PERFORMANCE OF THREE GRASSPEA VARIETIES WITH AND WITHOUT *RHIZOBIUM* INOCULANT

A THESIS

By

MD. IBRAHIM ALI

Examination Roll No. 0105

Semester: July–December 2007

Registration No. 01842

MASTER OF SCIENCE (M.S)

IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA-1207

NOVEMBER 2007

PERFORMANCE OF THREE GRASSPEA VARIETIES WITH AND WITHOUT *RHIZOBIUM* INOCULANT

A THESIS

By

MD. IBRAHIM ALI

Examination Roll No. 0105

Semester: July–December 2007

Registration No. 01842

Submitted to the Department of Soil Science,

Sher-e-Bangla Agricultural University, Dhaka

in partial fulfillment of requirement for the degree of

MASTER OF SCIENCE (M.S)

IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA-1207

NOVEMBER 2007

PERFORMANCE OF THREE GRASSPEA VARIETIES WITH AND WITHOUT *RHIZOBIUM* INOCULANT

By

Md. IBRAHIM ALI

Reg. No. 01842

A Thesis

Submitted to the Department of Soil Science,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of requirement for the degree of

MASTER OF SCIENCE (M.S)

IN

SOIL SCIENCE
Semester: July–December 2007

Approved as to style and contents by

Co-Supervisor
A.T.M. Shamsuddoha
Associate Professor
Department of Soil Science
Sher-e-Bangla Agril. University
Dhaka-1207

Supervisor
Dr. Md. Asadul Haque Bhuiyan
Senior Scientific Officer
Soil Science Division
Bangladesh Agril. Research Institute
Joydebpur, Gazipur-1701

Chairman
Dr. Alok Kumar Paul
Professor
Department of Soil Science
Sher-e-Bangla Agril. University
Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled "PERFORMANCE OF THREE GRASSPEA VARIETIES WITH AND WITHOUT *RHIZOBIUM* INOCULANT" submitted to the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 in partial fulfillment of the requirements for the degree of Master of Science (M.S) in Soil Science embodies the result of a piece of bonafide research work carried out by **Md. Ibrahim Ali**, Registration No. 01842 under my supervision and guidance. No. part of the thesis has been submitted for any other degree or diploma.

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

Dated: 30 November 2007
Place: Dhaka, Bangladesh

....
Supervisor
Dr. Md. Asadul Haque Bhuiyan
Senior Scientific Officer
Soil Science Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur-1701

Dedicated to

My

Beloved Parents,

Wife and Daughter

ACKNOWLEDGEMENTS

All praises are to the Almighty ALLAH for enabling me to complete the thesis for the degree of Master of Science (M.S) in Soil Science.

It is a great pleasure to express my profound sense of gratitude and indebtedness to my research supervisor Dr. Md. Asadul Haque Bhuiyan, Senior Scientific Officer, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Chairman of the Supervisory Committee Dr. Alok Kumar Paul, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for their constant guidance, active supervision, generous help and encouragement throughout the period of research work and in preparing this thesis.

I express ever indebtedness and profound regards to the member of my Supervisory Committee, A.T.M. Shamsuddoha, Associate Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for his valuable advice, continuous guide, technical suggestions and constructive criticisms on this thesis.

Profound appreciation and deep sense of gratitude are due to the Dr. Gopi Nath Chandra Sutradhar, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka and Professor Dr. Md. Nurul Islam, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for their kind cooperation and inspiration.

I extend my gratitude to Md. Zahangir Alam, Principal (Acting), Jatir Pita Bangabandhu Degree College, Chandra, Kaliakoir, Gazipur for awarding me deputation to complete the higher study and research work.

I am grateful to my teachers Dr. Md. Asaduzzaman Khan, Associate Professor, Mst. Afrose Jahan, Associate Professor, Md. Mosharraf Hossain, Assistant Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for their valuable teaching advice encouragement and cooperation during the whole study period.

I express my cordial thanks to Md. Saiful Islam Bhuiyan, Md. Issak, Saikat Chowdhury, Jharna Sarker, Lecturer, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for their cooperation during the research period.

I am also grateful to Haider, Taposh, Mizan and all the members of the Soil Science Field, Office and Laboratory, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for their co-operation during the study period.

I am highly grateful to Dr. Md. Shahabuddin Khan, Chief Scientific Officer and Head and Mokhlesur Rahman, Principal Scientific Officer (Ex. Head) and Dr. Delowara Khanam, Principal Scientific Officer, Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur for providing laboratory, library and computer facilities as well as moral support.

I am also thankful to Md. Yunus Miah, Md. Shafiqul Islam Bhuiyan, Md. Monirul Islam, Mst. Farhana Yeasmin, Md. Abdul Wahab Mollah, Afsari Khanam for their co-operation in conducting the experiment in the field and data collection in laboratory of BARI.

I am thankful to Mr. Md. Basharul Islam, Computer Operator, BARI for careful typing of the manuscript. I am also grateful to my colleagues and Governing Body of Jatir Pita Bangabandhu Degree College, Chandra, Kaliakoir, Gazipur for inspiration to complete the M.S. Degree.

I remember my parents, brothers and sisters for their sacrifice, blessings and inspiration throughout the academic life.

I am also grateful to all of my relatives, friends and well wishers who helped me directly or indirectly.

Finally, I express my sincere gratitude and appreciation to my wife Krishibid Marry Ibrahim and daughter Kanij Fatema (Jui) for their encouragement, patience, sacrifice and co-operation during the period of this work.

November 2007

The Author

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS, ACRONYMS AND SYMBOLS

AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
App.	Appendix
B	Boron
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BAUR	Bangladesh Agricultural University *Rhizobium*
BBS	Bangladesh Bureau of Statistics
BCR	Benefit and Cost Ratio
BNF	Biological Nitrogen Fixation
BRRI	Bangladesh Rice Research Institute
C	Carbon
CD	Cowdung
CEC	Cation Exchange Capacity
cm	Centimeter
cmol kg^{-1}	Centimole per kilogram
Cu	Copper
CV	Coefficient of Variation
DAS	Days After Sowing
DM	Dry Matter
DMRT	Duncan's Multiple Range Test
DW	Dry Weight
EC	Electrical Conductivity
FAO	Food and Agricultural Organization
Fe	Iron
FYM	Farm Yard Manure
g	Gram
JNKVV	Jaharlal Neheru Krishi Vishwa Viddyalaya
K	Potassium
kg	Kilogram
kg ha^{-1}	Kilogram per hectare

mg	Milligram
mm	Millimeter
Mn	Manganese
MP	Muriate of Potash
N	Nitrogen
nm	Nanometer
ODAP	beta-N-oxalyl alpha-beta-diamino-propionic acid
P	Phosphorus
ppm	Parts Per Million
PSO	Principal Scientific Officer
RARS	Regional Agricultural Research Station
RCBD	Randomized Complete Block Design
RLs	*Rhizobium Lathyrus sativus*
S	Sulphur
SSO	Senior Scientific Officer
t	ton
$t\ ha^{-1}$	Ton per hectare
TSP	Triple Superphosphate
USDA	United States Department of Agriculture
Zn	Zinc
$\mu g\ g^{-1}$	Microgram per gram

ABSTRACT

The experiment was conducted at the Central Research Farm of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the period for November 2006 to March 2007 to study the performance of three grasspea varieties with and without *Rhizobium*. There were six treatment combinations and four replications were laid out in Randomized Complete Block Design (RCBD) technique. The *Rhizobium* strain BARI RLs-10 was used for the above experiment. The selected varieties were BARI Khesari-1, BARI Khesari-2 and Jamalpur local. The above varieties were tested with or without *Rhizobium* inoculation. BARI Khesari-1 performed the best than other two varieties in respect of different parameters like nodule number and weight, root weight and shoot weight, root length and shoot length, leaf and branch number, seed yield, stover yield, plant height, 1000-seed weight, pods plant^{-1}, seeds pod^{-1}, N content in stover and seed, N uptake by stover and seed, protein content in seed. *Rhizobium* inoculation significantly increased nodule number and weight, root weight and shoot weight, root length and shoot length, leaf and branch number, seed yield, stover yield, plant height, 1000-seed weight, pods plant^{-1}, seeds pod^{-1}, N content in stover, N uptake by stover and seed, protein content in seed. Interaction effects revealed that BARI Khesari-1 with inoculation recorded the highest nodulation, yield and other parameters compared to other treatment combinations and uninoculated Jamalpur local gave the lowest yield.

Chapter I

INTRODUCTION

CHAPTER I

INTRODUCTION

Pulses account for only a small portion of the worlds food supply, but their qualitative importance is quite significant in supplementing the dietary requirements of people in developing countries like Bangladesh, India, Pakistan, Nepal and some other Asian countries. The food gap in Bangladesh has been expanding both quantitatively and qualitatively due to high population growth. On an average, Bangladeshi diet only of 8-10 percent of the protein intake originate from animal sources; the rest can be met from plant sources by increasing the consumption of pulses (Kabir, 1987).

The word *Lathyrus* is derived from the Greak "Lathuros" meaning a plant probably a pulse. Possibly it refers to *Lathyrus sativus* itself. *Sativus* comes from Latin verb "serere" which means to sow or cultivate, thereby is indicative of that which is cultivated (Westphal, 1974). The genus *Lathyrus* has about 130 species distributed all over temperate regions of northern hemisphere and the higher altitudes of tropical Africa and South America. Many species are used as fodder or in pastures, and a few are used as ornamental plants (Purseglove, 1974). *Lathyrus* is indigenous to Southern Europe and Western Asia. It has spread as a weed and also as a crop. It is extensively cultivated in the Indian sub-continent (India, Bangladesh, Burma, Nepal and Pakistan), Iran and to a small extent in the Middle Eastern countries, Southern Europe, and parts of Africa and South America (Westphal, 1974).

Lathyrus is a temperate crop. It is cultivated in the cold winter months in the Indian sub-continent. It can grow well under moderate temperatures ranging form 10-30^{0}C (Kay, 1979). *Lathyrus* is the hardiest of the pulse crops because it can tolerate flooding and droughts. It can be grown in areas of low rainfall (300-500 mm) and also in areas of high rainfall (up to 1500 mm) such as in Bangladesh. This attribute of tolerance to extremities of flooding and drought has made it very popular in drought prone areas where heavy rains may occur for short periods.

Lathyrus can be cultivated over many types of soils ranging from very poor marginal soils to rich Black Cotton Soils. Most commonly, *Lathyrus* is cultivated as a second season crop in low lying rice fields in clay soils which remain wet for a long time (Nezamuddin, 1970). It can withstand short drought periods and moderate soil salinity, better than peas (Serov, 1974).

Among the various pulses, grasspea (*Lathyrus sativus* L.) has occupied first in respect of area and production in Bangladesh. According to Bangladesh Bureau of Statistics (2005) grasspea covers an area of 1,59,186 hectares production about 1,34,180 tons annually. The average production of grasspea in the country is about 843 kg ha^{-1}. The land cultivated for grasspea in Bangladesh is usually marginal as in other pulses mostly rainfed since cereals like rice and wheat occupy majority of the productive and irrigated areas in the country. This is one of the main reasons for low and stagnant productivity of grasspea in the country. There is enough scope to overcome these constraints through cultivation of high yielding grasspea varieties, fitting them in our usual cropping system and use of seed inculation with effective *Rhizobium* strains for better nodulation, N_2-fixation and higher seed yield.

Being a legume, *Lathyrus* forms nodules with *Rhizobium leguminosarum* and fixes nitrogen symbiotically. Kolotilov (1976) indicated that seed inoculation with effective *Rhizobium* strain yielded similarly to those supplied with N, P and K. Bhuiya *et al.* (1982a and 1982b) studied the performance of locally isolated Bangladeshi strains of lathyrus *Rhizobium*. In a net house experiment, they (1982b) studied variability for nodule formation on main and lateral roots. In the field study (1982a), variability was observed for nodule number, dry matter and N uptake by the plant. A few strains were found to be consistently superior in performance with regards to degree and size of nodules set.

Grasspea like other pulses have the ability to fix atmospheric nitrogen through partnership with symbiotic root nodule bacteria. The ability of symbiotic fixation may offer an opportunity to improve soil fertility and crop productivity using no or less nitrogenous fertilizers. Research conducted at JNKVV, Jabalpur, India, has indicated that *Lathyrus* responds to up to 20 kg N and 40 kg P_2O_5 (Anonymous, 1972). However, considering the cost of fertilizers and farmers' reluctance to use them, Singh (1975) recommended 10 kg N and 20 kg P_2O_5 to be applied at the time of planting. No fertilizers, not even FYM, are given to *Lathyrus* in Bangladesh. Bhuiyan *et al.* (1998 and 1999) reported that *Rhizobium* inoculation significantly increased nodule number, nodule weight, shoot weight, stover yield and seed yield of grasspea.

The response of grasspea to N and P fertilization as well as to *Rhizobium* inoculation varies in different locations due to changes in climatic, abiotic and biotic conditions. Moreover, symbiotic N_2-fixation may be limited by lack of effective *Rhizobium* strain in a favourable environment.

The present investigation was, therefore, undertaken to evaluate the response of grasspea to inoculate with *Rhizobium* with the following objectives:

i) to determine the effect of *Rhizobium* inoculation on the nodulation, growth, yield, nitrogen uptake and protein yield of grasspea.

ii) to select the suitable grasspea variety as regards to nodulation, growth, yield, nitrogen uptake and protein yield.

iii) to investigate the host-*Rhizobium* specificity in grasspea varieties.

Chapter II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Literature on the study of *Rhizobium* inoculation in grasspea (*Lathyrus sativus*) is scanty. However, available information regarding the effect of *Rhizobium* inoculation on nodulation, growth, nitrogen uptake, host-*Rhizobium* specificity and yield of grasspea has been reviewed in this chapter.

2.1 Effect of variety

Available information on the effect of grasspea varieties in Bangladesh and in neibouring countries is scanty. However, available information on nodulation, dry matter production, yield, and N content and uptake of grasspea is cited here.

Hossain and Khatun (1987) carried out an experiment with one hundred thirty three germplasms of grasspea (*Lathyrus sativus*) and analyzed for their moisture, protein and beta-N-oxalyl alpha-beta-diamino-propionic acid contents (ODAP). They found that fifty three germplasms had more than 30% protein. Of these, 3668/25, 3600/2 (1983) and 3668/16 had approximately 35% protein. The ODAP contents varied from 0.62% to 1.55%. The cultivars had the lowest ODAP contents ranging between 0.62 and 0.79%.

Alam *et al.* (1988) conducted an experiment with three varieties of grasspea and found that the highest nodule number and nodule weight were observed in the advance line 3968 than the local varieties, Jamalpur local and Pahartali. They reported that all the three varieties of grasspea produced identical numbers of nodules. Nodule yield did not vary significantly with varieties. The highest nodule number and weight were observed in variety 3968 after inoculation. All the three varieties gave identical results in respect of root, shoot and grain yields in the presence or absence of nodulation. However, the stover yield of the crop varied significantly due to varietal differences.

Quader *et al.* (1988) conducted an experiment and observed that lines of grasspea were low yielding than that of local varieties.

Rahman *et al.* (1989) carried out field experiment and reported that the advance lines of grasspea were relatively low in neurotoxin content, early in maturity and low in seed yield but Jamalpur local variety was found to be high yielding as well as high in neurotoxin content.

Bhuiyan *et al.* (1997) conducted two field experiments with three grasspea varieties/advance lines namely Charbadna, Pahartali and 3970 at Central Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur on Red Brown Terrace Soils (Paleustults) and Agro-ecological Zones Region 28 during rabi seasons of 1989-1990 and 1990-1991. They found that varieties differed significantly for nodule number and nodule weight in 1990-91 but insignificantly in 1989-90. All other parameters like shoot weight, straw yield and grain yield did not differ among the two varieties and one advance line.

Bhuiyan *et al.* (1998) conducted two field experiments on grasspea at Regional Agricultural Research Station, Ishurdi under Agroecological Zone (AEZ), region 11 during the rabi seasons of 1992-93 and 1993-94. They observed that among two advance lines and one variety of grasspea, the advance line 8603 gave the highest nodule number, nodule weight and shoot weight in both the years. Both the advance lines produced significantly higher nodule number, nodule weight and shoot weight than the variety of Jamalpur local. The Jamalpur local variety showed the highest stover yield than the two advance lines. The stover yield of Jamalpur local variety was not statistically significant with the advance line

8603. Significantly higher seed yield (1.46 t ha^{-1} in 1993 and 1.50 t ha^{-1} in 1994) were observed by the variety Jamalpur local than the two advance lines.

Bhuiyan *et al.* (1999) carried out field experiments on grasspea at Central Farm of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur on Red Brown Terrace Soils (Paleustults) during November 1991–March 1994. Three advance lines/varieties of grasspea namely 8603, 8604 and Jamalpur local were inoculated with *Rhizobium* strain RLs-10. Results of 3 years observation showed that the advance lines 8603 and 8604 which had maximum nodulation did not give a high seed yield and Jamalpur local recorded maximum seed yield but did not show high nodulation as in the advance lines 8603 and 8604. The advanced line 8603 produced the highest nodule number (62.7, 52.2 and 39.1 $plant^{-1}$), nodule weight (81, 57 and 69 mg $plant^{-1}$) but Jamalpur local recorded the highest seed yield (1.67, 1.48 and 1.73 t ha^{-1}) owing to inoculation in 1991-92, 1992-93 and 1993-94, respectively.

Bhuiyan *et al.* (2006) conducted field experiments at Central Research Farm, BARI, Gazipur and Regional Agricultural Research Station (RARS), Jamalpur during rabi season of 2005-2006 with the objectives to study the response of *Rhizobium* inoculation with different plant genotypes at Agro-ecological zone 28 (AEZ-28) and Agro-ecological zone 9 (AEZ-9). Three varieties of grasspea viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local and rhizobial inoculum (*Rhizobium* strain RLs-10) were used in this experiment. They observed that among three varieties studied, BARI Khesari-1 gave significantly higher nodule number (31.4 $plant^{-1}$ at Gazipur and 19.2 $plant^{-1}$ at Jamalpur), nodule weight (96.1 mg $plant^{-1}$ at Gazipur and 35.8 mg $plant^{-1}$ at Jamalpur), root weight (0.06 g $plant^{-1}$ at Gazipur and 0.07 g $plant^{-1}$ at Jamalpur) and shoot weight (1.58 g $plant^{-1}$ at Gazipur and 1.10 g $plant^{-1}$ at Jamalpur). BARI Khesari-1 recorded higher stover yield (1.81 t ha^{-1}) at Gazipur but Jamalpur local at Jamalpur (1.52 t ha^{-1}). Seed yield was higher (1.17 t ha^{-1}) with BARI Khesari-1 at Gazipur and Jamalpur local (1.26 t ha^{-1}) at Jamalpur.

A field experiment was conducted at Central Research Farm, BARI, Gazipur and Regional Agricultural Research Station (RARS), Jamalpur during rabi season of 2006-2007 with the objectives to study the response of inoculation with different plant genotypes at Agro-ecological zone 28 (AEZ-28) and Agro-ecological Zone 9 (AEZ-9) (Bhuiyan *et al.*, 2007). Three varieties of grasspea viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local, and rhizobial inoculum (*Rhizobium* strain RLs-10) were used in this experiment. They reported that among three varieties, BARI Khesari-1 produced the highest nodule number (30.2 $plant^{-1}$ at Gazipur and 18.0 $plant^{-1}$ at Jamalpur), nodule weight (90.1 mg $plant^{-1}$ at Gazipur and 32.2 mg $plant^{-1}$ at Jamalpur), and shoot weight (1.43 g $plant^{-1}$ at Gazipur and 1.02 g $plant^{-1}$ with BARI Khesari-2 at Jamalpur).

2.2 Effect of *Rhizobium* inoculation

Few reports are available on the effect of *Rhizobium* inoculation on nodulation, dry matter production, and yield and N uptake of grasspea. The available information on nodulation, dry matter production, and yield and N uptake of grasspea is cited here.

Miyan (1979) carried out an experiment on grasspea for evaluating the performance of different locally isolated strains of *Rhizobium leguminosarum* and found that higher N accumulation and N uptake by grasspea in inoculated treatments.

Chowdhury (1982) carried out an experiment to evaluate the effect of *Rhizobium leguminosarum* on grasspea and noted significantly higher grain yield of grasspea results from *Rhizobium* inoculants compared to uninoculated control.

Bhuiya *et al.* (1983) conducted a field trial on five locally isolated khesari rhizobial strains to screen out the most efficient strain at the farmer's field of village Sutiakhali, Mymensingh for use as inocula using local variety of khesari as the test crop. The study revealed that seed inoculation with the strain BAU-439 increased the N yield by 20.7% over uninoculated control. Significantly higher number of effective nodules and N yield at 42 days of inoculation also corresponded with higher N yield at harvest. The results indicated the need of inoculation of khesari cultivar for optimizing nodulation and production of khesari in Bangladesh.

Islam and Bhuiya (1984) carried out a pot experiment to evaluate the effect of lime and *Rhizobium* inoculation on the growth of grasspea in Red Brown Terrace Soil. Results indicated positive response of grasspea on nodulation, dry matter yield and N uptake by plant tops to *Rhizobium* inoculation and lime application. The strain BAU-439 was the best inoculant tested on nodulation and N uptake both in the presence and absence of lime. They also added that inoculation with strain on BAU-444 of grasspea produced significantly higher number of effective nodules plant^{-1} compared to uninoculated ones.

Islam *et al.* (1987) carried out a field experiment with Charbadna variety of grasspea for evaluating the performance of peat based inocula prepared with three local strains of *Rhizobium leguminosarum* strains designated as BAU 421, BAU 439 , BAU 444 and mixed culture of the above strains. They noted that effective nodulation from all inoculant sources was reflected in terms of main root and branch root nodule count relative to uninoculated control observed after 35 days of sowing. The strain BAU 439 recorded the highest number of main root and branch root nodules. All the inoculant recorded higher results on shoot weight, N content and N uptake by shoot after 35 days of sowing, grain and straw yield as well as higher N content and N uptake by the crop. The strain BAU 439 appeared to be the best in recording results in all the parameters studied.

Alam *et al.* (1988) conducted a field trial to study the effects of *Rhizobium* inoculation on some yield parameters in three varieties of grasspea. The varieties chosen were local, 3968 and Pahartali. The *Rhizobium* inoculant was BAU-444 (peat based). All the varieties treated with *Rhizobium* produced significantly higher number of nodule. Weight, yield of root and shoot, yield of grain and stover, and N-content were compared with values obtained in the absence of nodulation. Beneficial effects of the use of *Rhizobium* inoculant was also seen in improved organic matter, total nitrogen and available phosphorus content of the soil. They further indicated that root nodulation of grasspea was highly influenced by *Rhizobium* inoculation. The number of nodules in the main and branch roots increased significantly due to inoculation. Plants receiving *Rhizobium* inoculation gave higher nodule yields than the uninoculated plants. Root and shoot yields of the crop recorded at 35 days of sowing were positively influenced by *Rhizobium* inoculation. Inoculation produced an encouraging effect on N content in shoot, grain and stover.

Bhuiyan *et al.* (1997) conducted two field experiments with three grasspea varieties/advance lines namely Charbadna, Pahartali and 3970 at Central Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur on Red Brown Terrace Soils (Paleustults) and Agro-ecological Zones Region 28 during rabi seasons of 1989-1990 and 1990-1991. They reported that *Rhizobium* inoculation significantly increased nodule numbers, nodule weights, shoot weights, straw yields and grain yields for two consecutive rabi seasons. They noted that plant receiving *Rhizobium* inoculation with strain RLs-10 gave significantly higher grain yields (33.3 and 36.8%) than uninoculated plants for 1989-90 and 1990-91, respectively.

Bhuiyan *et al.* (1998) conducted two field experiments on grasspea at Regional Agricultural Research Station, Ishurdi under Agroecological Zone (AEZ) region 11, during the rabi seasons of 1992-93 and 1993-94, and observed that there were significant beneficial effects of *Rhizobium* inoculation on nodule number, nodule weight, shoot weight, stover yield and seed yield in two advance lines and one variety of grasspea in both the years.

Bhuiyan *et al.* (1999) carried out field experiments on grasspea at Central Farm of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur on Red Brown Terrace Soils (Paleustults) during November 1991–March 1994. They found that seed inoculation with strain RLs-10 significantly increased nodule number (50.0, 43.0, 35.3 plant^{-1}), nodule weight (65.0, 49.0, 64.3 mg plant^{-1}), shoot weight (1.50, 1.25, 1.79 g plant^{-1}), stover yield (1.65, 1.58, 1.73 t ha^{-1}), seed yield (1.41, 1.32, 1.44 t ha^{-1}) for 1991-92, 1992-93, 1993-94, respectively. These results confirmed a good response of added inoculum.

Bhuiyan *et al.* (2006) conducted field experiments at Central Research Farm, BARI, Gazipur and Regional Agricultural Research Station (RARS), Jamalpur during rabi season of 2005-2006 with the objectives to study the response of inoculation with different plant genotypes at Agro-ecological zone 28 (AEZ-28) and Agro-ecological zone 9 (AEZ-9). Three varieties of grasspea viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local and rhizobial inoculum (*Rhizobium* strain RLs-10) were used in this experiment. They observed that inoculated plants gave significantly higher nodule number (27.1 plant^{-1} at Gazipur and 17.8 plant^{-1} at Jamalpur), nodule weight (83.8 mg plant^{-1} at Gazipur and 31.2 mg plant^{-1} at Jamalpur), root weight (0.06 g plant^{-1} at Gazipur and 0.07 g plant^{-1} at Jamalpur), shoot weight (1.52 g plant^{-1} at Gazipur and 1.10 g plant^{-1} at Jamalpur), stover yield (1.90 t ha^{-1} at Gazipur and 1.44 t ha^{-1} at Jamalpur) and seed yield (1.12 t ha^{-1} at Gazipur and 1.24 t ha^{-1} at Jamalpur).

A field experiment was conducted at Central Research Farm, BARI, Gazipur and Regional Agricultural Research Station (RARS), Jamalpur during rabi season of 2006-2007 with the objectives to study the response of inoculation with different plant genotypes at Agro-ecological zone 28 (AEZ-28) and Agro-ecological Zone 9 (AEZ-9) where three varieties of grasspea viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local, and rhizobial inoculum (*Rhizobium* strain RLs-10) were used (Bhuiyan *et al.*, 2007). They reported that inoculated plants gave significantly higher nodule number, nodule weight, root weight, shoot weight, stover yield and seed yield compared to non-inoculated plants.

2.3 Interaction effect of variety and *Rhizobium* inoculation

Rhizobium strain variations on nodulation, dry weight, yield characters and varietal specificity of grasspea are cited here.

Alam *et al.* (1988) conducted a field trial to study the effects of *Rhizobium* inoculation on some yield parameters in the three varieties of grasspea. The varieties chosen were local 3968 and Pahartali. The *Rhizobium* inoculant was BAU-444 (peat based). They reported that the variety x *Rhizobium* inoculated interaction for nodule number, nodule weight, shoot weight, stover yield and seed yield were significant but shoot N uptake was non-significant.

Bhuiyan *et al.* (1997) conducted two field experiments on two varieties namely Charbadna, Pahartali and an advance line namely 3970 at Central Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur on Red Brown Terrace Soils (Paleustults) and Agro-ecological Zones region 28 during rabi seasons of 1989-90 and 1990-91, and noted that the interaction between inoculated treatments and grasspea cultivars on nodule numbers and other parameters were insignificant both for 1989-90 and 1990-91. The higher nodule numbers were obtained in 1989-90 (21.1 plant^{-1}) and 1990-91 (21.5 plant^{-1}) for variety Pahartali with inoculation but the increases were not significant. They also observed that plant receiving inoculum for the two varieties and one line tested namely Pahartali, Charbadna and 3970 gave significantly higher nodule numbers, nodule weights, shoot weights, straw yields and grain yields. The grain yields of the variety Pahartali was 33 and 34% higher for the inoculated plants compared to uninoculated ones for the year 1990 and 1991, respectively.

Bhuiyan *et al.* (1998) conducted two field experiment on grasspea at Regional Agricultural Research Station, Ishurdi under Agro-ecological Zone (AEZ) region 11, during the rabi seasons of 1992-93 and 1993-94 and observed that the interaction between inoculated and grasspea cultivars for nodule number, nodule, weight, stover yield and seed yield were insignificant. It was significant only in shoot weight. They also reported that the highest nodule number (43.4, 31.8 plant^{-1}) were produced by the advance line 8603 at the inoculated treatments (46.3 and 30.2% increase of seed yield over uninoculated control). The same advance line recorded the highest nodule weight (93 mg plant^{-1}) for 1993-94 but in 1992-93, nodule weight was the highest (82 mg plant^{-1}) in the advance line 8304. Inoculated plants of 8603 had more shoot weight during both the seasons. Strain RLs-10 increased the seed yield of the advance lines and variety 8603, 8604 and Jamalpur local by 46.3 and 30.2%, 28.2 and 30.6%, and 48.7 and 30.0 in 1993 and 1994, respectively.

Bhuiyan *et al.* (1999) carried out field experiments on three grasspea (*Lathyrus sativus* L.) varieties at Central Farm of the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur on Red Brown Terrace Soils (Paleustults) during November 1991–March 1994 They reported that the variety x *Rhizobium* inoculation for nodule number, nodule weight, shoot weight, stover yield and seed yield were insignificant. It was significant only in shoot weight during 1993-94. The highest nodule number (62.7, 52.2, 39.1 plant^{-1}) were observed in the advance line 8603 at the inoculated treatment increasing 30.9, 33.0 and

23.8% higher seed yield over uninoculated control. The same advance line also recorded the highest nodule weight (81, 57, 69 mg plant^{-1}) than uninoculated control for 3 consecutive winter seasons. The Jamalpur local which gave the highest seed yield (1.67, 1.48, 1.73 t ha^{-1}) though the highest percent seed increase over control was recorded with the advance line 8603 in 1992-93 and with 8604 in 1991-92 and 1993-194.

Bhuiyan *et al.* (2006) conducted field experiments at Central Research Farm, BARI, Gazipur and Regional Agricultural Research Station (RARS), Jamalpur during rabi season of 2005-2006 with the objectives to study the response of inoculation with different plant genotypes at Agro-ecological zone 28 (AEZ-28) and Agro-ecological zone 9 (AEZ-9). Three varieties of grasspea viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local and rhizobial inoculum (*Rhizobium* strain RLs-10) were used in this experiment. Interaction effects of varieties and inoculant revealed that the highest nodule number (38.6 plant^{-1} at Gazipur and 22.6 plant^{-1} at Jamalpur), nodule weight (119.0 mg plant^{-1} at Gazipur and 43.5 mg plant^{-1} at Jamalpur), shoot weight (1.69 g plant^{-1} at Gazipur and 1.28 g plant^{-1} at Jamalpur) in the BARI Khesari-1 variety with inoculation. BARI Khesari-1 with inoculation gave the highest seed yield (1.30 t ha^{-1}) at Gazipur and Jamalpur local with inoculation gave the highest seed yield (1.36 t ha^{-1}) at Jamalpur.

A field experiment was conducted at Central Research Farm, BARI, Gazipur and Regional Agricultural Research Station (RARS), Jamalpur during rabi season of 2006-2007 with the objectives to study the response of inoculation with different plant genotypes at Agro-ecological zone 28 (AEZ-28) and Agro-ecological Zone 9 (AEZ-9) (Bhuiyan *et al.*, 2007). Three varieties of grasspea viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local, and rhizobial inoculum (*Rhizobium* strain RLs-10) were used in this experiment. They noted that BARI Khesari-1 gave the highest seed yield (1.20 t ha^{-1}) at Gazipur and Jamalpur local gave the highest seed yield (1.16 t ha^{-1}) at Jamalpur. The overall results indicated that BARI Khesari-1 gave the highest seed yield (1.35 t ha^{-1} at Gazipur and 1.33 t ha^{-1} at Jamalpur) with inoculation.

Chapter III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Details of the experimental materials and methods followed in the study are presented in this chapter. The experiment was conducted to find out the nodulation, biomass production, yield and N uptake of three grasspea varieties viz. BARI Khesari-1, BARI Khesari-2 and Jamalpur local during rabi season of 2006-07.

3.1 Experimental site

The experiment was carried out at the Bangladesh Agricultural Research Institute (BARI) Central Farm, Joydebpur, Gazipur. The experimental site is situated at 24.09^0 North Latitude and 90.50^0 'East Longitude. The elevation of the experimental site is 8.2 m above the sea level. The area belongs to the Agro-ecological Zone (AEZ 28): Madhupur Tract.

3.2 Soil

The experiment was conducted on Clay loam soil of the Order Inceptisols. The soil of BARI farm is high land having irrigation facilities. The morphological, physical and chemical characteristics of the experimental soil are presented in Tables 3.1 and 3.2.

Table 3.1. Morphological characteristics of the experiment field

Characters	BARI farm
General Soil Type	Shallow Grey Terrace Soil
Taxonomic soil classification:	
Order	Inceptisols
Sub-order	Aquept
Sub-group	Aeric Albaquept
Soil series	Chhiata
Parent material	Madhupur terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above Flood level

Table 3.2. Physical and chemical characteristics of the soils

Characteristics	BARI farm
Mechanical fractions:	
% Sand (0.2-0.02 mm)	27.5
% Silt (0.02-0.002 mm)	33.5
%Clay (< 0.002 mm)	39.0
Textural class	Clay loam
Colour	Grey
Consistency	Sticky and mud when wet
pH (1:2.5 Soil-Water)	6.3
CEC (cmol kg^{-1})	17.5
Exchangeable K (cmol kg^{-1})	0.22
Exchangeable Ca (cmol kg^{-1})	9.41
Exchangeable Mg (cmol kg^{-1})	7.15
Exchangeable Na (cmol kg^{-1})	0.15
Organic C (%)	0.95
Total N (%)	0.072
Available P (mg kg^{-1})	13.0
Available S (mg kg^{-1})	15.0
Available Zn (mg kg^{-1})	1.59
Available Cu (mg kg^{-1})	0.59
Available Fe (mg kg^{-1})	17.9
Available Mn (mg kg^{-1})	3.5

3.3 Climate

The climate of the experimental site is sub-tropical, wet and humid. Heavy rainfall occurs in the monsoon (Mid April to Mid August) and scanty during rest of the year. The weather data regarding rainfall, temperature and relative humidity prevailed during the study period (November 2006 to April 2007) is presented in App. 4.31.

3.4 Crop: Grasspea

3.5 Grasspea varieties

Three grasspea varieties viz. BARI Kheasri-1, BARI Kheasri-2 and Jamalpur local were used in the study. The salient characteristics of these varieties are presented below:

BARI Kheasri-1

BARI Khesari-1 was developed by Bangladesh Agricultural Research Institute (BARI) and it was released in 1985 by the National Seed Board. Plant height of this variety ranges from 60 to 65 cm, maximum field duration from 125 to 130 days and average yield from 1500 to 1600 kg ha^{-1}. In seedling stage the seedling is erect in nature; stem and leaf are dark green. Stems are comparatively bulky and leaves are broad. The colour of the flowers are blue and seeds are spotted light brownish. It is resistant to powdery mildew and downy mildew (Ann., 2004a).

BARI Khesari-2

BARI Khesari-2 was developed by BARI and it was released in 1996 by the National Seed Board. Plant height of this variety ranges from 55 to 60 cm; field duration is 125 to 130 days and average yield is 1600 to 1700 kg ha^{-1}. In seedling stage the seedling is erect in nature, stem and leaf are dark green. Stems are comparatively bulky and leaves are broad. The colour of the flowers are blue and seeds are spotted light brownish. It is resistant to powdery mildew and downy mildew (Ann., 2004b).

Jamalpur local

It is a popular local variety, which is frequently cultivated by the farmers of the Mymensingh and Jamalpur region in rabi season.

3.6 Treatments and experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Each plot was measured 5 m x 3 m.

A Crop variety: 3

1. BARI Khesari-1
2. BARI Khesari-2
3. Jamalpur local

B. *Rhizobium* inoculation: 2

1. Control
2. Inoculated

Hence, there were 6 treatment combinations as follows:

T_1: BARI Khesari-1 x Non-inoculated

T_2: BARI Khesari-1 x Inoculated

T_3: BARI Khesari-2 x Non-inoculated

T_4: BARI Khesari-2 x Inoculated

T_5: Jamalpur local x Non-inoculated

T_6: Jamalpur local x Inoculated

3.7 Replication: 4 (Four)

3.8 Land preparation

The experimental lands were opened with a power tiller on 10 November 2006 and subsequently ploughed followed by laddering. The lands were finally prepared on 14 November 2006.

3.9 Fertilizer application

After making the lay out of the experiment, the lands were fertilized on 16 November 2006 with 22, 42, 20, 5 and 1 kg ha^{-1} of P, K, S, Zn and B in the form of triple superphosphate (TSP), muriate of potash (MP), gypsum, zinc oxide and boric acid, respectively. No nitrogen as chemical fertilizer was applied in this experiment.

3.10 Preparation and amendment of peat material

The peat soil was collected from Gopalgonj and the pH was measured by glass electrode method. The pH of the peat soil was 4.5 and it was adjusted to 6.8 by adding $CaCO_3$. Fifty grams of amended peat having 8 percent moisture was taken in each polyethylene bag and the bags were sealed up. Then they were sterilized by autoclaving for three consecutive days for one hour each day. The sealed peat was ready for inoculation.

3.11 Inoculum preparation

The rhizobial inoculant was prepared in the Soil Microbiology Laboratory of Bangladesh Agricultural Research Institute (BARI) using the broth culture. The *Rhizobium* strain (BARI RLs-10) was collected from the stock culture of the laboratory. Yeast extract mannitol broth was prepared in a 500 ml Erlenmeyer flask. The liquid medium was sterilized for 30 minutes at 121^0 C at 15 PSI. The medium was kept for cooling. After cooling, a small portion of *Rhizobium* culture was aseptically transferred from agar slant to the liquid medium in the flask with the help of a sterile inoculation needle. The flask was then placed in the shaker at 28^0 C under 120 rpm to enhance rhizobial growth. After 4-5 days, the medium in the flask showed dense growth and then the broth culture was taken out from the shaker. From this ready broth, 30 ml were taken out by sterile syringe and injected into the polyethylene packet having the sterile peat. Finally, the moisture percent of the packet was adjusted to 50 percent. The inoculated packets were then incubated at 28^0C for two weeks to make them ready for seed inoculation.

3.12 Viability count of *Rhizobium*

Viability count of rhizobia in the inoculant was made one day before injecting the peat following plate count method (Vincent, 1970). The average number of rhizobia was approximately above 10^8 cells g^{-1} in the inoculant.

3.13 Procedure for inoculation

Inoculation was done just before sowing. Healthy grasspea seeds @ 55 g for each plot were taken into polyethylene bags separately and 2 ml of the sticker solution (4% gum acacia solution) was added to each bag with sterilized pipettes. It was followed by addition of 3 g of the desired peat based *Rhizobium* inoculant to each polyethylene bag and mixed thoroughly for uniform distribution and good adherence of inoculant on the surface of each seed.

3.14 Sowing

Grasspea was sown on 17 November 2006. Healthy seeds of grasspea @ 35 kg ha^{-1} were sown by hand as uniformly as possible in furrows. Different polyethylene bags were used for different treatments and the Non-inoculated seeds were sown first to avoid the risk of contamination. Seeds were sown in the afternoon and immediately covered with soil to avoid sunlight. Line to line distance was 30 cm and plant to plant distance was 10 cm.

3.15 Intercultural operation

Weeding was done at 12 and 35 days after sowing. Thinning was done on the same date of 1^{st} weeding to maintain optimum plant density. Plant to plant distance was maintained at 10.0 cm. A light irrigation was given after sowing for germination of seed. Pest did not infest the grasspea crop. No disease was observed in the experimental field.

3.16 Collection of samples

3.16.1 Soil

Soil samples from experimental plots were collected before sowing. The collected soil samples were dried, ground, sieved and stored for physical and chemical analysis.

3.16.2 Plant

Plant samples were collected at 20 days intervals to record data on nodule and shoot parameters. Ten plants from each plot were selected randomly and uprooted carefully by digging soil with the help of "khurpi". All possible precautions were taken to minimize the loss of nodules.

3.16.2.1 Study on nodulation

The plants uprooted for sampling were washed in running water cautiously to make them free from adhering soil particles and dipped in fresh water contained in a tray to avoid shrinkage of nodules. The nodules were counted, kept separately plot-wise and their dry weights were recorded.

3.16.2.2 Nodule number and mass

The data on nodule number and nodule mass were recorded by taking 10 randomly selected plants from each plot at different DAS. The data on nodule mass were expressed in mg $plant^{-1}$ on oven dry basis.

3.16.2.3 Shoot weight and root weight

After separation of the roots, the dry shoot and root weights of ten selected plants were recorded.

3.16.2.4 Shoot length and root length

Shoot length and root length of the plant samples of ten selected plants were recorded

3.16.2.5 Branch number and leaf number

Branch number and leaf number of ten selected plants were also taken

3.16.2.6 Harvesting and data recording on yield and yield contributing characters

Yield data were collected from an area of 5m x 3m of each plot. The seeds and stover were dried and weighed adjusting at 14% moisture content and yields were converted to t ha^{-1}. The following parameters were recorded:

i) Seed yield (t ha^{-1})
ii) Stover yield (t ha^{-1})
iii) Plant height (cm)
iv) Number of pods $plant^{-1}$
v) Number of seeds pod^{-1}
vi) 1000-seed weight (g)

3.16.2.7 Estimation of N

The N concentrations in stover and seed were determined by micro-Kjeldahl method.

3.17 Plant analysis

3.17.1 Collection and preparation of plant samples for chemical analysis

Plant samples (seed and stover) were collected from bulk harvest. The stover was washed under running tap water followed by rinsing with distilled water to remove surface contamination. The stover was immediately air-dried and was chopped off into smaller pieces. The seed and stover samples were then oven dried at 65°C for 24 hours. To obtain homogenous powder, the samples were finely ground and passed through a 60-mesh sieve. The samples were stored in polyethylene bags for N determination.

3.17.2 Chemical analysis of plant samples

Seeds and stover samples of grasspea were analyzed for determination of N concentrations following the methods described below:

Nitrogen

The plant samples (0.1 g grain, 0.2 g straw) were digested with conc. H_2SO_4, hydrogen peroxide and K_2SO_4-catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 10: 1: 0.1) at 200°C for one and a half-hour.

3.18 Nutrient uptake

Nitrogen uptake by grasspea was computed from the respective chemical concentration and dry matter yields.

3.19 Soil analysis

Methods of soil analysis are presented in Table 3.3

Table 3.3. Methods used for soil analysis

Soil Properties	Methods
Soil texture	Hydrometer method (Black, 1965). The texture class was determined using Marshall's Triangular Coordinates of USDA system
pH	Glass-electrode pH meter with 1:2.5 soil-water ratio (Jackson, 1973).
Organic carbon	Wet digestion method (Nelson and Sommers, 1982). The organic matter was oxidized by 1N potassium dichromate and the amount of organic carbon in the aliquot was determined by titration against 0.5N ferrous sulphate heptahydrate solution in presence of 0.025 M O-phenanthroline ferrous complex.
Total N	Microkjeldhal method (Bremner and Mulvaney, 1982). Soil sample was digested with conc. H_2SO_4 in presence of K_2SO_4 catalyst mixture (K_2SO_4: $CuSO_4$: Se = 10:1:1). Nitrogen in the digest was estimated by distilling the digest with 10N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.
NH_4^+-N	Extracted by 2M KCl solution (1:10 soil-extractant ratio). The aliquot was steam distilled with MgO and Devardas alloy (Keeney and Nelson. 1982).
CEC	Sodium acetate saturation method (Rhoades. 1982). The soil was leached with an excess of 1 M sodium acetate solution to remove the exchangeable cations and saturate the exchange material with sodium. The replaced sodium was determined by flame photometer.
Available P	Extracted by 0.5M $NaHCO_3$ (pH 8.5) and determined calorimetrically using molybdate blue ascorbic acid method (Olsen and Sommers, 1982).
Available K	Extracted by repeated shaking and centrifugation of the soil with neutral 1M NH_4OAc followed by decantation. The K concentration in the extract was determined by flame photometer as outlined by Knudsen *et al.* (1982).
Available S	Extracted by 500 ppm P solution form $Ca(H_2PO_4)_2$, H_2O and estimated by turbidity method using $BaCl_2$ (Fox *et al.*, 1964).
Available Zn	Extracted by 0.05N HCl solution and determined directly by AAS (Page *et al.*, 1982).
Available Cu Mn and Fe	Extracted by 0.005M DTPA solution and directly measured by AAS (Lindsay and Norvell, 1978).
Bulk density	Core sampling procedure (Black, 1965).
Water holding capacity	Determined gravimetrically using brass box following the method of Klute as described by Black (1965).

3.20 Calculation of protein concentration and protein yield

Protein concentration of grasspea seed was determined by multiplying the concentration of nitrogen in grasspea seed with 6.25.

Protein yield by grasspea seed was competed from protein concentration of seed and seed yields.

3.21 Statistical analysis

The collected data were analyzed statistically and Duncan's Multiple Range Test (DMRT) using a computer IRRISTAT and M-stat package programmes (Freed, 1992) adjudged the means. The correlation co-efficient and regression analysis were done for different variables wherever needed using Microsoft EXCEL programme 1997.

Chapter IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The experimental data in regarding to nodulation, dry matter production, plant growth, yield and yield attributing characters of three grasspea varieties were analyzed on the basis of the design and interpreted. The results of the experiments are presented and discussed in this chapter. Data on seed and stover yields, the yield contributing characters, and nutrient concentrations in seed and stover have also been recorded.

4.1 Total number of nodule

Observation on nodulation on roots of three grasspea varieties was done at 20 days after sowing (DAS) and data on nodulation was recorded at 20 days interval. The number of nodules increased progressively with the increasing growth period and reached the peak at 80 DAS (i.e. at 50% flowering stage) (Figs. 4.1-4.3 and App. 4.1.-4.3). The number of nodules started to decline after 80 DAS sharply.

Rhizobia are usually present in the soil and multiply in the rhizospheric zone of the plant when the seed germinates. Very early, these rhizobia penetrate the root of the young seedlings through a mechanism that remains poorly understood (FAO, 1983). The highest nodulation was observed at 80 DAS (i.e. at 50% flowering stage) and decreased thereafter. At harvesting stage, no nodules were observed. Nodule senescence started after 80 DAS. At 100 DAS, lower nodules were observed. This might be due to senescence of nodules at maturity/harvesting stage.

The results on the production of nodule plant^{-1} under different treatment i.e. varietal response, *Rhizobium* inoculant response and their interaction response at different growth stages have been presented in Figs. 4.1-4.3 and App. 4.1-4.3.

4.1.1 Effect of variety

Observation on total nodule number plant^{-1} revealed that varieties differed significantly among themselves (Fig. 4.1 and App. 4.1). This result conformed that nodule production varied from variety to variety (Murakami *et al.*, 1991; Patel and Patel, 1991; Pal and Lal, 1993; Bhuiyan *et al.*, 1999). Influence of three grasspea varieties on total nodule number was significant at all the sampling dates i.e. at 20, 40, 60, 80 and 100 DAS. The highest number of nodules (30.22 plant^{-1}) was produced by BARI Khesari-1 at 80 DAS, which was statistically similar to BARI Khesari-2 only at 20 DAS. The minimum number of total nodules (10.74 plant^{-1}) at 80 DAS was observed in Jamalpur local variety. The lowest number of total nodules (2.95 plant^{-1}) was noted with Jamalpur local at 20 DAS.

As stated earlier that the number of total nodule plant^{-1} increased with the advancement of growth up to 80 DAS, thereafter, started declining. It appeared that the peak nodulation in grasspea occurred between pre-flowering and pod filling stage. This might be due to peak nodulation in grasspea at 50% flowering stage and degeneration of nodules after pod filling stage. Patel and Patel (1991) reported that significantly more number of nodules plant^{-1} in mungbean was observed at 30 DAS followed by 45 and 15 DAS. Pal and Lal (1993) also reported that nodules were higher at 45 DAS than 60 DAS in mungbean. Akhtaruzzaman (1998) also observed maximum nodulation at 40 DAS than at 30 and 20 DAS in mungbean.

4.1.2 Effect of *Rhizobium*

There was a highly significant response of *Rhizobium* inoculant on the total number of nodule plant^{-1}, recorded at all sampling dates (Fig. 4.2 and App. 4.2). Inoculated plants produced significantly higher number of nodules over non-inoculated plant at different DAS. Inoculated plant produced significantly higher nodule number (24.25 plant^{-1}) at 80 DAS compared to uninoculated plant (16.66 plant^{-1}). The lowest number of nodules (3.05 plant^{-1})

was produced at 20 DAS with uninoculated plants. With respect to time of sampling, high nodule numbers were obtained at 80 DAS compared to all other sampling dates, which was supported by Datt and Bhardwaj (1995). They reported that the nodule number and nodule dry weight of cowpea increased significantly by *Rhizobium* inoculation at 45 DAS followed by 55, 30 and 15 DAS. This might be due to the high requirement of N at the flowering and pod-filling stage (Rennie and Kemp, 1984). Chowdhury *et al.* (1997) observed higher nodule number in inoculated mungbean at flowering stage than at pod filling or pre-flowering stage.

4.1.3 Interaction effect of variety and *Rhizobium*

The interaction between varieties and *Rhizobium* inoculation was significant on total nodule number at 40 and 60 DAS (Fig. 4.3 and App. 4.3). Number of total nodule plant^{-1} was the highest (35.2) at 80 DAS in inoculated BARI Khesati-1. It was observed that in all the control plots, nodules were lower irrespective of varieties at all DAS. BARI Khersari-1 and BARI Khesari-2 recorded identical nodule numbers at 40 DAS with inoculation. These results indicated that bio-fertilizer had influence on nodule production in grasspea varieties; other author also reported similar results (Naher, 2000).

4.2 Nodule weight

4.2.1 Effect of variety

The tested grasspea varieties differed in nodule weight at all sampling dates and the effect of inoculation on the nodule weight was also observed (Fig. 4.4 and App. 4.4). Nodule dry weight increased almost exponentially with the progress of crop growing up to 80 DAS. Varietal difference in nodule weight was prominent at 80 DAS, when BARI Khesari-1 gave much higher nodule weight than the BARI Khesari-2 and Jamalpur local varieties. However, the BARI Khesari-1 consistently produced more nodules dry weight. At 20 to 80 DAS, the nodule dry weight in BARI Khesari-1 exceeded to two tested varieties, when it produced about 55.05 plant^{-1}.

4.2.2 Effect of *Rhizobium*

Inoculation of *Rhizobium* markedly increased the nodule dry weight of grasspea compared to non-inoculated plant (Fig. 4.5 and App. 4.5). Increased nodulation under inoculation might be due to associative effect of bacteria and its activities resulting improvement in nodulation (Sarkar *et al.*, 1993). Nodule dry weight increased with *Rhizobium* application up to 80 DAS. Similar results were reported by Sairam *et al.* (1989); Datt and Bhardwaj (1995); Shukla and Dixit (1996b); Sharma and Khurana (1997); Dev (2000); Roy (2001).

4.2.3 Interaction effect of variety and *Rhizobium*

Up to 80 DAS, there was an increase in dry weight of nodules. The highest dry weight of nodule (66.50 mg plant^{-1} at 80 DAS) was recorded in BARI Khesari-1 with inoculation, which was significantly different from other interaction treatments (Fig. 4.6 and App. 4.6). The lowest nodule dry weight was noted in uninoculated Jamalpur local at 20 DAS.

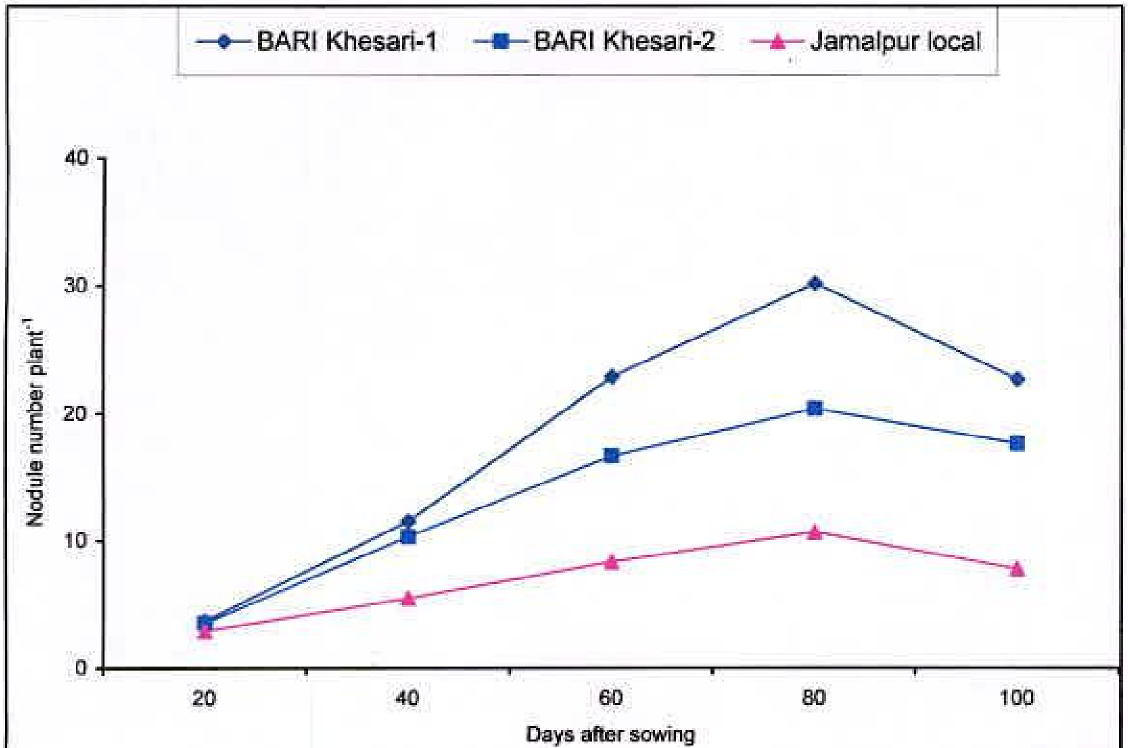

Fig. 4.1. Effects of varieties on nodule number of grasspea at different days after sowing (DAS)

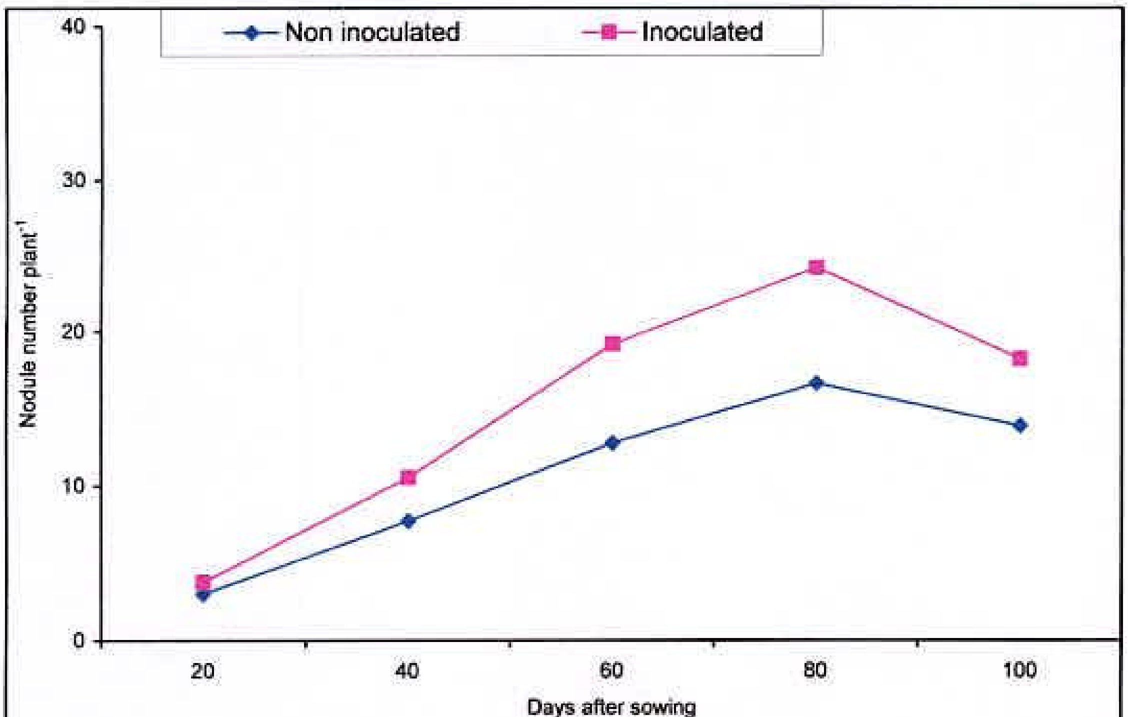

Fig. 4.2. Effects of rhizobial inoculant on nodule number of grasspea at different days after sowing (DAS)

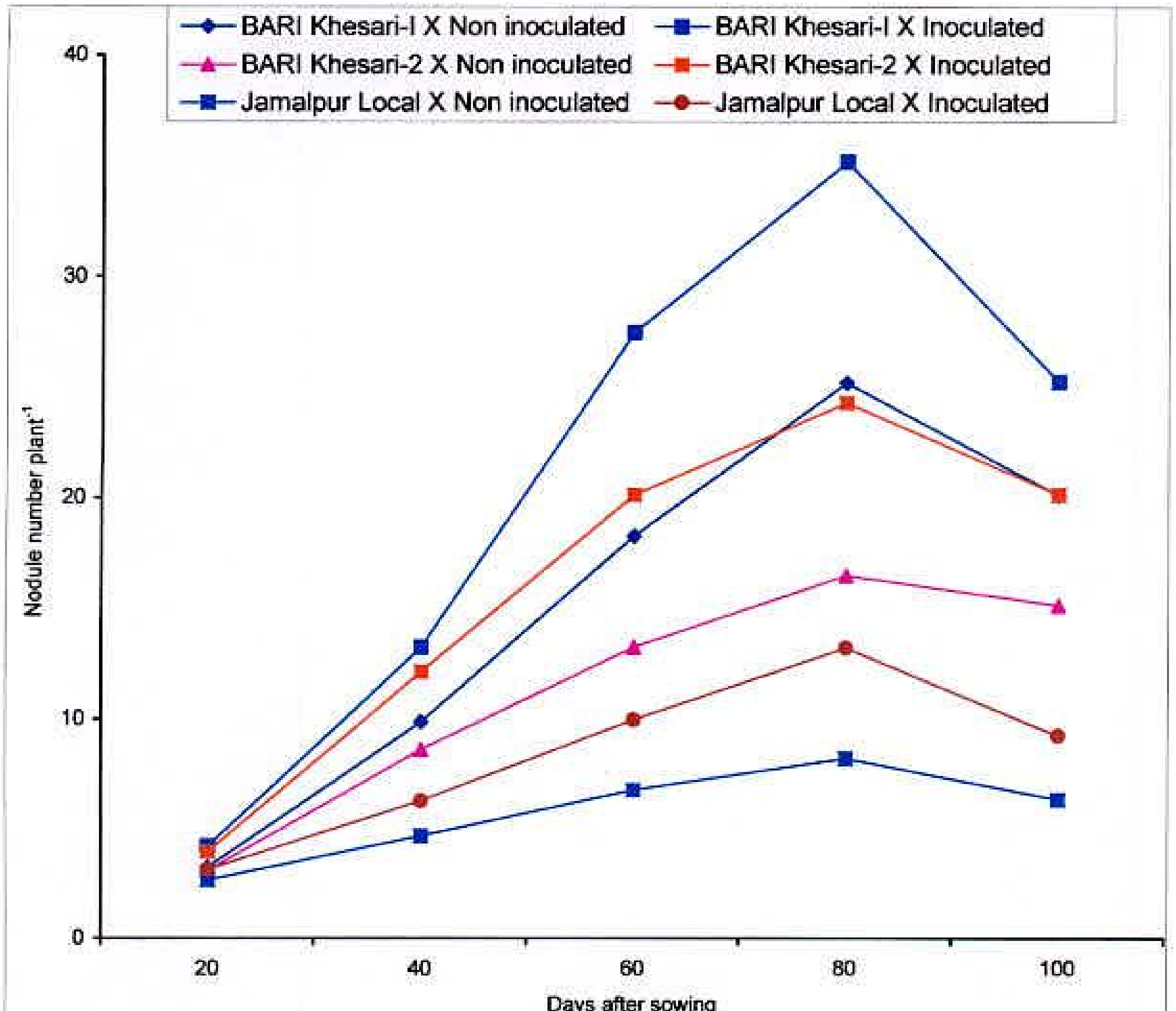

Fig. 4.3. Interaction effects of varieties and rhizobial inoculant on nodule number of grasspea at different days after sowing (DAS)

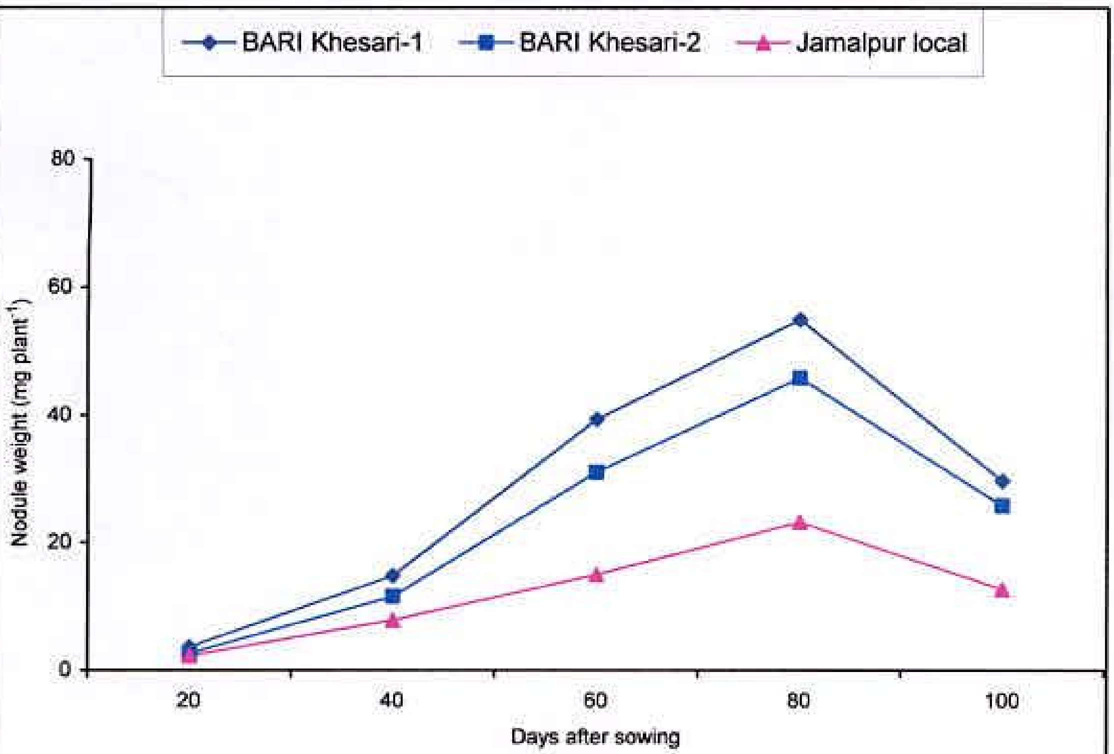

Fig. 4.4. Effects of varieties on nodule weight of grasspea at different days after sowing (DAS)

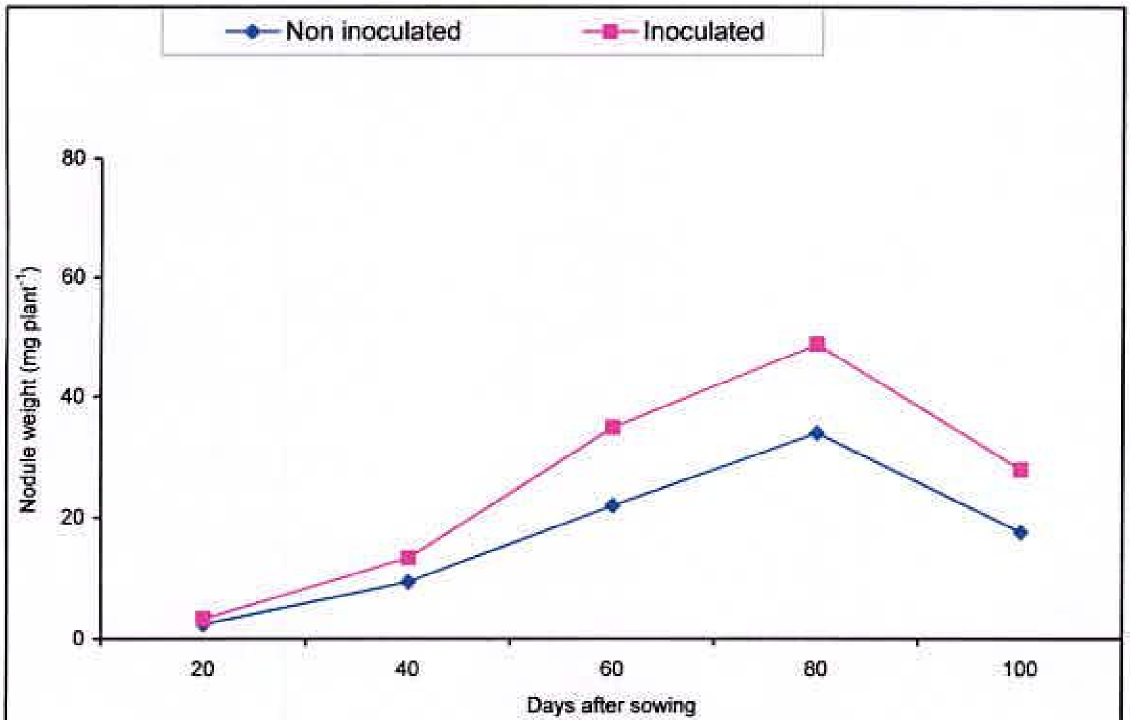

Fig. 4.5. Effects of rhizobial inoculant on nodule weight of grasspea at different days after sowing (DAS)

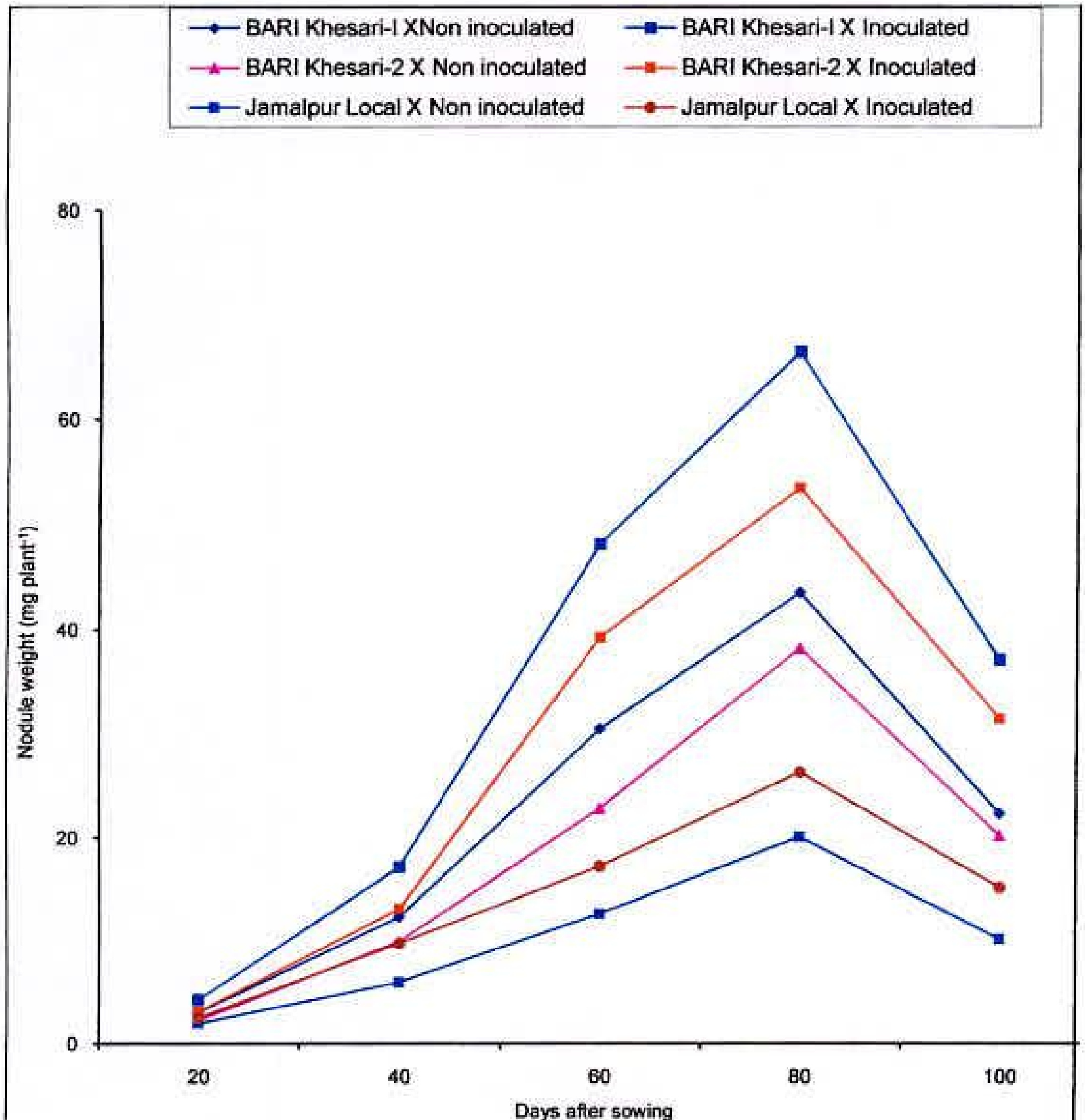

Fig. 4.6. Interaction effects of varieties and rhizobial inoculant on nodule weight of grasspea at different days after sowing (DAS)

4.3 Root weight

4.3.1 Effect of variety

Plant root dry matter and its rate of accumulation increased with plant age. Dry matter weight of root at all DAS was significantly different among cultivars while it was not so at 100 DAS (Fig. 4.7 and App. 4.7). It indicated a wide variation in root weight of different varieties of grasspea.

4.3.2 Effect of *Rhizobium*

Application of *Rhizobium* significantly increased the dry matter weight of root at all the sampling dates (Fig. 4.8 and App. 4.8). The maximum root dry matter weight (0.069 g $plant^{-1}$ at 100 DAS) was recorded in the inoculated plants while non--inoculated plants showed lower dry weight of root. Many researchers reported similar results. *Rhizobium* inoculation stimulated root growth and produced significantly more root dry matter. Inoculation promotes nitrogen fixation, which was also expressed through root dry matter production (Raut and Kohire, 1991).

4.3.3 Interaction effect of variety and *Rhizobium*

The effect of variety x *Rhizobium* on root dry matter weight was non--significant except at all DAS except at 40 DAS (Fig. 4.9 and App. 4.9). The maximum root dry weight (0.072 g $plant^{-1}$) at 100 DAS was recorded by the interaction effect of BARI Khesari-1 x Inoculant and the minimum dry matter weight was observed in the Jamalpur local x non--inoculated treatment. The results corroborated with the findings of Alam *et al.* (1988).

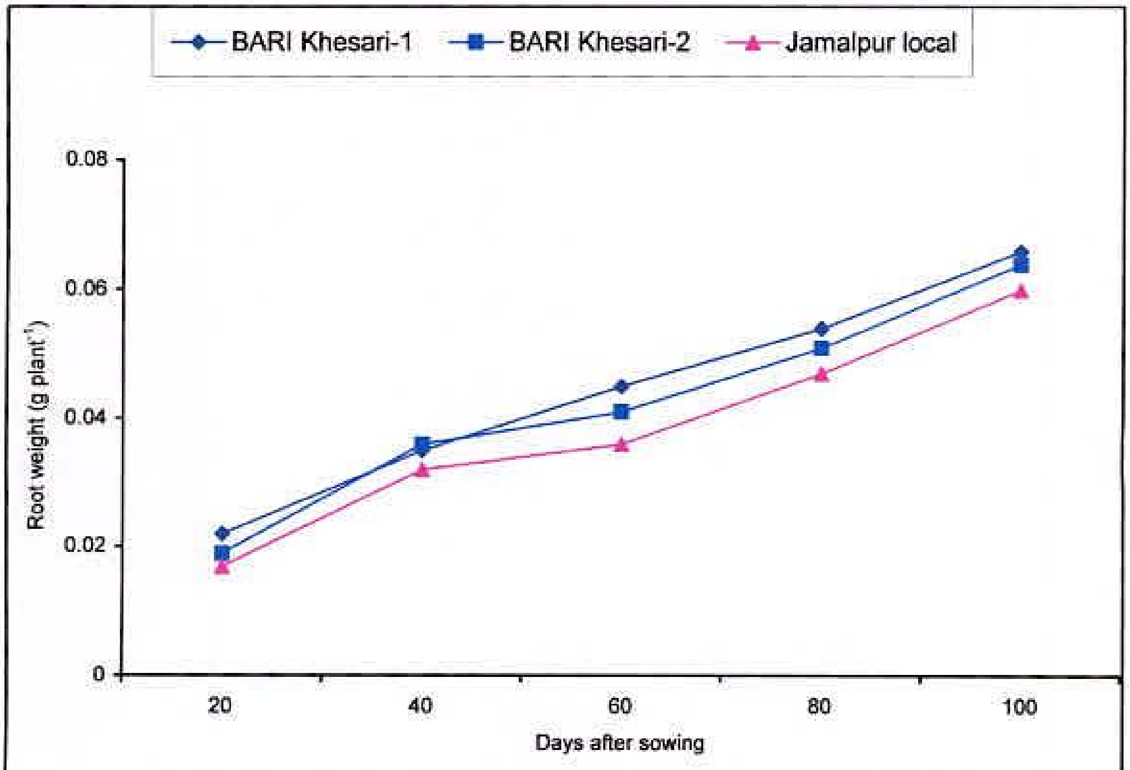

Fig. 4.7. Effects of varieties on root weight of grasspea at different days after sowing (DAS)

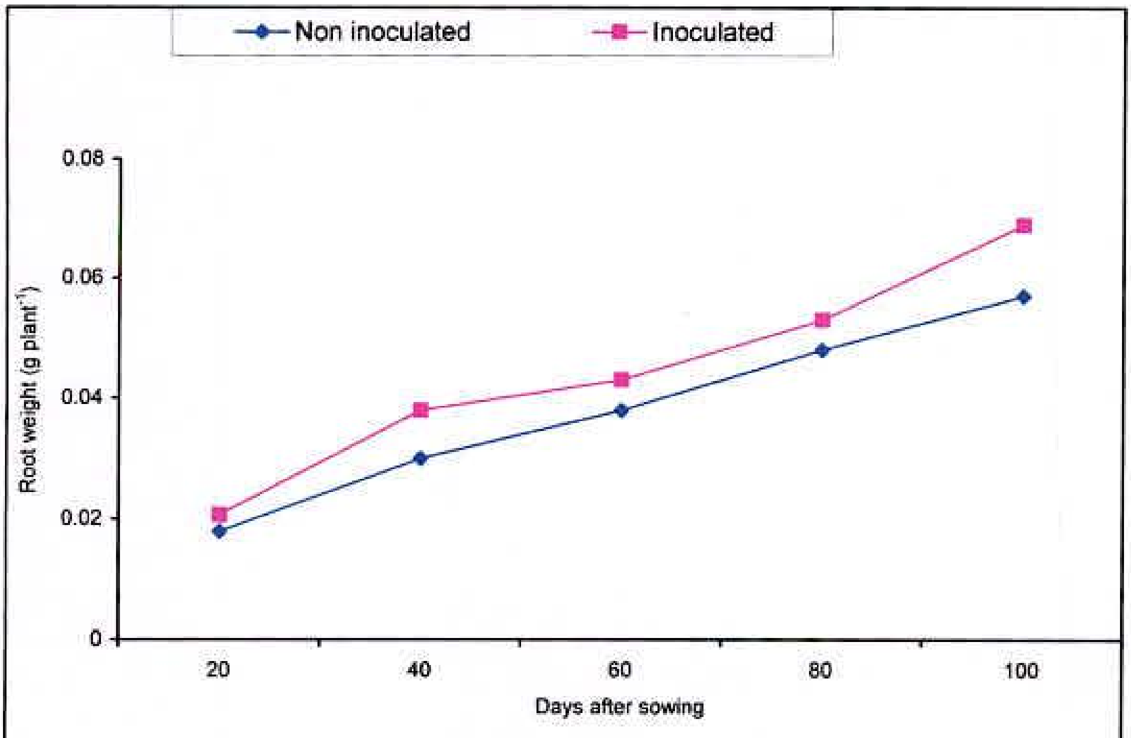

Fig. 4.8. Effects of rhizobial inoculant on root weight of grasspea at different days after sowing (DAS)

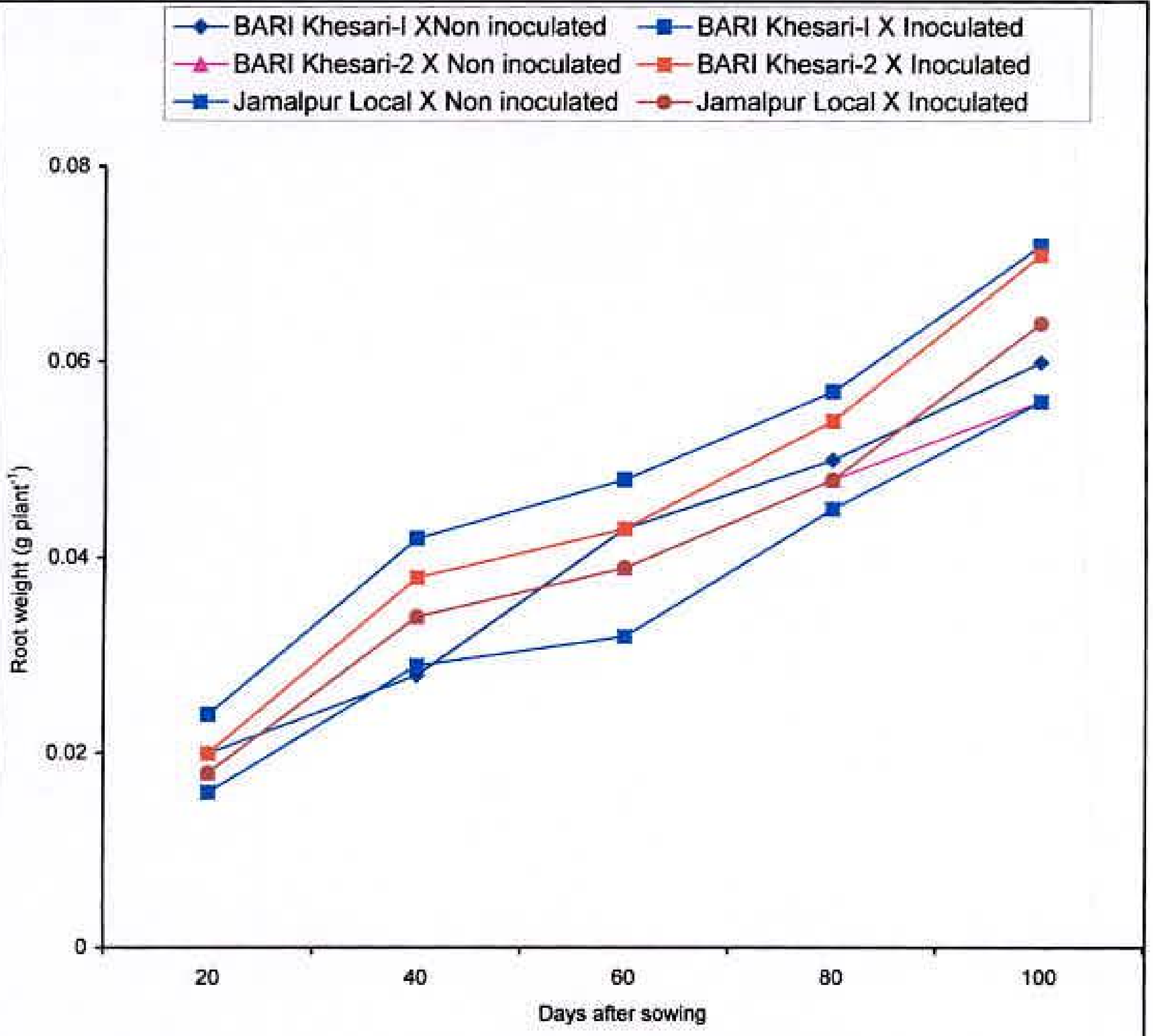

Fig. 4.9. Interaction effects of varieties and rhizobial inoculant on root weight of grasspea at different days after sowing (DAS)

4.4 Shoot weight

4.4.1 Effect of variety

Shoot dry matter weight of the tested genotypes is presented in Fig. 4.10 and App. 4.10. At the early growth stages (20 DAS), shoot dry weight was very low. With the progress of growing period, shoot dry weight increased progressively and peaked at 80 DAS. At 80 DAS, shoot dry weight of BARI Khesari-1 were similar to BARI Khesari-2 and Jamalpur local. Jamalpur local gave the lower yield. Shoot dry weight was significant among three varieties at 20 and 60 DAS. The results were in agreement with Bhuiyan (2004).

4.4.2 Effect of *Rhizobium*

Application of *Rhizobium* significantly increased the dry matter weight of shoot at all the sampling dates (Fig. 4.11 and App. 4.11). The effect of inoculation on shoot dry matter (mean of varieties) was pronounced at 100 DAS. The difference between inoculated and uninoculated plants was wider at 100 DAS. The maximum shoot dry matter weight (1.49 g $plant^{-1}$) at 100 DAS was recorded in the inoculated plants while non-inoculated plants showed lower dry matter weight of shoot. Das *et al.* (1999) and Bhuiyan (2004) reported higher dry matter yield in inoculated treatment over uninoculated treatment. *Bradyrhizobium* inoculation promoted nodulation and fixed more nitrogen, which was also expressed through dry matter production (Raut and Kohire, 1991).

4.4.3 Interaction effect of variety and *Rhizobium*

The effect of variety x *Rhizobium* on shoot dry matter weight was insignificant (Fig. 4.12 and App. 4.12). The maximum shoot dry matter weight (1.60 g $plant^{-1}$ at 100 DAS was recorded by BARI Khesari-1 x Inoculant and the minimum shoot dry matter weight was observed in Jamalpur local x uninoculated treatment. Bhuiyan *et al.* (1997) and Alam *et al.* (1988) reported similar results.

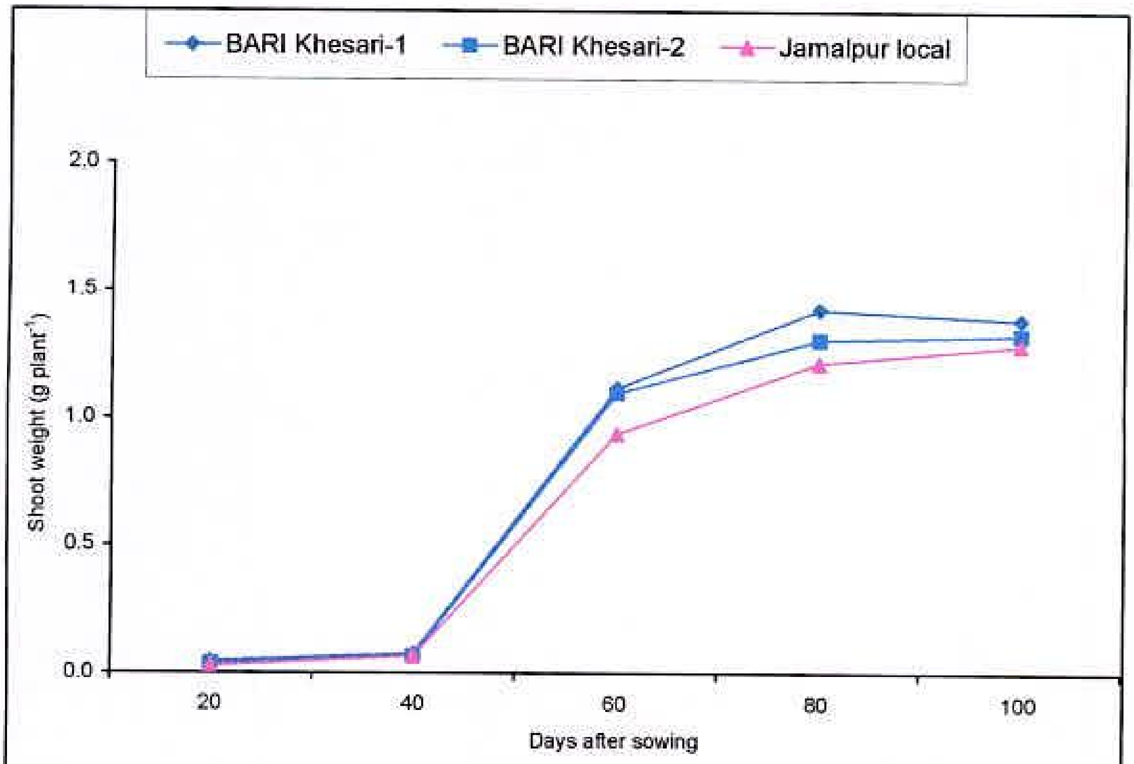

Fig. 4.10. Effects of varieties on shoot weight of grasspea at different days after sowing (DAS)

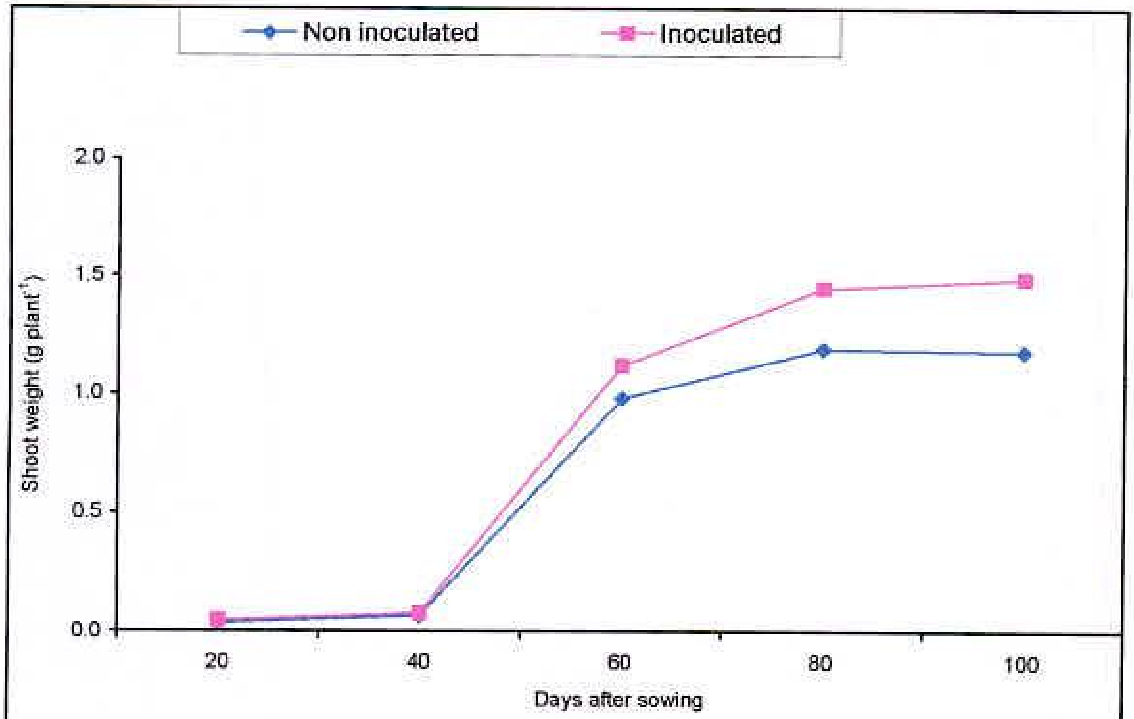

Fig. 4.11. Effects of rhizobial inoculant on shoot weight of grasspea at different days after sowing (DAS)

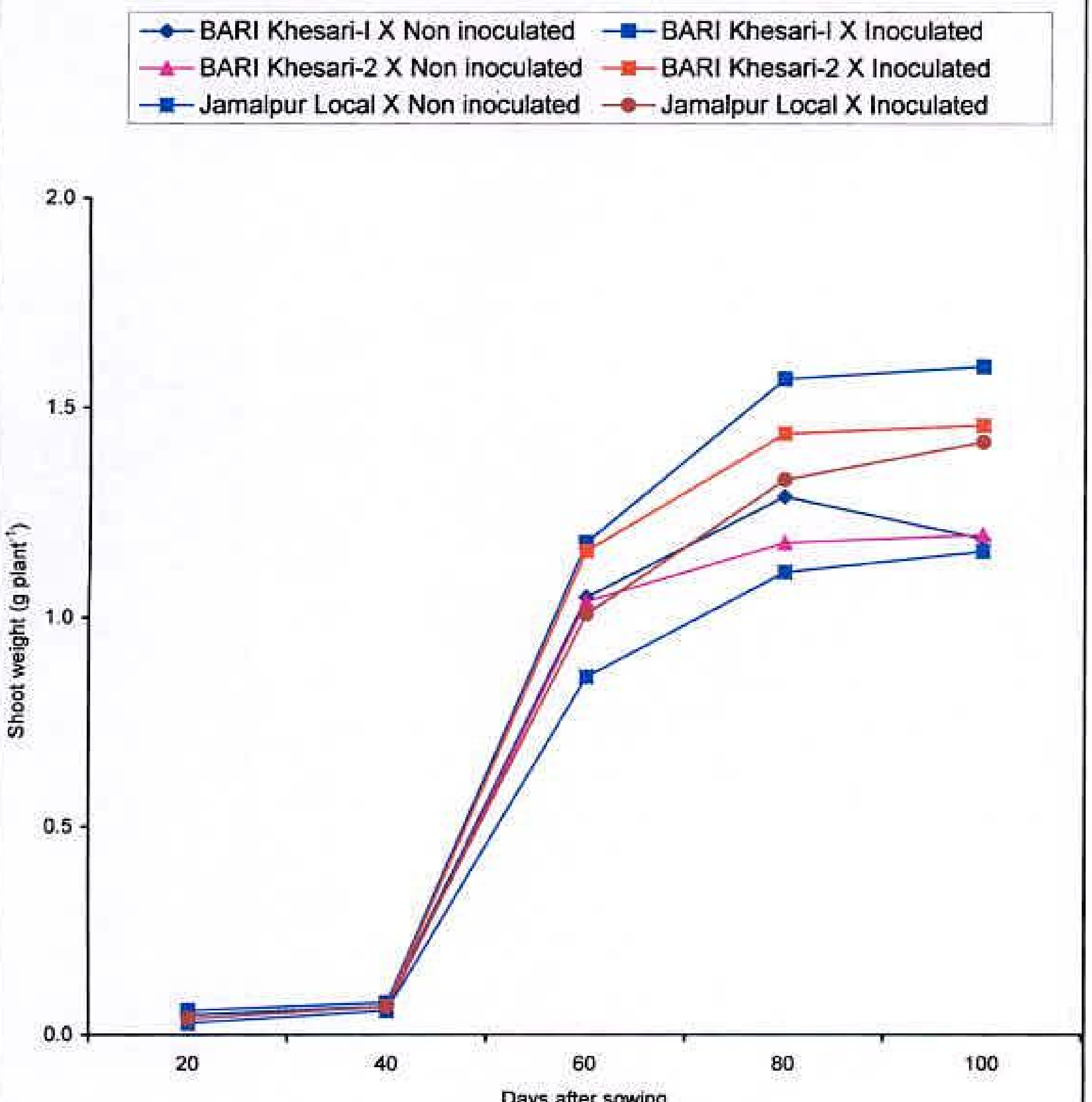

Fig. 4.12. Interaction effects of varieties and rhizobial inoculant on shoot weight of grasspea at different days after sowing (DAS)

4.5 Root length

4.5.1 Effect of variety

Plant root length increased with plant age. Root length was significantly different among cultivars at 40 and 80 DAS while it was not so at 20, 60 and 100 DAS (Fig. 4.13 and App. 4.13).

4.5.2 Effect of *Rhizobium*

Application of *Rhizobium* significantly increased the root length at 40 and 80 DAS (Fig. 4.14 and App. 4.14). The maximum root length (13.05 cm plant^{-1} at 100 DAS) was recorded in the inoculated plants while non--inoculated plants showed lower dry weight of shoot.

4.5.3 Interaction effect of variety and *Rhizobium*

The effect of variety x *Rhizobium* on root length was non--significant at all DAS except at 40 DAS (Fig. 4.15 and App. 4.15). The maximum root length (14.25 cm plant^{-1}) at 100 DAS was recorded by the interaction of BARI Khesari-1 x Inoculant and the minimum root length was observed in the Jamalpur local x non--inoculated treatment.

4.6 Shoot length

The results on shoot length at different growth stages for varietal, *Rhizobium* inoculant response and their interaction have been presented in Figs. 4.16-4.18 and App. 4.16-4.18.

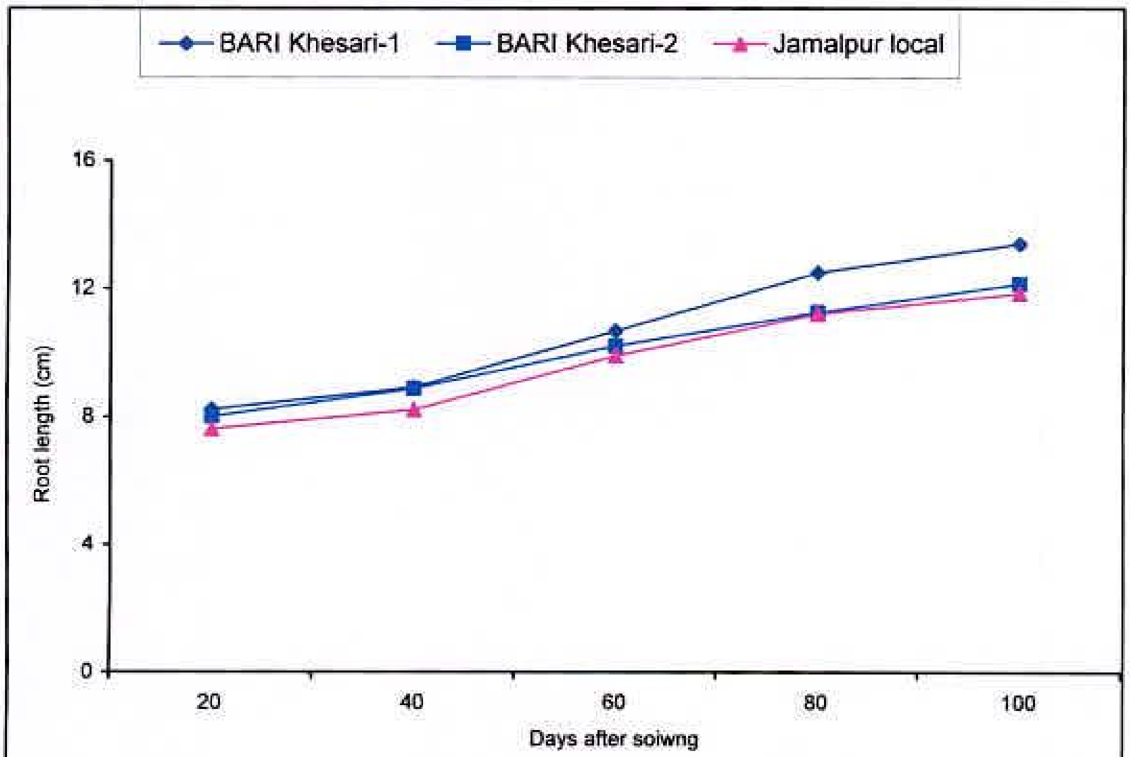

Fig. 4.13. Effects of varieties on root length of grasspea at different days after sowing (DAS)

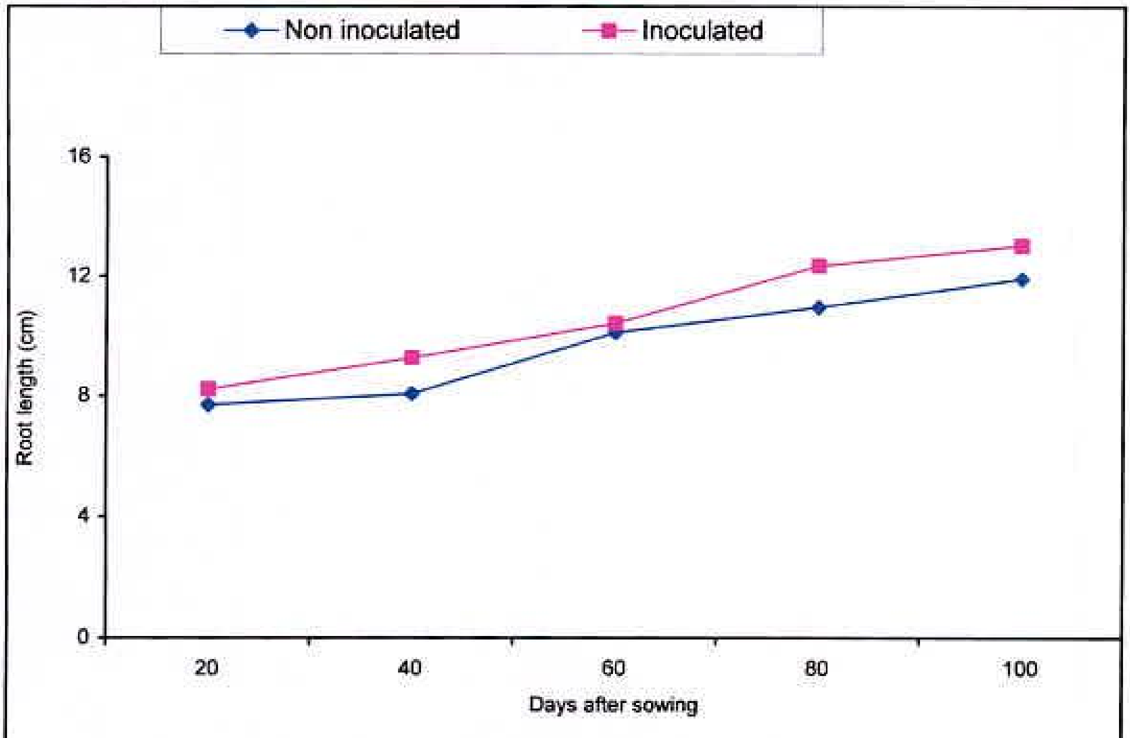

Fig. 4.14. Effects of rhizobial inoculant on root length of grasspea at different days after sowing (DAS)

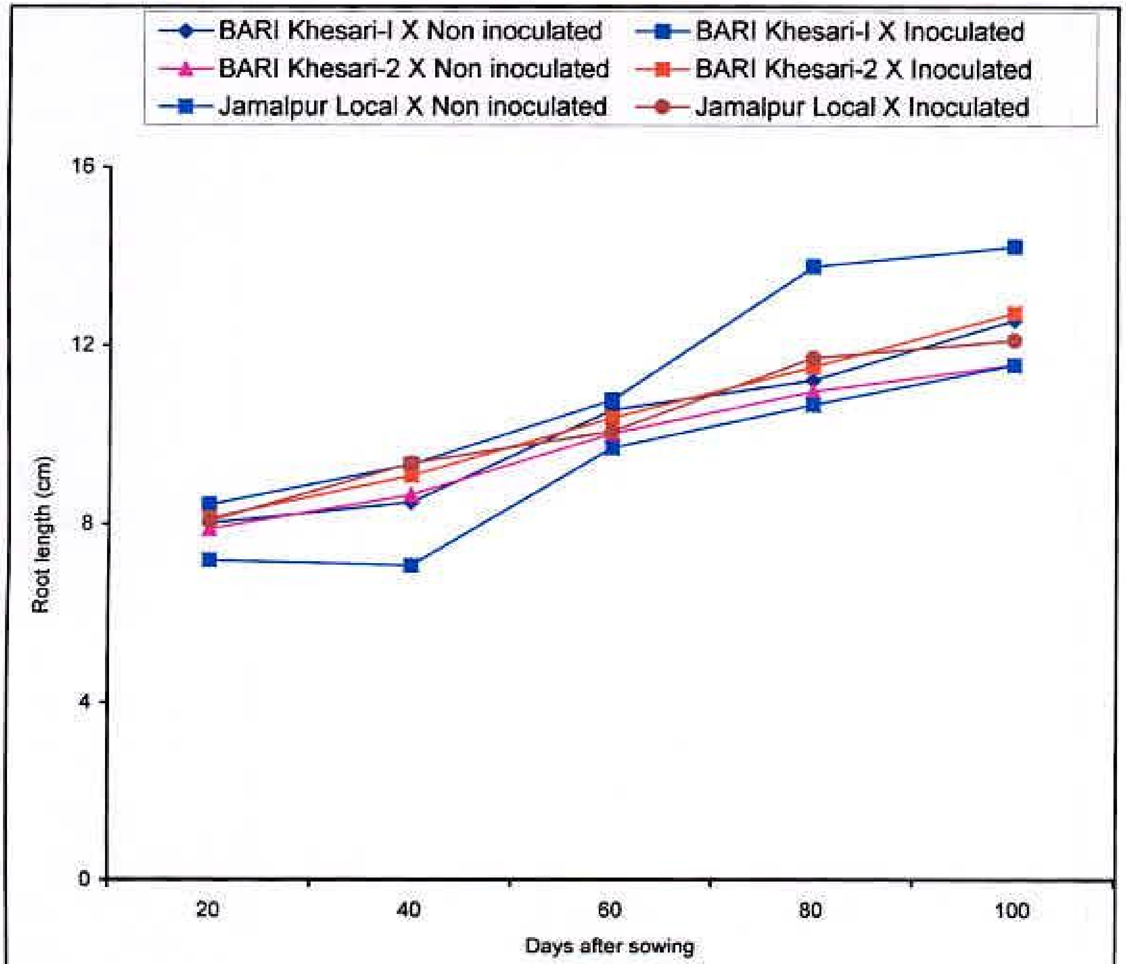

Fig. 4.15. Interaction effects of varieties and rhizobial inoculant on root length of grasspea at different days after sowing (DAS)

4.6.1 Effect of variety

Shoot length of different varieties varied significantly (Fig. 4.16 and App. 4.16). BARI Khesari-1 had the highest shoot length of 44.30 cm plant^{-1} and the lowest shoot length of 37.98 cm plant^{-1} was observed in Jamalpur local at 100 DAS. Shoot length increased over time irrespective of varietal differences. It appears that shoot length increased with age. Similar results regarding plant height of mungbean varieties were reported by Thakuria and Saharia (1990); Patra and Bhattacharyya (1998); Rahman (2000); Roy (2001). The tallest plant was recorded from BARI Khesari-1 in all cases, which was identical with that of BARI Khesari-2 at 60, 80 and 100 DAS. Jamalpur local produced the shortest plants in all the DAS. Similar findings were observed by Thakuria and Saharia (1990); Samanta *et al.* (1999); Nag *et al.* (2000); Naher (2000); Roy (2001); Haque *et al.* (2001); Bhuiyan *et al.* (2006) but the results differ with Mahmud (1997); Mozumder (1998). They reported that there was no significant difference among the different varieties. The genotypic variation might be responsible for this result.

4.6.2 Effect of *Rhizobium*

Rhizobium inoculation recorded significantly higher shoot length at all the stages of plant growth (Fig. 4.17 and App. 4.17). Shoot length significantly had higher values in inoculated treatment compared to non--inoculated treatment at all the DAS. This indicated that inoculated plants fixed more atmospheric N, causing a vigorous plant growth (Kumar and Agarwal, 1993). Similarly, significantly higher plant height in inoculated plants may be ascribed to more nitrogen supply to the crop through fixation by bacteria (Kumar and Agarwal, 1993). Plants grown without applied inoculant were consistently shorter at all the growth stages. Similar results were obtained by Ardeshna *et al.* (1993); Shukla and Dixit (1996a); Solaiman (1999); Naher (2000); Ashraf *et al.* (2003); Bhuiyan *et al.* (1999, 2006).

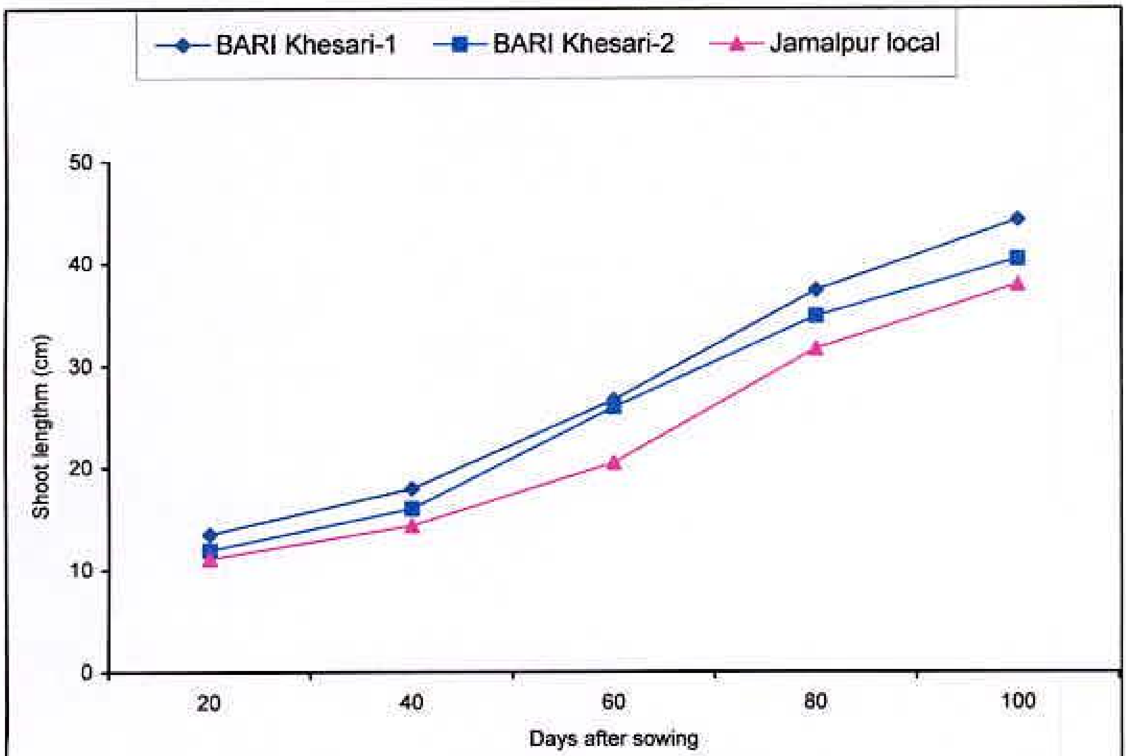

Fig. 4.16. Effects of varieties on shoot length of grasspea at different days after sowing (DAS)

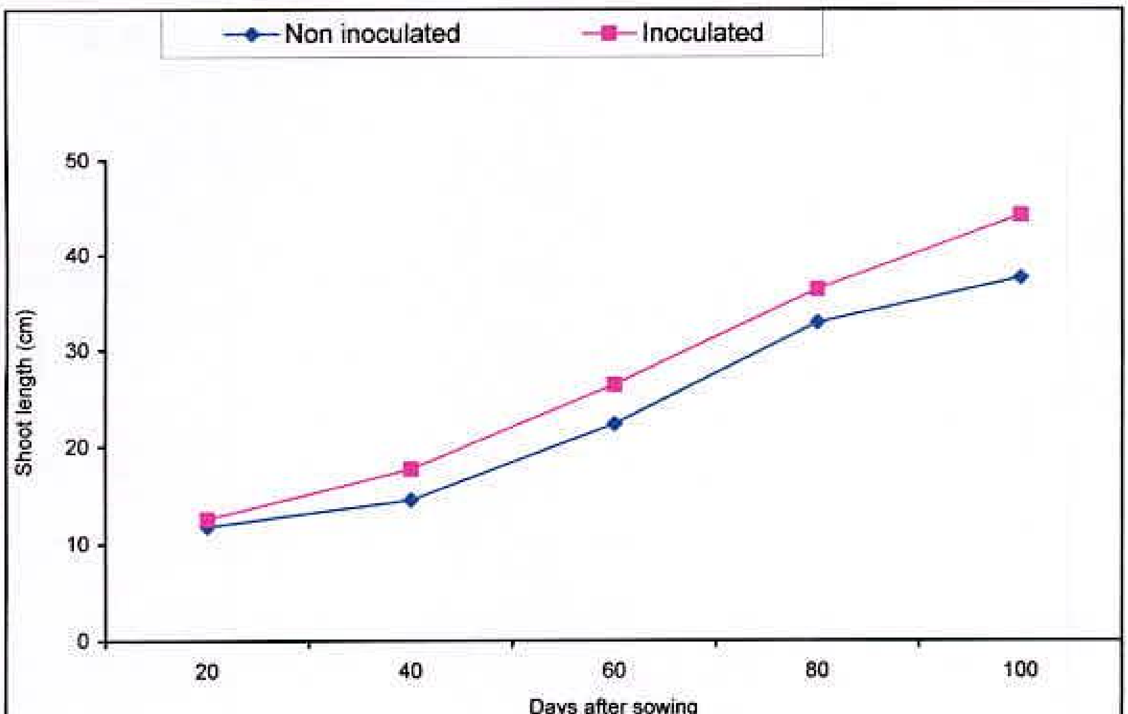

Fig. 4.17. Effects of rhizobial inoculant on shoot length of grasspea at different days after sowing (DAS)

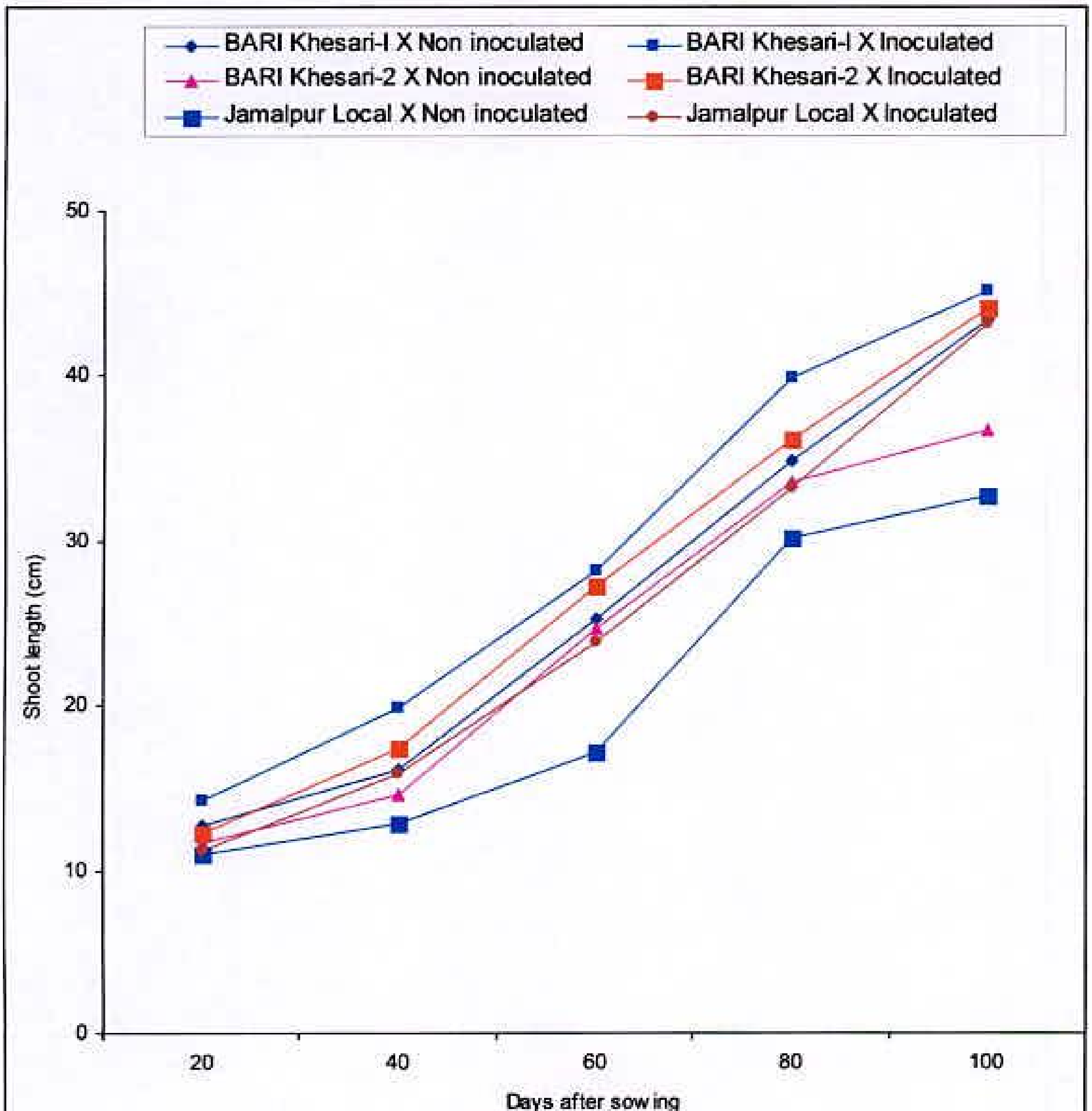

Fig. 18. Interaction effects of varieties and rhizobial inoculant on shoot length of grasspea at different days after sowing (DAS)

4.6.3 Interaction effect of variety and *Rhizobium*

There was no significant interaction effect between variety and seed inoculation at all the sampling dates except 100 DAS (Fig. 4.18 and App. 4.18). The highest shoot length of 45.2 cm plant^{-1} was observed in inoculated BARI Khesari-1 at 100 DAS, while the lowest in non--inoculated Jamalpur local variety. These findings are in conformity with the findings of Mozumder (1998); Naher (2000); Bhuiyan *et al.* (2007).

4.7 Leaf number

The results on leaf number at different growth stages for varietal, *Rhizobium* inoculant response and their interaction have been presented in Figs. 4.19-21 and App. 4.19-4.21.

4.7.1 Effect of variety

Leaf number of different varieties varied significantly except at 20 and 40 DAS (Fig. 4.19 and App. 4.19). BARI Khesari-1 had the highest leaf number (114.55 plant^{-1}) at 100 DAS. The lowest leaf number (6.29 plant^{-1}) was observed in Jamalpur local at 20 DAS. Leaf number increased over time irrespective of varietal differences. In all the sampling dates, the rate of increase was sharp. It appears that leaf number increased upto 100 DAS.

4.7.2 Effect of *Rhizobium*

Rhizobium inoculation recorded significantly increase number of leaf at all the sampling dates except at 20 DAS (Fig. 4.20 and App. 4.20). Leaf number significantly had higher values in inoculated treatment compared to non--inoculated treatment at all the DAS.

4.7.3 Interaction effect of variety and *Rhizobium*

There was no significant interaction effect between variety and seed inoculation on leaf number (Fig. 4.21 and App. 4.21). The highest leaf number of 120.50 plant^{-1} was observed in inoculated BARI Khesari-1 at 100 DAS, while lowest in non--inoculated Jamalpur local.

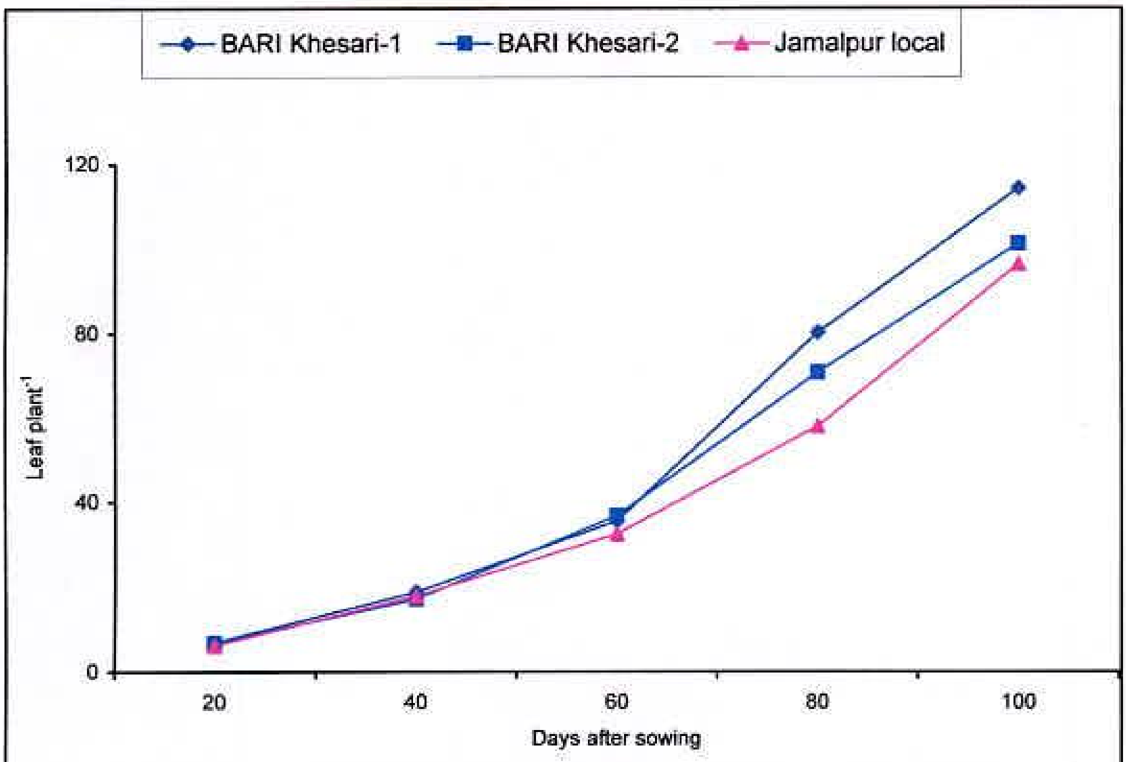

Fig. 4.19. Effects of varieties on leaf plant^{-1} of grasspea at different days after sowing (DAS)

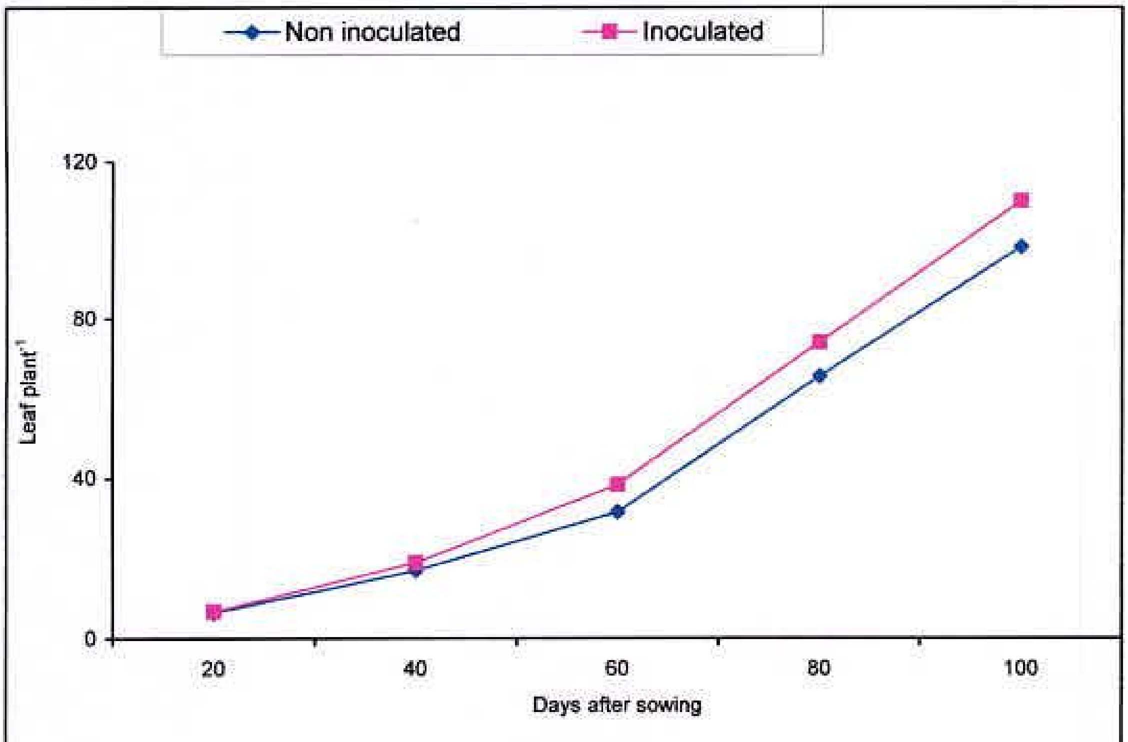

Fig. 4.20. Effects of rhizobial inoculant on level plant^{-1} of grasspea at different days after sowing (DAS)

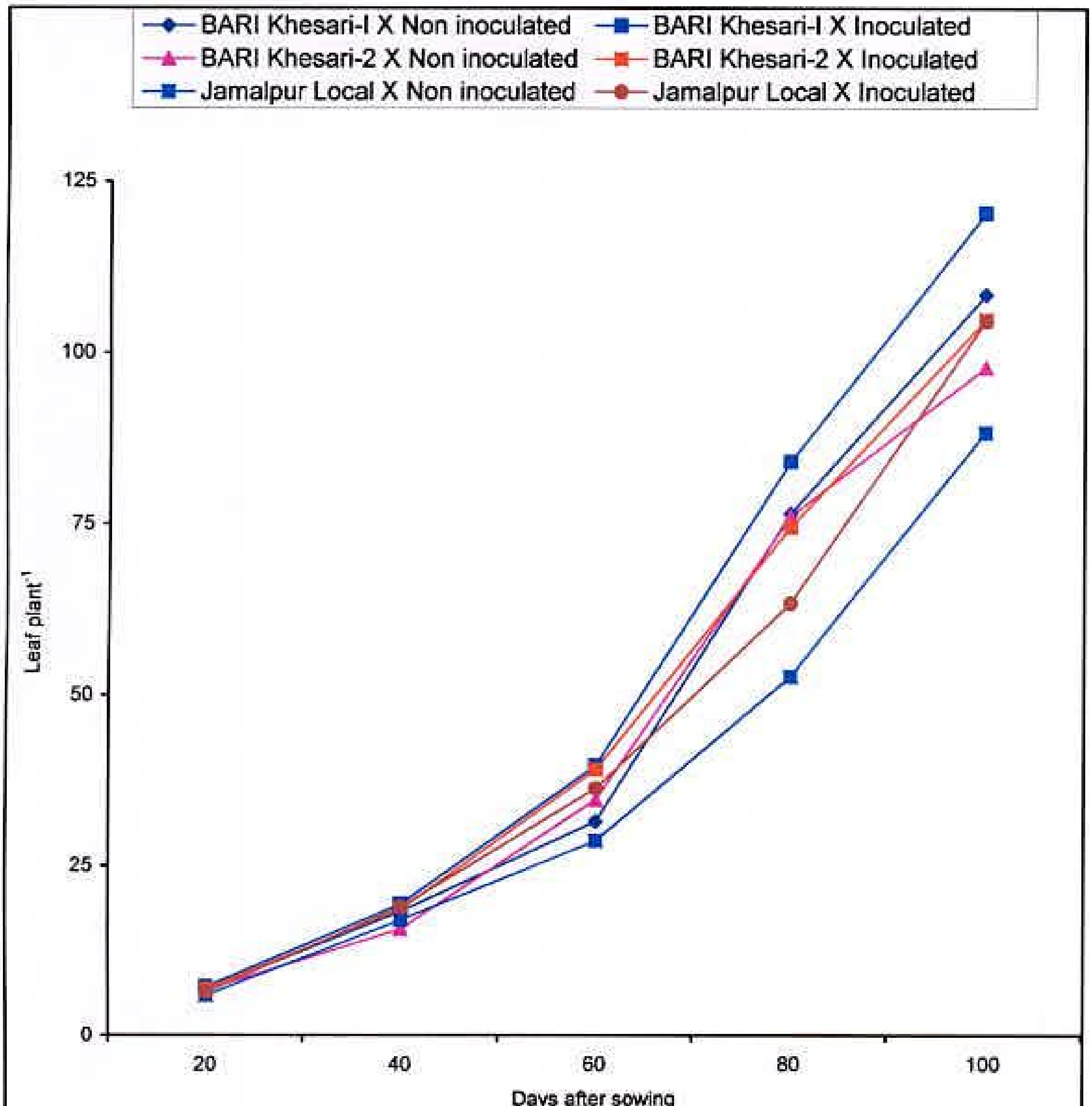

Fig. 4.21. Interaction effects of varieties and rhizobial inoculant on leaf plant^{-1} of grasspea at different days after sowing (DAS)

4.8 Branches plant^{-1}

The *Rhizobium* inoculant response on branch plant^{-1} was significant at 60 and 80 DAS and varietal response was significant at 20 and 80 DAS but variety x *Rhizobium* interaction response was not significant.

4.8.1 Effect of variety

Grasspea variety BARI Khesari-1 produced higher branches plant^{-1} being statistically identical to the other varieties at 20 and 80 DAS (Fig. 4.22 and App. 4.22). BARI Khesari-1 had the maximum number of branches plant^{-1} (5.37) at 100 DAS while Jamalpur local had the minimum.

4.8.2 Effect of *Rhizobium*

Application of *Rhizobium* significantly increased branches plant^{-1} (3.82 at 60 DAS and 4.63 at 80 DAS) over the non--inoculated control (Fig. 4.23 and App. 4.23). The results are in agreement with the findings of Shukla and Dixit (1996a); Naher (2000) who reported that inoculation significantly increased the number of branches plant^{-1}.

4.8.3 Interaction effect of variety and *Rhizobium*

No significant interaction effect was observed between variety and seed inoculation on branches plant^{-1} (Fig. 4.24 and App. 4.24). The highest number of branches (5.57) was produced by BARI Khesari-2 with *Rhizobium* and Jamalpur local in non--inoculated control produced the minimum.

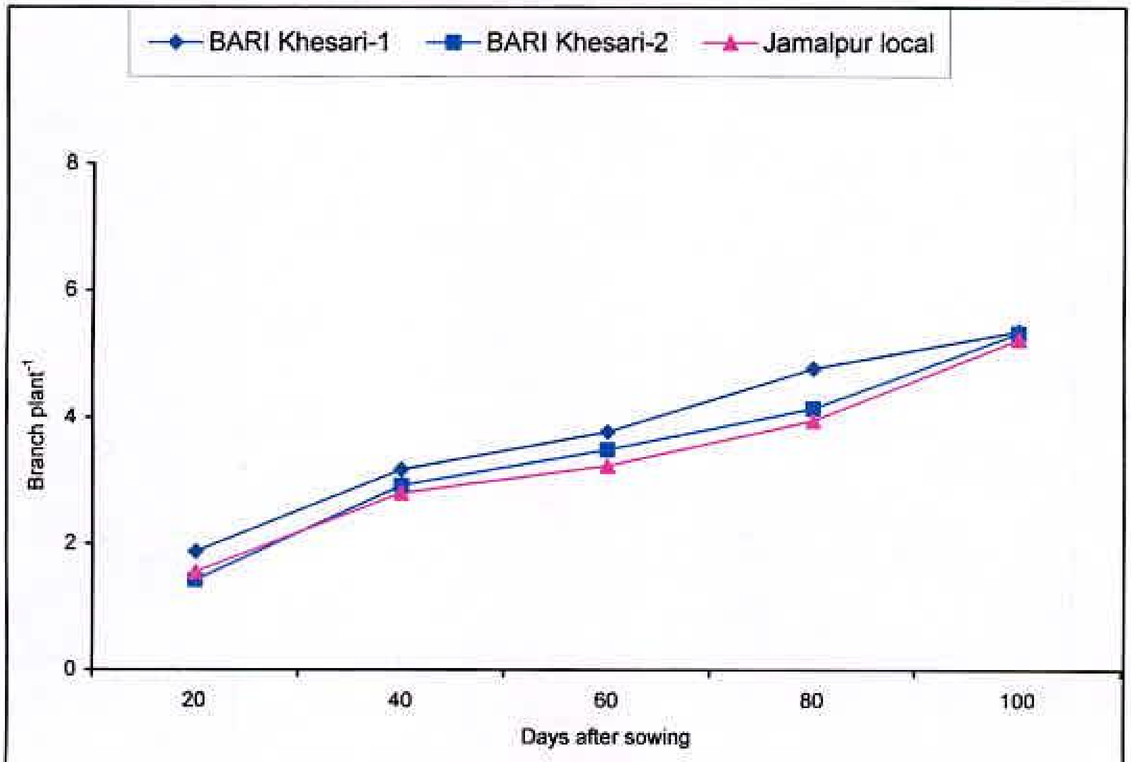

Fig. 4.22. Effects of varieties on branch plant^{-1} of grasspea at different days after sowing (DAS)

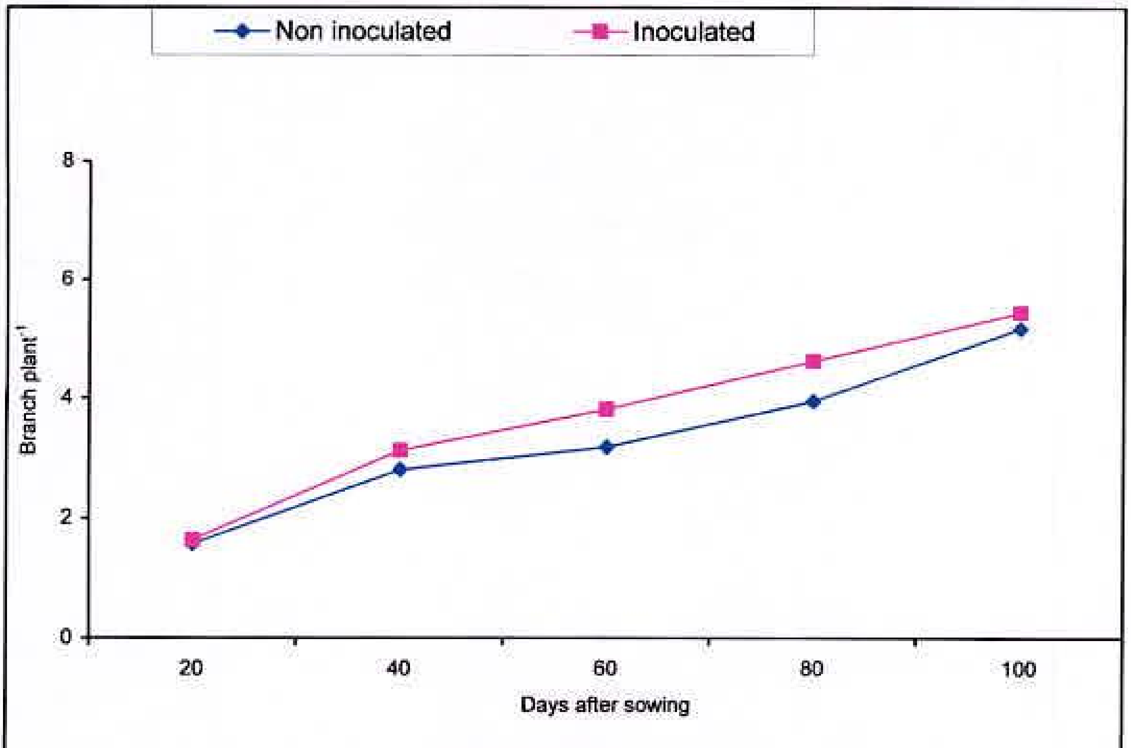

Fig. 4.23. Effects of rhizobial inoculant on branch plant^{-1} of grasspea at different days after sowing (DAS)

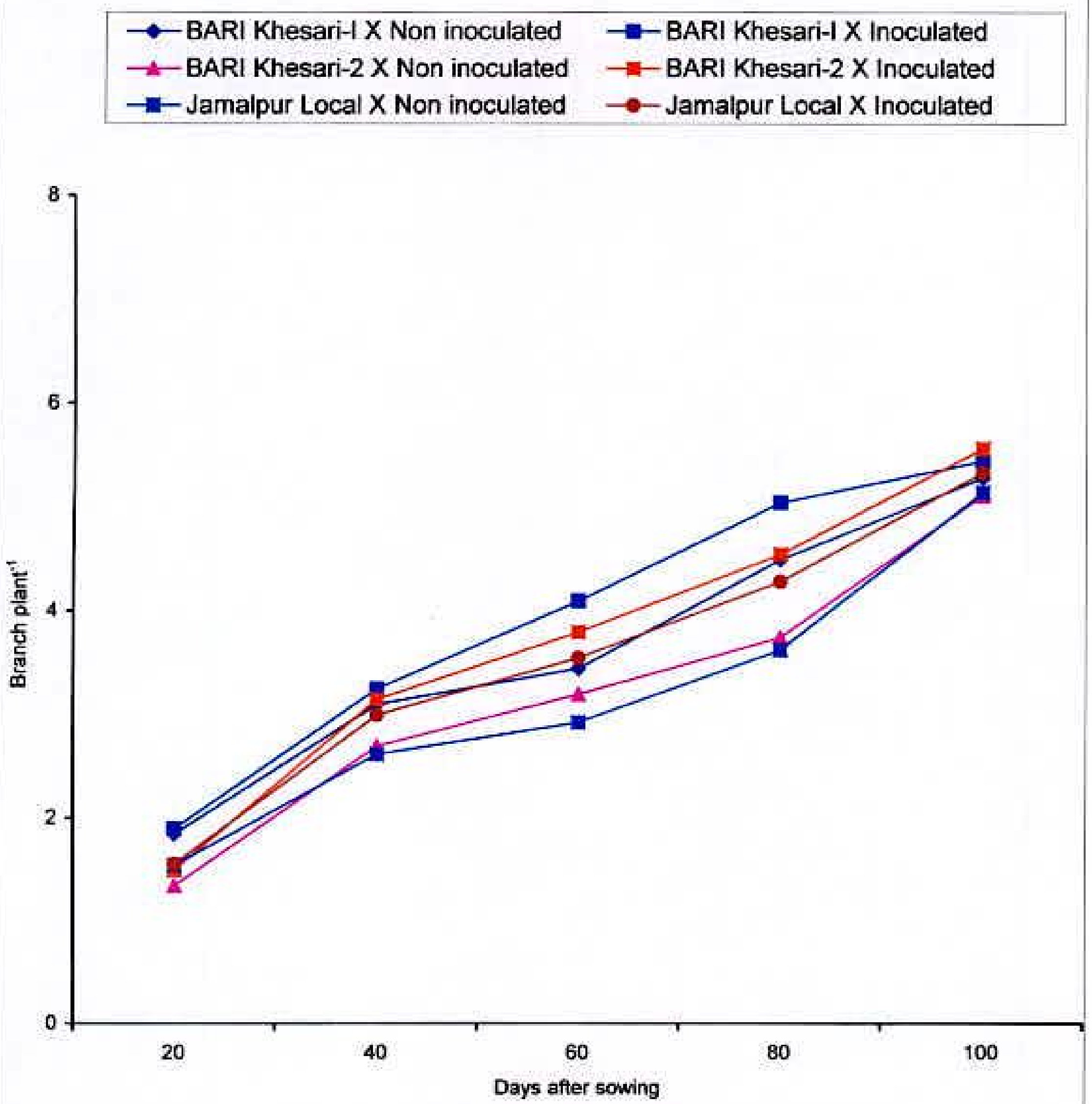

Fig. 4.24. Interaction effects of varieties and rhizobial inoculant on branch plant^{-1} of grasspea at different days after sowing (DAS)

4.9 Plant height

The results on plant height for varietal, *Rhizobium* inoculant response and their interaction have been presented in Tables 4.1-4.3.

4.9.1 Effect of variety

Plant height of different varieties varied significantly (Table 4.1). BARI Khesari-1 had the highest plant height of 47.90 cm plant^{-1}. The lowest plant height (36.50 cm plant^{-1}) was observed in Jamalpur local. Similar results regarding plant height of grasspea varieties were reported by Bhuiyan *et al.* (2006, 2007). The tallest plant was recorded from BARI Kheasar-1 which was identical with that of BARI Kheasari-2. The genotypic variation might be responsible for this result.

4.9.2 Effect of *Rhizobium*

Rhizobium inoculation recorded significantly higher plant height (Table 4.2). Plant height significantly had higher values in inoculated treatment compared to non--inoculated treatment. This indicated that inoculated plants fixed more atmospheric N, causing a vigorous plant growth (Kumar and Agarwal, 1993). Similarly, significantly higher plant height in inoculated plants may be ascribed to more nitrogen supply to the crop through fixation by bacteria (Kumar and Agarwal, 1993). Plants grown without applied inoculant were consistently shorter. Similar results were obtained by Ardeshna *et al.* (1993); Shukla and Dixit (1996a); Solaiman (1999); Naher (2000); Ashraf *et al.* (2003); Bhuiyan *et al.* (2006, 2007).

4.9.3 Interaction effect of variety and *Rhizobium*

There was no significant interaction effect between variety and seed inoculation (Table 4.3). The highest plant height of 50.90-cm plant^{-1} was observed in inoculated BARI Kheasari-1, while lowest in non--inoculated Jamalpur local (34.80 cm plant^{-1}). These findings are in conformity with the findings of Mozumder (1998); Naher (2000); Bhuiyan *et al.* (2006, 2007).

4.10 Seed yield

The seed yield of the tested grasspea ranged between 0.92 and ~ 1.35 t ha^{-1}, which was quite reasonable yield in the tropical climate while the stover yield ranged from 1.43 to 1.95 t ha^{-1}.

4.10.1 Effect of variety

The different varieties of grasspea varied significantly in terms of seed yield (Fig. 4.25 and App. 4.25). The highest seed yield (1.20 t ha^{-1}) was recorded in BARI Khesari-1 that was statistically similar to BARI Khesari-2. BARI Khesari-1 produced higher dry weight, root nodules and pods $plant^{-1}$, which resulted in higher seed yield. BARI Khesari-2 recorded the second highest seed yield (1.18 t ha^{-1}). Jamalpur local gave the minimum yield (1.00 t ha^{-1}). The present result is in agreement with Samanta *et al.* (1999) who reported that varieties of mungbean differed significantly in seed yield. In modern varieties, the reasons for obtaining higher seed yield might be due to high dry matter accumulation, more number of pods $plant^{-1}$ and 1000-seed weight as compared to local variety. Bhuiyan *et al.* (1998, 2007) also reported similar results.

4.10.2 Effect of *Rhizobium*

Seed inoculation with *Rhizobium* significantly increased the seed yield of grasspea (Fig. 4.26 and App. 4.26). The increase in yield due to *Rhizobium* inoculation compared to non-inoculated control was 26%. The increase in yield in inoculated treatment might be attributed to increased nodules $plant^{-1}$ and nodule dry weight, resulting in higher dry-matter accumulation during the growth period and translocation of more photosynthate to the seed (Rani and Kodandaramaiah, 1997). Ashraf *et al.* (2003) showed that seed inoculation with

Bradyrhizobium strain significantly increased mungbean seed yield. Bhuiyan *et al.* (1999, 2006) also reported similar results in grasspea due to *Rhizobium* inoculation.

4.10.3 Interaction effect of variety and *Rhizobium*

The interaction effects of different varieties of grasspea and *Rhizobium* inoculant were not significant in terms of seed yield (Fig. 4.27 and App. 4.27). BARI Khesari-1 gave higher yield compared to other varieties both under inoculated and non-inoculated conditions. Among the grasspea varieties, Jamalpur local gave the lowest seed yield. The results are in agreement with the findings of Bhuiyan *et al.* (1997, 2007).

4.11 Stover yield

4.11.1 Effect of variety

Results presented in Fig. 4.25 and App. 4.25 show that BARI Khesari-1 produced the highest stover yield which was statistically similar to that found in BARI Khesari-2 but statistically higher over Jamalpur local. The highest stover yield (1.79 t ha^{-1}) recorded by BARI Khesari-1 was attributed to influence of higher branches $plant^{-1}$ and increased plant height. Jamalpur local variety gave the lowest stover yield (1.53 t ha^{-1}). Bhuiyan *et al.* (1997, 2006) found similar results.

4.11.2 Effect of *Rhizobium*

Rhizobium inoculation significantly increased the stover yield over non-inoculated one (Fig. 4.26 and App. 4.26). *Rhizobium* inoculation increased the stover yield by 19% over non-inoculated control. Increased nodulation due to seed inoculation resulting in increase in the vegetative growth, which has increased the seed yield as well as stover yield. The results obtained are in accordance with Shukla and Dixit (1996a); Solaiman (1999); Bhuiyan *et al.* (1998, 2007).

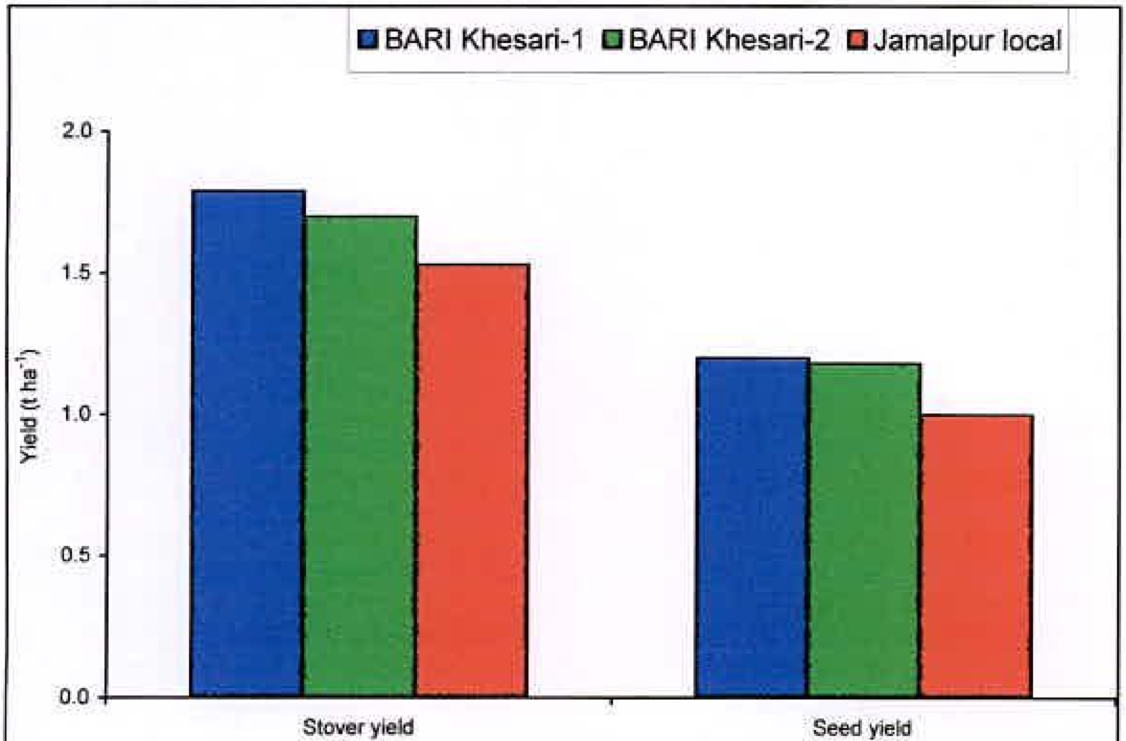

Fig. 4.25. Effect of variety on yield of grasspea

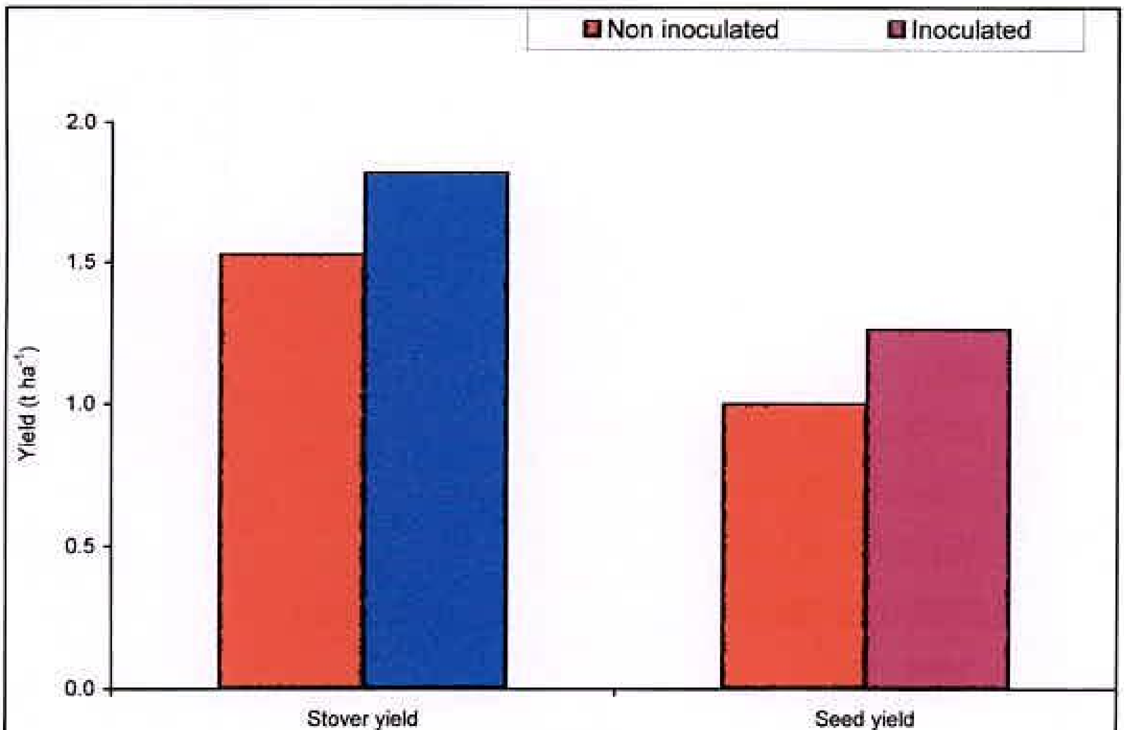

Fig. 4.26. Effect of rhizobial inoculant on yield of grasspea

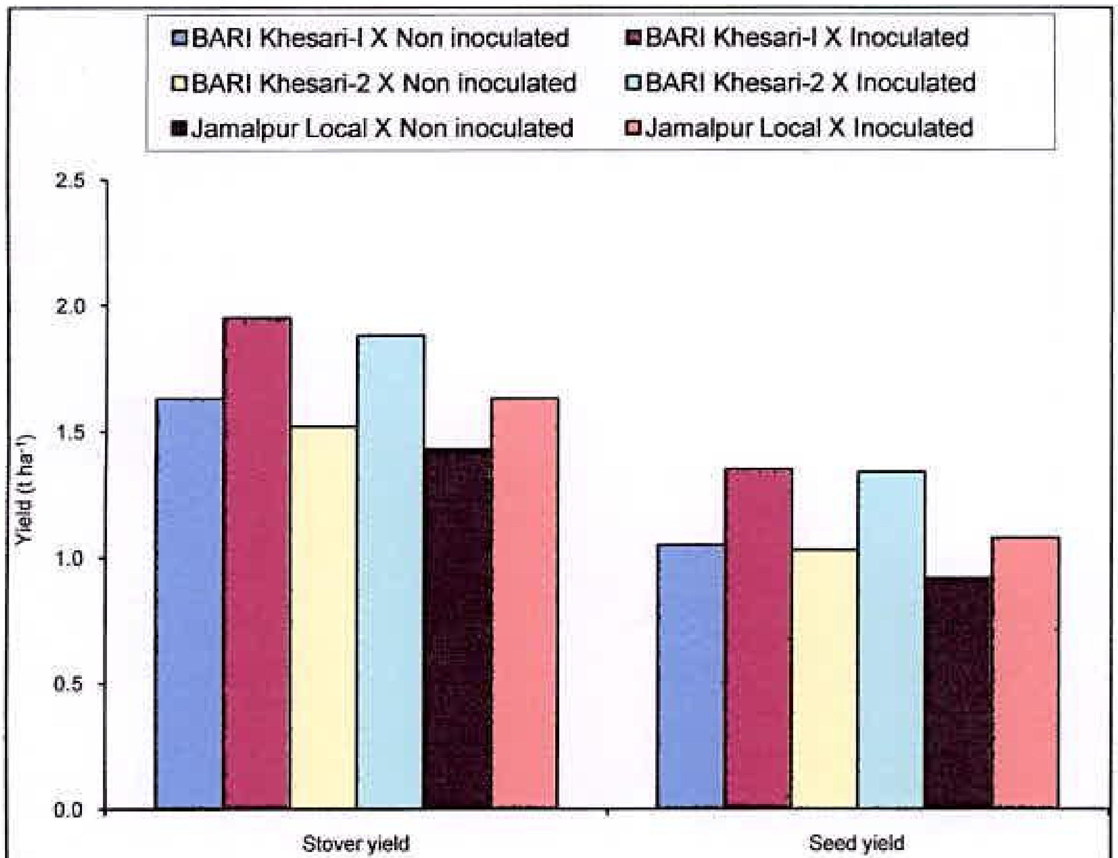

Fig. 4.27. Interaction effects of variety and rhizobial inoculant on yield of grasspea

4.11.3 Interaction effect of variety and *Rhizobium*

The stover yields were higher in BARI Khesari-1 (Fig. 4.27 and App. 4.27). The maximum stover yield (1.95 t ha^{-1}) was obtained in BARI Khesari-1 with *Rhizobium* inoculation, which was higher over any other interaction treatments. This was probably due to better utilization of *Rhizobium* with BARI Khesari-1. The lowest stover yield (1.43 t ha^{-1}) was with uninoculated Jamalpur local. Similar non--significant results on stover yield in grsspea were observed by Bhuiyan *et al*. (1999, 2006).

4.12 Pods $plant^{-1}$

The effect of variety, inoculation and their interaction effect on pods $plant^{-1}$ were not significant (Tables 4.1-4.3).

4.12.1 Effect of variety

Varietal effects on pods $plant^{-1}$ was non--significant (Table 4.1). The pod $plant^{-1}$ (mean of inoculated and non-inoculated treatment) was the highest (13.40 $plant^{-1}$) in BARI Khesari-1 and the lowest in Jamalpur local (11.20 $plant^{-1}$).

4.12.2 Effect of *Rhizobium*

Rhizobium inoculation increased the number of pods $plant^{-1}$ though it was non--significant (Table 4.2). Inoculated plants (average of all varieties) produced 1 pod more than the uninoculated plants. Similar response of the grasspea varieties may be attributed to their parental similarities and similarities in genotypic make-up.

4.12.3 Interaction effect of variety and *Rhizobium*

Varietal and *Rhizobium* inoculant effects on pods $plant^{-1}$ was non--significant (Table 4.3). The highest pods $plant^{-1}$ was observed in inoculated BARI khesari-1.

Table 4.1. Effect of variety on yield attributes of grasspea

Variety	Plant height (cm)	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)
BARI Khesari-1	47.90 a	13.40	4.30	43.20
BARI Khesari-2	47.10 a	11.75	4.22	41.90
Jamalpur local	36.50 b	11.20	3.80	41.80
SE (±)	0.67	-	-	-
Sig.	**	NS	NS	NS

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level
NS = Non- significant

Table 4.2. Effect of inoculant on yield and yield attributes of grasspea

Inoculant	Plant height (cm)	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)
Non-inoculated	41.57 b	11.58	3.92	41.17 a
Inoculated	46.10 a	12.65	4.30	43.43 b
SE (±)	0.55	-	-	0.36
Sig.	**	NS	NS	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level
NS = Non- significant

Table 4.3. Interaction effects of variety and rhizobial inoculant on yield attributes of grasspea

Treatment	Plant height (cm)	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)
BARI Khesari-1 X U	44.90	12.55	4.10	41.90
BARI Khesari-1 X I	50.90	14.25	4.50	44.50
BARI Khesari-2 X U	45.00	11.30	4.00	41.00
BARI Khesari-2 X I	49.20	12.20	4.45	42.80
Jamalpur Local X U	34.80	10.90	3.65	40.60
Jamalpur Local X I	38.20	11.50	3.95	43.00
SE (±)	-	-	-	-
Sig.	NS	NS	NS	NS
CV (%)	4.3	16.2	13.7	3.0

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non- significant

4.13 Seeds pod^{-1}

The effect of variety, inoculation and their interaction effect on seeds pod^{-1} was not significant (Tables 4.1-4.3).

4.13.1 Effect of variety

The number of seeds pod^{-1} did not differ significantly among the varieties (Table 4.1). BARI Khesari-1 produced the highest number of seeds pod^{-1} (4.30), which was statistically similar to all other varieties.

4.13.2 Effect of *Rhizobium*

Rhizobium inoculation did not significantly increase number of seeds pod^{-1} (Table 4.2). Similar results were obtained by Mozumder (1998) and Naher (2000), who reported that *Rhizobium* inoculation did not significantly increase the number of mature seed pod^{-1}.

4.13.3 Interaction effect of variety and *Rhizobium*

Variety x *Rhizobium* interaction effect on the number of seeds pod^{-1} was not statistically significant (Table 4.3). Higher number of seeds pod^{-1} (4.50) was observed in inoculated BARI Khesari-1.

4.14 1000-seed weight

The mean effects of variety and interaction effect on 1000-seed weight were non--significant but effect of *Rhizobium* was significant (Table 4.1-4.3).

4.14.1 Effect of variety

Thousand-seed weight of three grasspea varieties did not differ significantly (Table 4.1). Maximum weight of 1000-seeds (43.20 g) was obtained in BARI Khesari-1 (average of inoculum). The results are in conformity with the findings of Bhuiyan *et al.* (1988; 1999, 2006).

4.14.2 Effect of *Rhizobium*

Rhizobium inoculation significantly increased the 1000-seed weight over no inoculation (Table 4.2). Results showed that 1000-seed weight (mean over variety) was higher (43.43 g) in inoculated plants over non-inoculated plants. This result was similar with the result of Shukla and Dixit (1996a; 1996b); Provorov *et al.* (1998); Naher (2000); Bhuiyan *et al.* (1997, 2007).

4.14.3 Interaction effect of variety and *Rhizobium*

The interaction effect of variety x *Rhizobium* inoculation was not significant in respect of 1000-seed weight (Table 4.3). This might be due to the similar response of different varieties with *Bradyrhizobium*. Thousand-seed weight was highest in inoculated

BARI Khesari-1 (44.50 g) and it was the lowest in uninoculated Jamalpur local (40.60 g). Bhuiyan *et al.* (2006, 2007) reported similar results.

4.15 Nitrogen content in stover and seed

4.15.1 Effect of variety

The tested grasspea varieties differed significantly in nitrogen uptake (Table 4.4). The highest N content (2.05% in stover and 3.02% in seed) was observed by BARI Khesari-1 which was different from BARI Khesari-2 and Jamalpur local. Alam *et al.* (1988) found similar results.

Table 4.4. Effect of variety on N content in grasspea

Variety	N content in stover (%)	N content in seed (%)
BARI Khesari-1	2.05 a	3.02 a
BARI Khesari-2	2.00 b	2.95 b
Jamalpur local	1.96 c	2.92 b
SE (±)	0.011	0.018
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

4.15.2 Effect of *Rhizobium*

Effects of *Rhizobium* inoculation on N concentration in grasspea stover and seed was significant (Table 4.5). The inoculated plant accumulated about 3.04% more N in stover and 2.05% more N in seed than the non-inoculated plant. It might be due to higher concentration of nitrogen in inoculated grasspea. Islam *et al.* (1987) reported higher N content in shoot due to *Rhizobium* inoculation over uninoculated control. Solaiman (1999) illustrated that inoculation of mungbean with *Rhizobium* increased nitrogen concentration and uptake. In the present experiment, the N content in seed and stover was more prominent in inoculation with *Bradyrhizobium*, which was in agreement with Das *et al.* (1999) who observed that N uptake in greengram was significantly higher due to *Bradyrhizobium* inoculation. Similar result was observed by Bhuiyan (2004) in mungbean.

Table 4.5. Effect of rhizobial inoculant on N content in grasspea

Inoculant	N content in stover (%)	N content in seed (%)
Non-inoculated	1.97 b	2.93 b
Inoculated	2.03 a	2.99 a
SE (±)	0.011	0.014
Sig.	**	*

In a column, the figures(s) having different letter(s) differed significantly
* and ** Significant at 5% and 1% level, respectively

4.15.3 Interaction effect of variety and *Rhizobium*

Nitrogen content in seed and stover was higher under *Rhizobium* inoculated plots than uninoculated plots in all the varieties (Table 4.6). It was because of higher number of bacteria available under inoculated plots, which increased N fixation (Shukla and Dixit, 1996b). The highest stover and seed nitrogen content was observed in inoculated BARI Khesari-1 and the lowest in uninoculated Jamalpur local.

Table 4.6. Interaction effects of variety and rhizobial inoculant on N content in grasspea

Treatment	N content in stover (%)	N content in seed (%)
BARI Khesari-1 X U	2.01	3.00
BARI Khesari-1 X I	2.09	3.04
BARI Khesari-2 X U	1.97	2.92
BARI Khesari-2 X I	2.03	2.98
Jamalpur Local X U	1.94	2.88
Jamalpur Local X I	1.98	2.95
SE (±)	-	-
Sig.	NS	NS
CV (%)	1.8	1.7

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non- significant

4.16 Nitrogen uptake by stover and seed

4.16.1 Effect of variety

Observation on nitrogen uptake by grasspea shoot and seed revealed that varieties differed significantly among themselves (Fig. 4.28 and App. 4.28). The highest uptake of N (36.80 kg ha^{-1}) was recorded by BARI Khesari-1, which was at per with BARI Khesari-2. Higher nitrogen uptake was due to higher biomass production. Uptake of N by seed and stover differed significantly (Fig. 4.29 and App. 4.29). Variety BARI Khesari-1 produced the highest seed and stover nitrogen uptake. Jamalpur local recorded the lowest uptake. The results are in agreement with Alam *et al.* (1988).

4.16.2 Effect of *Rhizobium*

Effect of *Rhizobium* inoculation on nitrogen uptake by grasspea shoot and seed was significant (Fig. 4.29 and App. 4.29). It might be due to higher concentration of nitrogen and higher shoot yields of grasspea. Khanam (2002) described similar findings. She found that *Rhizobium* inoculated chickpea plants showed significantly higher uptake of nitrogen into seed and stover than non--inoculated plants. Inoculated mungbean and blackgram significantly increased uptake of N compared to non--inoculation (Singh *et al.*, 1993). Solaiman (1999) illustrated that inoculation of mungbean with *Bradyrhizobium* increased nitrogen content and uptake. In the present experiment, the N uptake by seed and stover was more prominent in inoculation with *Rhizobium*, which is in agreement with Das *et al.* (1999) who observed that N uptake in greengram was significantly higher due to *Bradyrhizobium* inoculation along with P fertilizers. Shukla and Dixit (1996b) and Bhuiyan (2004) also documented similar results.

4.16.3 Interaction effect of variety and *Rhizobium*

Nitrogen uptake in seed and stover was higher under *Rhizobium* inoculated plots than non--inoculated plots in all the varieties (Fig. 4.30 and App. 4.30). It was because of higher number of bacteria available under inoculated plots, which increased N fixation (Shukla and Dixit, 1996b). The highest stover and seed nitrogen uptake was observed in inoculated BARI Khesari-1 and the lowest in non--inoculated Jamalpur local. Alam *et al.* (1988) and Bhuiyan (2004) reported similar results.

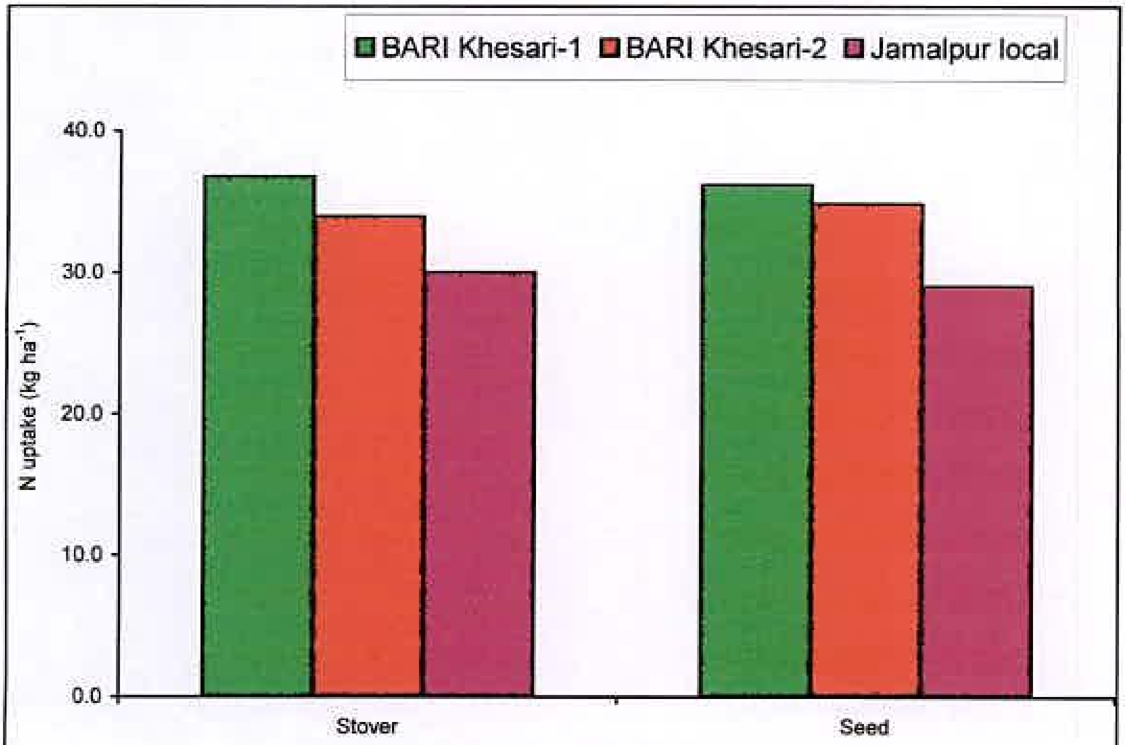

Fig. 4.28. Effect of variety on N uptake by grasspea

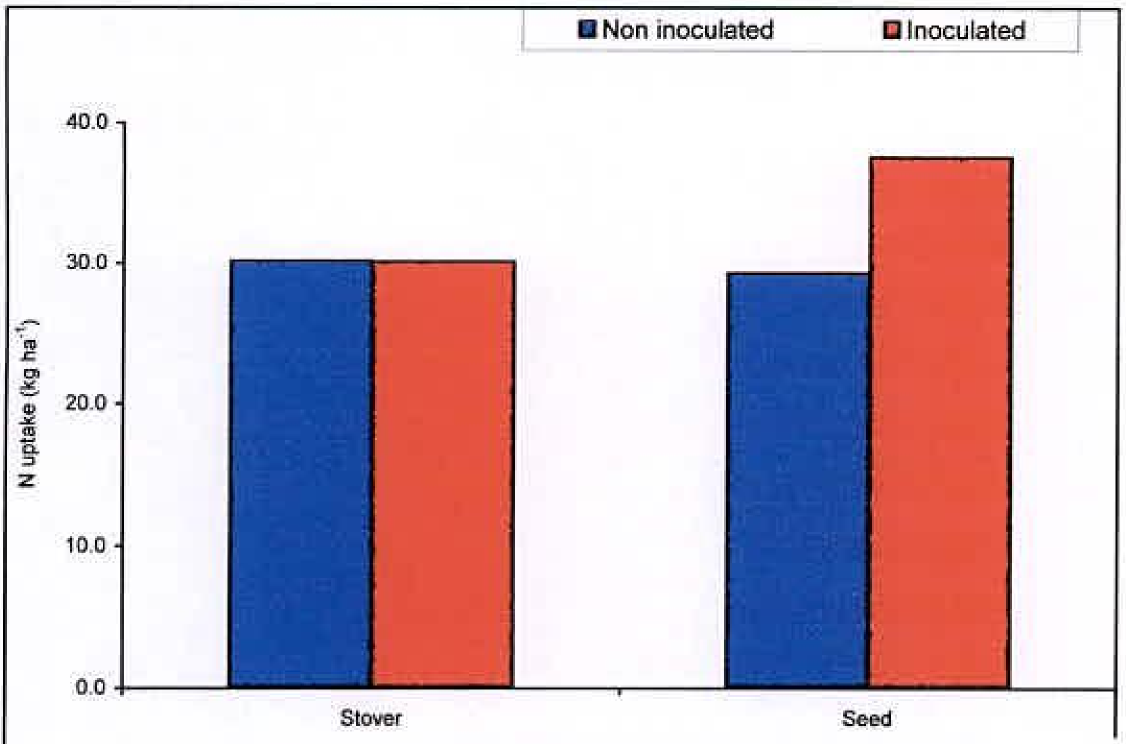

Fig. 4.29. Effect of rhizobial inoculants on N uptake by grasspea

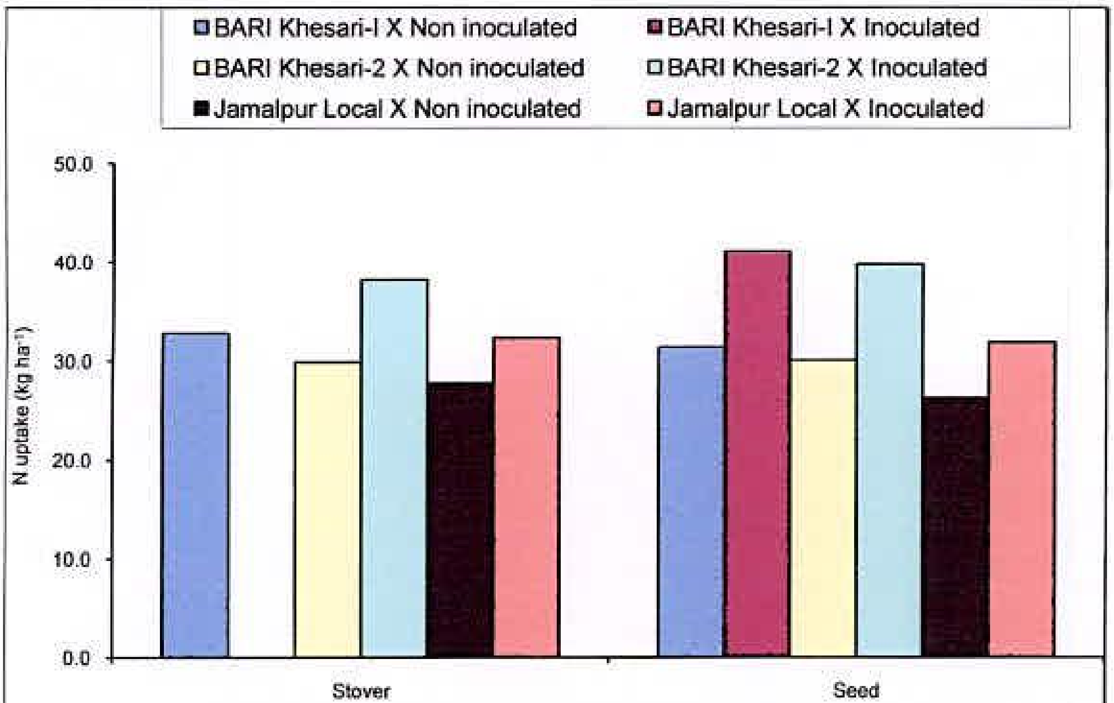

Fig. 4.30. Interaction effects of variety and rhizobial inoculant on N uptake by grasspea

4.17 Protein concentration in seed

4.17.1 Effect of variety

Protein concentration in seeds varied significantly among the varieties (Table 4.7). The highest protein concentration in seed was observed in BARI Khesari-1. This variety produced significantly higher protein content (18.88%), which was differed from BARI Khesari-2 and Jamalpur local. The protein content was the lowest (18.22%) in Jamalpur local.

Table 4.7. Effect of variety on protein content and protein yield in grasspea

Variety	Protein content (%)	Protein yield (kg ha^{-1})
BARI Khesari-1	18.88 a	227 a
BARI Khesari-2	18.28 b	218 a
Jamalpur local	18.22 b	182 b
SE (±)	0.12	8.31
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

4.17.2 Effect of *Rhizobium*

Protein concentration in seeds of inoculated plants was greater than non-inoculated plants (Table 4.8). The highest percentage of protein (18.69) was recorded with inoculated grasspea. Inoculated grasspea produced significantly higher content of protein (18.69%) over non-inoculated control. Khanam (2002) reported that *Rhizobium* significantly increased protein content in chickpea seeds. Bhuiyan (2004) also observed similar results.

Table 4.8. Effect of rhizobial inoculant on protein content and protein yield in grasspea

Inoculant	Protein content (%)	Protein yield (kg ha^{-1})
Non-inoculated	18.23 b	183 b
Inoculated	18.69 a	235 a
SE (±)	0.10	6.78
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

4.17.3 Interaction effect of variety and *Rhizobium*

Interaction of variety and *Rhizobium* was not significant in protein concentration in grasspea (Table 4.9). This might be due to the similar response of three varieties with *Rhizobium* inoculation on protein concentration. The highest protein concentrations were always found in inoculated BARI Khesari-1 and the lowest in uninoculated Jamalpur local.

4.18 Protein yield in seed

4.18.1 Effect of variety

Protein yield varied significantly among the varieties (Table 4.7). The highest protein yield (227 kg ha^{-1}) in seed was observed in BARI Khesari-1 which was identical to BARI Khesari-2; and the lowest (182 kg ha^{-1}) in Jamalpur local.

Table 4.9. Interaction effect of variety and rhizobial inoculant on protein content and protein yield in grasspea

Treatment	Protein content (%)	Protein yield (kg ha^{-1})
BARI Khesari-1 X U	18.75	196
BARI Khesari-1 X I	19.00	257
BARI Khesari-2 X U	17.94	188
BARI Khesari-2 X I	18.63	249
Jamalpur Local X U	18.00	165
Jamalpur Local X I	18.44	199
SE (±)	-	-
Sig.	NS	NS
CV (%)	1.8	11.2

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non- significant

4.18.2 Effect of *Rhizobium*

Protein yield by seeds of grasspea were significantly higher over control when *Rhizobium* inoculated the plants (Table 4.8). The inoculated plants showed the maximum protein yield of seeds. The highest yield of protein was recorded with inoculated grasspea. Inoculated grasspea produced the highest amount of protein (235 kg ha^{-1}) over control. Khanam (2002) documented similar observation. She reported that *Rhizobium* significantly increased protein control in chickpea seeds.

4.18.3 Interaction effect of variety and *Rhizobium*

Interaction of variety and *Rhizobium* did not differ significantly in respect of protein yield in grasspea (Table 4.9). This might be due to the similar response of three grasspea varieties on protein yield. Interaction of variety and *Rhizobium* on protein yields was non--significant. Highest protein yield was found in inoculated BARI Khesari-1 (257 kg ha^{-1}).

4.19 Correlation

Correlation matrix among the plant characters of grasspea has been shown in Tables 4.10-4.12. Most of the plant characters were strongly correlated among themselves. In the present study, nodule number had positive and significant correlation with nodule weight and other plant characters also correlated among themselves (Tables 4.11-4.12).

A highly significant and positive correlation was observed between yield and yield contributing parameters (Table 4.11), except seed yield and pods $plant^{-1}$, stover yield and pods $plant^{-1}$, 1000-seed weight and seeds pod^{-1}. These results confirmed the findings of Khanam (2002). They observed positive and significant correlation of nodule number with nodule weight, root weight, and shoot weight of inoculated chickpea and soybean. Solaiman (1999) found positive correlation among mungbean growth, N uptake and yield parameters. Seed and stover yield were also strongly correlated with N content, N uptake, protein content and protein yield of grasspea (Table 4.12).

Figures 4.31-4.42 represents the relationship among different plant characters of grasspea. A positive and linear correlation was observed between nodule number and nodule weight (Fig. 4.31), nodule number and root weight (Fig. 4.32), nodule number and shoot weight (Fig. 4.33), nodule number and root length (Fig. 4.34), nodule number and shoot length (Fig. 4.35), nodule number and seed yield (Fig. 4.36), nodule number and stover yield (Fig. 4.37), nodule number and N uptake (Fig. 4.38). Similar positive and linear correlation was also found between nodule weight and seed yield (Fig. 4.39), nodule weight and stover yield (Fig. 4.40), nodule weight and N uptake (Fig. 4.41), nodule weight and protein yield uptake (Fig. 4.42), shoot weight and seed yield (Fig. 4.43), shoot weight and stover yield (Fig. 4.44), stover yield and seed yield (Fig. 4.45), seed yield and protein yield (Fig. 4.46).

Table 4.10. Correlation matrix among different plant characters of grasspea at 80 DAS (n = 24)

Characters	Correlation coefficient (r value)						
	Nodule weight	Root weight	Shoot weight	Root length	Shoot length	Leaf number	Branches
Nodule number	0.878^{**}	0.689^{**}	0.508^{*}	0.625^{**}	0.657^{**}	0.728^{**}	0.659^{**}
Nodule weight	-	0.761^{**}	0.402^{NS}	0.512^{*}	0.709^{**}	0.802^{**}	0.596^{**}
Root weight	-	-	0.108^{NS}	0.269^{NS}	0.589^{**}	0.710^{**}	0.325^{NS}
Shoot weight	-	-	-	0.504^{*}	0.412^{*}	0.253^{NS}	0.507^{*}
Root length	-	-	-	-	0.437^{*}	0.313^{NS}	0.523^{**}
Shoot length	-	-	-	-	-	0.696^{**}	0.466^{*}
Leaf number	-	-	-	-	-	-	0.544^{*}

Table 4.11. Correlation matrix among yield and yield contributing characters of grasspea (n = 24)

Characters	Correlation coefficient (r value)				
	Stover yield	1000-seed weight	Plant height	Pods plant^{-1}	Seeds pod^{-1}
Seed yield	0.957^{**}	0.826^{**}	0.806^{**}	0.286^{NS}	0.503^{*}
Stover yield	-	0.875^{**}	0.794^{**}	0.329^{NS}	0.462^{*}
1000-seed weight	-	-	0.562^{**}	0.317^{NS}	0.288^{NS}
Plant height	-	-	-	0.415^{*}	0.475^{*}
Pods plant^{-1}	-	-	-	-	-0.012^{NS}

Table 4.12. Correlation matrix among yield and nutrient content of grasspea (n = 24)

Characters	Correlation coefficient (r value)						
	Stover yield	N content in stover	N uptake by stover	N content in seed	N uptake by seed	Protein content	Protein yield
Seed yield	0.957*	0.882**	0.955**	0.728**	0.996**	0.578**	0.996**
Stover yield	-	0.918**	0.996**	0.816**	0.968**	0.726**	0.968**
N content in stover	-	-	0.946**	0.862**	0.908**	0.722**	0.908**
N uptake by stover	-	-	-	0.834**	0.969**	0.736**	0.969**
N content in seed	-	-	-	-	0.785**	0.868**	0.785**
N uptake by seed	-	-	-	-	-	0.634**	1.00**
Protein content	-	-	-	-	-	-	0.635**

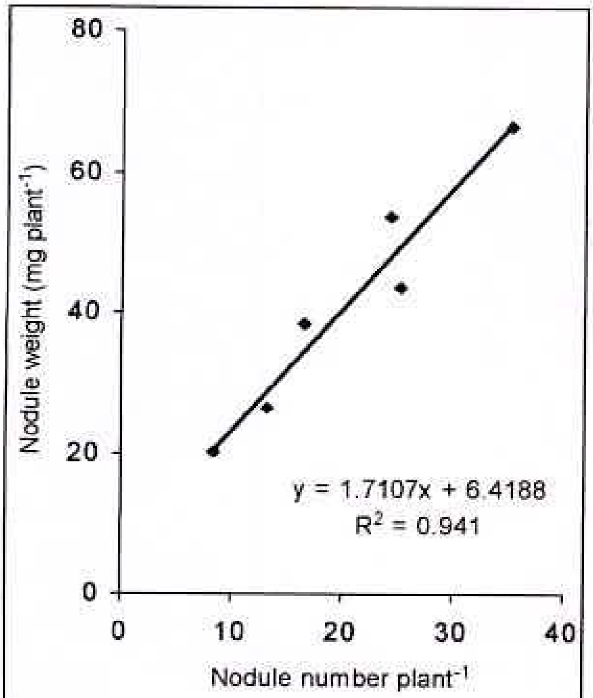

Fig. 4.31. Relationship between nodule number and nodule weight of grasspea at 80 DAS

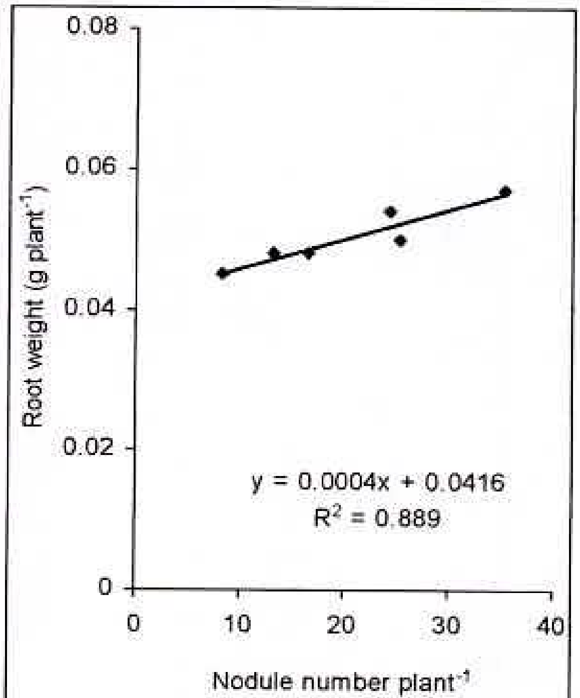

Fig. 4.32. Relationship between nodule number and root weight of grasspea at 80 DAS

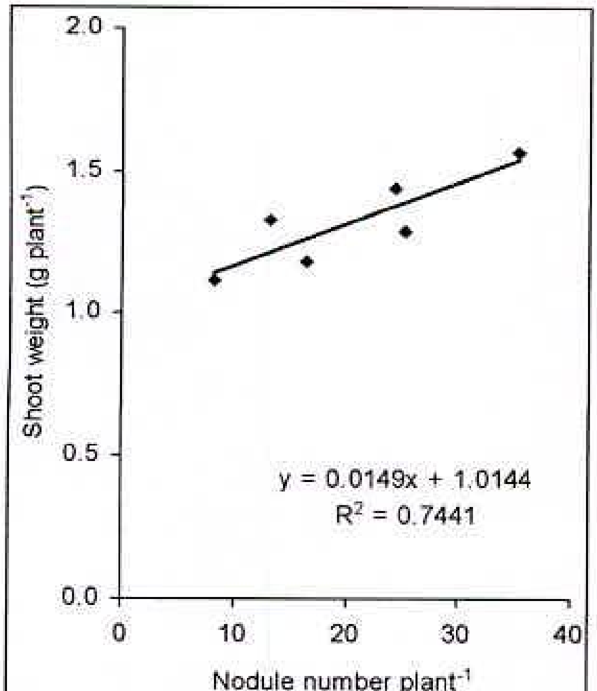

Fig. 4.33. Relationship between nodule number and shoot weight of grasspea at 80 DAS

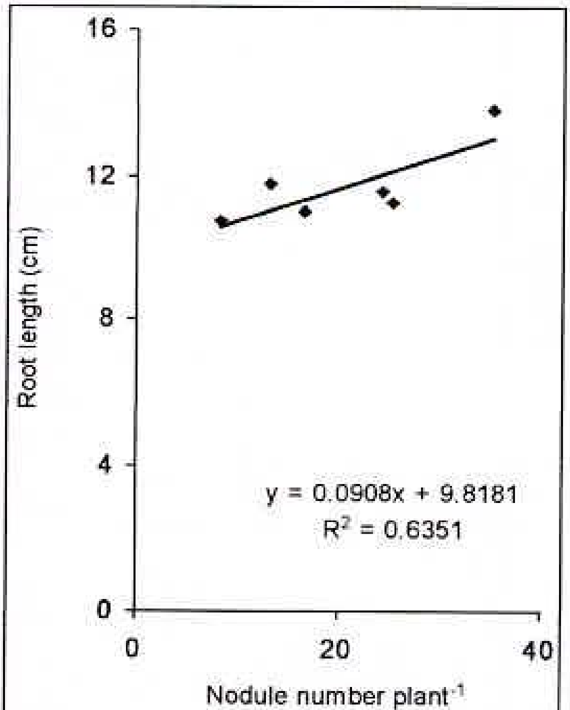

Fig. 4.34. Relationship between nodule number and root length of grasspea at 80 DAS

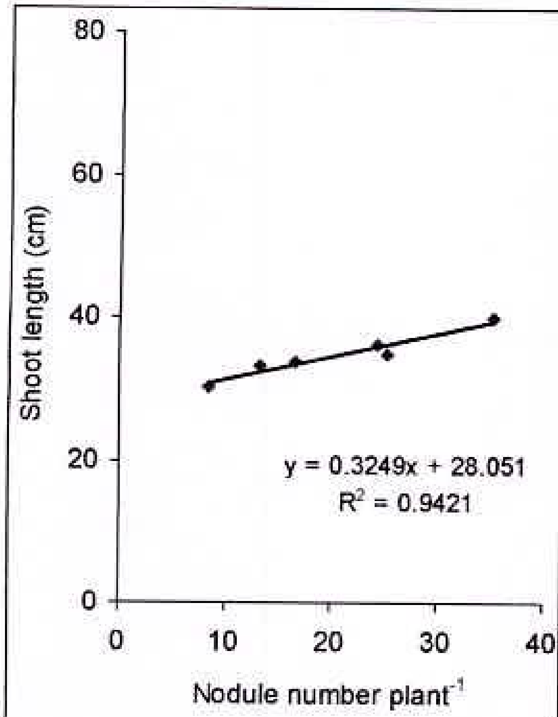

Fig. 4.35. Relationship between nodule number and shoot length of grasspea at 80 DAS

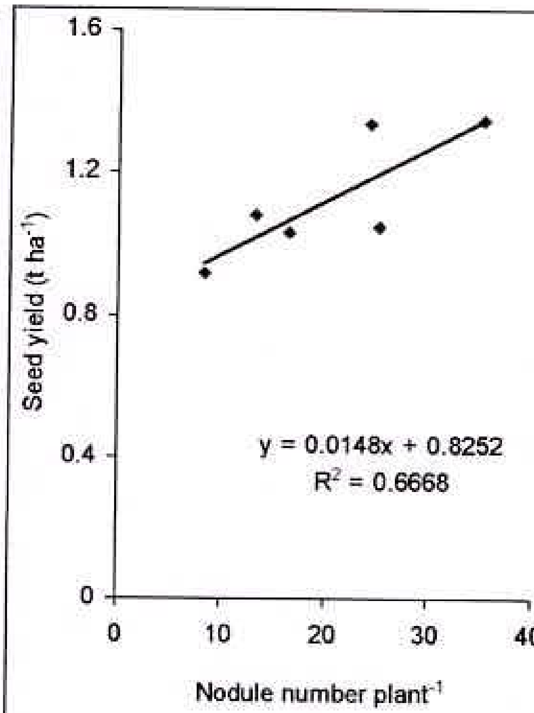

Fig. 4.36. Relationship between nodule number and seed yield of grasspea

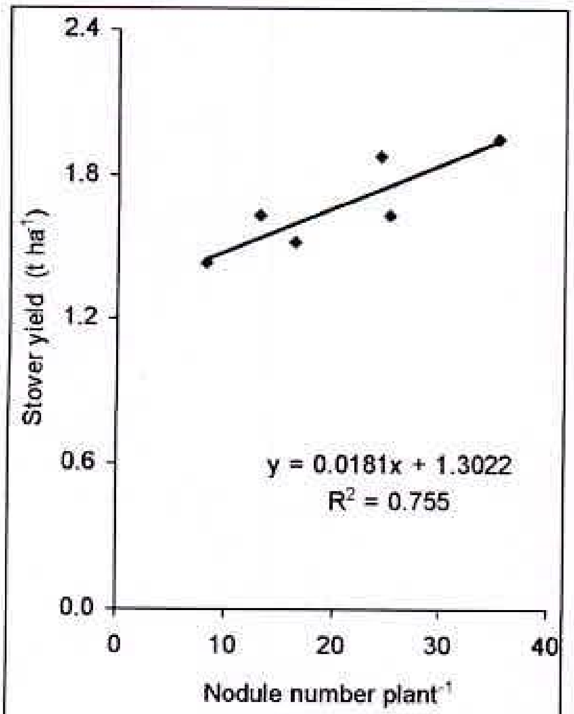

Fig. 4.37. Relationship between nodule number and stover yield of grasspea

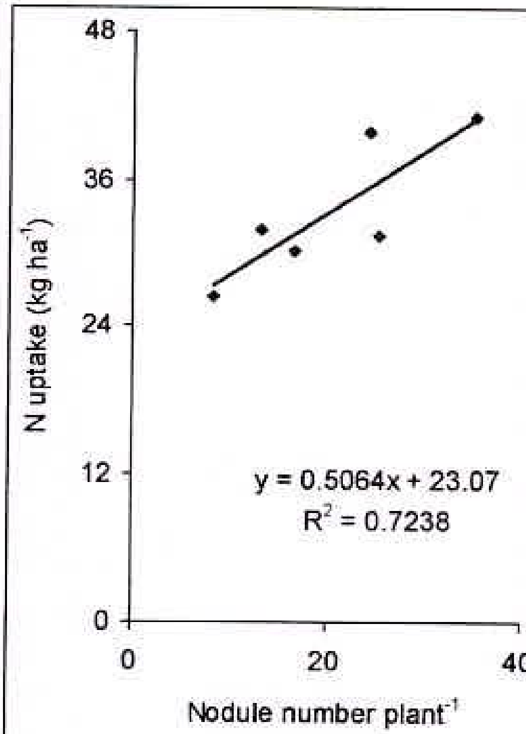

Fig. 4.38. Relationship between nodule number and N uptake of grasspea

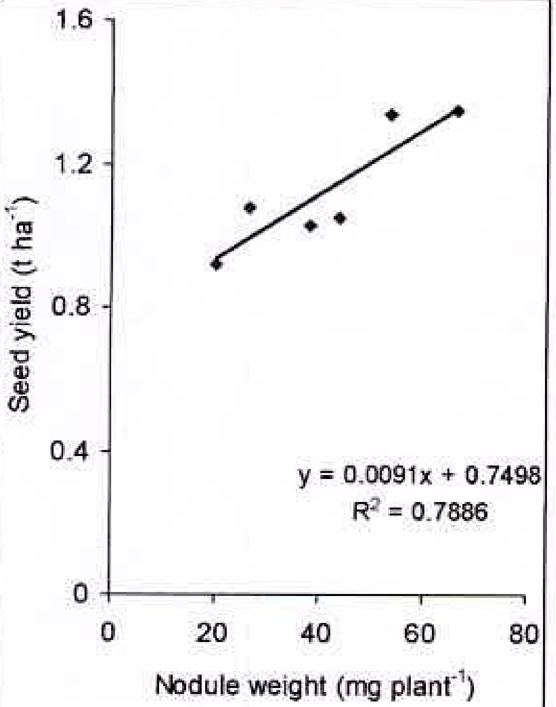

Fig. 4.39. Relationship between nodule weight and seed yield of grasspea

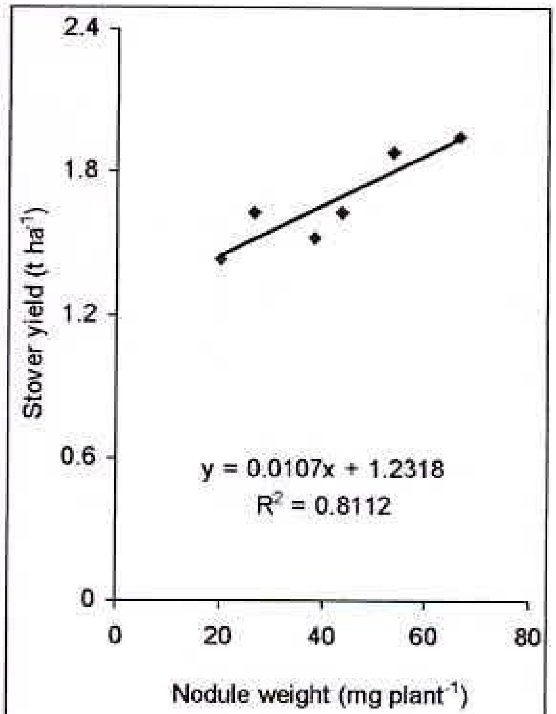

Fig. 4.40. Relationship between nodule weight and stover yield of grasspea

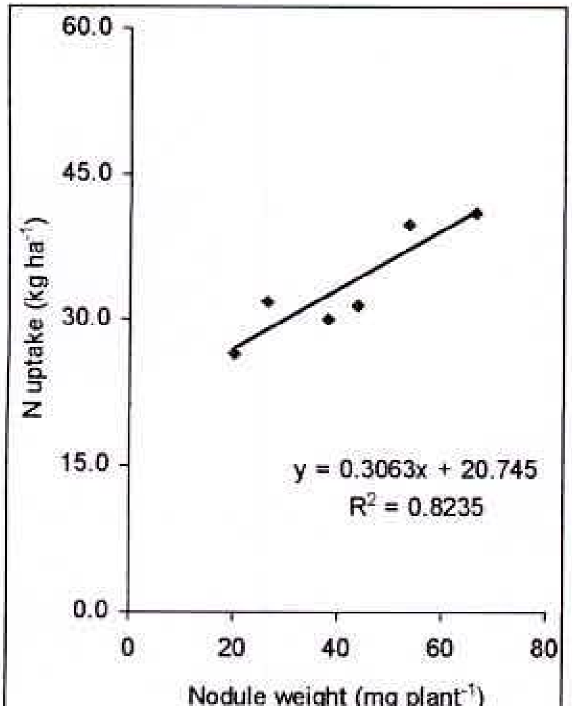

Fig. 4.41. Relationship between nodule weight and N uptake of grasspea

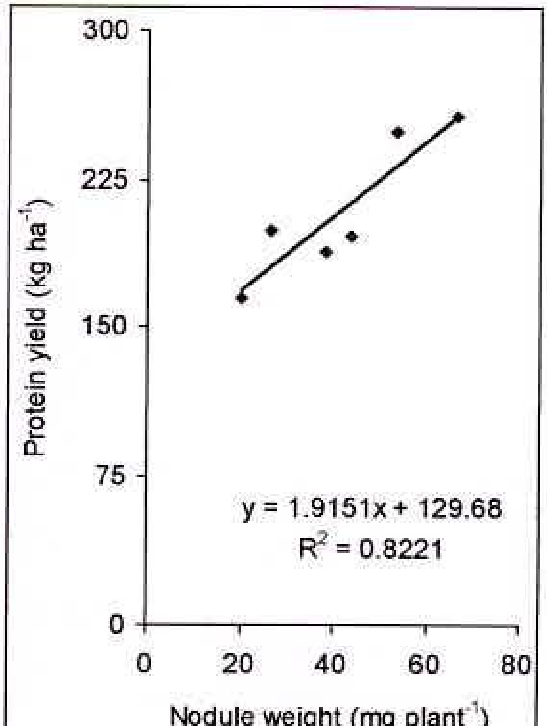

Fig. 4.42. Relationship between nodule weight and protein yield of grasspea

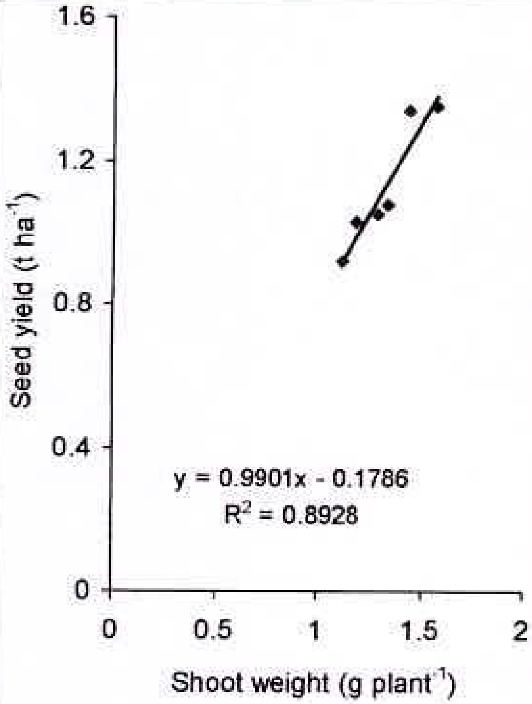

Fig. 4.43. Relationship between shoot weight and seed yield of grasspea

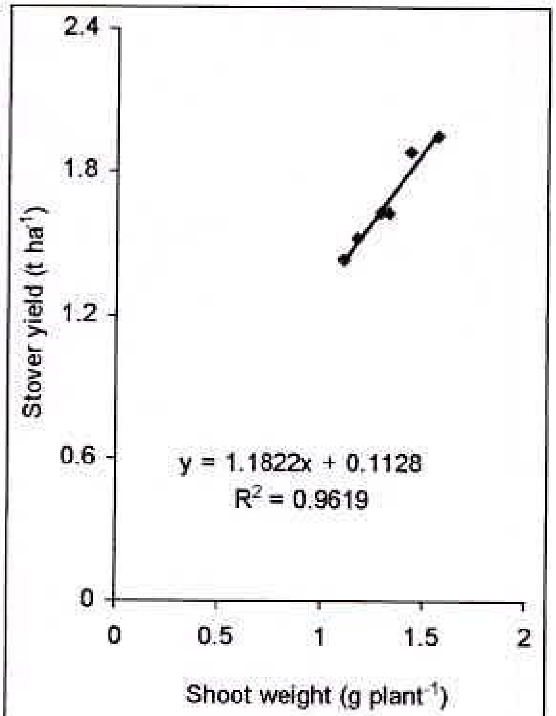

Fig. 4.44. Relationship between shoot weight and stover yield of grasspea

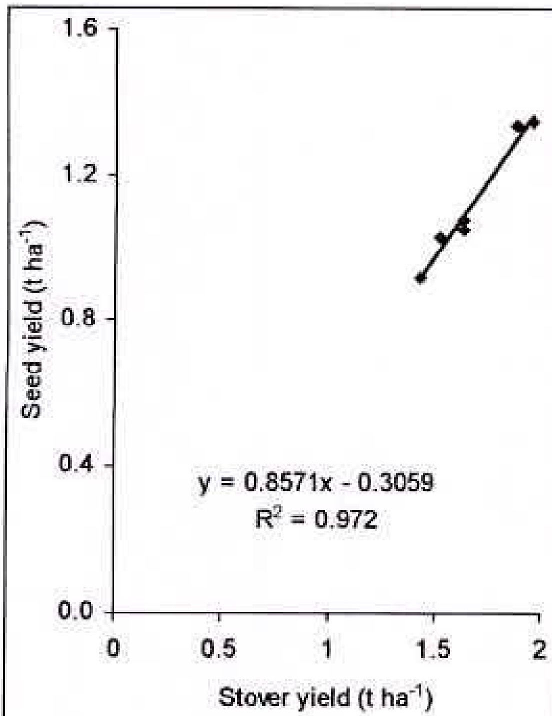

Fig. 4.45. Relationship between stover yield and seed yield of grasspea

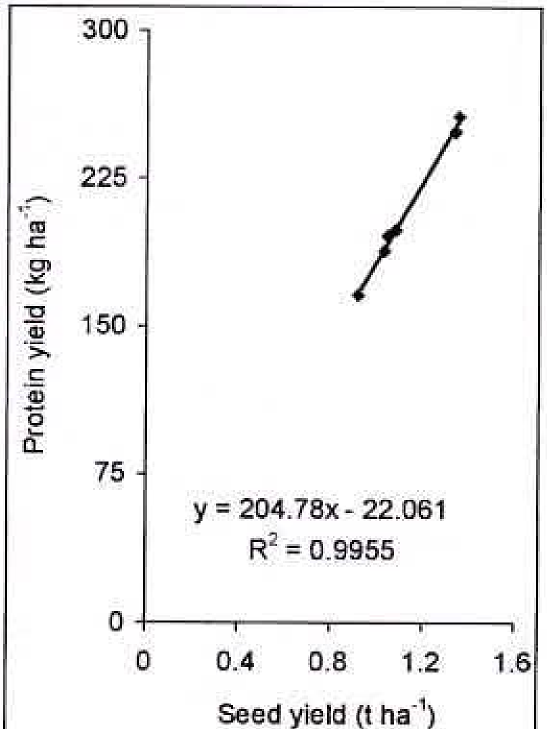

Fig. 4.46. Relationship between seed yield and protein yield of grasspea

Chapter V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was carried out during Rabi season of 2006-07 at Bangladesh Agricultural Research Institute (BARI) Central Farm in the Madhupur Tract (AEZ 28, Paleaustult) of Bangladesh with an objective of finding out the nodulation, biomass production and yield, N uptake and protein yield by different grasspea varieties in presence and absence of *Rhizobium* inoculation. A summary of methodology and results of this study is given below.

5.1 EXPERIMENT: Performance of three different grasspea varieties with and without *Rhizobium* innoculant

The soil of the experimental field initially had a pH of 6.3, organic carbon 0.95%, total N 0.072%, available P 13.0 $\mu g\ g^{-1}$, exchangeable K 0.22 cmol kg^{-1} soil, available S 15.0 $\mu g\ g^{-1}$, available Zn 1.59 $\mu g\ g^{-1}$. The experiment was designed with six treatment combinations, laid out in a randomized complete block design (RCBD) with four replications. Each plot size was 5 m x 3 m. Three grasspea varieties viz. BARI Khesari-1, BARI Khesari-2 and Jamalpurl local were used in the study. Each variety was either treated and not treated with *Rhizobium* inoculant.

The seeds were sown in November 2006 and harvested in March 2007. All recommended cultural practices were followed to grow the crop. Frequent samplings were done at different dates from 20 days after sowing (DAS) to on wards for counting nodule number and nodule biomass, and dry matter production, root & shoot length. The crop was harvested at maturity, seed and stover yields were recorded at 14% moisture content. The seed and stover samples were chemically analyzed for N content. All the data were statistically analyzed by F-test and the differences between treatments means were adjudged by Duncan's Multiple Range Test (DMRT).

Significant influences of the graaspea varieties were observed on nodulation, dry matter production and yields (seed and stover) and nutrient uptake by the crop. The highest nodule number, nodule weight, root weight, shoot weight, root length, shoot length, leaves and branches, seed and stover yields of grasspea were obtained from BARI Khesari-1. Jamalpur local recorded the lowest nodulation, dry matter production and yields. BARI Khesari-1 produced the highest seed yield (1.20 t ha^{-1}) and stover yield (1.79 t ha^{-1}). Higher number of pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight was also recorded in BARI Khesari-1.

Application of *Rhizobium* inoculant produced significant effect on various crop characters. The highest nodule number $plant^{-1}$ of 24.25 at 80 DAS, and nodule weight of 48.81 mg $plant^{-1}$ were recorded in *Rhizobium* inoculated plots. Seed inoculation significantly increased seed (1.26 t ha^{-1}, 26% increase over control) and stover (1.82 t ha^{-1}) yields of grasspea. *Rhizobium* inoculation also significantly increased pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight.

Inoculated BARI Khesari-1 produced highest nodule number, nodule weight and shoot weights. Highest seed and stover yields as well as yield attributes such as pods $plant^{-1}$, seed pod^{-1} were also recorded in inoculated BARI Khesari-1. The highest N concentration, N uptake, protein concentration and protein yield were also observed in inoculated BARI Khesari-1. Considering nodulation, biomass production, seed and stover yields, and protein yield, BARI Khesari-1 was found as the best variety among the three. BARI Khesari-2 produced the second highest seed yield and lowest seed yield was observed in Jamalpur local.

5.2 Conclusions

The present study revealed the following important findings:

1. Nodule number and nodule weight of grasspea increased progressively up to 80 days of sowing seeds (DAS) and thereafter started reducing in numbers until harvesting due to spontaneous degeneration.

2. Among three grasspea varieties, BARI Khesari-1 was found the best in respect of nodule formation for N_2-fixation, growth and yield (grain and stover). Therefore, this may be considered as the suitable variety for cultivation at Agroecological zone-28 (Madhupur Tract) of Bangladesh.

5.3 Recommendation and suggestions for future research

1. Considering the increasing trend of soil fertility reduction, the use of rhizobial inoculant should be used for cultivation of grasspea.

2. Instead of applying nitrogenous fertilizers for grasspea production bio fertilizer (rhizobial inoculant fertilizer) should be used. Because nitrogenous fertilizer is now a days a costly chemical fertilizer in Bangladesh. So rhizobial inoculant should be used in different pulses like grasspea for higher production of pulses to meet up the protein requirement of our suit motherland, Bangladesh. Grasspea may draw the attention of farmers for three reasons- (i) it is a short duration crop (not only a green manure) which will return cash money; (ii) a good source of plant protein; (iii) a good fodder for milch cattle; and (iv) it improves soil fertility and maintains crop productivity which is so vital for ailing soil conditions of Bangladesh.

REFERENCES

REFERENCES

Akhtaruzzaman, M.A. 1998. Influence of rates of nitrogen and phosphorus fertilizers on the productivity of mungbean (*Vigna radiata* (L.) Wilczek). Ph. D. Thesis, IPSA, Salna, Gazipur. pp. 1-181.

Alam, M.T., M. Jahiruddin, Z.H. Bhuiya and M.S. Hoque. 1988. Response of three cultivars of grasspea to *Rhizobium* inoculation. Bangladesh J. Microbiol. 5(2): 11-16.

Anonymous, 1972. Final Report of Scheme for Research Work on *Lathyrus* and its Substitute Crops (1972). Department of Agron., JNKVV, Jabalpur, India.

Anonymous. 2004a. BARI Khesari-1. Khesarir Unnata Jat (in Bengali), Pulses Research Centre, Bangladesh Agril. Res. Inst., Ishurdi, Pabna.

Anonymous. 2004b. BARI Khesari-2. Khesarir Unnata Jat (in Bengali), Pulses Research Centre, Bangladesh Agril. Res. Inst., Ishurdi, Pabna.

Ardeshna, R.B., M.M. Modhwadia, V.D. Khanpara and J.C. Patel. 1993. Response of greengram (*Phaseolus radiatus*) to nitrogen, phosphorus and *Rhizobium* inoculation. Indian J. Agron. 38(3): 490-492.

Ashraf, M., M. Mueen-Ud-Din and N.H. Warraich. 2003. Production efficiency of mungbean (*Vigna radiata* L.) as affected by seed inoculation and NPK application. Inter. J. Agric. Biol. 5(2): 179-180.

BBS. 2005. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics. Mininstry of Planning, Dhaka.

Bhuiya, Z.H., M.R. Islam, A.B.M. Alam and M.S. Haque. 1983. Effect of different locally isolated strains of *Rhizobium leguminosarum* on nodulation, N uptake and yield of khesari (*Lathyrus sativus* L.). Bangladesh J. Soil Sci. 19: 63-67.

Bhuiya, Z.H., M.S. Miyan and M.S. Hoque. 1982a. Performance of different locally isolated strains of *Rhizobium leguminossrum* on grasspea in field conditions, Proc. 6-7th Annual Conf. of Bangladesh Assoc. for Advancement of Sci., 7-11 Feb. 1982, BARI, Gazipur.

Bhuiya, Z.H., M.S. Miyan and M.S. Hoque. 1982b. Performance of some locally isolated strains of *Rhizobium leguminossrum* on grasspea, Proc. 6-7th Annual Conf. Bangladesh Assoc. for Advancement of Sci., 7-11 Feb. 1982, BARI, Gazipur.

Bhuiyan, M.A.H. 2004. Evaluation of introducing mungbean into cereal based cropping pattern for sustainable soil fertility and productivity. Ph.D Thesis, Dept. of Soil Sci., Bangladesh Agril. Univ., Mymensingh. pp.1-217.

Bhuiyan, M.A.H., D. Khanam and M.R. Khatun. 1999. Varietal screening of grasspea (*Lathyrus sativus*) in presence and absence of *Rhizobium* inoculation. Indian J. Agric. Sci. 69(5): 336-339.

Bhuiyan, M.A.H., D. Khanam, M.E. Ali, M.R. Khatun and M.S. Zaman. 2007. Influence of variety and site on the response of grasspea to inoculation with elite strains *Rhzobium*. Annual Report, Dept. of Soil Sci. Bangladesh Agril. Res. Inst. pp. 251-255.

Bhuiyan, M.A.H., D. Khanam, M.E. Ali, M.R. Khatun, M.S. Zaman and M.M. Rahman. 2006. Influence of variety and site on the response of grasspea to inoculation with elite strains of *Rhzobium*. Annual Report, Dept. of Soil Sci., Bangladesh Agril. Res. Inst. pp. 204-207.

Bhuiyan, M.A.H., D. Khanam, M.R. Khatun, M.H.H. Rahman and A.K.M. Rahman. 1998. Response of grasspea varieties to inoculation with rhizobial strain. Bangladesh. J. Agril. Res. 23(1): 173-178.

Bhuiyan, M.A.H., M.H.H. Rahman, D. Khanam and A.K.M. Hossain. 1997. Effect of inoculation and varietal interactions of grasspea. Bangladesh J. Sci. Res. 15(2): 207-212.

Black, C.A. 1965. Methods of Soil Analysis, Part I. Agron. Monograph. 9. ASA Madison. Wisconsin. USA.

Bremner, J.M. and C.S. Mulvaney. 1982. Total Nitrogen *In*. Methods of Soil Analysis, Ed. Page, AL., Miller, R.H. and Keeney, D.R. 1982. Amer. Soc. Agron. Agron. Inc. Madison, Wisconsin. USA. pp. 595-622.

Chowdhury, M.H. 1982. Effect of *Rhzobium leguminosarum* inoculation on grasspea. M.Sc. (Ag.) Thesis, Dept. of Soil Sci., Bangladesh Agril. Univ., Mymensingh.

Chowdhury, M.M.U., J. Haider, A.J.M.S. Karim and T. Hossain. 1997. Nitrate reductase activity in mungbean (*Vigna radiata* (L.) Wilczek) leaves, roots and nodules in relation to *Bradyrhizobium* inoculation and phosphorus application. Annals Bangladesh Agric. 7(2): 145-148.

Das, P.K., A.K. Sethi, M.K. Jena and R.K. Patra. 1999. Effect of P sources and dual inoculation of VA-mycorrhiza and *Rhizobium* on dry matter yield and nutrient uptake by greengram (*Vigna radiata* L.). J. Indian Soc. Soil Sci. 47(3): 466-470.

Datt, N. and K.K.R. Bhardwaj. 1995. Nitrogen contribution and soil improvement by legume green-manuring in Rice-Wheat cropping on an Acid Clay Loam soil. J. Indian Soc. Sci. 43(4): 603-607.

Dev, P. 2000. Response of molybdenum on the growth and yield of summer mungbean with and without inoculation. M.S. Thesis, Dept of Soil Sci., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-111.

FAO. 1983. Technical Handbook of Symbiotic Nitrogen Fixation (Legume/*Rhizobium*). Food and Agriculture Organization of the United Nations, Rome.

Fox, R.L., R.A. Olsen and H.F. Rhoades. 1964. Evaluating the sulphur status of soil by plant and soil test. Soil Sci. Soc. Am. Proc. 28: 243-246.

Freed, R.D. 1992. MSTAT-C. Crop and Soil Science Department, Michigon State University, USA.

Haque, M.M., A.T.M.S. Islam, M.S. Alam and M.N. Islam. 2001. Effect of planting time on yield and quality of selected summer mungbean cultivars. Bangladesh J. Agril. Res. 26(1): 7-14.

Hossain, M. and F. Khatun. 1987. Protein and ODAP contents of some germplasms of grasspea. Bangladesh J. Agril. Res. 12(1): 26-30.

Islam, M.R. and Z.H. Bhuiya. 1984. Effect of lime and *Rhizobium* inoculation on nodulation, dry matter yield and N uptake by grasspea. Bangladesh J. Soil Sci. 20: 1-6.

Islam, M.R., Z.H. Bhuiya, M.S. Hoque and M.A.R. Khan. 1987. Performance of some *Rhizobium* inoculants on grasspea. Bangladesh J. Agril. Sci. 14(2): 77-85.

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi, India.

Kabir, M.R. 1987. Effect of *Rhizobium* inoculation and nitrogen fertilization on nodulation, growth and yield of lentil. M.Sc. Thesis, Dept. of Soil Sci., Bangladesh Agril. Univ., Mymensingh, pp. 1-61.

Keeney, D.R. and D.W. Nelson. 1982. Nitrogen inorganic Forms. *In*: Methods of Soil Analysis. part 2. 2nd Ed. Page, A.L. Miller, R.H. and Keeney, D.R. 1982. Amer. Soc. Agron. Inc. Madison, Wisconsin., USA. pp. 643-693.

Kay, D.E. 1979. Food Legume, Crop and Product Digest No. 3, Tropical Products Institute, London.

Khanam, D. 2002. Biodiversity of arbuscular mycorrhizal fungi in agricultural crops and their interaction with *Rhizobium* on chickpea (*Cicer arietinum* L.). Ph. D. Thesis. Bangabandhu Sheikh Mujibur Rahman Agric. Univ., Gazipur. pp. 1-226.

Knudsen, D., GA. Petterson and P.F. Pratt. 1982. Lithium, Sodium and Potassium, *In*. Methods of Soil Analysis, Part 2, 2nd Ed., Page. A.L., Miller. R.H. and Keeney, D.R. 1982. Amer Soc. Agron. Inc. Madi. Wis., USA. pp. 225-245.

Kolotilov, V.V. 1976. Effectiveness of Inoculation of *Lathyrus sativus* Seeds in Relation to fertilizers, Byulleten Instituta Rastenie Vodstva Imeni N.I. Vavilova No. 60: 44-46.

Kumar, P. and J.P. Agarwal. 1993. Response of lentil (*Lens esculentus*) to *Rhizobium* inoculation, nitrogen and phosphorus fertilization. Indian J. Agron. 38(2): 318-320.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. Soil Sci. Soc. Am. J. 42: 421-428.

Mahmud, M.S. 1997. Growth, yield and quality of mungbean as influenced by sowing environment. M.S. Thesis, Dept. of Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-63.

Mian, M.S. 1979. Performance of different locally isolated strains *Rhzobium leguminosarum* on grasspea. M.Sc. (Ag.) Thesis, Dept. of Soil Sci. Bangladesh Agril. Univ. Mymensingh.

Mozumder, S.N. 1998. Effect of nitrogen and rhizobial fertilizer on two varieties of summer mungbean (*Vigna radiata* L. Wilczek). M.S. Thesis, Dept. of Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-76.

Murakami, T., S. Siripin, P. Wadisirisuk, N. Boonkerd, T. Yoneyama, T. Yokoyama and H. Imai. 1991. The nitrogen fixing ability of mungbean (*Vigna radiata*). Proc. Mungbean Meeting. Chiang Mai, Thailand. 23-24 Feb 1990. Trop. Agric. Res. Centre, Bangkok, Thailand. pp. 187-198.

Nag, B.L., A.K.M.M. Rahman, B.K. Goswami, N.K. Halder and M.H. Ullah. 2000. Effect of sowing time of mungbean on seed yield under rainfed conditions. Bangladesh J. Agril. Res. 25(2): 203-210.

Naher, S. 2000. Comparative performance of bio-fertilizer and chemical fertilizer on the yield and yield contributing characters of mungbean. M.S. Thesis, Dept. of Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-62.

Nezamuddin, S. 1970. Miscellaneous Crops – Khesari. *In*: Kachroo, P. (Ed). Pulse Crops of India. ICAR, New Delhi, India.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, Organic carbon and Organic matter. *In*: Methods of Soil Analysis. Part. 2. 2nd Ed. Page, A.L., Miller, R.H. and Keeny, D.R. (Eds.). Amer. Soc. Agron. Madison, Wisconsin, USA. pp. 539-579.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus, *In*: Methods of Soil Analysis. Part II. 2nd Ed. Page, A.L. Miller, R.H. and Keeney, D.R. 1982. Amer. Soc. Agron. Inc. Madison, Wisconsin, USA. pp. 403-430.

Page, A.L., R.H. Miller and D.R. Keeney. 1982. Methods of Soil Analysis. Part 2. 2nd Ed. Amer. Soc. Agron., Inc., Medison, Wisconsin, USA.

Pal, G. and B. Lal. 1993. Nodulation and rooting pattern of summer greengram (*Phaseolus radiatus*) as influenced by irrigation variables. Indian J. Agric. Sci. 38(1): 129-131.

Patel, F.M. and L.R. Patel. 1991. Response of greengram varieties to phosphorus and *Rhizobium* inoculation. Indian J. Agron. 36(2): 295-297.

Patra, D.K. and P. Bhattacharyya. 1998. Response of cowpea rhizobia on nodulation and yield of mungbean (*Vigna radiata* L. Wilczek). J. Mycopath. Res. 36(1): 17-23.

Provorov, N.A., U.B. Saimnazarov, I.U. Bahromoy, D.Z. Pulatova, A.P. Kozhemyakov and G.A. Kurbanov. 1998. Effect of rhizobia inoculation on the seed (herbage) production of mungbean (*Phaseolus aureus* Roxb.) grown at Uzbekistan. J. Arid Envir. 39(4): 569-575.

Purseglove, J.W. 1974. Tropical Crops, Dicotylednos. Longman, England.

Quader, M., M.A.A. Miah, M. Wahiduzzaman and M. Rahman. 1988. Present status of *Lathyrus stains* L. research in Bangladesh. Paper presented at the Conf. on *Lathyrus* stains and the Eradication of Lathyrism, held during 2-6 May 1988 at London, UK. Ciba Foundation.

Rahman, M.M., M. Quader and J. Kumar. 1989. Status of khesari breeding and future strategy. *In*: Advances in Pulses Research in Bangladesh. Proc. Sec. Nat. Workshop on Pulses, held during 6-8 June 1989. Inter. Crops Res. Inst. for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, pp. 25-28.

Rahman, M.S. 2000. Effect of planting method and sowing date on the yield and yield contributing characters of mungbean varieties (*Vigna radiata*). M.S. Thesis, Dept of Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-90.

Rani, B.P. and D. Kodandaramaiah. 1997. Response of soybean (*Glycine max*) to inoculation with varying nitrogen levels. Indian J. Agron. 42(1): 135-137.

Raut, R.S. and O.D. Kohire. 1991. Phosphorus response in chickpea (*Cicer arietinum* L.) with *Rhizobium* inoculation. Legume Res. 14(2): 78-82.

Rennie, R.J. and G.A. Kemp. 1984. ^{15}N determined time course for N_2-fixation in two cultivars of field bean. Agron. J. 76: 146-154.

Rhoades, J.D. 1982. Cation Exchange Capacity. *In*: Methods of Soil Analysis. Part-2, 2nd Ed. (Page, A.L., Miller, R.H. and Keeney, D.R. eds.). 1982. Amer. Soc. Agron., Inc., Madison, Wisconsin, USA. pp. 149-157.

Roy, A.K. 2001. Response of biofertilizer to nodulation, growth and yield of different varieties of summer mungbean (*Vigna radiata* L.). M.S. Thesis, Dept of Soil Sci., Bangladesh Agril. Univ., Mymensingh, Bangladesh. pp. 1-123.

Sairam, R.K., P.S. Tomar, A.S. Harika and T.K. Ganguly. 1989. Effect of phosphorus levels and inoculation with *Rhizobium* on nodulation, leghaemoglobin content and nitrogen uptake in fodder cowpea. Legume Res. 12(1): 27-30.

Samanta, S.C., M.H. Rashid, P. Biswas and M.A. Hasan. 1999. Performance of five cultivars of mungbean under different dates of sowing. Bangladesh J. Agril. Res. 24(3): 521-527.

Sarkar, R.K., S. Karmakar and A. Chakraborty. 1993. Response of summer greengram (*Phaseolus radiatus*) to nitrogen, phosphorus application and bacterial inoculation. Indian J. Agron. 38(4): 578-581.

Serov, V.M. 1974. On the Drought and Salt-Resistance of Pea and *Lathyrus sativus*. Trudy on Prikladnoi Botanike, Genetike i Selektsii, 53(3): 123-131.

Sharma, P. and A.S. Khurana. 1997. Effect of single and multistrain *Rhizobium* inoculants on biological nitrogen fixation in summer mungbean, *Vigna radiata* (L.) Wilczek. Res. and Dev. Reporter. 14(1-2): 8-11.

Shukla, S.K. and R.S. Dixit. 1996a. Nutrient and plant population management in summer greengram (*Phaseolus radiatus*). Indian J. Agron. 41(1): 78-83.

Shukla, S.K. and R.S. Dixit. 1996b. Effect of *Rhizobium* inoculation, plant population and phosphorus on growth and yield of summer greengram (*Phaseolus radiatus*). Indian J. Agron. 41(4): 611-615.

Singh, A.K., R.K. Choudhary and R.P.R. Sharma. 1993. Effect of inoculation and fertilizer levels in yield, yield attributes and nutrient uptake of greengram (*Phaseolus radiatus*) and blackgram (*P. mungo*). Indian J. Agron. 38(4): 663-665.

Singh, L. 1975. Lathyrus (Khesari/Teoda) Cultivation in Madhya Pradesh and Prevention of Lathyrism. Technical Bulletin No. 26, J.N. Krishi Vishwa Vidyalaya, Jabalpur, India.

Solaiman, A.R.M. 1999. Response of mungbean to *Bradyrhizobium* sp. (*Vigna*) inoculation with and without phosphorus and potassium fertilization. Bangladesh J. Sci. Res. 17(2): 125-132.

Thakuria, A. and P. Saharia. 1990. Response of greengram genotypes to plant density and phosphorus levels in Summer. Indian J. Agron. 35(4): 431-432.

Vincent, J.M. 1970. Selective Indicator Media. A. Manual for the practical study of the root nodule bacteria. IBP Hand Book No. 15: 4.

Westphal, E. 1974. Pulses in Ethiopia, their taxonomy and agricultural significance, Ph.D Thesis, Landouwhoge School, Wageningen, Netherlands.

APPENDICES

App. 4.1. Effects of varieties on nodule number of grasspea at different days after sowing (DAS)

Variety	Nodule number plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	3.77 a	11.57 a	22.90 a	30.22 a	22.71 a
BARI Khesari-2	3.58 a	10.39 b	16.71 b	20.42 b	17.67 b
Jamalpur local	2.95 b	5.52 c	8.40 c	10.74 c	7.84 c
SE (±)	0.11	0.19	0.50	0.69	0.65
Sig.	**	**	**	**	**

In a column, the figures(s) having same letter are not significantly different
** Significant at 1% level

App. 4.2. Effects of rhizobial inoculant on nodule number of grasspea at different days after sowing (DAS)

Inoculant	Nodule number plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	3.05 b	7.74 b	12.79 b	16.66 b	13.90 b
Inoculated	3.81 a	10.57 a	19.21 a	24.25 a	18.25 a
SE (±)	0.09	0.15	0.41	0.56	0.53
Sig.	**	**	**	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

App. 4.3. Interaction effects of varieties and *Rhizobium* on nodule number of grasspea at different days after sowing (DAS)

Treatment	Nodule number plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	3.29	9.89 b	18.29 b	25.23	20.13
BARI Khesari-1 X I	4.25	13.25 a	27.50 a	35.20	25.29
BARI Khesari-2 X U	3.15	8.63 c	13.27 c	16.50	15.17
BARI Khesari-2 X I	4.00	12.15 a	20.15 b	24.33	20.17
Jamalpur Local X U	2.71	4.71 e	6.81 e	8.25	6.39
Jamalpur Local X I	3.19	6.32 d	9.98 d	13.23	9.28
SE (±)	-	0.26	0.71	-	-
Sig.	NS	**	**	NS	NS
CV (%)	8.8	5.8	8.9	9.5	11.4

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
In a column, the figures(s) having same letter are not significantly different
** Significant at 1% level
NS = Non significant

App. 4.4. Effects of varieties on nodule weight of grasspea at different days after sowing (DAS)

Variety	Nodule weight (mg plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	3.72 a	14.83 a	39.38 a	55.05 a	29.79 a
BARI Khesari-2	2.73 b	11.59 b	31.11 b	45.92 b	25.91 ab
Jamalpur local	2.32 b	7.94 c	15.02 c	23.28 c	12.80 c
SE (±)	0.14	0.31	0.91	2.00	1.09
Sig.	**	**	**	**	**

In a column, the figures(s) having same letter are not significantly different
** Significant at 1% level

App. 4.5. Effects of rhizobial inoculant on nodule weight of grasspea at different days after sowing (DAS)

Inoculant	Nodule weight (mg plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	2.48 b	9.48 b	22.05 b	34.02 b	17.65 b
Inoculated	3.36 a	13.42 a	34.95 a	48.81 a	28.00 a
SE (±)	0.12	0.25	0.74	1.63	0.89
Sig.	**	**	**	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

App. 4.6. Interaction effects of variety and *Rhizobium* on nodule weight of grasspea at different days after sowing (DAS)

Treatment	Nodule weight (mg plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	3.10	12.39	30.54 c	43.60 c	22.39 c
BARI Khesari-1 X I	4.33	17.27	48.22 a	66.50 a	37.18 a
BARI Khesari-2 X U	2.29	10.00	22.90 d	38.28 c	20.29 cd
BARI Khesari-2 X I	3.17	13.17	39.32 b	53.55 b	31.52 b
Jamalpur Local X U	2.05	6.05	12.72 c	20.18 cd	10.28 e
Jamalpur Local X I	2.59	9.82	17.31 d	26.38 d	15.31 e
SE (±)	-	-	1.29	2.82	1.54
Sig.	NS	NS	**	*	*
CV (%)	13.6	7.7	9.0	13.6	13.5

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
In a column, the figures(s) having same letter are not significantly different
* and ** Significant at 5% and 1% level, respectively
NS=Non significant

App. 4.7. Effects of varieties on root weight of grasspea at different days after sowing (DAS)

Variety	Root weight (g plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	0.022 a	0.035 a	0.045 a	0.054 a	0.066
BARI Khesari-2	0.019 b	0.036 b	0.041 b	0.051 a	0.064
Jamalpur local	0.017 c	0.032 c	0.036 b	0.047 b	0.060
SE (±)	0.00060	0.00098	0.0014	0.0014	-
Sig.	**	**	**	**	NS

In a column, the figures(s) having same letter are not significantly different
** Significant at 1% level
NS = Non significant

App. 4.8. Effects of rhizobial inoculant on root weight of grasspea at different days after sowing (DAS)

Inoculant	Root weight (g plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	0.018 b	0.030 b	0.038 b	0.048 b	0.057 b
Inoculated	0.0207 a	0.038 a	0.043 a	0.053 a	0.069 a
SE (±)	0.00049	0.00080	0.0012	0.0011	0.017
Sig.	**	**	**	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

App. 4.9. Interaction effects of variety and *Rhizobium* on root weight of grasspea at different days after sowing (DAS)

Treatment	Root weight (g plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	0.020	0.028 c	0.043	0.050	0.060
BARI Khesari-1 X I	0.024	0.042 a	0.048	0.057	0.072
BARI Khesari-2 X U	0.018	0.034 bc	0.039	0.048	0.056
BARI Khesari-2 X I	0.020	0.038 ab	0.043	0.054	0.071
Jamalpur Local X U	0.016	0.029 c	0.032	0.045	0.056
Jamalpur Local X I	0.018	0.034 bc	0.039	0.048	0.064
SE (±)	-	0.0014	-	-	-
Sig.	NS	**	NS	NS	NS
CV (%)	8.8	8.2	9.7	7.6	9.5

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
In a column, the figures(s) having same letter are not significantly different
** Significant at 1% level
NS = Non significant

App. 4.10. Effects of varieties on shoot weight of grasspea at different days after sowing (DAS)

Variety	Shoot weight (g plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	0.05 a	0.08	1.12 a	1.43	1.39
BARI Khesari-2	0.04 b	0.07	1.10 a	1.31	1.33
Jamalpur local	0.03 c	0.07	0.94 b	1.22	1.29
SE (±)	0.0011	-	0.05	-	-
Sig.	**	NS	*	NS	NS

In a column, the figures(s) having same letter are not significantly different
* and ** Significant at 5% and 1% level, respectively
NS = Non significant

App. 4.11. Effects of rhizobial inoculant on shoot weight of grasspea at different days after sowing (DAS)

Inoculant	Shoot weight (g plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	0.04 b	0.07 b	0.98 b	1.19 b	1.18 b
Inoculated	0.05 a	0.08 a	1.12 a	1.45 a	1.49 a
SE (±)	0.00086	0.0031	0.04	0.073	0.070
Sig.	**	*	*	*	**

In a column, the figures(s) having different letter(s) differed significantly
* and ** Significant at 5% and 1% level, respectively

App. 4.12. Interaction effects of variety and *Rhizobium* on shoot weight of grasspea at different days after sowing (DAS)

Treatment	Shoot weight (g plant^{-1})				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	0.05	0.07	1.050	1.29	1.19
BARI Khesari-1 X I	0.06	0.08	1.18	1.57	1.60
BARI Khesari-2 X U	0.03	0.06	1.04	1.18	1.20
BARI Khesari-2 X I	0.04	0.07	1.16	1.44	1.46
Jamalpur Local X U	0.03	0.06	0.86	1.11	1.16
Jamalpur Local X I	0.04	0.07.	1.01	1.33	1.42
SE (±)	-	-	-	-	-
Sig.	NS	NS	NS	NS	NS
CV (%)	7.1	15.3	13.0	19.2	18.3

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non significant

App. 4.13. Effects of varieties on root length of grasspea at different days after sowing (DAS)

Variety	Root length (cm)				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	8.24	8.93 a	10.69	12.53 a	13.43
BARI Khesari-2	8.02	8.89 a	10.23	11.28 b	12.18
Jamalpur local	7.64	8.23 b	9.92	11.23 b	11.88
SE (±)	-	0.20	-	0.33	-
Sig.	NS	*	NS	*	NS

In a column, the figures(s) having same letter are not significantly different
* Significant at 5% level
NS = Non significant

App. 4.14. Effects of rhizobial inoculant on root length of grasspea at different days after sowing (DAS)

Inoculant	Root length (cm)				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	7.71	8.08 b	10.12	10.98 b	11.93
Inoculated	8.23	9.28 a	10.43	12.37 a	13.05
SE (±)	-	0.16	-	0.27	-
Sig.	NS	**	NS	**	NS

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level
NS = Non significant

App. 4.15. Interaction effects of variety and *Rhizobium* on root length of grasspea at different days after sowing (DAS)

Treatment	Root length (cm)				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	8.03	8.50 a	10.58	11.25	12.60
BARI Khesari-1 X I	8.45	9.35 a	10.80	13.80	14.25
BARI Khesari-2 X U	7.90	8.67 a	10.05	11.00	11.60
BARI Khesari-2 X I	8.15	9.10 a	10.40	11.55	12.76
Jamalpur Local X U	7.20	7.08 b	9.73	10.70	11.60
Jamalpur Local X I	8.08	9.38 a	10.10	11.75	12.15
SE (±)	-	0.28	-	-	-
Sig.	NS	*	NS	NS	NS
CV (%)	7.7	6.5	7.0	8.0	13.7

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
In a column, the figures(s) having same letter are not significantly different
* Significant at 5% level
NS = Non significant

App. 4.16. Effects of varieties on shoot length of grasspea at different days after sowing (DAS)

Variety	Shoot length (cm)				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	13.53 a	18.03 a	26.74 a	37.44 a	44.30 a
BARI Khesari-2	11.99 b	16.04 b	26.00 a	34.92 ab	40.48 a
Jamalpur local	11.13 b	14.40 c	20.56 b	31.74 b	37.98 b
SE (±)	0.29	0.31	0.74	1.16	1.09
Sig.	**	**	**	*	**

In a column, the figures(s) having same letter are not significantly different
* and ** Significant at 5% and 1% level, respectively

App. 4.17. Effects of rhizobial inoculant on shoot length of grasspea at different days after sowing (DAS)

Inoculant	Shoot length (cm)				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	11.83 b	14.57 b	22.39 b	32.94 b	37.63 b
Inoculated	12.61 a	17.75 a	26.47 a	36.45 a	44.20 a
SE (±)	0.24	0.25	0.60	0.94	0.89
Sig.	*	**	**	*	**

In a column, the figures(s) having different letter(s) differed significantly
* and ** Significant at 5% and 1% level, respectively

App. 4.18. Interaction effects of variety and *Rhizobium* on shoot length of grasspea at different days after sowing (DAS)

Treatment	Shoot length (cm)				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	12.78	16.17	25.25	34.95	43.40 a
BARI Khesari-1 X I	14.28	19.90	28.23	39.93	45.20 a
BARI Khesari-2 X U	11.70	14.68	24.69	33.65	36.75 b
BARI Khesari-2 X I	12.28	17.40	27.30	36.18	44.20 a
Jamalpur Local X U	11.00	12.85	17.23	30.22	32.75 b
Jamalpur Local X I	11.26	15.95	23.88	33.25	43.20 a
SE (±)	-	-	-	-	1.53
Sig.	NS	NS	NS	NS	*
CV (%)	6.8	5.4	8.5	9.4	7.5

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
In a column, the figures(s) having same letter are not significantly different
* Significant at 5% level
NS = Non significant

App. 4.19. Effects of varieties on leaf number of grasspea at different days after sowing (DAS)

Variety	Leaf number plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	7.08	18.93	35.72 b	80.43 a	114.55 a
BARI Khesari-2	6.93	17.25	37.03 a	70.96 b	101.50 b
Jamalpur local	6.29	18.06	32.65 b	58.18 c	96.65 b
SE (±)	-	-	1.08	2.54	2.72
Sig.	NS	NS	*	**	**

In a column, the figures(s) having same letter are not significantly different
* and ** Significant at 5% and 1% level, respectively
NS = Non significant

App. 4.20. Effects of rhizobial inoculant on leaf number of grasspea at different days after sowing (DAS)

Inoculant	Leaf nunber plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	6.58	17.10 b	31.74 b	65.57 b	98.37 b
Inoculated	6.95	19.05 a	38.52 a	74.14 a	110.10 a
SE (±)	-	0.37	0.88	2.07	2.22
Sig.	NS	**	**	*	**

In a column, the figures(s) having different letter(s) differed significantly
* and ** Significant at 5% and 1% level, respectively
NS = Non significant

App. 4.21. Interaction effects of variety and *Rhizobium* on leaf number of grasspea at different days after sowing (DAS)

Treatment	Leaf number plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	6.85	18.40	31.61	76.60	108.60
BARI Khesari-1 X I	7.30	19.45	39.82	84.25	120.50
BARI Khesari-2 X U	6.85	15.80	34.80	76.25	98.00
BARI Khesari-2 X I	7.00	18.70	39.25	74.66	105.00
Jamalpur Local X U	6.03	17.11	28.80	52.85	88.50
Jamalpur Local X I	6.55	19.00	36.50	63.50	104.80
SE (±)	-	-	-	-	-
Sig.	NS	NS	NS	NS	NS
CV (%)	13.4	7.2	8.7	10.3	7.4

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non significant

App. 4.22. Effects of varieties on branch of grasspea at different days after sowing (DAS)

Variety	Branch plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1	1.88 a	3.18	3.78	4.78 a	5.37
BARI Khesari-2	1.43 b	2.93	3.50	4.15 b	5.34
Jamalpur local	1.56 b	2.81	3.24	3.96 b	5.24
SE (±)	0.091	-	-	0.13	-
Sig.	**	NS	NS	**	NS

In a column, the figures(s) having same letter are not significantly different
** Significant at 1% level
NS = Non significant

App. 4.23. Effects of rhizobial inoculant on branch of grasspea at different days after sowing (DAS)

Inoculant	Branch plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
Noninoculated	1.58	2.81	3.19 b	3.96 b	5.18
Inoculated	1.65	3.13	3.82 a	4.63 a	5.45
SE (±)	-	-	0.20	0.11	-
Sig.	NS	NS	*	**	NS

In a column, the figures(s) having different letter(s) differed significantly
* and ** Significant at 5% and 1% level, respectively
NS = Non significant

App. 4.24. Interaction effects of variety and *Rhizobium* on branch of grasspea at different days after sowing (DAS)

Treatment	Branch plant^{-1}				
	20 DAS (07.12.06)	40 DAS (27.12.06)	60 DAS (16.01.07)	80 DAS (05.02.07)	100 DAS (25.02.07)
BARI Khesari-1 X U	1.85	3.10	3.45	4.50	5.29
BARI Khesari-1 X I	1.90	3.25	4.10	5.05	5.45
BARI Khesari-2 X U	1.35	2.70	3.20	3.75	5.12
BARI Khesari-2 X I	1.50	3.15	3.80	4.55	5.57
Jamalpur Local X U	1.55	2.62	2.93	3.63	5.15
Jamalpur Local X I	1.56	3.00	3.55	4.29	5.34
SE (±)	-	-	-	-	-
Sig.	NS	NS	NS	NS	NS
CV (%)	15.8	17.0	19.5	8.9	16.8

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non significant

App. 4.25. Effect of variety on yield of grasspea

Variety	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})
BARI Khesari-1	1.79 a	1.20 a
BARI Khesari-2	1.70 a	1.18 a
Jamalpur local	1.53 b	1.00 b
SE (±)	0.04	0.04
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

App. 4.26. Effect of rhizobial inoculant on yield of grasspea

Inoculant	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})
Noninoculated	1.53 a	1.00 a
Inoculated	1.82 b	1.26 b
SE (±)	0.04	0.03
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level
NS = Non significant

App. 4.27. Interaction effects of variety and rhizobial inoculant on yield of grasspea

Treatment	Stover yield ($t\ ha^{-1}$)	Seed yield ($t\ ha^{-1}$)
BARI Khesari-1 X U	1.63	1.05
BARI Khesari-1 X I	1.95	1.35
BARI Khesari-2 X U	1.52	1.03
BARI Khesari-2 X I	1.88	1.34
Jamalpur Local X U	1.43	0.92
Jamalpur Local X I	1.63	1.08
SE (±)	-	-
Sig.	NS	NS
CV (%)	7.3	9.9

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non significant

App. 4.28. Effect of variety on N uptake in grasspea

Variety	N uptake by stover ($kg\ ha^{-1}$)	N uptake by seed ($kg\ ha^{-1}$)
BARI Khesari-1	36.80 a	36.24 a
BARI Khesari-2	34.03 a	34.95 a
Jamalpur local	30.03 b	29.10 b
SE (±)	1.06	1.33
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

App. 4.29. Effect of rhizobial inoculant on N uptake in grasspea

Inoculant	N uptake by stover (kg ha^{-1})	N uptake by seed (kg ha^{-1})
Noninoculated	30.15 b	29.27 b
Inoculated	37.09 a	37.58 a
SE (±)	0.86	1.09
Sig.	**	**

In a column, the figures(s) having different letter(s) differed significantly
** Significant at 1% level

App. 4.30. Interaction effect of variety and rhizobial inoculant on N uptake in grasspea

Treatment	N uptake by stover (kg ha^{-1})	N uptake by seed (kg ha^{-1})
BARI Khesari-1 X U	32.82	31.41
BARI Khesari-1 X I	40.79	41.08
BARI Khesari-2 X U	29.88	30.10
BARI Khesari-2 X I	38.18	39.80
Jamalpur Local X U	27.76	26.32
Jamalpur Local X I	32.30	31.87
SE (±)	-	-
Sig.	NS	NS
CV (%)	8.9	11.2

U = Without *Rhizobium*, I = Inoculated with *Rhizobium*
NS = Non significant

App. 4.31. Weather data prevailed during the study period

Name of month	Average atmospheric temperature (^{0}C)		Average rainfall (mm)	Average relative humidity (%)	Sunshine hours	
	Minimum	Maximum			Total	Mean
November 2006	18.53	29.71	-	85.65	193.46	6.41
December 2006	13.09	27.03	-	84.22	209.48	6.76
January 2007	10.58	24.61	-	84.78	142.70	4.60
February 2007	15.03	26.69	1.71	78.45	153.72	5.49
March 2007	17.23	30.71	0.91	73.24	250.55	8.08
April 2007	22.84	33.13	1.80	81.90	191.66	6.39

Source : Meteorological Department, BARI, Joydebpur, Gazipur.