

International Journal of Advanced Biochemistry Research

NAAS JOURNAL
RATING: 5.29

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(6): 1629-1635
www.biochemjournal.com
Received: 13-04-2026
Accepted: 15-05-2026

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Integrated management of root rot of soybean (*Glycine max* (L.) Merrill)

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i6Ss.8897>

Abstract

The experiment was conducted in Randomized Block Design with nine treatments and in three replications. It was revealed from the present investigation includes different studies viz., isolation, identification, pathogenecity studies and management of pathogens by using organic - amendments, bio - agents and fungicides. The pathogens were isolated from the infected roots of soybean plants. The pure culture of pathogen was obtained by hyphal tip method. On the basis of morphological characters, the pathogens were identified as *Rhizoctonia bataticola* which produced brown to black, right angle branched mycelia with septa. Some fungicides viz, Carboxin + Thiram, Carboxin + Thiram + Carbendazim, Carbendazim, Mancozeb and Carbendazim + Mancozeb and bio – agents viz, *Trichoderma harzianum*, *Pseudomonas fluorescens* and *Trichoderma harzianum* + *Pseudomonas fluorescens*, were tested *in vitro* against *Rhizoctonia bataticola* by poison food technique. Fungicides Carboxin + Thiram, Carboxin + Thiram + Carbendazim, Carbendazim and Carbendazim + Mancozeb were found 100% effective in controlling the radial mycelial growth of the test pathogen upto 7th days after inoculation. The soil application, seed treatment and soil drenching with fungicides, organic amendments and bioagents treatment (T₈) Pre- sowing soil application of FYM enriched with *Trichoderma harzianum* and *Pseudomonas fluorescens* 2.5 kg and 5 kg respectively + neem cake 500 kg/ha + Seed Treated with *Trichoderma harzianum* (4 g/kg seed) and *Pseudomonas fluorescens* (10g/kg seed) was found most effective in reducing the incidence of root rot. The highest grain yield (2012 kg/ha) was recorded in treatment (T₈) Pre- sowing soil application of FYM enriched with *Trichoderma harzianum* and *Pseudomonas fluorescens* 2.5 kg and 5 kg respectively + neem cake 500 kg/ha + Seed Treated with *Trichoderma harzianum* (4 g/kg seed) and *Pseudomonas fluorescens* (10g/kg seed) followed by in (T₁) Seed Treated with Carboxin + Thiram (2.0 g/kg seed) + soil drench with Carboxin + Thiram at 50 DAS i.e 1979 kg/ha. Higher ICBR and maximum net return (1:64.33) and (23160 Rs/ha) was (T₅) Pre-sowing soil application of *Pseudomonas fluorescens* @ 5kg/ha + Seed Treated with *Pseudomonas fluorescens* (10 g/kg seed) and (1:8.64) and (23240 Rs/ha) (T₁) (Seed Treated with Carboxin + Thiram (2.0 g/kg seed) + soil drench with 0.1% Carboxin + Thiram + Carbendazim at 50 DAS.) respectively is recommended for the management of root rot of soybean.

Keywords: *Rhizoctonia bataticola*, soybean, root rot, *Trichoderma harzianum*, *Pseudomonas fluorescens*

Introduction

Soybean (*Glycine max* (L.) Merrill) is a species of legume belongs to the family Leguminosae and sub-family Papilionoidae and native to East Asia. Soybean plant is classed as an oilseed rather than a pulse by the UN Food and Agricultural Organization (FAO). It is an ancient crop which is being used as food, feed and also in industry for various purposes. The crop is presently grown in most of the part of the world and is a primary source of vegetable oil and protein. It contains 40.0 per cent protein, 8.77 per cent fats, 27.12 per cent nitrogen, 5.89 per cent ash, 5.96 per cent fiber and nutritional superiority on account of containing essential amino acids, unsaturated fatty acids, carbohydrates, vitamins and minerals. Soybean tocopherols have been used as antioxidants for vegetable oils. Recent research studies indicate that women who eat soybean rich diets are up to eight times less likely to develop breast cancer than other women, probably because of the presence of *anti-estrogen* compound such as phytoestrogens (Sharma, 1996). Presently it is contributing 43% to the total oilseeds and 25% to oil production of the country (Anonymous, 2014) [4].

During 2012-13, it is estimated that the crop worldwide covered an area of 109.11 million hectares producing 268.27 million metric tons with productivity of 2.46 tons per hectare. In India, area and production of soybean have reached to 10.7 million ha and 14.14 million tons during the year 2012

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from meager area of 0.03 million ha and production 0.01 million tons in 1970, which is a magnificent enlarge (Anonymous, 2014) [4]. In Maharashtra, area under soybean during 2013-14 covered 38.70 lakh ha with 46.46 lakh metric ton production and obtained 12.04 q/ha productivity (Anonymous, 2013) [3]. Soybean grown in Vidarbha (2013-14) on an area 21.34 lakh ha with 18.78 lakh MT production and 7.68 q/ha productivity (Anonymous, 2013) [3].

The root rot pathogenic fungi are major threat for this crop as these fungi attack on the root of the plant and destroy the proper functioning of the plant to take water and other nutrients upward. *Sclerotium rolfsii*, *Rhizoctonia solani*, *R. bataticola* (*Macrophomina phaseolina*), *Fusarium* spp., *Phytophthora* spp. and *Pythium* spp. are considered as major soybean seedling pathogens, which contribute to stand reduction. Among these, root rot of soybean caused by *Rhizoctonia bataticola* (Taub.) Butler (pycnidial stage *Macrophomina phaseolina* (Tassi) Goid) Yield losses 30-50 per cent due to *Macrophomina phaseolina* in soybean crop have been reported (Yang and Navi, 2005) [36]. Plant losses up to 77 per cent were reported in soybean due to *Rhizoctonia bataticola* (Taub.) Butler (Muthusamy and Mariappan, 1991) [24]. *Rhizoctonia bataticola* reduces the yield of soybean by 2-21 per cent (Wrather and Koenning, 2006) [35]. Yield reductions results from post emergence death of seedling and weakening root rot as well as premature death of infected plants.

Recent reports in the field of bio - control in controlling crop diseases include the use antagonistic fungi either singly or in combination with other beneficial bacteria at low or recommended dose of the chemical pesticides or botanicals help to manage the diseases. The integrated use of genetic, molecular and ecological approaches will form the basis for significant advances in bio - control research. In particular, additional efforts in following areas will be essential for developing a more complete understanding of bio - control and for making practical use of bio - control strategies for agriculture.

Material and Methods

Isolation and identification

The culture of *Rhizoctonia bataticola* used in the present investigation was isolated from infected roots and basal stem of soybean plant collected from the field trials test will be conducted during *khari*f, 2013-14 at Plant Pathology Research Farm, College of Agriculture, Nagpur.

An isolate of the pathogen from the infected portion of root and stem were cut into 3 mm small bits and surface sterilized with 0.1 per cent HgCl₂ solution for one minute and three subsequent washing with sterilized distilled water was given. The bits were then placed on previously poured solidified PDA medium in petri plates. The plates were incubated at 27±2 °C for 7 days. The slides were prepared and examined under research microscope for identification.

Mass Multiplication of *Rhizoctonia bataticola*

Sorghum: sand medium was used for mass multiplication of the test pathogen. It was prepared by mixing 100 gm sorghum, 50 gm dry sand and 50 ml distilled water in 250 ml capacity conical flask and autoclaved at 15 lbs psi for 15 minutes. Autoclaved mixture then inoculated with pure culture of *Rhizoctonia bataticola*. The inoculated flasks were incubated at room temperature for two weeks. The mass inoculum of *Rhizoctonia bataticola* was used for experiment. The prepared inoculum was mixed in pot soil to test the efficacy of fungicides and bio-agents against *Rhizoctonia bataticola*.

Pathogenicity test (Koch's Postulate)

The seeds of soybean (var. JS-335) obtained from Plant Pathology Section, College of Agriculture, Nagpur was used. The pots were disinfected with 5 per cent formalin solution. Soil sterilization was done with the help of 10 per cent formalin solution. Two weeks old growth of pathogen, *Rhizoctonia bataticola* on sorghum: sand medium was mixed separately in upper 15 cm layer of soil, 72 hour prior to sowing. The pots containing sterilized soil without inoculum served as control. Before sowing, the seeds of soybean were surface sterilized with 2 per cent sodium hypochloride solution for 2 minutes followed by three washings with distilled sterile water. Ten seeds were sown in pot containing *Rhizoctonia bataticola* and the pots without inoculum served as control treatment.

Re - isolation

The infected roots were used for re-isolation as per procedure the culture obtained was confirmed for growth with original culture from which isolations were made and to prove pathogenicity.

In vitro study

To test the efficacy of tested fungicides and bio - agents poisoned food technique (Rai *et al.* 2007) [28] was used against *Rhizoctonia bataticola*. Potato Dextrose Agar medium was prepared and distributed at the rate of 100 ml in 250 ml conical flasks, autoclaved at 15 lbs psi for 15 minutes then before solidification of medium different fungicides with desired concentration were incorporated aseptically in different flasks. These flasks were shaken thoroughly and poured in Petri plates at the rate 20 ml/ plate likewise three plates for each treatment were poured. One set of three plates was poured without any fungicide to serve as control. After solidification of medium, plates were inoculated with eight days old pathogens separately. The five mm mycelial discs selected from peripheral growth of the test pathogen by cork borer were used for inoculating the plates by keeping one disc per plate in the centre in inverted position so as to make the mycelial growth touch the surface medium. The inoculated plates were incubated at room temperature for seven days.

The colony diameter of the fungal pathogen on medium was recorded and percent inhibition was calculated by using the following formula (Nene and Thapliyal, 1993) [26].

$$\text{Per cent inhibition} = \frac{C - T}{C} \times 100$$

Where,

- C = Mycelial growth in control (cm)
- T = Mycelial growth in treatment (cm)

3.2.6 Efficacy of fungicides organic amendments and bio - agents against *Rhizoctonia bataticola* in vivo

An experiment was conducted in randomized block design in nine treatments with three replication. The treatment details are given below.

- Design: RBD
- Variety: JS-335
- Replications: 03
- Treatments: 09
- Plot size: Gross Plot 2.70 m × 3.0 m Net Plot 1.80 m × 2.80 m
- Spacing: 45 x 5 cm

- Method of sowing: Dibbling
- Date of sowing: 4 July 2013
- Fertilizer dose: 30 kg N, 70 kg P and 30 kg K /ha
- Date of harvesting: 25 Oct 2013

Treatment details

Treatment No.	Treatments
T ₁	: Seed Treated with Carboxin + Thiram (2.0 g/kg + soil drench with 0.1% Carboxin + Thiram + Carbendazim at 50 DAS
T ₂	: Seed Treated with Carboxin + Thiram (2.0 g /kg - seed) + soil drench with Carbendazim + Mancozeb (0.25) at 50DAS
T ₃	: Pre-sowing soil application of neem cake @ 500kg/ha + Seed Treated with Carboxin + Thiram (2 g/kg seed)
T ₄	: Pre-sowing soil application of Trichoderma harzianum @2.5kg/ha + Seed Treated with Trichoderma harzianum (4 g/kg seed)
T ₅	: Pre-sowing soil application of Pseudomonas fluorescens @ 5kg/ha+ Seed Treated with Pseudomonas fluorescens (10 g/kg seed)
T ₆	: Pre- soil application of FYM enriched with Trichoderma harzianum @ 2.5 kg/ton FYM + neem cake 500 kg/ha + Seed Treated with Trichoderma harzianum (4 g/kg seed)
T ₇	: Pre- soil application of FYM enriched with Pseudomonas fluorescens 5 kg/ton FYM +neem cake 500 kg/ha + Seed Treated with Pseudomonas fluorescens (10 g/kg seed)
T ₈	: Pre- soil application of FYM enriched with Trichoderma harzianum and Pseudomonas fluorescens 2.5 kg and 5 kg respectively + neem cake 500 kg/ha + Seed Treated with Trichoderma harzianum (4 g/kg seed) and Pseudomonas fluorescens (10g/kg seed)
T ₉	: Control

With respect to soil application, treatments of neem cake alone and FYM enriched with bio - control agents in combinations imposed 15 days earlier to sowing. Soil drench with chemical fungicides taken after 50 DAS.

3.2.7 Observations

The observation on per cent disease incidence of root rot and yield recorded. The per cent disease index recorded by adopting 0-9 rating scale as per 40th Annual Group Meeting Proceeding and Technical Programme of AICRP on Soybean.

Rating	Description
0	No mortality
1	1% mortality
3	1.1-10% mortality
5	10.1-25% mortality
7	25.1-50% mortality
9	More than 50% mortality

The percent disease incidence, Percent disease index was calculated by using following formula.

$$\text{Percent disease incidence} = \frac{\text{Total Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

$$\text{Percent disease index (PDI)} = \frac{\text{Intensity in category values}}{\text{Number of plants} \times \text{Maximum category value}} \times 100$$

The per cent disease control was calculated by the following formula

$$\text{PDC} = \frac{\text{PDI in control} - \text{PDI in treatment}}{\text{PDI in control}} \times 100$$

Where,

- PDC - Per cent disease control
- PDI - Per cent disease index

Grain yield (kg/plot)

The grain yield kg/plot was recorded after threshing, cleaning and drying up to moisture 9% and then weighed the yield with the of electronic balance.

Grain yield (kg/ha)

The grain yield kg/ha was calculated by using the grain yield per plot and expressed in kilograms per hectare.

Economic analysis

Incremental cost benefit ratio

The net return per hectare (Rs) was worked out for all the treatments by subtracting the Treatment cost from the gross returns. The Incremental cost benefit ratio (ICBR) was also calculated as follows

$$\text{ICBR} = \frac{\text{Net Returns}}{\text{Cost of treatment}}$$

Statistical analysis

All the data were statistically analyzed as per the procedure mentioned in statistical procedure for agriculture research. (Gomez and Gomez, 1983) ^[14].

Results and Discussion

Isolation of pathogen

The *Rhizoctonia bataticola* was isolated from infected soybean plants showing symptoms like withering and drying, by using tissue segment method. Small pieces of tissue from the infected collar region along with some healthy tissue were cut with sterile scalpel. Then the pieces were surface sterilized with 0.1 per cent HgCl₂ solution for one minute and three subsequent washing with sterilized distilled water was given. The sterilized pieces were transferred to PDA plated Petri plates. Plates were incubated at 27±2 °C and observed periodically for growth of the fungus. The pathogen culture was purified by single hyphal tip method and maintained on PDA by periodical transfer throughout the present investigation.

4.2 Identification of pathogen

The fungus produced radial hyaline colonies, which later became carbonaceous brown to black. Mycelium was septate and dark brown in colour. Typical right-angled branching of mycelium observed. Sclerotia were black, varied from spherical to irregular in shape and size measured 80 to 85 µm. Isolates were identified as *Rhizoctonia bataticola* dense masses of sclerotia on PDA that gave a black appearance to cultures. Sclerotia were irregularly spherical and within appropriate size

ranges in diameter. Thus, the fungus under present investigation was identified as *Rhizoctonia bataticola* (Taub.)

4.3 Pathogenicity test

Pathogenicity of *Rhizoctonia bataticola* isolate was carried out by soil inoculation technique using JS-335 variety of soybean.

Table 1: Pathogenicity test with isolate of *Rhizoctonia bataticola* on soybean

Pathogen	No. of seeds sown	No. of affected seedlings	Per cent root rot
<i>Rhizoctonia bataticola</i>	10	8	80.00
Control	10	0	00.00

The association, isolation and pathogenicity of *Rhizoctonia bataticola* was proved and observed the mortality to the extent of 80.00 per cent due to *Rhizoctonia bataticola* (Table 1).

Initially the symptom was noticed on aerial parts of the plant in the form of drooping off the tips of the plant and cotyledon leaves. Pre-emergence rot of seedlings was observed and the survived plants showed stunted growth followed by wilting and drying of leaves and stems. When the infected plants were pulled out the taproot was blackened and devoid of lateral as well as finer roots. The uprooted seedlings showed grayish black discoloration of the roots and numerous black sclerotia was observed on affected roots. Several workers have found soil inoculation method as most suitable in establishing the disease caused by *Rhizoctonia bataticola*. Potentiality of this pathogens on soybean was also proved by Hooda and Grover (1983) [17], El-Fiki *et al.* (1998) [12], Yaqub and Shahzad (2005) [37], Rayatpanah *et al.* (2012) [31] and Amrutha *et al.* (2014) [2].

4.4 Symptomology

Symptoms of root rot (*Rhizoctonia bataticola*)

The affected soybean plants showed overall yellowing followed by drooping of leaves, at initial stage and later on dried off. Plants bearing leaves appeared weak and dark lesions on the bark at ground level was also noticed in field plots appeared first as reddish-brown lesions on the hypocotyls close to the cotyledons, then turned ashy-gray to black. Sclerotial and mycelial inoculums were almost equally effective in causing seedling. Affected seedlings were pulled up easily and underground parts softened and rotted which left in the soil. Similar results evaluated by Meyer *et al.* (1974) [21] and Mayee and Datar (1986) [20].

4.5 Morphology of the fungi of *Rhizoctonia bataticola*

The bits of *Rhizoctonia bataticola* were inoculated and incubated on PDA medium at room temperature. After 24 hr, the mycelial growth started from fungus bit. The colour of the mycelium in the beginning was white, but after 48 hr gradually

it changed. The colour turned dark grey due to sclerotial formation. The mycelium was closely septate, hyaline and thick walled, hyphal branches arise at right angles to the parent hyphae after third day from incubation, the fungus produced sclerotia. On 6th day, sclerotia were dark gray to brown colour and irregular round in shape. On 8th day old culture showed dark brown to dark grey colour of the colony. At high temperature, fungus growth covered the Petri plates in six to seven days and mycelial strands were oily in appearance and partially fluffy or aerial. However, at low temperature did not show oil and fluffy growth. Fungus growth was close horizontally parallel to the medium surface. *R. bataticola* observed under the microscope at 40x magnification exhibited colourless hyphae when young, but became brown to black with age. The hyphae were composed of uniform thick cell. The branches arise at right or at lesser angle, septate and constricted at the base. The hyphae branched out repeatedly forming terminally bushy growth, which ultimately developed into sclerotia.

4.6 In vitro evaluation of fungicides and bio - agents against *Rhizoctonia bataticola* causing root rot of soybean

Some fungicides viz, Carboxin + Thiram (2g/litre), Carboxin + Thiram + Carbendazim (1g/litre), Carbendazim (1g/litre), Mancozeb (2.5g/litre) and Carbendazim + Mancozeb (2.5g/litre) and the bio-agents were evaluated at recommended concentration in the laboratory for their efficacy against *R. bataticola* by applying poisoned food technique. The results obtained are presented in Table 2.

Fungicides and bio - agents significantly inhibited the growth of *Rhizoctonia bataticola*. Fungicides viz, Carboxin + Thiram (2g/litre) Carboxin + Thiram + Carbendazim (1g/litre), Carbendazim (1g/litre), Mancozeb (2.5g/litre) and Carbendazim + Mancozeb (2.5g/litre) completely inhibited the radial growth of *R. bataticola* at 3, 5, and 7th DAI with 100% growth inhibition (Table 1). These results are in conformity with the reports of Mishra (1982) [22], Rai *et al.* (2007) [28], Kumar *et al.* (2011) [18], Arora *et al.* (2013) [5], and Sultana and Ghaffar (2013) [33] respectively.

Among the bio - agents combination with *Trichoderma harzianum* + *Pseudomonas fluorescens* treatment recorded minimum radial mycelial growth at 3rd DAI (22.8 mm) with (63.46 per cent) inhibition over control. There was slight increase in the radial mycelial growth from 5th to 7th DAI with minimum per cent inhibition in both the bio-agent treatments. The beneficial effect due to *Trichoderma harzianum*, *Pseudomonas fluorescens* and *Trichoderma harzianum* + *Pseudomonas fluorescens* in controlling the *R. bataticola* have been reported by Vyas (1994) [34], Gaikwad and Nimbalkar (2003) [13], Lokesh and Benagi (2007) and Kumar *et al.* (2011) [18].

Table 2: In vitro efficacy of fungicides and bio - agents against *Rhizoctonia bataticola* causing root rot of soybean

Treatment	Treatment details	Mycelial growth (mm)3rd DAI	Mycelial growth (mm)5th DAI	Mycelial growth (mm)7th DAI	Growth inhibition over control (%)7th DAI
T ₁	Carboxin + Thiram	0.00*	0.00	0.00	100.00
T ₂	Carboxin + Thiram + Carbendazim	0.00	0.00	0.00	100.00
T ₃	Carbendazim	0.00	0.00	0.00	100.00
T ₄	Mancozeb	0.00	0.00	0.00	100.00
T ₅	Carbendazim + Mancozeb	0.00	0.00	0.00	100.00
T ₆	<i>Trichoderma harzianum</i>	24.50	27.80	28.00	68.88
T ₇	<i>Pseudomonas fluorescens</i>	24.60	28.16	30.75	65.93

T ₈	<i>Trichoderma harzianum</i> + <i>Pseudomonas fluorescens</i>	22.80	25.50	27.93	68.96
T ₉	Control	62.40	81.16	90.00	—
	F Test	Sig.	Sig.	Sig.	Sig.
	SE ± (m)	0.384	0.380	0.372	4.316
	CD (P = 0.05)	1.143	1.130	1.107	12.826

Mean of three replication

4.7 Efficacy of fungicides, organic amendments and bio – agents against per cent root rot of soybean.

The integrated effect of pre-sowing soil application, seed treatment and soil drenching with fungicides, organic amendments and bio - agents in root rot incidence was studied in field condition and results obtained presented in table 3.

Results (Table 3) revealed that the all the treatments were found effective in reducing the incidence of root rot in comparison to control. The data indicated that treatment T₈- Pre- soil application of FYM enriched with *T. harzianum* and *P. fluorescens* 2.5 kg and 5 kg respectively + neem cake 500 kg/ha + ST with *T. harzianum* (4g/kg seed) and *P. fluorescens* (10g/kg seed), T₁- ST with *Carboxin* + *Thiram* (2.0 g/kg seed) + soil drench with 0.1% *Carboxin* + *Thiram* at 50 DAS, T₆- Pre-soil application of FYM enriched with *T. harzianum* 2.5 kg/ton

FYM + neem cake 500 kg/ha + ST with *T. harzianum* (4g/kg seed), T₃- Pre-sowing Soil application of neem cake 500kg/ha + ST with *Carboxin* + *Thiram* (2 g/kg seed) were found most effective as least% root rot (10.35, 11.08, 12.59 and 13.33% respectively) observed with maximum per cent root rot reduction i.e. 61.19, 58.44, 52.79 and 50.0% respectively. Treatment T₄- Pre-sowing soil application of *Trichoderma harzianum* 2.5kg/ha + ST with *T. harzianum* (4g/kg seed) was found next best application as minimum root rot (15.52%) with 41.77% root rot control observed.

These results are in agreement with the work of Elad *et al.* (1980)^[38], Vyas (1994)^[34], Gaikwad and Nimbalkar (2003)^[13], Dubey (2003)^[10], Bohra and Mathur (2004)^[7] and Rajpurohit and Nema (2012)^[29].

Table 3: Efficacy of fungicides, organic amendments and bioagents against per cent root rot of soybean and ICBR Ratio

Treatments	% Root rot	% Root rot reduction	Yield (kg/ plot)	Yield (kg/ ha)	Yield increase over control	Cost (Rs) (A)	Cost of treatment/ha (Rs/ha) (B)	Net Returns (Rs/ha) (C) (A-B)	ICBR (D) (C/B)
T ₁	11.08 (3.32)*	58.44	1.60	1979	926	25928	2688	23240	1:8.64
T ₂	17.07 (4.13)	35.98	1.45	1794	741	20748	1129	19619	1:17.37
T ₃	13.33 (3.64)	50.00	1.52	1881	828	23184	2729	20455	1:7.49
T ₄	15.52(3.88)	41.77	1.47	1823	770	21560	412	21148	1:51.33
T ₅	21.48(4.63)	19.43	1.53	1893	840	23520	360	23160	1:64.33
T ₆	12.59(3.52)	52.79	1.57	1942	889	24892	4452	20440	1:4.59
T ₇	18.88(4.34)	29.18	1.56	1930	877	24556	4400	20156	1:4.58
T ₈	10.35(3.18)	61.19	1.63	2012	959	26852	4605	22247	1:4.83
T ₉	26.66(5.16)	-	0.85	1053	-	-	-	-	-
'F' Test	Sig.	-	Sig.	Sig.	-	-	-	-	-
SE ± (m)	0.20	-	0.04	49.93	-	-	-	-	-
CD(P=0.05)	0.61	-	0.12	148.37	-	-	-	-	-

Figures in parenthesis are square root transformed value

(Price rate: Soybean grain yield @ Rs 28 / kg, FYM @ Rs 1000 / ton Neem cake @ Rs 6 / kg, *Trichoderma harzianum* @ Rs 100 / kg, *Pseudomonas fluorescens* @ Rs 40 / kg, Vitavax (*Carboxin* + *Thiram*) @ Rs 1900 / kg, Carbendazim+ Mancozeb @ Rs 400 /kg, Soil application, Seed treatment and Soil drenching labour @ Rs 120 / day ICBR = Net Returns/Cost of treatment /ha (Rs).

4.8 Efficacy of fungicides, organic amendments and bio – agents on yield of soybean

Integrated effect of pre-sowing soil application with FYM, Neem - cake, bio-agents and fungicide was studied in field condition and Results obtained pertaining to yield is presented in Table 3.

It is evident from the Table 3 that all the treatments were found effective in regard the yield of soybean. Data in respect of yield, showed in the range of 1053 to 2012 kg/ha. Treatment T-8 Presowing soil application of FYM enriched with *Trichoderma harzianum* and *Pseudomonas fluorescens* 2.5 kg and 5 kg respectively + neem cake 500 kg/ha + Seed Treated with *Trichoderma harzianum* (4 g/kg seed) and *Pseudomonas fluorescens* (10g/kg seed) and T-2 Seed Treated with *Carboxin* + *Thiram* (2.0 g/kg seed) + soil drench with *Carboxin* + *Thiram*

at 50 DAS recorded higher yield 2012 and 1979 kg/ha respectively, these result are in agreement with the reports of Hadar *et al.* (1979) Dar *et al.* (2011)^[8], Ekbote (2005)^[11] and Mishra *et al.* (2011)^[23].

4.9 ICBR Ratio

Integrated effect different treatments on management of root rot of soybean was studied in field condition, incremental cost benefit ratio calculated based on yield, and expenditure incurred during cultivation and are presented in Table 3.

It is evident from the Table 3 that indicate the Incremental cost benefit ratio (ICBR). The T-5 Pre-sowing soil application of *Pseudomonas fluorescens* @ 5kg/ha + Seed Treated with *Pseudomonas fluorescens* (10 g/kg seed) Recorded maximum ICBR and maximum net return i e, 1:64.33 and 23160 rs/ha as it required minimum cost, secondly the maximum net return was obtained in T₁ Seed Treated with *Carboxin* + *Thiram* (2.0 g/kg seed) + soil drench with 0.1% *Carboxin* + *Thiram* + Carbendazim at 50 DAS.) i e Rs 23240 rs / ha. with ICBR Ratio 1:8.64, followed by T-8 Pre- soil application of FYM enriched with *Trichoderma harzianum* and *Pseudomonas fluorescens* 2.5 kg and 5 kg respectively + neem cake 500 kg/ha + Seed Treated with *Trichoderma harzianum* (4 g/kg seed) and *Pseudomonas*

fluorescens (10g/kg seed) Rs 22247 / ha. With ICBR Ratio 1:4.83,

5. Conclusions

It is concluded from the present investigation that soil application, and seed treated with *Trichoderma harzianum* and *Pseudomonas fluorescens* and seed treatment and soil drenching with Carboxin + Thiram, Carbendazim + Mancozeb (0.25), can be used for controlling the *Rhizoctonia bataticola*

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