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Integrated Disease Management (IDM) Modules against Karnal Bunt (*Tilletia indica*) of Wheat

Vishwakarma S. K. [a++], Singh R. [a#*], Khilari K. [a#], Mishra P. [a#], Singh H. [b#] and Yadav M. K. [c#]

[a] *Department of Plant Pathology, Sardar Vallabhbhahi Patel University of Agriculture & Technology, Meerut- 250110, U.P., India.*
[b] *Department of Entomology, Sardar Vallabhbhahi Patel University of Agriculture & Technology, Meerut-250110, U.P., India.*
[c] *Department of Agricultural Biotechnology, Sardar Vallabhbhahi Patel University of Agriculture & Technology, Meerut- 250110, U.P., India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Wheat (*Triticum aestivum* L.) belonging to family "Gramineae" and genus "*Triticum*", is one of the world's most widely cultivated food grain crop, due to its wider adaptability to different agro-climatic and soil conditions. Karnal bunt (*Tilletia indica*) is an important wheat disease with implications for wheat grain quality and inflicts changes in chemical composition of infected grains. IDM modules evaluated under pot and field condition revealed that all the thirteen modules were significantly effective and observed lower disease incidence of karnal bunt. Module M_{11} andM_8 recorded nil (0.00%) disease incidence in both condition. The maximum incidence was recorded (0.425%) and

[++] *Ph.D. Scholar;*
[#] *Professor;*
**Corresponding author: E-mail: rameshsingh@svpuat.edu.in;*

(0.81%) in M_{12} followed by M_5 (0.395%) and (0.68%) whereas minimum incidence was observed in M_9 (0.002%) and (0.05%) under pot and field respectively. However, in the field maximum yield (44.65 q/ha) and test weight (36.04 g) was recorded in module M_{11}, followed by (44.30q/ha) and (35.91g) in M_8, while, minimum yield (40.35q/ha) and test weight (35.30g) was observed in M_{12}.

Keywords: Karnal bunt; Tilletia indica; incidence; module; treatments.

1. INTRODUCTION

Wheat, (*Triticumae stivum* L.) belonging to family "Gramineae" and genus "*Triticum*", is one of the world's most widely cultivated food grain crop, due to its wider adaptability to different agro-climatic and soil conditions. Globally, the nutria rich cereals are grown altogether in 215.48 million hectare area with the annual production 731.40 million metric tons. In India, during 2020-21, wheat has been cultivated in 30.22 million hectare and production has made another landmark achievement by producing 99.9 million metric tons with an average national productivity of 33.71 q/ha [1]. Many factors of biotic and abiotic stresses pose serious threats to sustain production, productivity and quality of wheat in Indian subcontinent and through-out the world [2]. Out of these different biotic stresses, karnal bunt (*Tilletia indica*) is an important wheat disease with implications for wheat grain quality and inflicts changes in chemical composition of infected grains [3]. Karnal bunt is also a disease of quarantine interest and it affects the international trade of commercial wheat grain and movement of wheat throughout the world. With the advent of new stringent laws in import/export, there is zero tolerance limits on shipment of wheat from karnal bunt prone regions [4]. The loss due to Karnal Bunt is difficult to estimate because the disease reduces seed quality, inflicts changes in the chemical composition of infected grains and renders seed useless for consumption. Nevertheless, in India, loss in yield due to the disease has been calculated as 1/3 x yield x per cent infection as the disease covers one third of an area under wheat cultivation in India [5]. The financial losses caused by the disease are substantial, ranging from 5-20% in India. The losses in grain quality due to Karnal bunt have serious economic repercussions, even though the losses in grain yield are minimal. The economic importance of this disease is generally not measured by the loss in grain quantity but by grain quality which gets deteriorated due to *Tilletia indica* [6].

2. METHODS AND MATERIALS

An experimental trial (field and pot) for the evaluation of different Integrated Disease Management (IDM) Modules (treatments) against karnal bunt of wheat was conducted at Crop Research Center Chiraudi (CRC), Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during the year 2021 and 2022. The trial was conducted in 4.0 x 3.0 m^2 plots under irrigated condition with recommended package and practices. The experiment was laid out in a Randomized Block Design (RBD) with 3 replications and 13 treatments (Modules) using karnal bunt susceptible variety HD-2967. When crop reached to boot leaf stage each of the ten heads in each plot was inoculated (4-5 times at one day intervals) with 3 ml of sporidial suspension of *T. indica* (10,000 spores/ml). Sterilized water sprayed in sub-plots served as control. After 48 hours of artificial inoculation, each fungicides was sprayed at their recommended dosage rates at two crop stages first at boot stage and second at ear emergence stage (Table 1). Inoculated plants were tagged and labeled and field moisture was maintained. At maturity, the inoculated heads were harvested, hand threshed and percent seed infections for each module was determined. The data collected included the numbers of infected and uninfected seeds every ten spikes to evaluate the incidence of the disease (% seeds infected). The incidence of the disease for each entry was calculated by using the following formula Aujla et al. [7].

Percent disease incidence

$$= \frac{\text{Number of bunted grains in 10 spike}}{\text{Total number of grain in 10 spike}} \times 100$$

And Percent Disease control was calculated with the help of the following formula:

Percent disease control

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

Whereas, PDI = Percent Disease Incidence

Fig. 1. Culture of *Tilletiaindica* in PDB, 2. Artificial inoculation of spore suspension, 3. Fungicide spray on experimental field and 4. Infected grains of wheat

Table 1. Details of the IDM modules

Module	Seed Treatment	Soil Treatment	Foliar Spray	
M_1	Hot water (52^0C) for 10 min.	*Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Propiconazole 25% EC @ 0.1% at ear emergence	
M_2	Thiram 75% DS @ 2.5 g/Kg seed	*Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Tebuconazole 25.9% EC @ 0.1% at ear emergence	
M_3	Late sowing	*Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Pressmud @ 10t/ha.	Azoxystrobin 23% SC @ 0.1% at ear emergence	
M_4	Hot water (52^0C) for 10 min.	*Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Pressmud @ 10t/ha.	Tebuconazole 25.9% EC @ 0.1% at ear emergence	
M_5	Salt (NaCl) @ 20%	*Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Azadirachtin (Neem Oil) @ 0.3% at ear emergence	
M_6	Thiram 75% DS @ 2.5 g/Kg seed	*Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Azadirachtin (Neem Oil) @ 0.3% at ear emergence	
M_7	Hot water (52^0C) for 10 min.	*Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Pressmud @ 10t/ha.	Azadirachtin (Neem Oil) @ 0.3% at ear emergence	
M_8	Salt (NaCl) @ 20%	*Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	**Bootstage**	**Ear emergence**
			Propiconazole 25% EC @ 0.1%	Azadirachtin (Neem Oil) @ 0.3%
M_9	Thiram 75% DS @ 2.5 g/Kg seed	*Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Tebuconazole 25.9% EC @ 0.1%	Azadirachtin (Neem Oil) @ 0.3%
M_{10}	Hot water (52^0C) for 10 min.	*Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Azoxystrobin 23% SC @ 0.1%	Azadirachtin (Neem Oil) @ 0.3%
M_{11}	Thiram 75% DS @ 2.5 g/Kg seed	*Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha.	Propiconazole 20% EC @ 0.1%	Azoxystrobin 23% SC @ 0.1%
M_{12}	Late sowing without treatment			
M_{13}	Control	Control	Control	

3. RESULTS AND DISCUSSION

IDM modules evaluated under pot condition revealed that all the thirteen modules were significantly effective and observed lower disease incidence of karnal bunt (Table 2). Module M_{11} [seed treatment with Thiram 75% DS @ 2.5 g/kg seed, soil treatment with *Bacillus subtilis* (CFU 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha. and Propiconazole 20% EC @ 0.1%booting stage+ Azoxystrobin 23% SC @ 0.1% at ear emergence stage] and M_8 [seed treatment with salt (NaCl) @ 20%, soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. +Vermicompost @ 10t/ha andPropiconazole 25% EC @ 0.1% at booting stage and Azadirachtin (Neem Oil) @ 0.3% at ear emergence stage) recorded nil (0.00%) disease incidence. After control the maximum incidence was recorded (0.425%) in M_{12} [late sowing] followed by M_5 (0.395%) [Seed treatment with salt (NaCl) @ 20%, soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha + Vermicompost @ 10t/ha. and foliar spray with Azadirachtin (Neem Oil) @ 0.3% at ear emergence] whereas minimum incidence was observed in M_9 (0.001%). [seed treatment with Thiram 75% DS @ 2.5 g/Kg seed, soil treatment with *Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha + Vermicompost @ 10t/ha and foliar spray with].

Studies on management of karnal bunt were conducted to evaluate thirteen IDM modules, under field condition revealed that all the modules were significantly effective and recorded lower disease incidence of karnal bunt (Table 3). However, under natural condition module M_{11} [seed treatment with Thiram 75% DS @ 2.5 g/Kg seed, soil treatment with *Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha. and Propiconazole 20% EC @ 0.1% booting stage+ Azoxystrobin 23% SC @ 0.1% at ear emergence stage] and M_8 [seed treatment with salt (NaCl) @ 20%, soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha. and Propiconazole 25% EC @ 0.1% at booting stage and Azadirachtin (Neem Oil) @ 0.3% at ear emergence stage] observed nil (0.00%) incidencefollowed by M_9 [seed treatment with Thiram 75% DS @ 2.5 g/Kg seed, soil treatment with *Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha + Vermicompost @ 10t/ha. and foliar spray with Tebuconazole 25.9% EC @ 0.1% at booting stage and Azadirachtin (Neem Oil) @ 0.3% at ear emergence stage] (0.005%) was recorded. The other modules were recorded higher disease incidence *viz.,* M_{12} (0.81%) [Late sowing], M_5 (0.68%) [Seed treatment with salt (NaCl) @ 20%, soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha + Vermicompost @ 10t/ha. and foliar spray with Azadirachtin (Neem Oil) @ 0.3% at ear emergence] and M_7 (0.60%) [seed treatment with Hot water (52^0C) for 10 min., soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha + Pressmud @ 10t/ha and foliar spray with Azadirachtin (Neem Oil) @ 0.3% at ear emergence].

Table 2. Evaluation of IDM modules against *T. indica* (Pot)

Modules	**Disease Incidence (2021-22)**	**Disease Incidence (2022-23)**	**Plant Disease over Control (2021-22)**	**Plant Disease over Control (2022-23)**	**Average DI (Both year)**
M_1	0.026	0.028	94.90	94.71	0.027
M_2	0.019	0.022	96.27	95.84	0.020
M_3	0.210	0.200	58.82	62.26	0.205
M_4	0.090	0.110	80.39	79.24	0.100
M_5	0.390	0.400	23.52	24.52	0.395
M_6	0.250	0.270	50.98	49.05	0.260
M_7	0.310	0.300	39.22	43.39	0.305
M_8	0.000	0.000	100	100	0.000
M_9	0.000	0.005	100	99.05	0.002
M_{10}	0.150	0.140	70.58	73.58	0.145
M_{11}	0.000	0.000	100	100	0.000
M_{12}	0.430	0.420	15.68	20.75	0.425
M_{13}	0.510	0.530	0	0	0.520
CD at 5%	**0.03**	**0.03**			

Table 3. Evaluation of IDM Modules against karnal bunt of wheat (Experimental Field)

Module	Disease Incidence 2021-22	Plant Disease over control (%) (2021-22)	Disease Incidence (%) 2022-2023	Plant Disease over control (%) (2022-23)	Average Disease Incidence (%)
M_1	0.15	83.14	0.17	80.46	0.16
M_2	0.09	89.88	0.11	87.35	0.10
M_3	0.47	47.19	0.45	48.27	0.46
M_4	0.21	76.40	0.20	77.01	0.20
M_5	0.67	24.71	0.60	20.68	0.68
M_6	0.53	40.45	0.56	35.63	0.54
M_7	0.59	33.71	0.61	29.88	0.60
M_8	0.00	100	0.00	100	0.00
M_9	0.04	95.50	0.06	93.10	0.05
M_{10}	0.33	62.92	0.35	59.77	0.34
M_{11}	0.00	100	0.00	100	0.00
M_{12}	0.83	6.74	0.79	9.19	0.81
M_{13}	0.89	0	0.87	0	0.88
CD at 5%	**0.06**	**0.06**			

Data from Table 4 also revealed that all the modules were significantly effective and recorded higher yield and test weight compared to unprotected control. However, the maximum yield and test weight was recorded (44.65 q/ha) and (40.59g) in module M_{11} [seed treatment with Thiram 75% DS @ 2.5 g/Kg seed, soil treatment with *Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha. and Propiconazole 20% EC @ 0.1%booting stage+ Azoxystrobin 23% SC @ 0.1% at ear emergence stage] followed by (44.30 q/ha) and (40.38 g) M_8 [seed treatment with salt (NaCl) @ 20%, soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha and Propiconazole 25% EC @ 0.1% at booting stage and Azadirachtin (Neem Oil) @ 0.3% at ear emergence stage], after control the minimum yield and test weight was observed (40.35q/ha) and (37.50 g) in M_{12} (Late sowing) respectively.

Karnal bunt pathogen is predominantly soil-borne rather than seed-borne like the dwarf bunt; seed treatment with fungicide is ineffective for the total eradication of infection [8,9]. However, it might reduce the likelihood of infection [10]. The biggest issue with utilize existing fungicides is that when the chemical washes off the spore, karnal bunt spores may develop [6].

Table 4. Effect of IDM moduleson yield (q/ha) and 1000 grain weight (test weight) of wheat

Module	Yield (q/ha)		Increase yield over control (%)		Average yield	1000 grain weight (gram)		
	2021-22	2022-23	2021-22	2022-23		2021	2022	Ave.
M_1	43.60	43.20	9.00	7.73	43.40	39.92	39.68	39.80
M_2	43.90	43.70	9.75	8.98	43.80	40.09	39.87	39.98
M_3	42.30	42.10	5.75	4.98	42.20	39.19	38.76	38.97
M_4	43.10	42.80	7.75	6.73	42.95	39.86	39.39	39.62
M_5	40.60	40.50	1.50	0.99	40.55	37.96	37.71	37.83
M_6	41.90	41.70	4.75	3.99	41.80	38.77	38.43	38.68
M_7	41.50	41.30	3.75	2.99	41.40	38.23	38.09	38.16
M_8	44.40	44.20	11.00	10.22	44.30	40.44	40.33	40.38
M_9	44.10	43.90	10.25	9.47	44.00	40.26	40.11	40.18
M_{10}	42.70	42.50	6.75	5.98	42.60	39.63	39.17	39.40
M_{11}	44.80	44.50	12.00	10.97	44.65	40.67	40.52	40.59
M_{12}	40.30	40.40	0.75	0.75	40.35	37.56	37.47	37.50
M_{13}	40.00	40.10	0	0	40.05	37.10	37.21	37.15
CD at 5%	**5.20**	**5.18**				**1.78**	**1.72**	

DI= Disease Incidence, Ave. = Average

Foliar sprays of Propiconazole, Tebuconazole, Hexaconzole, Thifluzamide, Diniconazole etc. were shown to be effective against natural infection in India [11].

All the fungicides singly or in combinations significantly increased the disease control and yield increased as compared to control. Efficacy of such combination products in managing many fungal diseases has been reported by various workers across the world [12,13]. Different fungicides vary in their efficacy to control karnal bunt. Nagy and Moldovan reported that fungicides containing Difenoconazole (Dividend 030 FS 1.0 l/t), Tebuconazole (Raxil 060 FS 0.5 l/t), Fludioxonil + Epoxiconazole (Maxim Star DS 1.5 kg/t), Tebuconazole + Thiram (Raxil T 515 FS 2.0 l/t) had a very good efficiency in controlling the common bunt even under artificial infections. Singh et al. [14] compared the efficacy of different fungicides found that the maximum disease control (99.8%) was achieved Propiconazole (0.1) by a single spray controlled (96.46%) disease, followed by Hexaconazole (92.87%) in the post-inoculation treatment. Singh et al. [14] evaluated the efficacy of seven fungicides viz; Tilt 250, Folicur, Bavistin, Thiram, Vitavax, Benlate and Dithane M-75 of different groups against *Tilletiaindica*and reported that out of seven, two fungicides viz; Tilt 250 EC and Folicur to be the most effective as they have inhibited the fungal growth completely [15-17].

4. CONCLUSION

Among all the 13 modules (treatments) evaluated at field conditions, the best module was found to be effective, against karnal bunt of wheat wasmodule M_{11} [seed treatment with Thiram 75% DS @ 2.5 g/Kg seed, soil treatment with *Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha. and Propiconazole 20% EC @ 0.1%booting stage+ Azoxystrobin 23% SC @ 0.1% at ear emergence stage] andM_8[seed treatment with salt (NaCl) @ 20%, soil treatment with *Pseudomonas fluroscens* (cfu 2×10^8/g) @ 5Kg/ha. + Vermicompost @ 10t/ha. andPropiconazole 25% EC @ 0.1% at booting stage and Azadirachtin (Neem Oil) @ 0.3% at ear emergence stage] observed nilincidence (0.00%), whereas, minimum disease incidencewas observed in M_9(0.005%)[Seed treatment with Thiram 75%DS @ 2.5 g/Kg seed, soil treatment with *Bacillus subtilis* (cfu 2×10^8/g) @ 5Kg/ha.+ Vermicompost @ 10t/ha and foliar spray with Tebuconazole 25.9%EC @ 0.1% at booting stage and Azadirachtin (Neem Oil) @ 0.3% at ear emergence stage]. Similar results were also recorded with test weight (40.59g) and yield (44.65q/ha) in module M_{11} and M_8 (40.38g & 44.30q/ha).

5. FUTURE SCOPE

The fungus *Tilletia indica* inciting Karnal bunt disease of wheat is a serious concern for import of wheat to Karnal bunt free countries. The grain quality deterioration caused by Karnal bunt fungus is known to have serious implications in the world wheat trade due to strict quarantine regulations. Understanding pathogen population is an important aspect for exploiting resistance, especially when dealing with a heterothallic fungus. Several diagnostic techniques have been devised for the accurate identification of the fungus. This seed, soil and air borne pathogen have lesss chemical control measures so an integrated disease management strategy is the best approach to combating the disease.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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