Effects of Inoculation of *Rhizobium* and Arbuscular Mycorrhiza, Poultry litter, Nitrogen, and Phosphorus on Growth and Yield in Chickpea

A. R. M. Solaiman†, M. G. Rabbani, and M. N. Molla

Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh

ABSTRACT: The experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur to study the response of chickpea (*Cicer arietinum* L) to dual inoculation of *Rhizobium* and arbuscular mycorrhiza, poultry litter, nitrogen, and phosphorus on spore population and colonization, nodulation, growth, yield attributes, and yield. The performance of *Rhizobium* inoculant alone was superior to control in all the parameters of the crop studied. Among the treatments dual inoculation of *Rhizobium* and arbuscular mycorrhiza in presence of poultry litter performed best in recording number and dry weight of nodules, dry weight of shoots and roots, number of pods/plant, number of seeds/pod, and seed yields of chickpea. The highest seed yield of 3.96 g/plant was obtained by inoculating chickpea plants with dual inoculation of *Rhizobium* and arbuscular mycorrhiza in association with poultry litter. Treatments receiving dual inoculation of *Rhizobium* and arbuscular mycorrhiza in presence of nitrogen and phosphorus, *Rhizobium* inoculant in presence of nitrogen and phosphorus, and that of arbuscular mycorrhiza in presence of nitrogen and phosphorus were similar as that of treatment receiving dual inoculation of *Rhizobium* and arbuscular mycorrhiza in presence of poultry litter. From the view point of nodulation, growth, yield attributes, and yields of chickpea, dual inoculation of *Rhizobium* inoculant and arbuscular mycorrhiza along with poultry litter was considered to be the balanced combination of nutrients for achieving the maximum output from cultivation of chickpea in Shallow Red Brown Terrace Soil of Bangladesh.

***Keywords*:** Chickpea, *Rhizobium*, Arbuscular mycorrhiza, Poultry litter, Nitrogen, Phosphorus

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops grown in Bangladesh. It is one of the protein rich crop and has occupied third position both in production (11,000 tons) and area under cultivation (15,385 ha) in Bangladesh (Anonymous, 2002). The leguminous plants can form two types of symbiotic association with microorganisms: one with *Rhizobium* involved in atmospheric nitrogen fixation and another with arbuscular mycorrhizal (AM) fungi concerned with the uptake of phosphorus and other nutrients (Crush, 1974). The association of AM fungi increase uptake of immobile nutrients, especially phosphorus and micronutrients (Douds & Miller, 1999). Most legumes are associated with nitrogen fixing organisms and AM fungi (Muthakumar & Udaiyan, 1995). This double symbiosis enables legumes to accumulate large amount of nutrients even under sub-optimal soil conditions. Generally legumes have less extensive root systems and are dependent on colonization by native AM fungi for their nutritional needs (Bethlenfalvay & Newton, 1991). There have been several studies on the interaction between AM fungi and rhizobia associated with legumes. Some works have been done on dual inoculation of *Rhizobium* -AM on soybean (Barakah & Heggo, 1998) and green gram (Balachandar & Nagarajan, 1999). A synergistic effect of dual inoculation with AM fungi and bradyrhizobia / rhizobia on growth and nutrition in legumes has been demonstrated by many researchers (Badr El-Din & Moawad, 1988). The root system of chickpea can be infected by arbuscular mycorrhizal fungi and by nitrogen fixing bacteria. These two microorganisms are beneficial to the plant and the possibility of a direct interaction between the fungus and bacterium was considered. Organic farming with poultry litter is gaining popularity day by day. Poultry litter can supply a good amount of N and P. But no attempt has been made to asses the effects of dual inoculation of *Rhizobium*, AM, poultry litter, N, and P on chickpea. Therefore, it is essential to determine the effect of dual inoculation of *Rhizobium*, AM, poultry litter, nitrogen (N), and phosphorus (P) on chickpea. Keeping these facts in mind, the present investigation was carried out to study the role of *Rhizobium* inoculant, AM fungi, poultry litter, N, and P on spore population and colonization of AM, nodulation, growth, yield attributes and yield of chickpea.

†Corresponding author: (Phone) 880-2-9252850-2 Extn 2040 (E-mail) arm_solaiman@yahoo.com <Received August 11, 2005>

MATERIALS AND METHODS

A pot experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, using chickpea variety BARI Chola-5 as the test crop. The soil was sterilized by solarization (Rupela & Sudarshana, 1990).

Collected soil clods were broken and weed and other unwanted materials were removed. The soil was silty clay loam having sand 16.8%, silt 47.6%, clay 35.6%, organic carbon 0.94%, pH 6.70, CEC 15.50 meq/100 g soil, total nitrogen 0.069%, available P 12.50 ppm, available K 0.32 meq /100 g soil, exchangeable Ca 6.5 meq/100 g soil, exchangeable K 7.44 meq/100 g soil, exchangeable Mg 3.30 meq /100 g soil, exchangeable Na 0.76 meq /100 g soil, number of *Rhizobium* 4.1 × 10^5/ g soil. Ten kilogram solar sterilized soils were put in an earthen pot. Nitrogen 0.53 g/ pot in the form of urea, phosphorus 0.56 g P_2O_5 / pot in the form of triple super phosphate, poultry litter 25 g/pot, arbuscular mycorrhiza 25 g/pot were applied to pot according to the treatments assigned. Potassium 0.43 g K_2O / pot, sulphur 0.56 g S/pot and molybdenum 0.02 g Mo/pot were applied as basal dose in the form of Muriate of potash, Zypsum, and Sodium molybdenum, respectively. The experiment was laid out in a randomized complete block design (RCRD) with 3 replications. There were eight treatment combinations, viz T_1 Control, T_2 *Rhizobium* (*R*), T_3 Arbuscular mycorrhiza (AM), T_4 Poultry litter (PL), T_5 Arbuscular mycorrhiza (AM) + Nitrogen (N) + Phosphorus (P), T_6 *Rhizobium (R)* + Arbuscular mycorrhiza (AM)+Phosphorus (P), T_7 *Rhizobium (R)* + Arbuscular mycorrhiza (AM) + Poultry litter (PL), and T_8 *Rhizobium (R)* + Arbuscular mycorrhiza (AM) + Nitrogen (N) + Phosphorus (P). Roots of sorghum (*Sorghum vulgare* L) with rhizosphere soil were used as AM inoculum which was collected from BARI. Twenty five g inoculum was applied per pot. A layer of inoculum was first placed in each pot filled with non-sterilized soil and was covered with a thin soil layer of 2 cm in which seeds were sown. *Rhizobium* strain RCa-2001 was used as inoculum. Counts of viable rhizobia were taken following the Drop Plate Method of Miles & Misra (1938). Then 1.12 g containing 1.5 × 10^9 cells/g *Rhizobium* inoculum was mixed with 56 g seeds with the help of gum arabic. Four seeds of chickpea treated with mercuric chloride for surface sterilization were sown in each pot. Pots were irrigated up to saturation to allow the soil and inoculum to settle down in the pots. After germination of seeds, two healthy plants were allowed to grow per pot, others were uprooted carefully. Pots were watered whenever necessary to maintain field moisture condition. Intercultural operations (weeding and mulching) were done as and when necessary to ensure the normal growth of the crop. The pots were carefully observed regularly to record any change of plant growth. No insecticide was used during the growth period. The plants were free from insects and diseases.

The plants were carefully uprooted with minimum disturbance of roots so that no nodules were left in the soil. The roots were washed with tap water and finally rinsed with distilled water. The nodules were separated from roots and then nodule number and weight were recorded. The shoot, root, and nodules were first air-dried and then oven-dried at 65°C for 72 hours. For assessing AM colonization one hundred root segments of 1 cm long were stained according to Koske & Gemma (1989). The percentage of AM root colonization was estimated by root slide technique (Read *et al.*, 1976) and the spore population was determined following the wet sieving and decanting method (Gerdemann & Nicolson 1963). All data were analyzed in the computer using MSTAT-5 programme.

RESULTS AND DISCUSSION

Root colonization

The effects of different combinations of *Rhizobium*, AM, N, and P on root colonization are presented in Table 1. The highest root colonization (70%) was found with the treatment T_8 (*R* + AM + N + P) that was significantly higher over other treatments but statistically similar to T_5 and T_7 The lowest

Table 1. Root colonization and spore number in rhizosphere soil of chickpea.

Treatment	Percent root colonization	Number of spore/ 100 g soil
T_1 Control	0.0 c	7.0 c
T_2 *Rhizobium* (*R*)	0.0 c	17.3 c
T_3 Arbuscular mycorrhiza (AM)	52 0 b	65 0 b
T_4 Poultry litter (PL)	10.0 c	20.0 c
T_5 AM+N+ P	63.3 ab	107 5 a
T_6 *R*+N+P	6.0 c	10.3 c
T_7 *R*+AM+PL	61.7 ab	105.0 a
T_8 *R*+AM+N+P	70.0 a	117.5 a
CV (%)	13.0	11.9

Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT

colonization was found in control. Percent root colonization was increased significantly by dual inoculation with *Rhizobium* and AM than that of single inoculation with AM. Similar results were reported by Nwoko & Sanginga (1999) who reported increased root colonization in soybean by dual inoculation of *Rhizobium* and AM. The increase of percent root colonization by dual inoculation was also reported by Naqvi & Mukerji (1998). They got higher percent root colonization by dual inoculation of *Glomus fasciculatum* (AM) and *Rhizobium* in *Leucaena leucocephala*. In this study dual inoculation was more effective when N and P fertilizer exist in soil. Similar result was reported by Maksoud *et al.* (1995) who noted the best performance of soybean by dual inoculation along with N and P fertilizers. Colonization percentage of AM was more in dual inoculation and it was enhanced to a greater extent due to addition of chemical fertilizers.

Number of spore/ 100 g soil

Arbuscular mycorrhizal inoculation, either individually or in combination with *Rhizobium* or dual inoculation along with N and P fertilizers significantly increased spore population over control (Table 1). The highest numbers of population (117.50/100 g soil) was obtained by the treatment T_8 (*R*+AM+N+P). The effect of this treatment was statistically similar to the treatment T_5 and T_7. Dual inoculation was found to be superior to individual inoculation which is in agreement with Tarafdar & Rao (1997) who reported that the number of AM spores in the rhizosphere soil of clusterbean, mungbean and mothbean were increased significantly upon AM inoculation. In this study *Rhizobium* alone or along with N and P fertilizers produced comparatively poor number of spores. But plants applied with AM, N, and P exhibited considerable number of spores.

Nodulation

The effects of different combinations of *Rhizobium*, AM, and P on number of nodule and dry weight nodule was significant (Table 2). The highest number of nodule (84.17/ plant) was obtained with the treatment T_7 receiving *Rhizobium* along with AM and PL but the effect of this treatment was statistically similar to T_6 and T_8. The effects of *Rhizobium* alone were also statistically similar to the treatment T_6 and T_8 Among the different treatments the lowest number of nodule was obtained with arbuscular mycorrhiza alone which was statistically similar to the effect of poultry litter and control. The highest number of nodule was recorded with *R*+AM+PL that may be attributed to greater availability of P, which is crucial for nodulation (Hayman, 1986). In this treatment plants obtained P from added poultry litter as well as inoculated AM that formed association with plant root, extracted native soil P from greater volume of soil, thereby increased plant P and hence nodulation. These results are in good agreement with Burity *et al.* (2000) who reported increased nodulation due to dual inoculation as compared to single inoculation with *Rhizobium*. Again, statistically identical nodule number of the treatment T_6 and T_8 suggests that P required for nodulation may be supplemented by applying chemical fertilizer or by inoculating the crops with AM fungi. In case of dry weight of nodule, the highest dry weight (0.235 g) was also recorded with the treatment T_7 which was statistically similar with T_6 and T_8. Hernandez & Hernandez (1996) recorded significantly increased nodule number and nodule weight of soybean at flowering stage with *Rhizobium*-AM inoculation in absence of added N.

Table 2. Effect of different combinations of *Rhizobium* inoculant, arbuscular mycorrhiza, nitrogen, and phosphorus on number of nodule, plant height, root length, & dry weight of nodule, root and shoot of chickpea.

Treatment	Number of nodules per plant	Dry weight of nodule (g)	Plant height (cm)	Root length (cm)	Dry weight of shoot (g)	Dry weight of root (g)
T_1 Control	1.3 c	0.010 c	14.2 d	10 2 e	1.28 d	0.27 c
T_2 *Rhizobium* (*R*)	55.0 b	0 100 b	20.2 c	20.5 cd	2.06 c	0.47 b
T_3 Arbuscular mycorrhiza (AM)	3.8 c	0.015 c	14.3 d	16.3 d	1.53 cd	0.42 bc
T_4 Poultry litter (PL)	5.8 c	0.025 c	24.1 b	23 0 bc	3.39 b	0.49 b
T_5 AM +N + P	10.8 c	0 030 c	24.2 ab	19.1 cd	3.48 b	0 65 ab
T_6 R+ N + P	74.2 ab	0.195a	26.3 ab	26.8 ab	4.55 a	0.69 a
T_7 R+ AM + PL	84 2 a	0 235a	27.3 a	30.2 a	4.87 a	0.80 a
T_8 . R+ AM +N + P	76.3 ab	0.200 a	26.7 a	28.2 a	4.66 a	0.79 a
CV (%)	9 0	6.31	7.3	9.2	7.9	19.6

Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT

Plant height

The maximum plant height was obtained with the treatment T_7 receiving *Rhizobium* along with AM and PL but the effect of this treatment was statistically similar to T_5, T_6 and T_8 (Table 2). Plant height (27.3cm) recorded by this treatment differed significantly with all other treatments except T_5, T_6, and T_8. Data revealed that with few exceptions dual inoculation along with PL (*R*+AM+PL) showed significant increase in plant height compared to *Rhizobium* or AM alone. Setua *et al* (1999) obtained maximum plant height in maize due to the influence of AM along with 30 kg P ha^{-1}. Balachandar & Nagarajan (1999) recorded maximum plant height in green gram by the dual inoculation of *Rhizobium* and AM along with 50% recommended nitrogen and phosphorus fertilizers. Data also showed better response of dual inoculation than that of single inoculation in the present study. Similar results were also reported by several researchers (Burity *et al*., 2000). Further *Rhizobium* along with AM and PL showed better performance than *Rhizobium* alone and as well as AM alone. Dual inoculation with chemical fertilizer (N and P) showed better performance than single inoculation of AM and PL only.

Dry weight of shoot

The effects of different combinations of *Rhizobium*, AM, and P on dry weight of shoot of chickpea were significantly influenced (Table 2). The highest dry weight of shoot of 4.87 g/plant was recorded in *R*+AM+PL at 50% flowering stage and was statistically similar to T_6 and T_8. The lowest dry weight of shoot was recorded in control. Dual inoculation of *R*+AM with N and P increased dry weight of shoot compared to plants inoculated with individual endophyte (*Rhizobium* or AM). This indicates the host's ability to channel energy to shoot production due to an increased efficiency of the roots by AM fungi (Bethlenfalvay *et al.*, 1982). Solaiman & Habibullah (1990) stated that *Rhizobium* inoculated groundnut in presence of P, K, and Mo gave significant amount of total dry matter yield per plant compared to the treatment of 100 kg N ha^{-1} at farm fertility at 50% flowering stage of the crop.

Root length

The effects of different treatments on root length of chickpea were found significant (Table 2). With respect to root length, the highest length of 30.21 cm per plant was recorded with the treatment T_7 receiving *R*+AM+PL at 50% flowering stage. This might be due to the adequate supply of nitrogen from biological fixation by *Rhizobium* and proper supply of P fertilizer, which enhanced vegetative growth and greater translocation of photosynthate and thereby root growth, which is in agreement with the findings of Balachandar & Nagarajan (1999). All the treatments recorded significantly higher root length over control. The lowest root length (10.22 cm) was recorded in control.

Dry weight of root

There were significant variations in root dry weight recorded with different treatments of the crop (Table 2). The highest dry weight of root was recorded by the treatment T_7 receiving *R*+AM+PL and was statistically similar to T_5, T_6, and T_8 but significantly higher over *Rhizobium*, AM, PL alone, and control. The lowest dry weight root was found in control.

Table 3. Effect of different combinations of *Rhizobium* inoculant, arbuscular mycorrhiza, nitrogen, and phosphorus on yield attributes and yield of chickpea

Treatment	Number of pods/ plant	Number of seeds/ pod	1000-seed weight (g)	Seed yield (g/plant)	Stover yield (g/plant)
T_1 Control	3.0 d	0.53 d	66.7 d	0.68 d	0 22 d
T_2 *Rhizobium* (*R*)	11 2 bc	1.52 b	113.7 ab	2.08 b	0.50 b
T_3. Arbuscular mycorrhiza (AM)	7.8 cd	1.00 c	86 3 cd	1.12 c	0 36 c
T_4 Poultry litter (PL)	8.5 c	1.00 c	104.2 bc	1.32 c	0.46 b
T_5 AM +N + P	15.2 ab	2.00 a	117.8 ab	3 55 a	0.73 a
T_6 R+ N + P	15.5 ab	2 00 a	132.7 a	3.61 a	0.77 a
T_7 R+ AM + PL	18.0 a	2 33 a	134 2 a	3.96 a	0.84 a
T_8 R+ AM +N + P	17.2 a	2.00 a	132.5 a	3.75 a	0.80 a
CV (%)	6.8	5 0	6.7	6.8	9.3

Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT

Number of pods per plant

There was a significant variation in the number of pods per plant with the different treatments (Table 3). The highest number of pod was obtained with the treatment T_7 receiving *R*+AM+PL and was statistically similar to T_5, T_6, and T_8 but significantly higher over *Rhizobium*, AM, PL alone, and control. The lowest number of pod was found in control. Double symbiosis of *R*+AM with PL increased pod number significantly compared to single inoculation. Hernandez & Hernandez (1996) reported that dual inoculation significantly increased pod numbers of soybean over control.

Number of seeds per pod

The effects of *Rhizobium*, AM and P in recording the number of seeds per pod were significant (Table 3). Plant receiving *Rhizobium* and AM in combination with PL produced the highest number of seeds per pod. The effect of this treatment was statistically similar to T_5, T_6, and T_8 and superior to other treatments. *Rhizobium* inoculant recorded comparatively higher number of seeds than AM. It was observed that biologically fixed N exhibited a significant effect on the number of seeds per pod. Das *et al.* (1997) got significantly higher seed yield with *R*+AM compared with no inoculation. Moreover, the results revealed that the dual inoculation along with N and P fertilizers together or separately recorded significantly higher seed yields compared to inoculation alone which is in agreement with Balachandar & Nagarajan (1999). The lowest number of seeds per pod was obtained in control.

1000-seed weight

Rhizobium inoculant (T_2) alone significantly increased 1000-seed weight compared to control (Table 3). The highest 1000-seed weight (134.2 g) was recorded with the treatment T_7 (*R*+AM+PL) and statistically similar to the treatment T_2, T_5, T_6, and T_8. The combined effect of *Rhizobium* inoculant, AM, and PL might have led to better assimilation of N for the plants that resulted the larger seeds. Solaiman *et al* (2003) reported that *Rhizobium* inoculant significantly increased 1000-seed weight of chickpea compared to control.

Seed yield

There was a significant effect of different treatments in increasing seed yield (Table 3). The highest seed yield of 3.96 g/plant was found with the treatment T_7 receiving *R*+AM+PL. The effect of this treatment was statistically similar to the treatment T_5, T_6, and T_8. All the treatments produced significantly higher seed yield over control. The lowest seed yield was found in control. These findings have the resemblance with the result of Carling *et al.* (1996) who reported that AM fungi and P fertilization increased pod weight of groundnut. In this study, it was revealed that the dual inoculation of *Rhizobium*, AM along with PL recorded significantly higher seed yields compared to *Rhizobium* and AM alone which is in agreement with Balachandar & Nagarajan (1999).

Stover yield

The trend of increase in stover yield was similar as that of seed yield/plant. The effect of different treatments on stover yield was significant (Table 3). All the treatments significantly increased stover yield compared to control. The highest stover yield (0.84 g) at 50% flowering stages were recorded with treatment T_7 receiving *R*+AM+PL which was statistically similar to T_5, T_6, and T_8 but superior to *Rhizobium,* AM, poultry litter, and control.

REFERENCES

Anonymous, 2002 Statistical Yearbook of Bangladesh. 2002. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. P. 131.

Badr, El-Din, S M. S and H Moawad 1988. Enhancement of nitrogen fixation in lentil, feba bean, and soybean by dual inoculation with rhizobia and mycorrhiza. Plant and Soil 108 : 117-124.

Balachandar, D and P Nagarajan. 1999. Dual inoculation of vesicular arhuscular mycorrhiza and *Rhizobium* in green gram. Legume Res. 22 : 177-180.

Barakah, F. N. and A M Heggo. 1998. Moisture stress, bradyrhizobia, vesicular arbuscular mycorrhiza, and P fertilizer effects on soybean growth, nutrient content, and phosphatase activity under calcareous soil. Ann. Agril. Sci. Cairo 43 : 461 - 475.

Bethlenfalvay, G. J. and W E. Newton 1991. Agroecological aspects of mycorrhizae and nitrogen fixing legume symbiosis *In* The Rhizophere and plant Growth. D L Keister and P. B Cregan (eds.) Netherlands: Kluwer Academic Publishers, pp. 349-354

Bethlenfalvay, G. J , R. S. Pacovsky, H. G. Bayne, and A. E. Stafford. 1982. Interactions between nitrogen fixation, mycorrhizal colonization and host plant growth in the Phaseolus-*Rhizobium*-Glomus symbiosis Plant Physiol. 70 : 446-450.

Burity, H. A., M. D. C. P. De Lyra, E. S. De Souza, S A. C D. Mergulhao, and M L. R. B. Da Silva 2000 Effectiveness of inoculation with AMF and *Rhizobium* on *Mimosa caesalpinifolia* seedlings, under different phosphorus levels. Pesqui. Agropecu. Bras. 35 : 801-807.

Carling, D. E., R. W Roncadori, and R. S. Hussey. 1996. Interactions of arbuscular mycorrhizae, *Meloidogyne arenaria*, and phosphorus fertilization on peanut. Mycorrhiza 6 : 9-13.

Crush, J. R. 1974. Plant growth responses to vesicular arbuscular mycorrhiza. VII. Growth and nodulation in some herbage legumes. New Phytol. 73: 743-756.

Das, P. K., P. N Sahoo, and M. K. Jena. 1997. Effect of VA-mycorrhiza and rhizobia inoculation on nutrient uptake, growth attributes and yield of green gram (*Vigna radiata* L.). Environ. Ecol. 15: 830-833.

Douds, D. D and P Miller. 1999. Biodiversity of arbuscular mycorrhizal fungi in agroecosystems Agril. Ecosyst. Enviro. 74 : 77-93.

Gerdemann, J. W. and T H. Nicolson. 1963. Species of mycorrhizal endogone species extracted from soil by wet sieving and decanting method. Trans. Brit Mycol. Soc. 46 : 235-246

Hayman, D. S.1986. Mycorrhizas of nitrogen-fixing legumes. J. Appl. Microbiol Biotech. 2 : 121-145.

Hernandez, A. and A. N. Hernandez. 1996. Effect of the AM-*Rhizobium* interaction in cultivation of soybeans (*Glycin max*.). Cultivose Tropicales 17 : 5-7

Koske, R. E and J. N. Gemma 1989. A modified procedure for staining roots to detect VA mycorrhizas. Mycol Res. 92 : 486-488

Maksoud, H K. A. E., H. Moawad, and R. N. Saad 1995. Performance of soybean as affected by *Bradyrhizobium japonicum* and VA mycorrhiza under different levels of P and N ferilization. Egyptian J Microbiol. 30 · 401-414.

Miles, A. A. and S. S. Misra 1938 The estimation of the bactericidal power of blood. J. Hyg Cambridge 38 : 732-749

Muthakumar, T. and K. Udaiyan. 1995. Influence of vesicular arbuscular mycorrhiza and *Rhizobium sp.* on growth responses and nutrient status of Tephrosia purea Pers. Acta Botanica Indica 23 : 75-80.

Naqvi, N S. and K. G. Mukerji. 1998. Mycorrhization of micro propagated *Leucaena leucocephala* (Lam) de Wit. Symbiosis 24 103-113.

Nwoko, H. and N Sanginga 1999. Department of promiscuous soybean and herbaceous legumes on arbuscular mycorrhizal fungi and their response to bradyrhizobial inoculation in low P soils. Appl. Soil. Ecol. 13 251-258.

Read, D. J., H. K. Koucheki, and J. Hodgaon. 1976 Vesicular arbuscular mycorrhiza in natural vegetation systems. New Phytol. 77 641-653.

Rupela, O P and M. R. Sudarshana 1990. Displacement of native rhizobia nodulating chickpea (*Cicer arietinum* L) by an inoculation strain through soil solarization. Biol. Fertil. Soils 10 : 207-212.

Setua, G. C., R Kar, J. K. Ghosh, S. K. Das, and B. Saratchandra. 1999. Response of direct inoculation of AM on growth, leaf number, and phosphorus uptake in maize. Ind J.Agril Sci 69 . 444-448.

Solaiman, A. R. M. and A K. M. Habibullah 1990. Response of groundnut to *Rhizobium* inoculation. Bangladesh J. Soil Sci 21(1) : 42-46.

Solaiman, A R. M., M. S. Mahmud, and M. S. Hoque. 2003. Response of lentil to *Rhizobium* inoculant and nitrogen Yield and yield contributing characters. Bangladesh J. Life Sci. 15(2) : 71-77

Tarafdar, J C. and A V. Rao 1997. Response of arid legumes to AM fungal inoculation. Symbiosis 22 265-274.