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Effects of *Rhizobium* Inoculant, Nitrogen, Phosphorus, and Molybdenum on Nodulation, Yield, and Seed Protein in Pea

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ABSTRACT : The effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on nodulation, dry matter production, yield attributes, pod and seed yields, protein and phosphorus contents in seed of pea (*Pisum sativum*) var. IPSA Motorshuti-3 were assessed by a field experiment. Among the treatments *Rhizobium* inoculant in combination with 25 kg P and 1.5 kg Mo/ha performed best in recording number of nodules/plant, total dry matter yield, number of pods/plant, number of seeds/pod, 1000-seed weight, green pod yield, green and mature seed yields of pea. The highest green pod yield of 15.37 t/ha (97.05% increase over control) and green seed yield of 9.6 t/ha (69.31% increase over control) were obtained by inoculating pea with *Rhizobium* inoculant in association with 25 kg P and 1.5 Mo/ha. The effects of 60 or 120 kg N/ha were comparable to *Rhizobium* inoculant in most cases. There were positive correlations among yield attributes, yield, protein and phosphorus contents in seeds of pea. From the viewpoint of yield attributes, yield, and seed quality, application of *Rhizobium* inoculant along with 25 kg P and 1.5 kg Mo/ha was considered to be the balanced combination of nutrients for achieving the maximum output from cultivation of pea in Shallow-Red Brown Terrace Soil of Bangladesh.

Keywords: *Rhizobium*, nitrogen, phosphorus, molybdenum, yield, seed quality, pea

Pea (*Pisum sativum*) is a cool season crop. It is grown mainly for edible green seeds. It can be used as fodder crop and to some extent it has the potentiality to serve as green manure. Dry seeds contain 15 - 35% protein, 20 - 50% starch, 4 - 10% sugar, 0.6 - 1.5% fat and 2 - 4% mineral (Makasheva, 1983). As pea is a short durable crop it's cultivation is highly profitable and preferable to the farmers. In Bangladesh only 18447 ha of land is under pea cultivation where its production is 14,285 MT which is lower than other vegetables (BBS, 1997). Inclusion of peas 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 pea (Khondaker *et al.*, 2003). Many researchers (Rahman *et al.*, 1994; Solaiman, 1999a, b, c; Solaiman & Habibullah 1990; Solaiman *et al.*, 2003a, b) have reported the beneficial effects of inoculation of grain legumes. 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). A significant increase in pod yield was obtained by *Rhizobium* inoculation of peas (Feng *et al.*, 1997). It was observed that seed yield and protein content was increased by 120 - 170 kg/ha and 18 - 25%, respectively with *Rhizobium* inoculation (Tolkachev *et al*, 1994). The importance of phosphorus on nodulation and yield of legumes is now well established. It is reported that application of P with *Rhizobium* inoculant enhances yield of legumes (Solaiman & Habibullah, 1990; Raychaudhuri *et al.*, 1997). Low P content affects the yield potential of soybean (Cassman *et al.*, 1980). Ranjan *et al.* (1962) observed that phosphorus deficiency adversely affected protein synthesis in legumes. Molybdenum is indispensable for a variety of plant species especially for legumes forming root nodules because it is directly involved in the nitrogen fixing enzyme, nitrogenase and nitrogen reduction enzyme, nitrate reductase. Application of Mo at the rate of 1.5 kg/ha along with *Bradyrhizobium* inoculant increased seed yield of soybean (Solaiman, 1999a). Bangabandhu Sheikh Mujibur Rahman Agricultural University in Bangladesh recently released a high yielding pea variety, IPSA Motorshuti-3 but information on the effect of *Rhizobium* inoculant in combination with phosphorus and molybdenum on this variety is not available in this country. In view of these, the present study was undertaken to assess the effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on nodulation, dry matter production, yield attributes, yield, and seed quality of pea.

MATERIALS AND METHODS

A field experiment was conducted at the experimental

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farm of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh with a view to find out the effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on nodulation, dry matter production, yield attributes, yield, and nutrient content in seeds of pea. The soil of the farm was Shallow-Red Brown Terrace Soil under Madhupur Tract (AEZ No. 28) and was classified as Inceptisols. It was of clay loam texture and contained 0.71% organic carbon, 11.64 (me/100 g dry soil) CEC, 0.076% total N, 12.5 ppm available phosphorus and had a pH 6.2. The number of *Rhizobium* per g of soil was 6.6×10^4. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3.0 m × 2.5 m. The treatments were T_1. Control, T_2 *Rhizobium* inoculant *(R)*, T_3. 60 kg N /ha, T_4. 120 kg N/ha, T_5. 15 kg P/ha, T_6. 25 kg P/ha, T_7. 35 kg P/ha, T_8. 45 kg P/ha, T_9. *R* + 15 kg P/ha, T_{10}. *R* + 25 kg P/ha, T_{11}. *R* + 35 kg P/ha, T_{12}. *R* + 45 kg P/ha, T_{13}. *R* + 15 kg P + 1.5 kg Mo/ha, T_{14}. *R* + 25 kg P + 1.5 kg Mo/ha, T_{15}. *R* + 35 kg P + 1.5 kg Mo/ha, T_{16}. *R* + 45 kg P + 1.5 kg Mo/ha Total amounts of urea (60 and 120 kg N/ha), triple superphosphate (15, 25, 35, and 45 kg P/ha) and ammonium molybdate (1.5 kg Mo/ha) were applied to the plots during final land preparation. IPSA Motorshuti-3, a newly released high yielding pea variety 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 4.86×10^8 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 30 cm × 5 cm. From each plot five plants were randomly selected at vegetative (35 days after sowing (DAS), flowering (52 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 ringed 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 and their total weights were recorded as dry matter yield. Oven-dried shoots were grinded in a grinding machine (Wiley Cutting Mill, Model 1029-B, Yoshida Seisakusho Co. Ltd., Japan) for chemical analysis. Data on nodulation, dry matter production, pods/plant, seeds/pod, nutrient content in seeds were taken from five randomly selected plants from each plot. Green pod and green seed yields were estimated from the yields 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. 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. Oven-dried seeds were grinded in a grinding machine (Vibrating Sample Mill, Model-T1 200, Heiko Seisakusho. Ltd Tokyo, Japan.) for chemical analysis. Total N content in seed was determined by ashing the seed materials using salicylic acid modified Kjeldahl method following sulphuric acid digestion and then stem distillation and titration assay (Wilde *et al*, 1979). The crude protein content was estimated by multiplying the %N in seed with a factor 6.25. Total P was determined by nitric perchloric acid digestion followed by vanadomolybdate colorimetric method (Barton, 1948). 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). Correlations between different characters were also calculated.

RESULTS AND DISCUSSION

Nodulation

Seeds inoculated with *Rhizobium* strains markedly enhanced nodule number/plant over control at vegetative, flowering, and pod filling stages (Table 1). Khondaker *et al.* (2003) observed that 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 peas and observed 100% nodule in pot experiments and above 90% in field experiment due to *Rhizobium* inoculant. *Rhizobium* inoculated chickpea variety, Barichhola-6 produced 258% and 298% higher number of nodules at preflowering and flowering stages, respectively over its uninoculated control (Eusuf Zai *et al*, 1999). Treatments T_9, T_{10}, T_{11}, and T_{12} containing *Rhizobium* inoculant along with P at the rate of 15, 25, 35, and 45 kg/ha, respectively recorded slightly higher number of nodules compared to the treatment T_2 containing *Rhizobium* inoculant alone but their effects were statistically similar at vegetative, flowering, and pod filling stages. Treatments T_{13}, T_{14}, T_{15}, and T_{16} receiving *Rhizobium* inoculant along with P at the rate of 15, 25, 35 and 45 kg and Mo at the rate of 1.5 kg/ha, respectively had significant beneficial effect over the treatment T_2 receiving *Rhizobium* inoculant alone at all the growth stages except T_{16} having *Rhizobium* inoculant in presence of 45 kg P and 1.5 kg Mo/ha at vegetative stage. The highest numbers of nodules of 66.30, 57.30, and 36.00/plant were recorded by the treat-

Table 1. Effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on number of nodules and dry matter yield at different growth stages of pea

Treatments	Number of nodules/plant			Dry matter yield (g/plant)		
	Vegetative stage	Flowering stage	Pod filling stage	Vegetative stage	Flowering stage	Pod filling stage
T_1. Control	20.40 g	18.20 e	8 33 de	1.04d	2.38g	4.73d
T_2 *Rhizobium* inoculant *(R)*	54.60 de	34.80 c	22.00 b	1 43abc	3.19f	6.97b
T_3. N_{60}	29.80 f	20.80 de	10.20 cde	1.47abc	3.20f	6.98b
T_4. N_{120}	24.00 g	17.80 e	6.93e	1.50abc	3.22f	7 13b
T_5. P_{15}	22.40 g	20.20 de	10.60 cde	1.28c	3 13f	5.84c
T_6. P_{25}	24 00 g	21.20 de	12.20 cd	1 30bc	3.15f	5.85c
T_7 P_{35}	25.20 fg	21.40 de	14 60 c	1.31abc	3.16f	5.86c
T_8. P_{45}	26.60 fg	25.40 d	14.20 c	1.32abc	3.17f	5.91c
T_9. *R*+ P_{15}	55.30 de	34 85 c	22.24 b	1.43abc	3 51e	6 97b
T_{10}. *R*+ P_{25}	57.50 cde	35 20 c	23.28 b	1.44abc	3 58e	6.98b
T_{11} *R*+ P_{35}	57 52 cde	36.40 c	24.14 b	1.44abc	3.71d	7.16b
T_{12}. *R*+ P_{45}	58 15 cde	36.20 c	24.80 b	1.45abc	3.76d	7.21b
T_{13}. *R*+ P_{15}+$Mo_{1\,5}$	61.50abc	51.40 b	33.00 a	1.52ab	4.39c	7.97a
T_{14}. *R*+P_{25}+$Mo_{1\,5}$	66.30 a	57.30 a	36.00 a	1.53a	4.67a	8.24a
T_{15}. *R*+P_{35}+$Mo_{1\,5}$	63.50 ab	56.80 ab	34.80 a	1 52ab	4.52b	8.09a
T_{16}. *R*+P_{45}+$Mo_{1\,5}$	59 40 bcd	52.75 ab	32.90 a	1 51ab	4.32c	7.99a
CV (%)	5.56	7.96	10.38	8.13	1.62	2 68

Figures shown with N, P and Mo represent kg/ha.
Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT.

ment T_{14} (*Rhizobium* inoculant + 25 kg P +1.5 kg Mo/ha) at vegetative, flowering, and pod filling stages of the crop, respectively. Maurya *et al* (1993) observed that *Rhizobium* inoculant in presence of Mo increased nodule number in *Vigna mungo*. In this study maximum nodules were found at vegetative stage, later nodule number was declined sharply, possibly due to utilization of nodule nitrogen by the rapidly developing seeds causing decay of nodules. It appeared that increasing the N level from 60 to 120 kg/ha markedly decreased the number of nodules per plant. Chamberland (1982) also reported that high N fertilizer depressed nodulation in cowpea and ultimately decreased yield.

Dry matter production

Treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo/ha) recorded the highest dry matter yields of 1.53, 4.67, and 8.24 g/plant at vegetative, flowering, and pod filling stages, respectively (Table 1). The effect of this treatment on dry matter yield at vegetative stage was, however, statistically similar to other treatments except treatments T_5, T_6, and T_1 receiving 15 or 25 kg P/ha and control, respectively but at flowering and pod filling stages, treatments receiving Mo performed better than other treatments. The lowest dry matter yield was recorded in control at all the growth stages of the crop. Micanovic *et al.* (1996) and Khondaker *et al* (2003) stated that average dry matter yield of pea was increased by *Rhizobium* inoculation over uninoculated control. Dry weight of shoot was increased remarkably in inoculated mungbean over control as reported by Solaiman (1999b) and Solaiman *et al.* (2003a). Ashgar *et al* (1988) observed that *Rhizobium* inoculation had a significant positive influence on root dry weight.

Number of pods/plant

Rhizobium inoculant along with P at the rate of 15, 25, 35, and 45 kg and Mo at the rate of 1.5 kg/ha (T_{13}, T_{14}, T_{15}, and T_{16}) recorded significantly higher number of green pods/plant compared to the treatment containing *Rhizobium* inoculant alone. The effects of the treatments consisting of *Rhizobium* inoculant and different doses of P and Mo were statistically similar (Table 2). Lower number of pods/plant was observed in treatments receiving N at the rate of 60 or 120 kg/ha. Similar trend was observed in number of mature pod (Table 2). The highest number of green pods (12.00)

Table 2. Effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on yield attributes of pea.

Treatment	Number of pods/plant		Number of mature seeds/pod	1000-seed wt (g)	
	Green pod	Mature pod		Green	Mature
T_1. Control	4.57 f	5.93 e	2.40 f	208.03 g	120.60 h
T_2 *Rhizobium* inoculant *(R)*	7.80 cde	8.35 cd	3.50b-e	220.33 ef	133 12fg
T_3. N_{60}	8.0 b-e	8.40 c	3.36 cde	223.27 de	137.45 fg
T_4. N_{120}	7.1 def	7.33 cde	3 10 def	224.77 cde	138.30 f
T_5. P_{15}	5.00 f	6 20 de	2.48 f	210.27 g	123.10 h
T_6. P_{25}	5.20 f	6.60 cde	2.46 f	211.03 g	132.85 fg
T_7. P_{35}	5 80 ef	6.80 cde	2.72 ef	215.03 fg	133 60 fg
T_8. P_{45}	5.80 ef	7.00 cde	2 80 ef	219.40 ef	136.16 fg
T_9. *R*+ P_{15}	7.8 cde	8 40 c	3.75 bcd	228.10 bcd	148 88 e
T_{10}. *R*+ P_{25}	8.00 b-e	8.45 c	3 83 bcd	230.57 bc	151.36 cd
T_{11}. *R*+ P_{35}	8 10 b-e	8.50 c	3.90 bcd	231.67 b	152.33 cd
T_{12}. *R*+ P_{45}	8.25 b-e	8.60 c	3 96 abc	232.10 b	153.50 cd
T_{13}. *R*+ P_{15}+$Mo_{1\,5}$	10 20 ab	11.45 ab	4.15 abc	249.13 a	158.56 ab
T_{14}. *R*+P_{25}+$Mo_{1\,5}$	12.00 a	13 15 a	4.72 a	250.03 a	161.35 a
T_{15} *R*+P_{35}+$Mo_{1\,5}$	10.60 ab	11.41 ab	4.27 ab	249.37 a	159.43 ab
T_{16}. *R*+P_{45}+$Mo_{1\,5}$	10.40 ab	11.25 ab	4.25 ab	245.83 a	158.75 ab
CV (%)	15.08	10.99	10.29	1.24	1.82

Figures shown with N, P and Mo represent kg/ha.
Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT.

and mature pods (13.15)/plant were recorded with the treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo/ha). This result is in agreement with the findings of Solaiman (1999c) and Solaiman *et al.* (2003b) who conducted experiments with chickpea and lentil, respectively. Feng *et al* (1997) reported that number of pods was increased due to *Rhizobium* inoculation of pea. Table 5 of this study shows that there was a positive correlation between the number of pods/plant and mature seed yield of the crop (r=0.784**).

Number of seeds/pod

Treatments containing *Rhizobium* inoculant along with P at the rate of 15, 25, 35, and 45 kg and Mo at the rate of 1.5 kg/ha (T_{13}, T_{14}, T_{15}, and T_{16}) were statistically similar and recorded significantly higher number of mature seeds/pod compared to control (Table 2). The highest number of mature seeds/pod (4.72) was found in treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo/ha). The lowest number of mature seeds/pod (2.40) was found in uninoculated control. It was observed that *Rhizobium* inoculant in association with P and Mo led to increase the number of mature seeds/pod in pea. These findings have the resemblance with the results of Rahman *et al.* (1994) and Solaiman *et al* (2003b). In the present study (Table 5) number of seeds/pod had a positive correlation with mature seed yield (r= 0.738**).

1000–seed weight

Rhizobium inoculant (T_2) alone significantly increased 1000-green seed weight compared to control (Table 2). Treatments containing *Rhizobium* inoculant along with P at the rate of 15, 25, 35, and 45 kg and Mo at the rate of 1.5 kg/ha (T_{13}, T_{14}, T_{15}, and T_{16}) were statistically similar and recorded higher 1000-green seed weight compared to *Rhizobium* inoculant alone. The single effects of *Rhizobium* inoculant and that of N at the rate of 60 and 120 kg/ha were statistically similar. Similar trend was observed in 1000-mature seed weight of the crop (Table 2). The highest weights of 1000-green seed (250.03 g) and mature seed (161.35 g) were recorded with the treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo /ha). The combined effect of *Rhizobium* inoculant, P, and Mo might have led to better assimilation of N for the plants that resulted the larger seeds. This finding has the resemblance with the result of Solaiman (1999 b). Zaman *et al.* (1996) observed that 1000-seed weight was increased by 34.42% over control due to application of Mo. Solaiman (1999c) and Solaiman *et al* (2003b) reported that *Rhizobium* inoculant significantly increased

1000-seed weight of chickpea compared to control. Table 5 of this study shows that there was a high positive correlation between 1000-seed weight and mature seed yield of the crop (r=0.807**).

Green pod yield

The highest average green pod yield (15.37 t/ha) was found with treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo/ha) which was 97% higher than that of control (Table 3). The effect of this treatment was followed by the treatments T_{15}, T_{16}, and T_{13}. The lowest green pod yield was noted under control. There was no significant yield variation among the treatments T_{14}, T_{15}, and T_{16} These findings have the resemblance with the result of Srivastava & Verma (1985) who reported that application of 25.8 kg P, 0.5 kg Mo/ha and seed inoculation with *Rhizobium leguminosarum* gave maximum pod yield of pea.

Green seed yield

Treatment T_2 receiving *Rhizobium* inoculant alone was superior to control and the treatments consisting of different doses of P alone but was statistically similar to the treatments T_9, T_{10}, T_{11}, T_{12}, T_3, and T_4 (Table 3). Addition of P at the rate of 15, 25, 35, and 45 kg and Mo at the rate of 1.5 kg/ha along with *Rhizobium* inoculant (T_{13}, T_{14}, T_{15}, and T_{16}) produced significantly higher green seed yield compared to other treatments and there was no significant difference among these treatments. Treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo/ha) produced the maximum green seed yield (9.60 t/ha). In the present study (Table 5) green seed yield of pea showed positive correlation with mature seed yield (r=0.871**) and as well as number of nodules/plant of the crop (r=0.797**).

Mature seed yield

Rhizobium inoculant (T_2) alone and application of N at the rate of 60 or 120 kg/ha had statistically similar effect in producing seed yield (Table 3). Mature seed yield in N treated plots was comparatively lower because of lower number of pods/plant, seeds/pod, and 1000-seed weight of the crop. Graham & Scott (1984) reported that higher dose of N fertilizer reduced grain production in cowpea. Treatment T_{14} (*Rhizobium* inoculant + 25 kg P + 1.5 kg Mo/ha) recorded the highest mature seed yield (3.16 t/ha) which was 134% higher over the uninoculated control. The effect of T_{14} was similar to T_{15} in recording mature seed yield. Tolkachev *et al* (1994) carried out an experiment and found increased

Table 3. Effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on green pod, green and mature seed yields of pea.

Treatment	Green pod yield (t/ha)	Increase over control (%)	Green seed yield (t/ha)	Increase over control (%)	Mature seed yield (t/ha)	Increase over control (%)
T_1. Control	7.80 h	-	5.67 d	-	1.35 j	-
T_2 *Rhizobium* inoculant *(R)*	11.36 e	45.64	7.90 b	39.33	2.53 e-h	87.41
T_3. N_{60}	12 17 c	56.03	8.36 b	47.44	2 57 efg	90.37
T_4. N_{120}	11.93 cd	52.95	8.13 b	43.39	2.56 efg	89.63
T_5. P_{15}	9.52 g	22.05	6.82 c	20.28	2.07 i	53.33
T_6. P_{25}	9.84 fg	26.15	7 06 c	24.51	2.30 hi	70.37
T_7. P_{35}	10.03 fg	28.60	7.23 c	27.51	2.34 gh	73.33
T_8. P_{45}	10.17 f	30.38	7.26 c	28.04	2.38 fgh	76 30
T_9. R+ P_{15}	11.40 de	46.15	7.93 b	39.86	2.56 efg	89.63
T_{10}. R+ P_{25}	11 70 cde	50.00	8.03 b	41.62	2.59 def	91 85
T_{11}. R+ P_{35}	11.93 cd	52.95	8.17 b	44 10	2.60 def	92.59
T_{12}. R+ P_{45}	12.21 c	56.54	8.38 b	47.80	2 63 cde	94.81
T_{13}. R+ P_{15}+$Mo_{1\,5}$	14.75 b	89.10	9.56 a	68.61	2.82 cd	108.88
T_{14}. R+P_{25}+$Mo_{1\,5}$	15.37 a	97.05	9.60 a	69.31	3 16 a	134.07
T_{15}. R+P_{35}+$Mo_{1\,5}$	14.92 ab	91.28	9.49 a	67 37	3.10 ab	129.63
T_{16}. R+P_{45}+$Mo_{1\,5}$	14.83 ab	90.12	9.53 a	68.08	2.86 bc	111.85
CV (%)	2 80	-	3.49	-	5.48	-

Figures shown with N, P and Mo represent kg/ha.
Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT.

Table 4. Effects of *Rhizobium* inoculant, nitrogen, phosphorus, and molybdenum on phosphorus and crude protein contents in green and mature seed of pea.

Treatment	Protein content in seed (%)		Phosphorus content in seed (ppm)	
	Green seed	Mature seed	Green seed	Mature seed
T_1 Control	13.75 c	14.00 c	1189 d	1230 d
T_2 *Rhizobium* inoculant *(R)*	19.95 b	20.85 b	1437 c	1516 c
T_3. N_{60}	23.75 a	26 25 a	1479 bc	1536 bc
T_4. N_{120}	21.44 ab	23.94 ab	1480 bc	1543 bc
T_5 P_{15}	14.50 c	15.75 c	1448 c	1537 bc
T_6. P_{25}	14.44 c	15.81 c	1449 c	1626 abc
T_7. P_{35}	19 90 b	20.45 b	1450 c	1641 abc
T_8. P_{45}	20.00 b	20.75 b	1462 c	1676 abc
T_9. R+ P_{15}	20.06 b	21.57 b	1557 ab	1706 abc
T_{10}. *R*+ P_{25}	20 75 ab	21.63 b	1565 a	1726 abc
T_{11}. *R*+ P_{35}	22.19 ab	21.88 b	1570 a	1736 abc
T_{12}. *R*+ P_{45}	22.25 ab	22.50 ab	1579 a	1740 abc
T_{13}. *R*+ P_{15}+$Mo_{1\,5}$	22.13 ab	23.31 ab	1578 a	1746 ab
T_{14}. *R*+P_{25}+$Mo_{1\,5}$	22.38 ab	23 88 ab	1580 a	1755 ab
T_{15}. *R*+P_{35}+$Mo_{1\,5}$	23.19 ab	24.25 ab	1592 a	1757 ab
T_{16}. *R*+P_{45}+$Mo_{1\,5}$	22.31 ab	24.25 ab	1598 a	1769 a
CV (%)	10.15	11.66	3.07	8 016

Figures shown with N, P and Mo represent kg/ha.
Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT

Table 5. Relationship between different characters of pea recorded at pod filling and harvesting stages.

Factors of correlation	Correlation co-efficient (r value)
Number of nodules vs number of pods/plant	0.784**
Number of nodules vs green seed yield	0.797**
Number of nodules vs protein content in green seed	0.467*
Green seed yield vs mature seed yield	0.871**
Number of pods per plant vs mature seed yield	0.784**
Number of seeds per pod vs mature seed yield	0.738**
1000 - seed weight vs mature seed yield	0.807**
n=48 r value $P_{0\,05}$=0.325, $P_{0\,01}$=0.418	

*significant at 5% level of probability.
**significant at 1% level of probability

yield of peas with *Rhizobium* inoculant. *Rhizobium* inoculant increased 33 - 46% seed yield in chickpea and lentil over control as reported by Solaiman (1999c) and Solaiman *et al.* (2003b). Sharma (1992) also observed that application of Mo (1.5 kg ammonium molybdate/ha) recorded 26.2% higher seed yield of soybean compared to control. Mature seed yield of pea showed positive correlation with number of pods/plant (r=0.784**) and number of seeds/pod (r=0.738**) of the crop (Table 5).

Protein content in seed

The effect of *Rhizobium* inoculant (T_2) on protein content of both green and mature seeds of pea was significant (Table 4). The highest protein contents were recorded in green (23.75%) and mature (26.25%) seeds by the treatment T_3 (60 kg N/ha). The effect of this treatment was statistically similar to the treatments T_4, T_{12}, T_{13}, T_{14}, T_{15}, and T_{16}. The performance of *Rhizobium* inoculant was superior to con-

trol. Similar trend in protein content was observed in mature seed of the crop (Table 4). The above results have similarity with the findings of Solaiman (1999b) and Solaiman *et al* (2003b) who conducted experiment with mungbean and lentil, respectively. Protein content of grain and available N in soil were increased with increasing dose of Mo along with *Rhizobium* inoculation (Singh *et al.*, 1992). Gupta & Vyas (1994) observed that seed protein content of soybean was increased by Mo application. Tolkachev *et al* (1994) conducted experiment with peas and showed that protein content was increased by 18-25% with rhizobial inoculation. Table 5 shows that there was a positive correlation between number of nodules and protein content in green seed of pea (r=0.467**).

Phosphorus content in seed

The effect of *Rhizobium* inoculant (T_2) on phosphorus content both in green and mature seeds was significant (Table 4). The highest amounts of P were recorded by the treatment T_{16} (*Rhizobium* inoculant + 45 kg P +1.5 kg Mo/ha) in green (1598 ppm) and mature (1769 ppm) seeds but the effect of this treatment was statistically similar to the treatments T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}, and T_{15}. Arya & Kalra (1988) reported that P content in seed was increased with the application of 50 kg P_2O_5/ha. The lowest amounts of P both in green seed (1189 ppm) and mature seed (1230 ppm) were recorded in control.

REFERENCES

Arya, M. P. S. and G. S. Kalra.1988. Effect of phosphorus does on the growth, yield and quality of summer mung (*Vigna radiata* L. Wilczek) and soil nitrogen. Ind. J. Agril. Res 22(1) . 23-30.

Asghar, A B., B. Roider Khan, and J. H Keating.1988. Effect of inoculation and phosphate fertilizer on lentil under rainfed conditions in upland Baluctistan Lens Newsletter. 15 (1) : 29-33

Barton, C. J 1948. Analytical Chemistry. 20:1068-1073.

BBS (Bangladesh Bureau of Statistics). 1997 Year Book of Agricultural Statistics of Bangladesh p. 61.

Cassman, K. G., A. S. Whitney, and K. R. Stockinger 1980. Root growth and dry matter distribution of soybean as affected by phosphorus stress, nodulation, and nitrogen source. Crop Sci. 20 : 239-243.

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.

Eusuf Zai, A. K E., A. R. M. Solaiman, and J. U. Ahmed. 1999. Response of some chickpea varieties to *Rhizobium* inoculation in respect of nodulation, biological nitrogen fixation and dry matter yield. Bangladesh J Microbiol. 16 · 135-144.

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.

Graham, R. A. and T. W. Scott. 1984. Response of cowpea to nitrogen and inoculation in Trinidad. Trop. Agric. 61(1) : 56-58.

Gupta, P K. and K. K. Vyas. 1994. Effect of phosphorus, zinc and molybdenum on the yield and quality of soybean. Legume Res. 17(1): 5-7

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.

Makasheva, R K. H. 1983. The Pea. Oxonian Press Pvt. Ltd., New Delhi, pp 7-8.

Maurya, B. R., K. Kishor, and P. C. Ram 1993. Effect of iron and molybdenum on urd bean. J. Maharastra Agril. Univ. 18(1) : 128.

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

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.

Ranjan, S., R. K Pandey, R. K. Srivastava, and M. M. Laloraya. 1962. Effect of phosphorus deficiency on the metabolic changes in free aminoacids in certain leguminous crop plants. Nature. 193 · 997-998.

Raychaudhuri, M., K. Kumar, and S. Raychaudhuri. 1997. Effect of *Rhizobium japonicum* and phosphorus on nutrient uptake and yield of soybean (*Glycin max*) in an Ultisol of Manipur hills. Ind. J. Agril. Sci. 67(10) : 459-462.

Sharma, U. C. 1992. Response of soybean to micronutrient in acidic soil of Negaland Ind. J. Hill Farm. 5(1) : 75-76.

Singh, B. R., B. Khandelwal, and B. Singh 1992. Effect of manganese and molybdenum fertilization with *Rhizobium* inoculation on the yield and protein content of cowpea. J. Ind. Soc Soil Sci. 40(4) : 738 - 741.

Solaiman, A. R. M 1999a. Effects of *Bradyrhizobium japonicum* inoculation and molybdenum on soybean Bangladesh J. Bot. 28(2) . 181-183.

Solaiman, A. R. M. 1999b. 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. 1999c. Nitrogenase activity, yield and yield contributing characters of chickpea as influenced by *Rhizobium* inoculant in presence and absence of nitrogen. Bangladesh J. Sci.Tech. 1(1) · 141-144

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., D. Hossain, and M M. Haque. 2003a. Response of mungbean varieties to *Rhizobium* inoculation in respect of nodulation, nitrogenase activity, dry matter yield, and nitrogen uptake Korean J Crop Sci. 48(5) : 355-360

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

Srivastava, S. N. L and S. C Verma. 1985. Effect of nitrogen, phosphorus and molybdenum fertilization on growth, nodulation, and residual fertility in field pea. Ind. J Agril. Res. 19(3) : 131-137.

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.

Wilde, S A., R. B Corney, and J. G. Iyer. 1979. Soil and Plant Analysis for Tree Culture Soil Science, University of Wisconsin, G.K. Voigt, Yale School of Forestry. p. 78

Zaman, A K. M. M., M. S. Alam, B Roy, and A. H. Beg. 1996 Effect of B and Mo application on mungbean. Bangladesh J. Agril. Res. 21(1) : 118-124