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Effect of *Azospirillum brasiliense* on incidence of sheath blight [*Rhizoctonia solani* (Kuhn)] on basmati rice, its growth parameters and yield

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Abstract
Paddy (*Oryza sativa* L.) is a cereal grain and in its domesticated form is the staple food of over half of the world's population, particularly in Asia and Africa. Basmati rice is a variety of long, slender-grained aromatic rice which is traditionally grown in the Indian subcontinent, mainly India, Pakistan, Sri Lanka and Nepal. A field experiment was conducted at Central Research Field, SHUATS, Prayagraj in the *Kharif* season of 2023-2024 under *in vitro* conditions to evaluate the efficacy of *Azospirillum brasiliense* against Sheath Blight [*Rhizoctonia solani* (Kuhn)] of basmati rice and to check its growth parameters and yield. The most effective treatment was T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) which significantly increased plant height (121.26 cm), number of tillers (20.50), panicle length 28.40 cm), yield (4.80 t/ha) and B: C ratio 1:2.425 and significantly decreased plant disease intemsity (20.66%) when compared to treated check T_6 (Carbendazim 50%WP @ 400 g/ha) and untreated check T_0 (control).

Keywords: Sheath blight, *Rhizoctonia solani*, *Azospirillum brasiliense*, basmati rice

Introduction
Paddy (*Oryza sativa* L.) belongs to family Poaceae is one of the most important food crops and feeds more than 60 per cent population of India. Rice grain contains a variety of complex carbohydrates, amino acids, minerals, nutritional fiber, and vitamins. [21]. World population is increasing and it is assumed that 14,886 million tons (MT) of foods need to be produced in 2050 to meet up the food demand. Worldwide 514.42 MT rice is produced where China produces 28% of the total, followed by India (26%), Bangladesh (7%), Indonesia (6%), Vietnam (5%), and Thailand (4%) [6]. The major rice producing states in India with respect to its share in total rice production of the nation were West Bengal (14.37%), Uttar Pradesh (13.73%), Andhra Pradesh (12.23%), Punjab (10.58%), Odisha (7.11%), Chhattisgarh (6.31%), Tamil Nadu (5.2%), Bihar (5.17%), Assam (4.49%) and Haryana (3.75%). [7]. Rice is affected by fungi, bacteria, and viruses, the fungal diseases sheath blight (caused by *Rhizoctonia solani*), blast (caused by *Magnaporthe oryzae*), and brown spot (caused by *Bipolaris oryzae*) are prominent destructive pathogens. Among them, *Rhizoctonia solani* Kuhn causing sheath blight of rice (teleomorph: *Thanatephorus cucumeris* (Frank) (Donk)) is a widespread destructive pathogen, considered as the second most significant disease after rice blast [10]. Disease occurs in warm and humid areas, conditions favoured by the pathogen, and causes yield losses due to sheath blight ranged from 14 to 35% and worldwide it ranges 4- 50% albeit yield loss depend on the crop stage, virulence of the pathogen, time of infection and environmental conditions [9]. *Rhizoctonia* isolates are grouped as uninucleate *Rhizoctonia*, binucleate *Rhizoctonia* (teleomorphs: *Ceratobasidium* spp. and *Tulasnella* spp.) and multinucleate *Rhizoctonia* (teleomorphs: *Thanatephorus* spp. and *Waitea* spp. [14]. The disease appears at tillering stage on leaf sheath as elliptical or oval to irregular, 1-3 cm long, greenish gray spots with brown margin at or above the water line. Presence of many such spots on the leaf sheath gives the appearance of snake skin. Under favourable conditions, the infection spreads rapidly to the upper plant parts and also to the neighbouring plants by means of runner hyphae, ultimately causing death of whole leaf, tiller and the plant. Infected plants are usually found in a circular pattern, locally referred to as 'bird's nest' [5]. Keeping the above points in view, the present investigation was carried out to manage Sheath Blight

of basmati rice. Due to environmental pollution and resistance produced by chemical fungicides, nowadays biological control is considered a good alternative for crop protection. Among biocontrol agents, there are plant growth-promoting bacteria, such as members of the genus *Azospirillum brasilense*, produce siderophores (spirilobactin), exhibiting different yields and rates of production according to their origin [16]. A high-affinity iron transport system capable of 59Fe uptake from a 59 Fe (III)-spirilobactin complex was also induced in *A. brasilense* grown under iron deficiency [1]. *Azospirillum brasilense* is also effectively used as a resistance inducer in several crops Aside from the promotion of plant growth, *A. brasilense* Sp245 protects plants against pathogen attacks, such as *Rhizoctonia* spp. The biocontrol effect of *A. brasilense* Sp245 on the fungal rhizospheric community has been confirmed by denaturing gradient gel electrophoresis (DGGE) profiles of the rhizospheric microbial community [12].

Materials and Methods

A field experiment was conducted at the Agricultural Research Farm of Sam Higginbottom Institute of Agriculture, Technology and Sciences Prayagraj, Uttar Pradesh during *Kharif* season 2023-2024. Geographically, Prayagraj is located at longitude of 81.50º E latitude 25.27° N and at an elevation of 98 meters from Mean Sea Level (MSL) in Prayagraj district of U.P. The climate at Prayagraj is typical semi-arid and sub-tropical which prevails in the eastern part of Uttar Pradesh The site selected was uniform, cultivable with typical sandy loam soil having good drainage.

Randomized Block Design (R.B.D) comprising of 7 treatments and 3 replications. Plot area was maintained at 2.0 X 1.0 = 2.0 m^2 (42 hills per plot) spacing of spacing 20 cm (row x row) and 15 cm (plant x plant) and 2-3 seedlings/hill and fertilizer schedule of Urea: P_2O_5 MOP @ 100: 120: 100 kg/ha Urea was applied in three equal splits. Irrigation was given in the field as and when required and frequent weeding was done to keep the plot free from weeds. Seedling dip and foliar application of *Azospirillum brasiliense* was done as per schedule at 45, 60 and 75 day after transplanting. Data on Sheath Blight of Basmati Rice incidence was recorded at 15 day intervals starting from appearance of disease and final data was taken into consideration. The percent disease incidence was calculated by using the formula given by [20].

$$PDI = \frac{\text{Sum of individual rating}}{\text{No of leaves examined x Maximum disease scale}} \times 100$$

Results and Discussion

The disease intensity of paddy was first taken at 60 DAT. Minimum disease intensity was seen in the treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) – 11.96% followed by T_5 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha) – 14.40%, , T_3 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 ml/ha) – 14.90%, T_1 (*Azospirillum brasilense* SD @ 30 ml/l) – 15.35% and , T_4 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha) – 15.75% as compared to treated check T_6 (Carbendazim 50%WP @ 400 g/ha) – 9.33% and untreated check T_0 (control) – 17.33%.

Disease intensity of paddy taken at 75 DAT. Minimum disease intensity was seen in the treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) – 15.36% followed by T_3 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 l/ha) – 17.93%, T_1 (SD with *Azospirillum brasilense* @ 30 ml/l) 18.56% , T_4 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha) – 19.20% and T_5 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha) – 19.30% as compared to treated check T_6 (Carbendazim 50%WP @ 400 g/ha) – 12.23% and untreated check T_0 (Control) – 22.60%.

Disease intensity of paddy taken at 90 DAT. Minimum disease intensity was seen in the treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) – 20.66% followed by T_4 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha) – 22.86%, T_3 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 ml/ha) – 23.53%, T_1 (*Azospirillum brasilense* SD @ 30 ml/l) – 23.63% and T_5 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha) – 23.83% as compared to treated check T_6 (Carbendazim 50%WP @ 400 g/ha) – 16.90% and untreated check in T_0 (control) 26.66%.

Effect of treatments on yield of paddy

The maximum yield was obtained from the treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) – 4.80 t/ha followed by T_3 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 ml/ha) – 4.43 t/ha, T_1 (*Azospirillum brasilense* SD @ 30 ml/l) – 4.10 t/ha, T_4 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha) – 4.06 t/ha and T_5 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha) –3.76 t/ha as compared to treated check T_6 (Carbendazim 50%WP @ 400 g/ha) – 5.23 t/ha and untreated check T_0 (control) – 2.60 t/ha.

Benefit Cost ratio

The untreated plants T_0 (control) shows significantly reduced Benefit Cost Ratio from all the treatments. Benefit Cost Ratio was significantly increased in treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) – 1:2.425 followed by T_3 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 ml/ha) – 1:2.128 , T_1 (*Azospirillum brasilense* SD @ 30 ml/l) – 1:1.952 , T_4 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha) – 1:1.827 and T_5 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha) – 1:1612 as compared to treated check T_6 (Carbendazim 50%WP @ 400 g/ha) – 1:2.645 t/ha and the lowest was recorded in untreated check T_0 (control) – 1:0.875.

Effect of treatments on disease intensity (%) of paddy at 60, 75 and 90 DAT

Treatment number	Treatments	Disease intensity (%)		
		45 DAS	60 DAS	75 DAS
T_0	control (untreated)	17.33^{f}	22.60^{d}	26.66^{d}
T_1	*Azospirillum brasilense* SD @ 30 ml/l	15.35^{de}	18.56^{c}	23.63^{c}
T_2	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha	11.96^{b}	15.36^{b}	20.66^{b}
T_3	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 ml/ha	14.90^{cd}	17.93^{c}	23.53^{c}
T_4	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha	15.75^{e}	19.20^{c}	22.86^{c}
T_5	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha	14.40^{e}	19.30^{c}	23.83^{c}
T_6	Carbendazim 50% WP @ 400 g/ha	9.33^{a}	12.23^{a}	16.90^{a}
F test		S	S	S
CD @ 5%		0.63	1.48	1.14

SD- Seedling dip , FS- Foliar spray

Effect of treatment details on yield (t/ha) of Paddy

Treatment	Treatment Details	YIELD(t/ha)
T_0	control (untreated)	2.60^{f}
T_1	*Azospirillum brasilense* SD @ 30 ml/l	4.10^{d}
T_2	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha	4.80^{b}
T_3	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 400 ml/ha	4.43^{c}
T_4	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 500 ml/ha	4.06^{d}
T_5	*Azospirillum brasilense* SD @ 30 ml/l + FS @ 600 ml/ha	3.76^{e}
T_6	Carbendazim 50% WP @ 400 g/ha	5.23^{a}
F test		S
CD @ 5%		0.28

SD – Seedling dip , FS- Foliar spray

Benefit Cost Ratio

Treatment	Yield (q/ha)	Price (Rs/q)	Gross return (Rs/ha)	Total cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_0	2.6	3000	78,000	41,590	36,410	1:0.875
T_1	4.1	3000	1,23,000	41,665	81,335	1:1.952
T_2	4.8	3000	1,44,000	42,040	1,01,960	1:2.425
T_3	4.43	3000	1,32,000	42,190	89,810	1:2.128
T_4	4.06	3000	1,20,000	42,340	77,660	1:1.827
T_5	3.7	3000	1,11,000	42,490	68,510	1:1.612
T_6	5.2	3000	1,56,000	42,790	1,13,270	1:2.645

The probable reason for such findings may be that, *Azospirillum* inoculation may hav affected increases in total plant dry weight, N level in shoots and grains, total tillers, fertile tillers and ears, spikes and grains/ spike, grain weight, plant height and leaf size, germination rates, root system viz. root length and volume, and causes early heading and flowering, chlorophyll, carotenoid, soluble protein, sugar and photosynthetic rate to varying level in 7 paddy seedlings [5]. Inoculation of *Azospirillum* results in up-regulation of oxidative stress genes in leaves and down-regulation in roots whether inoculated on seeds or by leaf spray and this is strongly correlated with the synthesis of phytohormones (*A. brasilense* strains Ab-V5 and Ab-V6 includes indole-3-acetic acid, indole 3-ethanol, indole-3-lactic acid and salicylic acid) and by eliciting genes related to plant-stress tolerance and defence against pathogens [4]. Another important feature of *Azospirillum* is related to biological control of plant pathogens [2, 8, 11] enabled by the synthesis of siderophores, and limiting the availability of iron (Fe) to phytopathogens [11] or causing alterations in the metabolism of the host plant, including the synthesis of a variety of secondary metabolites that increase plant resistance to infection by pathogens, a mechanism known as induction of systemic resistance (ISR) [15, 18].

Conclusion

From the present study, it can be concluded that the treatment treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) significantly reduced the disease intensity of sheath blight (*Rhizoctonia solani*) of paddy, and significantly increased plant height of paddy (cm), number of tillers per plant, panicle length (cm), yield (t/ha) and cost benefit ratio. Therefore, it is concluded that treatment T_2 (*Azospirillum brasilense* SD @ 30 ml/l + FS @ 300 ml/ha) is most effective against sheath blight of paddy when compared treated check T_6 (Carbendazim 50% WP @ 400 g/ha) and untreated check T_0 (Control). The present investigation was limited to one crop season (*Kharif*), under the climatic conditions of Prayagraj (U.P.) therefore, to substantiate the present result more such trials are required for further recommendation.

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