EFFECT OF BIO-FERTILIZER ON YIELD AND SEED QUALITY OF BLACKGRAM WITH COMBINATION OF NITROGEN AND PHOSPHORUS

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CERTIFICATE

*This is to certify that the thesis entitled "**EFFECT OF BIO-FERTILIZER ON YIELD AND SEED QUALITY OF BLACKGRAM WITH COMBINATION OF NITROGEN AND PHOSPHORUS,** Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **INSTITUTE OF SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **MD. SHAKHAOWAT HOSSAIN**, Registration No. 13-05425 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

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Dedicated to

My

Beloved Parents

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ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from March 2019 to June 2019 to observe the effect of bio-fertilizer on yield and seed quality of blackgram with combination of nitrogen and phosphorus. The experiment consisted of two factors *viz*. Factor A: two bio-fertilizer levels; (i) B_0 = Without bio-fertilizer (control) and (ii) B_1 = With bio-fertilizer and Factor B: Five N+P levels; F_0 = Control (without N+P fertilizer), F_1 = 40% lower than recommended doses of N+P fertilizer, F_2 = 20% lower than recommended doses of N+P fertilizer, F_3 = recommended doses of N+P fertilizer, F_4 = 20% higher than recommended doses of N+P fertilizer and F_5 = 40% higher than recommended doses of N+P fertilizer. The experiment was conducted in split-plot design with three replications. A significant variation among the treatments was found while bio-fertilizer application and different levels of N+P fertilizers applied in different combinations. The maximum number of pods plant^{-1} (38.52), pod length (4.22 cm), number of seeds pod^{-1} (6.50), 1000-seed weight (44.05 g), seed yield (1.76 t ha^{-1}), stover yield (3.40 t ha^{-1}) and biological yield (5.16 t ha^{-1}) were obtained from the treatment combination of B_1F_3 but the highest harvest index (34.28%) was obtained from the treatment combination of B_1F_2 whereas the lowest was from the treatment combination of B_0F_0. Considering seed quality parameters, all the parameters were significantly affected by combined effect of bio-fertilizer and N+P treatments. The highest percent germination (94.70%) and shoot length (25.40 cm) were obtained from the treatment combination of B_1F_3 but the highest root length (10.86 cm) and dry weight plant^{-1} (0.15 g) and also lowest electrical conductivity (7.83) were obtained from the treatment combination of B_1F_4 compared to all other treatment combinations. As a result, it can be accomplished that application of bio-fertilizer and N+P treatment combination B_1F_3 is very much effective for higher yield and better seed quality of blackgram.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celsius
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
µg	=	Microgram

CHAPTER I

INTRODUCTION

Agricultural sector is the backbone of Bangladesh economy providing employment to 45% of the total population and contributes about 14.79% of GDP (BER, 2017). Pulses constitute an integral part of human diet and are potential source of protein for the millions of people of Bangladesh. They contribute 2.3% value added to agriculture in Bangladesh (Niaz *et al*., 2013). Pulses are considered as 'the meat of the poor' because still pulses are the cheapest source of protein (Hamjah, 2014). The per capita consumption of pulse in Bangladesh is only 14.3 g day^{-1}, which is much lower than WHO recommendation of 45 g day^{-1} and Indian Council of Medical Research recommendation of 60 g day^{-1} (HIES, 2010; Afzal *et al*., 1999).

Blackgram (*Vigna mungo* L. Hepper) is one of the highly priced pulses in Bangladesh. It is locally known as 'Mashkalai' belongs to the family Leguminosae and it is extensively grown in both tropical and sub-tropical countries of the world. It contains approximately 25-28% protein, 4.5-5.5% ash, 0.5-1.5% oil, 3.5-4.5% fiber and 62-65% carbohydrate on dry weight basis. It has been reported that the average yield of blackgram is about 1000 kg ha^{-1} and the protein content is 25-26% (BINA, 2004). In spite of its various uses, its cultivation is decreasing day by day both in acreage and yield (BBS, 2006).

Total cultivated area in Bangladesh is 8031161 hectares of which pulses constitute 420763 hectares i.e., 5.24% of total cultivated land (BBS, 2004). About a dozen pulse crops are grown in the winter and summer seasons. Among these, Grass pea, lentil, chickpea, blackgram, mung bean, 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.

Among the pulses, blackgram is very much popular in Bangladesh and ranks 3rd in terms of consumption and total area in which different varieties of this crop are cultivated (BBS, 2014). Total cultivated area in Bangladesh is 9805360 hectares of which 44.63%, 18.28% and 10.20% are suitable, moderately suitable and marginally suitable for blackgram production (BARC, 2016). It improves the soil fertility status by fixing a tremendous amount (63-342 kg ha^{-1} per season) of atmospheric nitrogen in soil (Kaisher *et al*., 2010). Its foliage and stems are also used as good source of fodder as well as green manuring and cover crops.

The yield of blackgram is very low compared to other legume crops. Pulses contribute 2.3% value added to agriculture (BBS, 2014). Moreover, pulses are excellent sources of proteins, but they are treated as minor crops and receive little attention from farmers and policymakers. To increase blackgram production, biofertilizer with different combinations of inorganic fertilizer can be an important alternative (Hayat *et al*., 2010).

Biofertilizers are mostly named as microbial inoculants which are capable of controlling some of the nutritional element in the soil from useless to usefull by the crop plant from their biological processes (Amit and Satish, 2015). Biofertilizer like Rhizobium, Azotobacter, Azospirillum and blue green algae (BGA) are in use since long time ago. Rhizobium inoculants is popularly used for leguminous crops. Since many years, biofertilizers are used as in large amount as an eco-friendly process which has reduced the use of chemical fertilizer. This improve soil fertility status and for enhancement of crop production by their biological activity in the rhizosphere (Geol *et al*., 1999).

In recent years, biofertilizers have started on large scale as a promising component of integrating nutrient supply system in agriculture. Biofertilizer are organic product which contain living cells of various types of microorganism, which are capable of converting important elements from unavailable to available form through biological processes (Vessey, 2003) and also accelerate microbial process to augment to extend the availability of the nutrient in a form which can easily assimilated by plant (Subba-Rao, 1986 and Amit and Satish, 2015).

Fertilizer management is an important part for blackgram production and N is a greatest portion of fertilizer management because N is required for cellular synthesis of enzymes, proteins, chlorophyll, DNA and RNA and therefore it is required for plant growth and production of food and feed. Inadequate supply of available N frequently results in plants that have slow growth, depressed protein levels, poor yield of low quality and inefficient water use (Hayat *et al*., 2010). When the chemical fertilizers were first introduced into the agriculture field, most of the problems faced by farmers to increase yield of their plantation have been solved. However, chemical fertilizers slowly started to show their side effect on human and environment (Zakaria, 2009). Adequate supply of N may minimize the yield reduction through reducing slow rate of dry matter accumulation, leaf senescence and low partitioning efficiency of assimilates to grain (Rahman, 1991). Saini and Thakur (1996) stated that moderate doses of nitrogen (60 kg N ha^{-1}) significantly increased the plant height, branches $plant^{-1}$ and leaf area index of grain legumes compared to no N. 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 application to legumes plays a key role in the formation of energy rich phosphate bonds, phospholipids and for development of root system (Tisdale *et al.*, 1985). It also improves the crop quality and resistance to diseases. Phosphorus application to legumes not only benefits the particular crop but also improves the soil nitrogen content for the succeeding non-legume crops requiring lower doses of nitrogen application. It is also an essential constituent of majority of enzymes which are of great importance in the transformation of energy, carbohydrate metabolism, fat metabolism and also in respiration (catabolism of carbohydrates) in plants. It is closely related to cell division and development. Phosphorus stimulates seed setting, hastens maturity and enhanced protein content. It plays an important role in the nutrition of legumes and also improves biological nitrogen fixation and quality of grains (Kumar *et al.*, 2009).

Chemical fertilizers have several negative impacts on environment and sustainable agriculture. Therefore, biofertilizers are recommended in these conditions and growth prompting bacteria have been used as a replacement of chemical fertilizers (Wu *et al.*, 2005). Growth promoting bacteria induced increasing plant yield as clone in plants root (Gholami *et al.*, 2009) and they include Azotobacter, Azospiri-llum and Pseudomonas (Turan *et al.*, 2006, Banerjee *et al.*, 2006).

Biofertilizer is a natural product carrying living microorganisms derived from the root or cultivated soil. So they don't have any ill effect on soil health and environment (Vessey, 2003). Besides their role in atmospheric nitrogen fixation and phosphorous, these also help in stimulating the plant growth hormones providing better nutrient uptake and increased tolerance towards drought and moisture stress. A small dose of biofertilizer is sufficient to produce desirable results because each gram of carrier of biofertilizers contains at least 10 million viable cells of a specific strain (Anandaraj and Delapierre, 2010). Biofertilizers can be expected to reduce the use of chemical fertilizer and pesticides. The microorganisms in biofertilizers restore the soil's natural nutrient cycle and build soil organic matter. It has been shown that it increases crop yield by 20-30%, replace chemical nitrogen and phosphorus by 25% in addition to stimulating plant growth. Finally it could provide protection against drought and some soil borne diseases. Biofertilizers in association with chemical fertilizers have enormous economic and environmental advantages. The biological fertilizers have been shown to have a special importance as appropriate replacement for chemical fertilizers, through to improving of soil fertility and providing nutrition requirement of plant (Shahdi, 2010).

The purpose of this study was to evaluate the effect of bio-fertilizer on yield and seed quality of blackgram with combination of nitrogen and phosphorus. With this respect the study was carried out with the following objectives:

- To find out the effect of bio fertilizer on yield and seed quality of blackgram,
- To observe the effect of N and P level on yield and seed quality of blackgram and
- To find out the suitable combination of biofertilizer and P+N fertilizer on seed yield and quality.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made in this section to collect and study the relevant information available in the home and abroad regarding the effect of bio-fertilizer on yield and seed quality of blackgram with combination of nitrogen and phosphorus to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion.

2.1 Role of bio-fertilizer

A bio-fertilizer is simply a substance which contains living microorganisms which when applied to the soil, a seed or plant surface colonizes the rhizosphere and promotes growth by increasing the supply or availability of nutrients to the host plant. A bio-fertilizer is a modernized form of organic fertilizer into which beneficial microorganisms have been incorporated (Swathi, 2010).

According to Chun-Li *et al*. (2014), though the practice of using chemical fertilizers and pesticides accelerates soil acidification, it also poses the risk of contaminating ground water and the atmosphere. It also weakens the roots of plants thereby making them to be susceptible to unwanted diseases. In this regard, attempts have recently been made towards the production of nutrient rich high quality fertilizer (Biofertilizer) to ensure bio-safety. Biofertilizer has been identified as an alternative to chemical fertilizer to increase soil fertility and crop production in sustainable farming. These potential biological fertilizers would play the key role in productivity and sustainability of soil and also protect the environment as eco-friendly and cost effective inputs for the farmers (Khosro and Yousef, 2012).

According to Hari and Perumal (2010) bio-fertilizer is most commonly referred to as selected strains of beneficial soil microorganisms cultured in the laboratory and packed in suitable carriers. In a large sense, the term biofertilizer may be used to include all organic resources for plant growth which are rendered in available form for plant absorption through microorganisms or plant associations or interactions (Khosro and Yousef, 2012).

Conventional agriculture plays an important role in meeting the food needs of a growing human population, which has led to an increasing dependence on the use of chemical fertilizers and pesticides for increased productivity (Santos *et al*., 2012). Chemical fertilizers are industrially made substances which are composed of known quantities of nitrogen, phosphorus and potassium. The use of chemical fertilizers causes air and ground water pollution as a result of eutrophication of water bodies (Youssef and Eissa, 2014).

Biofertilizers keep the soil environment rich in all kinds of macro and micro nutrients via nitrogen fixation, phosphate and potassium solubilisation or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil (Sinha *et al*., 2014).

Bio-fertilizers play an important role in improving fertility of the soil. In addition, their application to soil improves the structure of the soil and minimizes the sole use of chemical fertilizers. Under low land conditions, the application of blue green algae (BGA) plus *Azospirillum* proved significantly beneficial in improving yield of grain. Bio-fertilizers inoculation with *Azotobacter* and *Rhizobium* and Vesicular Arbuscular *Mycorrhiza* gave the highest increase in straw and grain yield of wheat plants with rock phosphate as phosphate fertilizer (Ritika and Uptal, 2014).

Azolla is inexpensive, economical, eco-friendly, which provides benefit in terms of carbon and nitrogen enrichment of soil. It was recorded microorganisms such as *Bacillus subtilis*, *Thiobacillus thioxidans* and *Saccharomyces* species can fix atmospheric nitrogen symbiotically and about 80–90% nitrogen demand could be supplied by soya bean through symbiosis (Ritika and Uptal, 2014).

Bio-control, a modern approach of disease management can be a significant role of bio-fertilizer in agriculture. *Trichoderma* based bio-fungicides has been found promising to control root rot of mung bean (Ritika and Uptal, 2014). Growth, yield and quality parameters of certain plants significantly increased with bio-fertilizers containing bacterial nitrogen fixers, phosphate and potassium solubilizing bacteria and microbial strains of some bacteria (Khosro and Yousef, 2012). The importances of biofertilizers are highlighted below: Secretion of plant growth hormones which help in plant growth, Protection of the plant against attack by pathogens, Improvement soil fertility, No special care is necessary while using bio-fertilizer, Reduction in the use of chemical fertilizers, Bio-fertilizers are cost effective compared to synthetic fertilizer, Promotes growth of plants, Bio-fertilizers restore the soil's natural, nutrient cycle and build soil organic matter and Bio-fertilizer provides protection against drought (Khosro and Yousef, 2012).

Biofertilizers, when applied as seed or soil inoculants, multiply and participate in nutrient cycling and leads to crop productivity. Generally, 60% to 90% of the total applied fertilizer is lost and the remaining 10% - 40% is taken up by plants. Hence biofertilizers can be important component of intergrated nutrient management systems for to sustaining agricultural productivity and a healthy environment (Adesemoye and Kloepper, 2009).

The application of biofertilizer to the soil increases the biodiversity which constitutes all kinds of useful bacteria and fungi including the arbuscular mycorrhiza fungi (AMF) called plant growth promoting rhizobacteria (PGPR) and nitrogen fixers. There are so many microorganisms thriving in the soil, especially in the rhizosphere of plant. A considerable number of these microorganisms possess a functional relationship and constitute a holistic system with plants. They have beneficial effects on plant growth (Vessey

(2003). Application of beneficial microorganisms in agricultural practices started about 60 years ago and it is now evident that these beneficial microbes can also enhance plant resistance to adverse environmental stresses e. g., water and nutrient deficiency and heavy metal contamination.

2.2 Advantages of bio-fertilizer over chemical fertilizers

Inorganic fertilizers have become very popular in Nigeria and throughout the world because they are easily affordable and have the advantage of fast action owing to their prompt release of nutrients. However, there has been much research on the demerits of inorganic fertilizers and this has revealed that they have disadvantages which cannot be overlooked. Most of the problems associated with harvested crops and some of the pollution of our natural environment occurred as a result of inorganic fertilizer use (Rosen and Horgan, 2009).

The world's demand for fertilizer has risen greatly in the past few decades. Apart from the high cost, inorganic fertilizers when applied incorrectly, excessively or inadequately have negative effects. Many of the fertilizers imported into the country were wasted as farmers refused to purchase them. When interviewed, yam farmers complained that the fertilizers were responsible for the early decay of harvested yam tubers. It is also no secret that crops cultivated with inorganic fertilizers have less flavor, taste, and aroma than those cultivated without inorganic fertilizers (Ifokwe, 1988).

Excessive fertilizer application leads to salt burn and in most cases leads to the death of young plants (Laboski, 2011). Because they are non-biodegradable, long term use of inorganic fertilizers result in accumulation of harmful substances and acidification of the soil thereby causing a decrease in the fertility of the soil (Taylor, 1997). Due to their high solubility in water, inorganic fertilizers applied to the soil could be leached deep into the soil (where plant roots cannot reach) and into underground water causing pollution (Ifokwe, 1988).

According to Ifokwe (1988) different types of fertilizers are suitable for different soil types. To get fertilizers which will suit a particular soil, the soil needs to be analyzed. According to him, most of the fertilizers imported into the country are not suitable for our soil thereby giving negative rather than positive results; besides one requires a good knowledge before applying it but today, every illiterate farmer applies fertilizers without understanding how it works and its side effects. All these problems can however be avoided by the use of indigenous fertilizers which is environment friendly. These fertilizers known as bio-fertilizers can achieve all that is achievable with inorganic fertilizers and even more without any side effects.

Bio-fertilizers are environment friendly and do not cause pollution unlike inorganic fertilizers which often 'run off' into water bodies causing eutrophication and 'blue baby syndrome' (acquired methemoglobinemia) when the nitrate level is above 10 mg/L (Knobeloch *et al*., 2009).

Bio-fertilizers have long lasting effects due to their slow nutrient release. The nutrients from bio-fertilizers are released to plants slowly and steadily for more than one season. As a result, long term use of bio-fertilizer leads to the buildup of nutrients in the soil thereby increasing the overall soil fertility. In addition, bio-fertilizers have been found to help control of plant diseases such as pythium root rot, rhizoctonia root rot, chill wilt and parasitic nematode (Mahimaraja *et al*., 2008).

Bio-fertilizer acts as a soil conditioner adding organic matter to the soil which helps to bind the soil particles together preventing soil eructing, desertification, and erosion while increasing the water retention capacity of the soil. It enriches the soil with beneficial microorganisms while boosting the already existing ones unlike chemical inorganic fertilizers which acidify the soil making it hard for microorganisms to survive (Swathi, 2010).

Bio-fertilizers contain a wide range of nutrients which are often absent in inorganic fertilizers (these include trace elements). Studies have shown that application of nitrogen fertilizer in some weather conditions cause emission of nitrous oxide which has a global warming effect potential 296 higher times than that of an equal mass of carbon dioxide (Galloway, 2007, Grabber and Galloway, 2008).

Methane emissions from crop fields (notably rice paddy fields) are increased by the application of ammonium based fertilizers whereas the composting of animal waste in a confined place or in an anaerobic condition (an important process in the production of bio-fertilizer), reduces the addition of methane to the atmosphere as these add methane to the atmosphere when left to decay on their own. Bio-fertilizer when compared to raw (undegraded) organic manure has the advantage of easier assimilation by plants and also the odor reduces after degradation (Swathi, 2010).

Again, the risk with raw organic manure is that it may contain pathogens such as *Salmonella* Spp. which may contaminate crops such as leafy vegetables and lead to the ingestion of the pathogen when the product is consumed. Bio-fertilizer also contains useful microorganisms which may not be present in organic (degraded) fertilizer (Khosro and Yousef, 2012). These bio-fertilizers can be produced from cheap waste materials which are abundant in Nigeria and the cost of production is low compared to inorganic fertilizers which required high energy.

2.3 Effect of bio-fertilizers on growth and yield of crops

Thakur *et al*. (2018) conducted an experiment to study the effect of *Rhizobium* and Phosphorus Solublizing Bacteria (PSB) on the horticultural and yield traits in French bean var. Contender. Six treatments comprising seed treatments (with and without *Rhizobium*), seed treatment (with and without PSB) along with the combination of 60 % dose of recommended quantity of Calcium Ammonium Nitrate and 75 % dose of recommended quantity of Single Super Phosphate and organic matter were evaluated. The results revealed that T_5 treatment, i.e.

Rhizobium+ PSB+ Organic matter resulted in more number of pods plant^{-1} (20), pod length (18 cm) and pod yield ha^{-1} (140 q ha^{-1}) .

Mohammad *et al*. (2017) showed that application of PM @ 5 t ha^{-1} + Rhizobium + PSB significantly increased the seed and straw yield of mungbean over control, PM @ 2.5 t ha^{-1}, PM @ 5 t ha^{-1} and PM @ 2.5 t ha^{-1} + Rhizobium + PSB. The application of PM @ 5 t ha^{-1} + Rhizobium + PSB significantly higher the grain yield over control, PM @ 2.5 t ha-1, PM @ 5 t ha^{-1} and PM @ 2.5 t ha^{-1} + Rhizobium + PSB by 52.63, 25.17, 7.15 and 15.20 percent respectively.

Choudhary *et al*. (2017) conducted a field experiment entitled the effect of bio-fertilizers on growth and yield of blackgram in sandy loamy soil having the medium in available nitrogen (181.21), low phosphorus (16.0) and medium potassium (257.37) during the Rabi season of 2015-2016 with the objectives of select appropriate variety and to evaluate the effect of bio-fertilizers on growth and yield of blackgram. The experiment consists of 8 treatments: T_1 (Biofertilizer + Black-gram KU96-3), T_2 (Biofertilizer +Black-gram pu30), T_3 (Biofertilizer + Blackgram PU35), T_4 (Biofertilizer=Black-gram ITI941), T_5 (Biofertilizer + Black-gram ITI956), T_6 (Biofertilizer + Black-gram JU86), T_7 (Biofertilizer + Black-gram NUL7) and T_8 (Biofertilizer + Black-gram -PU31). The result showed that significant plant height, number of leaves, number of branches plant^{-1}, length of pod, number of seeds per pod, number of pods plant^{-1}. The highest number of pods plant^{-1} was found in T_5 (980 kg ha^{-1}). The lowest number of pods plant^{-1} was recorded at T_1 (736 kg ha^{-1}) and significantly T_5 treatment was found to be superior in all the characters and higher benefit cost ratio. It can be concluded that the cultivation is beneficial.

Khatkar *et al*. (2007) carried out a field experiment during kharif 2005 to study the effect of biofertilizers and sulphur levels on growth and yield of Blackgram. The treatments comprised of seed inoculation with Rhizobium and PSB and different levels of sulphur (0, 20 and 30 kg ha^{-1}). The results revealed that application of sulphur @ 20 kg ha^{-1}+ dual inoculation with Rhizobium and PSB significantly increased the growth characters and yield of blackgram.

Amit and Satish (2015) stated that bio-fertilizers are commonly called microbial inoculants which are capable of stopping important nutritional elements in the soil from non-usable to usable form by the crop plants through their biological processes. For the last one-decade, biofertilizers are used in large quantity as an eco-friendly approach to reduce the use of chemical fertilizers, improve soil fertility status and for improvement of crop production by their biological activity in the rhizosphere. The seeds of *Vigna mungo* were treated with bio-fertilizers for 45 days as compared to untreated. It was observed that the plants treated with experimental bio-fertilizer Rhizobium showed excellent result in the morphological and bio-chemical parameters.

Kannan *et al*. (2015) tested leghaemoglobin for all root nodules and rhizobial isolates of respectives root nodules by cyanmethemoglobin method. Among these nodules leghaemoglobin concentration is high in the root nodules of *A. hypogaea* GN 7, *M. putika* TN3, *V. radiata* GG3 and *V. mungo* BG2 showed that the absorbance value of 0.088, 0.044, 0.024, 0.020. In conclude that those selected leguminous plants nodules leghaemoglobin levels highly varied in quantitatively.

Lal and Khan (2014) reported that in vitro studies showed that inoculation with Rhizobium accelerated the germination velocity during first five days and caused subsequent improvement in root and shoot length and biomass. Rhizobium inoculation drastically enhanced the mobilization efficiency which resulted in vigorous seedlings. In vivo studies on nodulation and plant growth showed nodulation in untreated and inoculated seed-derived plants both; however the later had significantly high values for plant height and biomass, and nodule number and biomass in both the crops (blackgram and greengram).

Mir *et al*. (2013) reported from an experiment that that inoculation of blackgram seeds with PSB recorded slightly higher grain yield (7.49 q ha^{-1}) as compared to no inoculation (7.39 q ha-^{1}).

Patel *et al*. (2013) reported from an experiment that significantly highest seed yield (1350.19 kg ha^{-1}) and stalk yield (2153.29 kg ha$^{-1)}$ with PSB inoculation over uninoculation in blackgram.

Rajesh *et al*. (2013) observed that all the growth and yieldparameters were increased with combined application of biofertilizers in blackgram.

Kumawat *et al*. (2013) observed that seed inoculation with PSB markedly enhanced yield attributes, seed (10.11 q ha$^{-1)}$, haulm (20.88 q ha^{-1}), biological (30.98 q ha^{-1}) yields of blackgram.

Selvakumar *et al*. (2012) reported the maximum germination percentage, fresh and dry weight, number of pods plant^{-1}, seed yield plant^{-1}, hundred seed weight in blackgram with the inoculation of biofertilizers especially Rhizobium with PSB treatment when compared to others. Biofertlization also perform significant improvement in plant productivity and quality of blackgram. Root nodules plant^{-1} were increased with the inoculation of biofertilizers especially Rhizobium with PSB treatment when compared to others. Rhizobium with PSB inoculated plants produced one new protein band with molecular weight of 77.5 kDa.

Hussain *et al*. (2011) reported that the combined inoculation of Rhizobium + PSB slightly improved growth characters (plant height, dry matter production, number an weight of nodules plant^{-1} at maximum flowering) and yield attributes (branches and pod plant^{-1}, seeds per pod, test weight) of blackgram than Rhizobium and PSB inoculated separately. A significant increase was recorded in straw yield with combined inoculation of Rhizobium + PSB over separate inoculations. Combined inoculation of Rhizobium + PSB proved beneficial for boosting seed yield of blackgram under temperate condition of Kashmir.

Kadam *et al*. (2010) reported a significant increase in seed yield of blackgram with the application of vermicompost @ 2.5 t ha^{-1} combined with PSB inoculation.

Sethi and Adhikary (2009) reported that seed inculation with Rhizobium significantly increased the number of nodules, height of plant and number of pods $plant^{-1}$ over control. It was also observed that seed inoculation with Rhizobium significantly increased the pod yield of groundnut by 22% over control.

Kausale *et al*. (2009) observed that nodules number $plant^{-1}$, dry matter $plant^{-1}$, pod and haulm yield of groundnut crop increased significantly with the application of dual inoculation of seed with Rhizobium +PSB.

Kachhave *et al*. (2009) observed the highest number of nodules (30.35) $plant^{-1}$, fresh weight and dry weight of nodules 85.47 and 27.39 mg $plant^{-1}$ was recorded in dual inoculation without chemical fertilizers respectively in blackgram.

Chakrabarti *et al*. (2007) reported that plant inoculated dually with VAM and Rhizobium recorded to have the maximum mycorrhizal colonization, number of nodules, root and shoot height, fresh and dry weight of blackgram as compared to the plants being inoculated with either of the two organisms.

Khatkar *et al*. (2007) revealed that application of sulphur @ 20 kg ha^{-1} + dual inoculation with Rhizobium and PSB significantly increased the growth charecters of blackgram.

Basu *et al*. (2006) found that inoculation with Rhizobium and Phosphobacterium to groundnut seed gave about 47.90 per cent and 28.76 percent higher potassium uptake as compared to no inoculation.

Qureshi *et al*. (2005) found that the combined application of FYM and phosphate solubilizer inoculums in soybean seed significantly increased organic carbon and available phosphorus content of soil over control.

Dude and Raut (2005) observed that the combined inoculation of Rhizobium and VAM resulted in higher nodulation, root length, dry matter, pod yields and nitrogen content of groundnut crop over control.

Jain and Trivedi (2005) studied the effect of Bradyrhizobium and Phosphate Solublizing Bacteria (PSB) alone or in combination with different levels of phosphorus on soybean and noticed that the application of 19.65 kg P ha^{-1} with Rhizobium and PSB registered higher seed yield, oil content and protein content of the crop over control.

Vijayakumar and Lakshminarasimhan (2004) reported that seed inoculation of groundnut with Glomus fasciculatum (VAM) and Rhizobium gave significantly higher root and shoot dry weight, number of nodules $plant^{-1}$, nodules dry weight $plant^{-1}$ and pod yield ha^{-1} over control. They also reported increased yield and N, P and K content with inoculation of Rhizobium and VAM in groundnut seed over control.

Singh and Rai (2004) found that combined application of RDF (NPK + FYM + Biofertilizers) significantly increased protein and oil content of soybean seed over control.

Panwar and Singh (2003) conducted an experiment at ICAR research complex on groundnut and found that seed inoculation with Rhizobium or PSB marginally improved yield but their combined application increased pod yield significantly over control.

Baktash *et al*. (2003) conducted a field experiment to study the effect of six inoculum strains (756, 1000, 1371, 1402, 7001, and 7029) of Rhizobium japonicum [Bradyrhizobium japonicum] on the oil, protein and carbohydrate content of groundnut seeds and significant differences were observed in oil, protein and carbohydrate content.

Marimuthu *et al*. (2002) conducted an experiment on groundnut and they found that seed inoculation with Rhizobium significantly increased number of nodules plant^{-1} over control.

Patil (2002) conducted a field experiment on clayey soil during Kharif season on pigeonpea. He reported that pigeonpea seeds inoculated with bio-fertilizers (*Rhizobium* and *P. striata*) significantly increased growth parameters *viz*., Plant height, number of branches at 30, 60 and 90 DAS and also yield attributes like number of pods plant^{-1}, grains per pod, grain yield plant^{-1} and test weight of pigeonpea. Significantly the highest grain (1279 kg ha^{-1}) and stover (2697 kg ha^{-1}) yields were also reported by seed inoculation with bio-fertilizers.

More *et al*. (2002) recorded that seed inoculation with phosphate solubilizing bacteria significantly increased number of pods plant^{-1}, test weight and dry pod yield of groundnut over no inoculation.

Umamaheswari *et al*. (2001) found that application of NPK with Rhizobium or PSB inoculation in groundnut seed significantly increased pod yield over control.

Chinnamuthu and Venkatakrishnan (2001) observed significant improvement in seed yield (977 kg ha^{-1}) of sunflower as compared to control (848 kg seed ha^{-1}) with inoculation of VAM @ 1 t ha^{-1} soil application.

Tarafdar and Rao (2001) carried out a field experiment and noted significant increase in seed yield of clusterbean with inoculation of VAM (Glomus mosseas) to soil.

Dubey (2001) found that seed treatment with phosphate solubilizing bacteria significantly increased the P uptake over no inoculation in soybean.

Mahala (1999) reported that Rhizobium inoculation with soybean significantly increased seed and stover yields of crop over control.

Namdeo and Gupta (1999) conducted a field experiment at Sehor (M.P.) to study the efficacy of biofertilizer on pigeonpea. They reported that seed inoculation with phosphobacteria produced 9.9 per cent higher grain yield as compared to 100 percent recommended fertilizer rate alone.

Mehta *et al*. (1995) reported that seed inoculation of groundnut with PSB significantly increased the plant spread and number of branches plant^{-1} over control.

2.4 Effect of Biofertilizer with chemical fertilizers

Ye *et al*. (2020) carried out a field trial and continuous pot experiments to investigate the possibility of a plant beneficial Trichoderma strain and its bio-organic fertilizer product in saving chemical fertilizer application and in improving crop quality of tomato. Four treatments were set up: a reduced application of chemical fertilizer (75% of the conventional application) plus *Trichoderma*-enriched bio-organic fertilizer (BF), organic fertilizer (OF) or *Trichoderma* spore suspension (SS), with using the 100% rate of the conventional chemical fertilizer as the control (CF). The results showed that the total soluble sugar, Vitamin C and nitrate accumulations were, respectively, +up to 24%, +up to 57% and –up to 62% in the tomatoes of the BF treatment compared to those of the control (CF). And both of the pot and field trials revealed that reduced rates of chemical fertilizer plus bio-organic fertilizer produced tomato yields equivalent to those obtained using the 100% of the chemical fertilizer. However, application with the inoculant alone (SS) or combined with the organic fertilizer alone (OF) would lead to a yield decreases of 6–38% and 9–35% over the control. The results suggest that the Trichoderma bio-organic fertilizer could be employed in combination with the appropriate rates of chemical fertilizers to get maximum benefits regarding yield, quality and fertilizer savings.

Shekhawat *et al*. (2018) conducted a field experiment on sandy clay loam soil which is slightly alkaline in nature to asses the effect of phosphorus, vermicopost & biofertilizer on soil health and nutrient content & uptake of blackgram. The experiment was laid out in randomized block design with four replications. The experiment comprised of nine treatment combinations. The results of study revealed that application of 40 kg P_2O_5 ha^{-1} + 2.5 t vermicompost ha^{-1} + Rhizobium + PSB showed significantly higher nutrient content & uptake of blackgram and good soil health.

Mondal *et al*. (2017) carried out an experiment to study the impact of reduced dose of chemical fertilizer and its combination with biofertilizer and vermicompost on morpho-physiological and biochemical traits of mustard (*Brassica campestris* cv. B9). Mustard was cultivated using a full recommended dose of chemical fertilizer (N:P:K–100:50:50) and along with six different reduced doses of chemical fertilizer combined with biofertilizers and vermicompost. The performance of the crop was adjudged in terms of various parameters viz. leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR), crop growth rate (CGR), net assimilation rate (NAR), photosynthetic rate (PR), harvest index (HI) and biochemical attributes such as total chlorophyll, sugar and proline content of physiologically active leaves of mustard. Differential significant ($p< 0.05$) treatment response was reflected for the studied traits during crop maturity. It was concluded that 25% reduced dose of chemical fertilizer and its combination with vermicompost (T4) was optimum for most of the parameters studied as compared to the control at both crop stages.

Maya-Yadav *et al*. (2017) conducted a field experiment on loamy sand soil to study the effect of phosphorus levels and bio-fertilizers on productivity, nutrient content and uptake of urban. Experiment consisted of four treatments of phosphorus levels (0, 20, 40 and 60 kg ha^{-1}) and four treatments of bio-fertilizers (control, PSB, VAM and PSB + VAM) thereby making sixteen treatment combinations tested in randomized block design with three replications. Result indicated that application of phosphorus up to 40 kg ha^{-1} significantly increased grain and straw yield, net returns, protein content in grain, nitrogen, phosphorus and potassium concentration in grain and straw and total uptake of nitrogen, phosphorus and potassium over preceding levels and remained at par with 60 kg ha^{-1}. Whereas, raising the level of phosphorus from 0 to 20 kg ha^{-1} registered the highest agronomic efficiency, apparent recovery and physiological efficiency of phosphorus after that, it showed significant decline up to 60 kg ha^{-1}. Combined inoculation of seed and soil with PSB + VAM significantly increased the grain and straw yield, net returns, nitrogen, phosphorus and potassium concentration in grain and straw, their total uptake as well as protein content in grain and available phosphorus in soil after crop harvest over PSB, VAM and control, whereas, the highest agronomic efficiency and apparent recovery of P recorded under PSB + VAM inoculation and physiological efficiency under control.

Rajasekaran *et al*. (2017) studied the comparative effects on FYM, Inorganic fertilizers and Biofertilizers on growth of blackgram (*Vigna mungo* L.). The thirteen treatments were studied under this experiments. The highest growth was recorded in combined application of biofertilizers alone. The inorganic fertilizers and organic manures are gradually increased in growth, and biochemical contents. Hence the use of biofertilizers should be encouraged. They found that biofertilizers constitute the best renewable source of nutrient supply to plants and as supplement to chemical fertilizers and organic manures. Biofertilizers help to provide and keep the soil with all the minerals and microorganisms required for plant growth. Their application is easy, cost effective and does not cause any pollution problem.

Amruta *et al*. (2016) conducted a field experiment to assess the response of nutrient levels and spacing on seed quality attributes of blackgram cv. LBG-625 (Rashmi). Experimental results revealed that fertilizer application of

50:100:100 + Blackgram rhizobia (250 g ha^{-1}) + PSB- Bacillus megaterium (250 g ha^{-1}) recorded highest test weight (39.27 g), germination (90.60%), root length (15.77 cm), shoot length (13.43cm), mean seedling length (29.20 cm), mean seedling dry weight (57.99 mg), seedling vigour index-I (2656), seedling vigour index-II (525), total dehydrogenase activity (0.998), protein content (23.16%), field emergence (86.56 %) lowest electrical conductivity (0.813 dSm^{-1}) were superior over other fertilizer treatments.

Trujillo-Tapia and Ramírez-Fuentes (2016) carried out a study with Corn V-524 that was seeded in plant pots in sandy-loam soil, pH 6.2, N total 0.102 % and organic matter 6% to prove that the application of bio-fertilizers can reduce the use of chemical nitrogen fertilizers without affecting the nitrogen requirements of the plants. The concentration of nitrates and ammonium in the soil was higher in the control and the bio-fertilizer than in the application of chemical fertilizer. The biofertilizer contributed the nitrogen required by the plant, reducing the use of chemical fertilizer by up to 50%. The continuous use of chemical fertilizer in agricultural fields causes the degradation of the soil and provokes environmental pollution; furthermore, it is damaging to human health. The use of bio-fertilizers made of cyanobacteria is a promising alternative for the agricultural production.

Nagar *et al*. (2016) reported that the favorable effects of phosphorus with vermicompost and biofertilizers, on soil properties may also be due to increased microbial activities which in turn release organic acids to bring down to soil pH to a range where the activities of plant nutrients are maximum. The increase in microbial activity due to the addition of organic manure and biofertilizer, which enhance activity of enzymes that play a key role in transformation, recycling and availability of plant nutrients in soil. Thus, improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances. Similar results were reported by Mohammad *et al*. (2017).

Amruta *et al*. (2015) conducted a field experiment to assess the response of nutrient levels and spacing on growth and yield attributes of Blackgram cv. LBG-625 (Rashmi). Experimental results revealed that fertilizer application of 50:100:100 NPK kg ha^{-1}+Blackgram rhizobia (250 g ha^{-1}) + PSB- *Bacillus megaterium* (250 g ha^{-1}) with the spacing of 60 x 10 cm recorded significantly higher number of branches $plant^{-1}$ (5.60), number of leaves $plant^{-1}$ (29.87), plant spread $plant^{-1}$ (756.00), number of cluster plant-1 (14.07), number of pods $cluster^{-1}$ (22.60), number of pods $plant^{-1}$ (54.40), pod weight $plant^{-1}$ (g) (22.60), seed recovery percent (98.45) and processed seed yield (q ha^{-1}) (15.83) as compared to rest of the treatments.

Mir *et al*. (2013) conducted a field experiment to study the effect of levels of phosphorus, sulphur and Phosphorus Solubilizing Bacteria (PSB) on growth, yield and nutrient content of blackgram for consecutive two years 2004 and 2005. The crop growth parameters *viz*., plant height, number of nodules and number of leaves $plant^{-1}$, yield and nutrient content increased significantly with the application of high levels of phosphorus, sulphur with or without bio-fertilizer inoculation. Application of 60 kg P_2O_5 ha^{-1} recorded maximum plant height (49.9 cm), number of leaves $plant^{-1}$ (50.8), number of nodules $plant^{-1}$ (27.8), haulm yield (28.9 q ha^{-1}), grain yield (8 q ha^{-1}) and phosphorus, sulphur and protein content of grain (0.356 %, 0.253% and 22.64%, respectively) as compared to lower levels. Inoculation of blackgram seeds with phosphorus solubilizing bacteria recorded slightly higher grain yield (7.49 q ha^{-1}) as compared to no inoculation (7.39 q ha^{-1}).

Kausale *et al*. (2009) observed that nodules number, dry matter accumulation, pod and haulm yield of groundnut crop increased with application of 100% RDF (25 : 50) N and P_2O_5 kg ha^{-1}, Rhizobium or PSB seed inoculation. On loamy sand soil at Jobner, application of 30 kg P_2O_5 ha^{-1} significantly increased the plant height and number of branches $plant^{-1}$ in cowpea as compared to lower levels (Keshwa *et al*., 2009).

Javaid (2009) reported that nodule number was significantly enhanced by inoculation of either of the two *B. japonicum* strains in NPK and un-amended soils. A marked increase in nodule biomass was also recorded due to *B. japonicum* inoculation in these 2 types of soils.

Kumar and Elamathi (2007) reported that the maximum number of root nodules of blackgram were obtained under application of N @ 20 kg ha^{-1} + seed inoculation with Rhizobium.

Rajput and Kushwah (2005) conducted an experiment with the application of bio-fertilizer on production of pea. On the basis of three years pooled data, the highest yield was recorded with the application or recommended doses of fertilizer followed by soil application of bio-fertilizer mixed 25 kg FYM along with 50% recommended dose of fertilizer and were at par statistically. So the use of biofertilizer saved 50% N, P (10 kg N, 25 kg P_2O_5). It also saved the financial resource as well as FYM.

Hossain and Suman (2005) conducted an experiment to evaluate the effect of *Azotobacter*, *Rhizobium* and different levels of urea N on growth, yield and N-uptake of lentil. Among the treatments *Azotobacter* plus *Rhizobium* inoculation had significant effect on nodule formation, plant height, number of seeds, seed and stover yields, compared to uninoculated controls. The highest seed yield was recorded for the treatment *Azotobacter* + *Rhizobium* that was statistically similar to that of 100% N and *Rhizobium* with the corresponding yields of 1533 and 1458 kg ha^{-1}, respectively. The dual inoculation of *Azotobacter* and *Rhizobium* significantly influenced all the crop characters including N contents, N uptake by seed and shoot as well as protein content of seed. The highest N-uptake by seed (78.61 kg ha^{-1}) was recorded for the treatment *Azotobacter* + *Rhizobium* and N-uptake by shoot (53.87 kg ha^{-1}) was recorded for the treatment 100% N. The performances of *Azotobacter* or *Rhizobium* alone were not as good as *Azotobacter* + *Rhizobium* in most cases. Therefore, inoculation of both *Azotobacter* and *Rhizobium* together may be a good practice to achieve higher seed yield of lentil.

2.5 Effect of N + P fertilizers

Jha *et al*. (2015) revealed that application of 100% RDF + Zn + Fe (N:P:K 20:30:15 kg ha^{-1} + $ZnSO_4$ 5 kg ha^{-1} + $FeSO_4$ 5 kg ha^{-1}) recorded significantly highest plant height (34.18 cm), dry matter (10.31 g $plant^{-1}$), leaf area index (2.216), number of pods (32.38 $plant^{-1}$), number of seeds (6.88 pod^{-1}), seed yield (870 kg ha^{-1}), straw yield (1843 kg ha^{-1}), biological yield (2713 kg ha^{-1}), harvest index (32.10%) in blackgram over the rest of the treatments, but it was at par with 100% RDF, 50% RDF + 50% RDN through FYM and FYM 4t ha^{-1}.

Choudhary and Yadav (2011) carried out a field study on loam sand at Jobner (Rajasthan) and reported that application of 20 kg N + 40 kg P_2O_5 ha^{-1} to cowpea produced significantly higher dry matter per metre row length, number of branches $plant^{-1}$, plant height, total chlorophyll content and number and weight of root nodules $plant^{-1}$ over lower doses of nitrogen and phosphorus. They also reported that yield attributes (number of pods/plant and seeds per pod) and yield (seed, straw and biological) of cowpea increased significantly with increasing levels of fertility upto 100% RDF (20 kg N + 40 kg P_2O_5 ha^{-1}).

Rathore *et al*. (2010) observed that application of 100% RDF (N @ 20 kg ha^{-1} + P_2O_5 @ 60 kg ha^{-1} + K_2O @ 20 kg ha^{-1} + S @ 20 kg ha^{-1}) produced significantly higher yield attributing traits (number of clusters and pods $plant^{-1}$) and seed and straw yield over 50% RDF.

Jadhav *et al*. (2009) conducted a field experiment on soybean at Rahuri, Maharashtra and reported that the application of 50 kg N + 75 kg P_2O_5 ha^{-1} and 75 kg N + 75 kg P_2O_5 ha^{-1} recorded significantly higher seed yield over the application of 25 kg N + 37.5 kg P_2O_5 ha^{-1} and over control.

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.

Geetha and Velayutham (2009) revealed that basal application of N and P fertilizers @ 12.5: 25 kg ha^{-1} (10 days prior to harvest of rice crop) to blackgram favoured plant height, leaf area index, dry matter production, net assimilation rate, crop growth rate, relative growth rate.

Shivakumar and Ahlawat (2008) conducted a field experiment at IARI, New Delhi on soybean- wheat cropping system and reported that application of 100% RDF (30:33:33.2 kg NPK ha^{-1}) significantly increased plant height, number of branches $plant^{-1}$ and dry matter accumulation than 50% RDF and control.

Abraham *et al*. (2008) conducted a field experiment at Allahabad (U.P.) on groundnut and reported that application of 75% (15 kg N: 60 kg P_2O_5 : 15 kg K_2O ha^{-1}) RDF recorded significantly higher nut yield over 25% and 50% RDF but it was at par with 100% RDF.

Sheoran *et al*. (2008) found that application of 12.5 kg N + 40 kg P2O5 ha^{-1} increased seed yield by 4.3% as compared to 12.5 kg N + 20 kg P2O5 ha^{-1}, which in turn recorded significant yield increase to the tune of 15.47% over no fertilizer application.

Mathur *et al*. (2007) reported that increase fertility level from 10 + 20 to 20 + 40 kg N + P_2O_5 ha^{-1} significantly enhanced pods $plant^{-1}$ (15.5%). As a consequence of higher value of yield parameters, grain yield (9.6%) and straw yield (24.4%) of mungbean also increased significantly.

Thorave and Dhonde (2007) reported that application of 25:50 NP kg ha^{-1} gave the highest plant height and total dry matter accumulation $plant^{-1}$ at harvest in summer groundnut.

Tickoo *et al*. (2006) carried out an experiment with mungbean cultivars Pusa 105 and Pusa Vishal sown at 22.5 and 30.0 cm spacing and supplied with 36-46 and 58-46 kg of N-P ha^{-1} in a field experiment conducted in New Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t ha^{-1}, respectively) compared to cv. Pusa 105. Nitrogen and phosphorus rates had no significant effects on both the biological and grain yield of the crop.

Lal (2004) conducted an experiment in Uttar Pradesh, India during 2002-03 to observe the effects of N (at 0, 20, 40 and 60 kg ha^{-1}) and P (at 0, 30, 60 and 90 kg ha^{-1}) on the seed yield of pea cv. Arkel and French bean [phaseolus vulgaris]. N at 40 kg ha^{-1} was optimum for the maximum pea and bean seed yields. Seed yield of both crops increased with increasing P rates up to 60 kg ha^{-1}.

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}.

Shinde *et al*. (2000) conducted an experiment at Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during summer 1998 on clay soil. The results revealed that application of 25 kg N + 25 kg P_2O_5 ha^{-1} produced the maximum pod and haulm yield of groundnut.

Patel *et al*. (1998) conducted an experiment at Indore, Madhya Pradesh with peas cv Arkel with 20 kg N + 34.4 kg P + 33.3 kg K ha^{-1}, 33.3 kg K ha^{-1}, Rhizobium inoculant, 3 kg phosphate solubilizing microorganisms (PSM) ha^{-1}, Rhizobium + PSM. Application of 50% NP significantly compared with recommended level of nutrients (20 kg N + 34.4 kg P + 33.3 kg K ha^{-1}) applied through chemical fertilizers.

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}.

Verma *et al*. (1997) conducted a field experiment at Nauri, Soaln, on a sandy soil to evaluate the effect of N (0, 15, 30 or 45 kg N ha^{-1} and P (0, 13, 26 or 39 kg P ha^{-1}) levels on the yield and macronutrient concertrations of peas. They concluded that 15 kg N and 26 kg P ha^{-1} were the optimum doses for maximum yield and high nutrient concentrations in peas.

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}.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from March to June 2019. Detailed of the experimental materials and methods followed in the study are presented in this chapter. The experiment was conducted to study the e effect of bio-fertilizer on yield and seed quality of blackgram with combination of nitrogen and phosphorus.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Research Farm, Dhaka-1207, Bangladesh. It is located at 90°22′ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28 (Appendix I).

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September). Details of weather data in respect of temperature (^{0}C), rainfall (mm) and relative humidity (%) for the study period was collected from Bangladesh Meteorological Department, Agargoan, Dhaka-1207 (Appendix II).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was well drained loamy in texture with pH 6.5.

3.4 Details of the experiment

3.4.1 Treatments

The experiment consisted of 2 factors:

Factor A: Bio-Fertilizer - 2 levels

1. B_0 = Control (without Bio-fertilizer)
2. B_1 = Bio-fertilizer

Factor B: N+P combination - 6

1. F_0 = Control (without fertilizer)
2. F_1 = 40% lower than recommended doses of N+P
3. F_2 = 20% lower than recommended doses of N+P
4. F_3 = Recommended dose of N+P
5. F_4 = 20% higher than recommended doses of N+P
6. F_5 = 40% higher than recommended doses of N+P

The nitrogenous (N) and phosphate (P) fertilizers were applied in the form of urea and triple super phosphate (TSP). The recommended doses of biofertilizer, urea and TSP, and other fertilizers have been presented in section 3.4.2.

Treatment combinations

B_0F_0, B_0F_1, B_0F_2, B_0F_3, B_0F_4, B_0F_5, B_1F_0, B_1F_1, B_1F_2, B_1F_3, B_1F_4, B_1F_5.

3.4.2 Recommended doses of fertilizer for blackgram

The recommended doses of fertilizer was as follows-

Name of fertilizer	Doses
Urea	45 kg ha^{-1}
TSP	90 kg ha^{-1}
MoP	40 kg ha^{-1}
Gypsum	50 kg ha^{-1}

3.5 Design and layout of the experiment

The experiment was laid out in split-plot design with three replications. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 2.7 × 2.0 m^2. The distances between plot to plot and replication to replication were 0.25 m and 0.75 m, respectively. The layout of the experiment is shown in (Appendix IV).

3.6 Crop/planting material

BARI Mash-3 (Hemanta) was used as planting material.

3.6.1 Description of Bio-fertilizer

Rhizobium was used as biofertilizer on the seeds prior to sowing. Seeds were treated with Rhizobium and kept overnight for best result. 5g of Rhizobium was mixed with 500gm of blackgram seed and sown in the field.

3.6.2 Description of crop

BARI Mash-3

BARI Mash-3 (Hemanta) was developed by BARI in 1996. Seed color is blakish.. It has a height of 35-38 cm. Leaves are trifoliate, alternate and green. Seeds are drum-shaped and blackish, seed larger than local variety. It has a 1000-seed weight of 40-45 g. It has cooking time 30-37 min, crop duration 65-70 days.

3.7 Sowing of seeds and crop management

3.7.1 Seed collection

Seeds of BARI Mash-3 (Hemanta) were collected from Pulse division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.7.2 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis. The physical and chemical characteristics of the soil have been presented in (Appendix III).

3.7.3 Preparation of experimental land

A pre- sowing irrigation was given on 22 March, 2019. After that the land was open with the help of a tractor drawn disc harrow, then ploughed with rotary plough twice followed by laddering to achieve a good tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on 24 March, 2019 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

3.7.4 Sowing of seed

Seeds were sown in the field on 25 March, 2019. The field was labeled properly and was divided into 36 plots. The seeds of BARI Mash-3 (Hemanta) were sown by hand in 30 cm apart from lines with continuous spacing at about 3 cm depth at the rate of 40 g plot^{-1}.

3.8 Intercultural operations

3.8.1 Thinning

The plots were thinned out on 15 days after sowing to maintain a uniform plant stand which facilitates proper aeration and light for optimum growth and development of the crops.

3.8.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done, first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.8.3 Irrigation

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other two irrigation were given 3 days before weeding.

3.8.4 Drainage

Drainage channel were properly prepared to easy and quick drained out of excess water.

3.8.5 Plant protection measures

The crop was infested by insects and diseases, those were effectively and timely controlled by applying recommended insecticides and fungicides. Malathion 18 ml/L and Ripcord 20ml/L uses as protection measure.

3.9 Harvesting and post-harvest operation

Maturity of crop was determined when 80-90% of the pods become straw color. The harvesting of BARI Mash-3 (Hemanta) were done up to 5 June, 2019. Five pre-selected plants per plot were harvested from which different yield attributing data were collected and 1 m^2 area from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain yields $plot^{-1}$ was determined and converted to kg ha^{-1}.

3.10 Recording of data

Ten plants from each plot were marked from the inner rows and all the growth data were collected from those plants. At maturity stage, five sample plants were collected randomly from each plot avoiding border rows and central 1 m^2 area. The yield attributes data were collected from these five plants.

3.10.1 Crop growth characters

1. Plant height
2. Number of primary branches plant^{-1}
3. Dry weight plant^{-1}

3.10.2 Yield contributing characters

1. Number of pods plant^{-1}
2. Pod length
3. Number of seeds pod^{-1}
4. 1000-seed weight

3.10.2 Yield parameters

1. Seed yield
2. Stover yield
3. Biological yield
4. Harvest index

3.10.3 Seed quality parameters

After obtaining grain yield from the field, quality of seeds were tested in Laboratory on 20 June, 2019 and data on following parameters were collected:

1. Percent germination
2. Shoot length
3. Root length
4. Dry weight plant^{-1}
5. Electrical conductivity

3.11 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study given below:

3.11.1 Crop growth characters

Plant height

The height of 5 randomly selected plants from each plot were marked and plant height data was taken from that plants at 15, 30, 45 DAS and at harvest. Plant height was measured from the above ground portion of the plants and expressed in centimeter (cm).

Number of primary branches plant^{-1}

Number of primary branches plant^{-1} was counted carefully from 5 randomly pre-selected plants from each plot and averaged them to get branches plant^{-1}. It was done at 30, 45 DAS and at harvest.

Dry weight plant^{-1}

Randomly selected 5 plants from each plot excluding the harvest area were uprooted and dried in an oven at 70°C for 72 hours and weighed. The average value was recorded in g plant^{-1}.

3.11.2 Yield contributing parameters

Number of pods plant^{-1}

The pods of five randomly collected plants in each plot were counted and then averaged them to get number of pods plant^{-1}.

Pod length

Pod length was measured from randomly selected 20 pods from 10 plants with a meter scale. From base of the pod to tip was considered to measure pod length. Average length was counted as pod length and expressed in cm.

Number of seeds pod^{-1}

The number of seeds pods^{-1} was recorded randomly from selected pods at the time of harvest. Data were recorded as the average of 20 pods from each plot.

Thousand seed weight

Thousand seeds from each plot were collected and their weight was taken by digital electric balance in gram (g).

3.11.3 Yield parameters

Grain yield

Total grains of central 1 m^2 area in each plot was weighed and then converted into ton ha^{-1}. The grain weight was taken at 12% moisture content.

Stover yield

To record stover yield ha^{-1}, 1 m^2 plants from center of the plot were harvest and after separation of seeds, stover was weighed in kg after proper sun drying. The weight was converted per ha basis and was expressed in ton as stover yield t ha^{-1}.

Biological yield

Biological yield was calculated by the following formula:

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

Harvest index (%)

Harvest index (HI) was calculated by the following formula:

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

3.11.4 Seed quality test

Percent germination

The number of sprouted and germinated seeds was counted daily. Germination was recorded at 24 hrs interval and continued up to 10 days. More than 2 mm long plumule and radicle was considered as germinated seed.

The germination was calculated using the following formula:

Germination (%) = $\frac{Total\ number\ of\ germinated\ seeds}{Total\ seed\ placed\ for\ germination} \times 100$

Shoot length

The shoot length of 10 seedlings from each seedling was measured finally at 10 DAS. Measurement was done using the unit centimeter (cm) by a meter scale.

Root length

The Root length of ten seedlings from each seedling was recorded finally at 10 DAS. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

Dry weight seedling^{-1}

Randomly selected 10 seedlings from each plot was uprooted and dried in an oven at 70°C for 72 hours and weighed. The average value was recorded in g plant^{-1}.

Electrical conductivity

Simply; three replicates of 50 seeds are weighed and then placed in a measured amount of deionized water. The seeds are soaked for 24 hours at 20 degrees celsius temperature. The leachate of the water is measured by an electrical conductivity meter.

3.12 Statistical analysis

The data obtained for different parameters were analyzed statistically. The mean values of all the characters were calculated and the analysis of variance (ANOVA) was performed by the 'F' (variance ratio) test using MSTAT-C software. The significance of the difference among the treatment means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

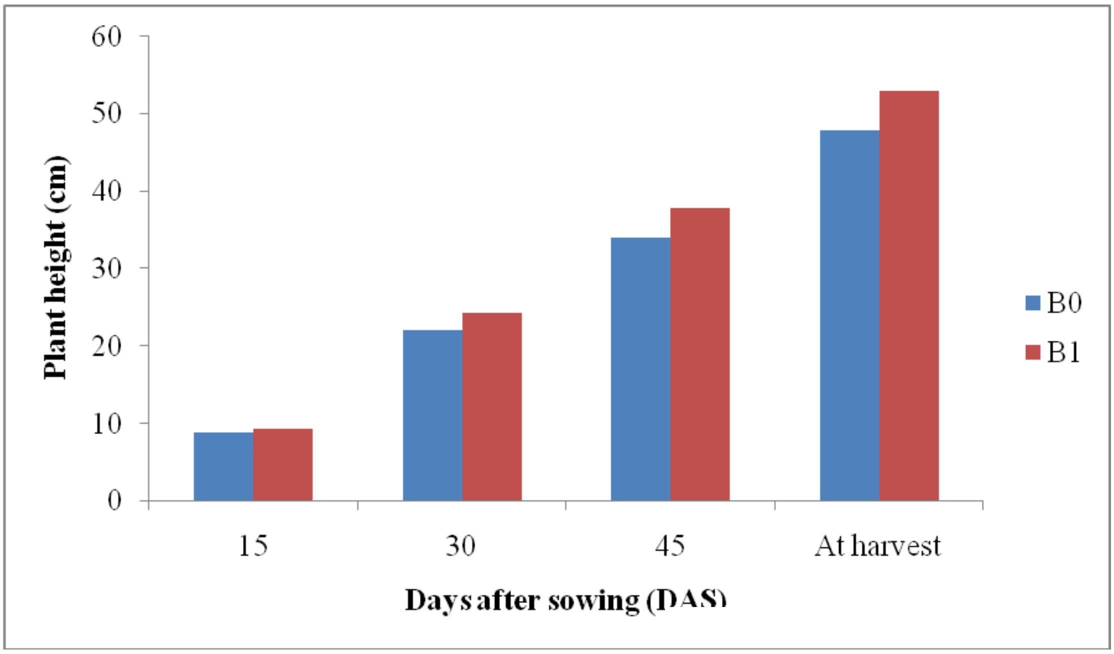
The study was carried out to find the effect of bio-fertilizer on yield and seed quality of blackgram with combination of nitrogen and phosphorus. The effect of different nitrogen, phosphorus and bio-fertilizer and their interaction on growth yield contributing characters and yield and also seed quality have been presented and discussed in this chapter under the following heads through different Tables and graphs:

4.1 Growth parameters

4.1.1 Plant height

Effect of bio-fertilizer

Significant variation on plant height of blackgram was found at different growth stages except at 15 DAS as influenced by different bio-fertilizer treatment (Fig. 1 and Appendix V). The figure revealed that irrespective of bio-fertilizer application, plant height increased gradually with the advances of plant growth stages. Results also revealed that the maximum plant height (9.27, 24.21, 37.77 and 53.04 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment B_1 (with bio-fertilizer) whereas the minimum plant height (8.78, 22.02, 33.98 and 47.3 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the control treatment B_0 (without bio-fertilizer). Similar result was also observed by the findings of Choudhary *et al*. (2017) and Lal and Khan (2014).

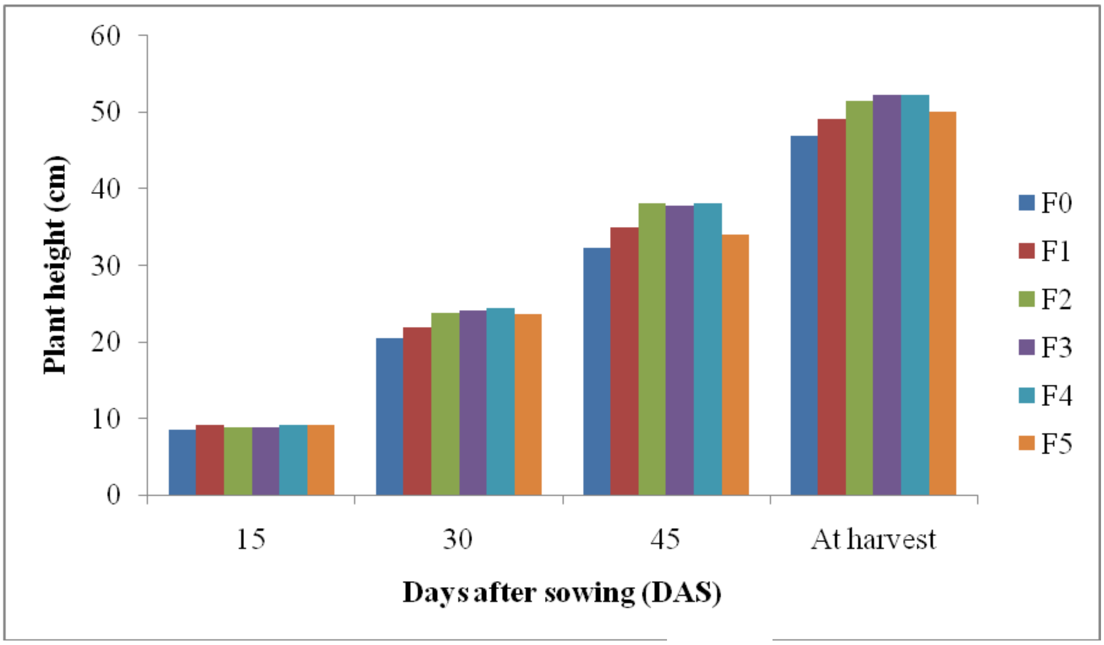


B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

Fig. 1. Effect of bio-fertilizer on plant height at different growth stages of blackgram (LSD$_{(0.05)}$ = NS, 0.422, 0.611 and 0.753 at 15, 30, 45 DAS and at harvest, respectively).

Effect of N+P

Plant height of blackgram at different growth stages was significantly influenced by different N+P treatments except at 15 DAS (Fig. 2 and Appendix V). It can be inferred from the result that plant height showed an increasing trend with the increases of growth stages of plant and the growth continued up to at harvest irrespective of N+P fertilizer level. However, the tallest plant (9.21, 24.55, 38.19 and 52.38 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment F_4 (20% Higher than recommended doses of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) and F_3 (Recommended dose of N+P) at 45 DAS and at harvest. Likewise, the shortest plant (8.65, 20.53, 32.42 and 47.03 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the control treatment F_0 (without fertilizer). Similar result was also observed by the findings of Jha *et al*. (2015) and Choudhary and Yadav (2011).



F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

Fig. 2. Effect on N+P on plant height at different growth stages of blackgram ($LSD_{(0.05)}$ = NS, 0.781, 0.794 and 0.856 at 15, 30, 45 DAS and at harvest, respectively).

Combined effect of bio-fertilizer and N+P

Significant variation was observed on plant height of blackgram at different growth stages except 15 DAS as influenced by combined effect of bio-fertilizer and N+P (Table 1 and Appendix V). It was observed that the tallest plant (9.73, 25.17, 40.87 and 55.63 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_1F_4 which was statistically similar with the treatment combination of B_1F_2 and B_1F_3 at 30, 45 DAS and at harvest. The shortest plant (8.53, 19.13, 31.30 and 44.97 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of B_0F_1 at harvest.

Table 1. Plant height of blackgram as influenced by biofertilizer and different combinations of nitrogen and phosphorus

Treatments	Plant height (cm)			
	15 DAS	30 DAS	45 DAS	At harvest
B_0F_0	8.53	19.13 g	31.30 e	44.97 g
B_0F_1	8.65	20.30 f	33.53 cd	46.70 fg
B_0F_2	8.73	22.83 cd	35.33 bc	48.62 ef
B_0F_3	8.79	23.18 cd	35.60 b	49.60 de
B_0F_4	8.92	23.93 b	35.87 b	49.13 e
B_0F_5	9.03	22.72 d	32.23 de	47.93 ef
B_1F_0	8.77	21.93 e	33.53 cd	49.10 e
B_1F_1	9.73	23.57 bc	36.43 b	51.60 cd
B_1F_2	9.17	24.87 a	40.87 a	54.50 ab
B_1F_3	9.07	25.05 a	40.27 a	55.13 a
B_1F_4	9.50	25.17 a	40.50 a	55.63 a
B_1F_5	9.37	24.68 a	36.00 b	52.30 bc
$LSD_{(0.(05)}$	NS	0.748	1.829	2.264
CV (%)	6.79	6.49	6.26	7.10

B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

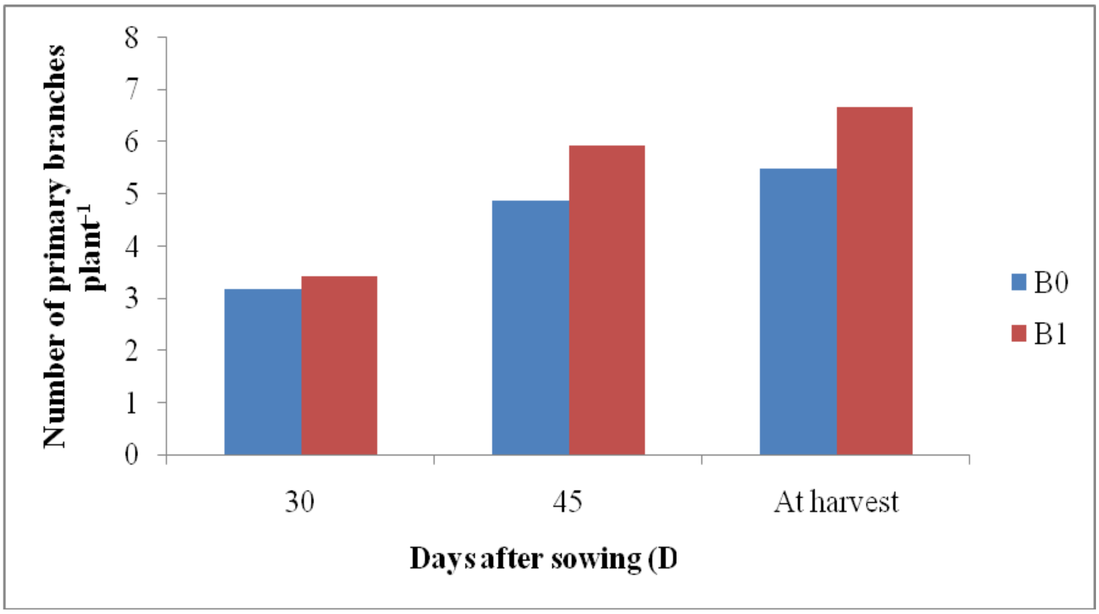
4.1.2 Number of primary branches plant^{-1}

Effect of bio-fertilizer

Number of primary branches plant^{-1} was not significantly influenced at 30 DAS but at 45 DAS and at harvest significant effect was observed (Fig. 3 and Appendix VI). It was found that the maximum number of primary branches plant^{-1} (3.42, 5.93 and 6.68 at 30, 45 DAS and at harvest, respectively) was obtained from the treatment B_1 (with bio-fertilizer) whereas the minimum number of primary branches plant^{-1} (3.18, 4.88 and 5.50 at 30, 45 DAS and at harvest, respectively) was obtained from the control treatment B_0 (without bio-fertilizer). Hussain *et al*. (2011) and Choudhary *et al*. (2017) also found similar result which supported the present study.

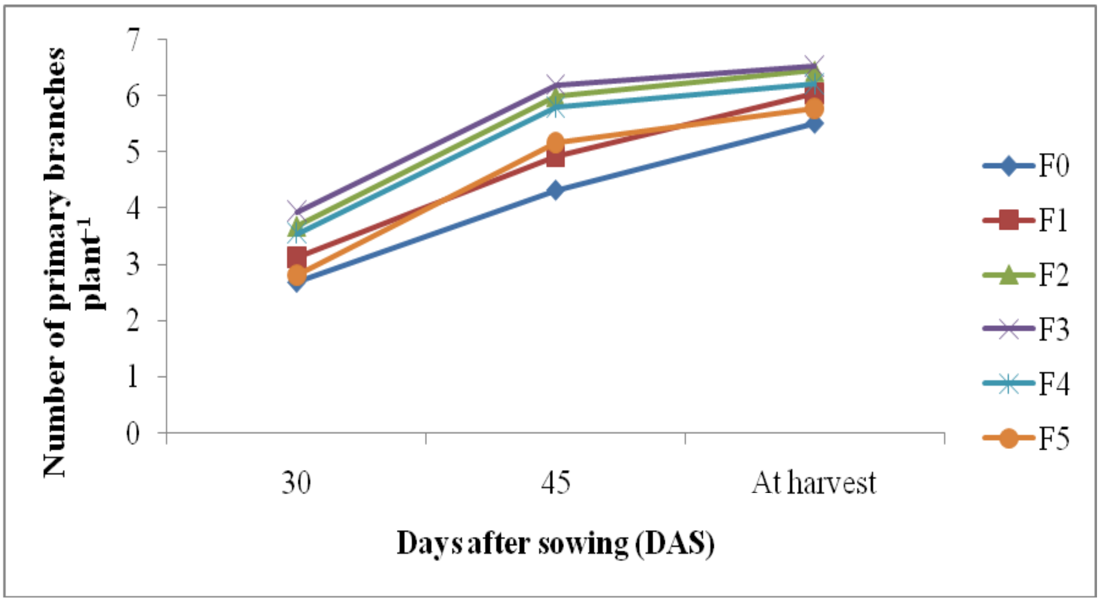
Effect of N+P

Remarkable variation was found on number of branches plant^{-1} due to different levels N+P treatments in blackgram (Fig. 4 and Appendix VI). Results revealed that number of branches plant^{-1} increased progressively with the progress of growth stages, irrespective of different level of N+P fertilizations. The rate of increase was same throughout the growth period up to harvest. It was observed that the highest number of primary branches plant^{-1} (3.94, 6.20 and 6.53 at 30, 45 DAS and at harvest, respectively) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) and F_4 (20% Higher than recommended doses of N+P) at all growth stages. The lowest number of primary branches plant^{-1} (2.68, 4.32 and 5.51 at 30, 45 DAS and at harvest, respectively) was obtained from the control treatment F_0 (without fertilizer) which was statistically similar with F_1 (40% lower than recommended doses of N+P) at 45 DAS. Choudhary and Yadav (2011) and Shivakumar and Ahlawat (2008) also found similar result with the present study.



B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

Fig. 3. Effect of bio-fertilizer on number of branches plant^{-1} at different growth stages of blackgram ($LSD_{(0.05)}$ = NS, 0.371 and 0.706 at 30, 45 DAS and at harvest, respectively).



F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

Fig. 4. Effect on N+P level on number of branches plant^{-1} at different growth stages of blackgram ($LSD_{(0.05)}$ = 0.509, 0.668 and 0.394 at 30, 45 DAS and at harvest, respectively).

Combined effect of bio-fertilizer and N+P

Significant variation was observed on number of branches plant^{-1} at different growth stages due to combined effect of bio-fertilizer and N+P (Table 2 and Appendix VI). Results indicated that the highest number of primary branches plant^{-1} (4.13, 6.87 and 7.18 at 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_1F_3 which was statistically identical with the treatment combination of B_1F_1, B_1F_2 and B_1F_4 at the time of harvest. The lowest number of primary branches plant^{-1} 2.64, 4.10 and 5.09 (at 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of B_0F_1, B_0F_4 and B_0F_5.

Table 2. Number of primary branches plant^{-1} of blackgram as influenced by bio-fertilizer and different combinations of nitrogen and phosphorus

Treatments	Number of primary branches plant^{-1}		
	30 DAS	45 DAS	At harvest
B_0F_0	2.72 f	4.10 e	5.09 d
B_0F_1	3.17 de	4.53 de	5.20 d
B_0F_2	3.39 d	5.17 bc	5.83 bc
B_0F_3	3.75 c	5.53 b	5.87 bc
B_0F_4	3.20 de	5.10 bc	5.60 cd
B_0F_5	2.85 f	4.83 cd	5.40 cd
B_1F_0	2.64 f	4.53 de	5.93 bc
B_1F_1	3.09 e	5.33 bc	6.87 a
B_1F_2	4.00 ab	6.83 a	7.07 a
B_1F_3	4.13 a	6.87 a	7.18 a
B_1F_4	3.90 bc	6.50 a	6.83 a
B_1F_5	2.75 f	5.50 b	6.17 b
$LSD_{(0.05)}$	0.229	0.559	0.557
CV (%)	8.44	8.14	7.48

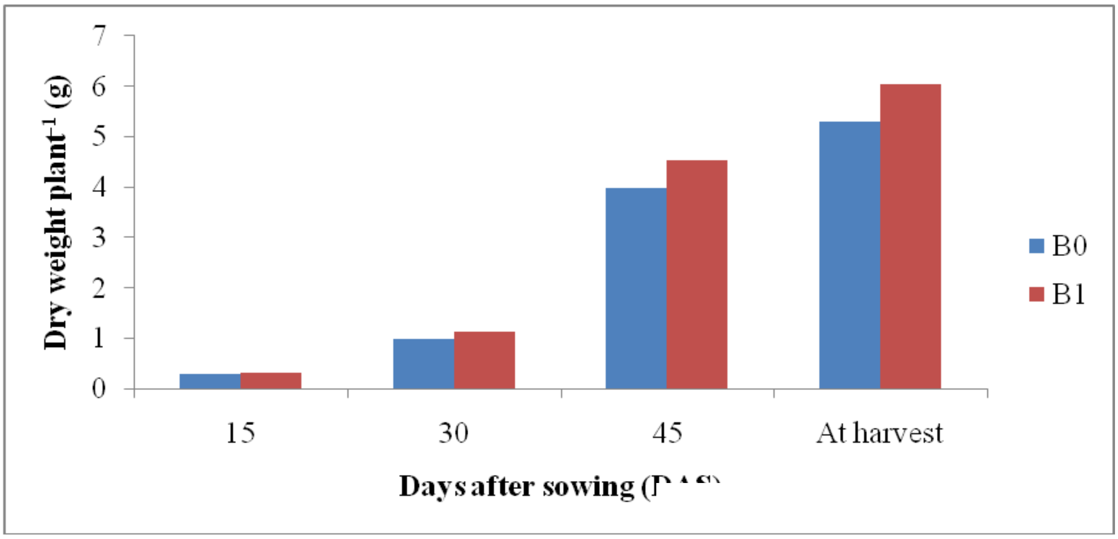
B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

4.1.3 Dry weight plant^{-1}

Effect of bio-fertilizer

Significant variation was found on dry weight plant^{-1} at all growth stages except at 15 and 30 DAS influenced by different bio-fertilizer treatment (Fig. 5 and Appendix VIII). Results indicated that the higher dry weight plant^{-1} (0.30, 1.12, 4.52 and 6.03 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower dry weight plant^{-1} (0.28, 0.99, 3.98 and 5.30 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the control treatment B_0 (without bio-fertilizer). The result obtained from the present study was similar with the findings of Selvakumar *et al*. (2012), Hussain *et al*. (2011) and Kausale *et al*. (2009).

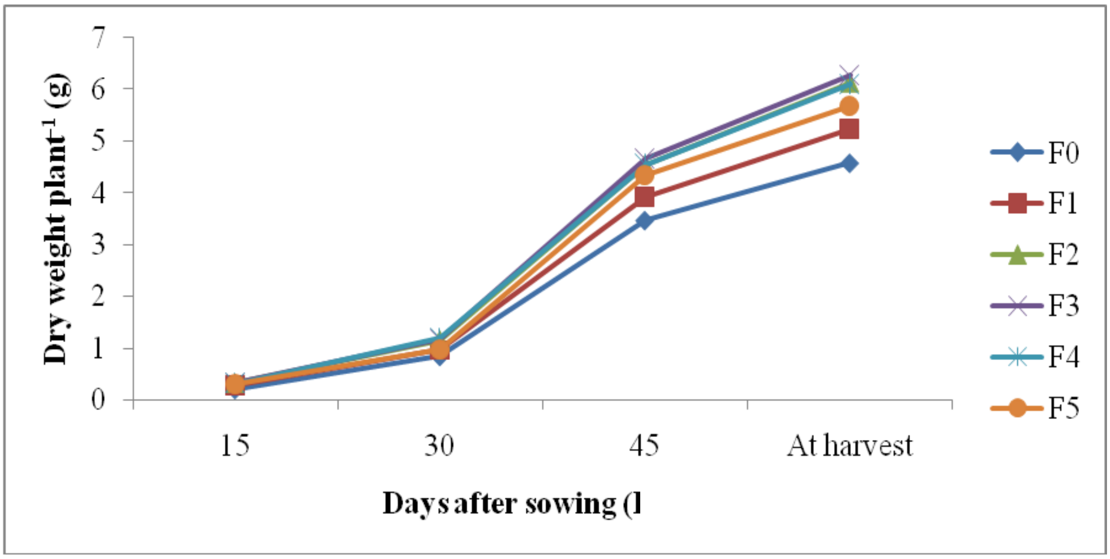


B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

Fig. 5. Effect of bio-fertilizer on number of branches plant^{-1} at different growth stages of blackgram ($LSD_{(0.05)}$ = NS, NS, 0.144 and 0.271 at 15, 30, 45 DAS and at harvest, respectively).

Effect of N+P

Significant influence was recorded in case of dry weight plant^{-1} due to different levels N+P treatments in blackgram at all growth stages except at 15 DAS (Fig. 6 and Appendix VIII). Results showed that dry weight plant^{-1} increased gradually with the advancement of growth stages, irrespective of different level of N+P fertilizations. The rate of increase was much higher from 30 to 45 DAS after that the rate of increase was slower than earlier stage. On the other hand, increasing rate was much slower in the earlier stage (15-30 DAS). It was found that the highest dry weight plant^{-1} (0.33, 1.18, 4.67 and 6.28 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) and F_4 (20% Higher than recommended doses of N+P). Similarly, the lowest dry weight plant^{-1} (0.20, 0.84, 3.47 and 4.58 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the control treatment F_0 (without fertilizer) which was significantly different from other treatments. Similar result was also observed by Jha *et al*. (2015), Choudhary and Yadav (2011) and Geetha and Velayutham (2009) which supported the present study.



F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

Fig. 6. Effect on N+P level on number of branches plant^{-1} at different growth stages of blackgram ($LSD_{(0.05)}$ = NS, 0.126, 0.162 and 0.205 at 15, 30, 45 DAS and at harvest, respectively).

Combined effect of bio-fertilizer and N+P

Significant variation was observed on dry weight plant^{-1} of blackgram at different growth stages except at 15 DAS influenced by combined effect of bio-fertilizer and N+P (Table 3 and Appendix VIII). It was found that the highest dry weight plant^{-1} (0.35, 1.29, 4.95 and 6.68 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_1F_3 which was statistically similar with B_1F_2 and B_1F_4 at the time of harvest. The lowest dry weight plant^{-1} (0.19, 0.81, 3.07 and 4.27 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_0F_0 which was significantly different from other treatment combinations.

Table 3. Dry weight plant^{-1} of blackgram as influenced by bio-fertilizer and different combination of nitrogen and phosphorus

Treatments	Dry weight plant^{-1} (g)			
	15 DAS	30 DAS	45 DAS	At harvest
B_0F_0	0.19	0.81 g	3.07 g	4.27 f
B_0F_1	0.25	0.95 e	3.50 f	4.96 e
B_0F_2	0.31	1.08 c	4.27 d	5.68 c
B_0F_3	0.31	1.07 c	4.38 cd	5.87 b
B_0F_4	0.31	1.10 c	4.40 cd	5.60 cd
B_0F_5	0.30	0.94 e	4.27 d	5.43 d
B_1F_0	0.22	0.87 f	3.88 e	4.89 e
B_1F_1	0.29	0.97 de	4.34 cd	5.50 d
B_1F_2	0.33	1.23 b	4.79 b	6.55 a
B_1F_3	0.35	1.29 a	4.95 a	6.68 a
B_1F_4	0.32	1.27 ab	4.72 b	6.61 a
B_1F_5	0.29	1.01 d	4.44 c	5.93 b
$LSD_{(0.05)}$	NS	0.054	0.143	0.179
CV (%)	9.34	8.19	9.67	12.84

B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

4.2 Yield contributing parameters and yield

4.2.1 Number of pods plant^{-1}

Effect of bio-fertilizer

There observed a significant variation on number of pods plant^{-1} of blackgram affected by different bio-fertilizer treatment (Table 4 and Appendix IX). Results showed that the higher number of pods plant^{-1} (34.89) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower number of pods plant^{-1} (31.54) was obtained from the control treatment B_0 (without bio-fertilizer). Similar result was also observed by Thakur *et al*. (2018), Choudhary *et al*. (2017) and Selvakumar *et al*. (2012) which supported the present study.

Effect of N+P

Significant variation was remarked on number of pod plant^{-1} as influenced due to different N+P treatments in blackgram (Table 4 and Appendix IX). Results indicate that the number of pods plant^{-1} increased gradually with the increases of N+P level and the highest increase was recorded with F_3 (Recommended dose of N+P) treatment, after that the production of pods plant^{-1} reduced gradually up to the highest dose of N+P fertilizer (F_5). It was found that the highest number of pods plant^{-1} (37.03) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) whereas the lowest number of pods plant^{-1} (27.52) was obtained from the control treatment F_0 (without fertilizer). The results obtained from the present study were similar with the findings of Rathore *et al*. (2010), Choudhary and Yadav (2011) and Jha *et al*. (2015) which supported the present study.

Combined effect of bio-fertilizer and N+P

Significant influence was recorded on number of pods plant^{-1} due to combined effect of bio-fertilizer and N+P in blackgram (Table 4 and Appendix IX). Results showed that the highest number of pods plant^{-1} (38.52) was obtained from the treatment combination of B_1F_3 which was statistically similar with the treatment combination of B_1F_2 and B_1F_4. The lowest number of pods plant^{-1} (25.77) was obtained from the treatment combination of B_0F_0 which was significantly different from other treatments.

4.2.2 Pod length (cm)

Effect of bio-fertilizer

Non-significant variation was recorded on pod length of blackgram affected by different bio-fertilizer treatment (Table 4 and Appendix IX). However, the maximum pod length (3.93 cm) was obtained from the treatment B_1 (with bio-fertilizer) whereas the minimum pod length (3.70 cm) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

Significant influence was observed on pod length of blackgram due to different levels N+P treatments (Table 4 and Appendix IX). It was observed that the highest pod length (4.09 cm) was achieved from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_1 (40% lower than recommended doses of N+P), F_2 (20% lower than recommended doses of N+P) and F_4 (20% Higher than recommended doses of N+P). The lowest pod length (3.40 cm) was obtained from the control treatment F_0 (without fertilizer) which was statistically similar with F_5 (40% Higher than recommended doses of N+P).

Combined effect of bio-fertilizer and N+P

Pod length of blackgram was affected significantly due to combined effect of bio-fertilizer and N+P (Table 4 and Appendix IX). It was observed that the treatment combination of B_1F_3 gave the highest pod length (4.22 cm) which was statistically similar with the treatment combination of B_1F_2. The lowest pod length (3.23 cm) was obtained from the treatment combination of B_0F_0 which was significantly different from all other treatment combinations.

4.2.3 Number of seeds pod^{-1}

Effect of bio-fertilizer

Number of seeds pod^{-1} was significant with the application of different bio-fertilizer treatment in blackgram (Table 4 and Appendix IX). Results represented in the table showed that the higher number of seeds pod^{-1} (5.95) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower number of seeds pod^{-1} (5.46) was obtained from the control treatment B_0 (without bio-fertilizer). Hussain *et al*. (2011) and Choudhary *et al*. (2017) also found similar result with the present study.

Table 4. Yield contributing parameters of blackgram as influenced by biofertilizer, different levels of nitrogen and phosphorus and their combinations

Treatments	Yield contributing parameters			
	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	1000-seed weight (g)
Effect of bio-fertilizer				
B_0	31.54 b	3.70	5.46 b	39.59 b
B_1	34.89 a	3.93	5.95 a	42.28 a
$LSD_{0.05}$	0.627	NS	0.056	1.053
CV(%)	6.22	5.39	6.71	5.75
Effect of N+P levels				
F_0	27.52 d	3.40 c	5.05 c	38.08 d
F_1	31.15 c	3.82 ab	5.34 bc	39.49 c
F_2	36.40 ab	4.03 a	6.05 a	41.67 b
F_3	37.03 a	4.09 a	6.17 a	42.78 a
F_4	35.87 b	3.95 a	6.09 a	42.42 a
F_5	31.32 c	3.60 bc	5.53 b	41.18 b
$LSD_{(0.05)}$	0.931	0.282	0.347	0.664
CV (%)	5.71	6.13	8.82	6.69
Combined effect of bio-fertilizer and N+P levels				
B_0F_0	25.77 g	3.23 f	4.92 e	36.67 f
B_0F_1	28.43 f	3.73 d	5.27 cd	37.83 e
B_0F_2	34.87 bc	3.90 c	5.70 b	39.77 d
B_0F_3	35.53 b	3.95 bc	5.83 b	41.50 b
B_0F_4	34.17 c	3.87 c	5.78 b	41.45 b
B_0F_5	30.47 e	3.50 e	5.23 cd	40.33 cd
B_1F_0	29.27 ef	3.57 e	5.17 d	39.50 d
B_1F_1	33.87 c	3.90 c	5.40 c	41.15 bc
B_1F_2	37.92 a	4.15 a	6.40 a	43.57 a
B_1F_3	38.52 a	4.22 a	6.50 a	44.05 a
B_1F_4	37.57 a	4.03 b	6.40 a	43.40 a
B_1F_5	32.17 d	3.70 d	5.83 b	42.03 b
$LSD_{(0.05)}$	1.317	0.093	0.187	0.9391
CV (%)	5.71	6.13	8.82	6.69

B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

Effect of N+P

Variation on number of seeds pod^{-1} was found significant due to different N+P treatments in blackgram (Table 4 and Appendix IX). The data indicated that number of seeds pod^{-1} increased gradually with increased N+P levels and the highest increase was found with F_3 (Recommended dose of N+P) level, after that seeds pod^{-1} reduced gradually with the higher dose. However, the highest number of seeds pod^{-1} (6.17) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) and F_4 (20% Higher than recommended doses of N+P). The lowest number of seeds pod^{-1} (5.05) was obtained from the control treatment F_0 (without fertilizer) which was statistically similar with F_1 (40% lower than recommended doses of N+P). The result obtained from the present study was similar with the findings of Jha *et al*. (2015) and Choudhary and Yadav (2011) which supported the present study.

Combined effect of bio-fertilizer and N+P

The recorded data on number of seeds pod^{-1} was significant affected by combined effect of bio-fertilizer and N+P levels in blackgram (Table 4 and Appendix IX). The highest number of seeds pod^{-1} (6.50) was obtained from the treatment combination of B_1F_3 which was statistically similar with the treatment combination of B_1F_2 and B_1F_4 whereas the lowest number of seeds pod^{-1} (4.92) was obtained from the treatment combination of B_0F_0 which was significantly different from all other treatment combinations.

4.2.4 Weight of 1000-seeds (g)

Effect of bio-fertilizer

Significant variation was found on 1000-seed weight of blackgram due to different bio-fertilizer treatment (Table 4 and Appendix IX). Results showed that the higher 1000-seed weight (42.28 g) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower 1000-seed weight (39.59 g) was obtained from the control treatment B_0 (without bio-fertilizer) which indicated that bio-fertilizer treated plot showed 6.79% heavier seed than bio-fertilizer untreated plot.

Effect of N+P

Significant influence was noted on 1000-seed weight of blackgram due to different N+P level treatments (Table 4 and Appendix IX). The data showed a gradual increase in trend with the increases of higher doses. The highest 1000-seed weight was found with F_3 (Recommended dose of N+P) treatment after that it was reduced markedly with the further higher doses. The highest 1000-seed weight (42.78 g) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically identical with F_4 (20% Higher than recommended doses of N+P) whereas the lowest 1000-seed weight (38.08 g) was obtained from the control treatment F_0 (without fertilizer).

Combined effect of bio-fertilizer and N+P

Significant variation was observed on 1000-seed weight of blackgram due to combined effect of bio-fertilizer and N+P levels (Table 4 and Appendix IX). Results showed that the highest 1000-seed weight (44.05 g) was obtained from the treatment combination of B_1F_3 which was statistically identical with the treatment combination of B_1F_2 and B_1F_4. The lowest 1000-seed weight (36.67 g) was obtained from the treatment combination of B_0F_0 which was significantly different from other treatment combinations.

4.3 Yield parameters

4.3.1 Seed yield

Effect of bio-fertilizer

Seed yield of blackgram was found significant with the application of different bio-fertilizer treatment (Table 5 and Appendix X). The results revealed that B_1 (Bio-fertilizer) showed the superiority by producing 18.38% higher yield over B_0 (without bio-fertilizer). However, the higher seed yield (1.61 t ha^{-1}) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower seed yield (1.36 t ha^{-1}) was obtained from the control treatment B_0 (without bio-fertilizer). The result on seed yield obtained from the present study was similar with findings of Thakur *et al*. (2018), Lal and Khan (2014) and Hussain *et al*. (2011) which supported the present study.

Effect of N+P

Variation on seed yield ha^{-1} was noted as significant due to different N+P level treatments (Table 5 and Appendix X). The data on seed yield demonstrated a gradual increase in trend with the increases of higher doses and F_3 (Recommended dose of N+P) treatment showed highest seed yield and after that it was reduced with the higher doses. However, the highest seed yield (1.64 t ha^{-1}) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) whereas the lowest seed yield (1.28 t ha^{-1}) was obtained from the control treatment F_0 (without fertilizer) which was significantly different from other treatments. Jha *et al*. (2015), Choudhary and Yadav (2011), Rathore *et al*. (2010) and Mathur *et al*. (2007) found similar results on seed yield with the present study.

Combined effect of bio-fertilizer and N+P

The recorded data on seed yield was affected significantly by combined effect of bio-fertilizer and N+P level (Table 5 and Appendix X). It was observed that the highest seed yield (1.76 t ha^{-1}) was achieved from the treatment combination of B_1F_3 which was statistically similar with the treatment combination of B_1F_2 and B_1F_4. Similarly, the lowest seed yield (1.12 t ha^{-1}) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of B_0F_5.

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

Effect of bio-fertilizer

Different bio-fertilizer treatment showed significant variation on stover yield of blackgram (Table 5 and Appendix X). Results revealed that the higher stover yield (3.18 t ha^{-1}) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower stover yield (2.84 t ha^{-1}) was obtained from the control treatment B_0 (without bio-fertilizer). Similar result was also observed by Patil (2002) and Mahala (1999).

Effect of N+P

Different levels N+P treatments indicated significant influence on stover yield of blackgram (Table 5 and Appendix X). It was observed that comparatively both higher and lower doses of nutrients showed lower stover yield. However, the highest stover yield (3.22 t ha^{-1}) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically similar with F_2 (20% lower than recommended doses of N+P) and F_4 (20% Higher than recommended doses of N+P). Likewise, the lowest stover yield (2.79 t ha^{-1}) was obtained from the control treatment F_0 (without fertilizer) which was statistically at per with F_5 (40% Higher than recommended doses of N+P). The results obtained from the present study was similar with the findings of Mathur *et al*. (2007), Rathore *et al*. (2010), Jha *et al*. (2015), Choudhary and Yadav (2011) which supported the present study.

Combined effect of bio-fertilizer and N+P

Combined effect of bio-fertilizer and N+P treatment showed distinct variation on stover yield of blackgram (Table 5 and Appendix X). Results revealed that the highest stover yield (3.40 t ha^{-1}) was obtained from the treatment combination of B_1F_3 which was statistically similar with the treatment combination of B_1F_2 and B_1F_4. The lowest stover yield (2.50 t ha^{-1}) was obtained from the treatment combination of B_0F_0 which was significantly different from other treatment combinations.

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

Effect of bio-fertilizer

Biological yield of blackgram was significantly affected with the application of different bio-fertilizer treatment (Table 5 and Appendix X). Results revealed that the higher biological yield (4.79 t ha^{-1}) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower biological yield (4.20 t ha^{-1}) was obtained from the control treatment B_0 (without bio-fertilizer). Kumawat *et al*. (2013) also found similar result with the present study.

Table 5. Yield and harvest index of blackgram as influenced by biofertilizer, different levels of nitrogen and phosphorus and their combinations

Treatments	Yield and harvest index			
	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Effect of bio-fertilizer				
B_0	1.36 b	2.84 b	4.20 b	32.18 b
B_1	1.61 a	3.18 a	4.79 a	33.57 a
$LSD_{0.05}$	0.034	0.046	0.041	0.277
CV(%)	5.76	6.21	6.36	4.33
Effect of N+P levels				
F_0	1.28 e	2.79 c	4.07 c	31.35 d
F_1	1.45 c	2.99 b	4.45 b	32.57 b
F_2	1.61 ab	3.13 ab	4.74 a	33.94 a
F_3	1.64 a	3.22 a	4.86 a	33.74 a
F_4	1.57 b	3.11 ab	4.68 a	33.61 a
F_5	1.35 d	2.84 c	4.19 c	32.05 c
$LSD_{(0.05)}$	0.066	0.143	0.232	0.508
CV (%)	4.06	7.37	8.06	5.25
Combined effect of bio-fertilizer and N+P levels				
B_0F_0	1.12 f	2.50 g	3.62 h	30.94 e
B_0F_1	1.30 e	2.85 ef	4.15 f	31.33 de
B_0F_2	1.50 cd	2.97 c-e	4.47 e	33.60 c
B_0F_3	1.52 cd	3.04 cd	4.56 de	33.35 c
B_0F_4	1.49 d	2.95 de	4.44 e	33.52 c
B_0F_5	1.20 ef	2.75 f	3.87 g	31.00 e
B_1F_0	1.43 d	3.08 cd	4.51 e	31.76 d
B_1F_1	1.60 bc	3.14 bc	4.74 cd	33.82 a-c
B_1F_2	1.72 a	3.29 ab	5.01 ab	34.28 a
B_1F_3	1.76 a	3.40 a	5.16 a	34.14 ab
B_1F_4	1.66 ab	3.26 ab	4.92 bc	33.70 bc
B_1F_5	1.49 d	2.93 de	4.42 e	33.73 bc
$LSD_{(0.05)}$	0.108	0.179	0.187	0.4757
CV (%)	4.06	7.37	8.06	5.25

B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

Effect of N+P

Variation on biological yield of blackgram was significant due to different N+P level treatments (Table 5 and Appendix X). It was found that the highest biological yield (4.86 t ha^{-1}) was obtained from the treatment F_3 (Recommended dose of N+P) which was statistically identical with F_2 (20% lower than recommended doses of N+P) and F_4 (20% Higher than recommended doses of N+P) whereas the lowest biological yield (4.07 t ha^{-1}) was obtained from the control treatment F_0 (without fertilizer) which was statistically identical with F_5 (40% Higher than recommended doses of N+P). Jha *et al*. (2015) and Choudhary and Yadav (2011) also found similar result which supported the present study.

Combined effect of bio-fertilizer and N+P

The recorded data on biological yield was affected significantly by combined effect of bio-fertilizer and N+P level (Table 5 and Appendix X). Results showed that the highest biological yield (5.16 t ha^{-1}) was obtained from the treatment combination of B_1F_3 which was statistically similar with the treatment combination of B_1F_2. The lowest biological yield (3.62 t ha^{-1}) was obtained from the treatment combination of B_0F_0 which was significantly different from other treatment combinations.

4.3.4 Harvest index (%)

Effect of bio-fertilizer

Harvest index was significantly affected due to application of different bio-fertilizer treatment in blackgram (Table 5 and Appendix X). The higher harvest index (33.57%) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower harvest index (32.18%) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

Variation on harvest index was found significant due to different N+P treatments in blackgram (Table 5 and Appendix X). The highest harvest index (33.94%) was obtained from the treatment F_2 (20% lower than recommended doses of N+P) which was statistically at per with F_3 (Recommended dose of N+P) and F_4 (20% Higher than recommended doses of N+P). The lowest harvest index (31.35%) was obtained from the control treatment F_0 (without fertilizer) which was significantly different from other treatments. Similar result was also observed by Jha *et al*. (2015) which was conformity of the present study.

Combined effect of bio-fertilizer and N+P

The recorded data on harvest index was affected significantly by combined effect of bio-fertilizer and N+P levels in blackgram (Table 5 and Appendix X). The highest harvest index (34.28%) was obtained from the treatment combination of B_1F_2 which was statistically similar with the treatment combination of B_1F_1 and B_1F_3. The lowest harvest index (30.94%) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of $B_0F_1$and B_1F_0.

4.4 Seed quality parameters

4.4.1 Percent germination

Effect of bio-fertilizer

Different bio-fertilizer treatment had significant influence on percent (%) seed germination (Table 6 and Appendix XI). Results indicated that the higher percent germination (88.92%) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower percent germination (84.43%) was obtained from the control treatment B_0 (without bio-fertilizer). It means that bio-fertilizer enhanced percent germination by 3.59%.

Effect of N+P

Significant variation was found on percent (%) seed germination influenced by different N+P treatments (Table 6 and Appendix XI). Results showed that the highest percent germination (91.60%) was obtained from the treatment F_3 (Recommended dose of N+P) which was significantly different from other treatments. The lowest percent germination (81.15%) was obtained from the treatment F_5 (40% Higher than recommended doses of N+P) which was statistically identical with control treatment F_0 (without fertilizer).

Combined effect of bio-fertilizer and N+P

Significant variation was found on percent (%) seed germination as influenced by combined effect of bio-fertilizer and N+P level (Table 6 and Appendix XI). Results revealed that the highest percent germination (94.70%) was obtained from the treatment combination of B_1F_3 which was significantly different from other treatment combinations. The lowest percent germination (80.17%) was obtained from the treatment combination of B_0F_5 which was statistically similar with the treatment combination of B_0F_0.

4.4.2 Shoot length

Effect of bio-fertilizer

Shoot length was significantly influenced by different bio-fertilizer treatment in blackgram (Table 6 and Appendix XI). Results showed that the higher shoot length (21.77 cm) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lowest shoot length (19.51 cm) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

There observed a significant variation on shoot length of blackgram as influenced by different N+P level treatments (Table 6 and Appendix XI). The highest shoot length (23.42 cm) was obtained from the treatment F_3

(Recommended dose of N+P) which was statistically similar with F_4 (20% Higher than recommended doses of N+P). The lowest shoot length (16.26 cm) was obtained from the control treatment F_0 (without fertilizer) which was significantly different from other treatments.

Combined effect of bio-fertilizer and N+P

The recorded data on shoot length was significantly influenced by combined effect of bio-fertilizer and N+P level in blackgram (Table 6 and Appendix XI). It was observed that the highest shoot length (25.40 cm) was obtained from the treatment combination of B_1F_3 which was statistically at per with B_1F_4. The lowest shoot length (15.83 cm) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of B_0F_5 and B_1F_0.

4.4.3 Root length

Effect of bio-fertilizer

Significant variation on root length of blackgram was observed as influenced by different bio-fertilizer treatment (Table 6 and Appendix XI). It was found that the higher root length (9.47 cm) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lower root length (8.98 cm) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

Root length of blackgram was significantly influenced by different N+P treatments (Table 6 and Appendix XI). Results showed that the highest root length (10.48 cm) was obtained from the treatment F_4 (20% Higher than recommended doses of N+P) which was significantly different from other treatments. The lowest root length (8.24 cm) was obtained from the control treatment F_0 (without fertilizer) which was statistically similar with F_1 (40% lower than recommended doses of N+P) treatment.

Combined effect of bio-fertilizer and N+P

Root length of blackgram was significantly influenced by combined effect of bio-fertilizer and N+P level (Table 6 and Appendix XI). It was observed that the highest root length (10.86 cm) was obtained from the treatment combination of B_1F_4 which was statistically similar with the treatment combination of B_1F_3. The lowest root length (8.10 cm) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of B_1F_0.

4.4.4 Dry weight plant^{-1}

Effect of bio-fertilizer

Dry weight seedling^{-1} was not significantly influenced by different biofertilizer treatment (Table 6 and Appendix XI). However, numerically the maximum dry weight seedling^{-1} (0.12 g) was obtained from the treatment B_1 (with bio-fertilizer) whereas the minimum dry weight seedling^{-1} (0.11 g) was obtained from the control treatment B_0 (without bio-fertilizer).

Effect of N+P

No significant variation on dry weight seedling^{-1} of blackgram was found as influenced by different N+P level treatments (Table 6 and Appendix XI). However, the maximum dry weight seedling^{-1} (0.14 g) was obtained from the treatment F_4 (20% Higher than recommended doses of N+P) whereas the minimum dry weight seedling^{-1} (0.10 g) was obtained from the control treatment F_0 (without fertilizer).

Table 6. Seed quality parameters of blackgram as influenced by bio-fertilizer, different levels of nitrogen and phosphorus and their combinations

Treatments	Seed quality parameters				
	Percent germination	Shoot length (cm)	Root length (cm)	Dry weight $seedling^{-1}$ (g)	Electrical conductivity
Effect of bio-fertilizer					
B_0	84.43 b	19.51 b	8.98 b	0.11	9.243 a
B_1	88.92 a	21.77 a	9.47 a	0.12	8.872 b
$LSD_{0.05}$	1.285	0.752	0.471	NS	0.314
CV(%)	4.87	9.83	7.64	5.27	5.39
Effect of N+P levels					
F_0	82.82 d	16.26 d	8.24 d	0.10	10.05 a
F_1	85.82 c	19.78 c	8.84 cd	0.11	9.99 a
F_2	89.65 b	21.52 b	9.10 bc	0.11	9.30 b
F_3	91.60 a	23.42 a	9.70 b	0.13	8.92 b
F_4	89.00 b	23.16 a	10.48 a	0.14	7.87 c
F_5	81.15 d	19.70 c	9.010 bc	0.12	8.23 c
$LSD_{(0.05)}$	1.765	1.377	0.701	NS	0.446
CV (%)	6.49	12.17	9.37	7.02	6.88
Combined effect of bio-fertilizer and N+P levels					
B_0F_0	81.10 fg	15.83 e	8.10 e	0.09	10.47 a
B_0F_1	84.13 e	19.10 cd	8.80 cd	0.11	9.50 c
B_0F_2	87.17 cd	20.97 bc	9.00 cd	0.11	9.80 bc
B_0F_3	88.50 c	21.44 b	9.13 c	0.11	9.70 c
B_0F_4	85.50 de	22.01 b	10.10 b	0.12	7.90 e
B_0F_5	80.17 g	17.71 de	8.77 cd	0.12	8.33 de
B_1F_0	84.53 e	16.70 e	8.37 de	0.10	9.80 bc
B_1F_1	87.50 c	20.47 bc	8.87 cd	0.11	10.30 ab
B_1F_2	92.13 b	22.07 b	9.20 c	0.12	8.80 d
B_1F_3	94.70 a	25.40 a	10.27 ab	0.14	8.13 e
B_1F_4	92.50 b	24.30 a	10.86 a	0.15	7.83 e
B_1F_5	82.13 f	21.70 b	9.25 c	0.13	8.13 e
$LSD_{(0.05)}$	1.824	1.947	0.633	NS	0.5305
CV (%)	6.49	12.17	9.37	7.02	6.88

B_0 = Control (without Bio-fertilizer), B_1 = Bio-fertilizer

F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of N+P, F_2 = 20% lower than recommended doses of N+P, F_3 = Recommended dose of N+P, F_4 = 20% Higher than recommended doses of N+P, F_5 = 40% Higher than recommended doses of N+P

Combined effect of bio-fertilizer and N+P

The recorded data on dry weight seedling^{-1} was not significantly influenced by combined effect of bio-fertilizer and N+P level in blackgram (Table 6 and Appendix XI). However, the highest dry weight seedling^{-1} (0.15 g) was obtained from the treatment combination of B_1F_4 whereas the lowest dry weight seedling^{-1} (0.09 g) was obtained from the treatment combination of B_0F_0.

4.4.5 Electrical conductivity

Effect of bio-fertilizer

Significant variation on electrical conductivity of blackgram seeds was found as influenced by different bio-fertilizer treatment (Table 6 and Appendix XI). Results showed that the higher electrical conductivity (9.24) was obtained from the control treatment B_0 (without bio-fertilizer) whereas the lower electrical conductivity (8.87) was obtained from the treatment B_1 (with bio-fertilizer).

Effect of N+P

Electrical conductivity of blackgram seeds was significantly affected by different N+P treatments (Table 6 and Appendix XI). Results revealed that the highest electrical conductivity (10.05) was obtained from the control treatment F_0 (without fertilizer) which was statistically identical with F_1 (40% lower than recommended doses of N+P) treatment. The lowest electrical conductivity (7.87) was obtained from the treatment F_4 (20% Higher than recommended doses of N+P) which was statistically identical with F_5 (40% Higher than recommended doses of N+P).

Combined effect of bio-fertilizer and N+P

Electrical conductivity of blackgram seeds was significantly influenced by combined effect of bio-fertilizer and N+P level (Table 6 and Appendix XI). Results showed that the highest electrical conductivity (10.47) was obtained from the treatment combination of B_0F_0 which was statistically similar with the treatment combination of B_1F_1. The lowest electrical conductivity (7.83) was obtained from the treatment combination of B_1F_4 which was statistically similar with the treatment combination of B_0F_4, B_0F_5, B_1F_3 and B_1F_5.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from March 2019 to June 2019 to evaluate the effect of bio-fertilizer on yield and seed quality of blackgram with combination of nitrogen and phosphorus. The experiment consisted of two factors *viz*. (1) Factor A: two bio-fertilizer levels; (i) B_0 = Without bio-fertilizer (control) and (ii) B_1 = With bio-fertilizer and (2) Factor B: Five N + P levels; F_0 = Control (without fertilizer), F_1 = 40% lower than recommended doses of fertilizer, F_2 = 20% lower than recommended doses of fertilizer, F_3 = Recommended doses of fertilizer, F_4 = 20% higher than recommended doses of fertilizer and F_5 = 40% higher than recommended doses of fertilizer. The experiment was conducted in split-plot design with three replications. Data on different growth and yield parameters and also seed quality parameters were recorded. The collected data were statistically analyzed for assessment of the treatment effect. A significant variation among the treatments was found while Bio-fertilizer application and different levels of N+P fertilizers applied in different combinations.

Regarding bio-fertilizer effect, in terms of growth parameters, plant height, number of branches plant^{-1} and dry weight plant^{-1} were not significantly affected at 15 DAS but at 30, 45 DAS and at harvest these were significantly affected. Results indicated that the tallest plant (9.27, 24.21, 37.77 and 53.04 cm at 15, 30, 45 DAS and at harvest, respectively), number of primary branches plant^{-1} (3.42, 5.93 and 6.68 at 30, 45 DAS and at harvest, respectively) and dry weight plant^{-1} (0.30, 1.12, 4.52 and 6.03 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment B_1 (with bio-fertilizer). Similarly, the shortest plant (8.78, 22.02, 33.98 and 47.3 cm at 15, 30, 45 DAS and at harvest, respectively), number of primary branches plant^{-1} (3.18, 4.88 and 5.50 at 30, 45 DAS and at harvest, respectively) and dry weight plant^{-1}

(0.28, 0.99, 3.98 and 5.30 g at 15, 30, 45 DAS and at harvest, respectively) were obtained from the control treatment B_0 (without bio-fertilizer). Considering yield contributing parameters and yield parameters affected by bio-fertilizer treatment, the highest number of pods plant^{-1} (34.89), pod length (3.93 cm), number of seeds pod^{-1} (5.95), 1000-seed weight (42.28 g), seed yield (1.61 t ha^{-1}), stover yield (3.18 t ha^{-1}), biological yield (4.79 t ha^{-1}) and harvest index (33.57%) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lowest number of pods plant^{-1} (31.54), pod length (3.70 cm), number of seeds pod^{-1} (5.46), 1000-seed weight (39.59 g), seed yield (1.36 t ha^{-1}), stover yield (2.84 t ha^{-1}), biological yield (4.20 t ha^{-1}) and harvest index (32.18%) were obtained from the control treatment B_0 (without bio-fertilizer). Considering seed quality parameters, bio-fertilizer treatments showed significant effect on all studied parameters except dry weight plant^{-1}. Results indicated that the highest percent germination (88.02%), seedling shoot length (21.77 cm), root length (9.47 cm) and dry weight plant^{-1} (0.12 g) was obtained from the treatment B_1 (with bio-fertilizer) whereas the lowest electrical conductivity (8.87) was also obtained from the treatment B_1 (with bio-fertilizer). Similarly, the lowest percent germination (84.43%), shoot length (19.51 cm), root length (8.98 cm) and dry weight plant^{-1} (0.11 g) were obtained from the control treatment B_0 (without bio-fertilizer) whereas the highest electrical conductivity (9.24) was also obtained from the control treatment B_0 (without bio-fertilizer).

Regarding N+P fertilizer effect, in terms of growth parameters, the longest plant (9.21, 24.55, 38.19 and 52.38 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment F_4 (20% Higher than recommended doses of N+P) but the maximum number of primary branches plant^{-1} (3.94, 6.20 and 6.53 at 30, 45 DAS and at harvest, respectively) and dry weight plant^{-1} (0.33, 1.18, 4.67 and 6.28 g at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment F_3 (Recommended dose of N+P). Again, the lowest plant height (8.65, 20.53, 32.42 and 47.03 cm at 15, 30, 45

DAS and at harvest, respectively), number of primary branches plant^{-1} (2.68, 4.32 and 5.51 at 30, 45 DAS and at harvest, respectively) and dry weight plant^{-1} (0.20, 0.84, 3.47 and 4.58 g at 15, 30, 45 DAS and at harvest, respectively) were obtained from the control treatment F_0 (without fertilizer). Considering yield contributing parameters and yield, all the studied parameters were significantly affected by N+P fertilizer treatments. The highest number of pods plant^{-1} (37.03), pod length (4.09 cm), number of seeds pod^{-1} (6.17), 1000-seed weight (42.78 g), seed yield (1.64 t ha^{-1}), stover yield (3.22 t ha^{-1}) and biological yield (4.86 t ha^{-1}) were obtained from the treatment F_3 (Recommended dose of N+P) but the highest harvest index (33.94%) was obtained from the treatment F_2 (20% lower than recommended doses of N+P). F_2 (20% lower than recommended dose) showed statistically similar yield (1.61 t ha^{-1}), pods plant^{-1} (36.40), pod length (4.03 cm) and seeds pod^{-1} (6.05) with F_3 (Recommended dose of N+P) treatment. The lowest number of pods plant^{-1} (27.52), pod length (3.40 cm), number of seeds pod^{-1} (5.05), 1000-seed weight (38.08 g), seed yield (1.28 t ha^{-1}), stover yield (2.79 t ha^{-1}), biological yield (4.07 t ha^{-1}) and harvest index (31.35%) were obtained from the control treatment F_0 (without fertilizer). Considering seed quality parameters, N+P fertilizer treatments showed significant effect on all studied parameters. Results showed that the highest percent germination (91.60%) and shoot length (23.42 cm) were obtained from the treatment F_3 (Recommended dose of N+P) but the highest root length (10.48 cm) and dry weight plant^{-1} (0.14 g) was obtained from the treatment F_4 (20% Higher than recommended doses of N+P). The lowest electrical conductivity (7.87) was also obtained from the treatment F_4 (20% Higher than recommended doses of N+P). Likewise, the lowest percent germination (81.15%) was obtained from the treatment F_5 (40% Higher than recommended doses of N+P) but the lowest shoot length (16.26 cm), root length (8.24 cm) and dry weight plant^{-1} (0.10 g) were obtained from the control treatment F_0 (without fertilizer). The highest electrical conductivity (10.05) was also obtained from the control treatment F_0 (without fertilizer).

Regarding combined effect of bio-fertilizer and N+P fertilizer treatments, in terms of growth parameters, all studied parameters were affected significantly. The tallest plant (9.50, 25.17, 40.50 and 55.63 cm at 15, 30, 45 DAS and at harvest, respectively) was obtained from the treatment combination of B_1F_4 but the highest number of primary branches plant^{-1} (4.31, 6.87 and 7.18 at 30, 45 DAS and at harvest, respectively) and dry weight plant^{-1} (0.35, 1.29, 4.95 and 6.68 g at 15, 30, 45 DAS and at harvest, respectively) were obtained from the treatment combination of B_1F_3. Again, the shortest plant (8.53, 19.13, 31.30 and 44.97 cm at 15, 30, 45 DAS and at harvest, respectively), number of primary branches plant^{-1} 2.72, 7.10 and 5.09 (at 30, 45 DAS and at harvest, respectively) and dry weight plant^{-1} (0.19, 0.81, 3.07 and 4.27 g at 15, 30, 45 DAS and at harvest, respectively) were obtained from the treatment combination of B_0F_0. Considering yield contributing parameters and yield, all the studied parameters were significantly affected by combined effect of bio-fertilizer and N+P treatments. The highest number of pods plant^{-1} (38.52), pod length (4.22 cm), number of seeds pod^{-1} (6.50), 1000-seed weight (44.05 g), seed yield (1.76 t ha^{-1}), stover yield (3.40 t ha^{-1}) and biological yield (5.16 t ha^{-1}) were obtained from the treatment combination of B_1F_3 but the highest harvest index (34.28%) was obtained from the treatment combination of B_1F_2. On the other hand, B_1F_2 also showed similar result with B_1F_3 in most of the parameters including yield and yield attributes. But the lowest number of pods plant^{-1} (25.77), pod length (3.23 cm), number of seeds pod^{-1} (4.92), 1000-seed weight (36.67 g), seed yield (1.12 t ha^{-1}), stover yield (2.50 t ha^{-1}), biological yield (3.62 t ha^{-1}) and harvest index (30.94%) were obtained from the treatment combination of B_0F_0. Considering seed quality parameters, all the parameters were significantly affected by combined effect of bio-fertilizer and N+P treatments. The highest percent germination (94.70%) and shoot length (25.40 cm) were obtained from the treatment combination of B_1F_3 but the highest root length (10.86 cm) and dry weight plant^{-1} (0.15 g) were obtained from the treatment combination of B_1F_4. The lowest electrical conductivity (7.83) was also obtained from the treatment combination of B_1F_4. Accordingly, the lowest percent germination (80.17%) was obtained from the treatment combination of B_0F_5 but the lowest shoot length (15.83 cm), root length (8.10 cm) and dry weight plant^{-1} (0.09 g) were obtained from the treatment combination of B_0F_0. The highest electrical conductivity (10.47) was also recorded from the treatment combination of B_0F_0.

Conclusion

From the above results, it can be concluded that application of bio-fertilizer and N+P treatment combinations is very much promising for higher blackgram yield and better quality of seed. Comparing control treatment, the treatment combination of B_1F_3 (bio-fertilizer with recommended dose of N+P) and B_1F_2 (bio-fertilizer with 20% lower than recommended doses of N+P) showed better performance on growth, yield attributes and yield of blackgram. On the other hand, for quality performance, B_1F_3 (Bio-fertilizer with recommended dose of N+P) showed better result. So, it may be concluded that for yield performance B_1F_2 and B_1F_3 combinations and for seed quality performance B_1F_3 combination seems promising in the present study.

Recommendation

The present research work was done at the Sher-e-Bangla Agricultural University in one season only. More trial on this work in different locations of the country is needed to validate the present results.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

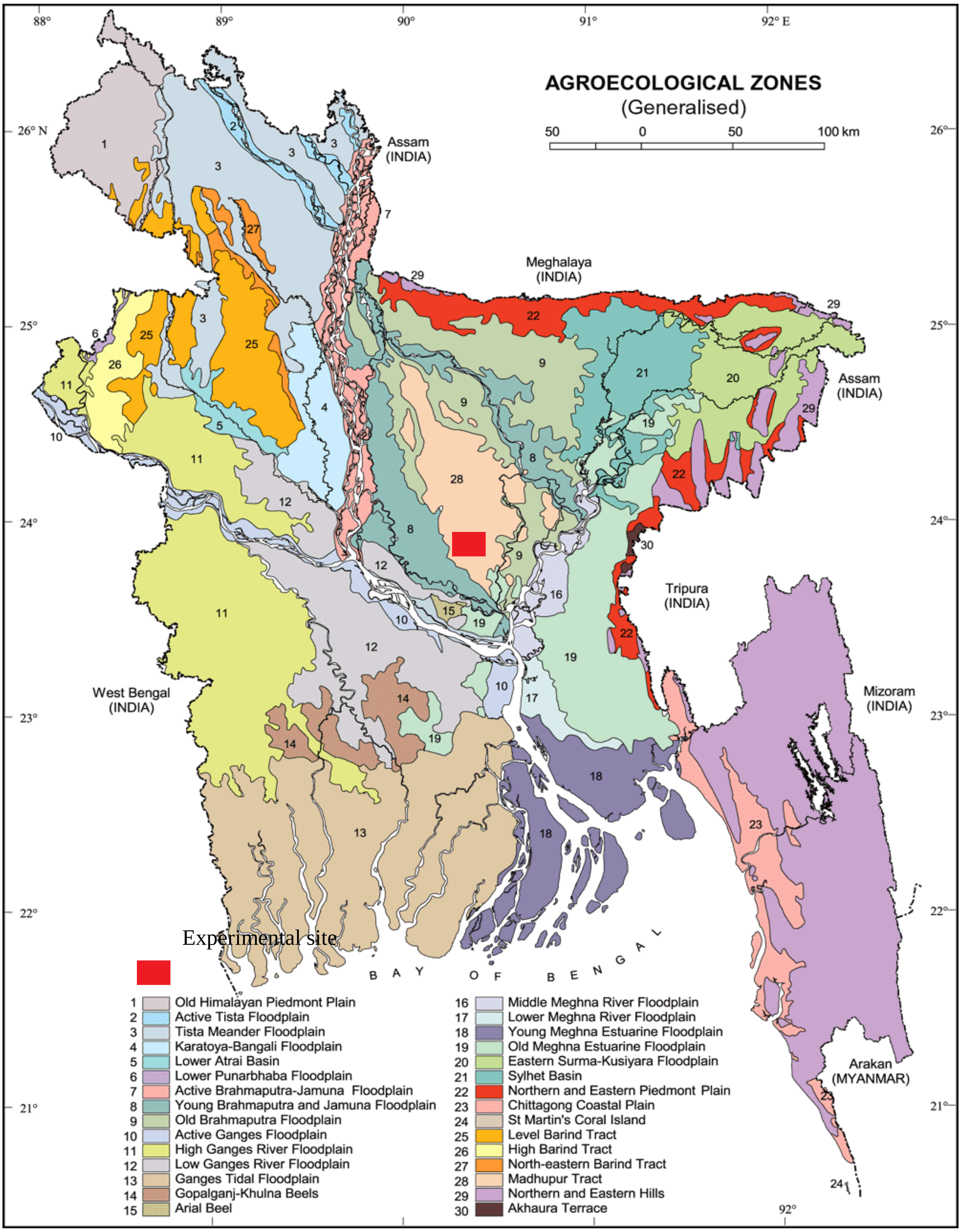

Figure 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from August 2018 to October 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	August	31.00	25.60	28.30	80.00	348
2018	September	30.8	21.80	26.30	71.50	78.52
2018	October	30.42	16.24	23.33	68.48	52.60

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

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

A. 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)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
% Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field

Factor A: Bio-Fertilizer

1. B_0 = Control (without Bio-fertilizer)
2. B_1 = Bio-fertilizer

Factor B: N+P Level

1. F_0 = Control (without fertilizer)
2. F_1 = 40% lower than recommended dose
3. F_2 = 20% lower than recommended dose
4. F_3 = Recommended dose of fertilizer
5. F_4 = 20% higher than recommended dose
6. F_5 = 40% higher than recommended dose

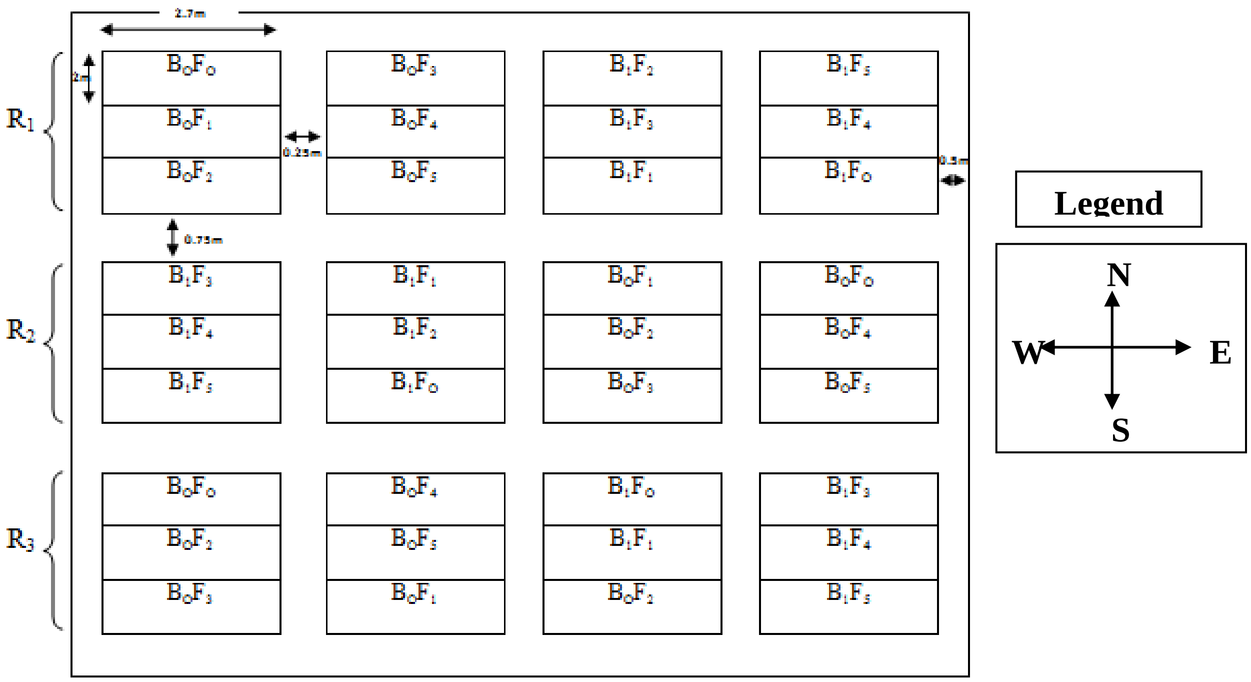

Figure 8. Layout of the experimental plot for split-plot

Appendix V. Mean square of plant height of blackgram as influenced by biofertilizer and different levels of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of plant height			
		15 DAS	30 DAS	45 DAS	At harvest
Replication	2	1.044	2.243	7.283	3.206
Factor A	1	NS	43.42*	129.27*	245.07*
Error	2	0.89	3.129	0.210	0.368
Factor B	5	NS	14.42*	37.85*	26.50*
AB	5	NS	0.786**	3.165*	1.255**
Error	20	0.375	2.250	3.838	6.607

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of number of primary branches plant^{-1} of blackgram as influenced by bio-fertilizer and different levels of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of number of primary branches plant^{-1}		
		30 DAS	45 DAS	At harvest
Replication	2	0.550	0.213	1.261
Factor A	1	NS	9.922*	12.46*
Error	2	0.173	0.954	1.323
Factor B	5	1.550*	3.136*	0.920*
AB	5	0.207**	0.351**	0.164**
Error	20	0.370	0.362	0.407

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of dry weight plant^{-1} of blackgram as influenced by bio-fertilizer and different levels of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of dry weight plant^{-1}			
		15 DAS	30 DAS	45 DAS	At harvest
Replication	2	0.001	0.044	0.068	0.174
Factor A	1	NS	0.121**	2.630*	4.716*
Error	2	0.001	0.004	0.389	0.012
Factor B	5	NS	0.125**	1.288*	2.567*
AB	5	NS	0.008**	0.103**	0.063**
Error	20	0.001	0.011	0.169	0.529

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of yield contributing parameters of blackgram as influenced by bio-fertilizer and different levels of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Number of pods plant^{-1}	Pod length	Number of seeds pod^{-1}	1000-seed weight
Replication	2	6.675	0.059	3.661	3.603
Factor A	1	100.80*	NS	2.205*	65.206*
Error	2	6.115	0.158	0.176	4.072
Factor B	5	86.35*	0.424**	1.298*	20.246*
AB	5	2.201**	0.007**	0.088**	0.985*
Error	20	3.598	0.055	0.535	2.276

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of yield parameters of blackgram as influenced by bio-fertilizer and different levels of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	2	0.038	0.009	0.020	3.733
Factor A	1	0.583*	1.040*	3.180*	17.30*
Error	2	0.003	0.002	0.002	1.351
Factor B	5	0.134**	0.174*	0.611*	6.630*
AB	5	0.005**	0.026**	0.037**	2.325*
Error	20	0.004	0.017	0.019	2.984

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Mean square of seed quality parameters of blackgram as influenced by bio-fertilizer and different levels of nitrogen and phosphorus

Sources of variation	Degrees of freedom	Mean square of seed quality parameters				
		Percent germination	Shoot length	Root length	Dry weight plant^{-1}	Electrical conductivity
Replication	2	2.394	0.094	0.133	0.001	0.412
Factor A	1	181.17*	46.10**	2.132*	NS	1.243**
Error	2	4.254	14.72	2.185**	0.001	0.001
Factor B	5	101.61*	42.68*	3.594*	NS	4.837*
AB	5	5.467**	2.986**	0.241	NS	1.162**
Error	20	9.147	6.307	1.100	0.001	2.339

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level