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Contribution of the *Rhizobium* Inoculation on Plant Growth and Productivity of Two Cultivars of Berseem (*Trifolium alexandrinum* L.) in Saline Soil

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Abstract: The present study was undertaken on the interactive effect of *Rhizobium* seed culture treatment and saline irrigation on the plant growth and productivity (fodder/biological yield) in two cultivars (WARDAN and BB 2) of berseem. The experiment was conducted following completely randomized block design method considering three replicates and data were subjected to statistical analysis of variance using three factorial randomized design method. Two sets of plots were maintained in which one set contained non-inoculated while another set contained inoculated seeds with *Rhizobium* culture, which were irrigated with saline waters of different electrical conductivities (0, 3, 6, 7.2, 10, 12 and 14 dS m^{-1}). The observations were recorded at two durations i.e., 90 and 120 DAS. The plant growth has been enhanced at lower levels of salinity (3 to 7.2 dS m^{-1}) and invariably inhibited at 10 dS m^{-1} and beyond. Inoculation with *Rhizobium* culture had expressed synergistic effects on growth and productivity at both durations particularly at lower EC levels and also minimized the deleterious effect of salinity at 10 to 14 dS m^{-1} to some extent. The yield characteristics (biological and fodder yield) had been differentially affected in berseem. Cv. WARDAN had registered maximum yield at the final harvest in *Rhizobium* inoculated sets at 3, 6 and 7.2 dS m^{-1}. Similar findings were recorded for total green and dry weight fodder yield/plot (kg m^{-2}). Our findings proves that cv. WARDAN might be tried on saline soils to obtain some biomass.

Key words: Efficiency, bacterial culture, yield, total green fodder yield/plot, dry weight fodder yield/plot, salt stress

INTRODUCTION

Salinization is the accumulation of water soluble salts in the soil column or regolith to a level that has a drastic impact on agricultural production, environmental health and economic welfare of the country (Rengasamy, 2006). Salt affected land comprises of 19% of the 2.8 billion hectares of arable land on earth and an increase in this menace is posing a serious threat to agriculture globally. Most such areas are in the tropics and the Mediterranean regions (Surange *et al*., 1997). Rapidly increasing soil salinity has multifarious effects on plant growth and productivity. It is a very acute problem in agriculture. This is mainly due to total concentration of soluble salts or osmotic potential of soil water (Flowers, 2004; Katerji *et al*., 2005). Excess of soluble salts in the soil leads to osmotic stress (Munns, 2002), which results in specific ion toxicity and ionic imbalances and the consequences lead to plant demise (Rout and Show, 2001).

It has attracted the attention of many investigators and practical agricultural workers because of the need to increase yield on saline soils and to develop and utilize new saline areas.

Most of the crops tolerate salinity to a threshold level and above which yield decreases as the salinity increases (Khan *et al*., 2006).

Legumes are more sensitive to salinity than their Rhizobial partners. Consequently, Symbiosis is more sensitive to salt stress than free-living Rhizobia (Zahran, 1999). The sensitivity can be attributed to toxic ion accumulations in different plant tissues which disturb some enzyme activities. *Rhizobium*-legume symbiosis in arid region is particularly important for locations where the area of saline soils is increasing and becoming a threat to plant productivity.

In recent years a renewed interest in nitrogen-fixing legumes has led to a reevaluation of berseem clover

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(*Trifolium alexandrinium* L.) as a winter and spring forage and as a cover crop and green manure crop. Legumes served an important need by producing high quality forages without using commercially produced nitrogen fertilizer and help to feed the meat-producing animals of the world as well as humans. Nitrogen fixation by natural means cuts down on the use of artificial fertilizers. This not only saves money but helps to prevent the many problems brought about by excessive use of commercial nitrogen and ammonia fertilizers such as eutrophication of rivers and lakes, generation of acid rain and overgrowth of agricultural land by non-food crops.

For successful *Rhizobium*-legume symbiosis in the saline environment include Rhizobial colonization and invasion of the rhizosphere root hair infection. The possibility has been explored of the *Rhizobium*-legume symbiosis to improve the productivity of saline soil.

Plant scientists have adopted various strategies to overcome the salinity. One of the important of them is to exploit genetic variability of the available germplasm to identify a tolerant genotype that may sustain a reasonable yield on salt affected soil (Ashraf *et al*., 2006).

Berseem is considered as moderately salt tolerant (Winter and Lauchli, 1982) and well known for its use as fodder. Little informations are available on efficacy of *Rhizobium* under saline irrigation. Hence, the present study was undertaken on the interactive effect of *Rhizobium* seed culture treatment and saline irrigation on the growth and productivity of berseem.

MATERIALS AND METHODS

Sampling of soil and preparation of field: The field experiment has been designed to study the efficacy of *Rhizobium trifolii* on plant growth, forage and biological yield under saline irrigation. The observations have been recorded only at 90 and 120 DAS. Experiment was conducted from 5th November, 2006 to 31st March, 2007 at a farmhouse located on Kath road, Harthla, Moradabad, U.P. India. Minimum and maximum temperature and relative humidity were measured regularly during the whole course of experimentation from 5/11/06 to 31/03/07 (Table 1).

Table 1: Average minimum, maximum temperature and relative humidity

	Temperature (°C)		
Month	Minimum	Maximum	Relative humidity (%)
November	14.76	26.80	61.40
December	10.19	22.39	58.00
January	8.22	20.10	48.32
February	9.32	22.42	43.41
March	13.74	27.22	52.00

The experimental field was prepared and all agronomic practices were adopted for sowing and cultivation of berseem crop. It was harrowed and ploughed thoroughly for mixing of the soil. A suitable quantity of cow dung manure was mixed thoroughly. Before mixing of the manure, soil samples were subjected to physico-chemical analysis.

The experimental plots were divided into micro plots measuring 1×1 m each (inner size) and these plots were lined with polythene sheets at a depth of 15" to avoid lateral leaching of salts. Two sets of plots were maintained in which one set contained non-inoculated while another set contained inoculated seeds with *Rhizobium* culture. Each set of salinity was based on randomized block design with triplicates. The experimental plots, which were irrigated with saline waters of different electrical conductivities (3, 6, 7.2, 10, 12 and 14 dS m^{-1}). The experimental plots were thoroughly cleared of the grass roots etc., before sowing of the seeds. The control sets were irrigated with tubewell water. The saline solutions of different ECs were prepared by mixing the salts of NaCl, Na_2SO_4, $NaHCO_3$ and $CaCl_2$ in tubewell water. The quantity of salts dissolved was followed as mentioned by US Salinity Laboratory Staff (1954).

Methods of application of *Rhizobium* inoculants: Seeds of the two cultivars viz., cv. WARDAN and BB2 were divided into two lots and one lot was treated with culture of *Rhizobium trifolii* and another lot was kept untreated. The seed treatment has been found to be the suitable method of *Rhizobium* inoculation. Some adhesive was used to make proper contact between seeds and inoculants (bacteria). About 900 g soil base culture was sufficient to inoculate the seeds for one hectare area in case of legumes. A 10% jaggery (gur) solution was used as sticker for *Rhizobium* cells to seed. First the solution was spread over the seeds and mixed to build up a thin coat over the seeds. After ascertaining the proper coating of slurry over the seeds, the inoculant was sprinkled over the seeds and the content was again mixed thoroughly. Then content was dried in the shade by spreading thinly on a polythene sheet at least for overnight.

The seeds were sown 2 cm deep in furrow in linear rows, which were apart at a distance of 20 cm from each other and each experimental plot (1×1 m) had three rows. The sowing rate was 1 g in each plot. Moradabad experienced megre rains during the whole course of investigation and saline irrigations were sufficient for cultivation of the crop.

The observations were recorded on various parameters of growth, fodder and total biological yield at 90 and 120 days after sowing. Before each observation, the field was irrigated with tube well water so that the sampling could be done easily with out damaging the roots. The plant samples were brought to the laboratory and the roots were thoroughly washed under running tap water with out damaging roots and nodules. The samples were collected randomly from inoculated and non-inoculated plots of each salinity treatment (3-14 dS m^{-1}) including controls.

All observations were recorded in triplicates and data were subjected to statistical analysis of variance using three factorial randomized design method (Bruning and Kintz, 1977).

RESULTS AND DISCUSSION

Table 2 and 3 reveals that dry weight of shoot and root of all berseem varieties generally enhanced upto 7.2 dS m^{-1} and significantly declined beyond this EC at both durations i.e., 90 and 120 DAS ($p<0.001$). Inoculation with *Rhizobium* culture had further promoted at all EC levels. The dry weight of the root and shoot were generally higher in *Rhizobium* culture inoculated sets at 120 DAS (Table 3). Muhammad and Hussain (2010) also confirmed that various concentrations of salt had a highly significant effect upon the shoot and root dry weight of five cultivars of medicinal plants.

In addition to this, root length enhanced in cv. BB 2 at 10 dS m^{-1}. Therefore, it is evident that the lower limits of salinity favoured root growth. Salinity induced root growth had also been observed in desi chick pea by Elsheikh and Wood (1990) and Singh *et al.* (2001).

The experimental findings also indicate that the root growth (Table 3) has been affected lesser than the shoot growth (Table 2) which confirm the earlier findings of Bernstein and Hayward (1958), Eaton (1942), Strogonov (1962), Bernstein and Kafkafi (2002), Cheeseman (1988) and Rawson *et al.* (1988) though the roots are exposed directly to the saline environment (3 to 14 dS m^{-1}). Overall picture indicates that root dry weight had been increased upto 7.2 dS m^{-1} but decreased at higher levels (10, 12 and 14 dS m^{-1}) however, the cultivars had shown differential responses to salinity and inoculation with *Rhizobium* culture. Exceptionally, cv. WARDAN exhibited significant increases in both *Rhizobium* culture treated as well as non-treated sets ($p<0.001$) leaving apart untreated sets at 90 DAS. Viegas *et al.* (1999), Camara *et al.* (2000), Murillo-Amador and Troyo-Dieguez (2000) and

Table 2: Effect of saline water irrigation on dry weight of shoot in two cultivars of berseem (*Trifolium alexandrinum* L.) Mean±SE (n = 3)

	Dry weight of shoot (g $plant^{-1}$)							
	Days after sowing							
	Cv. WARDAN				Cv. BB 2			
Salinity of irrigation	90		120		90		120	
water (dS m^{-1})	NR	R	NR	R	NR	R	NR	R
Control	1.12±0.04	1.50±0.09	1.44±0.01	1.76±0.14	0.83±0.20	1.02±0.14	1.55±0.02	1.78±0.01
3	1.21±0.02	1.99±0.13	2.00±0.12	2.44±0.13	1.29±0.08	1.51±0.09	1.62±0.04	2.50±0.05
6	1.75±0.01	2.05±0.22	2.13±0.05	2.60±0.07	1.25±0.03	1.55±0.03	1.78±0.21	2.57±0.23
7.2	1.35±0.03	1.97±0.05	2.12±0.09	2.30±0.10	1.22±0.13	1.42±0.08	1.65±0.01	2.41±0.13
10	0.34±0.06	1.31±0.04	0.98±0.12	1.36±0.04	0.67±0.21	0.86±0.13	1.13±0.03	1.35±0.08
12	0.31±0.04	0.96±0.04	0.59±0.07	1.23±0.03	0.42±0.04	0.76±0.06	0.74±0.05	1.09±0.04
14	0.28±0.05	0.47±0.05	0.35±0.07	0.65±0.08	0.23±0.07	0.32±0.01	0.47±0.14	0.70±0.06

NR: Non-treated, R: Rhizobium culture treated

Table 3: Effect of saline water irrigation on dry weight of root in two cultivars of berseem (*Trifolium alexandrinum* L.) Mean±SE (n = 3)

	Dry weight of root (g $plant^{-1}$)							
	Days after sowing							
	Cv. WARDAN				Cv. BB 2			
Salinity of irrigation	90		120		90		120	
water (dS m^{-1})	NR	R	NR	R	NR	R	NR	R
Control	0.18±0.01	0.21±0.07	0.18±0.03	0.25±0.05	0.18±0.04	0.20±0.04	0.20±0.03	0.24±0.02
3	0.24±0.00	0.31±0.04	0.25±0.03	0.36±0.01	0.20±0.06	0.24±0.06	0.24±0.04	0.29±0.06
6	0.30±0.02	0.32±0.06	0.32±0.07	0.38±0.07	0.21±0.04	0.24±0.09	0.24±0.01	0.32±0.02
7.2	0.14±0.03	0.24±0.14	0.20±0.12	0.31±0.01	0.20±0.04	0.25±0.02	0.25±0.05	0.28±0.03
10	0.12±0.12	0.19±0.01	0.16±0.02	0.21±0.05	0.12±0.02	0.16±0.03	0.16±0.12	0.22±0.02
12	0.09±0.11	0.14±0.07	0.13±0.09	0.18±0.06	0.11±0.02	0.13±0.02	0.12±0.07	0.16±0.01
14	0.08±0.02	0.10±0.03	0.09±0.02	0.17±0.01	0.08±0.04	0.11±0.04	0.10±0.06	0.13±0.03

NR: Non-treated, R: Rhizobium culture treated

Agarwal *et al*. (2008) proved that salinity decreased root and shoot growth of the seedlings. Demiral (2005) also reported that salinity decreased growth of two barley cultivars to different extent.

Leaf growth is very important parameter as it is directly concerned with the productivity of the plants. The dry weight of leaves/plant has been measured which is directly related with photosynthetic area and plant productivity. It has also expressed similar behavior and increased from 90 to 120th day stage in both varieties, thus indicating continued growth upto 120 DAS. The growth had been enhanced upto 7.2 dS m^{-1} and declined at higher ECs in both varieties of berseem. Shonubi (2010) also reported that excess salt become toxic in the old leaves. That is why as the salt concentration increased, dry weight of leaves decreased. Varietal differences showed that greater dry matter was produced in cv. WARDAN and minimum in cv. BB 2 in both non-*Rhizobium* and *Rhizobium* culture treated sets at 120 DAS (Table 4). *Rhizobium* culture applications had invariably and significantly enhanced the dry weight of leaves/plant ($p<0.001$) irrespective of saline irrigations in both cultivars at both durations. The adverse effect of higher salinities is also confirmed by the findings of Jaiswal *et al*. (1975) and Malik *et al*. (1977) in pea and Singh and Mangal (1974) in okra. The reduction in leaf growth and leaf area under saline conditions has also been recorded by several workers (Neves-Piestun and Bernstein, 2001; Hu and Schmidhalter, 2001; Bernstein *et al*., 1993a, b; Yeo *et al*., 1991; Rawson *et al*., 1988; Lazof and Bernstein, 1998). Salt induced leaf damages are considered to reduce the photosynthetic leaf area and hence yield potential in Avacado (Ayers *et al*., 1951; Bingham *et al*., 1968). Jiang *et al*. (2004) also reported that dry weight of leaves of seedlings of two cotton cultivars were significantly inhibited by NaCl treatment.

Fodder (economic yield) and total plant dry weight (biological yield) of berseem cultivars had been differentially affected with saline irrigations (Table 5 and 6). Fodder (economic yield) includes all above ground parts of the plant (stem, leaves and flowers), which has been recorded on per plant basis at 90th and 120th day stage whereas biological yield includes the dry weight of all plant parts (root, stem, leaves, flowers and nodules), which has been differentially affected with irrigation with saline waters and inoculation with *Rhizobium* culture. The

Table 4: Effect of saline water irrigation on dry weight of leaves in two cultivars of berseem (*Trifolium alexandrinum* L.) Mean±SE (n = 3)

	Dry weight of leaves (g $plant^{-1}$)							
	Days after sowing							
	Cv. WARDAN				Cv. BB 2			
	90		120		90		120	
Salinity of irrigation water (dS m^{-1})	NR	R	NR	R	NR	R	NR	R
Control	0.57±0.04	0.77±0.08	1.25±0.04	1.34±0.03	0.47±0.04	0.61±0.14	0.65±0.21	0.84±0.06
3	0.75±0.01	0.85±0.04	1.38±0.01	1.48±0.04	0.62±0.06	0.74±0.02	0.81±0.09	1.26±0.02
6	1.21±0.02	1.25±0.02	1.40±0.02	1.47±0.02	0.73±0.02	0.88±0.02	0.87±0.07	1.29±0.03
7.2	0.69±0.02	0.92±0.01	1.26±0.01	1.38±0.01	0.55±0.21	0.70±0.01	0.75±0.04	1.28±0.02
10	0.28±0.08	0.61±0.08	0.54±0.04	0.92±0.02	0.44±0.03	0.59±0.03*	0.64±0.11*	0.74±0.04
12	0.25±0.01	0.50±0.04	0.35±0.04	0.63±0.12	0.30±0.03	0.56±0.03	0.45±0.02	0.58±0.07†
14	0.19±0.01	0.26±0.03	0.30±0.01	0.54±0.03	0.25±0.01	0.44±0.01	0.35±0.08	0.46±0.04

NR: Non-treated, R: Rhizobium culture treated, †Non significant for days, *Non significant for treatment

Table 5: Effect of saline water irrigation on total dry weight in two cultivars of berseem (*Trifolium alexandrinum* L.) Mean±SE (n = 3)

	Total dry weight (g $plant^{-1}$)							
	Days after sowing							
	Cv. WARDAN				Cv. BB 2			
	90		120		90		120	
Salinity of irrigation water (dS m^{-1})	NR	R	NR	R	NR	R	NR	R
Control	1.92±0.05	2.55±0.09	2.94±0.02	3.46±0.04	1.53±0.01	1.89±0.02	2.47±0.13	2.94±0.01
3	2.28±0.05	3.24±0.03	3.72±0.03	4.41±0.17	2.17±0.07	2.58±0.09	2.79±0.07	4.18±0.05
6	3.30±0.04	3.71±0.21	3.89±0.07	4.59±0.04	2.26±0.03	3.36±0.13	3.01±0.10	4.31±0.09
7.2	2.25±0.07	3.26±0.04	3.63±0.01	4.10±0.03	2.02±0.04	2.45±0.05	2.74±0.03	4.07±0.07
10	0.78±0.12	2.16±0.09	1.74±0.01	2.58±0.03	1.27±0.10	1.67±0.05	1.99±0.08	2.29±0.04
12	0.67±0.07	1.60±0.07	1.11±0.03	2.11±0.01	0.86±0.08	1.49±0.04	1.36±0.03	1.88±0.09
14	0.56±0.07	0.86±0.05	0.76±0.05	1.40±0.03	0.59±0.05	0.92±0.04	0.96±0.01	1.31±0.17

NR: Non-treated, R: Rhizobium culture treated cultivars have expressed genetic variations in yield potential and expressed almost similar pattern under various saline irrigations. Both fodder yield as well as total plant dry weight had been increased progressively and significantly ($p<0.001$) with the advancement of plant age and also with saline irrigations upto 7.2 dS m^{-1} and declined at higher salinity regimes (10 to 14 dS m^{-1}) in all cultivars. Same results were observed by Francois (1994) who reported that vegetative growth of different species of canola were unaffected by soil salinity upto 10 dS m^{-1}. The unfavourable effects of salinity on fodder and total biological yield has also been reported in several cereal, pulse and oil crops (Dravid and Goswami, 1987; Grieve *et al*., 1999). The yield characteristics (biological and fodder yield) had been differentially affected in berseem. Field trial had registered maximum fodder yield (economic yield) at the final harvest in *Rhizobium* inoculated sets of cv. WARDAN at 3, 6 and 7.2 dS m^{-1} (Table 6). The similar pattern has been expressed by total plant dry weight (Table 5). Table 7 also indicates that similar findings were recorded for fodder yield (green fodder and dry weight kg m^{-2}). These sets corresponded with the higher fodder yield as well as total plant dry matter indicating that these sets have assimilated highest amount of carbon and subsequently produced maximum fodder and total yield due to maximum photosynthetic leaf area/plant ($p<0.001$). Hussain *et al*. (2002) also confirmed the present findings who reported that high salinity levels decreased total green and dry matter yield as well as root dry weight of berseem while *Rhizobium* inoculation had a positive effect on total green fodder and total dry matter of plant, fodder protein and nitrogen fixation than the similar level of salinity without inoculation.

Cv. BB 2 produced minimum leaf dry weight/plant hence, would have produced least leaf area/plant and subsequently resulted in minimum fodder yield and total plant dry matter in both inoculated and uninoculated sets under various saline treatments whereas cv. WARDAN produced maximum. On the basis of mean productivity Shirinzadeh *et al*. (2010) proved that corn cultivars SC 704 and SC 703 produced higher grain yield under both stress and non stress conditions while cv. SC 720 produced lower under normal conditions. Based on the results that have been obtained in course of the present investigation, it may be assumed that plant productivity can be improved in saline soil by proper soil management such as use of salt resistance varieties and biofertilizer as *Rhizobium*. The inoculation of the seeds had invariably

Table 6: Effect of saline water irrigation on economic yield in two cultivars of berseem (*Trifolium alexandrinum* L.) Mean±SE (n = 3)

	Economic yield (g $plant^{-1}$)							
	Days after sowing							
	Cv. WARDAN				Cv. BB 2			
	90		120		90		120	
Salinity of irrigation water (dS m^{-1})	NR	R	NR	R	NR	R	NR	R
Control	1.69±0.03	2.27±0.03	2.73±0.02	3.15±0.61	1.30±0.01	1.63±0.03	2.24±0.12	2.65±0.10
3	1.96±0.02	2.84±0.08	3.42±0.05	3.97±0.06	1.91±0.09	2.25±0.02	2.49±0.07	3.81±0.13
6	2.93±0.02	3.30±0.07	3.58±0.04	4.14±0.01	1.98±0.02	3.04±0.02	2.71±0.07	3.91±0.07
7.2	2.04±0.05	2.89±0.10	3.41±0.04	3.73±0.11	1.77±0.04	2.12±0.05	2.44±0.01	3.72±0.05
10	0.62±0.03	1.92±0.03	1.54±0.21	2.33±0.03	1.11±0.03	1.45±0.02	1.80±0.02	2.12±0.05
12	0.56±0.04	1.46±0.03	0.99±0.13	1.90±0.01	0.72±0.01	1.32±0.02	1.22±0.09	1.70±0.04
14	0.47±0.04	0.73±0.05	0.66±0.09	1.21±0.03	0.48±0.05	0.78±0.08	0.84±0.41	1.16±0.07

NR: Non-treated, R: Rhizobium culture treated

Table 7: Effect of saline water irrigation on green fodder yield/plot in four cultivars of berseem (*Trifolium alexandrinum* L.) Mean±SE (n = 3)

	Days after sowing							
	Green fodder yield $plot^{-1}$ (kg m^{-2})				Dry fodder yield $plot^{-1}$ (kg m^{-2})			
	120		120		120		120	
	Cv. WARDAN		Cv. BB 2		Cv. WARDAN		Cv. BB 2	
Salinity of irrigation water (dS m^{-1})	NR	R	NR	R	NR	R	NR	R
Control	4.18±0.04	4.80±0.03	3.70±0.04	3.96±0.01	1.05±0.04	1.20±0.02	0.784±0.02	0.839±0.02
3	4.40±0.10	5.20±0.01	4.20±0.04	4.54±0.01	1.10±0.06	1.30±0.02	0.889±0.01	0.961±0.02
6	4.80±0.07	6.00±0.08	4.42±0.03	4.86±0.03	1.20±0.03	1.50±0.04	0.936±0.07	1.03±0.07
7.2	4.38±0.03	5.50±0.09	3.98±0.01	4.25±0.05	1.10±0.01	1.38±0.03	0.843±0.05	0.900±0.03
10	2.58±0.10	2.80±0.05	3.28±0.12	3.58±0.08	0.65±0.10	0.70±0.06	0.695±0.12†	0.758±0.12†
12	2.22±0.02	2.32±0.40#	2.82±0.07	3.10±0.01	0.56±0.02	0.58±0.21#	0.597±0.10†	0.657±0.14†
14	1.85±0.13	2.00±0.36#	2.20±0.09	2.30±0.38#	0.463±0.04	0.50±0.35#	0.466±0.42†	0.487±0.23†#

NR: Non-treated, R: *Rhizobium* culture treated, †Non-significant for cultivar, #Non significant for *Rhizobium* improved the yield irrespective of the saline regimes. The maximum yield was recorded in *Rhizobium* inoculated sets of cv. WARDAN at 3 to 7.2 dS m^{-1} confirming the earlier observations. Crop yields are greatly improved in nodulated plants; legumes can also grow well in poor soils where there is not enough fixed nitrogen to support other types of plants. After harvest legume roots left in the soil decay, releasing organic nitrogen compounds for uptake by the next generation of plants. Farmers take advantage of this natural fertilization by rotating a leguminous crop with a non leguminous one. *Rhizobium leguminosaram* bv. *Trifolli* can colonize rice roots endophytically in the field, where rice is grown in rotation with Egyptian berseem clover (*Trifolium alexandrium*) and can supplement 25-33% of the recommended rate of N fertilizer for rice (Yanni and El-Fattah, 1999).

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