35 DAT	50 DAT	At harvest
Replication	2	1.046	0.395	1.290	0.288
Treatment	10	NS	3.132*	24.438*	24.606*
Error	20	0.000	0.114	0.246	0.386

* = Significant at 5% level of significance

Appendix V: Performance of chickpea on number of nodules $plant^{-1}$ under different levels of nitrogen, phosphorus with rhizobium inocula

Source of variation	Degrees of freedom	Mean square			
		Number of nodules/plant			
		20 DAT	35 DAT	50 DAT	At harvest
Replication	2	0.285	0.438	0.015	0.509
Treatment	10	11.585*	12.893*	22.599*	19.216*
Error	20	0.112	0.218	0.236	0.228

* = Significant at 5% level of significance

Appendix VI: Performance of chickpea on dry weight $plant^{-1}$ under different levels of nitrogen, phosphorus with rhizobium inocula

Source of variation	Degrees of freedom	Mean square			
		Dry weight $plant^{-1}$			
		25 DAT	50 DAT	75 DAT	At harvest
Replication	2	0.201	1.673	4.437	0.865
Treatment	10	0.068**	0.122**	8.906*	13.205*
Error	20	0.002	0.004	0.116	0.128

* = Significant at 5% level of significance
** = Significant at 1% level of significance

Appendix VII: Performance of chickpea on yield contributing characters under different levels of nitrogen and phosphorus with rhizobium inocula

Source of variation	Degrees of freedom	Mean square		
		Number of pods $plant^{-1}$	Number of seeds/pod	1000 seed wt
Replication	2	0.443	0.028	0.939
Treatment	10	7.044*	0.205**	10.169*
Error	20	1.233	0.004	2.216

* = Significant at 5% level of significance
** = Significant at 1% level of significance

Appendix VIII: Performance of chickpea on yield parameters under different levels of nitrogen, phosphorus with rhizobium inocula

Source of variation	Degrees of Freedom	Mean square			
		Yield/plant (g)	Yield(kg ha^{-1})	Stover yield	Harvest index (%)
Replication	2	0.136	0.008	0.022	0.436
Factor A	10	9.391**	0.311*	0.237*	18.334*
Error	20	1.004	0.008	0.012	0.035

* = Significant at 5% level of significance