Plant Archives Vol. 25, Supplement 1, 2025 pp. 546-550 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.073

STUDY ON DEVELOPMENT OF IDM MODULE FOR THE MANAGEMENT OF FUSARIUM WILT IN CHICKPEA CAUSED BY *FUSARIUM OXYSPORUM* F.SP. *CICERI* UNDER CLIMATE CHANGE IN CENTRAL PLANE ZONE OF UTTAR PRADESH INDIA

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(Date of Receiving : 30-07-2024; Date of Acceptance : 02-10-2024)

ABSTRACT

Fusarium wilt, caused by *Fusarium oxysporum* f.sp. *ciceri*, is a major soil-borne disease affecting chickpea production worldwide, which losses up to 10% yield annually. The present study was conducted during the *Rabi* seasons of 2022-23 and 2023-24 at Student Instructional Farm (S.I.F.), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, to evaluate the efficacy of various Integrated Disease Management (IDM) modules for managing Fusarium wilt in chickpea. The modules involved combinations of *Trichoderma harzianum*, *Pseudomonas fluorescens*, *Rhizobium*, organic amendments (vermicompost and neem cake), and salicylic acid applied through seed modules, soil application, and foliar spray. The results showed that the IDM module integrating soil application of *Trichoderma harzianum*, seed modules with *Pseudomonas fluorescens*, and foliar spray of salicylic acid was the most effective, achieving a significant reduction in disease incidence by 80.30% at 30 DAS, 72.12% at 60 DAS, and 73.60% at 90 DAS over the control. Other IDM modules, including those utilizing vermicompost and neem cake, also showed promising results, reducing disease incidence by up to 72.15%. The use of chemical amendments like boric acid showed relatively lower effectiveness. The results suggest that integrated approaches involving biocontrol agents and organic amendments are not only effective in controlling Fusarium wilt but also environmentally sustainable, contributing to soil health improvement and reduced dependency on chemical fungicides. Thus, the adoption of IDM practices can provide a robust, eco-friendly, and sustainable solution for managing chickpea wilt under changing climate conditions and ensuring stable chickpea production.

***Keywords*:** Fusarium wilt, IDM, Chickpea, *T. harzianum, P. fluorescens,* Salicylic Acid

Introduction

Chickpea (*Cicer arietinum* L.) is one of the earliest domesticated grain legumes and holds significant historical and agricultural importance. It is widely cultivated across South Asia, the Mediterranean, and parts of Africa, where it serves as a staple food due to its high nutritional content, which includes proteins, essential amino acids, and a variety of vitamins and minerals (Kumar *et al.,* 2011). Its nutritional profile makes chickpea a critical component of diets in these regions, contributing significantly to food and nutritional security (Jukanti *et al.,* 2012). Additionally, chickpea is a vital crop in sustainable agricultural systems, due to its ability to fix atmospheric nitrogen and improve soil health, thus reducing dependency on chemical fertilizers (Singh *et al.,* 2014). However, chickpea production is frequently threatened by various biotic stresses, particularly

Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *ciceri*. Fusarium wilt is one of the most severe soil-borne diseases affecting chickpea worldwide, causing yield losses ranging from 5 to 10% annually (Haware *et al.,* 1990). The pathogen is capable of surviving in soil for up to six years even in the absence of a host plant, making its management particularly challenging (Nene and Reddy, 1987). The persistence and adaptability of this pathogen make Fusarium wilt a major constraint to chickpea production, especially under the changing climate conditions that are expected to alter pathogen dynamics and disease severity (Singh *et al.,* 2012). The increasing reliance on chemical fungicides for managing Fusarium wilt has raised concerns about soil health, environmental sustainability, and the development of fungicide-resistant strains (Sharma *et al.,* 2010). Consequently, there is a pressing need to develop Integrated Disease Management (IDM) strategies that incorporate environmentally friendly and sustainable methods for disease control. IDM approaches integrate various control measures, including seed modules, soil application, and foliar sprays, to effectively reduce disease incidence while minimizing adverse impacts on the ecosystem (Nene and Reddy, 1987). Climate change further complicates the management of Fusarium wilt. Factors such as increased temperatures, altered rainfall patterns, and shifts in cropping systems can influence the incidence and severity of the disease (Sharma and Pande, 2013). These changing environmental conditions necessitate a comprehensive approach to disease management that considers the dynamic interactions between the pathogen, host plant, and environment. Developing IDM modules tailored to these evolving conditions is crucial for ensuring the long-term sustainability and resilience of chickpea production (Sharma *et al.,* 2010). To evaluate the efficacy of IDM modules combining seed modules, soil application, and foliar sprays for the management of Fusarium wilt in chickpea under climate change conditions. By integrating various control measures, the study seeks to develop a robust strategy that reduces reliance on chemical fungicides, enhances the use of biological control agents, and promotes the adoption of resistant cultivars (Sharma and Pande, 2013). Ultimately, the goal is to provide farmers with an effective and sustainable disease management solution that safeguards chickpea yields and contributes to food security.

Material and Method

The field experiments were conducted at the Student Instructional Farm (SIF) during the *Rabi* seasons of 2022-23 and 2023-24, while laboratory work was carried out in the Bio-Control Laboratory, Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.). The study was designed to develop an Integrated Disease Management (IDM) module for managing Fusarium wilt in chickpea using various modules such as seed modules, soil application, and foliar spray. The experiments were set up in a Randomized Block Design (RBD) with 14 moduless and 3 replications, utilizing the chickpea variety 'JG 62', which is susceptible to Fusarium wilt. Each plot measured 5 m x 3 m, with a row-to-row spacing of 30 cm and a plant-to-plant spacing of 10 cm. The 14 modules included combinations of chemical and biological agents such as salicylic acid, DPHP, hydrogen peroxide, calcium chloride, boric acid, and bio-agents like *Trichoderma harzianum* and *Pseudomonas fluorescens*. The materials used in laboratory experiments included a variety of inorganic chemicals, media ingredients, glassware, and equipment like hot air ovens, autoclaves, B.O.D. incubators, laminar airflow cabinets, and instruments such as cork borers, inoculation needles, scalpels, and forceps. Observations were recorded at 30, 60, and 90 days after sowing (DAS) to assess disease incidence and plant growth parameters. Disease incidence was calculated as: Disease Incidence (%) = (Number of infected plants / Total number of plants observed) x 100. Visual assessments were made based on symptoms like vascular discoloration, yellowing, and wilting. Plant samples from each module were analyzed for disease severity using a standard scale, and the results were statistically evaluated to determine the efficacy of each module in managing Fusarium wilt under the given climatic conditions.

Result and Discussion

The results of the study on the evaluation of different IDM modules for managing Fusarium wilt in chickpea at 30, 60, and 90 days after sowing (DAS) during the 2022-23 and 2023-24 cropping seasons under field conditions are presented in Table 2. and Fig- 1. The results indicate that all IDM modules significantly reduced wilt incidence compared to the control. The most effective module was the combination of soil application with *Trichoderma harzianum* (2.5 kg/ha), seed modules with *Pseudomonas fluorescens* (10 gm/kg seed), and foliar application of salicylic acid (100 ppm), Mawar *et al.* (2020) which resulted in the lowest pooled wilt incidence across all stages: 2.76% at 30 DAS, 11.25% at 60 DAS, and 21.93% at 90 DAS, with reductions over control of 80.30%, 72.12%, and 73.60%, respectively. This effectiveness can be attributed to the combined use of bio-agents and salicylic acid, which have been shown to enhance plant resistance and suppress pathogen growth through various mechanisms (Sharma *et al.,* 2010; Singh *et al.,* 2012).

Similarly, the module incorporating *Pseudomonas fluorescens* as a soil application (2.5 kg/ha), seed modules with *Trichoderma harzianum*, and salicylic acid foliar application achieved significant reductions in wilt incidence, with pooled reductions of 76.03% at 30 DAS, 70.47% at 60 DAS, and 72.65% at 90 DAS. The bio-control efficacy of *Pseudomonas fluorescens* and *Trichoderma harzianum* is well-documented, as these microbes compete with the pathogen for nutrients and space, produce antifungal metabolites, and induce systemic resistance in the host plant (Nene and Reddy, 1987; Sharma and Pande, 2013). Another effective module was soil application of *Trichoderma harzianum*, seed modules with *Rhizobium*, and salicylic acid foliar spray, which recorded pooled reductions of 77.84%, 71.47%, and 72.96% at 30, 60, and 90 DAS, respectively. The modules using organic amendments like vermicompost and neem cake, along with biocontrol agents, also showed considerable reductions in disease incidence. Manhunath *et al.* (2020) For example, the soil application of vermicompost (3 ton/ha), seed modules with *Trichoderma harzianum*, and foliar spray of salicylic acid showed a pooled reduction of 73.53% at 30 DAS and 72.15% at 90 DAS. Vermicompost is known to improve soil health, enhance microbial activity, and provide a conducive environment for the proliferation of beneficial microbes, which contribute to disease suppression (Edwards *et al.,* 2007). In contrast, the use of boric acid powder as a soil amendment, combined with bioformulation modules and salicylic acid, was less effective compared to the other modules. The pooled reductions for these modules ranged from 39.49% to 52.2% at 30 DAS and 53.3% to 59.99% at 60 DAS. These results suggest that boric acid alone might not be as effective in controlling Fusarium wilt, and its combination with other modules needs optimization (Saraf *et al.,* 1998). The control modules exhibited the highest wilt incidence throughout the study, with 14.04% at 30 DAS, 42.63% at 60 DAS, and 84.46% at 90 DAS, highlighting the severe impact of Fusarium wilt in the absence of any management strategy. These results are consistent with the findings of previous studies that reported significant yield losses in chickpea due to Fusarium wilt when effective management strategies were not implemented (Haware *et al.,* 1990).

Conclusion

Integrating various IDM modules significantly reduced Fusarium wilt incidence in chickpea under field conditions during the 2022-23 and 2023-24 cropping seasons. The most effective modules was a combination of *Trichoderma harzianum* soil application, *Pseudomonas fluorescens* seed modules, and salicylic acid foliar spray, which achieved over 80% disease reduction at 30 DAS and maintained high effectiveness throughout the crop cycle. Other IDM strategies, including the use of vermicompost and neem cake, also showed promising results. The findings suggest that adopting IDM practices involving biocontrol agents and organic amendments can be a sustainable and eco-friendly alternative to chemical fungicides, thereby improving chickpea yield and soil health. This research highlights the importance of integrated approaches in managing soil-borne diseases and adapting crop management to changing climate conditions for long-term agricultural sustainability.

Table 1: IDM Modules

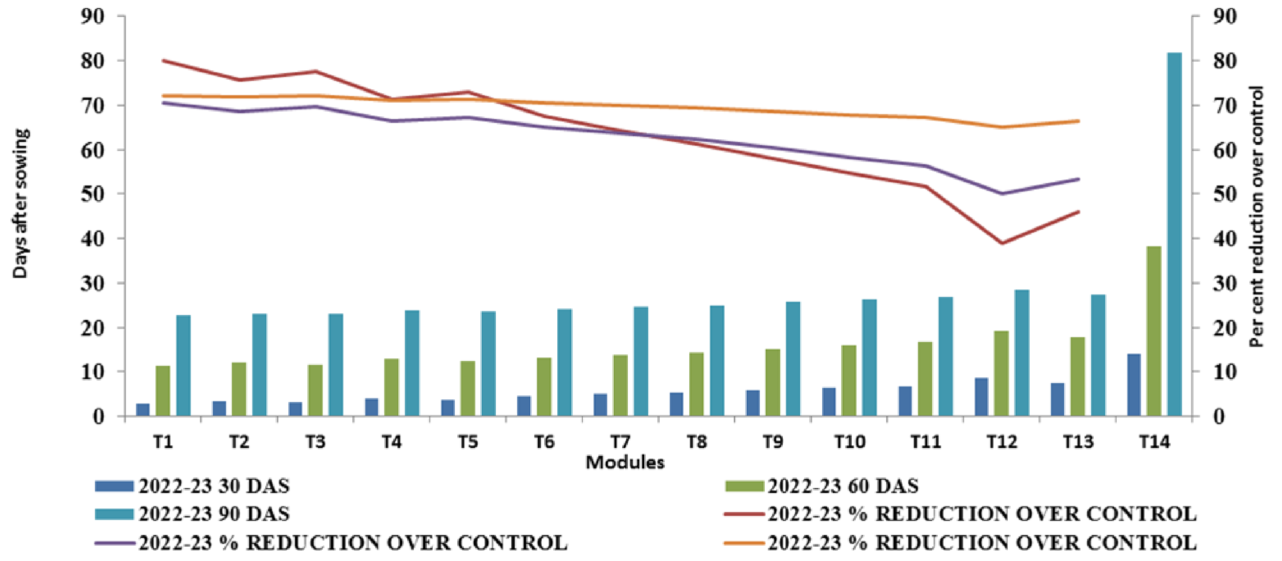
Modules	Module details
T_1	Soil application with bioformulation of *Trichoderma harzianum* @ 2.5 kg/ha + Seed treatment with *Pseudomonas fluorescens* bioformulation of @ 10 gm/kg seed+foliar application of Salicylic acid @ 100 ppm.
T_2	Soil application with bioformulation of *Pseudomonas fluorescens* @ 2.5 kg/ha + seed treatment with bioformulation of *Trichoderma harzianum* @ 10 gm/kg seed + foliar application of Salicylic acid @ 100 ppm.
T_3	Soil application with bioformulation of *Trichoderma harzianum* @ 2.5 kg/ha + seed treatment with Rhizobium @ 20 g/kg seed + foliar application of Salicylic acid @100 ppm.
T_4	Soil application with bioformulation of *Pseudomonas fluorescens* @ 2.5 kg/ha + seed treatment with Rhizobium @ 20 g/kg seed + foliar application of Salicylic acid @ 100 ppm.
T_5	Soil application with vermicompost @ 3 ton /ha + seed treatment with *Trichoderma harzianum* @ 10 gm/kg seed + foliar application of Salicylic acid @100 ppm
T_6	Soil application with vermicompost @ 3 ton/ha + seed treatment with bioformulation of *Pseudomonas fluorescens* @ 10 g/kg + foliar application ofSalicylic acid @ 100 ppm
T_7	Soil application with vermicompost @ 3 ton /ha + seed treatment with Rhizobium @ 20 g/kg seed + foliar application of Salicylic acid @ 100 ppm.
T_8	Soil application with neem cake @ 0.4 ton/ha + seed treatment with bioformulation of *Trichoderma harzianum* @ 10 g/kg seed + foliar application of Salicylic acid @ 100 ppm.

T_9	Soil application with neem cake @ 0.4 ton/ha + seed treatment with bioformulation of *Psedomonas fluorescens* @ 10 g/kg + foliar application of Salicylic acid @ 100ppm.
T_{10}	Soil application with neem cake @ 0.4 ton/ha + seed treatment with Rhizobium @ 20 g/kg + foliar application of Salicylic acid @ 100 ppm.
T11	Soil application with boric acid powder @ 3 kg/ha + seed treatment with bioformulation of *Trichoderma harzianum* @ 10 g/kg seed + foliar application of Salicylic acid @ 100 ppm.
T12	Soil application with boric acid powder @ 3 kg/ha + seed treatment with bioformulation of *Pseudomonas fluorescens* @ 10 gm/kg seed + foliar application of Salicylic acid @ 100 ppm.
T13	Soil application with boric acid powder @ 3 kg/ha + seed treatment with Rhizobium @ 20 g/kg + foliar application of Salicylic acid @ 100 ppm.
T14	Control

Table 2: Evaluation of IDM modules on wilt incidence at 30, 60, and 90 days under field condition during 2022-23 and 2023-24.

	WILT INCIDENCE																	
	2022-23						2023-24						POOLED					
Modules	30 DAS	% Reduction over control	60 DAS	% Reduction over control	90 DAS	% Reduction over control	30 DAS	% Reduction over control	60 DAS	% Reduction over control	90 DAS	% Reduction over control	30 DAS	% Reduction over control	60 DAS	% Reduction over control	90 DAS	% Reduction over control
T1	2.81	79.98	11.30	70.51	22.75	72.20	2.72	80.62	11.2	73.72	21.12	74.99	2.76	80.30	11.25	72.12	21.93	73.60
T2	3.42	75.64	12.04	68.58	23.1	71.78	3.31	76.4	11.78	72.36	22.36	73.52	3.36	76.03	11.91	70.47	22.73	72.65
T3	3.15	77.56	11.65	69.60	22.89	72.03	3.07	78.13	11.36	73.35	22.05	73.89	3.1	77.84	11.50	71.47	22.47	72.96
T4	4.01	71.43	12.87	66.42	23.78	70.95	3.92	72.07	12.34	71.05	22.99	72.78	3.96	71.75	12.60	68.73	23.38	71.86
T5	3.78	73.07	12.5	67.38	23.45	71.35	3.65	74.00	11.99	71.87	22.84	72.95	3.71	73.53	12.24	69.63	23.14	72.15
T6	4.56	67.52	13.34	65.19	24.12	70.53	4.41	68.58	12.68	70.25	23.49	72.18	4.48	68.05	13.01	67.72	23.80	71.36
T7	5.02	64.24	13.89	63.76	24.56	69.99	4.84	65.52	13.48	68.37	23.88	71.72	4.93	64.88	13.68	66.07	24.22	70.86
T8	5.45	61.18	14.45	62.30	25.02	69.43	5.34	61.96	13.77	67.69	24.3	71.22	5.39	61.57	14.11	64.99	24.66	70.33
T9	5.89	58.04	15.12	60.55	25.78	68.50	5.77	58.90	14.35	66.33	25.12	70.25	5.83	58.47	14.73	63.44	25.45	69.38
T10	6.34	54.84	16.04	58.15	26.34	67.82	6.11	56.48	14.92	65.00	25.57	69.72	6.22	55.66	15.48	61.57	25.95	68.77
T11	6.78	51.70	16.75	56.30	26.78	67.28	6.62	52.84	15.48	63.68	25.8	69.45	6.7	52.2	16.11	59.99	26.29	68.36
T12	8.58	38.88	19.1	50.168	28.56	65.11	8.41	40.09	18.57	56.43	27.94	66.91	8.49	39.49	18.83	53.30	28.25	66.01
T13	7.56	46.15	17.89	53.32	27.45	66.46	7.4	47.29	16.87	60.42	26.76	68.31	7.48	46.72	17.38	56.87	27.10	67.39
T14 (Controle)	14.04		38.33		81.86		14.04		42.63		84.46		14.04		40.48		83.16	
SEm(±)	0.25		0.67		1.21		0.24		0.66		1.99		0.25		0.66		1.20	
CD (P=0.05)	0.72		1.94		3.52		0.71		1.92		3.47		0.72		1.93		3.49	
CV (%)	7.43		7.19		7.22		7.44		7.25		7.26		7.43		7.21		7.24	

Fig.1: Evaluation of IDM modules on wilt incidence at 30, 60, and 90 days under field condition during 2022-23 and 2023-24.



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