Effects of *Rhizobium* Inoculant, Compost, and Nitrogen on Nodulation, Growth, and Yield of Pea

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ABSTRACT: The effects of *Rhizobium* inoculant, compost, and nitrogen on nodulation, growth, dry matter production, yield attributes, and yield of pea (*Pisum sativum*) var. IPSA Motorshuti-3 were assessed by a field experiment. Among the treatments *Rhizobium* inoculant alone performed best in recording number and dry weight of nodules/plant. The highest green seed yield of 8.38 ton/ha (36.9% increase over control) and mature seed yield of 2.97 ton/ha (73.7% increase over control) were obtained by the application of 90 kg N/ha. The effects of 60 kg N/ha, *Rhizobium* inoculant alone and *Rhizobium* inoculant along with 5 ton compost/ha were same as the effect of 90 kg N/ha in recording plant height, root length, dry weight of shoot, and root both at preflowering and pod filling stages, number of mature pods/plant, number of mature seeds/pod, 1000-seed weight, green, and mature seed yields of pea.

***Keywords*: *rhizobium*, compost, nitrogen, pea**

Pea (*Pisum sativum*) is grown as vegetable crop during the winter season in Bangladesh. The importance of pea as vegetable crop has also sharply increased although the production of canned green peas still does not meet the demand. In Bangladesh only 17,192 ha of land is under garden pea cultivation where its production is 13,735 MT which is lower than other vegetables (Anonymous, 2004). Pea crop benefits the farming system due to its ability to fix atmospheric nitrogen in the symbiosis with *Rhizobium*, which makes N-fertilization unnecessary and the cycling of N from plant residues may reduce the need for N-fertilization in succeeding crops (Jensen, 1988). Inclusion of pea in crop rotation helps improvement of soil fertility and yield of the succeeding crops (Rana & Sharma, 1993). Seed inoculation with *Rhizobium* strains is known to influence nodulation and growth of garden pea (Khondaker *et al.*, 2003). Many researchers (Rabbani *et al.*, 2005; Solaiman *et al.*, 2003) have reported the beneficial effects of inoculation of grain legumes. A significant increase in pod yield was obtained by *Rhizobium* inoculation of garden pea (Feng *et al.*, 1997). Successful production of pea depends on various factors. Addition of manure, compost increased total organic matter, macro- nutrients (N, P, Mg, Na, Ca, and K), and micro-nutrients (Cu, Zn, and Mn) in the amended soils according to the rate of compost application (Wong *et al.*, 1999). Fertilizer is one of the most important factors, which assured more crop production. Most of the Bangladeshi farmers use only nitrogen fertilizer. Urea is generally used for enriching soil nitrogen. Nitrogen constitutes a part of the protein, the nucleic acids (RNA and DNA), chlorophyll, phosphamide, and other organic compounds. Higher N supply favours vegetative growth and higher rate of protein synthesis. The use of biological nitrogen fixation technology in the form of efficient strains of *Rhizobium* inoculation in grain legumes may be sufficient to meet the requirement of N in normal soil. Research report showed that *Rhizobium* inoculated plants added 80 kg N/ha and average dry matter yield was increased in pea plants over uninoculated control (Micanovic *et al.*, 1996). Bangabandhu Sheikh Mujibur Rahman Agricultural University recently released a high yielding pea variety but information on the effect of *Rhizobium* inoculant in combination with compost and nitrogen on this variety is not available in our country. Therefore, it is imperative to investigate the effect of *Rhizobium* inoculant, compost, and nitrogen for successful cultivation of the crop in our agro climatic conditions. In view of these, the present study was undertaken to assess the effects of *Rhizobium* inoculant, compost, and nitrogen on nodulation, growth, dry matter production, yield attributes, and yield of pea.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur to find out the effects of *Rhizobium* inoculant, compost, and nitrogen on nodulation, growth, dry matter production, yield attributes, and yield of pea. The soil of the farm was Shallow Red Brown Terrace Soil under Madhupur Tract (AEZ No. 28). It was of clay loam texture and contained 0.76% organic carbon, 11.80 (me/100 g dry soil) CEC, 0.079% total N, 12.3 ppm available phosphorus, 0.58 (meq/100 g dry soil) exchangeable K and had a pH 6.1. The number of *Rhizobium* per g of

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soil was 6.8 x 10^4. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The unit plot size was 3.0 m x 2.5 m. The treatments were control (T_1), *Rhizobium* inoculant (R)(T_2), R + 20 kg N/ha (T_3), R + 5 ton compost/ha (T_4), 10 ton compost/ha (T_5), 30 kg N/ha + 5 ton compost/ha (T_6), 30 kg N/ha (T_7), 60 kg N/ ha (T_8), and 90 kg N/ha (T_9). Total amounts of urea (20, 30, 60 and 90 kg N/ha) and compost (5, 10 ton/ha) were applied to the plots during final land preparation. Compost was prepared by mixing cow excrement with rice straw which generally contains 1% N on dry weight basis. Pea variety IPSA Motorshuti -3 was used as the test crop. The seeds of pea were inoculated with the *Rhizobium* inoculant containing the mixed culture of strains TAL 634 and TAL 640. The inoculant was prepared in the Soil Science Laboratory of BSMRAU using the broth culture and sterilized peat as carrier. Viable number of *Rhizobium* of the inoculant was 4.86 x 10^8 cell/g as estimated following the method of Miles & Misra (1938). The inoculant was applied at the rate of 15 g/ kg of seed using gum arabic as sticking agent. After inoculation, the seeds were air-dried. Seeds were sown with a spacing of 30cm x 5 cm. From each plot five plants were randomly selected at preflowering (40 DAS) and pod filling (65 DAS) stages of the crop. The selected plants were carefully uprooted so that no nodules were left in the soil. The roots were washed with clean water and finally rinsed with distilled water. The nodules from the roots of each plant were separately collected and counted. The shoot and root of the plants were first air-dried separately and then oven-dried at 65°C for 72 hours. During harvesting stage the number of pods/plant and number of seeds/pod were recorded from five randomly selected plants from each plot. Green seed yield was estimated from the yield of plants grown in half portion of each plot and mature seed yield was estimated from the yield of plants grown in the remaining half portion of each plot. Thousand seed weight was estimated from the mature seeds. The crop was finally harvested at full physiological maturity. The seeds were first air-dried and then oven-dried at 65°C for 72 hours. The recorded data on various characters of the crop were statistically analysed and the differences between the treatment means were compared by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Number of nodules/plant

Number of nodules/plant markedly enhanced with *Rhizobium* inoculated seeds over control at preflowering and pod filling stages (Table 1). Khondaker *et al.*(2003) observed that garden pea variety, BARI Motorshuti-1 in combination with *Rhizobium* inoculation produced the highest number of nodules at flowering and pod filling stages. Feng *et al.*(1997) conducted a number of pot and field experiments on many cultivars of garden peas and observed 100% nodule in pot experiments and above 90% in field experiment due to *Rhizobium* inoculant. In this study treatments T_4 containing *Rhizobium* inoculant along with 5 ton compost/ha recorded slightly lower number of nodules compared to the treatment T_2 containing *Rhizobium* inoculant alone but their effects were statistically same at preflowering and pod filling stages. Treatments T_3 receiving *Rhizobium* inoculant along with 20 kg N/ha was also statistically same with the treatment T_4. The highest number of nodules of 16.8 and 10.2/plant was recorded by the

Table 1. Effects of *Rhizobium* inoculant, compost, and nitrogen on number and dry weight of nodules at preflowering and pod filling stages of pea.

Treatments	Number of nodules/plant		Dry weight of nodules (mg/plant)	
	Preflowering stage	Pod filling stage	Preflowering stage	Pod filling stage
Control (T_1)	3.60 c[†]	3.10 c	13.0 c	10.0 d
Rhizobium inoculant (R) (T_2)	16.80a	10.20 a	40.0 a	30.0 a
R+ 20 kg N/ha (T_3)	11.13 b	6.95 b	30.0 b	20.2 bc
R+ 5 ton compost/ha (T_4)	14.87 ab	9.47 ab	32.5 ab	28.5 ab
10 ton compost/ha (T_5)	4.33 c	3.33 c	20.7 c	11.0 cd
30 kg N/ha +5 ton compost/ha (T_6)	3.90 c	3.67 c	20.0 c	12.7 cd
30 kg N/ha (T_7)	3.73 c	3.40 c	20.0 c	12.7 cd
60 kg N/ha (T_8)	3.70 c	3.00 c	14.0 c	12.0 cd
90 kg N/ha (T_9)	3.00 c	2.60 c	12.0 c	10.0 d
CV (%)	14.1	13.9	11.1	12.0

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

Table 2. Effects of *Rhizobium* inoculant, compost, and nitrogen on plant height and root length at preflowering and pod filling stages of pea.

Treatments	Plant height (cm)		Root length (cm)	
	Preflowering stage	Pod filling stage	Preflowering stage	Pod filling stage
Control (T_1)	28.4 c†	52.0 c	11.3 b	11.7 b
Rhizobium inoculant (R) (T_2)	34.5 ab	69.7 ab	14.2 a	14.8 a
R+ 20 kg N/ha (T_3)	32.4 b	66.3 ab	14.0 a	14.5 a
R+ 5 ton compost/ha (T_4)	34.8 ab	73.5 a	15.2 a	15.8 a
10 ton compost/ha (T_5)	31.2 b	61.6 b	14.2 a	14.4 a
30 kg N/ha + 5 ton compost/ha (T_6)	33.0 b	74.1 a	14.5 a	14.8 a
30 kg N/ha (T_7)	32.9 b	61.0 b	14.3 a	14.5 a
60 kg N/ha (T_8)	36.4 a	74.6 a	14.6 a	14.8 a
90 kg N/ha (T_9)	37.2 a	75.2 a	14.6 a	14.9 a
CV (%)	5.0	13.2	11.0	16.1

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

treatment T_2 at preflowering and pod filling stages of the crop, respectively. It was observed that increasing N level from 30 to 90 kg/ha did not affect. However, Chamberland (1982) also reported that high N fertilizer depressed nodulation in cowpea and ultimately decreased yield.

Dry weight of nodules/plant

Dry weight of nodules/plant was significantly influenced by different treatments (Table 1). The highest dry weights of nodules of 40.0 and 30.0 mg/plant were recorded with the treatment T_2 containing *Rhizobium* inoculant alone at preflowering and pod filling stages, respectively. Solaiman (1999) reported that *Rhizobium* inoculant significantly increased dry weight of nodules in mungbean as compared to control. Treatment T_4 containing *Rhizobium* inoculant along with 5 ton compost/ha was statistically same as the treatment T_2. Treatment T_3 containing *Rhizobium* inoculant along with 20 kg N/ha was statistically same as the treatment T_4. The lowest dry weights of nodules of 12.0 and 10.0 mg/plant were produced by the treatment 90 kg N/ha at preflowering and pod filling stages, respectively.

Plant height and root length

The highest plant heights of 37.2cm and 75.2cm and root lengths of 14.6cm and 14.9cm were recorded with the treatment T_9 receiving 90 kg N/ha at preflowering and pod filling stages, respectively, but its effect was same as the treatment T_8 containing 60 kg N/ha T_4 containing *Rhizobium* inoculant along with 5 ton compost/ha and T_2 receiving *Rhizobium* inoculant alone (Table 2). Solaiman & Rabbani (2003) reported that maximum plant height and root length of garden pea was obtained by the application of 60 as well as 120 kg N/ha, which is close to our findings. Maurya & Sanorria (1986) stated that inoculation of chickpea seeds increased root growth of the plant. Higher N application to soil favoured in increasing vegetative growth of the crop which resulted in increasing the plant height appreciably. Above findings indicate that chemical or biologically fixed N is the most dominating factor influencing the plant height as well as root length.

Dry matter production

Dry weights of shoot and root of pea were influenced significantly due to *Rhizobium* inoculant, compost and nitrogen (Table 3). The highest dry weight of shoot of 1.35 and 4.88 g/plant and dry weight of root 0.21 and 0.30 g/plant were recorded by the treatment T_9 receiving 90 kg N/ha at preflowering and pod filling stages, respectively. Above finding has the resemblance with the result of Mahmud *et al.* (1997) who reported higher dry weight of shoot with increasing level of nitrogen in lentil. The effects of *Rhizobium* inoculant alone on dry weight of shoot and root were statistically same with the treatments T_4, T_6, and T_8 at preflowering and pod filling stages, respectively. Dry weight of shoot was increased remarkably in inoculated mungbean over control as reported by Solaiman (1999). The lowest dry weight of shoot and root were recorded in control. Micanovic *et al.* (1996) stated that average dry matter yield of pea increased by *Rhizobium* inoculation over uninoculated control.

Number of mature pods/plant

The highest number of pods of 11.7/plant was recorded with the treatment T_9 receiving 90 kg/ha which was statistically same as the treatment T_8, T_4, and T_2 (Table 4). This

Table 3. Effects of *Rhizobium* inoculant, compost, and nitrogen on dry weight of shoot and root at preflowering and pod filling stages of pea.

Treatments	Dry weight of shoot (g/plant)		Dry weight of root (g/plant)	
	Preflowering stage	Pod filling stage	Preflowering stage	Pod filling stage
Control (T_1)	0.70 c†	1.51 b	0.07 b	0.09 c
Rhizobium inoculant (R) (T_2)	1.08 ab	3.80 a	0.20 a	0.22 ab
R+ 20 kg N/ha (T_3)	1.00 b	3.67 a	0.18 a	0.20 a
R+ 5 ton compost/ha (T_4)	1.09 ab	3.91 a	0.21 a	0.23 ab
10 ton compost/ha (T_5)	0.99 b	3.54 a	0.18 a	0.19 b
30 kg N/ha + 5 ton compost/ha (T_6)	1.27 ab	4.56 a	0.20 a	0.27 ab
30 kg N/ha (T_7)	1.01 b	3.35 a	0.20 a	0.22 ab
60 kg N/ha (T_8)	1.34 a	4.81 a	0.21 a	0.28 ab
90 kg N/ha (T_9)	1.35 a	4.88 a	0.21 a	0.30 a
CV (%)	14.5	17.4	13.8	10.2

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

Table 4. Effects of *Rhizobium* inoculant, compost, and nitrogen on yield attributes and yield of pea.

Treatments	Number of mature pods/plant	Number of mature seeds/pod	Green seed yield (ton/ha)	Mature seed yield (ton/ha)	1000-mature seed weight (g)
Control (T_1)	8.8 c†	3.87 c	5.59 d	1.45 e	120.5 c
Rhizobium inoculant (R) (T_2)	10.7 ab	4.63 ab	7.26 c	1.95 cd	130.1 ab
R+ 20 kg N/ha (T_3)	10.3 b	4.33 b	7.25 c	1.90 cd	125.7 b
R+ 5 ton compost/ha (T_4)	11.0 ab	4.85 ab	7.51 abc	2.55 ab	130.4 ab
10 ton compost/ha(T_5)	10.5 b	4.53 ab	7.45 c	2.32 bc	129.7 b
30 kg N/ha + 5 ton compost/ha(T_6)	10.5 b	4.57 ab	8.21 ab	2.59 ab	132.2 ab
30 kg N/ha (T_7)	10.2 b	4.50 b	7.39 bc	1.91 cd	129.5 b
60 kg N/ha (T_8)	10.9 a	4.80 ab	8.27 ab	2.75 a	134.2 ab
90 kg N/ha (T_9)	11.7 a	5.05 a	8.38 a	2.97 a	135.0 a
CV (%)	5.4	6.8	8.5	7.5	5.3

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

result is in agreement with the findings of Solaiman *et al.* (2003) who conducted experiments with lentil. *Rhizobium* inoculant along with compost at the rate of 5 ton/ha recorded higher number of pods/plant compared to the treatment containing *Rhizobium* inoculant alone and *Rhizobium* inoculant along with N at the rate of 20 kg/ha but their effects were statistically same. Feng *et al.*(1997) reported that number of pods was increased due to *Rhizobium* inoculation of garden pea. Biologically fixed N or urea N favoured vegetative growth and as well as formation of edible pods. The effect of the treatment receiving *Rhizobium* inoculant alone was also statistically same as the treatments T_3, T_4, T_5, T6, and T_7. Lower number of pods/plant was observed in control.

Number of mature seeds/pod

The highest number of mature seeds/pod (5.05) was found in treatment T_9 receiving 90 kg N/ha but its effect was statistically same as the treatment T_8, T_6, T_5, T_4, and T_2 (Table 4). The effect of the treatment T_2 receiving *Rhizobium* inoculant alone was same as the treatments T_3, T_4, T_5, T_6, T_7, and T_8. These findings have the resemblance with the results of Rahman *et al.* (1994) and Solaiman *et al.* (2003). It was observed that biologically fixed N or urea exhibited a significant effect on the number of seeds /pod. The lowest number of mature seeds/pod (3.87) was found in uninoculated control.

Green seed yield

Treatment T_9 receiving 90 kg N/ha produced the highest green seed yield (8.38 ton/ha) which was 36.9% higher than that of control (Table 4). The effect of this treatment was statistically same as to the treatments T_8, T_6, T_5, T_4, and T_2 receiving *Rhizobium* inoculant alone.

The lowest green pod yield being noted under control. Further, there was no significant yield variations among the treatments T_2, T_3, T_4, T_5, T_6, T_7, and T_8 but their effects were superior over control. Tolkachev *et al.*(1994) carried out an experiment and found increased yield of peas with *Rhizobium* inoculant.

Mature seed yield

Rhizobium inoculant (T_2) alone and the treatments T_3, T_4, T_5, T_6, and T_7 had same effect in respect of mature seed yield (Table 4). Treatment T_9 receiving 90 kg N/ha recorded the highest mature seed yield (2.97 ton/ha) which was 73.7% higher over control. The effect of treatment T_9 was same as T_8, T_6, T_4, and T_2 *Rhizobium* inoculant alone in recording mature seed yield. *Rhizobium* inoculant increased 46% seed yield in lentil over control as reported by Solaiman *et al.*(2003).

1000-mature seed weight

Treatment T_9 receiving 90 kg N/ha recorded the highest 1000-mature seed weight of 135.0 g (Table 4). The single effect of *Rhizobium* inoculant (T_2) was statistically same as the treatments T_8, T_6, T_4, and T_2. Results showed that biologically fixed N or urea N enhanced seed weight of the crop which might have led to better assimilation of N for the plants that resulted better vegetative growth of pea and ultimately produced the larger seeds.

REFERENCES

Anonymous. 2004. Yearbook of Agricultural Statistics of Bangladesh, 2001. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p 62.

Chamberland, E. 1982. Predicting the N, P, and K requirement of legumes grown in mineral soil. Peas and Beans. Can. J. Soil Sci. 62 : 663-672.

Feng, Y., C. Pan, D. Wang, Y. Li, and C. Wei. 1997. Isolation of nodule bacteria from *Pisum sativum* and the application of nitragin from the isolate. J. Trop. Sub Trop. Bot. 5(2): 47-53.

Jensen, E. S. 1988. The role of pea cultivation in the nitrogen economy of soils and succeeding crops. *In:* Legumes in Farming Systems. P. Plancquaert and R. Haggar (eds). Kluwer Academic Publishers. London. pp. 3-15.

Khondaker, M., A. R. M. Solaiman, A. J. M. S. Karim, and M. M. Hussain. 2003. Responses of pea varieties to *Rhizobium* inoculation: Nitrogenase activity, dry matter production, and nitrogen uptake. Korean J. Crop Sci. 48(5) : 361-368.

Mahmud, M. S., A. R. M. Solaiman, M. S. Hoque, and M. A. Hashem. 1997. Influence of *Rhizobium* inoculantion and nitrogen on nodulation, growth and N uptake of lentil. Annals of Bangladesh Agriculture. 7(2) : 139-143.

Maurya, B. R. and C. L. Sanorria. 1986. Beneficial effects of coinoculating chickpea and seed with *Rhizobium, Azotobactor* and *Pseudomonas.* Ind. J. Agric. Sci. 56(6) : 463-466.

Micanovic, D., Z. Saric., V. Raicevic, S. Jevtic, and B. Lazic. 1996. Possibility of nitrogen fixation in *Pisum sativum* and *Triticum aestivum.* Proc. First Balkan Symposium on Vegetables and Potatoes, Belgrade, Yegoslavia. 4-7 June. Acta Hort. 2(462) : 823-827.

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

Rabbani, M. G., A. R. M. Solaiman, K. M. Hossain, and T. Hossain. 2005. Effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on nodulation, yield, and seed protein in pea. Korean J. Crop Sci. 50(2) : 112-119.

Rahman, M. H. H., M. Z. Islam, M. A. H. Bhuiyan, D. Khanam, A. K. M. Hossain, and A. F. M. Rahman. 1994. Effect of rhizobial inoculum with and without chemical fertilizers on chickpea in Haplaquepts. Bangladesh J. Agric. Sci. 21(2) : 273-277.

Rana, K. S. and S. K. Sharma. 1993. Effect of rabi legumes on nitrogen economy and productivity of direct seeded upland rice. Crop Res. Hisar. 6(1) : 165-167.

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.

Solaiman, A. R. M. and M. G. Rabbani. 2003. Performance of pea (*Pisum sativum*) as affected by *Rhizobium* inoculant, N, P and Mo application. Bangladesh J. Soil Sci. 27-29 : 13-22.

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.

Tolkachev, N. Z., P. A. Donchenko, A. V. Knyazev, N. M. Kosenko, and V. F. Patyka. 1994. Methods of enhancing the efficiency of legume-*Rhizobium* symbiosis. Fiziol. Biok. Kul Rast. 26(4) : 344-351.

Wong, J. W. C., K. K. Ma, K. M. Fang, and C. Cheung. 1999. Utilization of a manure compost for organic farming in Hong Kong. Bioresource Technology. 67(1) : 43-46.