Combined and Individual action of bioagents and fungicides on seed yield of Soybean (*Glycine max* L. Merrill)

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Abstract: A field experiment was conducted during kharif 2011, at Field Experimentation Centre, Department Genetics and Plant breeding, Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHIATS), Allahabad (U.P). The experiment was conducted in Randomized Block Design along with ten treatments, which were replicated thrice. The treatments included individual and combined treatment of bioagents (*Rhizobium, Trichoderma viride, Pseudomonas fluorescence, Bacillus subtilis,* VAM) and fungicides (Thiram and Carbendazim). This study showed that the seeds treated with combinations of bioagents (*Rhizobium* @ 30 g/kg seed+*Bacillus subtilis* @ 30 g/kg seed+VAM @ 15 kg/ha+*Trichoderma viride* @10 g/kg) recorded significantly higher field emergence (88.33%), days to 50% flowering (34.33 days), plant height at harvest (48.57 cm), number of pods (61.70 at harvest), seed index (9.27 g), seed yield (11.46 g $plant^{-1}$ and 25.47 q ha^{-1}) and benefit: cost ratio (2.70).

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1. Introduction:

Soybean is known as the "Golden Bean" of the 20th Century. Soybean has great potential as an exceptionally nutritive and very rich protein food. Soybean ranks first amongst oilseed crops in the world; the area under soybean crop is 94 million hectare with annual production of 232 million tonnes with an average productivity of 2400 kg ha^{-1}. In India it is grown on an area of 9.62 million hectare with annual production 10.82 million tonnes with an average productivity of 1124 kg ha^{-1} (Anonymous 2011).

The continuous use of chemical inputs in agriculture is one of the main causes of imbalance in the soil microbial activity, which leads to the outbreak of many diseases in crop plants. Cultivated soybean is affected by several species of fungi that cause severe yield losses and majority of them are pathogenic and are seed-transmitted, thus demanding chemical seed treatment. Brazil is the world's second largest producer of soybean, has more than 90% of the farmers treating seeds with fungicides. However, besides the negative effects on the environment and human health, one main problem reported in the country is that fungicides often drastically reduce the viability of *Bradyrhizobium* cells, decreasing nodulation and nitrogen fixation rates (Hungria *et al* 2005). In this context, instead of using chemicals use of micro-organisms as biological control agents may represent an alternative method to control pathogenic fungi (Cubeta *et al.* 1985), Bernal *et al*. 2002).

Innovative research on kharif soybean at the Department of Genetics and Plant Breeding, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad has been carried out to assess the efficiency of bioagents and fungicides and to elucidate the synergistic effects of combination treatments of bioagents in soybean.

2. Materials and methods

The field experiment was conducted during kharif 2011 at Field Experimentation Centre, Department of Genetics and Plant Breeding, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad. This experiment was conducted to know the effect of fungicides and individual and combined treatment of bioagents on seed yield. Before sowing the seeds were treated with bioagents along with jaggery solution as an adhesive. Treated seeds were dried under shade for an hour and used for sowing. The treatments consisting of T_0 (Control), T_1 (*Rhizobium* @ 30 g/kg seed), T_2 (*Pseudomonas fluorescens*@ 30 g/kg seed), T_3 (*Bacillus subtilis* @ 30 g/kg seed), T_4 (*Trichoderma viride* @ 10 g/kg seed), T_5 (VAM @ 15 kg/ha T_6 (Thiram @ 2 g/kg seed), T_7 (Carbendazim @ 2 g/kg seed), T_8 (*Rhizobium* @ 30 g/kg seed + *Bacillus subtilis* @ 30 g/kg seed + VAM @ 15 kg/ha + *Trichoderma viride* @ 10 g/kg seed) and T_9 (*Rhizobium* @ 30 g/kg seed + *Pseudomonas fluorescens*@ 30 g/kg seed + VAM @ 15kg/ha + *Trichoderma viride* @ 10g/kg seed). Standard agronomic practices and plant protection measures were taken as per schedule. Observations were recorded on five randomly selected plants per replication for field emergence, plant height; number of pods/plant, seed index and seed yield/plant and days to 50% flowering and days to maturity were recorded on plot basis.

The economics of seed production was computed by taking in to consideration the cost of bioagents and fungicides apart from the other costs that are common to all treatments as per package of practice. The total value of the actual produce was calculated and the net income was worked out by deducting the cost of seed production from the value of actual produce. The benefit cost ratio was worked out using net income and total cost of seed production.

Benefit cost ratio was worked out as follows-

$$\text{*B: C ratio} = \frac{\text{Gross returns (Rs. /ha)}}{\text{Total cost of cultivation (Rs. /ha)}}$$

***B:C- Benefit : Cost Ratio**

3. RESULTS AND DISCUSSION

Field Emergence:

A significant difference in field emergence was observed among the treatments. Maximum field emergence was recorded in T_8 (88.33%) which was statistically on par with T_2 (85.33%). The higher field emergence percentage may be due to release of plant growth promoting substances, nutrient mobilization, enhanced nutrient uptake and antgonistic property of *Trichoderma viride* and *Bacillus substillus* against seed and soil borne pathogens (table 1).

Plant height:

The plant height at harvest differed significantly among the treatments. Maximum plant height was recorded T_8 (48.57 cm) which was on par with T_9 (46.10 cm), T_3 (44.50 cm) and T_1 (42.30 cm) (Table 1). The increase in plant height was due to extensive root develpopment which has resulted in uptake of nitrogen and phosphorus, further attributed to increased cell elongation and multiplication, nutrients transportation towards above ground parts and plant growth promoting substances released by different bioagents during crop growth. Similar response due to co inoculation was observed by Tomar *et al*., (1996) in gram and Parashuram Gani (2003) in greengram.

Number of pods per plant:

The number of pods per plant at 60 days after sowing differed significantly among the treatments. Maximum number of pods per plant was observed in T_8 (50.37) which was statistically on par with T_9 (4.77), T_7 (43.03), T_1 (42.03) and T_3 (41.10). The number of pods per plant at harvest differed significantly among the treatments. Maximum number of pods per plant was noticed in T_8 (61.70) which were statistically on par with T_9 (59.43) and T_7 (54.37). The increase in number of pods may be due to the more number of branches per plant, decreased flower drop and increased pod setting, nutrient mobilization, nutrient uptake, release of plant growth promoting substances by microbial inoculants and antagonistic activity against pathogens.

Seed yield per plant:

Treatments differed significantly among each other for seed yield per plant. Highest seed yield per plant was recorded in T_8 (11.46g) which was on statistically par with T_9 (10.59g). The appreciable increase in yield may be attributed to extensive root development which resulted in uptake of nitrogen and phosphorous and their transportation towards above ground parts, plant growth promoting substance secreted by microorganims helped in various metabolic activites and control of pathogens and in the proliferation of benefical organisms in the rhizosphere which led to higher plant,number of branches and number of pods per plant in turn led to higher seed yield per plant, net plot yield and seed yield per hectare. Similar reesponse due to co-inoculation was observed by Mohammad and Hussain (2003) in mungbean.

Table 1: Effect of bioagents and fungicides on seed yield attributes in Soybean

Treatments	FE (%)	DF	PHH	NPH	SI (g)
T_0	69.33	29.67	34.77	48.43	7.37
T_1	73.67	30.33	42.30	53.37	8.60
T_2	85.33	31.67	38.90	50.50	8.63
T_3	76.67	32.67	44.50	52.43	8.72
T_4	74.00	30.67	40.17	50.97	8.58
T_5	73.00	31.33	35.04	52.30	8.67
T_6	75.33	30.33	41.83	50.43	7.66
T_7	81.33	33.33	37.63	54.37	7.45
T_8	88.33	34.33	48.57	61.70	9.27
T_9	84.33	32.00	46.10	59.43	8.60
S. Em. ±	1.37	0.91	1.74	2.39	0.26
CD (P=0.05)	4.07	2.72	5.17	7.11	0.79
CV (%)	3.04	5.01	7.36	7.76	5.48

Seed index:

The seed index differed significantly among the treatments. Maximum seed index was recorded in T_8 (9.27g) which was on par with T_3 (8.72g). Bioagents play a important role in nitrogen and phosphorous mobilization and uptake, which were very much essential in synthesis of nucleic acid and proteins,they also reduce the infection of seed borne pathogen and they release plant growth promoters there by better diversion of photosynthates to seeds and better accumulation of food reserves in the seeds. Similar response due to co-inoculation was observed by Simple *et al*., (2003) in chickpea, Yuming *et al*., (2003) in soybean and Almas and Khan (2003) in greengram.

Legends:

FE- Field emergence, DF- Days to 50% flowering, PHH - Plant height at harvest, NPH- No. of pods at harvest, SI- Seed index, T_0: Control, T_1: *Rhizobium* @ 30 g/kg seed, T_2: *Pseudomonas fluorescens*@ 30 g/kg seed, T_3: *Bacillus subtilis* @ 30 g/kg seed, T_4: *Trichoderma viride* @ 10 g/kg seed, T_5: VAM @ 15 kg/ha, T_6: Thiram @ 2 g/kg seed, T_7: Carbendazim @ 2 g/kg seed, T_8: *Rhizobium* @ 30 g/kg seed + *Bacillus subtilis* @ 30 g/kg seed + VAM @ 15 kg/ha + *Trichoderma viride* @ 10 g/kg seed and T_9: *Rhizobium* @ 30 g/kg seed + *Pseudomonas fluorescens*@ 30 g/kg seed + VAM @ 15kg/ha + *Trichoderma viride* @ 10g/kg seed .

Seed yield:

Significant difference in seed yield per hectare was observed among the treatments. Highest seed yield per hectare was recorded in T_8 (25.47q) which was statistically on par with T_9 (23.53q) treatment. The probable reason for such findings was due to more number of pods per plant and seed index.

Economics:

Maximum total returns, net returns and benefit cost was recorded in T_8 (Rs 63310, Rs 36251 and 2.7 respectively) followed by T_9 (Rs. 58504, Rs. 31444 and 2.5 respectively), T_6 (Rs. 56810, Rs 31686 and 2.6 respectively), T_5 (Rs. 56699, Rs. 29686 and 2.4 respectively), T_2 (Rs. 54784, Rs. 29567 and 2.5 respectively), T_4 (Rs. 54655, Rs. 29502 and 2.5 respectively), T_7 (Rs. 52943, Rs. 27807 and 2.5 respectively) and T_3 (Rs. 50696, Rs. 25492 and 2.3 respectively) while minimum was encountered in T_0 (Rs 47694, Rs 22581 and 2.2, respectively) (table 2).

Table 2: Seed yield and Economics of Soybean

Treatments	Seed yield (q/ha)	Net profit (Rs)	Benefit cost of ratio
T_0	19.19	26981	2.30
T_1	20.07	29011	2.39
T_2	22.04	33891	2.62
T_3	20.39	29803	2.43
T_4	21.99	33882	2.63
T_5	22.81	33736	2.47
T_6	22.85	33907	2.62
T_7	21.30	32154	2.55
T_8	25.47	39827	2.70
T_9	23.53	35021	2.49
S. E. m±	1.00	--	--
CD (P=0.05)	2.98	--	--
CV (%)	7.90	--	--

Legends:

T_0: Control, T_1: *Rhizobium* @ 30 g/kg seed, T_2: *Pseudomonas fluorescens* @ 30 g/kg seed, T_3: *Bacillus subtilis* @ 30 g/kg seed, T_4: *Trichoderma viride* @ 10 g/kg seed, T_5: VAM @ 15 kg/ha, T_6: Thiram @ 2 g/kg seed, T_7: Carbendazim @ 2 g/kg seed, T_8: *Rhizobium* @ 30 g/kg seed + *Bacillus subtilis* @ 30 g/kg seed + VAM @ 15 kg/ha + *Trichoderma viride* @ 10 g/kg seed and T_9: *Rhizobium* @ 30 g/kg seed + *Pseudomonas fluorescens*@ 30 g/kg seed + VAM @ 15kg/ha + *Trichoderma viride* @ 10g/kg seed .

4. Conclusion

From the present study, it is quite evident that the bioagents is very efficient botanicals for creating genetic variability in soybean. It has also been concluded from the present investigation that the treatment combination of bioagents, i.e. T_8 (*Rhizobium* @ 30 g/kg seed + *Bacillus subtilis* @ 30 g/kg seed + VAM @ 15 kg/ha + *Trichoderma viride* @ 10 g/kg seed) showed a significant results as compared to individually treatment of bioagents and fungicides and having also significant role in field emergence, days to 50% flowering, plant height, number of branches, number of pods/plant, seed index, seed yield per plant and high benefit cost ratio.

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