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RESPONSE OF SOYBEAN TO INOCULATION WITH VARIOUS CULTURES OF *RHIZOBIUM JAPONICUM*

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Field experiments carried out with different indigenous cultures of *Rhizobium japonicum* at Pantnagar revealed that inoculation with effective strain of *R. japonicum* was imperative for successful cultivation of soybean. There was better nodulation and higher bacteroid and leghaemoglobin content in the nodules in the case of inoculated plants. Application of fertilizer nitrogen adversely affected the nodulation. Indigenous cultures E-188 (peat), E-188 (lignical), E-188 + E-400 (peat), SB-1 and SB-16 (peat) proved as effective as imported culture 'Nitragin'. Peat-based cultures were better than sand and broth cultures. Combination of effective strains improved the efficiency of inoculation as against single effective strain.

INTRODUCTION

In India, very little work has been reported on the comparative performance of various cultures of *Rhizobium japonicum* for inoculation of soybean seeds. In most of the trials conducted at various centres, the imported mixed strains of *Rhizobium* in the form of commercial formulations such as 'Nitragin', 'Legume-aid', etc., have proved most effective. Import of inoculum from abroad for small area is feasible but as the area of soybean would increase in the country some indigenous and reliable sources will have to be developed. This will necessitate the production of rhizobial cultures indigenously. As a first step in this direction a series of experimental cultures have been prepared in either peat or soil or as broth so that their efficiency may be tested. The present investigation aims at evaluating the efficiency of several indigenously developed inocula in comparison to standard imported commercial inocula of repute.

MATERIALS AND METHODS

In all, three field experiments were conducted at Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. Experiment I was conducted during rainy season of 1970–71 on a sandy loam soil using variety Bragg, while Experiments II and III were conducted during spring season of 1971 on a silty loam soil using variety Traverse. Randomised complete block design was used. The treatment details are given in Tables I, II and III. The performance was evaluated in terms of nodulation, bacteroid content and leghaemoglobin synthesis in fresh nodules at 60th day of crop age and bean yield at the time of crop harvest. The bacteroid and leghaemoglobin estimations were made by following the methods described by Bergersen (1960) and Proctor (1963) respectively. The experimental data on grain yield were subjected to analysis of variance appropriate to the design.

Results and Discussion

The overall evaluation of the efficiency of inoculants as judged from the grain yield performance of Bragg variety in experiment I revealed that inoculation resulted in increased bean yield (about 16 per cent) as compared to uninoculated crop, which was statistically significant (Table I). The overall treatment variance, however, was non-significant because the differences between various inoculants themselves were negligible. The roots of the plants under uninoculated condition also had nodules, which should have been caused either by naturalised rhizobia present in the soil or by the ones comming-in due to contamination from the adjoining inoculated plots (Table I). Evaluation of nodulation at 60 days after planting (Table I) revealed that application of fertilizer nitrogen at 100 kg N/ha adversely affected this attribute. Adverse effect of large quantities of combined nitrogen on the microsymbiont has been reported by Stewart (1967) also. Bacteroid count and leghaemoglobin content (Table I) were quite low for nodules of uninoculated plants as compared to the

Table I

Number and fresh weight of nodules per plant, bacteroid and leghaemoglobin content per gram of fresh nodules at 60 days after planting and bean yield per hectare as influenced by inoculation treatments

Treatment	Number of nodules	Fresh weight of nodules (mg)	Number of bacteroids (X 10^4)	Leghaemo-globin content (μg)	Grain yield (q/ha)
Control (no inoculation)	49	1865	1615	186.00	23.07
100 kg N/ha (no inoculation)	40	751	1027	73.59	24.45
IASC-1 (Composite culture from I.A.R.I.)	65	1580	4853	145.36	28.43
IASC-2 (Mass culture from I.A.R.I.)	78	1817	1290	148.99	26.44
3 I 1646 (Single strain)	50	1365	8532	409.50	27.61
JNKVV (Composite culture from Jabalpur)	103	2496	8591	324.40	28.46
Nitragin (Mixed strain peat culture from USA)	111	2809	8085	293.14	27.63
SB-1 (Single strain, IARI)	47	1597	4478	151.58	26.35
SB-12 (Single strain, IARI)	51	1544	4273	237.77	26.63
SB-16 (Single strain, IARI)	75	696	4171	180.96	26.37
UPAU-2 (Single strain, Pantnagar)	36	1458	8255	161.83	26.84
USDA-136 (Single strain, USA)	32	1318	5505	250.42	27.42
S. Em. ±					1.15
C. D. at 5%					—
Inoculation vs. No inoculation					Sig.
C. V. %					8.6

nodules from plants inoculated with different cultures. This should explain as to why the uninoculated crop yielded lower than the inoculated one in spite of nodulation.

Experiment II was conducted with the same objective as Experiment I. Thirteen cultures were tested along with the uninoculated control on a site where no soybean crop was grown in the past. Inoculation with Nitragin, E-188 (peat) and E-188 (lignical) resulted in more than 220 per cent increase in the yield as compared to uninoculated control (Table II). Inoculation with SB-1 and SB-16 cultures caused more than 100 per cent increase in yield over control. Rest of the cultures failed to cause any significant improvement in the yield. The yield response occurred due to improvement in nodulation and bacteroid and leghaemoglobin content of nodules, all pointers to the effective symbiosis due to inoculation with effective cultures.

TABLE II

Number and dry weight of nodules per plant and bacteroid and leghaemoglobin content per gram of fresh nodules at 60 days after planting, and bean yield as influenced by inoculation treatments

Treatment	Number of nodules	Nodule dry weight (mg)	Bacteroid number ($X\ 10^4$)	Leghaemo-globin content (µg)	Bean yield (q/ha)*
Control	0.0	0.0	—	—	6.79 c
E-188 (Lignical)	22.0	147.5	2775	189.90	21.34 a
E-188 (Peat)	34.0	187.3	2875	204.46	25.37 a
E-188 (Sand)	0.0	0.0	—	—	8.92 c
FRS (Sand)	5.0	21.2	1895	125.00	9.96 c
IASC-2 (Mass culture)	0.0	0.0	—	—	7.12 c
Iowa State (Peat based)	0.0	0.0	—	—	6.89 c
Mixed IARI (Peat based)	4.0	17.7	2342	156.60	9.56 c
SB-1 (Single strain peat based)	2.5	11.6	1898	123.60	15.75 b
SB-12 (Single strain peat based)	0.0	0.0	—	—	7.84 c
SB-16 (Single strain, peat based)	8.0	24.0	2232	127.72	16.12 b
UPAU-2 (Single strain, broth)	3.6	15.6	2013	125.00	10.12 c
UPAU-3 (Mixed strain, broth)	0.0	0.0	—	—	7.87 c
Nitragin	33.0	198.6	2958	192.40	25.87 a
S. Em. ±					1.25
C. D. 5%					4.06
C. V. %					19.50

*Figures with identical letters are statistically not different from each other.

The fact that the indigenous cultures E-188 (peat) and E-188 (lignical) developed at JNKVV Jabalpur, proved as effective as Nitragin imported from U.S.A., points to the possibility of production of indigenous soybean inoculants as effective as the imported commercial inoculants of world repute.

TABLE III

Number and dry weight of nodules per plant, bacteroid and leghaemoglobin content per gram of fresh nodules at 60 days after planting, and bean yield as influenced by inoculation with various peat based inocula containing single or multiple strains

Treatment (Strains)	Number of nodules	Dry weight of nodules (mg)	Number of bacteroids (X 10^4)	Leghaemo-globin content (µg)	Bean yield (q/ha)
Control	0.00	0.00	—	—	7.37
E-177	11.00	92.20	2511	162.37	23.25
E-188	18.27	124.48	2675	207.27	23.84
E-400	22.00	152.00	2667	205.06	13.06
E-177 + E-188	12.15	111.97	1875	176.12	22·87
E-177 + E-400	22.05	142.05	3205	198.22	21.68
E-188 + E-400	18.15	159.08	3741	201.23	25.09
E-177 + E-188 + E-400	19.00	137.25	2774	211.00	22.44
Nitragin	21.75	146.00	2771	211.16	27.12
S. Em. ±					1.00
C. D. 5%					2.91
C. V. %					18.0

Several workers have reported failure of nodulation in legumes grown in rhizobia-free soil for the first year (Harty 1955; Harty and Bygott 1965; Balasundarum 1971). As has already been mentioned, nodulation failure was seen in case of inoculation treatments in this experiment also. These were mostly sand-based and liquid cultures. As against this, the peat-based cultures showed better performance. Peat provides better shelter to rhizobia and is effective in protecting them from unfavourable soil conditions. Like peat-based cultures, E-188 (lignical) culture also showed high efficiency, suggesting thereby that lignical may prove another potential carrier for indigenous inoculants which is an important observation in view of the fact that no large peat deposits have been noticed in our country as yet.

Experiment III was conducted to test the relative performance of single and combined strains of *R. japonicum* in peat-based cultures produced indigenously at Jabalpur as against 'Nitragin' and no inoculation control. Inoculation significantly increased the yield over uninoculated control by encouraging the nodulation (Table III). Indigenous inoculants E-188 and E-400 in combination were at par with the Nitragin, although each of them singly was slightly inferior to Nitragin. This indicates the necessity for the development of indigenous inoculants with multi-strains rather than single strain inoculants. Some of the combinations of strains tested in this experiment, however, were not found good and hence their antagonistic behaviour needs further investigation. Specific adaptation of the strains to the different environmental conditions and/or varieties may be a factor in their relative survival and performance.

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