

PERFORMANCE OF RHIZOBIA AND NITROGEN ON NODULATION, YIELD AND N UPTAKE BY SOYBEAN IN SALINE SOIL

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Abstract

Use of *Rhizobium inoculum* in the establishment of legumes has been widely recognized, especially in the areas where indigenous nodulation has been found to be inadequate. To study the effect of different rhizobial strains and N fertilizer on nodulation, growth, yield, N content and its uptake by soybean cv. Shohag in saline soil, a pot experiment was conducted in net house. Saline soil was collected from Fultala of Khulna district. The experiment was laid out in the factorial combination following completely randomized design. There were altogether 16 treatment combinations (4 inocula × 4 fertilizer levels) replicated thrice. Four inocula viz., No strain, strain-102, strain-J43 and mixed strains (102 and J43) and four Levels of N viz., 0 (N₀), 10 (N₁₀), 15 (N₁₅) and 20 (N₂₀) kg N ha⁻¹ were used. Both rhizobial strains and N alone or in combination significantly affected the nodulation, yield, N content and its uptake by soybean. The highest values of most of the parameters were recorded from the plant inoculated with strain-J43 except the number of leaves plant⁻¹. In case of N level, maximum values of all parameters were found when N was applied 15 kg ha⁻¹ which was identical with N₂₀. The treatment combination of strains-J43 and N₁₅ showed best performance with respect to major parameters studied. The overall results thus suggest that rhizobial strains along with 15 kg N ha⁻¹ can be used for producing higher yield and quality of soybean cv. Shohag in the salt affected soil.

Keywords: Different Rhizobial strain, Nitrogen doses, Nodulation, Salt effected Soil, Soyabean cv. Shohag.

Submitted: 27.07.2014

Reviewed: 22.10.2014

Accepted: 26.11.2014

1. INTRODUCTION

Technology developed in the advanced countries may not be immediately appropriate to the small holder farmers in the developing countries. Rhizobial inoculation of legumes is one such technology. Further, it has been reported that the legume crops enrich the fertility of the soil Rhizobial inoculation to seeds is well studied and exploitation of this beneficial Nitrogen fixing root nodule symbiosis represents a hallmark of successfully applied agricultural microbiology (Bruno *et al.*, 2003). Soybean (*Glycine max* L. Merril) is an important grain legume and oilseed crop of the world. About 83,695 thousand hectares of land in the world is under cultivation of soybean and annual production is approximately 1.89.234 thousand metric tons (FAO, 2004). As a grain legume, it is gaining important position in the agriculture of tropical countries including

India, Sri Lanka, Thailand and Bangladesh. As a legume crop, soybean can fix atmospheric N symbiotically and about 80-90% nitrogen demand could be supplied by soybean through symbiosis (Bieranvand *et al.*, 2003). Salinity is a major threat to crop productivity in Bangladesh, where it is developed due to frequent flood by sea water of the Bay of Bengal. Legume-rhizobium symbiosis may play a vital role for overcoming salinity problems. Nitrogen is a major limiting nutrient for plant growth and development. The deficiency of N is usually supplemented by high cost inorganic N fertilizers like urea. Unfortunately the use of this vital nutrient exceeds hardly 5-15% in some cases 30%. To reduce the costly fertilizer input *Rhizobium*-legume symbiosis could be a best alternative strategy of N amendment in soil. The symbiotically fixed N can meet up 30-90% N

requirement of the plant (Vessey, 2004). This fixed N is also act as renewable source of N if the legume crop is rotated with a non-leguminous one. Evidences (Podder *et al.*, 1999; Rani and Kodandaramaiah, 1997) showed that soybean is quite responsive to the inoculums and the yield of this crop can be increased to a considerable extent using inoculums. With the view in mind, a research work was conducted to achieve the following objectives: (1) to study the effects of different rhizobial strains on nodulation and yield of salt tolerant soybean. (2) To determine the N content and its uptake by soybean as influenced by different rhizobial strains and nitrogen doses.

2. MATERIALS AND METHODS

2.1. Place of Experiment

A pot experiment was carried out in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh during the period from July to November, 2013. Geographically the experimental site is located at 24°75' N

latitude and 90°50' E longitude at an elevation of 18 m above the sea level. The site belongs to the non-calcareous dark grey floodplain soil under the Agro-ecological Zone (AEZ-9) of Old Brahmaputra Floodplains. Soybean cv. Shohag was used as plant material for the experiment. Seeds were collected through the courtesy of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Bangladesh.

2.2. Experimental soil and meteorological conditions

The experimental soil was collected from Fultala of Khulna district. Physical and chemical status of initial soil sample was 8% sand, 70.60% Silt, 21.40% Clay, Silty loam Textural classes, P^H 8.0, 1.52% organic carbon, 2.63% organic matter, 0.18% total N, available phosphorus 15.02 $\mu\text{g g}^{-1}$, exchangeable potassium 0.64 cmol kg^{-1} , exchangeable calcium 3.84 cmol kg^{-1} , exchangeable magnesium 0.26 cmol kg^{-1} , available sulphur 97.57 $\mu\text{g g}^{-1}$. The meteorological data is presented below.

Table 1. Monthly record of temperature, rainfall, relative humidity and sunshine during the study period from July 2013 to November 2013

Month	Average air temperature (°C)			Total rainfall (mm) month ⁻¹	Relative humidity	Sunshine (hrs) month ⁻¹
	Maximu m	Minimu m	Averag e			
July	31.02	21.33	26.18	235.00	77.13	178.6
August	30.07	21.07	25.57	212.90	74.42	175.55
September	30.02	21.03	25.52	142.50	72.25	172.07
October	26.59	20.07	23.66	75.90	71.13	165.35
November	22.40	19.8	21.1	0.00	78.25	168.25

Source: Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

2.3. Experimental treatments

This was a two-factor experiment. The experimental factors comprised nitrogen fertilization levels of 0, 10, 15, 20 kg ha^{-1} and rhizobial strain include no strain, strain-102, strain-J43 and mixed strain of 102 and J43. The treatment will be further referred to as N₀, N₁₀, N₁₅ and N₂₀ whereas the rhizobial strains are

respectively referred to as S₀, S₁, S₂ and S₃. There were 16 treatment combinations (4 strains × 4 fertilizer levels) replicated thrice.

2.4. Experimental design and layout

The experiment was laid out in completely randomized design with 3 replications. Treatments were assigned at random to each unit pot for each replication. Forty eight pots

were arranged in the net house as per lay out plan. Pots having the diameter of 30 cm × 30 cm were used and soil in each pot was 8kg. Soils were collected from 0-15 cm depth, pulverized, inert materials, dead insect pests and plant residues were removed. The soil was air dried and then mixed thoroughly and placed in the pots at the rate of 8 kg pot⁻¹. Fertilizers at the recommended dose were added and thoroughly mixed with the soil before putting them in the pots. Urea, triple superphosphate, muriate of potash, gypsum and cow dung was applied according to the fertilizer recommendation guide (BARC, 2005). Half amount of urea and full doses of other fertilizers were applied three days before seed sowing. The rest half amount of urea was applied at 20 days after sowing (DAS). To avoid fungal infection seeds were surface sterilized by soaking the seeds with 1% sodium hypochlorite for one minute followed by washing 6-8 times in tap water and three times in distilled water. After sterilization, the seeds were soaked in rhizobial culture for two hours then 8-10 seeds were sown in each pot very carefully to avoid contamination among the rhizobial strains. Seeds were sown in the pots on July, 5, 2013 and covered by soil. Intercultural operations were done to ensure normal growth of the crops. Weeding and thinning were done simultaneously after 15 and 30 DAS. The seedlings of the crop emerged out within 6-8 DAS. Significant soil moisture content was maintained by daily addition of distilled water. The crop was attacked by pod borer and controlled by applying diazinon 1 liter ha⁻¹ on September, 14, 2013. The crop was harvested on the November 5, 2013, after 120 DAS. The total yield for each pot was recorded. The plant samples were tagged and oven dried for 72 hours until moisture content reaches to minimum condition. The dried materials of each treatment was weighed and stored for chemical analyses.

2.5. Parameters studied

The following parameters were calculated for each treatment.

Physical parameters included Nodule number

plant⁻¹, Number of pods plant⁻¹, Number of seeds plant⁻¹, Grain yield and Straw yield. Chemical and biochemical parameters included Nitrogen, Protein content.

2.6. Plant analysis

Total N content of the plant samples was determined by semi-micro kjeldahl method (Page *et al.*, 1982). The amount of N was calculated using the following formula:

$$\%N = \frac{(T - B) \times N \times 1.4 \times 100}{W}$$

Where,

T = Titre value (ML) for sample, B = Titre value (ML) for blank, N = Strength of H₂SO₄, W = Weight of sample, 1.4 = Correction factor

The uptake of N was calculated by multiplying the concentration of the nutrient in the grain with the grain yield. In order to determine crude protein in seeds a representative seed samples were taken from each treatment to determine total nitrogen in the seed through Microkjeldahl Method (Page *et al.*, 1982). Then the percentage of protein in seeds was calculated by multiplying the factor 6.25 (Morrison, 1956).

2.7. Statistical analysis

The data were analyzed statistically by F-test (Gomez and Gomez, 1984). The mean comparisons of the treatments were evaluated by least significant differences (LSDs) test at significance level P < 0.05. Analysis of variance was done following the Completely Randomized Design (CRD) with the help of computer package MSTAT developed by Russel (1989).

3. RESULTS AND DISCUSSION

3.1. Effects of different rhizobial strains and N on nodulation of soybean cv. Shohag

3.1.1. Nodules plant⁻¹

Different rhizobial strains significantly influenced the number of nodules plant⁻¹ in soybean. The highest number of nodules plant⁻¹

(27.58) was observed in plants inoculated with strain-J43 which was significantly higher than those of other treatments. Strain-102 and mixed strains (J43 and 102) inoculated plants produced identical number of nodules plant⁻¹. On the other hand, the lowest number of nodules plant⁻¹ (13.83) was counted from control (Table 2). Nodulation might be due to the effective symbiosis between legume and rhizobial strains. Thus, the findings of this experiment is in agreement with those of Slattery *et al.*, (2004) who reported that *Rhizobium leguminosarum bv viciae* is responsible for effective nodulation of faba bean, lentils and field pea. Egamberdiyeva *et al.*, (2004) investigated the effect of inoculation with *Bradyrhizobium japonicum* S-2492 on soybean nodulation. They observed positive effects on nodule number. Kavathiya and Pandey (2000) found 69 nodules plant⁻¹ by inoculating mungbean seed with *Rhizobium*. Different levels of N also showed significant variation with respect to number of nodules plant⁻¹. The highest and lowest number of nodules plant⁻¹ was 25.91 and 17.83 observed with the treatment N₁₅ and control which was identical with N₂₀ (Table 2). The interaction effect of different rhizobial strains and N fertilizer on the number of nodules plant⁻¹ revealed that the highest and lowest number of nodules plant⁻¹ was 30.33 and 5.00 found in the plant inoculated with rhizobial strain-J43×15 kg N ha⁻¹ and control treatment respectively

(Table 3). Increase in nodules per plant due to application of inoculation in combination with nitrogen fertilizer was reported by Rashid *et al.*, (1999).

3.1.2. Nodule dry weight plant⁻¹

The maximum and minimum nodule dry weight was 0.19 g and 0.06 g recorded from the plant inoculated with strain-J43 and non-inoculated plant. In Table 2, it is clear that there was no statistical difference in nodule dry weight of plants inoculated with strain-102 and mixed strains (102 and J43). Different rhizobial strains increase the nodulation of the plant compared to control. Içgen (2002) conducted a field experiment with five local and seven standard strains of *Rhizobium* and the maximum increase in nodule dry weight was found in rhizobial infection compared to control in soybean. Bhuiyan *et al.*, (1998) has stated that inoculation with *Rhizobium* increased nodule dry weight. Table 2 shows that when treated with different N levels 15 kg N ha⁻¹ showed highest (0.154g) and control showed lowest (0.09g) nodule dry weight +9plant⁻¹. The results from interaction effect of rhizobial strain and N fertilizer showed the highest and lowest nodule dry weight was 0.23g and 0.01g obtained from treatment combination of strain-J43 × 15 kg N ha⁻¹ and control. The rhizobial strain treatment in conjunction with N level influenced the nodule dry weight of the plant (Table 3).

Table 2. Effects of different rhizobial strains and different levels of N on nodule dry weight of soybean cv. Shohag

Strains	Fresh nodules plant ⁻¹ (No.)	Dry nodule wt. plant ⁻¹ (g)	Nitrogen levels	Fresh nodules plant ⁻¹ (No.)	Dry nodule wt. plant ⁻¹ (g)
Uninoculated	13.833	0.069	N ₀	17.833	0.097
Strain-102	25.500	0.131	N ₁₀	23.417	0.131
Strain J-43	27.583	0.199	N ₁₅	25.917	0.154
Mixed strain	24.417	0.123	N ₂₀	24.167	0.141
LSD _{P=0.05}	0.247	0.004	LSD _{P=0.05}	0.261	0.005

N₀ = Control, N₁₀ = 10 kg ha⁻¹, N₁₅ = 15 kg ha⁻¹, N₂₀ = 20 kg ha⁻¹

Table 3. Interaction effects of different rhizobial strains and N on nodulation of soybean cv. Shohag

Treatment combinations	Total nodule plant ⁻¹ (No.)	Nodule dry wt. (g)
S ₀ N ₀	5.000	0.016
S ₀ N ₁₀	15.333	0.079
S ₀ N ₁₅	18.667	0.096
S ₀ N ₂₀	16.333	0.084
S ₁ N ₀	21.667	0.108
S ₁ N ₁₀	25.667	0.129
S ₁ N ₁₅	28.000	0.147
S ₁ N ₂₀	26.667	0.141
S ₂ N ₀	24.333	0.160
S ₂ N ₁₀	27.667	0.193
S ₂ N ₁₅	30.333	0.235
S ₂ N ₂₀	28.000	0.208
S ₃ N ₀	20.333	0.103
S ₃ N ₁₀	25.000	0.122
S ₃ N ₁₅	26.667	0.140
S ₃ N ₂₀	25.667	0.129
LSD _{P=0.05}	0.065	0.001

S₀ = Control, S₁ = Strain 102, S₂ = Strain J43, S₃ = Mix. (102 & J43)
N₀ = Control, N₁₀ = 10 kg ha⁻¹, N₁₅ = 15 kg ha⁻¹, N₂₀ = 20 kg ha⁻¹

3.2. Effects of different rhizobial strains and N on yield and yield attributes of soybean cv. Shohag.

3.2.1. Number of pods and seeds plant⁻¹

Inoculation of different rhizobial strains showed significant difference in number of pod and seeds plant⁻¹. The maximum number of pod and seeds plant⁻¹ was 43.58 and 75.66 obtained from the plant inoculated with strain-J43. The minimum number of pod and seeds plant⁻¹ was 22.16 and 42.08 counted from control (Table 4). Similar results also obtained by Solaiman (1999) in chickpea, Feng *et al.*, (1997) in pea, Hoque and Haq (1994) in lentil. Podder *et al.* (1999) carried out a field experiment with soybean and found that

Bradyrhizobium inoculation had favourable effect on seed number per plant and yield. Number of pods and seeds plant⁻¹ was also affected by different levels of N. The maximum (39.08) and minimum (28.83) number of pod plant⁻¹ was recorded from the N₁₅ and control, respectively (Table 4). Almost similar observation was made by Kakar *et al.*, (2002) in pea. The highest number of seeds plant⁻¹ (65.83) was found in the treatment N₁₅ and control produced lowest seed plant⁻¹ (50.66). The interaction of different rhizobial strains and N showed that the highest number of pod and seeds was 49.33 and 88.66 obtained from strain-J43 × N₁₅ and lowest number of pod and seeds were 16.66 and 35.33 found from control (Table 5).

Table 4. Effects of different rhizobial strains and different levels of N on yield and yield attributes of soybean cv. Shohag

	No. of pod plant ⁻¹ (No.)	No. of seed plant ⁻¹ (No.)	Grain yield (kg ha ⁻¹)	Straw yield (Kg ha ⁻¹)
Strains				
Control	22.167	42.083	1244.33	1597.16
Strain-102	37.417	61.083	1392.25	2186.66
Strain-J43	43.583	75.667	1467.91	2407.41
Mix. (102 & J-43)	34.000	56.917	1364.16	2179.33
LSD _{P=0.05}	0.113	0.399	3.868	5.839
Nitrogen levels				
N ₀	28.833	50.667	1294.66	1931.66
N ₁₀	33.083	58.083	1354.25	2063.91
N ₁₅	39.083	65.833	1426.08	2280.66
N ₂₀	36.167	61.167	1393.66	2094.33
LSD _{P=0.05}	0.115	0.401	3.872	5.842

Table 5. Interaction effects of different rhizobial strains and N on yield and yield attributes of soybean cv. Shohag

Treatment combinations	No. of pod plant ⁻¹ (No.)	No. of seed plant ⁻¹ (No.)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
S ₀ N ₀	16.667	35.333	1129.00	1379.00
S ₀ N ₁₀	20.667	40.333	1240.00	1592.33
S ₀ N ₁₅	26.667	47.333	1323.00	1800.66
S ₀ N ₂₀	24.667	45.333	1285.33	1616.66
S ₁ N ₀	31.667	56.667	1344.33	1988.33
S ₁ N ₁₀	36.333	61.667	1359.33	2150.66
S ₁ N ₁₅	43.000	66.667	1441.66	2421.33
S ₁ N ₂₀	38.667	59.333	1423.66	2186.33
S ₂ N ₀	37.667	60.333	1380.66	2222.00
S ₂ N ₁₀	42.333	72.333	1474.66	2371.66
S ₂ N ₁₅	49.333	88.667	1529.00	2630.00
S ₂ N ₂₀	45.000	81.333	1487.33	2406.00
S ₃ N ₀	29.333	50.333	1324.66	2137.33
S ₃ N ₁₀	33.000	58.000	1343.00	2141.00
S ₃ N ₁₅	37.333	60.667	1410.66	2270.66
S ₃ N ₂₀	36.333	58.667	1378.33	2168.33
LSD _{P=0.05}	0.029	0.100	0.968	1.460

S₀ = Control, S₁ = Strain 102, S₂ = Strain J43, S₃ = Mix. (102 & J43)
N₀ = Control, N₁₀ = 10 kg ha⁻¹, N₁₅ = 15 kg ha⁻¹, N₂₀ = 20 kg ha⁻¹

3.2.2. Grain and straw yield

The highest grain and Straw yield were recorded from S₂ (strain-J43) treatment and N₁₅. The lowest was found from control treatment (Table 4). The interaction effect shows that the highest and lowest grain and straw yield were obtained at strain-J43 × N₁₅ and control respectively (Table 5).

3.3. Effects of different rhizobial strains and N on protein content of soybean cv. Shohag.

3.3.1. Grain and straw protein content

Different rhizobial strains inoculation influenced the straw and grain protein content of soybean. The highest grain and straw protein content was 44.06% and 41.31% recorded from

the plant inoculated with strain-J43. The lowest grain and straw protein content was 39.87% and 38.25% recorded from control treated plant respectively (Figure 1). Higher amount of N increase the N assimilation and ultimately increase the protein content of the plant. A similar finding was reported by Icen (2002). Grain and straw protein content varied due to different treatments of nitrogen level. Among the treatments the highest grain and straw protein content was 43.62% and 40.31%

obtained by the N₁₅ treatment and the lowest was 39.00% and 38.12% obtained from control (Figure 1). N₁₀ and N₂₀ treatments were statistically similar. The interacting effect of different rhizobial strains and N in protein content showed that the highest grain and straw protein content was 46.93% and 46.50% found from strain-J43 × N₁₅ and control recorded lowest grain (40.56%) and straw (39.68%) protein content (Figure 2).

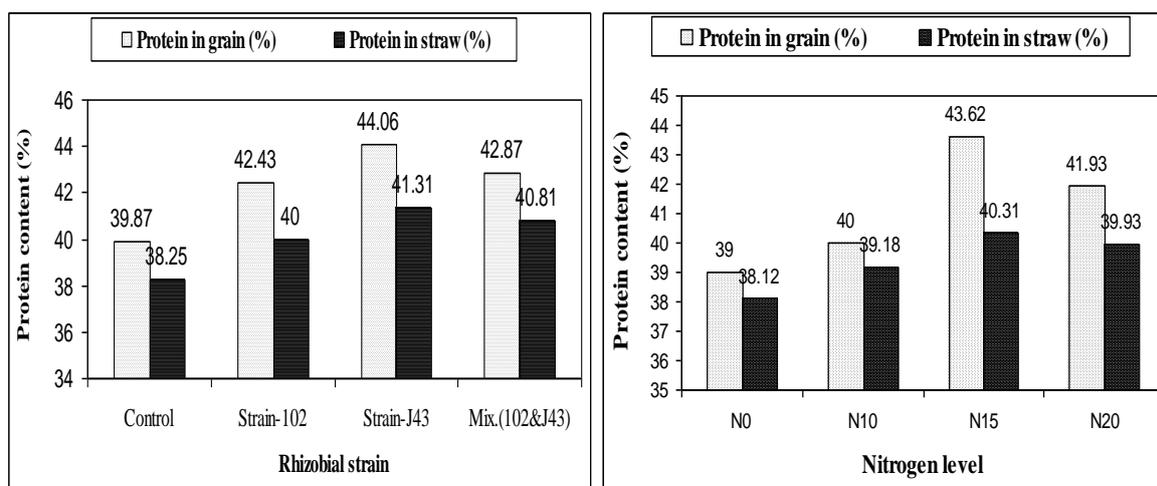
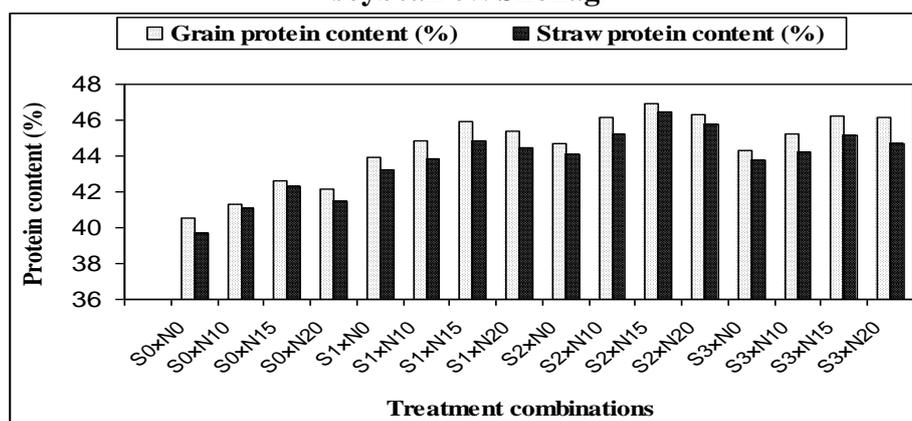


Figure 1. Effects of different rhizobial strains and different levels of N on protein content of soybean cv. Shohag.



S₀ = Control, S₁ = Strain 102, S₂ = Strain J43, S₃ = Mix. (102 & J43)
N₀ = Control, N₁₀ = 10 kg ha⁻¹, N₁₅ = 15 kg ha⁻¹, N₂₀ = 20 kg ha⁻¹

Figure 2. Interaction effects of different rhizobial strains and N on protein content of soybean cv. Shohag.

3.4. Effects of different rhizobial strains and N on N content and its uptake by soybean.

3.4.1. Grain N content and N uptake

When treat with different rhizobial strains the highest grain N content was 7.05% and

maximum grain N uptake was 103.48 kg ha⁻¹ obtained from strain-J43 and the lowest grain N content (6.38%) and minimum grain N uptake was 79.38 kg ha⁻¹ obtained from the control treated plant (Table 6). Seneviratne *et*

al., (2000), and Zhang *et al.*, (2002) reported significant increase in seed and shoot N of Soybean inoculated with *B. japonicum*. The findings of this experiment is in agreement with those of Kantar *et al.*, (2003) they reported that bacterial inoculation increased total N content (%) significantly compared to

control in chickpea. When treated with different N level the highest N content, grain N uptake was 6.98%, 99.54 kg ha⁻¹ and lowest N content, grain N uptake was 6.24%, 80.78 kg ha⁻¹ observed from treatment N₁₅ and control group respectively (Table 6).

Table 6. Effects of different rhizobial strains and different levels of N on N content and its uptake by soybean cv. Shohag

	Grain N		Straw N	
	Content (%)	Uptake (Kg ha ⁻¹)	Content (%)	Uptake (Kg ha ⁻¹)
Strains				
Control	6.38	79.38	6.12	97.74
Strain-102	6.79	94.53	6.40	139.94
Strain-J43	7.05	103.48	6.61	159.12
Mix. (102 & J43)	6.86	93.58	6.53	142.31
LSD _{P=0.05}	0.002	0.264	0.002	0.985
Nitrogen levels				
N ₀	6.24	80.78	6.10	117.83
N ₁₀	6.40	86.67	6.27	129.40
N ₁₅	6.98	99.54	6.45	147.10
N ₂₀	6.71	93.51	6.39	133.82
LSD _{P=0.05}	0.002	0.276	0.002	0.999

N₀ = Control, N₁₀ = 10 kg ha⁻¹, N₁₅ = 15 kg ha⁻¹, N₂₀ = 20 kg ha⁻¹

3.4.2. Straw N content and N uptake

The highest straw N content (6.61%) and N uptake (159.12 kg ha⁻¹) was estimated from the plant inoculated with strain-J43. The lowest straw N content (6.12%) and N uptake (97.74 kg ha⁻¹) was recorded from the non inoculated control plant. Higher straw N content might be due to the higher N fixation from the atmosphere by the inoculated rhizobial strains. The highest straw N content (6.45%) and straw N uptake (147.10 kg ha⁻¹) was observed in N₁₅ treatment on the other hand the lowest straw N content (6.10%) and N uptake (117.83 kg ha⁻¹) was observed in the control (Table 6).

4. CONCLUSIONS

Based on this research, we conclude that different rhizobial strains, N level and their symbiotic combinations significantly affected the nodulation, growth, yield, N contents and its uptake by soybean cv. Shohag under salt stress conditions. Many parameters were assessed, which included nodules plant⁻¹,

nodule dry weight plant⁻¹, pods plant⁻¹, seeds plant⁻¹, grain yield, straw yield, grain protein content, straw protein content, grain N content, straw N content, grain N uptake and straw N uptake and these parameter were maximum when treated with strain-J43 and N₁₅ treatment. Among 16 treatment combinations the best symbiotic combination was strain-J43×N₁₅ due to the effective symbiosis between legume and rhizobial strains which provide maximum nodulation, yield.

5. ACKNOWLEDGMENT

The authors express gratitude to Bangladesh Agricultural University, Mymensingh, Bangladesh for providing all types of technical assistance. Authors thankfully acknowledge the financial assistance from University Grants Commission (UGC), Bangladesh.

6. REFERENCES

- [1] Bruno, J. R., R. Alves, M. Boddey and U. Segundo, 2003. The success of BNF in soybean in Brazil. *Plant and Soil*. Online. DOI: 10.1023/A:252(1): 1-9
- [2] FAO, 2004. FAO year book production. Food and Agriculture Organization of the United Nations, Rome, Italy. P. 57-115.
- [3] Bieranvand, N. P., Rastin, N. S., Afarideh, H. and Sagheb, N. 2003. An evaluation of the N fixation capacity of some *Bradyrhizobium japonicum* strains for soybean cultivars. *Iran. J. Agric.Sci.* 34 (1): 97-104.
- [4] Vessey, J. K. 2004. Benefits of inoculating legume crops with rhizobia in the northern Great Plains. Online. *Crop Management* doi: 10.1094/CM-2004-0301-04-RV.
- [5] Podder, A. K., Hossain, M. B., Chanda, M. C., Islam, M. Z., Mondal, N. and Rahman, M. 1999. Selection of effective Bradyrhizobial strains for soybean cultivation for environmental management of Brahmaputra Floodplain Soil. *Bangladesh J. Environ. Sci.* 5:56-60.
- [6] Rani, B. P. And Kodandaramaiah, D. 1997. Response of soybean (*Glycinemax*) to *Rhizobium* inoculation under varying nitrogen levels. *Indian J. Agron.* 42(1):135-137.
- [7] BARC, 2005. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Dhaka. Bangladesh. P 85-96.
- [8] Page, A. L., Miller, R. H. and Keeney, D. R. (eds.). 1982. *Methods of Soil Analysis*. Part 2, 2nd ed. American Society of Agronomy, Inc. Soil Sci. Soc. Madison, USA. P. 539-622.
- [9] Morrison, F. B. 1956. *Feeds and feeding*. 22nd edn. The Morrison Publishing Company, Ithaca, New York, USA. P. 77.
- [10] Gomez, K. A. and Gomez, A. K. 1984. *Statistical Procedures for Agricultural Research*. 2nd edn, John Wiley and Sons, New York. P. 207-215.
- [11] Russel, D. F. 1989. M-STAT Director. Crop and Soil Science Department, Michigan State University, USA
- [12] Slattery, J. F., Pearce, D. J. and slattery, W. J. 2004. Effects of resident rhizobial communities and soil types on the effective nodulation of pulse legumes. *Soil Biol. Biochem.* 36:1339-1346.
- [13] Egamberdiyeva, D., Qarshieva, D. and Davranov, K. 2004. The Use of *Bradyrhizobium* to enhance growth and yield of soybean in calcareous soil in Uzbekistan, *J. P. I. Growth Reguln.* 23: 54-57.
- [14] Kavathiya, Y. A. and Pandey, R. N. 2000. Interaction studies on *Meloidogyne javanica*, *Rhizobium sp.* and *Macrophomina phaseolina* in mungbean. *J. Mycol. Plant Path.* 30: 91-93.
- [15] Rashid, A., Musa, M., Adal, N. K., Yaqub. M. and Chaudhury, G. A. 1999. Response of groundnut to *Bradyrhizobium* and a diazotroph bacterial inoculum under different levels of nitrogen. *Pakistan J. Soil.* 16:89-98.
- [16] Içgen, B. 2002. Evaluation of symbiotic effectiveness of various *Rhizobium cicer* strains. *Res. Microbial.* 153(6):69-72.
- [17] Bhuiyan, M.A.H., Khanam, D., Rahman, M.M. and Ali, M.M. 1998. Variation in the symbiotic effectiveness of *Bradyrhizobium* strains on soybean. *Bangla. J. Microbiol.* 15:25-30.
- [18] Feng, Y., Pan, C., Wang, D., Li, Y. and Wei, C. 1997. Isolation of nodule bacteria from *Pisum sativum* and the application of nitragine from the isolate. *J. Trop. Sub Trop. Bot.* 5(2):47-53.
- [19] Hoque, M. M. and Haq, M. F. 1994. Rhizobial Inoculation and Fertilization of Lentil in Bangladesh. *Lens Newsl.* 21: 29–30 P.
- [20] Kakar, A. A., Saleem, M., Shah, R. And Shah, S. A. Q. 2002. Growth and marketable green pod yield performance of pea (*Pisum sativum* L.) under varying levels of NPK fertilizers. *Asian J. Plant Sci.* 1(5):532-534.
- [21] Seneviratne, G., Van-Holm, L. H. J. And Ekanayake, E. M. H. G. S., 2000. Agronomic benefits of rhizobial inoculant use over nitrogen fertilizer application in tropical soybean. *Field Crop Res.* 68:199-203.
- [22] Zhang, H., Daoust, T. C., Charles, T. C., Driscoll, B. T., Prithiviraj, B. and Smith, D. L., 2002. *Bradyrhizobium japonicum* mutants allowing improved nodulation and nitrogen fixation of field grown soybean in short season area. *J. Agric. Sci.* 138:293-300.
- [23] Kantar, F., Elkoca, E., Ogutcu, H. and Angur, O. F. 2003. Chickpea Yields in Relation to *Rhizobium* Inoculation from Wild Chickpea at High Altitudes. *J. Agron. Crop Sci.* 189(5):291-297.