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Short Communication

On-Farm Application of Biofertilizer and Chemical Fertilizers on Lentil in Three Farmers' Field of Bangladesh

Md. Abdul Haque Bhuiyan[1*], Mollah Md. Kamruzzaman[2], Md. Sirajul Islam[3] and Kawsar Uddin Ahmad[4]

[1]Principal Scientific Officer, Soil Microbiology Laboratory, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh; [2]Principal Scientific Officer, Spices Research Sub-Station, BARI, Faridpur, Bangladesh; [3]Chief Scientific Officer, RARS, BARI, Jessore, Bangladesh; [4]Principal Scientific Officer, RARS, BARI, Jessore, Bangladesh

A field trial was conducted at Multi Location Trial (MLT) site in Kustia, Farming System Research & Development (FSRD) site, Ishan Gopalpur in Faridpur and Multi Location Testing (MLT) site of On-Farm Research Division, Bangladesh Agricultural Research Institute, Kuadabazar, Jessore, Bangladesh with the objective to evaluate the response of lentil *Rhizobium* biofertilizer and chemical fertilizers under farmers' field condition and to reduce the uses of N-fertilizer for lentil cultivation. On-farm results revealed that application of *Rhizobium* biofertilizer

Lentil (*Lens culinaris* L.) is cultivated during rabi season in Bangladesh under rainfed condition which occupies the top position in terms of popularity and has been placed second in respect of area and production[1]. About 80% of total lentil in the country is grown in greater Faridpur, Kustia, Jessore, Rajshahi and Pabna districts of Bangladesh. The yield of lentil is very poor (928 kg ha^{-1})[1]. There is a great possibility to increase its production by exploiting better colonization of their root and rhizosphere by *Rhizobium* bacteria, which can reduce nitrogenous fertilizer use and protect the environment as well. Unfortunately, there is a lack of sufficient, effective and resistant *Rhizobium* strains in soil. Moreover, degradation of *Rhizobium* occurs regularly. So, collection and screening of new *Rhizobium* strains and their sub-culturing and testing are necessary. For this reason, few indigenous *Rhizobium* strains were collected from different Agro-Ecological Zones (AEZs) of Bangladesh and were screened, tested at research stations and ultimately needed to be tested at farmers' level. Response of inoculation depends on soil type, cultivars, effectiveness of *Rhizobium* strains and its competitive ability with native *Rhizobium*[2-3]. Khanam *et al.*[4] found 46% higher seed yield in lentil at Meherpur, 30% higher at Faridpur and 33% higher at Jessore, Bangladesh with *Rhizobium* inoculum. They also observed that inoculated plant along with chemical fertilizers gave 72%, 59% and 75% higher yield over farmers' practice at Meherpur, Faridpur and Jessore, Bangladesh, respectively. Response of biofertilizer to lentil is available in research station but information on biofertilizer application in farmers' field is not sufficient. The present study was, therefore undertaken to evaluate the response of lentil to biofertilizer and chemical fertilizers under three farmers' field condition with the ultimate goal to reduce the uses of N-fertilizer for lentil cultivation.

The experiment was laid out in randomized complete block design (RCBD) having four replications with four treatments. The unit plot size was 4 m × 5 m. The variety BARI Masur–4 of lentil and peat based rhizobial inocula (strain BARI RLc-102) @ 1.50 kg ha^{-1} were used for the experiment. The native rhizobial populations in soils of three locations for the lentil were counted in the Soil Microbiology Laboratory of Bangladesh Agricultural Research Institute by the method of Vincent[5]. The soils of Kustia, Faridpur and Jessore contained 4.6, 3.7 and 3.4 cells in $Log_{10}g^{-1}$ soil. There were four treatments viz. T_1: 50-22-42-20 kg N-P-K-S ha^{-1}, T_2: 0-22-42-20 kg P-K-S ha^{-1} + Inoculum, T_3: 0-0-0-0 kg N-P-K-S ha^{-1} + Inoculum and T_4: Farmers' practice which were studied. Farmers' practice was: 20-12-17-0 kg N-P-K-S ha^{-1} at Kustia, 25-18-21-0 kg N-P-K-S ha^{-1} at Faridpur, 20-15-18-8 kg N-P-K-S ha^{-1} at Jessore. BARI Masur-4 and peat based *Rhizobium* inoculum was prepared in the Soil Microbiology Laboratory of BARI (BARIRLC[102]) and was used @ 1.5 kg ha^{-1}. Other chemical fertilizers i.e. P, K and S were applied in two treatments (T_1 and T_2) as basal dose @ 22 kg P ha^{-1} from TSP, 42 kg K ha^{-1} from MoP and 20 kg S ha^{-1} from gypsum but in farmers' practice, 20-12-17-0 kg N-P-K-S ha^{-1} at Kustia, 25-18-21-0 kg N-P-K-S ha^{-1} at Faridpur and 20-15-18-8 kg N-P-K-S ha^{-1} at Jessore were used. No chemical fertilizers were used in T_3 treatment. The crop was sown on 07 November in Kustia, 22 November at Faridpur and 16 November in Jessore.

Growth and development of plants in the field were carefully observed during the course of the experiment. Ten plants along

*** Corresponding author:**
Dr. MAH Bhuiyan, Principal Scientific Officer, Soil Microbiology Laboratory, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh, Tel. (Office): (02) 49270075, Cell. 01720051657, E-mail: mahbhuiyan63@yahoo.com

with roots were collected at 50% flowering stage from each unit plot and dry weight of roots; shoots and nodules including nodule numbers were recorded. The plants were harvested on 28 February in Kustia, 27 February in Faridpur and 02 March in Jessore during the following year. Data on plant height, 1000-seed weight, stover yield and seed yield at harvest were also taken. All the data were analyzed statistically[6].

On-farm response of rhizobial inoculation and chemical fertilizers on nodule number plant^{-1}, nodule weight (mg plant^{-1}), root weight (g plant^{-1}), shoot weight (g plant^{-1}), plant height (cm), 1000-seed weight (g), stover yield (t ha^{-1}), seed yield (t ha^{-1}) and percent yield increase over farmers' practice is presented in Table I.

In Kustia, the highest nodule number (15.30 plant^{-1}) and nodule weight (16.20 mg plant^{-1}) was found in T_2 (PKS + *Rhizobium* inoculum) treatment which was identical with only T_3 (*Rhizobium*) inoculum. Farmers' practice produced the lowest nodule number and nodule weight. Root weight and shoot weight was the highest in T_2 treatment (PKS + Inoculum) which was identical with T_1 treatment (NPKS). Plant receiving inoculum along with PKS fertilizers (T_2) produced the highest plant height, stover yield and seed yield (1.56 t ha^{-1}) though they were non-significant. The highest seed yield recorded by PKS + Inoculum was 24.8% higher over farmers' practice followed by T_1 and T_3 treatment. Farmers' practice (T_4) gave the lowest yield.

In Faridpur, the highest nodule number (16.13 plant^{-1}) and nodule weight (17.20 mg plant^{-1}) were also recorded in PKS + Inoculum (T_2) treated plot which was significantly higher over farmers' practice (T_4) and NPKS but identical to only Inoculum (T_3). Root and shoot weight, plant height, stover yield, 1000-seed weight and seed yield were non-significant. Though the highest seed yield (596 kg ha^{-1}, 58.9% higher over farmers' practice) was recorded by the same treatment (T_2). The overall yield was less at Faridpur due to delayed sowing and high temperature during the growing period.

Table 1. *Effect of rhizobial inoculum and chemical fertilizers on nodulation, dry matter production and yield of lentil at Kustia, Faridpur and Jessore.*

Treatment	Nodule number plant^{-1}	Nodule weight (mg plant^{-1})	Root weight (g plant^{-1})	Shoot weight (g plant^{-1})	Plant height (cm)	Stover yield (t ha^{-1})	1000-seed weight (g)	Seed yield (t ha^{-1})	Yield increase over FP (%)
Kustia									
T_1: NPKS	8.20b	8.50b	0.12a	1.09a	34.5	2.05	18.2	1.53	22.4
T_2: PKS+Inoc.	15.30a	16.20a	0.12a	1.14a	36.1	2.25	18.0	1.56	24.8
T_3: Inoculum	13.90a	14.40a	0.10b	0.90ab	34.5	1.90	16.5	1.40	12.0
T_4: FP*	7.10b	7.00b	0.09b	0.76b	35.3	1.85	17.3	1.25	-
CV (%)	14.0	14.0	11.0	15.0	12.3	14.8	4.3	11.6	-
Faridpur									
T_1: NPKS	11.00b	9.90b	0.09	1.18	23.9	0.265	18.1	0.530	41.3
T_2: PKS+Inoc.	16.13a	17.20a	0.10	1.22	23.0	0.280	18.7	0.596	58.9
T_3: Inoculum	14.03a	15.80a	0.09	1.09	24.6	0.258	17.8	0.328	-14.3
T_4: FP**	8.00c	7.70b	0.08	0.90	24.5	0.263	17.5	0.375	-
CV (%)	14.7	14.8	10.5	14.2	3.9	11.1	4.9	11.3	15.0
Jessore									
T_1: NPKS	7.23c	6.91b	0.08	1.40	28.2	1.35a	18.6a	1.18a	9.3
T_2: PKS+Inoc.	12.01a	12.00a	0.09	1.70	27.8	1.39a	18.3b	1.16a	7.4
T_3: Inoculum	9.62b	10.50a	0.08	1.35	28.4	1.15b	18.2b	1.03b	-4.6
T_4: FP***	4.50d	4.13c	0.07	1.28	27.5	1.33a	18.2b	1.08b	-
CV (%)	13.7	12.6	11.4	17.2	6.8	5.2	5.5	6.6	-

Means followed by common letter are not significantly different at 5% level by DMRT

T_1: $N_{50}P_{22}K_{42}S_{20}$ kg ha^{-1}, T_2: $P_{22}K_{42}S_{20}$ kg ha^{-1} + *Rhizobium* inoculum, T_3: *Rhizobium* inoculum, T_4: FP* ($N_{20}P_{12}K_{17}S_0$ kg ha^{-1}), T_4: FP** ($N_{25}P_{18}K_{21}S_0$ kg ha^{-1}), T_4: FP*** ($N_{20}P_{15}K_{18}S_8$ kg ha^{-1}), FP = Farmer's practice

In Jessore, PKS + Inoculum treated plot produced the highest nodule number (12.01 plant^{-1}) and nodule weight (12.00 mg plant^{-1}) which was significantly higher over farmers' practice. Nodule number was also significantly higher over full doses of NPKS and only inoculum treatment and farmers' practice. Nodule weight was significantly higher over full doses of NPKS and farmers practice but identical with only Inoculum. Root and shoot weight, and plant height were found non-significant. The highest stover and seed yield (1.18 t ha^{-1}, 9.3% higher over farmers' practice) was recorded in the NPKS treatment that was statistically identical with PKS + Inoculum but significantly higher from only inoculum (T_3) and farmers' practice (T_4) . Khanam *et al*.[3] reported higher nodule number (156-245%) and nodule weight (169-284%) due to *Rhizobium* inoculation in lentil. All non-inoculated plant gave lower number of nodule and nodule weight. They observed significant result on stover yield in lentil due to *Rhizobium* inoculation. Khanam *et al*.[4] found 167% and 342% higher nodule mass due to *Rhizobium* inoculum and PKS plus *Rhizobium* (T_2) at Meherpur; 60% and 106% higher nodule mass due to *Rhizobium* and PKS plus *Rhizobium* and 136% and 264% higher nodule mass due to *Rhizobium* and PKS plus *Rhizobium*, respectively. They also reported 46% higher seed yield in lentil at Meherpur, 30% higher at Faridpur and 33% higher at Jessore due to application of *Rhizobium* inoculum while 72% higher at Meherpur, 59% higher at Faridpur and 75% higher at Jessore due to *Rhizobium* inoculum plus full doses of PKS fertilizers. Others also reported higher nodule number, nodule weight and seed yield due to *Rhizobium* inoculation in lentil[7-10]. The results were also in agreement with the findings of Bhuiyan *et al.*[11] and Khanam *et al*.[4] who worked on lentil. In the present study, inoculated plant along with PKS fertilizers produced 7.4% to 58.9% higher yield over the locations.

Benefit cost ratio (BCR) analysis for lentil at Kustia, Faridpur and Jessore is presented in Table 2. For calculating benefit cost ratio analysis only cost of chemical fertilizers and *Rhizobium* inoculum were considered and other costs remained constant. Economic analysis revealed that T_3 treatment i.e., only inoculum gave the highest BCR (86.91) at Kustia followed by T_2 (PKS + Inoculum) and T_1 (NPKS). In Faridpur, the highest BCR was recorded in T_2 treatment whereas in Jessore, T_1 treatment gave the highest BCR. Khanam *et al*.[3] found that inoculated treatment with PKSZn fertilizers gave higher benefit cost ratio (6.44-7.68) in lentil. Bhuiyan and Khanam[12] found 8.71-9.61 BCR by PKSZn + *Rhizobium* inoculum treatment in chickpea.

For all the locations, positive and significant correlation of nodule number was found with nodule weight (Table 3). Nodule number

Table 2. *Benefit cost ratio analysis for lentil at farmers' field in Kustia, Faridpur and Jessore.*

Treatments	Yield (t ha^{-1})	Variable cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	Net return over farmer's practice (Tk. ha^{-1})	Benefit cost ratio
Kustia						
T_1: $N_{50}P_{22}K_{42}S_{20}$	1.53	5,032/-	1,14,750/-	1,09,718/-	17,904/-	3.56
T_2: $P_{22}K_{42}S_{20}$ + Inoculum	1.56	4,422/-	1,17,000/-	1,12,578/-	20,764/-	4.70
T_3: Inoculum	1.40	150/-	1,05,300/-	1,04,850/-	13,036/-	86.91
T_4: FP	1.25	1,936/-	93,750/-	91,814/-	-	-
Faridpur						
T_1: $N_{50}P_{22}K_{42}S_{20}$	0.53	5,032/-	39,750/-	34,718/-	8,884/-	1.77
T_2: $P_{22}K_{42}S_{20}$ + Inoculum	0.60	4,422/-	45,000/-	40,578/-	14,774/-	3.34
T_3: Inoculum	0.33	150/-	24,750/-	24,600/-	1,234/-	-8.23
T_4: FP	0.38	2,666/-	28,500/-	25,834/-	-	-
Jessore						
T_1: $N_{50}P_{22}K_{42}S_{20}$	1.18	5,032/-	88,500/-	83,468/-	5,051/-	1.00
T_2: $P_{22}K_{42}S_{20}$ + Inoculum	1.16	4,422/-	87,000/-	82,578/-	4,161/-	0.94
T_3: Inoculum	1.03	150/-	77,250/-	77,100/-	-1,317/-	-8.78
T_4: FP	1.08	2,583/-	81,000/-	78,417/-	-	-

Urea= Tk. 7.00 kg^{-1}, TSP= Tk. 17.00 kg^{-1}, MoP= Tk. 18.00 kg^{-1}, Gypsum= Tk. 8.00 kg^{-1}, *Rhizobium* inoculum= Tk. 100 kg^{-1}, Lentil= Tk. 75.00 kg^{-1}

Table 3. *Relationship between different parameters of lentil at farmers' field in Kustia, Faridpur and Jessore.*

Parameters	r values		
	Kustia	Faridpur	Jessore
Nodule number vs nodule weight	0.994^{**}	0.917^{**}	0.960**
Nodule number vs root weight	0.401^{NS}	0.688^{*}	-0.297^{NS}
Nodule number vs shoot weight	0.220^{NS}	0.615^{*}	0.575^{NS}
Nodule number vs stover yield	0.097^{NS}	0.119^{NS}	-0.181^{NS}
Nodule number vs seed yield	0.239^{NS}	-0.184^{NS}	0.069^{NS}
Nodule weight vs shoot weight	0.282^{NS}	0.566^{NS}	0.511^{NS}
Nodule weight vs stover yield	0.085^{NS}	0.129^{NS}	-0.168^{NS}
Nodule weight vs seed yield	0.238^{NS}	0.111^{NS}	0.074^{NS}
Shoot weight vs stover yield	-0.059^{NS}	0.148^{NS}	0.136^{NS}
Shoot weight vs seed yield	0.580^{NS}	0.226^{NS}	-0.164^{NS}
Stover yield vs seed yield	0.405^{NS}	0.514^{NS}	-0.030^{NS}

*Significant at 5% level, **significant at 1% level, NS: Non-significant

was correlated with root weight and shoot weight at Faridpur only. Bhuiyan *et al*.[13-14] reported positive and significant correlation between characters for the inoculated chickpea.

It was evident from the experiment that application of *Rhizobium* biofertilizer instead of applying nitrogenous fertilizer can achieve a higher yield of lentil at farmers' field in Kustia, Faridpur and Jessore.

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