APPLICATION OF *RHIZOBIUM* STRAINS AND DIFFERENT LEVELS OF NITROGEN ON THE GROWTH AND YIELD OF GRASSPEA

RAMANANDO DAS

DEPARTMENT OF AGRONOMY SHER-E-BANGLA AGRICULTURAL UNIVERSITY DHAKA-1207

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APPLICATON OF BIOLOGICAL STRAINS AND DIFFERENT LEVELS OF NITROGEN ON THE GROWTH AND YIELD OF GRASSPEA

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RAMANANDO DAS

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APPROVED BY:

Prof. Dr. Md. Fazlul Karim	**Prof. Dr. Parimal Kanti Biswas**
Supervisor	**Co-Supervisor**

Prof. Dr. Md. Shahidul Islam
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled " ***APPLICATION OF BIOLOGICAL STRAINS AND DIFFERENT LEVELS OF NITROGEN ON THE GROWTH AND YIED OF GRASSPEA"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***RAMANANDO DAS*** *registration. no.* ***13-05679*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: **June, 2020**

Dhaka, Bangladesh

Professor Dr. Md. Fazlul Karim

Department of Agronomy
SAU, Dhaka-1207
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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APPLICATION OF BIOLOGICAL STRAINS AND DIFFERENT LEVELS OF NITROGEN ON THE GROWTH AND YIELD OF GRASSPEA

ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka to study on the effect of biological strains and different levels of nitrogen on the growth and yield of grasspea during November, 2018 to March, 2019. The experiment consisted of two factors. Factor A: Biological strains (*Rhizobium* inoculums) (3); S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11 and factor B: Nitrogen levels (5); N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage. The experiment was laid out in Split Plot Design with three replications. Plant height, above ground dry matter weight $plant^{-1}$, branches $plant^{-1}$, nodules $plant^{-1}$, nodules dry weight $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, 1000 grain weight, grain yield, stover yield, biological yield and harvest index were compared for different treatments. Results of the investigation revealed that, biological strains and nitrogen levels had significant influence on most of the growth, yield and yield contributing characteristics of grasspea. The maximum grain yield (1.20 t ha^{-1}) was recorded where both biological strains BARI RLs 10 and BARI RLs 11 (S_3) were applied and the minimum grain yield (0.99 t ha^{-1}) was recorded where biological strain BARI RLs 10 (S_1) was applied. S_3 produced 21.21% more grain over S_1. The maximum grain yield (1.26 t ha^{-1}) was recorded where 10 kg N ha^{-1} + RF (N_2) was applied and the minimum grain yield (0.88 t ha^{-1}) was recorded where no fertilizer was applied (N_0). N_2 produced 43.18% more grain over N_0. The maximum grain yield (1.34 t ha^{-1}) was recorded where both biological strains BARI RLs 10 and BARI RLs 11 (S_3) along with 10 kg N ha^{-1} + RF (N_2) were applied and the minimum grain yield (0.75 t ha^{-1}) was recorded where biological strain BARI RLs 10 (S_1) along with no fertilizer (N_0) was applied. Treatment combination S_3N_2 produced 78.67% more grain over S_1N_0. So, it may be concluded that biological strains BARI RLs 10 and BARI RLs 11 along with 10 kg N ha^{-1} + RF could be a best production package to produce grasspea in different grasspea growing area in Bangladesh.

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LIST OF ACRONYMS

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

CHAPTER I

INTRODUCTION

Increasing crop production is a challenging job and for food security it will need to boosting up to 98% due to rapid growing population from 7,300 million to 9,700 million by 2050 (Elferink and Schierhorn, 2016). Pulse crop is an important food crop since it provides a good source of easily digestible dietary protein. A minimum intake of pulse by a human should be 80 g head^{-1} day^{-1}, whereas it is only 14.19 g in Bangladesh (BBS, 2017 and FAO, 1999). On an average in Bangladeshi diet only 8 to 10% of the protein intake originates from animal sources, the rest can be met from plant sources by increasing the consumption of pulses.

In Bangladesh, various types of pulse crops are grown. Grasspea (*Lathyrus sativus* L.) is one of the important pulse crops and is commonly known as khesari. It belongs to the family Fabaceae. It is the most important pulse crop not in terms of area (112029 ha) and production (119344 M. ton) but also for its high consumption as a common pulse in Bangladesh (BBS, 2017). In South Asian countries, grasspea is commonly grown for both grain and fodder purposes since ancient times (Hanbury *et al.*, 2000). The seeds contain about 10.0% water, 28.2% protein, 0.6% fat, 58.2% carbohydrate, and 3.0% minerals (Davis *et al.*, 2000). The presence of β-N-oxalyl-L-α,β-diamino-propionic acid (β-ODAP) in grasspea seeds is thought to increase vulnerability to neurolathyrism, a neurodegenerative disease. Grasspea is cultivated with minimum land preparation and without fertilizer application and insect, diseases or weed control. The average yield of grasspea in Bangladesh is 0.69 t ha^{-1} (BBS, 2017), which is very poor in comparison to that of other grasspea growing countries in the world. This poor yield may be attributed due to climatic condition, adaptation of varieties, disease and insect problems, poor crop management practices and non judicious application of fertilizer especially nitrogenous fertilizers/bio-fertilizers as nitrogen is the most important element for crop.

The availability of nitrogen is one of the key limiting factors in crop productivity. Because of the constraints on the production, availability and use of chemical nitrogenous fertilizers; biologically fixed nitrogen plays an important role in increasing the crop production. The term biofertilizer or called „microbial inoculants‟ can be generally defined as a preparation containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulytic micro-organisms used in soil or composting areas with the objective of increasing the numbers of such micro-organisms and accelerate certain microbial process to augment the extent of the availability of nutrients in a form which can assimilated by plant (Moinuddin *et al.*, 2014; Stephens and Rask, 2000). A judicious use of biofertilizers may be effective not only sustaining crop productivity and in soil health, but also in supplementing chemical fertilizers of crop (Jaipaul *et al*., 2011). 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). The integrated uses of biofertilizers with chemicals fertilizer can contribute to the increase in nitrogen content of the soil as well as increase the long time productivity. Introduction of efficient strains of *Rhizobium* in soils with low nitrogen may help augment nitrogen fixation and thereby boost production of crops. Recent studies also suggest that *Rhizobium* can exhibit plant growth promoting (PGP) activities with non-legumes. *Rhizobium* inoculation increased the root nodulation through better root development and more nutrient availability, resulting in vigorous plant growth and dry matter production which resulted in better flowering, fruiting and pod formation and ultimately there was beneficial effect on seed yield (Sardana *et al*., 2006).*Rhizobium* strains are present in all soils of Bangladesh but they may not be equally effective in nodulation and N-fixation. In this situation, supplementary use of superior strains in the soil can meet the challenge, so that the most effective nodulation and nitrogen fixation are obtained. Thus it was thought that there is a scope for utilizing the effective *Rhizobium* strains for obtaining more yield of grasspea under field conditions which may play vital role in improving soil environment and agricultural sustainability.

In Bangladesh, most of the soils are deficient in organic matter and nitrogen. To fulfill the demand of nitrogen, usually urea is being used. Nitrogen (N) is the most essential nutrient element and its adequate supply increases growth and yield of crop. Legumes although fix nitrogen from the atmosphere, there is evident that application of nitrogenous fertilizers becomes helpful in increasing the crop yield (Ardeshana *et al*., 1993). Nitrogen is most useful for pulse crops because it is the component of protein (BARC, 2005). Proper nitrogen management is inadequate in farmer‟s field which is burning cause for lower yield. Considering the above facts the present work was conducted to evaluate the response of nitrogen and bio-fertilizer on grasspea production with the following objectives:-

1. To examine the effect of biological strain on the plant characters, yield and yield attributes of grasspea,
2. To determine the application of nitrogen fertilizer on the growth and yield of grasspea , and
3. To study the combined effect of biological strain and nitrogen on grasspea production.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding the effect of biological strains and nitrogen fertilizer on the growth and yield of grasspea to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of biological strain

2.1.1 Plant height

An investigation on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L." variety Azad P-1 was carried out by Khan *et al*. (2017) during *Rabi* 2016- 2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF + *Azotobactor* (10g kg^{-1} seed), T_2 :RDF + *Rhizobium* (10g kg^{-1} seed), T_3: RDF + Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF + *Azotobactor* (20g kg^{-1} seed), T_5: RDF + *Rhizobium* (20g kg^{-1} seed), T_6: RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF+ *Azotobactor* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF + Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* 30g kg^{-1} seed recorded tallest plant height (50.65 cm) and the shortest one (42.2 cm) with control treatment (T_0).

An experiment was performed by Pramanik *et al*. (2014) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from February to June, 2010 to study the effect of biofertilizer and weeding on the growth characters and yield of summer mungbean (cv. Binamoog-7). Experimental treatments comprised of (a) five levels of biofertilizer: 0, 1, 2, 3, 4 kg ha^{-1} and (b) four levels of weeding: no weeding, one weeding, two weeding, and three weeding.

The results indicate that, the tallest plant (58.83 cm) was found from 4 kg ha^{-1} biofertilizer and the shortest plant (52.10 cm) was found from 1 kg ha^{-1} biofertilizer.

A field investigation was conducted by Malik *et al.* (2014) to synergistic use of *rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata* L.). The maximum significant increase in plant height was observed by the combined application of compost, *Rhizobium* and nitrogen compared to other treatments.

Khalilzadeh *et al.* (2012) carried out an experiment on growth characteristics of mungbean (*Vigna radiata* L.) affected by foliar application of urea and bio-organic fertilizers. They found that foliar application of urea and organic manure substantially improved the plant height.

2.1.2 Dry matter weight plant^{-1}

An experiment was conducted by Pramanik *et al*. (2014) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from February to June, 2010 to study the effect of biofertilizer and weeding on the growth characters and yield of summer mungbean (cv. Binamoog-7). Experimental treatments comprised of (a) five levels of biofertilizer: 0, 1, 2, 3, 4 kg ha^{-1} and (b) four levels of weeding: no weeding, one weeding, two weeding, and three weeding. The results indicate that, the highest dry matter plant^{-1} (17.78 g) was found from 2 kg ha^{-1} biofertilizer and the lowest dry matter plant^{-1} (16.05 g) was found from no biofertilizer treated plot.

2.1.3 Branches plant^{-1}

A field experiment on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L." variety Azad P-1 was carried out by Khan *et al*. (2017) during *Rabi* 2016- 2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF+ *Azotobacter* (10g kg^{-1} seed), T_2 :RDF + *Rhizobium* (10g kg^{-1} seed), T_3: RDF + Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF + *Azotobacter* (20g kg^{-1} seed), T_5: RDF+ *Rhizobium* (20g kg^{-1} seed), T_6: RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF + *Azotobacter* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF+ Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* + 30g kg^{-1} recorded highest number of branches $plant^{-1}$ (13.75) and with control it was recorded the lowest number of branches $plant^{-1}$ (11.65).

2.1.4 Nodules $plant^{-1}$

Khan *et al*. (2017) conducted an investigation on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L." variety Azad P-1 during *Rabi* 2016- 2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF + *Azotobacter* (10g kg^{-1} seed), T_2 :RDF + *Rhizobium* (10g kg^{-1} seed), T_3: RDF + Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF+ *Azotobacter* (20g kg^{-1} seed), T_5: RDF + *Rhizobium* (20g kg^{-1} seed), T_6:RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF + *Azotobacter* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF + Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* + 30g kg^{-1} recorded the highest nodules $plant^{-1}$ (21.95) and with control it was recorded the lowest nodules $plant^{-1}$ (12.60).

Malik *et al.* (2014) carried out an experiment on synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata* L.*)* and found that the combined application of *Rhizobium*, compost and 75% of the recommended mineral nitrogen (RMN) gave maximum nodules and dry weight.

A field experiment was performed by Nazmun *et al.* (2009) at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The highest effective nodules plant^{-1} (34.9) was recorded in combined application of *Bradyrhizobium* and *Azotobacter* inoculants and the lowest (23.1) was found in uninoculated control. The use of *Bradyrhizobium* inoculants alone gave the second highest nodule plant^{-1} in F_2 (31.2 plant^{-1}) followed by *Azotobacter* inoculants (29.8 plant^{-1}) and application of 20kg N ha^{-1} (25.1 plant^{-1}).

An experiment was conducted by Mozumder *et al.* (2003) to study the effect of *Bradyrhizobium* inoculum at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2. *Bradyrhizobium* inoculum and observed that nitrogen negatively affected on nodulation.

Maldal and Ray (1999) concluded in a field experiment where mungbean cv. B 105, B1 and Hooghly local were untreated, seed inoculated with *Rhizobium* and 20, 30 or 40 kg N ha^{-1} as urea were given. They reported that nodulation was greatest with inoculums in B 105.

Provorov *et al.* (1998) revealed that seed inoculums of mungbean (*Vigna radiate* L.) with Strain CLAM 1901 of *Bradyrhizobium* increased root nodules by 24 %, herbage by 46.6%, seed mass by 39.2%, 1000-seeds weight by 16% and seed N by 30%. These results were equivalent to applying 120 kg N ha^{-1}.

A study was carried out by Tripathi *et al*. (1994) regarding soybean, mungbean and groundnut grown on a clay soil in 1985 and 1986. Five N treatments were applied through 2 sources: No N sources (control), 20 N kg ha^{-1}, *Rhizobium* seed inoculum alone, inoculums with 10 kg N ha^{-1}, and inoculums with 20 kg N ha^{-1}. The combination of inoculants + 20 kg N ha^{-1} gave the highest crop yield and the maximum root nodules. Soybean and groundnut gave comparatively higher yields than *V. mungo* and *V. radiata*

2.1.5 Pods plant^{-1}

A field experiment regarding on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L.” variety Azad P-1 was carried out by Khan *et al*. (2017) during *Rabi* 2016-2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF + *Azotobactor* (10g kg^{-1} seed), T_2 :RDF + *Rhizobium* (10g kg^{-1} seed), T_3: RDF + Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF + *Azotobactor* (20g kg^{-1} seed), T_5: RDF+ *Rhizobium* (20g kg^{-1} seed), T_6: RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF + *Azotobactor* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF + Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* + 30g kg^{-1} recorded the highest number of pods $plant^{-1}$ (16.00) while recorded the lowest number of pods $plant^{-1}$ (10.75) was at control treatment.

Nazmun *et al.* (2009) carried out a field investigation at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The highest number of pods $plant^{-1}$ (20.5) was found in F_4 *(Bradyrhizobium + Azotobacter).* The use of *Bradyrhizobium,* or *Azotobacter* inoculants alone also recorded higher number of pods $plant^{-1}$over control and 20 kg N ha^{-1}.

A field trail was conducted by Basu and Bandyopadhyay (1990) during the Kharif season in west Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or Jca_1, and grown in presence of 0-40 kg N ha^{-1}. Inoculum increased number of pods plant $^{-1}$ and seeds pod^{-1} and N uptake. Jca_1 was superior to M-10. Number of pods plant $^{-1}$ and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate.

2.1.6 Seeds pod^{-1}

A field trial on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L." variety Azad P-1 was investigated by Khan *et al*. (2017) during *Rabi* 2016- 2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF + *Azotobactor* (10g kg^{-1} seed), T_2 :RDF +

Rhizobium (10g kg^{-1} seed), T_3: RDF+ Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF + *Azotobactor* (20g kg^{-1} seed), T_5: RDF + *Rhizobium* (20g kg^{-1} seed), T_6: RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF + *Azotobactor* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF + Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* + 30g kg^{-1} recorded the highest number of seeds pod^{-1} (6.45) and with control it was recorded the lowest number of seeds pod^{-1} (4.80).

Nazmun *et al*. (2009) conducted a field trial at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The highest number of seeds pod^{-1} was produced in F4 (*Bradyrhizobium* + *Azotobacter*). The use of *Bradyrhizobium* (F_2) or *Azotobacter* (F_3) alone or 20 kg Nha^{-1} (F_5) and control (F_1) recorded statistically identical number of seeds plant^{-1}.

2.1.7 1000-seed weight

An investigation on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L.” variety Azad P-1 was carried out by Khan *et al*. (2017) during *Rabi* 2016- 2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF + *Azotobactor* (10g kg^{-1} seed), T_2 :RDF + *Rhizobium* (10g kg^{-1} seed), T_3: RDF + Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF + *Azotobactor* (20g kg^{-1} seed), T_5: RDF + *Rhizobium* (20g kg^{-1} seed), T_6: RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF + *Azotobactor* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF + Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* + 30g kg^{-1} recorded the highest 1000-grain weight (17.45 g) and with control it was recorded the lowest 1000 grain weight (15.90 g).

A field study was conducted by Nazmun *et al.* (2009) at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The different bacterial fertilizers exerted significant on 1000-seed weight of Mungbean. The highest 1000 seed weight (34.1 g) was produced in F_4 (*Bradyrhizobium* + *Azotobacter*) followed by F_2 (33.1 g) and F_3 (30.8 g), F_5 (30.0 g) and the lowest 1000 seed weight (29.4g) was found in control (F_1).

Basu and Bandyopadhyay (1990) conducted a field investigation during the Kharif season in west Bengal where *Vigna radiata* was inoculated with *Rhizobium* strain M-10 or Jca_1 and grown in presence of 0-40 kg N ha^{-1}. Inoculum increased number of pods $plant^{-1}$ and seeds $plant^{-1}$ and N uptake. Jca_1 was superior to M-10. 1000 seeds weight and N uptake increased with increasing N rates up to 30 kg N ha^{-1}. Nitrogen uptake decreased at the highest N application rate.

2.1.8 Seed yield

An investigation on effects of biofertilizer on plant growth and yield character of *Pisum sativum* L." variety Azad P-1 was carried out by Khan *et al*. (2017) during *Rabi* 2016-2017. The single factor experiment was consisted of ten treatments *viz*., T_0: Control, T_1: RDF + *Azotobactor* (10g kg^{-1} seed), T_2 :RDF + *Rhizobium* (10g kg^{-1} seed), T_3: RDF + Phosphate solubilising bacteria (10g kg^{-1} seed), T4: RDF + *Azotobactor* (20g kg^{-1} seed), T_5: RDF + *Rhizobium* (20g kg^{-1} seed), T_6: RDF + Phosphate solubilising bacteria (20g kg^{-1} seed), T_7: RDF + *Azotobactor* (30g kg^{-1} seed) , T_8: RDF + *Rhizobium* (30g kg^{-1} seed) and T_9: RDF + Phosphate solubilising bacteria (30g kg^{-1} seed). They reported that, with the application of 100% RDF + *Rhizobium* + 30g kg^{-1} recorded the highest seed yield $plant^{-1}$ (17.35 g) and with control it was recorded the lowest seed yield $plant^{-1}$ (14.55 g).

An experiment was carried by Hossain *et al.* (2014) during the period from April, 2011 to July, 2011 to find out the yield performance of two mungbean with nitrogenous and bio fertilizers at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. The experiment comprised of two mungbean varieties (BARI mung-5 and BARI mung-6) fertilizers viz., control (without N and inoculum), urea (50 N kg ha^{-1}) and inoculated (*Bradyrhizobium* inoculums 1.5 kg ha^{-1}). The result of the experiment revealed that, the *Bradyrhizobium* inoculated plants showed the highest seed yield (876 kg ha^{-1}) which was statistically superior to other treatments. The lowest seed yield (716 kg ha^{-1}) was showed in non-inoculated plant.

A field study was performed by Pramanik *et al*. (2014) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from February to June, 2010 to study the effect of biofertilizer and weeding on the growth characters and yield of summer mungbean (cv. Binamoog-7). Experimental treatments comprised of (a) five levels of biofertilizer: 0, 1, 2, 3, 4 kg ha^{-1} and (b) four levels of weeding: no weeding, one weeding, two weeding, and three weeding. The experiment was laid out in a randomized complete block design with three replications. The results indicate that, the highest seed yield (1.96 t ha^{-1}) was found from 2 kg ha^{-1} biofertilizer and the lowest seed yield (1.54 t ha^{-1}) was found from no biofertilizer treated plot.

Hossain *et al.* (2014) performed a field trial to investigate the comparative roles of nitrogen (50 kg ha^{-1}) and inoculum *Bradyrhizobium* (1.5 kg ha^{-1}) in improving the yield of two mungbean varieties (BARI Mung-5 and BARI Mung-6) at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. BARI Mung-6 performed higher seed yield than BARI Mung-5.

A field investigation was conducted by Malik *et al.* (2014) on synergistic use of *Rhizobium*, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata* L.) and found that the combined application of *Rhizobium,* compost and 75% of the recommended mineral nitrogen (RMN) gave maximum grain yield plant^{-1}.

An experiment was conducted by Mozumder *et al.* (2003) to study the effect of *Bradyrhizobium* inoculum at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2. *Bradyrhizobium* innoculum increased dry matter production, nodulation, pod production, seed yield and harvest index and observed that increase of nitrogen fertilizer increased seed yield up to 40 kg N ha^{-1} and straw yield up to 60 kg N ha^{-1}.

2.1.9 Stover yield

An experiment was conducted by Hossain *et al.* (2014) during the period from April, 2011 to July, 2011 to find out the yield performance of two mungbean with nitrogenous and bio fertilizers at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. The experiment comprised of two mungbean varieties (BARI Mung-5 and BARI Mung-6) fertilizers viz., control (without N and inoculum), urea (50 N kg ha^{-1}) and inoculated (*Bradyrhizobium* inoculums 1.5 kg ha^{-1}). The result of the experiment revealed that, the highest stover yield of (2290 kg ha^{-1}) was obtained due to the application of inoculums which was superior to N50 and non-inoculated control (1500 kg ha^{-1}).

A field trial was conducted by Hossain *et al.* (2014) to investigate the comparative roles of nitrogen (50 kg ha^{-1}) and inoculum *Bradyrhizobium* (1.5 kg ha^{-1}) in improving the yield of two mungbean varieties (BARI Mung-5 and BARI Mung-6) at the Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka. BARI Mung-6 performed higher stover yield than BARI Mung-5.

A field experiment was carried out by Nazmun *et al.* (2009) at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh to study the effects of *Bradyrhizobium* and *Azotobacter* inoculum on growth and yield of mungbean varieties. The different bacterial fertilizers exerted significant on stover yield of Mungbean. The highest (3754 kg ha^{-1}) and the lowest stover yield (2644 kg ha^{-1}) was found in F_4 (*Bradyrhizobium* + *Azotobacter*) and in control (F_4), respectively.

2.1.10 Biological yield

Hossain *et al.* (2014) revealed that nitrogen and *Bradyrhizobium* inoculants showed significant increase the biological yield of Mungbean. The *Bradyrhizobium* inoculated plants showed the highest seed yield (876 kg ha^{-1}) which was statistically superior to other treatments. The lowest seed yield (716 kg ha^{-1}) was showed in non-inoculated plant.

Malik *et al.* (2014) reported that biological yield increased by the addition of compost, mineral N and *Rhizobium* inoculum. The lowest number of biological yield was recorded in control while it was being nourished by recommended mineral NPK fertilizers.

2.1.11 Harvest index

Mozumder *et al.* (2003) conducted an experiment to study the effect of *Bradyrhizobium* inoculum at different nitrogen level viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2 *Bradyrhizobium* inoculum and observed that nitrogen negatively affected on harvest index.

2.2 Effect of nitrogen levels

2.2.1 Plant height

A study was conducted by Achakzai *et al.* (2012) to evaluate the growth response of mungbean cultivars subjected to different rate of applied N fertilizer. The different N fertilizers exerted significant on plant height of Mungbean. The plants of T_2 (20 kg ha^{-1} N) gained maximum height (36.81 cm), whereas the short stature plants (29.64 cm) obtained in plots either receiving no fertilizer.

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

A field trial was carried out by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*Vigna radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (pods $plant^{-1}$ and seeds pod^{-1}) of greengram were augmented significantly due to foliar nutrition. The foliar application of 2% diammonium phosphate + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield attributes.

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

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

2.2.2 Dry matter weight $plant^{-1}$

Razzaque *et al.* (2017) carried out a pot investigation at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif II season of 2011 to investigate the growth, dry matter production and yield of mungbean genotypes under nutrient stress soil. Ten mungbean genotypes *viz.*, IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen fertilizer levels viz., 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results revealed that the highest dry matter weight plant^{-1} (32.58 g) was obtained from 60 kg N ha^{-1} while the lowest dry matter weight plant^{-1} (23.41g) was obtained from 0 kg N ha^{-1}.

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

Asaduzzaman *et al.* (2008) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of mungbean (*Vigna radiata* L.) to nitrogen and irrigation management. They found that 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage (35 DAS) significantly improved dry matter accumulation of mungbean.

A pot experiment was performed by Kabir *et al.* (2005) at the Environmental Stress Research Site of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during the summer (April to June) in 2001 to study the effect of nitrogen fertilizer on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). Three levels of nitrogen, low -13.30kg ha^{-1} (0.08g pot^{-1}), medium - 40kg ha^{-1} (0.24g pot^{-1}) and high – 60 kg ha^{-1}(0.36g pot^{-1}), which were equivalent to 33,100 and 150% of the recommended dose in Bangladesh, respectively, were used. They found that, the maximum above ground dry weight plant^{-1} (30.50 g) was recorded from high nitrogen dose (60 kg ha^{-1}or 0.36g pot^{-1}) and the minimum above ground dry weight plant^{-1} (25.30 g) was recorded from low nitrogen dose (13.30 kg ha^{-1}or 0.08 g pot^{-1}).

Yakadri *et al.* (2002) investigated the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of green gram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in dry matter content in above ground part.

2.2.3 Branches plant^{-1}

Achakzai *et al.* (2012) conducted an experiment was to evaluate the growth response of mungbean cultivars subjected to different rate of applied N fertilizer. Results regarding number of branches plant^{-1} exhibited that there was a significant difference among various treatments of N fertilizer when compared it with their control treatment (no fertilizer). The plants of T_6 (100 kg h^{-1} N) produced the maximum number of branches plant^{-1} (3.83), whereas the minimum was recorded for (3.17) no fertilizer use.

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

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

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

2.2.4 Nodules plant^{-1}

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

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

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

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

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

Murakami *et al*. (1990) reported that without N fertilizer, N fixation started at 12 days after sowing (DAS) increased rapidly at 34 DAS (flowering) to reach a peak at 45 DAS had a secondary peak at 60 DAS and then decreased until the plant died (83 DAS). With N fertilizer, N fixation started at 14 DAS, increased slowly to reach a much lower peak at 50 DAS and then decreased. Nodulation was greatly decreased by applied N, but fixation per unit nodule weight was similar in both N treatments. The rate of N derived from the air of 78 mungbean cultivar was 0-100% at 33 DAS and 76% in all cultivars at 60 DAS. The author suggested that these cultivars might respond more to applied N than high fixing cultivars.

2.2.5 Pods plant^{-1}

Razzaque *et al.* (2017) conducted a pot experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif II season of 2011 to investigate the growth, dry matter production and yield of mungbean genotypes under nutrient stress soil. Ten mungbean genotypes viz., IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen fertilizer levels *viz*., 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results revealed that the genotype IPSA 12 produced the highest pods plant^{-1} (30.16) at 60 kg N ha^{-1}. The lowest number of pods plant^{-1} (16.16) was recorded in genotype GK 63 with highest N dose but it was identical with of Bina moog 5 (16.83) with o kg N ha^{-1}.

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

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

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

A pot experiment was carried out by Kabir *et al.* (2005) at the Environmental Stress Research Site of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during the summer (April to June) in 2001 to study the effect of nitrogen fertilizer on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). Three levels of nitrogen, low -13.30kg ha^{-1} (0.08g pot^{-1}), medium - 40kg ha^{-1} (0.24g pot^{-1}) and high – 60 kg ha^{-1}(0.36g pot^{-1}), which were equivalent to 33,100 and 150% of the recommended dose in Bangladesh, respectively, were used. They found that, the maximum number of pods $plant^{-1}$ (48.30) was recorded from high nitrogen dose (60 kg ha^{-1}or 0.36g pot^{-1}) and the minimum number of pods $plant^{-1}$ (38.20) was recorded from low nitrogen dose (13.30 kg ha^{-1}or 0.08 g pot^{-1}).

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

2.2.6 Seeds $pods^{-1}$

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

N as urea at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea; and 1/2 basal N + 1/2 foliar spraying as urea + 40 ppm NAA. 2 % foliar spray of urea and NAA, applied at 35 DAS, resulted in the highest seeds pod^{-1}(7.67).

A pot experiment was carried out by Kabir *et al.* (2005) at the Environmental Stress Research Site of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during the summer (April to June) in 2001 to study the effect of nitrogen fertilizer on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). Three levels of nitrogen, low - 13.30kg ha^{-1} (0.08g pot^{-1}), medium - 40kg ha^{-1} (0.24g pot^{-1}) and high-
60 kg ha^{-1}(0.36g pot^{-1}), which were equivalent to 33,100 and 150% of the recommended dose in Bangladesh, respectively, were used. They found that, the maximum number of seeds pod^{-1} (9.70) was recorded from medium nitrogen dose (40 kg ha^{-1}or 0.24g pot^{-1}) and the minimum number of seeds pod^{-1} (7.70) was recorded from low nitrogen dose (13.30 kg ha^{-1}or 0.08 g pot^{-1}).

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

2.2.7 1000-seed weight

A pot experiment was conducted by Kabir *et al.* (2005) at the Environmental Stress Research Site of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during the summer (April to June) in 2001 to study the effect of nitrogen fertilizer on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). Three levels of nitrogen, low -13.30kg ha^{-1} (0.08g pot^{-1}), medium - 40kg ha^{-1} (0.24g pot^{-1}) and high-60 kg ha^{-1}(0.36g pot^{-1}), which were equivalent to 33,100 and 150% of the recommended dose in Bangladesh, respectively, were used. They found that, the maximum 1000 grain weight (37.10 g) was recorded from high nitrogen dose (60 kg ha^{-1}or 0.36g pot^{-1}) and the minimum 1000 grain weight (32.40 g) was recorded from low nitrogen dose (13.30 kg ha^{-1}or 0.08 g pot^{-1}).

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

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

2.2.8 Seed yield

Razzaque *et al.* (2017) conducted a pot experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during kharif II season of 2011 to investigate the growth, dry matter production and yield of mungbean genotypes under nutrient stress soil. Ten mungbean genotypes *viz*., IPSA-12, GK-27, IPSA-3, IPSA-5, ACC12890053, GK-63, ACC12890055, BARI Mung-6, BUmug- 4 and Bina moog- 5 and six nitrogen fertilizer levels viz., 0, 20, 40, 60, 80 and 100 kg N ha^{-1} were included as experimental treatments. Results revealed that the seed yield of mungbean varied from 7.33 g to 14.22 g $plant^{-1}$ and it was the maximum in IPSA 12 (14.22 g $plant^{-1}$) grown with 60 kg N ha^{-1} and the lowest in ACC12890053 (7.33 g $plant^{-1}$) followed by Bina moog 5 under control condition (no nitrogen).

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

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

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

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

Asaduzzaman *et al.* (2008) conducted an experiment at the experimental field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka to evaluate the response of mungbean (*Vigna radiata* L.) to nitrogen and irrigation management. They found that 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage (35 DAS) gave significantly maximum seed yield $plant^{-1}$ (5.53 g).

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

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

A field experiment was conducted by Raman and Venkataramana (2006) in Annamalainagar, Tamil Nadu, India to investigate the effect of foliar nutrition on crop nutrient uptake and yield of greengram (*V. radiata*). There were 10 foliar spray treatments, consisting of water spray, 2% diammonium phosphate at 30 and 45 days after sowing, 0.01% Penshibao, 0.125% Zn chelate, 30 ppm NAA. Crop nutrient uptake, yield and its attributes (number of pods per plant and number of seeds per pod) of green gram augmented significantly due to foliar nutrition. The foliar application of urea + NAA + Penshibao was significantly superior to other treatments in increasing the values of yield. The highest grain yield of 1529 kg ha^{-1} was recorded with this treatment.

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

A pot experiment was carried out by Kabir *et al.* (2005) at the Environmental Stress Research Site of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh, during the summer (April to June) in 2001 to study the effect of nitrogen fertilizer on salinity tolerance of mungbean (*Vigna radiata* L. Wilczek). Three levels of nitrogen, low -13.30kg ha^{-1} (0.08g pot^{-1}), medium - 40kg ha^{-1} (0.24g pot^{-1}) and high-60 kg ha^{-1}(0.36g pot^{-1}), which were equivalent to 33,100 and 150% of the recommended dose in Bangladesh, respectively, were used. They found that, the maximum seed yield plant^{-1} (15.20 g) was recorded from high nitrogen dose (60 kg ha^{-1}or 0.36g pot^{-1}) and the minimum seed yield plant^{-1} (11.60 g) was recorded from low nitrogen dose (13.30 kg ha^{-1}or 0.08 g pot^{-1}).

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

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

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

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

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

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

2.2.9 Stover yield

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

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

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

2.2.10 Biological yield

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

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

Results of an experiment conducted by Sardana and Verma (1987) in Delhi, India and stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in biological yield of mungbean.

2.2.11 Harvest index

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

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to study the effect of biological strains and different levels of nitrogen on the growth and yield of grasspea. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Site and soil

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

3.1.2 Climate and weather

The climate of the locality is subtropical which is characterized by high temperature and heavy rainfall during Kharif season (April-September) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The prevailing weather conditions during the study period have been presented in Appendix-III.

3.2 Plant materials

BARI Khesari-2 was used as planting material. BARI Khesari-2 was released and developed by BARI in 1996. Plant height of the cultivar ranges from 55 to 60 cm. Its life cycle is about 125-130 days after emergence. Average yield of this cultivar is about 1.50 to 2.00 t ha^{-1}. Seed size large, light grey color, 1000 seed weight is 50-55 g. The seeds of BARI Khesari-2 for the experiment were collected from BARI, Joydepur, Gazipur.

3.3 Treatments under investigation

There were two factors in the experiment namely biological strains *(Rhizobium)* and nitrogen levels as mentioned below:

A. Factor-1: Biological strains (*Rhizobium* inoculums)(3):

a) S_1: BARI RLs 10
b) S_2: BARI RLs 11 and
c) S_3: BARI RLs 10 + BARI RLs 11

B. Factor-2: Nitrogen levels(5):

a) N_0: No fertilizers
b) N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$ kg ha^{-1})
c) N_2: 10 kg N ha^{-1} + RF
d) N_3: 30 kg N ha^{-1} + RF
e) N_4: RF + additional 10 kg N ha^{-1} at flower initiation stage

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. In main plot there was *Rhizobium* strains treatment and in sub plot there was nitrogen fertilizer treatments. There are 15 treatment combinations and 45 unit plots. The unit plot size was 3 m^2 (2 m × 1.5 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

3.5 Land preparation

The experimental land was opened with a power tiller on 25th November, 2018. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on 30th November, 2018 and was ready for sowing seeds.

3.6 Fertilizer application

The fertilizers were applied as basal dose at final land preparation where P_2O_5, K_2O, S and B were applied @ 40 kg ha^{-1}, 20 kg ha^{-1}, 20 kg ha^{-1} and 1 kg ha^{-1}, respectively in all plots. Nitrogen fertilizer was applied as per treatment variables. All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.7 Sowing of seeds

Seeds were sown at the rate of 50 kg ha^{-1} in the furrow on 30th November, 2018 and the furrows were covered with the soils soon after seeding. Row to row distance is 30 cm and in rows seed to seed distance 10 cm were maintained.

3.8 Intercultural operations

3.8.1 Weed control

The crop was infested with some weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was done at 20 days after sowing followed by second weeding at 20 days after first weeding.

3.8.2 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre sowing and other two were given 2-3 days after weeding.

3.8.3 Plant protection measures

The crop was not infested with any insects or diseases, so any insecticide or fungicide were not applied during the experimentation period.

3.9 Harvesting and sampling

The crop was harvested at 110 DAS. The crop was harvested plot wise when about 80% of the pods became mature. Samples were collected from different places of each plot leaving undisturbed very small in the center. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated, cleaned and dried in the sun for 3 to 5 consecutive days for achieving safe moisture of seed.

3.10 Threshing

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

3.11 Drying, cleaning and weighing

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

3.12 Recording of data

The data were recorded on the following parameters

i. Plant height (cm)
ii. Above ground dry matter weight plant^{-1} (g)
iii. Branches plant^{-1} (no.)
iv. Nodules plant^{-1} (no.)
v. Nodules dry weight plant^{-1} (mg)
vi. Pods plant^{-1} (no.)
vii. Seeds pod^{-1} (no.
viii. 1000-seed weight (g)
ix. Seed yield (t ha^{-1})
x. Stover yield (t ha^{-1})
xi. Biological yield (t ha^{-1})
xii. Harvest index (%)

3.13 Procedure of recording data

i. Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 20, 40, 60, 80 DAS and harvest.

ii. Above ground dry matter weight plant^{-1}(g)

Ten plants were collected randomly from each plot at 20, 40, 60, 80 DAS and harvest. The sample plants were oven dried for 72 hours at 70°C and then dry matter content plant^{-1} was determined.

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

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

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

The 10 plants plot^{-1} from second line was uprooted and total number of nodules from ten plants was counted at 40, 60, 80 DAS and harvest and the mean value was determined.

v. Nodules dry weight plant^{-1} (mg)

The 10 plants plot^{-1} from second line was uprooted at 40, 60, 80 DAS and harvest; after counting the nodules of 10 selected plants the nodules were oven dried for 72 hours at 70°C and then nodules dry weight plant^{-1} was determined.

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

Pods plant^{-1} was counted from the 10 selected plant sample and then the average pod number was calculated.

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

Seeds pod^{-1} was counted from 30 selected pods of plants and then the average seed number was calculated.

viii. 1000-seed weight (g)

1000-grains were counted which were taken from the grain sample of each plot separately, then weighed in an electrical balance and data were recorded.

ix. Seed yield (t ha^{-1})

Seed yield was recorded on the basis of total harvested grains plot^{-1} and was expressed in terms of yield (t ha^{-1}). Grain yield was adjusted to 12% moisture content.

x. Stover yield (t ha^{-1})

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

xi. Biological yield (t ha^{-1})

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

xii. Harvest index (%)

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

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Biological weight)}} \times 100$$

Here, Biological yield = Grain yield + stover yield

3.14 Data analysis technique

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

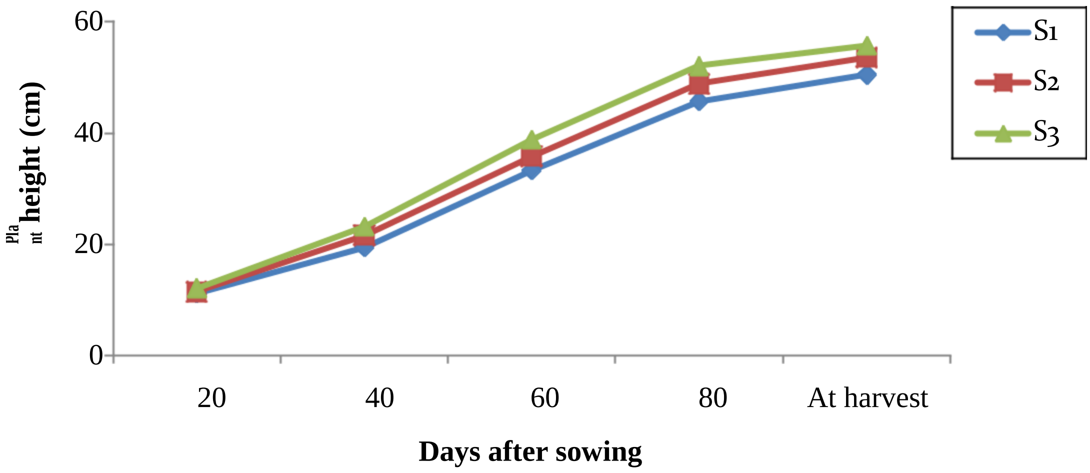
CHAPTER IV
RESULTS AND DISCUSSION

The data on different growth, yield contributing characters and yield were recorded to find out the faceable biological strain and optimum rate of nitrogen on grasspea. The results have been presented and discussed and possible interpretations have been given under the following headings:

4.1 Plant height (cm)

4.1.1 Effect of biological strain

Plant height of grasspea significantly differed due to the different biological strains during all the growth period except 20 days after sowing (DAS) (Fig-1). The tallest plant (23.20, 38.81, 52.06 and 55.73 cm at 40, 60, 80 DAS and harvest, respectively) was found from treatment S_3 which was statistically similar with S_2 at 80 DAS and harvest, while the shortest plant (19.53, 33.26, 45.77 and 50.47 cm at 40, 60, 80 DAS and harvest, respectively) was found from treatment S_1 which was statistically similar with S_1 at 60, 80 DAS and harvest. Similar findings also reported by Pramanik *et al*. (2014) and Bhattacharyya and Pal (2001) who concluded that *Rhizobium* strains significantly influenced the plant height of mungbean.

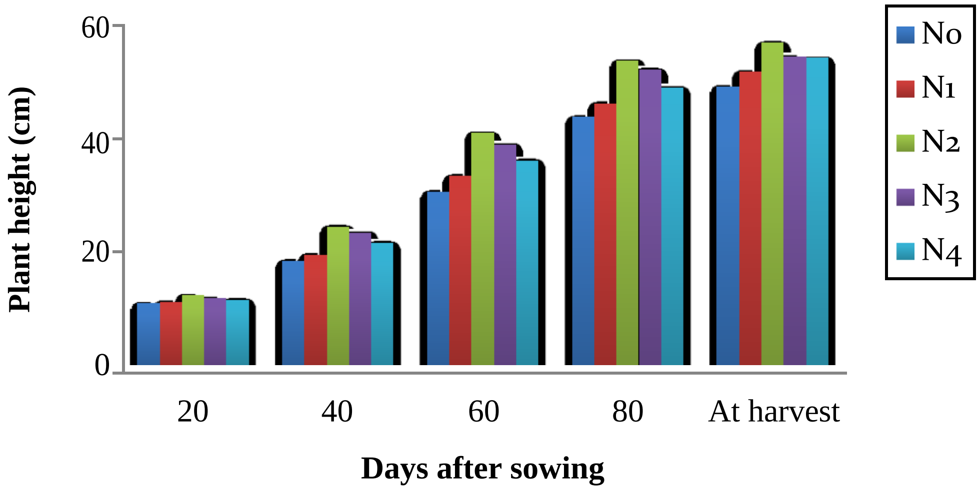


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 1.Effect of biological strain on the plant height of grasspea at different days after sowing ($LSD_{0.05}$=NS, 1.48, 2.54, 4.26 and 2.69 at 20, 40, 60, 80 DAS and harvest, respectively).

4.1.2 Effect of nitrogen levels

Plant height of grasspea significantly differed due to the different nitrogen levels (Fig 2). The tallest plant (12.34, 24.42, 40.92, 53.63 and 56.77 cm at 20, 40, 60, 80 DAS and harvest, respectively) was found from treatment N_2 which was statistically similar with N_3, N_4 and N_1 at 20 DAS and harvest; N_3 at 40 and 60 DAS; N_3 and N_4 at 80 DAS while the shortest plant (10.91, 18.40, 30.51, 43.68 and 49.11 cm at 20, 40, 60, 80 DAS, and harvest, respectively) was found from treatment control treatment (N_0) which was statistically similar with N_1, N_4 and N_3 at 20 DAS and harvest; N_1 at 40, 60 and 80 DAS. Tonmoy (2015), Saini and Thakur (1996) and Yein (1982) found the increased plant height of mungbean with nitrogen application. Kabir (2012) and Suhartatik (1991) observed that the application of 30 kg N ha^{-1} fertilizers significantly increased that plant height of mungbean.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 2. Effect of nitrogen levels on the plant height of grasspea at different days after sowing ($LSD_{0.05}$= 1.26, 2.44, 3.65, 4.81 and 5.85 at 20, 40, 60, 80 DAS and harvest, respectively).

4.1.3 Combined effect of biological strains and nitrogen levels

Combined application of biological strains (*Rhizobium)* and different doses of nitrogen had significant effect on the plant height of grasspea (Table 1). The result of the investigation revealed that the tallest plant (12.87, 26.33, 43.50, 56.70 and 60.10 cm at 20, 40, 60, 80 DAS and harvest, respectively) were found from treatment combination S_3N_2 which was statistically similar with rest of the treatment combinations except S_3N_2 at 20 DAS; with S_3N_3, S_3N_4, S_2N_2, S_2N_3 and S_1N_2 at 40 and 60 DAS; S_3N_3, S_3N_4, S_2N_2, S_2N_3, S_1N_2, S_2N_4, S_3N_1 and S_1N_3 at 80 DAS; with all the treatment combinations except S_1N_0, S_1N_1 and S_2N_0 at harvest. The shortest plant (10.33, 15.53, 27.04, 39.49 and 47 cm at 20, 40, 60, 80 DAS and harvest, respectively) were found from treatment combination S_1N_0 which was statistically similar with all the treatment combinations except S_3N_2 at 20 DAS; with S_1N_1 and S_2N_0 at 40 DAS; with S_1N_1, S_2N_0 and S_2N_1 at 60 DAS; with S_1N_1, S_1N_4, S_2N_0, S_2N_1 and S_3N_0 at 80

DAS and finally with all the treatment combinations except S_3N_2 and S_3N_3 at harvest. The findings was also coincide with the findings of Tonmoy (2015) and Malik*et al.* (2014) who found that the maximum significant increase in plant height was observed by the combined application of compost, *Rhizobium* and nitrogen compared to other treatments.

Table 1. Combined effect of biological strains and nitrogen levels on the plant height of grasspea at different days after sowing

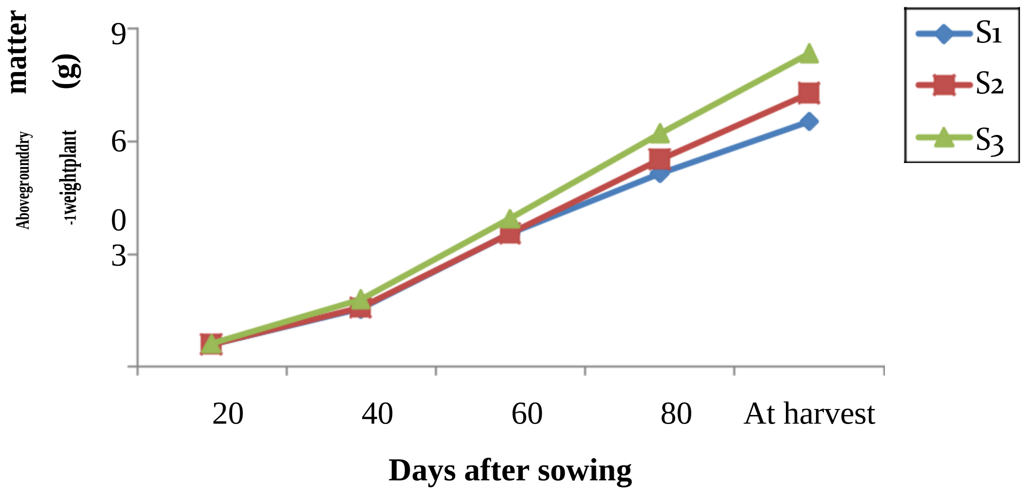
Treatment combinations	Plant height (cm) at different DAS				
	20	40	60	80	At harvest
S_1N_0	10.33 b	15.53 f	27.04 f	39.49 f	47.00 c
S_1N_1	10.80 ab	17.20 ef	30.00 ef	43.26 ef	49.30 bc
S_1N_2	12.07 ab	22.87 a-d	38.37 a-c	50.83a-e	53.40 a-c
S_1N_3	11.38 ab	21.97 b-d	36.88 bc	48.93 a-e	51.10 a-c
S_1N_4	11.03 ab	20.10 c-e	34.00 c-e	46.33 c-f	51.53 a-c
S_2N_0	10.87 ab	19.00 d-f	30.50 d-f	44.05 def	49.77 bc
S_2N_1	11.03 ab	20.07 c-e	33.30 c-f	45.66 c-f	52.63 a-c
S_2N_2	12.10 ab	24.07 a-c	40.90 ab	53.37 a-c	56.80 a-c
S_2N_3	11.93 ab	23.50 a-c	38.27 a-c	51.86 a-d	54.13 a-c
S_2N_4	11.40 ab	21.30 b-e	35.80 b-e	49.17 a-e	53.90 a-c
S_3N_0	11.53 ab	20.67 b-e	34.00 c-e	47.50 b-f	50.57 a-c
S_3N_1	11.77 ab	21.07 b-e	36.77 b-d	49.42 a-e	53.27 a-c
S_3N_2	12.87 a	26.33 a	43.50 a	56.70 a	60.10 a
S_3N_3	12.30 ab	24.57 ab	41.37 ab	55.43 ab	57.90 ab
S_3N_4	12.13 ab	23.37 a-c	38.40 a-c	51.27 a-e	56.83 a-c
LSD (0.05)	**2.18**	**4.22**	**6.31**	**8.33**	**10.12**
CV (%)	**11.16**	**11.68**	**10.43**	**10.12**	**11.29**

S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1
N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF+ additional 10kg N ha^{-1} at flower initiation stage

4.2 Above ground dry weight plant^{-1} (g)

4.2.1 Effect of biological strain

The above ground dry matter weight plant^{-1} of grasspea was significantly influenced by biological strains during all growth period except 20 and 60 DAS (Fig 3). Data revealed that the maximum above ground dry matter weight plant^{-1}(1.81, 6.21 and 8.35 g at 40, 80 DAS and harvest, respectively) was scored by treatment S_3, and the minimum above ground dry matter weight plant^{-1}(1.55, 5.16 and 6.53g at 40, 80 DAS and harvest, respectively) was scored by S_1 which was statistically similar with S_2 at 40, 80 DAS and harvest. Pramanik *et al*. (2014) and Bhattacharyya and Pal (2001) reported that biological strain significantly influenced the dry matter accumulation in mungbean. Hossain *et al*. (2014) and Nagarajan and Balachandar (2001) also reported that seed inoculation of *Rhizobium* enhanced biomass of Mungbean.

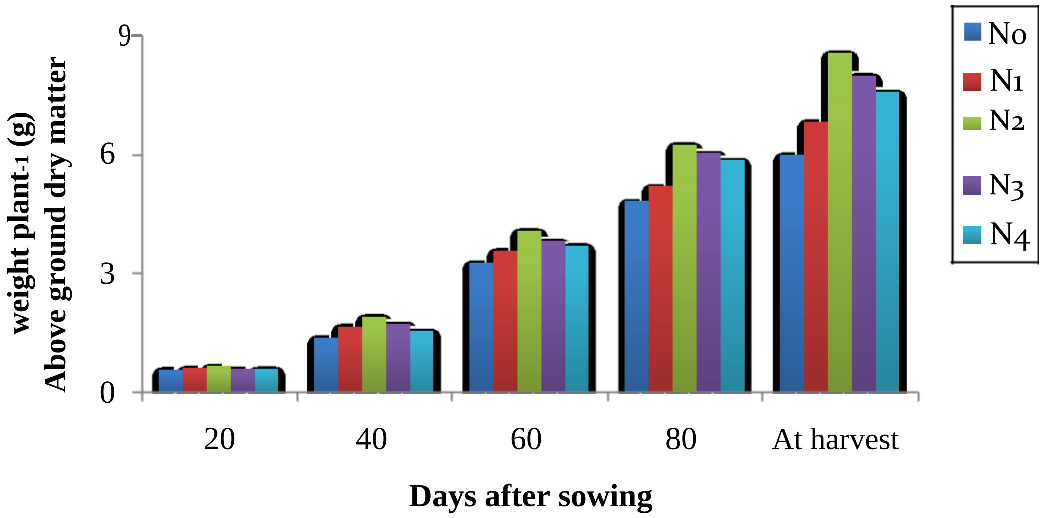


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 3. Effect of biological strain on the above ground dry matter weigh plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$=NS, 0.17, NS, 0.54 and 0.52 at 20, 40, 60, 80 DAS and harvest, respectively).

4.2.2 Effect of nitrogen levels

The above ground dry matter weight plant^{-1} of grasspea was significantly influenced by different nitrogen levels (Fig 4). Data revealed that the maximum above ground dry matter weight plant^{-1} (0.67, 1.91, 4.08, 6.24 and 8.56 g at 20, 40, 60, 80 DAS and harvest, respectively) was scored by treatment N_2 which was statistically similar with N_1 at 20 DAS; with N_3 at 60 DAS and harvest and with N_3 and N_4 at 80 DAS. The minimum above ground dry matter weight plant^{-1} (0.58, 1.38, 3.28, 4.82 and 5.99 g at 20, 40, 60, 80 DAS and harvest, respectively) was scored by treatment N_0 which was statistically similar with N_1, N_3 and N_4 at 20 DAS; with N_1 at 60 and 80 DAS. Kabir (2012) and Clark *et al.* (1980) observed that the dry matter accumulation increased with increase in levels of N at all growth stages. The split application of N fertilizer increased the rate of photosynthetic accumulation, leaf dry weight; stem dry weight which finally resulted in increased AGDM (above ground dry matter) production by plant at each stage of growth of plant. Razzaque *et al.* (2017) and Karmer (1988) revealed that, the accumulation of lower dry matter at N deficient conditions might be due to internal nutrient stress of plant which caused reduction in cell division, cell elongation, carbohydrate synthesis and hence the growth was reduced. These results agreed with Tonmoy (2015), Matsunaga *et al*. (2008), Mozumder *et al*. (2003), Akhtaruzzaman (1998), Agbenin *et al*. (1991) and Yein (1982).



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{5}40K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 4. Effect of nitrogen levels on the above ground dry matter weigh plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$=0.06, 0.17, 0.34, 0.57 and 0.82 at 20, 40, 60, 80 DAS and harvest, respectively).

4.2.3 Combined effect of biological strains and nitrogen levels

The above ground dry matter weight plant^{-1} of grasspea was significantly influenced by combined effect of biological strains (*Rhizobium)* and different doses of nitrogen (Table 2). Data revealed that the maximum above ground dry matter weight plant^{-1} (0.76, 2.13, 4.27, 7.00 and 9.40g at 20, 40, 60, 80 DAS and harvest, respectively) was scored by S_3N_2 which was statistically similar with S_3N_3 at 40 DAS; with S_3N_3, S_3N_4, S_3N_1, S_2N_2, S_1N_2 and S_1N_3 at 60 DAS; with S_3N_3, S_3N_4, S_2N_2 and S_2N_3 at 80 DAS and with S_3N_3, S_3N_4 and S_2N_2 at harvest. At 20 DAS, the minimum above ground dry matter weight plant^{-1} (0.57 g) was scored by S_1N_1 which was statistically similar with all the treatment combinations except S_3N_2. Again the minimum above ground dry matter weight plant^{-1} (1.30, 3.07, 4.50 and 5.10 g at 40, 60, 80 DAS and harvest, respectively) was scored by treatment combination S_1N_0 which was statistically similar with S_2N_0, S_1N_4, S_2N_4 and S_3N_0 at 40 DAS; with S_2N_0, S_1N_1, S_1N_4, S_2N_1, S_2N_3, S_2N_4 and S_3N_0 at 60 DAS; with S_2N_0, S_2N_1, S_1N_1, S_1N_3, S_1N_4 and S_3N_0 at 80 DAS and with S_2N_0 and S_1N_1 at harvest.

Table 2. Combined effect of biological strains and nitrogen levels on the above ground dry matter weight of grasspea at different DAS

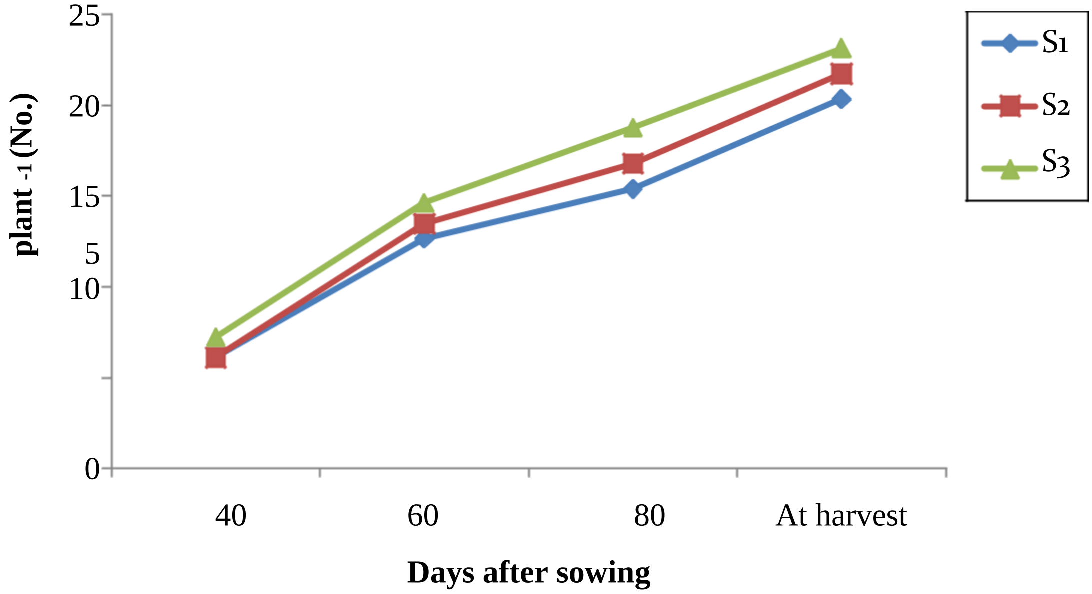
Treatment combinations	Dry matter weight (g plant^{-1}) at different DAS				
	20	40	60	80	At harvest
S_1N_0	0.60 b	1.30 g	3.07 d	4.50 g	5.10 h
S_1N_1	0.57 b	1.60 c-f	3.40 cd	5.07 e-g	6.13 f-h
S_1N_2	0.61 b	1.80 bc	4.03 ab	5.60 c-f	7.60 c-e
S_1N_3	0.59 b	1.60 c-f	3.80 a-c	5.33 d-g	6.90 d-g
S_1N_4	0.62 b	1.43 e-g	3.53 b-d	5.30 d-g	6.90 d-g
S_2N_0	0.56 b	1.33 fg	3.13 d	4.67 fg	5.67 gh
S_2N_1	0.62 b	1.63 b-e	3.47 b-d	5.00 e-g	6.60 e-g
S_2N_2	0.63b	1.80 bc	3.93 a-c	6.13 a-d	8.67 a-c
S_2N_3	0.61b	1.70 b-e	3.63 b-d	6.07 a-d	7.90 b-e
S_2N_4	0.58 b	1.47 e-g	3.57 b-d	5.73 b-e	7.57 c-e
S_3N_0	0.57 b	1.50 d-g	3.63 b-d	5.30 d-g	7.20 d-f
S_3N_1	0.65 b	1.77 b-d	3.87 a-c	5.53 d-f	7.73 c-e
S_3N_2	0.76 a	2.13 a	4.27 a	7.00 a	9.40 a
S_3N_3	0.59b	1.90 ab	4.00 ab	6.70 ab	9.17 ab
S_3N_4	0.58 b	1.77 b-d	4.00 ab	6.53 a-c	8.27 a-d
LSD (0.05)	**0.11**	**0.29**	**0.60**	**0.99**	**1.42**
CV (%)	**10.03**	**8.81**	**9.59**	**10.42**	**11.37**

S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1; N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

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

4.3.1 Effect of biological strain

Statistically significant variation was found in the branches plant^{-1} of grasspea due to application of different biological strain (Fig 5). The highest branches plant^{-1} (7.26, 14.64, 18.77 and 23.16 at 40, 60, 80 DAS and harvest, respectively) were recorded from S_3 treatment. At 40 DAS the lowest branches plant^{-1} (6.12) was recorded from S_2 treatment which was statistically at par with S_1. The lowest branches plant^{-1} (12.65, 15.39 and 20.35 at 60, 80 DAS and harvest, respectively) were recorded from S_1 treatment which were statistically at par with S_2 only at 60 DAS.

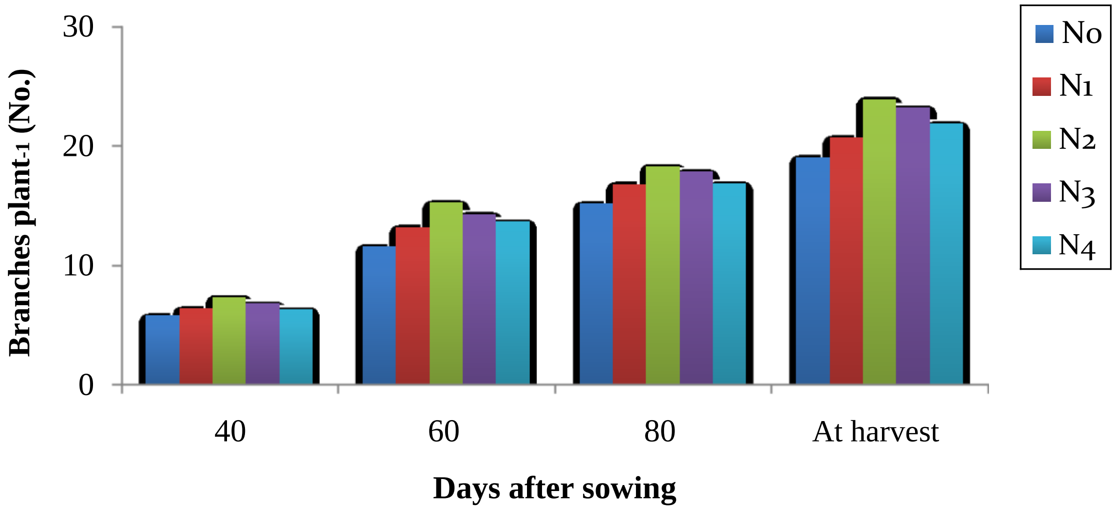


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 5. Effect of biological strain on the branches plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$= 0.49, 0.99, 1.25 and 1.21 at 40, 60, 80 DAS and harvest, respectively).

4.3.2 Effect of nitrogen levels

Statistically significant variation was found in the branches plant^{-1} of grasspea due to application of different doses of nitrogen (Fig 6). The highest branches plant^{-1} (7.32, 15.24, 18.31 and 23.92 at 40, 60, 80 DAS and harvest, respectively) were recorded from N_2 treatment which was statistically at par with N_3 and N_4 at 80 DAS and harvest. The lowest branches plant^{-1} (5.78, 11.60, 15.16 and 19.04 at 40, 60, 80 DAS and harvest, respectively) were recorded from N_0 treatment which was statistically at par with N_1 only at harvest. Similar results were noticed in mungbean by Tonmoy (2015), Achakzai *et al.* (2012) and Kabir (2012).



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{5}40K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 6. Effect of nitrogen levels on the branches plant^{-1} of grasspea at different days after sowing (LSD $_{(0.05)}$ =0.30, 0.52, 1.49 and 2.48 at 40, 60, 80 DAS and harvest, respectively).

4.3.3 Combined effect of biological strains and nitrogen levels

Statistically significant variation was found in the branches plant^{-1} of grasspea due to combined application of different biological strains and doses of nitrogen (Table 3). The highest branches plant^{-1} (8.23, 16.20, 20.47 and 25.80 at 40, 60, 80 DAS and harvest, respectively) was recorded from the treatment combination of S_3N_2which was statistically at par with S_3N_3, S_3N_1, S_3N_4, S_2N_2 and S_2N_3 at 80 DAS and with S_2N_2, S_3N_3, S_3N_4, S_2N_3, S_3N_1 and S_1N_3 at harvest. On the other hand, at 20 DAS the lowest branches plant^{-1} (5.13) recorded from S_2N_0 which was statistically at par with S_1N_0 . Again the lowest branches plant^{-1} (10.27, 13.73 and 17.43 at 60, 80 DAS and harvest, respectively) was recorded from S_1N_0which was statistically at par with S_2N_0, S_1N_4, S_1N_1, S_1N_3 and S_2N_1 at 80 DAS and with S_1N_1, S_1N_2, S_2N_0, S_2N_1, S_1N_4, S_3N_0 and S_2N_4 at harvest.

Table 3. Combined effect of biological strains and nitrogen levels on the branches plant^{-1} of grasspea at different DAS

Treatment combinations	No. of branches plant^{-1} at different DAS			
	40	60	80	At harvest
S_1N_0	5.53 ij	10.27 h	13.73 g	17.43 e
S_1N_1	5.93 hi	11.67 g	15.40 e-g	19.77 de
S_1N_2	6.87 b-e	14.47 b-d	16.40 c-f	21.37 b-e
S_1N_3	6.47 e-g	14.00 cd	16.13 d-g	22.60 a-d
S_1N_4	5.87 hi	12.87 ef	15.27 fg	20.60 b-e
S_2N_0	5.13 j	11.80 g	14.73 fg	19.90 c-e
S_2N_1	6.07 f-h	13.00 ef	16.20 d-g	20.00 c-e
S_2N_2	6.87 b-e	15.07 b	18.07 a-d	24.60 ab
S_2N_3	6.53 d-f	13.93 d	17.93 a-e	22.87 a-d
S_2N_4	6.00 g-i	13.67 de	17.07 b-f	21.27 b-e
S_3N_0	6.67 c-e	12.73 f	17.00 b-f	19.80 de
S_3N_1	7.07 bc	14.93 b	18.80 a-c	22.30 a-d
S_3N_2	8.23 a	16.20 a	20.47 a	25.80 a
S_3N_3	7.33 b	14.87 bc	19.47 ab	24.19 a-c
S_3N_4	7.00 b-d	14.47 b-d	18.13 a-d	23.72 a-d
LSD (0.05)	**0.53**	**0.91**	**2.58**	**4.30**
CV (%)	**4.82**	**3.95**	**9.02**	**11.74**

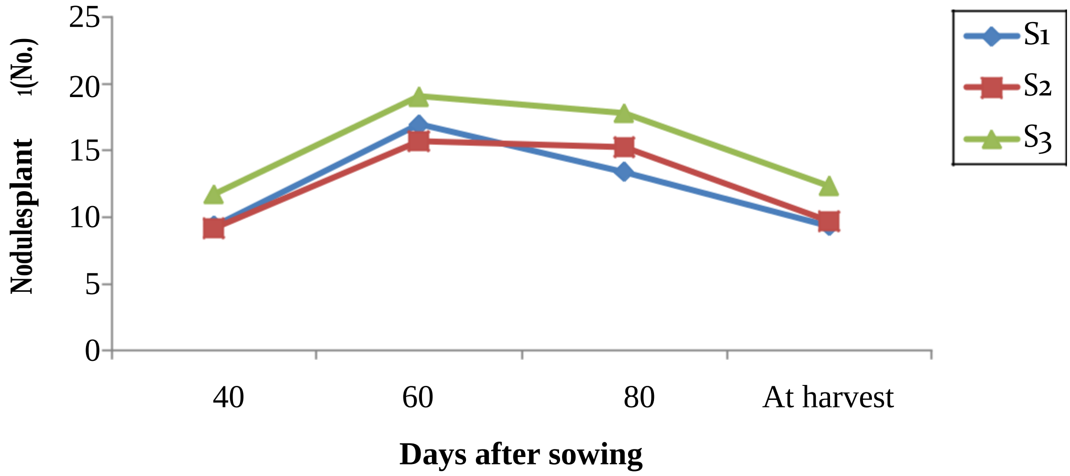
S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1; N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10 kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

4.4 Nodules plant^{-1} (No.)

4.4.1 Effect of biological strain

The nodules plant^{-1} of grasspea significantly differed due to the application of biological strains (Fig 7). The maximum nodules plant^{-1} (11.74, 19.08, 17.81

and 12.38 at 40, 60, 80 DAS and harvest, respectively) was received from treatment S_3 which was statistically similar with S_1 only at 60 DAS. The lowest nodules plant^{-1} (9.20 and 15.69 at 40 and 60 DAS, respectively) was received from treatment S_2 which was statistically similar with S_1 at 40 and 60 DAS. Again the lowest nodules plant^{-1} (13.41 and 9.33 at 80 DAS and harvest, respectively) was received from treatment S_1 which was statistically similar with S_2 only at harvest. Pramanik *et al.* (2014) and Chatterjee and Bhattacharjee (2002) reported that plants inoculated with *Rhizobium* strains and PSB showed increased rate of nodulation, N content and seed yield over control. Bhattacharyya and Pal (2001) reported that inoculation significantly influenced the number of nodules plant^{-1}.

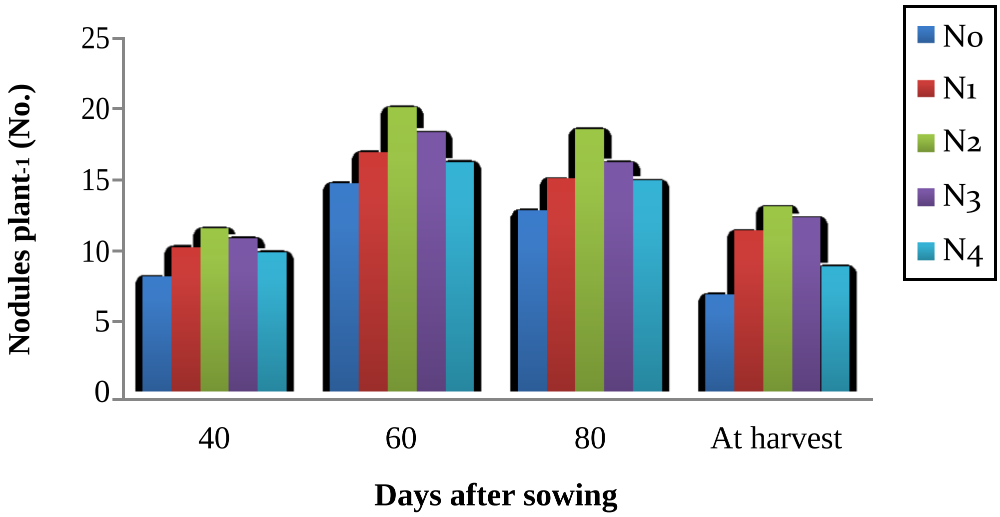


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 7. Effect of biological strain on the nodules plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$=2.31, 2.15, 1.70 and 0.88 at 40, 60, 80 DAS and harvest, respectively).

4.4.2 Effect of nitrogen levels

The nodules plant^{-1} of grasspea significantly differed due to the application of different nitrogen doses (Fig 8). The highest nodules plant^{-1} (11.50, 20.07, 18.53 and 13.07 at 40, 60, 80 DAS and harvest, respectively) was received from N_2 treatment which was statistically similar with N_3 only at harvest. The lowest nodules plant^{-1} (8.13, 14.71, 12.78 and 6.86 at 40, 60, 80 DAS and harvest, respectively) was received where no nitrogen was applied (N_0) which was statistically different from all the treatments except with N_4 at 60 DAS. Similar results were found in mungbean by Tonmoy (2015), Nursu‟aidah *et al.* (2014) and Kabir (2012).



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 8. Effect of nitrogen levels on the nodules plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$= 0.57, 1.72, 1.33 and 1.13 at 40, 60, 80 DAS and harvest, respectively).

4.4.3 Combined effect of biological strains and nitrogen levels

The nodules plant^{-1} of grasspea significantly differed due to the application of different biological strains and nitrogen doses (Table 4). The highest nodules plant^{-1} (13.33, 22.60, 20.33 and 14.57 at 40, 60, 80 DAS and harvest, respectively) were received from the treatment combination S_3N_2 which was statistically similar with S_3N_3 at 60 DAS; with S_3N_3 and S_2N_2 at 80 DAS and finally with S_3N_3 and S_3N_1 at harvest. The lowest nodules plant^{-1} (7.40 and 12.93 at 40 and 60 DAS, respectively) was received from treatment combination S_2N_0 which was statistically similar with S_1N_0 at 40 DAS and with S_1N_0, S_1N_4 and S_2N_4 at harvest. Again the lowest nodules plant^{-1} (10.47 and 5.60 at 80 DAS and harvest, respectively) was received from treatment combination S_1N_0 which was statistically similar with S_1N_1 and S_2N_0 at 80 DAS and with S_2N_0 and S_1N_4 at harvest. The results of my investigation was also supported by Tonmoy (2015) and Malik *et al.* (2014) who reported that combined application of biological strains and nitrogen increased the nodules plant^{-1} of mungbean.

Table 4. Combined effect of different biological strains and nitrogen levels on the nodules plant^{-1} of grasspea at different days after sowing

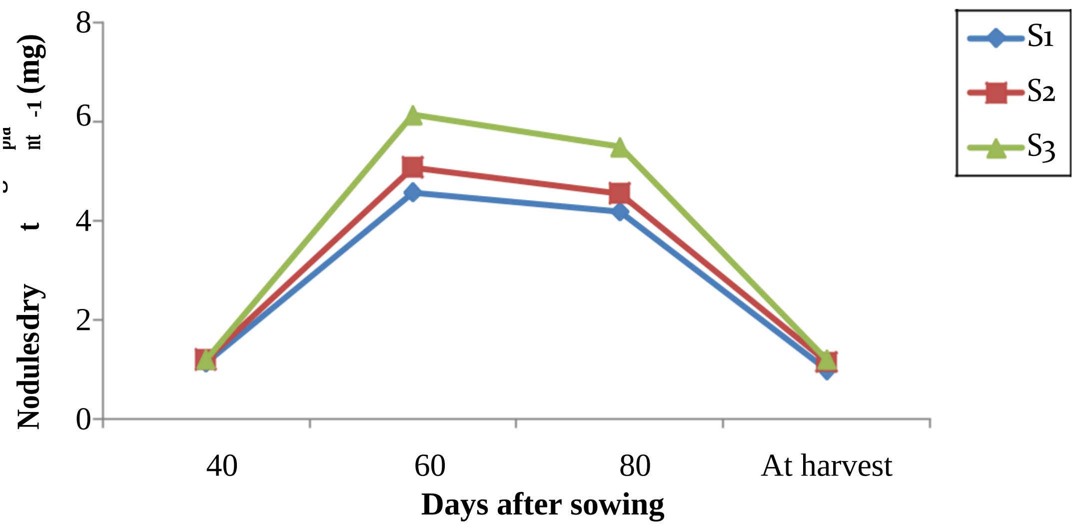
Treatment combinations	No. of nodules plant^{-1} at different DAS			
	40	60	80	At harvest
S_1N_0	7.73 h	14.93 ef	10.47 h	5.60 h
S_1N_1	9.00 fg	16.20 de	11.93 gh	9.87 ef
S_1N_2	10.77 cd	19.47 bc	16.67 b-e	12.23 b-d
S_1N_3	10.40 de	18.33 b-d	14.40 ef	11.70 c-e
S_1N_4	8.93 fg	15.87 d-f	13.60 fg	7.27 gh
S_2N_0	7.40 h	12.93 f	11.87 gh	6.63 gh
S_2N_1	9.47 e-g	16.20 de	15.93 c-e	10.39 de
S_2N_2	10.40 de	18.13 b-d	18.60 ab	12.40 bc
S_2N_3	9.87 d-f	16.80 c-e	15.40 c-f	11.47 c-e
S_2N_4	8.87 g	14.40 ef	14.47 d-f	7.77 g
S_3N_0	9.27 fg	16.27 de	16.00 c-e	8.33 fg
S_3N_1	12.17 b	18.33 b-d	17.27 bc	13.87 ab
S_3N_2	13.33 a	22.60 a	20.33 a	14.57 a
S_3N_3	12.20 b	19.80 ab	18.73 ab	13.67 ab
S_3N_4	11.73 bc	18.40 b-d	16.70 b-d	11.47 c-e
LSD (0.05)	**0.99**	**2.98**	**2.30**	**1.95**
CV (%)	**5.83**	**10.25**	**8.81**	**11.03**

S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1; N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

4.5 Nodules dry weight plant^{-1} (mg)

4.5.1 Effect of biological strain

The nodules dry weight plant^{-1} of grasspea varied significantly for the application of biological strains all the growth period except 40 DAS (Fig 9). The highest nodules dry weight plant^{-1} (6.13, 5.48 and 1.20 mg at 60, 80 DAS and harvest, respectively) was gained by S_3 treatment which was statistically similar with S_2 only at harvest. The lowest nodules dry weight plant^{-1} (4.57, 4.19 and 0.99 mg at 60, 80 DAS and harvest, respectively) was gained by treatment S_1 which was statistically similar with S_2 at 80 DAS.

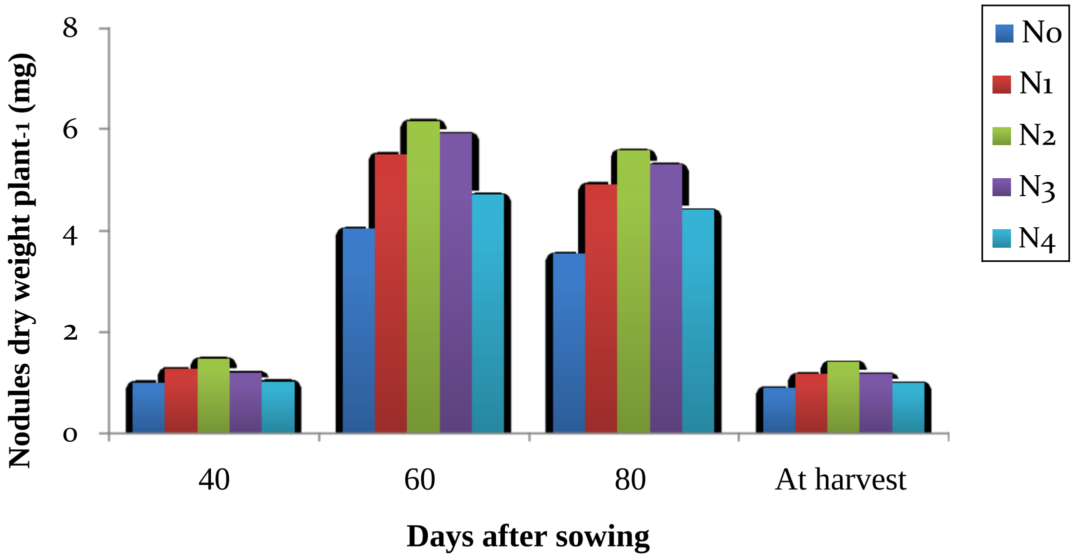


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 9. Effect of biological strain on the nodules dry weight plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$= NS, 0.49, 0.71 and 0.13 at 40, 60, 80 DAS and harvest, respectively).

4.5.2 Effect of nitrogen levels

The nodules dry weight plant^{-1} of grasspea varied significantly for the application of different nitrogen doses (Fig 10). The highest nodules dry weight plant^{-1} (1.46, 6.16, 5.57 and 1.39 mg at 40, 60, 80 DAS and harvest, respectively) was gained by N_2 treatment which was statistically similar with N_3 at 60 and 80 DAS. The lowest nodules dry weight plant^{-1} (0.99, 4.02, 3.53 and 0.88 mg at 40, 60, 80 DAS and harvest, respectively) was gained by N_0 treatment which was statistically different from all the treatments except with N_4 at 40 DAS and harvest. Kabir (2012) and Bachchhav *et al.* (1994) observed that nodule dry weight plant^{-1} was highest with 30 kg N ha^{-1} for mungbean.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 10. Effect of nitrogen levels on the nodules dry weight plant^{-1} of grasspea at different days after sowing ($LSD_{0.05}$= 0.10, 0.53, 0.49 and 0.10 at 40, 60, 80 DAS and harvest, respectively).

4.5.3 Combined effect of biological strains and nitrogen levels

The nodules dry weight plant^{-1} of grasspea varied significantly for the combined application of different biological strains and nitrogen doses (Table 5). At 40 DAS the highest nodules dry weight plant^{-1} (1.50 mg) was gained by both S_3N_2 and S_2N_2 treatment combinations which was statistically similar with S_1N_2. At 60 and 80 DAS the highest nodules dry weight plant^{-1} (6.83 and 6.20 mg, respectively) was gained by both S_3N_2 treatment combination which was statistically similar with S_3N_3 and S_3N_1 at 60 and 80 DAS. At harvest the highest nodules dry weight plant^{-1} (1.46 mg) was gained by S_2N_2 treatment combination which was statistically similar with S_3N_2, S_3N_3 and S_2N_1. At 40 DAS the lowest nodules dry weight plant^{-1} (0.93 mg) was gained by both S_1N_4 and S_3N_0 treatment combinations which was statistically similar with S_2N_0, S_2N_4, S_3N_4, S_1N_0 and S_1N_3. At 60, 80 DAS and harvest the lowest nodules dry weight plant^{-1} (3.20, 2.60 and 0.84 mg, respectively) was gained by S_1N_0 treatment combination which was statistically similar with S_1N_4 and S_2N_0 at 60 DAS; with S_2N_0, S_1N_4, S_1N_1, S_3N_0, S_2N_4 and S_1N_3 at harvest.

Table 5. Combined effect of different biological strains and nitrogen levels on the nodules dry weight of grasspea at different DAS

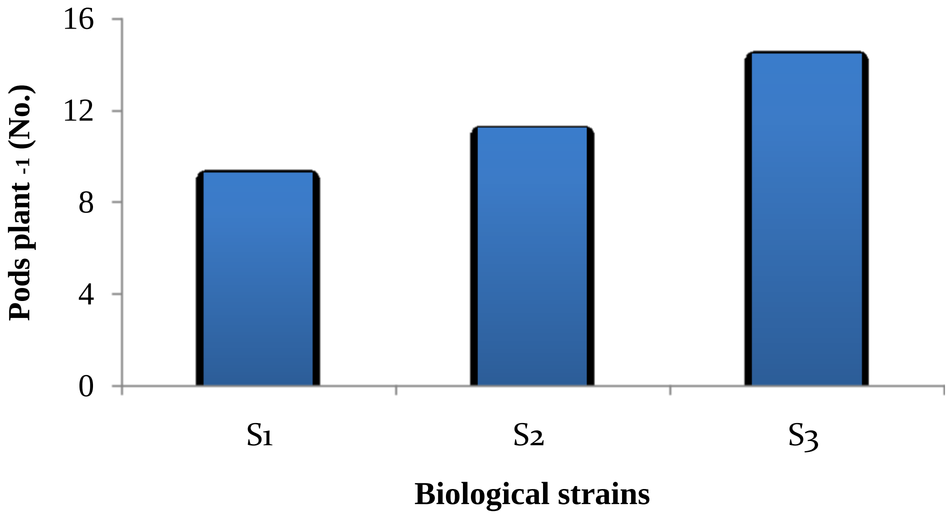
Treatment combinations	Nodule dry weight (g plant^{-1}) at different DAS			
	40	60	80	At harvest
S_1N_0	1.07 e-g	3.20 h	2.60 g	0.84 g
S_1N_1	1.23 b-e	4.93 ef	4.63 c-e	0.94fg
S_1N_2	1.37 ab	5.77 c-e	5.30 bc	1.27 b-d
S_1N_3	1.10 d-g	5.20 d-f	4.83 c-e	0.99 e-g
S_1N_4	0.93 g	3.73 gh	3.57 f	0.89 g
S_2N_0	0.97 g	3.97 gh	3.55 f	0.87 g
S_2N_1	1.33 bc	5.27 d-f	4.73 c-e	1.31 a-c
S_2N_2	1.50 a	5.87 b-d	5.20 cd	1.46 a
S_2N_3	1.20 c-f	5.80 c-e	4.93 c-e	1.15 c-e
S_2N_4	1.03 fg	4.50 fg	4.33 ef	0.94 fg
S_3N_0	0.93 g	4.90 ef	4.43 de	0.95 fg
S_3N_1	1.23 b-e	6.30 a-c	5.37 a-c	1.20 cd
S_3N_2	1.50 a	6.83 a	6.20 a	1.43 ab
S_3N_3	1.27 b-d	6.73 ab	6.10 ab	1.33a-c
S_3N_4	1.07 e-g	5.87 b-d	5.30 bc	1.11 d-f
LSD (0.05)	**0.17**	**0.91**	**0.84**	**0.18**
CV (%)	**8.45**	**10.28**	**10.56**	**9.56**

S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1; N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

4.6 Pods plant^{-1} (No.)

4.6.1 Effect of biological strain

Different biological strains showed significant difference in respect of pods plant^{-1} of grasspea (Fig 11). Among the different biological strain, S_3 scored the highest pods plant^{-1} (14.49) followed by S_2 (11.24). On the contrary, the lowest pods plant^{-1} (9.31) was scored by S_1. Nazmun *et al.* (2009) found the similar results in mungbean who reported that *Rhizobium* inoculums increased the pods plant^{-1} of mungbean.

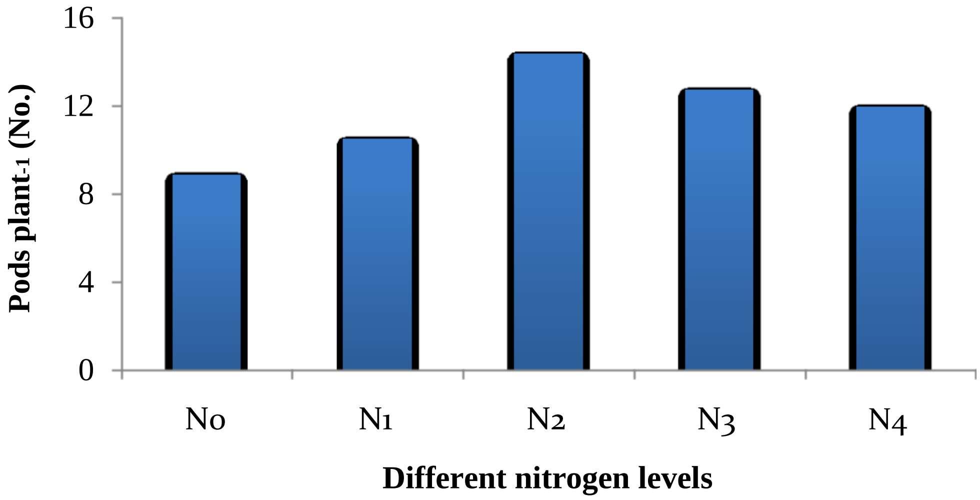


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig 11. Effect of biological strain on the pods plant^{-1} of grasspea ($LSD_{0.05}$=0.73).

4.6.2 Effect of nitrogen levels

Different nitrogen levels showed significant difference in respect of pods plant^{-1} of grasspea (Fig 12). Among the different nitrogen levels, N_2 scored the highest pods plant^{-1} (14.35) followed by N_3 (12.72) and N_4 (11.95). On the contrary, the lowest pods plant^{-1} (8.87) was scored by N_0. Optimum nitrogen restricted flower and pod dropping, which might have contributed to more pods plant^{-1} in our study. Razzaque *et al.* (2017) and Patra and Patel (1991) reported that pods plant^{-1} of mungbean increased with application of nitrogen fertilizer and excess application reduced pods plant^{-1} of mungbean. These results are in conformity with the findings of Tonmoy (2015), Kabir (2012), Anjum *et al*. (2006), Kulsum (2003), Ashraf (2001) and Nandan and Prasad (1998).



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 12. Effect of nitrogen levels on the pods plant^{-1} of grasspea ($LSD_{0.05}$=1.22).

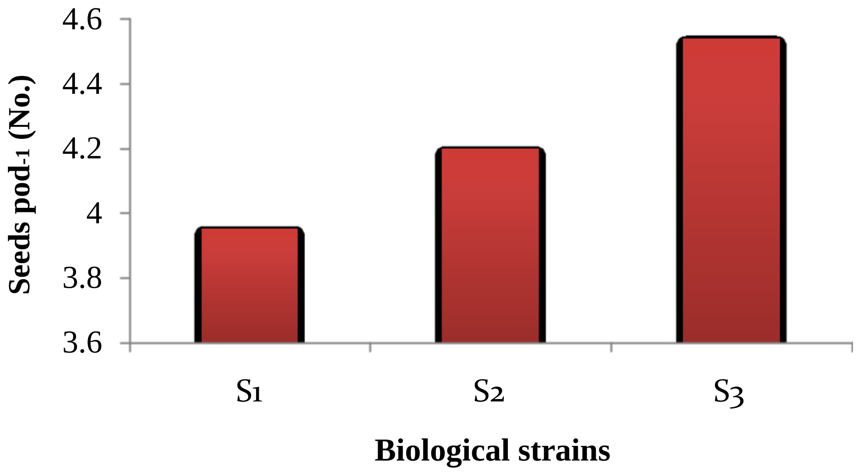
4.6.3 Combined effect of biological strains and nitrogen levels

Combined effect of different biological strains and nitrogen levels showed significant difference in respect of pods plant^{-1} of grasspea (Table 6). Among the treatment combinations, S_3N_2 scored the highest pods plant^{-1} (16.90) followed by S_3N_3 (14.96) and S_3N_4 (14.62). On the contrary, the lowest pods plant^{-1} (6.50) was scored by S_1N_0 which was statistically similar with S_2N_0 and S_1N_1.

4.7 Seeds pods^{-1} (No.)

4.7.1 Effect of biological strain

Seeds pod^{-1} of grasspea significantly varied due to biological strain difference (Fig 13). The findings revealed that, S_3 treatment gave the maximum seeds pod^{-1} (4.54) and the minimum one (3.95) was given by S_1.

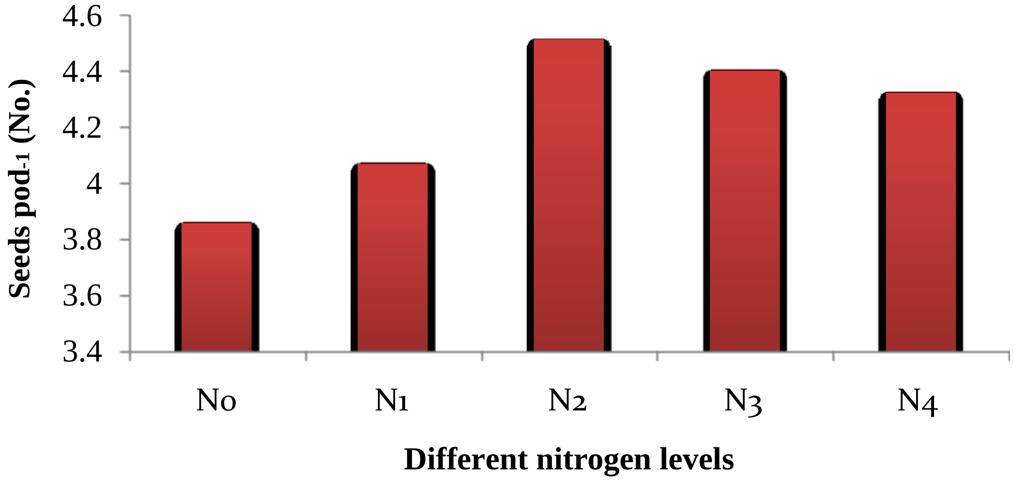


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig 13. Effect of biological strain on the seeds pods^{-1} of grasspea ($LSD_{0.05}$=0.20).

4.7.2 Effect of nitrogen levels

Seeds pod^{-1} of grasspea significantly varied due to different nitrogen levels (Fig 14). The findings revealed that, N_2 treatment gave the maximum seeds pod^{-1} (4.51) which was statistically similar with N_3 and N_4 and the minimum one (3.86) was given by N_0 which was statistically similar with N_1. This finding was supported by Tonmoy (2015), Kabir (2012), Mandal (2002) and Singh *et al.* (1993) who stated that application of nitrogen increased the seeds pod^{-1} of mungbean. Karle and Pawar (1998) reported that lentil seed production was higher with the application of 35 kg N ha^{-1} due to higher number of seeds pod^{-1}.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF+ additional 10kg N ha^{-1} at flower initiation stage

Fig. 14. Effect of nitrogen levels on the seeds $pods^{-1}$ of grasspea ($LSD_{0.05}$=0.32).

4.7.3 Combined effect of biological strains and nitrogen levels

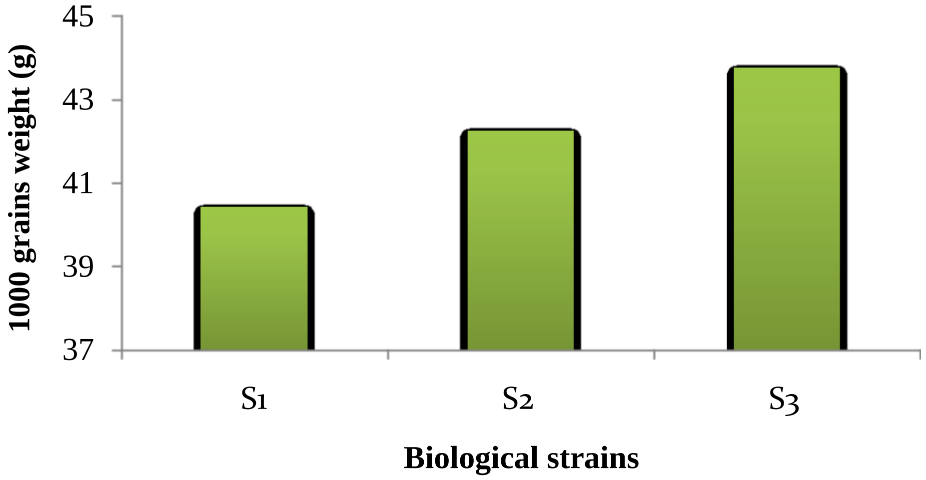
Seeds pod^{-1} of grasspea significantly varied due to combined effect of different biological strain and nitrogen levels (Table 6). The findings revealed that, S_3N_2 treatment combination gave the maximum seeds pod^{-1} (4.73) which was statistically similar with rest of the treatment combinations except S_1N_0, S_1N_1, S_2N_0, S_2N_1 and S_1N_4, and the minimum one (3.60) was given by S_1N_0 which was statistically similar with S_1N_1, S_2N_0, S_2N_1 and S_1N_4.

4.8 1000-seed weight (g)

4.8.1 Effect of biological strain

Different biological strains showed significant variations in respect of 1000-grains weight of grasspea (Fig 15). The maximum 1000-grains weight (43.76

g) was recorded from S_3 treatment followed by S_2 (42.25 g) and the minimum 1000-grains weight (40.42 g) was recorded from S_1 treatment followed by S_2 treatment (42.25 g).

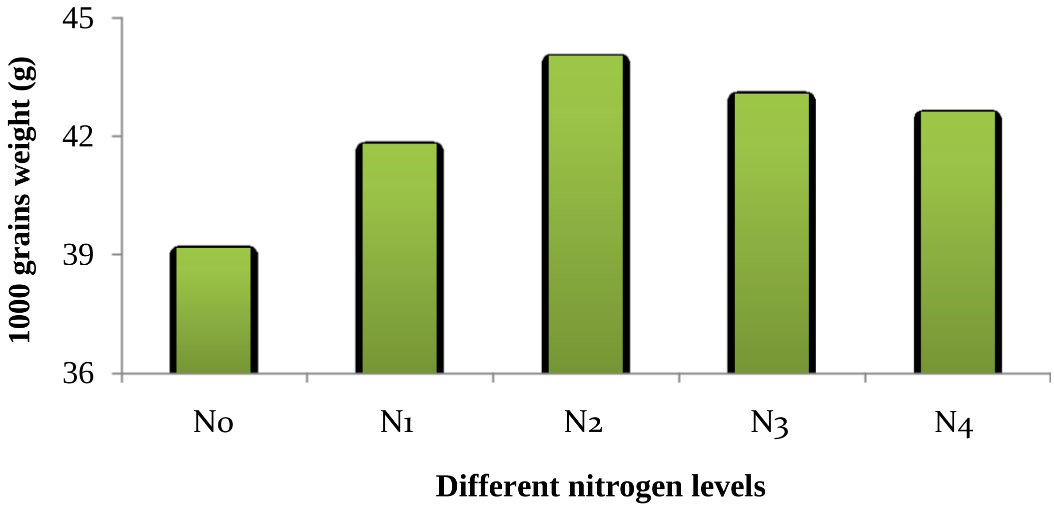


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 15. Effect of biological strain on the 1000 seed weight of grasspea ($LSD_{0.05}$=2.33).

4.8.2 Effect of nitrogen levels

Different nitrogen levels showed significant variations in respect of 1000-grains weight of grasspea (Fig 16). The maximum 1000-grains weight (44.03 g) was recorded from N_2 treatment followed by N_3 (43.08 g), N_4 (42.61 g) and N_1 (41.81 g) and the minimum 1000-grains weight (39.18 g) was recorded from N_0 treatment followed by N_1 (41.81 g), N_4 (42.61 g) and N_3 (43.08 g). Tonmoy (2015), Kabir (2012), Mahboob and Asghar (2002) and Sardana and Varma (1987) revealed that the application of nitrogen fertilizer was significantly increased the 1000-seed weight of mungbean.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{5}40K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF+ additional 10kg N ha^{-1} at flower initiation stage

Fig. 16. Effect of nitrogen levels on the 1000 seed weight of grasspea ($LSD_{0.05}$=4.13).

4.8.3 Combined effect of biological strains and nitrogen levels

Combined effect of different biological strains and nitrogen levels showed significant variations in respect of 1000-grains weight of grasspea (Table 6). The maximum 1000-grains weight (45.53 g) was recorded from S_3N_2 treatment combination which showed similarity with all the treatment combinations except S_1N_0 and the minimum 1000-grains weight (37.26 g) was recorded from S_1N_0 treatment combination which showed similarity with all the treatment combinations except S_3N_3 and S_3N_2.

Table 6. Combined effect of different biological strains and nitrogen levels on the yield contributing characteristics of grasspea

Treatment combinations	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	1000-grain weight (g)
S_1N_0	6.50 i	3.60 e	37.26 b
S_1N_1	8.27 g-i	3.63 e	40.00 ab
S_1N_2	11.96 de	4.20 a-d	42.87 ab
S_1N_3	10.20 e-g	4.23 a-d	41.27 ab
S_1N_4	9.60 f-h	4.10b-e	40.70 ab
S_2N_0	7.83 hi	3.73 de	39.63 ab
S_2N_1	9.50 gh	4.00 c-e	42.00 ab
S_2N_2	14.20 bc	4.60 ab	43.70 ab
S_2N_3	13.01 b-d	4.37 a-c	43.17 ab
S_2N_4	11.63 d-f	4.30 a-c	42.77 ab
S_3N_0	12.27 c-e	4.23 a-d	40.67 ab
S_3N_1	13.69 b-d	4.57 ab	43.43 ab
S_3N_2	16.90 a	4.73 a	45.53 a
S_3N_3	14.96 ab	4.60 ab	44.80 a
S_3N_4	14.62 b	4.57 ab	44.35 ab
LSD (0.05)	**2.12**	**0.55**	**7.15**
CV (%)	**11.35**	**7.73**	**10.06**

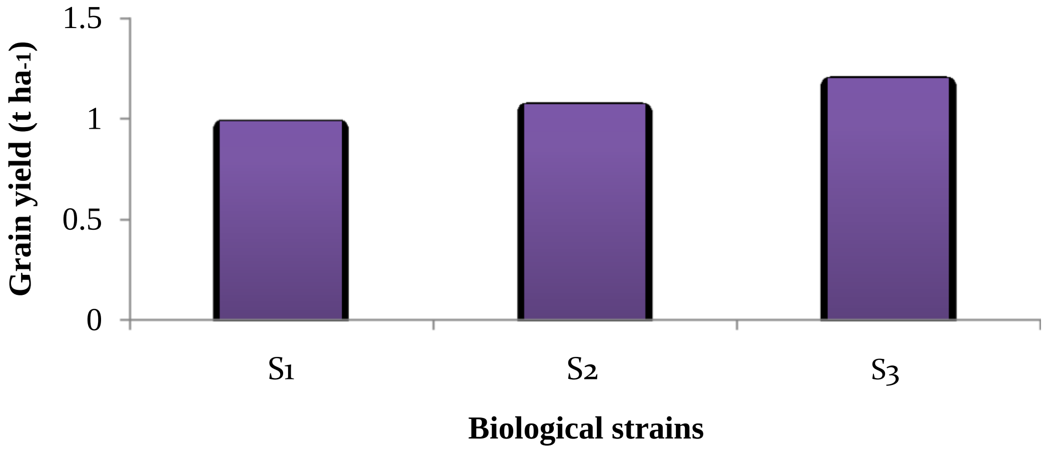
S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1; N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

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

4.9.1 Effect of biological strain

Grain yield of grasspea was significantly differed due to the application of biological strains (Fig 17). The result of the investigation revealed that the maximum grain yield (1.20 t ha^{-1}) was recorded where both biological strains BARI RLs 10 and BARI RLs 11 (S_3) were applied followed by S_2 (1.07 t ha^{-1}).

On the other hand the minimum grain yield (0.99 t ha^{-1}) was recorded where biological strain BARI RLs 10 (S_1) was applied. S_3 produced 21.21% more grain over S_1 and 12.15% more grain over S_2. Introduction of efficient strains of *Rhizobium* in soils with low nitrogen may help augment nitrogen fixation and thereby boost production of crops (Khan *et al*., 2017 and Bhat *et al*., 2013). *Rhizobium* association has been extensively explored in the root nodules of legumes where they fix atmospheric nitrogen. *Rhizobium* inoculation increased the root nodulation through better root development and more nutrient availability, resulting in vigorous plant growth and dry matter production which resulted in better flowering, fruiting and pod formation and ultimately there was beneficial effect on seed yield (Sardana *et al*., 2006). Pramanik *et al*. (2014) and Franco (1978) revealed that *Rhizobium* strains in association with the host plant were able to fix approximately 20% atmospheric nitrogen throughout the world annually. *Bradyrhizobium* inoculation increased mungbean seed yield from 4.3% to 16.2%. In Bangladesh, inoculation with increased 57% effective nodules, 77% dry matter production, 64% grain yield and 40% hay yield over un inoculated control in mungbean cultivation (Chanda *et al.,* 1991). Similar results were observed in mungbean by Tonmoy (2015), Hossain*et al.* (2014), Malik *et al.* (2014) and Nadeem *et al*. (2004)who concluded that the application of fertilizer with inoculated seed significantly increased the seed yield of mungbean.

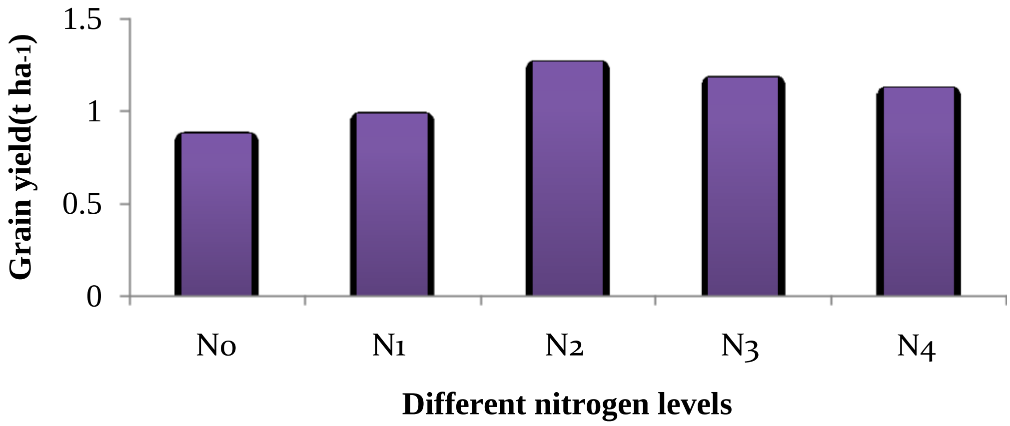


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 17. Effect of biological strain on the seed yield of grasspea ($LSD_{0.05}$=0.05).

4.9.2 Effect of nitrogen levels

Grain yield of grasspea was significantly differed due to the application of different nitrogen levels (Fig 18). The result of the investigation revealed that the maximum grain yield (1.26 t ha^{-1}) was recorded where 10kg N ha^{-1} + RF (N_2) was applied followed by N_3 (1.18 t ha^{-1}). On the other hand, the minimum grain yield (0.88 t ha^{-1}) was recorded where no fertilizer was applied (N_0) followed by N_1 (0.98 t ha^{-1}). N_2 produced 43.18% more grain over N_0 and 28.57% more grain over N_1. Nitrogen fertilizer, being the primary source of plant nutrition, is among the 17 elements needed for plant growth and development. In plants, nitrogen is associated with chlorophyll where process of photosynthesis takes place. Moreover, nitrogen is important in all phases of plant growth. Hence, ensuring its availability to plant in proper quantity is required to optimize yield. Nitrogen is an essential primary plant nutrient required in large quantity. Its deficiency leads to significant reduction in plant growth and yield components (Fan *et al.*, 2019 and Gojon, 2017). Smart N management practices are required for better crop growth, development and yield. Young plants find their initial nitrogen requirements through soil mineral nitrogen. After nodules have been established, N fixation succeeds to assimilation, reaches peak at pod developing stage and declines thereafter. Later, most of the seed filling is achieved by the redistribution of N from vegetative plant organs to the developing seeds. The beneficial effect of applied nitrogen is to retained more leaf area causing accelerated photosynthetic rate which led to more dry matter production and consequently higher yield obtained (Sushant *et al.*, 1999 and Dahatonde and Nalamwar, 1996). Patra and Bhattacharyya (1997) observed that the highest seed yield was obtained by applied urea at the rate of 25 kg N ha^{-1}. Mahboob and Asghar (2002) and Ashraf (2001) stated that there was general trend of increase in seed yield with the increase of N fertilizer but it was at par with 60 kg N ha^{-1} and thereafter decreased the seed yield of mungbean. These findings was agreed with Biswas and Hamid (1989) and Mitra and Ghildiyal (1988) that seed yield of mungbean is increased with increased nitrogen supply up to a limit and then decreased with increased further supplying of nitrogen. Similar results were observed in mungbean by Razzaque *et al.* (2017), Tonmoy (2015), Azadi *et al.* (2013) and Saini and Thakur (1996); in green gram by Kabir (2012) and Sarkar and Banik (1991).



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

Fig. 18. Effect of nitrogen levels on the Grain yield of grasspea ($LSD_{0.05}$=0.12).

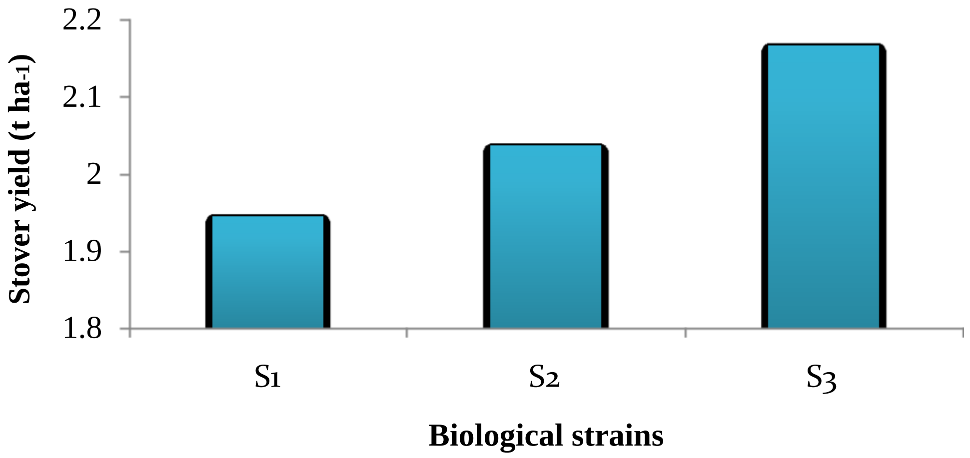
4.9.3 Combined effect of biological strains and nitrogen levels

Grain yield of grasspea was significantly differed due to the combined application of biological strains and different nitrogen levels (Table 7). The result of the investigation revealed that the maximum grain yield (1.34 t ha^{-1}) was recorded where both biological strains BARI RLs 10 and BARI RLs 11 (S_3) along with 10kg N ha^{-1} + RF (N_2) were applied which was statistically similar with S_2N_2, S_2N_3, S_3N_3, S_3N_4, S_3N_1 and S_1N_2. On the other hand the minimum grain yield (0.75 t ha^{-1}) was recorded where biological strain BARI RLs 10 (S_1) along with no fertilizer (N_0) was applied which was statistically similar with S_2N_0 and S_1N_1. Treatment combination S_3N_2 produced 78.67% more grain over S_1N_0. Tonmoy (2015) and Malik *et al.* (2014) found that the combined application of *Rhizobium,* compost and 75% of the recommended mineral nitrogen (RMN) gave the maximum grain yield of mungbean.

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

4.10.1 Effect of biological strain

Different biological strains showed significant variations in respect of stover yield of grasspea (Fig 19). Among the biological strains, S_3 showed the highest stover yield (2.17 t ha^{-1}), and S_1 showed the lowest stover yield (1.95 t ha^{-1}) which was statistically similar with S_2. Tonmoy (2015), Hossain *et al*. (2014), Nazmun *et al.* (2009) and Hossain (2004) reported that stover yields increased significantly due to inoculation of the seeds with *Rhizobium* strains.

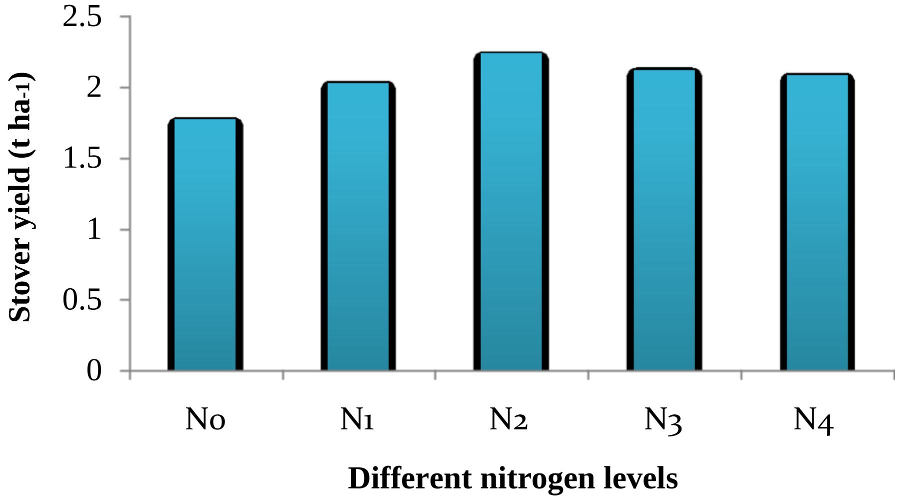


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 19. Effect of biological strain on the stover yield of grasspea ($LSD_{0.05}$=0.11).

4.10.2 Effect of nitrogen levels

Significant variation was observed on the stover yield of grasspea when different doses of nitrogen were applied (Fig 20). The highest stover yield of grasspea (2.24 t ha^{-1}) was recorded in N_2, which was statistically similar with rest of the treatment except N_0. The lowest stover yield (1.77 t ha^{-1}) was recorded in the N_0 treatment where no nitrogen was applied. The findings of our study was also similar with the findings of Tonmoy (2015), Rajender *et al*. (2003) and Srinivas *et al.* (2002) who found that nitrogen increased the stover yield of mungbean. Kabir (2012), and Arya and Kalra (1988) also reported that application of N at the rate of 50 kg ha^{-1} along with 50 kg P_2O_5 ha^{-1} increased lentil stover yield.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF+ additional 10kg N ha^{-1} at flower initiation stage

Fig. 20. Effect of nitrogen levels on the stover yield of grasspea ($LSD_{0.05}$=0.23).

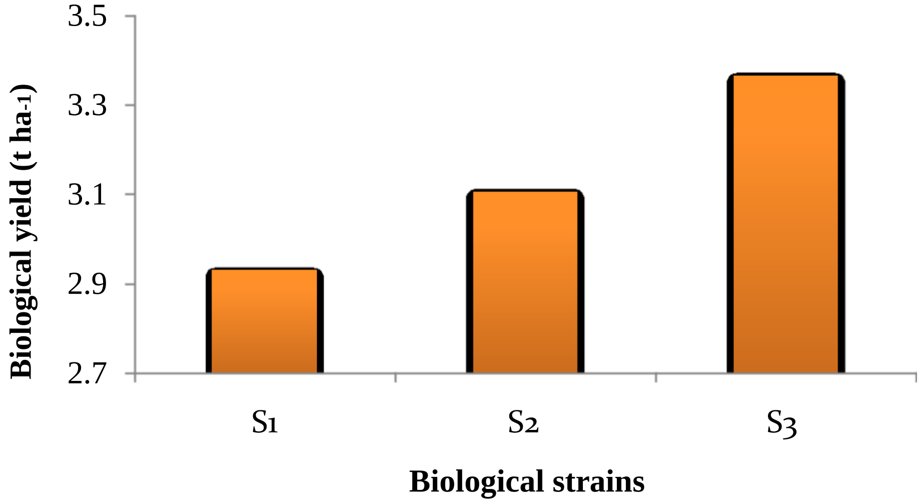
4.10.3 Combined effect of biological strains and nitrogen levels

Combined effect of different biological strains and nitrogen levels showed significant variations in respect of stover yield of grasspea (Table 7). Among the treatment combinations, S_3N_2 showed the highest stover yield (2.30 t ha^{-1}) which was statistically similar with rest of the treatment combinations except S_1N_0 and S_2N_0 and treatment combination S_1N_0 showed the lowest stover yield (1.65 t ha^{-1}) which was statistically similar with S_2N_0, S_1N_1, S_1N_3, S_1N_4, S_2N_1 and S_3N_0.

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

4.11.1 Effect of biological strain

Statistically significant variation was found in the biological yield of grasspea due to application of different biological strains (Fig 21). The highest biological yield (3.37 t ha^{-1}) was obtained from S_3 treatment and the lowest biological yield (2.93 t ha^{-1}) was obtained from S_1 treatment.

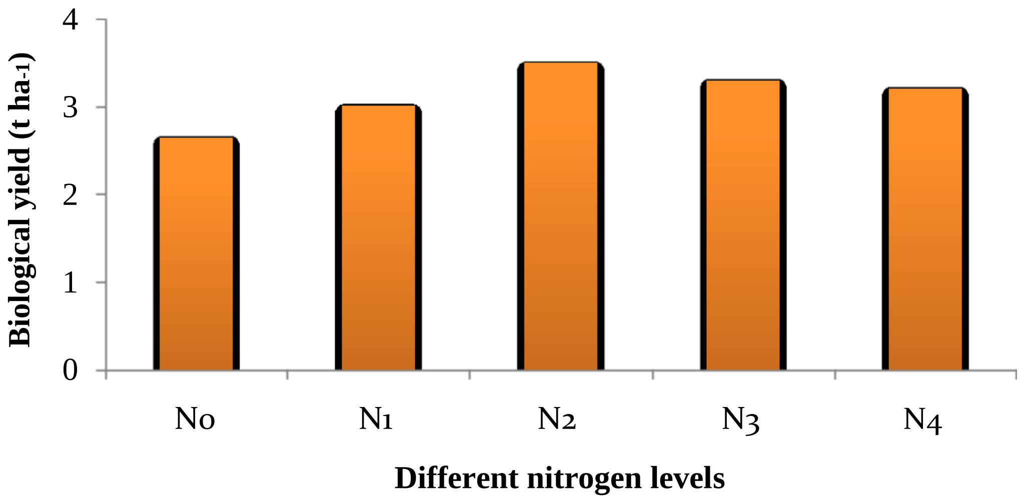


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 21. Effect of biological strain on the biological yield of grasspea ($LSD_{0.05}$=0.09).

4.11.2 Effect of nitrogen levels

Statistically significant variation was found in the biological yield of grasspea due to application of different doses of nitrogen (Fig 22). The highest biological yield (3.50 t ha^{-1}) was recorded from N_2 treatment which was statistically at par with N_3 and N_4 while the lowest biological yield (2.65 t ha^{-1}) was recorded from N_0 treatment which was statistically differed from other treatments. The findings was also coincided with the findings of Tonmoy (2015) and Malik *et al.* (2014) who found that biological yield increased by the addition of compost, mineral N and *Rhizobium* inoculums.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF+ additional 10kg N ha^{-1} at flower initiation stage

Fig. 22. Effect of nitrogen levels on the biological yield of grasspea ($LSD_{0.05}$=0.29).

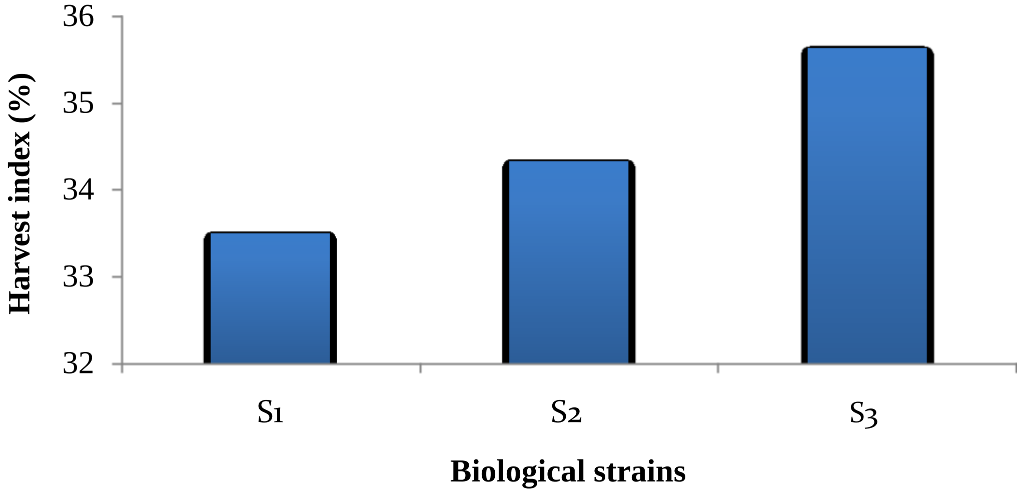
4.11.3 Combined effect of biological strains and nitrogen levels

Statistically significant variation was found in the biological yield of grasspea due to combined application of different biological strains and doses of nitrogen (Table 7). The highest biological yield (3.64 t ha^{-1}) was recorded from the treatment combination of S_3N_2 which was statistically similar with S_2N_2, S_3N_3, S_3N_4, S_2N_3, S_3N_1, S_2N_4 and S_1N_2, while the lowest biological yield (2.40 t ha^{-1}) was recorded from the treatment combination of S_1N_0 which was statistically similar with S_2N_0 and S_1N_1.

4.12 Harvest index (%)

4.12.1 Effect of biological strain

Harvest index of grasspea was not significantly influenced by different biological strains (Fig 23). Numerically the maximum and minimum harvest index (35.63 and 33.50%) was produced by S_3 and S_1 treatments, respectively.

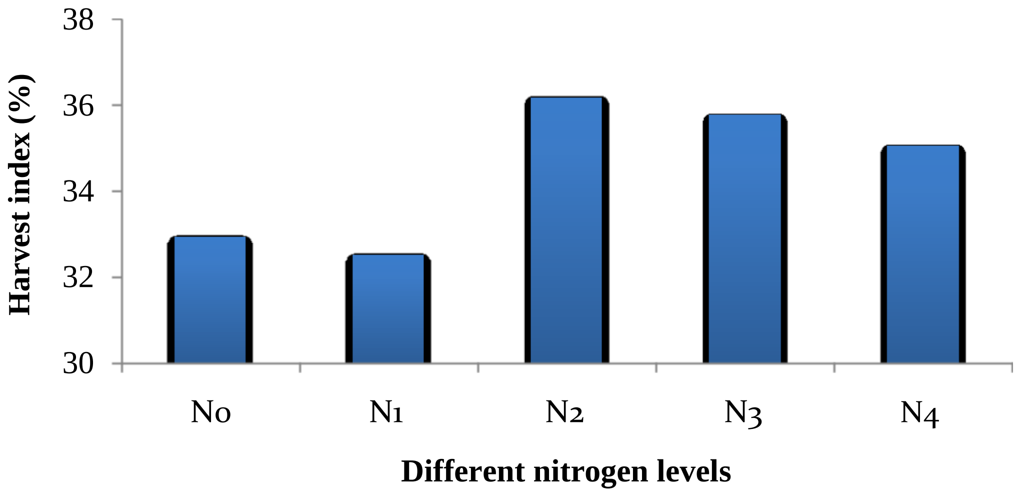


S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11

Fig. 23. Effect of biological strain on the harvest index of grasspea ($LSD_{0.05}$ =NS).

4.12.2 Effect of nitrogen levels

Harvest index of grasspea was significantly influenced by different levels of nitrogen (Fig 24). The result showed that the maximum harvest index (36.18%) was recorded from N_2 treatment which was statistically similar with N_3, N_4 and N_0 and the minimum harvest index (32.51%) was recorded from N_1 treatment which was statistically similar with rest of the treatment except N_2.



N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF+ additional 10kg N ha^{-1} at flower initiation stage

Fig. 24. Effect of nitrogen levels on the harvest index of grasspea ($LSD_{0.05}$ =3.29).

4.12.3 Combined effect of biological strains and nitrogen levels

Harvest index of grasspea was significantly influenced by combined effect of biological strains and different levels of nitrogen (Table 7). The result showed that the maximum harvest index (36.87%) was recorded from S_3N_2 treatment combination which was statistically similar with all the treatment combinations except S_1N_1, and the minimum harvest index (30.25%) was recorded from S_1N_1 treatment combination which was statistically similar with rest of the treatment combinations except S_1N_2 and S_3N_2.

Table 7. Combined effect of different biological strains and nitrogen levels on the yield characteristics of grasspea

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1N_0	0.75 h	1.65 b	2.40g	31.24 ab
S_1N_1	0.84 f-h	1.95 ab	2.79e-g	30.25 b
S_1N_2	1.18 a-d	2.11 a	3.30a-e	35.98 a
S_1N_3	1.12 b-e	2.02 ab	3.13b-e	35.65 ab
S_1N_4	1.04 d-f	1.99 ab	3.03c-e	34.37 ab
S_2N_0	0.82 gh	1.67 b	2.49fg	33.02 ab
S_2N_1	0.95 e-g	1.99 ab	2.94d-f	32.31 ab
S_2N_2	1.27 ab	2.29 a	3.56ab	35.69 ab
S_2N_3	1.18 a-d	2.13 a	3.31a-d	35.73 ab
S_2N_4	1.13 b-e	2.11 a	3.24 a-e	34.90 ab
S_3N_0	1.06c-e	2.01 ab	3.06b-e	34.54 ab
S_3N_1	1.16 a-d	2.15 a	3.31a-d	34.96 ab
S_3N_2	1.34 a	2.30 a	3.64a	36.87 a
S_3N_3	1.24 a-c	2.22 a	3.46a-c	35.93 ab
S_3N_4	1.20 a-d	2.15 a	3.36a-d	35.88 ab
LSD (0.05)	**0.20**	**0.39**	**0.51**	**5.70**
CV (%)	**10.93**	**11.33**	**9.64**	**9.80**

S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 1; N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November, 2018 to March, 2019 to investigate the effect of biological strains and different levels of nitrogen on the growth and yield of grasspea. The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors split plot design. Factor A: Biological strains (*Rhizobium* inoculums) (3); S_1: BARI RLs 10, S_2: BARI RLs 11and S_3: BARI RLs 10 + BARI RLs 11 and factor B: Nitrogen levels (5); N_0: No fertilizers, N_1: Recommended Fertilizers (RF) ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}), N_2: 10kg N ha^{-1} + RF, N_3: 30 kg N ha^{-1} + RF and N_4: RF + additional 10kg N ha^{-1} at flower initiation stage. The variety, BARI Khesari-2 was used in this experiment as the test crop. There were 15 treatment combinations. The total numbers of unit plots were 45. The size of unit plot was 3.00 m^2 (2.00 m × 1.50 m). N, P_2O_5, K_2O, S and Bwere applied during the final land preparation at the rate of 20 kg ha^{-1}, 40 kg ha^{-1}, 20 kg ha^{-1}, 20 kg ha^{-1} and 1 kg ha^{-1}, respectively following BARI recommendation. Data on different yield contributing characters and yield were recorded to find out the suitable *Rhizobium* strains and optimum rate of nitrogen for the highest yield of grasspea.

Different growth yield and yield contributing parameters were significantly influenced by different *Rhizobium* strains. The highest plant height (55.73 cm), above ground dry matter content plant^{-1} (8.35 g), branches plant^{-1} (23.16), nodules plant^{-1} (19.08), nodules dry weight plant^{-1} (6.13 mg), pods plant^{-1} (14.49), seeds pod^{-1} (4.54), 1000-grain weight (43.76 g), grain yield (1.20 t ha^{-1}), stover yield (2.17 t ha^{-1}) and biological yield (3.37 t ha^{-1}) was recorded from treatment BARI RLs 10 + BARI RLs 11 (S_3), and the lowest plant height (50.47

cm), above ground dry matter content plant^{-1} (6.53 g), branches plant^{-1} (20.35), nodules plant^{-1} (9.33), nodules dry weight plant^{-1} (0.99 mg), pods plant^{-1} (9.31), seeds pod^{-1} (3.95), 1000 grain weight (40.42 g), grain yield (0.99 t ha^{-1}), stover yield (1.95 t ha^{-1}) and biological yield (2.93 t ha^{-1}) was recorded from treatment BARI RLs 10 (S_1).

Different growth yield and yield contributing parameters were significantly influenced by different rate of nitrogen. The highest plant height (56.77 cm), above ground dry matter content plant^{-1} (8.56 g), branches plant^{-1} (23.92), nodules plant^{-1} (20.07), nodules dry weight plant^{-1} (6.16 mg), pods plant^{-1} (14.35), seeds pod^{-1} (4.51), 1000-grain weight (44.03 g), grain yield (1.26 t ha^{-1}), stover yield (2.24 t ha^{-1}), biological yield (3.50 t ha^{-1}) and harvest index (36.18%) was recorded from treatment 10kg N ha^{-1} + RF (N_2) and the lowest plant height (49.11 cm), above ground dry matter content plant^{-1} (5.99 g), branches plant^{-1} (19.04), nodules plant^{-1} (14.71), nodules dry weight plant^{-1} (4.02 mg), pods plant^{-1} (8.87), seeds pod^{-1} (3.86), 1000 grains weight (39.18 g), grain yield (0.88 t ha^{-1}), stover yield (1.77 t ha^{-1}) and biological yield (2.65 t ha^{-1}) was recorded from no fertilizer or control treatment (N_0). Again the lowest harvest index (32.51%) was recorded from RF ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}) ($N_1$).

Different growth yield and yield contributing parameters were significantly influenced by the combined application of *Rhizobium* strains and different nitrogen levels. The highest plant height (60.10 cm), above ground dry matter content plant^{-1} (9.40 g), branches plant^{-1} (25.80), nodules plant^{-1} (22.60), nodules dry weight plant^{-1} (6.83 mg), pods plant^{-1} (16.90), seeds pod^{-1} (4.73), 1000-grain weight (45.53 g), grain yield (1.34 t ha^{-1}), stover yield (2.30 t ha^{-1}), biological yield (3.64 t ha^{-1}) and harvest index (36.87%) was recorded from combined application of BARI RLs 10 + BARI RLs 11 (S_3) along with 10kg N ha^{-1} + RF (N_2), and the lowest plant height (47.00 cm), above ground dry matter content plant^{-1} (5.10 g), branches plant^{-1} (17.43), nodules dry weight plant^{-1} (3.20 mg), pods plant^{-1} (6.50), seeds pod^{-1} (3.60), 1000 grains weight (37.26 g), grain yield (0.75 t ha^{-1}), stover yield (1.65 t ha^{-1}) and biological yield (2.40 t ha^{-1}) was recorded from .The lowest nodules $plant^{-1}$ (12.93) was recorded from combined application of biological strain BARI RLs 11 (S_2) along with no fertilizer (N_0). Again the lowest harvest index (30.25 %) was recorded from combined application of biological strain BARI RLs 10 (S_1) along with RF ($N_{20}P_2O_{540}K_2O_{20}S_{20}B_1$(kg ha^{-1}) (N_1).

The results in this present piece of work indicated that the plants performed better in respect of seed yield in S_3N_2 treatment than the control treatment (S_1N_0). It can be therefore, concluded from these investigation that the combined application of BARI RLs 10 + BARI RLs 11 (S_3) along with 10kg N ha^{-1} + RF (N_2) was found to be the most suitable combination treatment for the highest yield of grasspea in AEZ 28 soils of Bangladesh.

However, to reach a specific conclusion and recommendation, more research work on grasspea under these treatment variables should be done in different Agro-ecological zones of Bangladesh to fit in cropping system for rich diet and improve the soil health.

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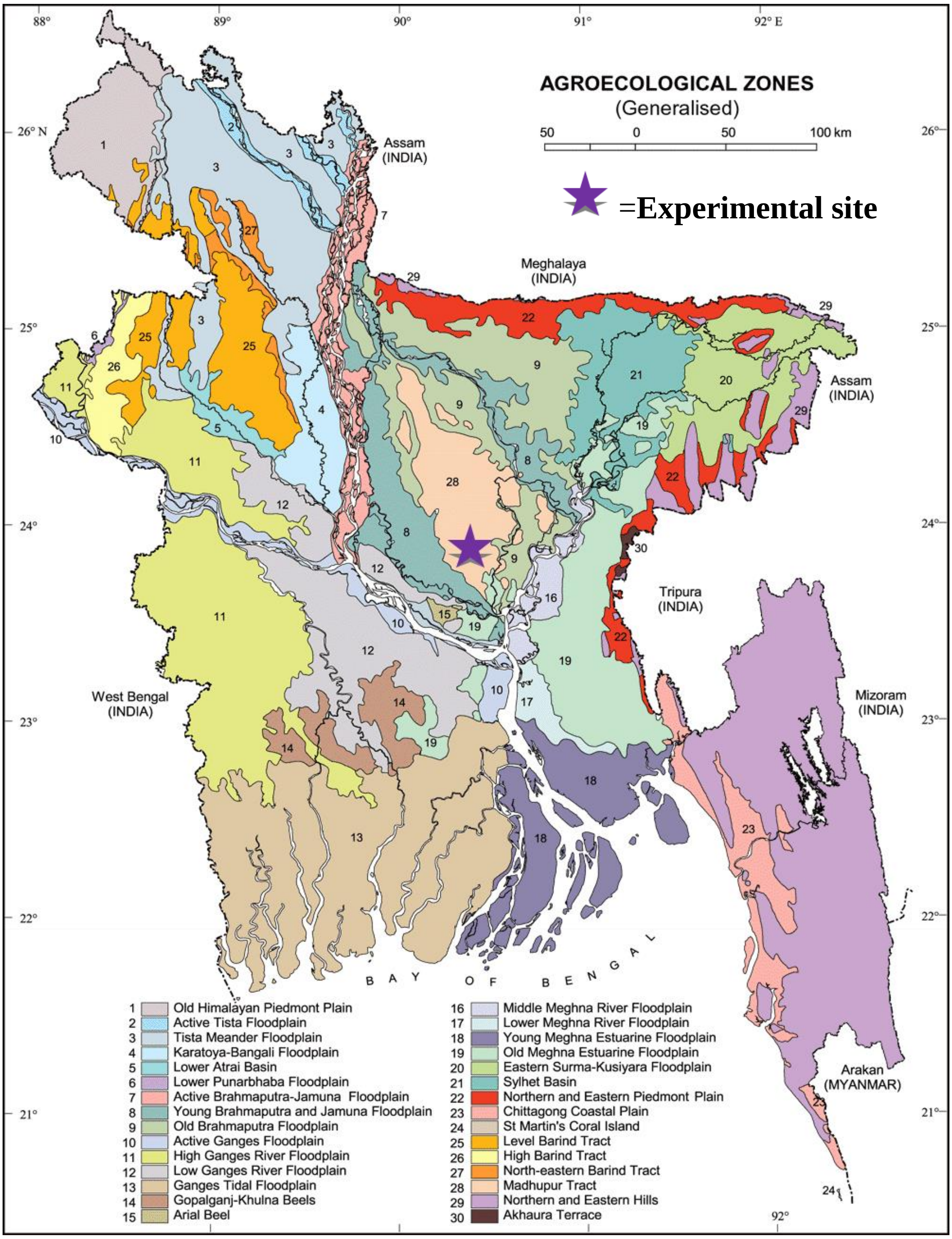
APPENDICES

Appendix I. Map showing the experimental site under the study



Appendix II. Characteristics of the soil of experimental field

A. Morphological characteristics of the experimental field

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

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

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

Appendix III. Monthly meteorological information during the period from November, 2018 to March, 2019

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018	November	25.50	6.70	54.75	0.0
	December	23.80	11.70	46.20	0.0
2019	January	22.75	14.26	37.90	0.0
	February	35.20	21.00	52.44	20.4
	March	34.70	24.60	65.40	165.0

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on the plant height of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of plant height at different days after sowing				
		20	**40**	**60**	**80**	**At harvest**
Replication	2	0.33	0.16	22.29	11.12	5.63
Biological strains (A)	2	3.85^{NS}	50.66*	115.93*	148.54*	104.62*
Error	4	1.53	2.12	6.26	17.62	7.03
Nitrogen levels (B)	4	2.85*	57.98*	156.04*	151.75*	75.98*
Biological strains (A) X Nitrogen levels (B)	8	0.05*	1.15*	1.27*	1.22*	2.29*
Error	24	1.67	6.27	14.04	24.46	36.09

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on above ground dry matter weight plant^{-1} of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of the above ground dry matter weight plant^{-1} at different DAS				
		20	40	60	80	At harvest
Replication	2	0.003	0.06	0.20	0.01	0.03
Biological strains (A)	2	0.01^{NS}	0.31*	0.79^{NS}	4.30*	12.64*
Error	4	0.002	0.03	0.20	0.28	0.27
Nitrogen levels (B)	4	0.01*	0.36*	0.78*	3.21*	9.09*
Biological strains (A) X Nitrogen levels (B)	8	0.01*	0.01*	0.02*	0.14*	0.17*
Error	24	0.004	0.021	0.125	0.34	0.71

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on the branches plant^{-1} of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of the branches plant^{-1} at different DAS			
		40	60	80	At harvest
Replication	2	5.06	25.85	10.16	6.38
Biological strains (A)	2	6.42*	14.92*	43.40*	29.62*
Error	4	0.23	0.96	1.52	1.41
Nitrogen levels (B)	4	3.02*	16.45*	13.29*	34.51*
Biological strains (A) X Nitrogen levels (B)	8	0.09*	0.72*	0.42*	2.05*
Error	24	0.10	0.29	2.35	6.52

*Significant at 5% level of significance

Appendix VII. Analysis of variance of the data on the nodules plant^{-1} of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of the nodules plant^{-1} at different DAS			
		40	60	80	At harvest
Replication	2	1.21	0.95	6.41	0.74
Biological strains (A)	2	30.28*	43.92*	73.02*	41.13*
Error	4	5.20	4.48	2.82	0.76
Nitrogen levels (B)	4	14.46*	37.52*	39.63*	59.79*
Biological strains (A) X Nitrogen levels (B)	8	0.41*	0.97*	2.04*	1.00*
Error	24	0.35	3.12	1.86	1.34

*Significant at 5% level of significance

Appendix VIII. Analysis of variance of the data on the nodules dry weight plant^{-1} of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of the nodules dry weight plant^{-1} at different DAS			
		40	60	80	At harvest
Replication	2	0.02	0.11	0.33	0.01
Biological strains (A)	2	0.02^{NS}	9.48*	6.68*	0.19*
Error	4	0.02	0.23	0.49	0.02
Nitrogen levels (B)	4	0.33*	7.04*	5.85*	0.34*
Biological strains (A) X Nitrogen levels (B)	8	0.01*	0.14*	0.25*	0.02*
Error	24	0.01	0.29	0.25	0.01

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on yield contributing characteristics of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of		
		Pods plant^{-1}	Seeds pod^{-1}	1000-grain weight
Replication	2	2.38	0.01	1.47
Biological strains (A)	2	102.86*	1.30*	41.94*
Error	4	0.52	0.04	5.27
Nitrogen levels (B)	4	39.70*	0.64*	30.43*
Biological strains (A) X Nitrogen levels (B)	8	0.84*	0.05*	0.29*
Error	24	1.76	0.11	17.99

*Significant at 5% level of significance

Appendix X. Analysis of variance of the data on yield characteristics of grasspea as influenced by combined effect of biological strains and nitrogen levels

Source of variation	df	Mean square of			
		Grain yield	Stover yield	Biological yield	Harvest index
Replication	2	0.01	0.06	0.09	15.90
Biological strains (A)	2	0.17*	0.19*	0.72*	17.40^{NS}
Error	4	0.002	0.01	0.01	10.77
Nitrogen levels (B)	4	0.22*	0.27*	0.94*	25.11*
Biological strains (A) X Nitrogen levels (B)	8	0.01*	0.01*	0.04*	2.60*
Error	24	0.01	0.05	0.09	11.42

*Significant at 5% level of significance

^{NS} Non significant