International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 2732-2735

Received: 10-03-2018
Accepted: 15-04-2018

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Management of banded blight disease incited by *Rhizoctonia solani* Kuhn. In foxtail millet (*Setaria italica* L.) by employing various biological control agents

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Abstract
The present study was undertaken to manage the banded blight disease of foxtail 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 agents *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 (24.45% and 45.33%) with higher grain and fodder yield over control.

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

Introduction

Millets have been in food use since time immemorial and an array of traditional healthy foods are prepared across rural India. Foxtail millet (*Setaria italica* L.), a crop rich in nutrients, originated in China. Presently, foxtail millet is extensively cultivated as a food and fodder crop throughout Eurasia and the Far East (Ning, 2015) [15]. Millets have been in food use since time immemorial and an array of traditional healthy foods are prepared across rural India. However, food use of millets is fast decreasing due to several reasons. Apart from health benefits, millets are also good source of energy, protein, vitamins and minerals (Ravindran, 1991) [20]. Millet foods are also known for their low glycemic index (Itagi, 2003 and Singh *et al*., 2010) [11, 22]. There is therefore a need to revive these important groups of health promoting foods to enhance nutritional quality of diets of consumers. Among the millets foxtail millet (*Setaria italica*) is an important underutilized grain, grown in various parts of India. It grows well even under adverse agro climatic conditions. It is also called as navane. Among the millets, foxtail millet is a good source of protein (12.3 g/100g) and dietary fiber (14 g/100g). The carbohydrate content is low (60.9 g/100g). Besides, it is rich in minerals (3 g/100g) and phytochemicals. Foxtail millet is a good source of ß carotene (126-191 µg/100g, Goudar *et al.*, 2011) [6]. This millet has been proved to be suitable for people suffering from metabolic disorders (Itagi, 2003) [11]. Hence, in the present study foxtail millet was chosen for development of nutritious bread.

Banded blight of foxtail millet incited by *Rhizoctonia solani* (Kuhn.) (Basidial stage: *Thanatephorus cucumeris* (Fr.) Donk) is one of the emerging malady in successful cultivation of foxtail millet. The *R. solani* is cosmopolitan fungus with a very wide host range (Nagaraj *et al.* 2017). The fungus has a worldwide distribution (Ogoshi, 1987) [16] and isolates of *R. solani* are highly variable in aggressiveness. 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. During *Kharif*, 2007 twenty one entries were screened against banded blight in foxtail millet. Two entries of foxtail millet (SIA 2757 and SIA 326) were free from the disease whereas 6 entries, *i.e.* TNAU 219, TNAU 248, SIA 2723, SIA 3036, SIA 3085 and GPUS 30, were found resistant (Jain and Gupta, 2010).

However, 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) [8, 21]. Furthermore, environmental conditions such as low light, cloudy days, high temperature and high relative humidity also favor the disease (Ou, 1985). The pathogen overwinters as soil-borne sclerotia and mycelium in plant debris; these constitute the primary inoculums. The disease is characterized by oval to irregular, light grey to dark brown lesions on the lower leaf sheath. In advanced stages, the lesions enlarge rapidly and coalesce to cover large portions of the sheath and leaf lamina. At this stage, the disease symptom is characterized by a series of copper or brown color bands across the leaves giving a very characteristic banded appearance.

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) [9]. 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) [7]. 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) [3]. 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 foxtail 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 (Suryanandi) was used in this experiment by imposing the following treatments: (Table 1)

Two trials were also conducted during *Kharif* 2016 and 2017 for the management of banded blight disease in foxtail millet. Banded blight (Anon, 1996) [1] was recorded by using 0 to 9 scale (Table 2).

The disease severity and yield were recorded and the data was statistically analysed by following the standard procedures (Gomez and Gomez, 1984) [5]. The percent disease index (PDI) was calculated by using the following formula:

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

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

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

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 (24.45%) 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 (68.60%) was recorded in T_2 (Seed treatment with *Pseudomonas flourescens* @ 10 g/kg). High grain (1465.22 kg/ha) and fodder yield (2488.89 kg/ha) was found in T_7 (Table 3).

Whereas, in *Kharif* 2017 the lowest sheath blight intensity (45.33%) 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 48.00% in T_6 *(i.e.,* 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) applied over an acre at the time of sowing) and the highest (62.67%) in T_4 whereas it was 92.00% in the control. However, high grain (1518.52 kg/ha) and fodder yield (2473.37 kg/ha) was found in T_7 (Table 4).

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 (24.45%) and (45.33%) respectively. The yield parameters like grain and fodder were also recorded highest in both the seasons.

Patro and Madhuri (2014) [18] 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) 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). Huang *et al* (2012) reported that *B. pumilus* SQR-N43 is a potent antagonist against *R. solani* Q1. Naeimi *et al*., (2010) reported that *T. harzianum* AS12-2 was the most effective strain in controlling rice sheath blight. *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) [3] and Tewari and Singh (2005) [24] who all found that *T. harzianum* was an effective BCA in controlling rice sheath blight.

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.

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

Treatments	Sheath blight (PDI)	Grain Yield (Kg/ha)	Fodder Yield (Kg/ha)
1	52.29 (46.32)*	1289.11	2181.89
2	68.60 (55.99)	1235.00	1969.55
3	53.46 (46.99)	1240.11	2047.45
4	45.94 (42.67)	1322.78	2197.33
5	35.56 (36.54)	1354.55	2322.22
6	40.24 (39.33)	1319.66	2222.45
7	24.45 (29.59)	1465.22	2488.89
8	94.92 (79.32)	1192.22	1873.56
SEm±	2.60	47.16	112.44
CD(P≤0.05)	7.88	143.01	341.00
CV %	9.55	6.27	9.00

* Figures in parentheses are arc sine transformed values

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

Treatments	Sheath blight (PDI)	Grain Yield (Kg/ha)	Fodder Yield (Kg/ha)
1	53.33 (46.92)*	1411.11	2001.29
2	56.00 (48.48)	1374.07	1583.29
3	49.33 (44.61)	1488.89	2250.85
4	62.67 (52.38)	1325.93	1714.76
5	49.33 (44.59)	1477.78	2264.62
6	48.00 (43.85)	1500.00	2331.32
7	45.33 (42.30)	1518.52	2473.37
8	92.00 (73.92)	1240.74	1149.31
SEm±	2.72	81.77	170.90
CD(P≤0.05)	8.25	247.98	518.29
CV %	9.49	9.99	15.02

* Figures in parentheses are arc sine transformed values

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