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Management of banded blight disease using biological control agents against *Rhizoctonia solani* Kuhn. In Barnyard millet

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Abstract
The present study was undertaken to manage the banded blight disease of barnyard millet using biocontrol agents therefore, aimed towards developing a sustainable integrated disease management (IDM). The field experiment was conducted during *Kharif* 2016 and 2017, at Agricultural Research Station, Vizianagaram. The disease severity and yield parameters (grain yield and straw yield) were evaluated against banded blight using different combinations of potential biocontrol agent's *viz*., *Bacillus subtilis, Pseudomonas flourescens* and *Trichoderma asperellum* in the field during 2016 and 2017. Among all treatments applied treatment T_7 (*i.e.* Soil application of value added *P. flourescens* + *T. asperellum* + *B. subtilis* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) applied over an acre at the time of sowing) showed maximum reduction in disease intensity (28.21 % and 64.00 %) with higher grain and fodder yield over control.

Keywords: Barnyard millet, biocontrol, *R. solani*, IDM

Introduction
Barnyard millet (*Echinochloa frumentacaea*) is one of the hardiest millets, which is called by several names *viz.*, Japanese barnyard millet, ooda, oadalu, sawan, sanwa, and sanwank. Nutritionally, Barnyard millet is an important crop. It is a fair source of protein, which is highly digestible and is an excellent source of dietary fibre with good amounts of soluble and insoluble fractions (Hadimani and Malleshi 1993; Veena *et al.* 2005) [12, 24]. The carbohydrate content is low and slowly digestible (Veena *et al.* 2005) [24], which makes the Barnyard millet a natural designer food.

In India, barnyard millet is the second important small millet after finger millet having production and productivity 87 thousand tonnes and 857 kg/ha, respectively (Padulosi *et al.* 2009) [18]. In India, it is mainly cultivated in two different agro-ecologies, one in mid hills of Himalayan region of Uttarakhand in the North and another in Deccan plateau region of Tamil Nadu in the south. Wild barnyard millet (*Echinochloa colona*) is commonly found in rice fields as weed and consumed as food during drought years in many states of India (Padulosi *et al.* 2009) [18].

Banded blight of barnyard millet incited by *Rhizoctonia solani* (Kuhn.) (Basidial stage: *Thanatephorus cucumeris* (Fr.) Donk) has an extensive host range. The pathogen is capable of causing various diseases on a variety of susceptible agriculturally important crops (Nagaraj *et al.* 2010) [16]. Lalu Das and Girija (1989) for the first time reported as sheath blight of ragi from Vellayani in kerala, where it occurred in a severe form. Barua and Lal (1981) [4] and Ahuja and Payak (1988) reported that *R. solani* f. sp. *sasakii* infects the *Echinochloa frumentacea* (barnyard millet) by artificial inoculations. However, no record is available in the literature, on natural occurrence of banded sheath blight disease on barnyard millet. This is the first report of natural occurrence of banded sheath blight disease on barnyard millet caused by *Rhizoctonia solani*. During *Kharif*, 2007 thirteen entries were screened against banded blight in barnyard millet. All the entries of barnyard millet showed resistant to moderately susceptible reaction (Jain and Gupta, 2010) [14]. The disease was observed in severe form at the Agricultural Research Station in Vizianagaram, The widespread adoption of new, susceptible, high-yielding cultivars with large numbers of tillers, and the changes in cultural practices associated with these cultivars, favor the development of sheath blight and contribute greatly to the

rapid increase in the incidence and severity of this disease in rice-producing areas throughout the world (Groth *et al*., 1991; Rush and Lee, 1992) [10, 21]. Furthermore, environmental conditions such as low light, cloudy days, high temperature and high relative humidity also favor the disease (Ou, 1985) [17]. The pathogen overwinters as soil-borne sclerotia and mycelium in plant debris; these constitute the primary inoculums. In microscopic examinations, the fungus appeared septate and branched. The branches arose at right angles (90^0) from below the septa and showed distinct constrictions at the point of origin of branch. Moniloid cells were visible after crushing the sclerotia (Kumar and Prasad, 2009) [5].

Control of the pathogen is difficult because of its ecological behavior, its extremely broad host range and the high survival rate of sclerotia under various environmental conditions (Groth *et al*., 2006) [11]. In the absence of a desired level of host resistance, the disease is currently managed by excessive application of chemical fungicides, which have drastic effects on the soil biota, pollute the atmosphere, and are environmentally harmful. Some potentially effective fungicides are highly phytotoxic to the crop and, if the disease is not severe, these fungicides may reduce yield (Groth *et al*., 1990) [9]. It is difficult to achieve control through host resistance or fungicides, therefore, biological control may be effective in minimizing the incidence of sheath blight (Das and Hazarika, 2000) [6]. So an experiment was conducted at Agricultural Research Station, Vizianagaram during *Kharif* 2016 and 2017.

Materials and Methods

A field experiment was conducted at Agricultural Research Station, Vizianagaram for the management of banded blight disease in barnyard millet by using potential biocontrol agents like *Bacillus subtilis*, *Pseudomonas flourescens* and *Trichoderma asperellum*. These isolates were collected from Department of Biological control, Vizianagaram. The experiment was laid out in randomized block design (RBD) with three replications at spacing of 22.5 × 10 cm with 3 × 3 m plot size. Standard agronomic practices of NPK – 50 kg, 40 kg, 25 kg were followed at the time of crop growth period. A susceptible variety (VMBC 331) was used in this experiment by imposing the following treatments: (Table 1)

Table 1: Treatments:

T1	Seed treatment with *Trichoderma asperellum* @ 10 g/kg
T2	Seed treatment with *Pseudomonas flourescens* @ 10 g/kg
T3	Seed treatment with *Bacillus subtilis* @ 10 g/kg
T4	Soil application of value added *P.f.* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) applied over an acre at the time of sowing
T5	Soil application of value added *T.a.* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) applied over an acre at the time of sowing
T6	Soil application of value added *B.s.* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) applied over an acre at the time of sowing
T7	Soil application of value added *P.f. + T.a. + B.s.* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) applied over an acre at the time of sowing
T8	Control

Two trials were also conducted during *Kharif* 2016 and 2017 for the management of banded blight disease in barnyard millet. Banded blight (Anon, 1996) was recorded by using 0 to 9 scale (Table 2).

Table 2: Standard Evaluation System (SES) scale for sheath blight disease

Score	Description	Reaction
0	No incidence	No disease/HR
1	Vertical spread of the lesions up to 20% of plant height	R
3	Vertical spread of the lesions up to 21-30% of plant height	MR
5	Vertical spread of the lesions up to 31-45% of plant height	MS
7	Vertical spread of the lesions up to 46-65% of plant height	S
9	Vertical spread of the lesions up to 66-100% of plant height	HS

The disease severity and yield were recorded and the data was statistically analysed by following the standard procedures (Gomez and Gomez, 1984) [8]. The percent disease index (PDI) was calculated by using the following formula:

$$PDI = \frac{\text{Sum of all the numerical ratings}}{\text{Number of observations} \times \text{Maximum disease grade}} \times 100$$

Statistical Analysis

The data was analyzed by applying statistical tools of ANOVA (Analysis of variance) technique for drawing conclusions from the data. Critical difference (C.D) was calculated to see the significant and non-significant difference between the mean values of sheath blight PDI in all the treatments.

Results and Discussion

In *Kharif* 2016 all the treatments were found significantly superior over check in controlling the disease. Among all the treatments tested, the lowest sheath blight intensity (28.21%) was recorded in T_7 (*i.e.* Soil application of value added *P. flourescens + T. asperellum + B. subtilis* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) whereas, highest (74.06 %) was recorded in T_2 (Seed treatment with *Pseudomonas flourescens* @ 10 g/kg). High grain (1666.67 kg/ha) and fodder yield (4133.56 kg/ha) was found in T_7 (Table 3).

Table 3: Management of banded sheath blight in Barnyard Millet *Kharif* 2016

Treatments	Sheath blight (PDI)	Grain Yield (Kg/ha)	Fodder Yield (Kg/ha)
1	65.53 (54.11)*	1546.67	3594.11
2	74.06 (59.46)	1428.61	3451.44
3	71.92 (58.13)	1480.56	3466.22
4	55.84 (48.37)	1548.89	3748.89
5	41.90 (40.32)	1624.72	4027.44
6	50.00 (45.00)	1550.83	3836.22
7	28.21 (32.02)	1666.67	4133.56
8	95.00 (77.19)	1350.56	3303.89
SEm±	1.96	47.48	128.99
CD(P≤0.05)	5.93	144.00	391.19
CV %	6.54	5.39	6.05

Whereas, in *Kharif* 2017 the lowest sheath blight intensity (64.00 %) was recorded in T_7 (*i.e.* Soil application of value added *P. flourescens* + *T. asperellum* + *B. subtilis* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) followed by 72.00 % in T_3 *(i.e.*, Seed treatment with *Bacillus subtilis* @ 10 g/kg) whereas it was recorded 94.67 % in the control. However, high grain (1218.52 kg/ha) and fodder yield (3048.15 kg/ha) was found in T_7 (Table 4).

Table 4: Management of banded sheath blight in Barnyard Millet *Kharif* 2017

Treatments	Sheath blight= (PDI)	Grain Yield (Kg/ha)	Fodder Yield (Kg/ha)
1	74.67 (60.01)*	1396.30	3433.33
2	81.33 (64.74)	1311.11	3337.04
3	72.00 (58.18)	1559.26	3559.26
4	73.33 (59.01)	1433.33	3488.89
5	81.33 (64.74)	1292.59	3355.56
6	77.33 (61.71)	1366.67	3433.33
7	64.00 (53.29)	1593.70	3729.63
8	94.67 (76.83)	1218.52	3048.15
SEm±	2.96	50.34	126.85
CD(P≤0.05)	8.98	152.68	384.70
CV %	8.23	6.24	6.42

The experiment conducted in both the seasons *Kharif* 2016 and 2017 revealed that the treatment T_7 (*i.e.* Soil application of value added *P. flourescens* + *T. asperellum* + *B. subtilis* (one kg talc formulation mixed in 25 kg FYM or vermicompost, incubated for 15 days) was most effective and recorded (28.21%) and (64.00 %) respectively. The yield parameters like grain and fodder were also recorded highest in both the seasons.

Patro and Madhuri (2014) reported that *P. flourescens* + *T. harzianum* followed by *P. flourescens* alone and *T. harzianum* alone are effective against *R. solani*. Pal *et al.*, (2015) revealed that seed treatment + 3 spraying with T. viride @ 1% was the most effective bio control treatment recording 10.93% pooled PDI against 34.41% in control plot and its performance was at par with the standard fungicide propiconazole @ 1%. The treatment also exhibited maximum increase in all the yield attributing factors recorded and gave a yield increase of 41.1% over control. Srinivas *et al.*, (2013) [22] depicts that all the bio-agents stopped the growth of *R. solani* after contact. The order of percent inhibition of *Trichoderma asperellum* (72.65%)>*Penicillium notatum* (64.07%)> *T. atroasperellum* (62.51%)>*T. harzianum* (42.18%)> *T. longibrachiatum* (38.29%)> *T. koninzii* (3.14%)> *Aspergillus Niger* (1.57%). *T. harzianum* (ThF2-1) gave the maximum inhibition of *R. solani* 618 (Montealegre *et al*., 2014) [15]. Huang *et al* (2012) [13] reported that *B. pumilus* SQR-N43 is a potent antagonist against *R. solani* Q1. *T. harzianum* (Jn14) and *T. hamatum* (T36) were the most effective isolates to inhibit *R. solani* mycelial growth (Barakhat *et al*., 2007). *Trichoderma* strains were effective both *in vitro* and *in vivo* was reported by Das and Hazarika (2000) [6] and Tewari and Singh (2005) [23] who all found that *T. harzianum* was an effective BCA in controlling rice sheath blight. Divya *et al.* evaluated thirteen entries of barnyard millet during *Kharif* 2014-15, where ACM 10-082 was recorded as moderately resistant. However, in the mean of all five locations the same was noted as highly resistant.

It is also possible to state that the signs that BCAs will be able to control sheath blight are good. Supplementing biological control with other, non-chemical control methods will improve disease control still more. On the other hand, biological control with the antagonists will lower the dependency on synthetic will it is hoped lead to a cleaner environment and healthier foods.

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