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INTEGRATED APPLICATION OF BIOFERTILIZER IN INCREASING GROWTH, NODULATION AND PRODUCTIVITY OF LENTIL (*Lens culinaris* Medikus) IN RED AND LATERITIC SOILS OF WEST BENGAL

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ABSTRACT
A field experiment was conducted in two *rabi* seasons of 2011-12 and 2012-13 at Agricultural Research Farm, Visva-Bharati, Sriniketan, Birbhum, West Bengal, India to study the integrated application of biofertilizer in increasing growth, nodulation and productivity of lentil (*Lens culinaris* Medikus) in red and lateritic soils of West Bengal. The results revealed that significantly highest seed yield of lentil was obtained when PGPR strain is inoculated with Rhizobium, and PSB strain due to significant increment in most of the parameter studied, as compared to uninoculated control and single inoculation of rhizobium, PSB and PGPR, respectively. Yield advantages due to inoculation with rhizobium + PSB strain, rhizobium + PGPR strain, PSB + PGPRstrain and rhizobium + PSB + PGPR strain were (30.21, 12.10, 7.32 and 5.77%), (30.69, 12.52, 7.72 and 6.17%), (25.69, 8.21, 3.60 and 2.10%) and (54.44, 32.96, 27.30 and 25.46%), respectively, as against the uninoculated control (764.67 Kg/ha), only rhizobium inoculation (719 kg/ha^{-1}), only PSB inoculation (751kg/ha^{-1}) and only PGPR inoculation (762kg/ha^{-1}) .

KEY WORDS: biofertilizers; bioinoculants; growth promotion; rhizobacteria, lentil, yield.

INTRODUCTION
Since rhizosphere is a favourable habitat for the proliferation of microorganisms, it exerts a potential impact on plant health and soil fertility. Its effectiveness in respect of its management is of particular importance for the legumes that fix atmospheric nitrogen. Seed inoculation with effective *Rhizobium* inoculants is an important practice. Besides, phosphate solubilizing bacteria (PSB) play a major role in the solubilization and uptake of native and soil phosphorous. Also there is a positive effect of PSB and plant growth promoting rhizobacteria (PGPR) on legume-rhizobia symbiosis. Even the synergism between PSB and PGPR may increase the competitiveness and efficiency of *Rhizobium* inoculation. Plant nutrients are essential for sustaining crop productivity as well as crop production either through application of chemical fertilizers, organic manures and biofertilizers or their combination. With this view, the present study was taken up to study the integrated application of biofertilizer in increasing growth, nodulation and productivity of lentil (*Lens culinaris* Medikus).

MATERIALS & METHODS
A consecutive two-year field experiment was conducted at at Agricultural Research Farm, Visva-Bharati, Sriniketan, Birbhum, West Bengal, India during *rabi* season of 2011-12 and 2012-13. The experimental site was located at 23^{0}39/ W latitude 87^{0}42/ E longitude and 58.9 m AMSL attitude and the soil was sandy loam having pH 5.99, organic carbon 0.48%, available $P_2O_5$70Kg/ha and available K_2O 118Kg/ha. The crop variety Subrata (WBL-58) was sown on December 13 and November 22 during 2011-12 and 2012-13, respectively. The experiment was laid out in RBD with four replications. Besides an uninoculated control, there were seven treatments of seed inoculation with *rhizobium* (*Rh*.) Phosphate solubilizing bacteria (PSB), plant growth promoting rhizobacteria (PGPR), Rh.+PSB, Rh.+PGPR, PSB+PGPR and Rh.+PSB+PGPR. The crop was fertilized with a uniform basal dose of K_2O at 20 Kg/ha applied through muriate of potash, respectively. Seed were inoculated with *Rhizobium*, PSB and PGPR prior to sowing as per treatments using 60 g. culture /Kg seed. The crop was raised following all the recommended agronomic practices and harvested on March 8 and 11 during 2012 and 2013, respectively. All the tested efficient strains of *Rhizobium*, PSB and PGPR, respectively were obtained from the office of the Assistant Director of Agriculture, Bolpur Block, Birbhum , West Bengal, India.

RESULTS & DISCUSSION
Effect on crop growth
Plant Growth Promoting Rhizobacteria (KB-133) alone increased the mean DMA of crop plants (0.67 and 1.35 g/plant) as compared to the uninoculated control (0.60 and 1.16 g/plant) at both 45 DAS and harvest. These results corroborated with the earlier findings of Van Loon et al., (1998) and Ramamoorthy *et al*. (2001). This is due to

increase in the nitrogen fixation, production of growth hormones, solubilization of phosphorous and enhancement in the uptake of essential plant nutrients *etc*. (Subba Rao, 1982; Pal *et al*., 1999; Enebak and Carey, 2000). Combined inoculation of Rh.+PSB+PGPR significantly increased DMA by 61.90% over uninoculated control and 44.96% over *Rhizobium* alone at harvest. Dual inoculation of PSB+PGPR and Rh. +PGPR also increased DMA by (17.24% and 5.43%) and (12.93 and 1.55%) as compared to uninoculated control (1.16 g/plant) and Rhizobium alone (1.29 g/plant) only at harvest. Similar result was also founded by Prasad *et al*. (2002) in urdbean and Chandra *et al*. (2002) in lentil due to synergistic effect. The combined inoculation of Rhizobium+ PSB+ PGPR recorded significantly more mean plant height (38.45 – 47.88 cm) in comparison to the rhizobium alone (32.44 – 44.57 cm) and uninoculated control (30.17-41.97 cm) both at 45 DAS and harvest (Table I).

TABLE 1: Effect of different *Rhizobium* inoculants on crop growth of lentil

Inoculated treatments	Plant height(cm)				Dry matter accumulation(g/plant)			
	45 DAS		Harvest		45 DAS		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Uninoculated control	29.80	31.53	42.40	41.53	0.57	0.63	1.21	1.10
Rhizobium (Rh.)	31.38	33.50	45.81	43.33	0.55	0.77	1.35	1.23
PSB	36.18	32.93	49.27	42.93	0.54	0.63	1.44	1.23
PGPR (*Azotobacter*)	35.08	33.48	47.53	43.48	0.62	0.71	1.44	1.25
Rh.+PSB	31.48	36.28	46.23	46.28	0.49	0.88	1.36	1.33
Rh.+PGPR	32.68	34.63	46.49	44.63	0.63	0.85	1.33	1.28
PSB +PGPR	33.93	34.15	46.24	43.65	0.63	0.78	1.38	1.33
Rh.+PSB+PGPR	40.51	36.38	49.37	46.38	0.43	0.96	1.94	1.80
S.Em±	1.61	1.07	1.66	1.03	0.04	0.03	0.05	0.04
C.D(P=0.05)	4.73	3.14	4.89	3.02	0.12	0.09	0.15	0.13
CV(%)	9.5	6.3	7.1	4.7	14.4	8.3	7.3	6.8

Effect on nodulation

The combined inoculation of Rhizobium+PSB+PGPR gave the significantly highest number (25.15 and 16.80 number of nodules per plant at 45 and 60 DAS) and dry weight (28.17 and 21.82 mg/plant) of nodules as compared to single inoculation of rhizobium (18.71 and 13.74 number of nodules/plant weighing 2079 and 18.02 mg/plant), PSB (20.51 and 13.99 number of nodules/plant weighing 19.83 and 17.56 mg/plant) and PGPR (20.38 and 13.88 number of nodules/plant weighing 20.55 and 16.58 mg/plant). These might be due to synergistic effect of Rhizobium+ PSB+PGPR that is known to enhance better modulation, growth and nitrogen fixation. Similar result was also recorded by Chandra et al,(2002). Combined inoculation of Rhizobium+PSB+PGPR increase mean nodule number by 20.09 – 56.31% and nodule dry weight by 10.99 – 50.00 % as compared to all the treatments.

TABLE 2: Effect of different treatments on nodulation in lentil

Inoculated treatments	Nodule no.(No./plant)				Nodule Weight(mg/plant)			
	45 DAS		Harvest		45 DAS		Harvest	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Uninoculated control	14.43	17.75	13.09	13.03	12.10	25.45	16.53	17.40
Rhizobium (Rh.)	16.53	20.88	13.93	13.55	10.90	30.68	17.55	118.48
PSB	21.81	19.20	14.42	13.55	10.50	29.15	17.09	18.03
PGPR (*Azotobacter*)	20.63	20.13	14.32	13.43	9.96	31.13	16.15	17.00
Rh.+PSB	18.48	22.95	13.60	14.35	11.90	38.85	17.88	18.83
Rh.+PGPR	16.83	23.35	13.55	14.23	12.10	35.68	17.55	18.48
PSB +PGPR	17.81	21.40	13.90	13.88	11.53	34.68	17.00	17.63
Rh.+PSB+PGPR	23.67	26.63	16.81	16.78	12.80	43.53	21.26	22.38
S.Em±	0.87	0.34	0.44	0.46	0.48	0.99	0.59	0.42
C.D(P=0.05)	2.56	1.00	1.29	1.36	1.42	2.92	1.73	1.23
CV(%)	9.3	3.2	6.2	6.6	8.4	5.9	6.7	4.5

Effect on seed yield

The individual inoculation of rhizobium, PSB and PGPR increased the mean seed yield by 16.16, 21.32 and 23.10% over uninoculation control (619 Kg/ha). Dual inoculation of Rhizobium+PGPR and PSB+PGPR increased by 30.69, 12.52, 7.72 & 6.17% and 25.69, 8.21, 3.60 & 2.10% over uninoculated control (619kg/ha), rhizobium alone (719kg/ ha), PSB alone (751 kg/ha) and PGPR alone (762 kg/ha),

respectively. The combined inoculation of rhizobium+ PSB+ PGPR significantly increased by 54.44, 32.96, 27.30 and 25.46% as against uninoculated control, Rhizobium, PSB and PGPR alone only, respectively (Table 3). Such positive effects of combined inoculation of Rhizobium+PSB+PGPR have also been reported by earlier worker (Chandra *et al*., 2002). These result indicated that combined inoculation of rhizobium+PSB+PGPR might be positively effect with each other due to providing plant growth hormones in rhizosphere leading to more yield (Zahir *et al*., 2004). These include increase in the nitrogen fixation, production of auxins, gibberellins, cytokinins, ethylene, solubilization of phosphorous, oxidation of sulfur, increase in availability of nitrate, extra cellular production of antibiotics, lytic enzymes, hydrocyanic acid, increases in root permeability, strict competition for the available nutrients and root sites, suppression of deleterious rhizobacteria, and enhancement in the uptake of essential plant nutrients *etc*. (Subba Rao,1982; Pal *et al*., 1999; Enebak and Carey, 2000). Such increase in yield might be attributed to better crop growth (plant height 34.28-38.45cm and DMA of 0.67 – 0.70 g/plant at 45 DAS), nodulation (20.38-25.15 nos. of nodules weighing 20.55-28.17 mg/plant at 45 DAS) and improvements in yield attributes *viz*. pod/plant, seed/pod and 100-seed weight. These results also corroborated with the earlier report of Prasad *et al*. (2002) and Zahir *et al*. (2004). Thus, seed inoculation with *Rhizobium* + PSB + PGPR proved to be an effective technique in improving growth, nodulation and productivity of lentil. The positive effect of PGPR on Rhizobium might be attracted to synthesis of growth promoting substances which lead to stimulate the root growth and elongation, thereby forming about more nodulation, nitrogen fixation and corp. yield (Rautela *et al*., 2001) in urdbean and in lentil (Chandra *et al*., 2002).

The study suggested that though the PGPR had favourable effect on lentil-*Rhizobium* symbiosis, selection of effective strains which were more compatible to *Rhizobium* would be necessary for obtaining the meaningful benefits from co-inoculation. However, further studies need to be made for conclusion of the present findings at other locations under different soil and agro ecological situations.

TABLE 3: Effect of Rhizobacteria inoculants on seed yield of lentil

Inoculated treatments	No. of branches plant^{-1}		No. of productive pods plant^{-1}		No. of seeds pod^{-1}		100 grain wt.(g)		Seed yield (kg ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Uninoculated control	5.48	4.72	30.40	29.73	1.70	1.80	1.68	1.70	687	551
Rhizobium (Rh.)	7.35	5.09	19.90	42.08	1.75	1.78	1.75	1.75	744	694
PSB	6.41	6.67	37.28	40.65	1.83	1.75	1.97	1.97	663	838
PGPR (*Azotobacter*)	6.87	6.51	37.54	40.88	1.80	1.80	1.96	1.97	682	842
Rh.+PSB	7.68	5.85	30.28	45.08	1.78	1.78	1.80	1.82	751	861
Rh.+PGPR	7.69	6.15	29.41	44.78	1.79	1.78	1.78	1.80	758	869
PSB +PGPR	7.15	6.27	29.26	46.43	1.79	1.75	1.82	1.83	694	862
Rh.+PSB+PGPR	8.95	6.76	43.16	49.15	1.90	1.85	2.04	2.06	871	1041
S.Em±	0.22	0.22	1.56	1.41	0.05	0.07	0.09	0.08	30.15	21.5
C.D(P=0.05)	0.66	0.63	4.57	4.13	0.15	0.20	0.25	0.23	88.6	60.03
CV(%)	6.4	7.2	9.3	6.7	5.7	7.8	9.4	8.4	7.5	5.5

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