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Integrated disease management for effective control of banded leaf and sheath blight in maize

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Abstract
This research aimed to evaluate various modules for the effective management of banded leaf and sheath blight (*Rhizoctonia solani*) in maize. The study was conducted at the Main Maize Research Station, Anand Agricultural University, Godhra, during the *kharif* seasons of 2019, 2020, and 2021. We applied a large plot sampling technique involving four modules, each with four repetitions, to evaluate different approaches for eco-friendly banded leaf and sheath blight disease management in maize. Parameters such as Disease Index (ranging from 1 to 9), plant height, final plant stand/net plot, number of cobs per plot, and grain yield (kg/ha) were recorded to assess the impact of these modules. Among the modules, the Integrated Disease Management (IDM) approach yielded the most significant results. This approach included seed treatment with *T. viride* at 10 g/kg seed and Thiram 75 WS at 3 g/kg seed, soil application of *T. viride* at 10 g/100g FYM/m^2, one foliar application of Azadirachtin 1500 ppm @ 4 ml/lit of water at 35 DAS, and one foliar application of Azoxystrobin 18.2% + Difenoconazole 11.4% (29.6 SC) @ 1 ml/litre of water at 50 DAS. This IDM module led to a remarkable reduction in banded leaf and sheath blight (BLSB) disease severity (11.80%) and resulted in the highest grain yield (5034 kg/ha) and fodder yield (5551 kg/ha) compared to the unprotected inorganic check. This study emphasizes the importance of integrated disease management (IDM) strategies for effectively controlling BLSB in maize. By combining biological agents, fungicides, and other treatments, IDM can enhance disease resistance, promote plant growth, and significantly improve crop yield and productivity.

Keywords: *Rhizoctonia solani*, maize disease management, banded leaf and sheath blight and integrated disease management (IDM)

Introduction
Maize (*Zea mays* L.) globally ranks as the third most important cereal crop following rice and wheat. It has been cultivated in India since the 17th century, covering an extensive 9.86 million hectares and yielding 30.16 million metric tons with a productivity of 3.05 t/ha. This versatile crop plays a pivotal role in ensuring food security and livelihoods, particularly in developing countries like India, where it finds diverse applications: feed (63%), food (23%), starch industries (12%), and other uses such as seeds (2%) (Malik *et al*., 2018).

Despite its importance, maize cultivation in India faces various challenges, with diseases emerging as a significant threat to both yield and crop quality (Shurtleff, 1980) [10]. India contends with 65 out of the reported 112 diseases worldwide, leading to yield losses estimated between 4% and 14% of the global maize harvest annually (Srinivasan *et al*., 2002; Oerke, 2006) [13, 4]. Among the numerous diseases, banded leaf and sheath blight (BLSB), caused by *Rhizoctonia solani* f. sp. sasakii Exner (Tu and Kimbrough, 1978) [16], stands out as one of the most destructive. It thrives in humid conditions with temperatures around 28°C (Tang *et al*., 2004) [15]. Initially reported as a sclerotial disease in Sri Lanka, BLSB goes by different names in various countries. In India, it has transformed from a minor issue to a severe epidemic, becoming a significant constraint for maize growers in various regions (Sharma *et al*., 1993) [7].

BLSB manifests as concentric bands and rings on the lower leaves and sheath of 40–45-day-old maize plants, often accompanied by discolored areas that later develop into sclerotia. This disease results in direct losses due to early plant death, stalk breakage, and ear rot in older plants, leading to significant grain yield reductions under favorable conditions (Singh and Sharma, 1976) [11]. Despite concerted efforts to control BLSB through fungicides and crop rotation, effective management remains a challenge for maize growers. Therefore, this study aims to assess different modules for the effective management of banded leaf and sheath blight in maize.

Materials and Methods

Study area, experimental design

A field experiment was conducted at Main Maize Research Station, Godhra, during the *kharif* seasons of 2019, 2020, and 2021 using a large-plot sampling technique in a completely randomized design (CRD) with a local maize cultivar. The experimental plots were divided into four equal sectors, treating each sector as one repetition. Rows were spaced 60 cm apart, with plants spaced 20 cm apart, following standard agronomical practices.

Module Setup

Each of the five modules occupied a 15 x 9 m plot, further divided into four sectors. Five plants were randomly selected for data collection from each sector. Before sowing, the soil in the modules received an application of *T. viride* fortified with 10 g/100g FYM/m2 as a bio-agent. Unamended plots were designated as the control group.

Seed Treatment

In the IDM, Organic, and Chemical modules, maize seeds were treated with a slurry of Thiram 75 WS at 3 g/kg seed and *T. viride* at 10 g/kg seed, either individually or in combination. After fungicide treatment, maize seeds were air-dried before sowing. Bio-agent treated seeds were kept overnight in a moist chamber to promote the establishment of the antagonist on the seed surface.

Treatment application and its detail

Different treatments were applied according to the specified schedule for each module and treatment. These modules were as follows:

M1: Organic Module - Seed treatment with *T. viride* at 10 g/kg seed, soil application of *T. viride* at 10 g/100g FYM/m2, one foliar spray of Azadirachtin 1500 ppm @ 4 ml/lit of water at 30 DAS, and two foliar sprays of *T. viride* at 10% (100 ml in 900 ml of water) at 40 DAS and 50 DAS.

M2: Chemical Module - Seed treatment with Thiram 75 WS at 3 g/kg seed, one foliar spray of Mancozeb 75WS at 2.5 g/liter of water at 35 DAS, and one foliar application of Azoxystrobin 18.2% + Difenoconazole 11.4% (29.6 SC) at 1 ml/liter of water at 50 DAS.

M3: IDM Module - Seed treatment with *T. viride* at 10 g/kg seed and Thiram 75 WS at 3 g/kg seed, soil application of *T. viride* at 10 g/100g FYM/m2, one foliar application of Azadirachtin 1500 ppm @ 4 ml/lit of water at 35 DAS, and one foliar application of Azoxystrobin 18.2% + Difenoconazole 11.4% (29.6 SC) at 1 ml/litre of water at 50 DAS.

M4: Recommended Module - Seed treatment with *T. viride* at 10 g/kg seed, soil application of *T. viride* at 10 g/100g FYM/m2, and four foliar sprays of *T. viride* at 10% (100 ml in 900 ml of water) at 30, 40, 50, and 60 DAS.

M5: Unprotected Inorganic Check - Utilization of the recommended dose of fertilizer.

The treatments were administered as per the specified schedule in each module and treatment.

Inoculation

Inoculations were conducted by inserting 3–4 fully colonized maize grains infected with *R. solani* between the rinds and enclosing sheaths of 30-day-old plants at the second or third basal internodes. The recommended doses of bio-pesticides, bio-agents, and fungicides were applied according to the respective modules. A water spray was used as the control treatment.

Observation recorded

Disease severity was recorded 45 days after inoculation using the 1-9 scale devised. The percent disease index, disease control, Plant height, Number of cob, plant stand and yield of grain and fodder were calculated.

$$\text{Disease severity (\%)} = \frac{\text{Sum of numerical rating of disease scale}}{\text{No. of plants examined} \times \text{Maximum grade}} \text{ X } 100$$

$$\text{Disease control (\%)} = \frac{C - T}{C} \text{ X } 100$$

Where, C is the percent disease incidence in the untreated plants and T is the percent disease incidence in the treated plants.

Statistical Analysis

The obtained data were subjected to statistical analysis of variance (ANOVA) after appropriate transformation to draw valid conclusion (Steel and Torrie, 1980) [14].

Results

The results presented in Table 1 indicate the effectiveness of various modules for the management of banded leaf and sheath blight (*Rhizoctonia solani*) in maize during three consecutive *Kharif* seasons (2019, 2020, and 2021). Notably, all modules, with the exception of the Unprotected Inorganic Check, showed significant effectiveness in reducing the Percent Disease Index (PDI) and achieved higher disease control percentages across the three years.

Percent Disease Index (PDI) and Disease Control

Among the modules, the Integrated Pest Management (IPM) module showed the most promising results. Specifically, it achieved the lowest PDI values of 11.56%, 13.65%, and 10.31% during the *Kharif* seasons of 2019, 2020, and 2021, respectively. In terms of disease control percentage, the IPM module also demonstrated remarkable outcomes. The highest disease control percentages were recorded in the IPM module, with values of 59.03%, 60.06%, and 55.85% for the *Kharif* seasons of 2019, 2020, and 2021, respectively, when compared to the Unprotected Inorganic Check. The chemical module was closely followed by the IPM module in terms of the lowest PDI and the highest disease control percentage.

Pooling the data across the three years, the IPM module retained its status as the most effective strategy, with the lowest PDI of 11.80%, closely followed by the chemical module with a PDI of 18.53%. In terms of disease control, the IPM module again outperformed other modules with a disease control percentage of 58.31%, while the chemical module maintained a substantial disease control rate of 47.06%.

The Recommended and Organic modules demonstrated

intermediate results in both PDI and disease control percentages, suggesting their potential utility in managing banded leaf and sheath blight, although they fell behind the more effective IPM and Chemical modules.

Overall, these findings underscore the importance of implementing integrated approaches such as IPM and judicious chemical management to effectively control banded leaf and sheath blight in maize. The study highlights that sustainable disease management practices can lead to consistent and substantial reductions in disease incidence, contributing to improved maize productivity.

Plant Height and Number of Cobs

The IDM module (M_3) consistently led in plant height, with an average of 175 cm. This suggests robust plant growth under this approach. The Chemical module (M_2) closely followed with an average plant height of 171 cm. The Organic module (T_1) exhibited an average plant height of 166 cm, while the Recommended module (M_4) displayed the lowest average plant height of 159 cm. The IDM module (M_3) also demonstrated the highest average number of cobs per plot (230-231) compared to other modules, indicating favorable reproductive performance.

Grain yield (kg/ha)

Among the tested different modules; based on the pooled data over the years, the highest grain yield was recorded in the IDM module (5034 kg/ha) which was followed by the chemical module (4669 kg/ha). The lowest grain yield was recorded in the unprotected inorganic module (3787 kg/ha).

Fodder yield (kg/ha)

Among the tested different modules; based on the pooled data over the years, the highest fodder yield was recorded in the IDM module (5551 kg/ha) which was followed by the chemical module (5447 kg/ha). The lowest fodder yield was recorded in the unprotected inorganic module (4519 kg/ha).

Economic Analysis

The Incremental Cost-Benefit Ratio (ICBR) of 1:2.00 indicated the highest return on investment, highlighting the cost-effectiveness of the IDM approach.

Discussion

These results are in corroboration with maintaining the proper population level and application of cattle compost (FYM) prior to planting, which helped in decreasing the disease level and its subsequent spread in the field (Sharma and Hembram, 1990) [8]. Rakesh *et al*., 2011 [5] tested Thiram 50 WP@ 2.5 g/kg of seed treatment effective against BLSB pathogen. *Trichoderma* sp. was found to be an effective biocontrol agent, providing as high as 68% inhibition of the mycelia of *R. solani* under *in vitro* conditions compared to the control of BLSB (Sharma *et al*., 2002) [9]. Singh and Singh (2011) [12] found the best performance of Validamycin (0.25%) and *T. viride* as a foliar spray compared to fungicides like Tilt (0.15%) and Bavistin (0.1%) and the bio-agent *P. florescence*, which contributed to higher maize grain yield over the check. Saikia and Gandhi (1995) [6] reported that *T. viride* was more effective than *T. harzianum* in reducing the mycelial growth of *R. solani* causing cauliflower stem rot. Khan and Sinha (2006) [2] reported that the maximum reduction in disease severity and incidence were recorded with FYM + *Trichoderma harzianum*. Seed treatment and soil application of this antagonist not only reduced the disease by more than 50%, but also increased grain yield approximately 1.4 times that of the control (Sharma *et al*., 2002) [9]. Divya *et al.* reported that among all the treatments, carbendazim recorded the least disease severity index (37.93%) and the lowest percent disease incidence (27.11%) in both seed and soil treatments, followed by seed treatment and soil treatment with *T. viride.*

Table 1: Evaluation of different modules for effective management of banded leaf and sheath blight (*Rhizoctonia solani*) of maize.

Treatment	Module	*Kharif*-2019		*Kharif*-2020		*Kharif*-2021		Pooled PDI (%)	Disease control %
		PDI (%)	Disease control %	PDI (%)	Disease control %	PDI (%)	Disease control %		
T_1	Organic module	31.69 (27.60)	34.69	36.19 (34.86)	33.32	33.09 (29.81)	22.01	33.65 (30.70)	30.00
T_2	Chemical module	24.36 (17.01)	49.79	27.66 (21.55)	49.04	24.46 (17.14)	42.35	25.50 (18.53)	47.06
T_3	IDM module	19.88 (11.56)	59.03	21.68 (13.65)	60.06	18.73 (10.31)	55.85	20.09 (11.80)	58.31
T_4	Recommended module	29.00 (23.50)	40.23	34.30 (31.76)	36.81	26.90 (20.47)	30.08	30.06 (25.09)	35.70
T_5	Unprotected inorganic check	48.52 (56.13)	-	54.28 (65.91)	-	42.43 (45.52)	-	48.41 (55.94)	-
	S.Em ± T	1.36	-	1.23	-	1.54	-	1.19	-
	Y	-		-		-		0.92	-
	T x Y	-		-		-		2.06	-
	CD (0.05%)	4.18	-	3.86	-	4.76	-	2.41	-
	CV (%)	8.73	-	7.11	-	10.60	-	8.80	-

BLSB = Banded leaf and sheath blight, *Figure in parenthesis are arcsign transformed values PDI = Percent disease index

Table 2: Evaluation of different modules for effective management of banded leaf and sheath blight (*Rhizoctonia solani*) of maize.

Treatment	Module	Plant height	No. of cobs/plot	Plant stand/plot		Yield (kg/ha)	
		Pooled	Pooled	Initial	Final	Grain	Fodder
T_1	Organic module	166	221	230	226	4269	4994
T_2	Chemical module	171	225	231	226	4669	5479
T_3	IDM module	175	230	231	228	5034	5551
T_4	Recommended module	159	224	229	224	4445	5224
T_5	Unprotected inorganic check	155	216	228	224	3787	4519
	S.Em± T	2.31	3.23	4.07	3.17	213.38	248.96
	Y	1.79	2.50	-	-	165.29	192.84
	T x Y	4.00	NS	-	-	NS	NS
	CD (0.05%)	Sig.	Sig.	NS	NS	432.76	504.91
	CV (%)	3.41	3.53	4.33	3.43	11.77	11.83

BLSB = Banded leaf and sheath blight

Conclusion

The study highlights the efficacy of the IDM module (M3) in effectively managing banded leaf and sheath blight (BLSB) of maize caused by *Rhizoctonia solani*. The IDM module, comprising seed treatment with *T. viride* and Thiram 75 WS, soil application of *T. viride*, and foliar applications of Azadirachtin and Azoxystrobin + Difenoconazole, demonstrated the highest disease control and significantly reduced disease severity. Additionally, the IDM module promoted plant growth and resulted in the highest grain and fodder yields among all modules. Overall, the results emphasize the significance of integrated disease management (IDM) strategies, which combine biological agents, fungicides, and other treatments, for effective control of BLSB in maize cultivation.

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