INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2004/06–3–547–551
http://www.ijab.org

Effect of Nitrogen and Rhizobium Inoculation on Yield, N-Uptake and Economics of Mungbean

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ABSTRACT

An experiment was conducted to evaluate the effect of inoculation fertilization combinations on two mungbean genotypes (NM 92 and NCM 209) to improve their nodulation, nitrogen fixation and yield. The interactions of genotypes with treatments were significant for N content of shoots and N-content of soil after harvest. The combination of inoculation + 30 kg N ha^{-1} gave the highest N-content of shoots in NCM 209 which was significantly higher than all the other treatment x genotype interactions and control except 60 kg N ha^{-1} in the same genotype. Maximum N contents of soil were found in plots where NCM 209 was treated with inoculation + 90 kg N ha^{-1} which was significantly different from all the other treatments in both genotypes except 90 kg N ha^{-1}, inoculation + 30 kg N ha^{-1} and inoculation + 60 kg N ha^{-1} in NCM 209 and 60 and 90 kg N ha^{-1} in combination with inoculation in NM 92. NCM 209 significantly increased economic yield as compared to NM 92 while NM 92 gave significantly higher N-content of nodules. Treatments showed significant differences for all the characters except biological yield. Plots treated with seed inoculation + 30 kg N ha^{-1} produced maximum N-content of nodules, N-content of shoots, economic yield and harvest index. While, control produced minimum N-content of nodules, and N-content of soil. Inoculation alone gave maximum net income in NCM 209 as compared to all treatments and control in both genotypes. It was followed by inoculation + 30 kg N ha^{-1} in the same genotype. In NM 92 inoculation + 30 kg N ha^{-1} gave maximum net income. Minimum net income was given by inoculation + 90 kg N ha^{-1} in NM 92. Maximum value of benefit cost ratio (BCR) was recorded in plots treated with inoculation alone in NCM 209 which was followed by inoculation + 30 kg N ha^{-1} in the same genotype. While minimum value of BCR was recorded in inoculation + 90 kg N ha^{-1} in NM 92

Key Words: Mungbean; N_2-fixation; Economic analysis

INTRODUCTION

The yield of pulses, like mungbean, in Pakistan is lower than other Asian countries. The reasons of low yields of pulses in Pakistan are numerous, but nutritional imbalance appears to be the major one. In general, the soils of rainfed areas of Pakistan are deficient in plant nutrients and have very low organic matter content (Ahmed *et al*., 1988). Nitrogen estimated from the organic fractions of barani soils ranges from 0.03-0.07% (Frederich *et al*., 1991). Low soil nitrogen is a key factor for inefficient water use and low crop yields in the rainfed areas of Pakistan (Khan *et al*., 1989).

Addition of optimum doses of nitrogen fertilizer can overcome the nitrogen deficiencies but may endanger soil structure and causes environmental risks by contaminating under ground water on one hand and increasing cost of production on the other. Thus it needs such a system of management which, for improving soil fertility and productivity, should be cheap and environment friendly. The legumes have advantage of improving soil fertility by fixing atmospheric nitrogen biologically and also by meeting a large portion of their nitrogen requirements from this process under favourable conditions. Root nodule forming bacteria invade the legume root hairs and result in the formation of nodules, where free air nitrogen is fixed. These bacteria, although present in most of the soils, vary in number and in their effectiveness in nodulation and N-fixation. It has been argued that usually native soil rhizobial populations are inadequate and are ineffective in biological nitrogen fixation. To ensure optimum rhizobia populations in the rhizosphere, seed inoculation of legumes with an efficient rhizobial strain is necessary. This helps to improve nodulation, N_2 fixation, crop growth and yield of leguminous crops (Henzell, 1988). The amount of nitrogen fixed by mungbean ranged from 0-55 kg ha^{-1} among the farmers' fields in the Swat and Dir valleys of the North West Frontier Province of Pakistan (Shah *et al*., 1997).

Mungbean is capable to meet its nitrogenous requirements by fixing the atmospheric nitrogen in the presence of compatible rhizobia, but the role of starter dose of nitrogen in increasing yield through rapid early growth resulting in better establishment of plants has been reported (Nazir, 1986). However, delay in nodule initiation and development (Herridge *et al*., 1984) and reduced nitrogenase activity have been observed in response to high soil NO_3 content (Child, 1980). With this higher doses of nitrogen reduce nitrogen fixation on one hand and increase cost of production on the other. Rhizobial inoculation is a cheaper and usually more effective agronomic practice to improve nodulation, nitrogen fixation, crop growth and yield of leguminous crops (Henzell, 1988). Considering the economic conditions of farmers, and cropping patterns of those areas where mungbean is sown, it is necessary to adopt such practices which should result in reducing the higher costs of nitrogen fertilizer, increasing the use of inoculants and therefore minimizing the possibilities of pollution caused by nitrogen fertilizer. The ultimate objective of such practices should be higher yields thus increasing the margin of profit for farmers. Keeping in view all these possibilities, a study on mungbean was proposed to evaluate the response of genotypes to various inoculation/fertilization combinations in terms of crop growth, N-fixation and yield and to determine the Benefit Cost Ratio of rhizobial inoculation/N-fertilization in terms of yield and net returns for the growers.

MATERIALS AND METHODS

To evaluate the response of mungbean (genotypes NM-92 and NCM-209) to inoculation and use of N-fertilizer, a field experiment was conducted at Research Farm of the University of Arid Agriculture, Rawalpindi ($33^0$38'N, $73^0$4'E) during Kharif 2000. Climate of the region is warm temperate. Average annual rainfall ranged from 550-770 mm with a summer dominance (70% between July and September). Meterological data were collected at RAMC, UAAR and is presented in Fig. 1. Soil at the experimental site was silty clay loam (Typic Ustochrepts). General characteristics of surface soil (0-10 cm) at the experimental site are given in Table I.

The experiment was laid out in split plot arrangement keeping varieties in main plots and fertilizer/inoculum treatments in sub-plots. Net plot size was 1.8 m x 3 m. The crop was planted on July 19, 2000 with a single row hand drill @ 20 kg ha^{-1} in 30 cm apart rows with plant to plant distance of 10 cm. Phosphorous was applied @ 60 kg ha^{-1} in the form of single super phosphate to all the plots before sowing. Seed was coated with rhizobium @ 500 g ha^{-1} before planting. All agronomic practices were kept uniform and normal for all treatments. Weeds were removed thrice manually i.e. 15, 30 and 45 days after sowing. Crop was harvested on 2nd October, 2000 and threshing was done manually.

The treatment combinations were as under:

1 Control
2 500 g Inoculum ha^{-1}
3 30 kg N ha^{-1}
4 60 kg N ha^{-1}
5 90 kg N ha^{-1}
6 Inoculum + 30 kg N ha^{-1}
7 Inoculum + 60 kg N ha^{-1}
8 Inoculum + 90 kg N ha^{-1}

Soil samples were collected before sowing and after harvesting from each plot to determine soil N- contents by using total soil nitrogen method (Anderson & Ingram, 1993). Economic yield and biological yield were also taken. Harvest index (%) values were calculated using the economic and Biological Yield. Data were economically analyzed to determine the feasibility and profitability of the crop by its ultimate economic returns and for this purpose benefit cost ratio (BCR) values were calculated by dividing gross income over total expenditure. Income of total biomass of each genotype of mungbean in response to each treatment was calculated as Gross income. Total expenditure was calculated by the sum total of cost of production of different operations carried out from sowing to harvesting and threshing. Total nitrogen content of nodules and shoot were also measured (Anderson & Ingram, 1993). The data collected were analyzed statistically using Fisher's Analysis of Variance Techniques and Least Significant Difference Test at 5% probability level to compare the differences among the treatment means (Steel & Torrie, 1980).

Fig.1. Comparison of rainfall of the year 2000 along with average of 30 years

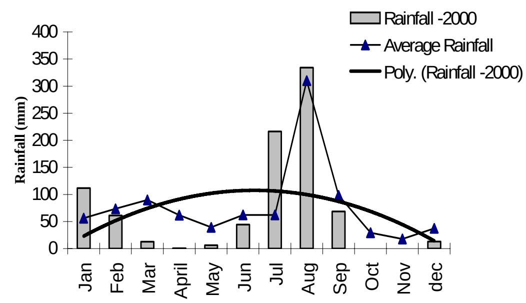

Table I. Surface soil (0-10 cm) properties of experimental site

Texture	Silty Clay Loam*
Bulk Density (g cm^{-3})	1.60
PH	7.20
ECe (d Sm^{-1})	0.33
Organic C (%)	0.65
NO_3-N (ug g^{-1})	6.3
Olsen P (mg kg^{-1})	7.8
Nitrogen (%)	0.02

***** Clay-28%, Silt-35%, Fine sand-35%, Coarses and-2%

RESULTS AND DISCUSSION

N-content of nodules. N-content of nodules is considered one of the important parameters for determining the nitrogen fixing ability of a plant. Data indicated that treatments and genotypes had highly significant effect on N-content of nodules while interaction of treatments with genotypes was non-significant (Table II). Two genotypes showed significant difference with NM 92 having significantly higher N-content in nodules as compared to NCM 209 (Table II). All treatments were significantly different as compared to control except 60 kg N ha^{-1}, 90 kg N ha^{-1} alone and in combination with inoculation. The highest N-content of nodules (2.80%) was recorded in plots treated with inoculation + 30 kg N ha^{-1} which was significantly different from all the other treatments except inoculation + 60 kg N ha^{-1} (Table II). Plots treated with inoculation alone and 30 kg N ha^{-1} showed intermediate response. Probably higher doses of nitrogen fertilizer inhibited nitrogen fixation in the nodules. Inoculation alone (2.68%) and in combination with 30 (2.80%) and 60 kg N ha^{-1} (2.71%) as well as 30 kg N ha^{-1} (2.64%) alone showed positive effect on N-content of nodules. The increase in nitrogen content of nodules due to inoculation was also reported by Ramaswami and Oblisami (1986) and increase in nitrogen content as well as number of nodules plant^{-1} due to the application of inoculation in combination with nitrogen fertilizer were also reported by Rashid *et al.* (1999).

N-content of shoots. It is elucidated that genotypes, treatments and interaction between the genotypes and treatments had highly significant effect on N-content of shoots. Two genotypes were significantly different from each other as NCM 209 showed significantly higher N-content (2.13%) in shoots than NM 92 (1.87%) (Table II). All the treatments significantly increased the N-content of shoots as compared to control except inoculation alone. Highest N-content (2.47%) were found in plots treated with inoculation + 30 kg N ha^{-1} which was significantly different from all the other treatments except 60 kg N ha^{-1} (Table II). Application of 30 kg N ha^{-1} alone and inoculation + 90 kg N ha^{-1} showed intermediate response. Among the interaction highest N-content of shoots (2.96%) were recorded in NCM 209 with plots treated with inoculation + 30 kg N ha^{-1} that was at par with 60 kg N ha^{-1} alone in the same genotype. These treatments were followed by inoculation + 60 kg N ha^{-1} in NCM 209 and 90 kg N ha^{-1} in NM 92. Application of 30 kg N ha^{-1} and inoculation + 90 kg N ha^{-1} in both genotypes while, inoculation + 30 kg N ha^{-1} and inoculation + 60 kg N ha^{-1} in NM 92 gave intermediate response, however, these treatments except inoculation + 30 kg N ha^{-1} and inoculation + 90 kg N ha^{-1} in NM 92 were at par with 60 kg N ha^{-1} in NM 92, 90 kg N ha^{-1} and control in NCM 209. The lowest N-content were found in plots treated with inoculation in both genotypes and in control in NM 92 (Table II). The increase in nitrogen uptake by plant due to inoculation and nitrogen fertilizer application was also reported by Paricha and Kar (1983), Moawad *et al.* (1988), Basu and Bandyopadhyay (1990) and Rashid *et al*. (1999).

N-content of soil. N-content of soil is an important parameter for determining the nitrogen fixing ability of plants. The data showed that treatments and the interaction of treatments with genotypes significantly affected nitrogen content of soil while the effect of genotypes was non- significant.

N-content of soil after harvesting (Table II) increased as compared with N-content of soil before sowing (Table I). All the plots treated with fertilizer in combination with inoculation increased the N-content of soil as compared to all the other treatments and control. The highest N-content of soil (0.043%) were recorded in plots treated with inoculation + 90 kg N ha^{-1} which was significantly different from control (0.025%) but was at par with all the other treatments (Table II). Lowest N-content (0.029%) were recorded in control, which was at par with inoculation alone, 30, 60 and 90 kg N ha^{-1} alone (Table II). Among the interaction the maximum N-content were found in plots where NCM 209 was treated with inoculation + 90 kg N ha^{-1} which was significantly different from all the other treatments in both genotypes except 90 kg N ha^{-1} alone, inoculation + 30 kg N ha^{-1} and inoculation + 60 kg N ha^{-1} in NCM 209 and 60 and 90 kg N ha^{-1} in combination with inoculation in NM 92. Lower N-content was found in control and inoculation alone in both genotypes, and 30 and 60 kg N ha^{-1} in NM 92. While application of 90 kg N ha^{-1} alone and 30 kg N ha^{-1} in combination with inoculation in NM 92 and 30 and 60 kg N ha^{-1} alone in NCM 209, gave intermediate response (Table II). Minimum soil N-content were recorded in

Table II. Effect of inoculation and use of nitrogen fertilizer on post harvest N-content of nodules, shoots in mungbean and soil (%)

Treatments	N-content of Nodules			N-content of Shoots			N-content of Soil		
	NM 92	NCM 209	Mean	NM 92	NCM 209	Mean	NM 92	NCM 209	Mean
Control	2.53	2.45	2.49 d	1.54 e	1.68 de	1.61 d	0.026 f	0.025 f	0.025 b
Inoculation	2.81	2.55	2.68 b	1.54 e	1.54 e	1.54 d	0.029 ef	0.030 ef	0.029 ab
30 kg N ha^{-1}	2.65	2.63	2.64 bc	1.82 cde	1.81 cde	1.81 c	0.030 ef	0.035 cde	0.033 ab
60 kg N ha^{-1}	2.62	2.54	2.58 cd	1.68 de	2.94 a	2.31 ab	0.032 de	0.037 bcd	0.035 ab
90 kg N ha^{-1}	2.58	2.50	2.54 d	2.66 b	1.68 de	2.17 b	0.034 cde	0.040 abc	0.037 ab
Inoculation + 30 kg N ha^{-1}	2.89	2.71	2.80 a	1.97 c	2.96 a	2.47 a	0.036 bcd	0.041 ab	0.039 a
Inoculation + 60 kg N ha^{-1}	2.74	2.68	2.71 ab	1.83 cd	2.66 b	2.24 b	0.040 abc	0.043 a	0.042 a
Inoculation + 90 kg N ha^{-1}	2.56	2.50	2.53 d	1.96 c	1.82 cde	1.89 c	0.041 ab	0.044 a	0.043 a
Mean	2.67 a	2.57 b		1.87 b	2.13 a		0.034	0.037	
LSD (0.05)	Treatment = 0.09161			Treatment =0.1754			Treatment = 0.01183		
	Genotype = 0.06803			Genotype = 0.1178			Genotype = NS		
	Treatment x genotype =NS			Treatment x genotype = 0.2481			Treatment x genotype = 0.005289		

The means having different letters in each row are significantly different from each other at five percent level of probability, where as having same letter indicate non-significant difference control plots of both the genotypes, however, inoculation alone in both genotypes and 30 and 60 kg N ha^{-1} in NM 92 did not differ significantly with control. The results showed that application of fertilizer nitrogen and inoculation both had a positive effect on N-content of soil. The increase in soil N-content due to inoculation and nitrogen fertilizer application was also reported by Daterao *et al.* (1990) and Rashid *et al.* (1999).

Economic yield. Final yield of mungbean is a function of integrated effect of its individual yield components. Data regarding economic yield per hectare (Table III) showed that treatments and genotypes significantly affected seed yield but effect of interaction of genotypes with treatments was non-significant. The two genotypes showed significant difference as NCM 209 gave significantly higher economic yield as compared to NM 92. All the treatments significantly enhanced the economic yield as compared to control except inoculation + 90 kg N ha^{-1} and inoculation + 60 kg N ha^{-1}. The maximum economic yield i.e. 768 and 910 kg ha^{-1} for NM 92 and NCM 209 respectively was recorded in plot treated with inoculation + 30 kg N ha^{-1} which was significantly different from inoculation + 60 kg N ha^{-1} and inoculation + 90 kg N ha^{-1} but it was at par with inoculation alone, 30, 60 and 90 kg N ha^{-1} alone (Table III). The minimum economic yield was recorded in inoculation + 90 kg N ha^{-1} which was followed by control and inoculation + 60 kg N ha^{-1}. The results showed that nitrogen doses of 30, 60 and 90 kg N ha^{-1} alone and application of inoculation alone and in combination with 30 kg N ha^{-1} had positive effect on economic yield of mungbean while higher doses of nitrogen in combination with inoculation affected the economic yield of mungbean, negatively.

Biological yield. The biomass determines the overall growth potential of a crop during a given period of time. Data on biological yield (Table III) elucidated that seed treatments, genotypes and the interaction between genotypes and treatments had non-significant effects, on the biological yield of this crop. The increased biological yield in both genotypes and in all treatments reflected high vegetative growth responding to the availability of nitrogen fertilizer/nitrogen content in soil and high moisture due to heavy rains during vegetative growth period. Although all the treatments were statistically non significant, but they increased the yield in all plots as compared to control except 30 kg N ha^{-1}, inoculation + 30 kg N ha^{-1} and inoculation + 60 kg N ha^{-1} in NM 92 and 90 kg N ha^{-1} in NCM 209. The plots treated with inoculation in combination with 30 kg N ha^{-1} showed maximum biological yield (4889 kg ha^{-1}) in NCM 209 which was followed by plots treated with inoculation alone, 30 kg N ha^{-1}, inoculation + 60 kg N ha^{-1} and inoculation + 90 kg N ha^{-1} in the same genotype. Both the genotypes had also non-significant effects on the biological yield of mungbean, however, NCM 209 was observed high in

Table III. Effect of inoculation and use of nitrogen fertilizer on economic yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) in mungbean

Treatments	Economic Yield (kg ha^{-1})			Biological Yield (kg ha^{-1})			Harvest Index (%)		
	NM 92	NCM 209	Mean	NM 92	NCM 209	Mean	NM 92	NCM 209	Mean
Control	661.3	791.7	726.5 c	4289.33	4613.33	4451.33	15.49	17.46	16.48 bc
Inoculation	718.3	908.0	813.2 ab	4379.67	4810.67	4605.17	15.57	19.53	17.55 ab
30 kg N ha^{-1}	742.0	876.0	809.0 ab	4282.33	4732.00	4507.17	17.36	18.64	18.00 ab
60 kg N ha^{-1}	723.0	863.0	793.0 ab	4534.00	4631.00	4582.50	15.96	19.08	17.52 ab
90 kg N ha^{-1}	690.7	888.0	789.3 ab	4503.33	4549.33	4526.33	15.53	19.63	15.58 ab
Inoculation + 30 kg N ha^{-1}	768.0	910.0	839.0 a	4262.00	4889.33	4575.67	18.22	18.68	18.45 a
Inoculation + 60 kg N ha^{-1}	669.3	871.0	770.2 bc	4289.33	4713.33	4690.83	14.61	18.18	16.40 bc
Inoculation + 90 kg N ha^{-1}	641.0	802.0	721.5 c	4819.67	4698.67	4624.83	14.24	16.93	15.58 c
Mean	701.7 b	863.7 a		4418.92	4722.08		15.87	18.52	
LSD (0.05)	Treatment = 53.35			Treatment =NS			Treatment = 1.702		
	Genotype = 45.23			Genotype = NS			Genotype = NS		
	Treatment x genotype =NS			Treatment x genotype = NS			Treatment x genotype = NS		

The means having different letters in each row are significantly different from each other at five percent level of probability, where as having same letter indicate non-significant difference

Table IV. Economic analysis of mungbean in response to rhizobial inoculation and different levels of nitrogen fertilizer

Treatments	Yield (kg ha^{-1})				Income (Rs ha^{-1})				Gross income (Rs ha^{-1})		Total expenditure (Rs ha^{-1}) of mungbean	Net income (Rs ha^{-1})		BCR (Benefit cost ratio)	
	Economic yield		Biological yield		Economic yield		Biological yield								
	NM 92	NCM 209	NM 92	NCM 209	NM 92	NCM 209	NM 92	NCM 209	NM 92	NCM 209		NM 92	NCM 209	NM 92	NCM 209
Control	661.3	791.7	4289.33	4613.33	16532.5	19792.5	4289.33	4613.33	20821.8	24405.8	9881.77	10940.1	14524.1	2.11	2.47
Inoculation	688.3	938.0	4379.67	4810.67	17207.5	23450.5	4379.67	4810.67	21587.2	28261.2	9931.77	11655.4	18329.4	2.12	2.84
30 kg N ha^{-1}	742.0	876.0	4282.33	4732.00	18550.0	21900.0	4282.33	4732.00	22832.3	26632.0	10409.08	12423.3	16222.9	2.19	2.56
60 kg N ha^{-1}	723.0	863.0	4534.00	4631.00	18075.0	21575.0	4534.00	4631.00	22609.0	26206.0	10934.77	11674.2	15271.2	2.07	2.39
90 kg N ha^{-1}	690.7	888.0	4503.33	4549.33	17267.5	22200.0	4503.33	4549.33	21770.8	26749.3	11465.32	10305.5	15284.0	1.90	2.33
Inoculation + 30 kg N ha^{-1}	768.0	910.0	4262.00	4889.33	19200.0	22750.0	4262.00	4889.33	23462.0	27639.3	10459.08	13002.9	17180.3	2.24	2.64
Inoculation + 60 kg N ha^{-1}	669.3	871.0	4289.33	4713.33	16732.5	21775.0	4289.33	4713.33	21021.8	26488.3	10984.77	10037.1	15503.6	1.91	2.41
Inoculation + 90 kg N ha^{-1}	641.0	802.0	4819.67	4698.67	16025.0	20050.0	4819.67	4698.67	20844.7	24748.7	11515.32	9329.4	13233.4	1.81	2.15

Market price of Mungbean: (Rs.25 per kg of seed and Straw: Rs. 1 per kg) biological yield as compared to NM 92 (Table III).

Harvest index. The physiological ability of a crop plant to convert proportion of dry mater into economic yield is measured in terms of harvest index. The higher the harvest index the more productive efficiency of a crop and vice versa. Seed inoculation and nitrogen fertilizer application significantly affected the harvest index but the effect of genotypes and interaction of treatments with genotypes was non-significant. Maximum harvest index (18.45%) was recorded in plots treated with inoculation + 30 kg N ha^{-1} which was at par with plots treated with 30, 60 and 90 kg N ha^{-1} alone and inoculation alone (Table III). Application of 90 kg N ha^{-1} alone and in combination of inoculation gave the lowest harvest index value (15.58%), which was at par with control and inoculation + 60 kg N ha^{-1}.

Economic analysis. Both the feasibility and profitability of a crop is determined by its ultimate economic returns. Data regarding the details of economic analysis along with all relevant calculations revealed that all treatments gave higher net income per hectare (in both genotypes) as compared to control in both genotypes except 90 kg N ha^{-1}, inoculation + 60 kg N ha^{-1} and inoculation + 90 kg N ha^{-1} in NM 92 and inoculation + 90 kg N ha^{-1} in NCM 209 (Table IV). Amongst the various treatments, the maximum net income i.e. Rs. 18329 ha^{-1} was obtained in case of inoculation alone in NCM 209 which was followed by inoculation + 30 kg N ha^{-1}, 30 kg N ha^{-1}, inoculation + 60 kg N ha^{-1}, 90 kg N ha^{-1}, 60 kg N ha^{-1} and inoculation + 90 kg N ha^{-1} in the same genotype (Table IV). In case of NM 92 the net income ha^{-1} was low as compared to NCM 209. The highest net income ha^{-1} (Rs. 13003) in NM 92 was given by inoculation + 30 kg N ha^{-1} which was followed by 30 kg N ha^{-1}, 60 kg N ha^{-1} and inoculation alone, respectively. The highest benefit cost ratio (BCR) was obtained in plots treated with inoculation alone in NCM 209 which was followed by inoculation + 30 kg N ha^{-1}, 30 kg N ha^{-1}, control, inoculation + 60 kg N ha^{-1}, 60 kg N ha^{-1} and 90 kg N ha^{-1} in NCM 209 and inoculation + 30 kg N ha^{-1} and 30 kg N ha^{-1} in NM 92, respectively. Higher nitrogen doses with and without inoculation in both genotypes gave lower values of benefit cost ratio (Table IV).

CONCLUSION

It could be concluded from the results that inoculation in combination with lower nitrogen dose produced maximum N-content of nodules, shoots, economic yield and harvest index. While maximum net income and benefit cost ratio was given by inoculation alone thus from the results of this study it is indicated that by inoculation alone the growers can harvest higher economic yields in relation to maximum net income and benefit cost ratio. But the research can never stand still so further studies are recommended to collect more information about the need of nitrogen fertilizer as a starter dose and better combinations of inoculation /fertilization under field conditions.

REFERENCES

Ahmed, N., J.G. Davide and M.T. Saleem, 1988. Fertility status of soils in dryland areas of Pakistan. In: *proceedings of International Seminar on Dryland Agriculture in Pakistan*, pp: 22–49. Nov.6–8,1988. Fauji Fertilizer Company Ltd., Lahore

Anderson, J.M and J.S.I. Ingram, 1993. *Tropical Soil Biology and Fertility*. A Handbook of Methods. C.A.B. International, Wallingfold, U.K. 70–4 and 82–7

Basu, T.K. and S. Bandyopadhyay, 1990. Effects of rhizobium inoculation and nitrogen application on some yield attributes of mung. *Environ. Ecol*., 8: 650–4

Child, J.J., 1980. Nitrogen fixation by free living rhizobium and its implications. In: *Recent Advances in Biological Nitrogen Fixation*. N.S. Suba, (ed) p: 337. Oxford and IBH Publishing Company, 66 Janpath, New Delhi

Daterao, S.H., B.A. Lakhdive and A.B. Turkhede, 1990. Effect of Rhizobium seed inoculation of green gram with and without molybdenum on grain yield and nitrogen status of soil. *PKV Res. J*., 14: 75–7

Frederich, W.S., S.B.Walls, A. Rehman and M.S. Nawaz, 1991. *Groundnut Production in Pakistan*. p: 81. BARD Project, PARC, Islamabad

Herridge, D.F., R.J. Rougley and J. Brockwell, 1984. Effect of rhizobium and soil nitrate on the establishment and functioning of the soybean symbiosis in the field. *Australian J. Agric. Res*., 35: 149–61

Henzell, E.F., 1988. The role of biological nitrogen fixation research in solving problems in tropical agriculture. *Plant and Soil*. 108: 15–21

Khan, A.R., A. Qayyam and G.A. Chaudhary, 1989. A country paper on soil, water and crop management systems for dryland agriculture in Pakistan. In: *Soil, water and crop/livestock management system for rainfed agriculture in near east region*. C.E. Whitman, J.F. Parr, R.I. Papendick, and R.E. Meyer (eds.). pp: 88–102. ICARDA, USAID

Moawad, H., S.M.S.B. El–Din and M.A. Khalafullah, 1988. Field performance of rhizobial inoculants for some important legumes in Egypt. In: *Nitrogen fixation by Legumes in Mediterraneen Agriculture*. D.P. Beck and L.A. Moteron (eds). pp: 235–44. Aleppo, Syria: ICARDA

Nazir, M.S., 1986. Effect of phosphorus alone or in combination with starter nitrogen on yield potential of three gram varieties. Consolidated progress report. Field Crops Absts., 37: 3175, 198

Paricha, P.C. and M. Kar, 1983. Improving symbiotic nitrogen fixation and productivity in black gram (*Vigna mungo* L.). *Current Sci*., 52: 1143–5

Ramaswami, P.P.O. and G. Oblisami, 1986 Influence of nitrogen. Phosphorus and inoculation on nitrogen fixation and yield in black gram (*Vigna mungo* L.) *National Seminar on Microbial Ecology*.p: 2. Jan. 23–24, 1986

Rashid. A., M. Musa, N.K. Aadal, M. Yaqub and G.A. Chaudhry, 1999. Response of groundnut to Bradyrhizobium and a Diazotroph bacterial inoculum under different levels of nitrogen. *Pakistan J. Soil*., 16: 89–98

Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics, A Biometrical Approach.* pp: 232–51. 1st Ed., McGraw Hill Book Co., New York

Shah, Z., S.H. Shah, M.B. Peoples, and D.F. Herridge, 1997. Surveys of N_2 fixation of Lentil, Mungbean, Blackgram in farmer's fields in North West Frontier Province, Pakistan. In: *Extending Nitrogen Fixation Research to Farmer's Fields*. pp: 333–43 Proceedings of an International Workshop on Managing Legume Nitrogen Fixation in the Cropping System of Asia, 20–24 Aug 1996. ICRISAT Asia Centre, India

(Received 01 March 2004; Accepted 10 April 2004)