

EVALUATION OF FUNGICIDES FOR THE MANAGEMENT OF POWDERY MILDEW CAUSED BY *ERYSIPHE POLYGINI* IN FENUGREEK (*TRIGONELLA FOENUM-GRAECUM*)

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ABSTRACT

A field study was conducted at Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat, over four consecutive Rabi seasons (2018-19, 2019-20, 2020-21 and 2021-22) using a randomized block design with three replications to assess the efficacy of two fungicides against powdery mildew in fenugreek (cv. Gujarat Methi-2). Among all treatments, hexaconazole 5 SC at 0.0063% (Tf) consistently recorded the lowest disease intensity (pooled mean:11.34%) and the highest seed yield (2309 kg/ha), being at par with hexaconazole 0.005% and wettable sulphur 0.25%. The untreated control showed the highest disease intensity (38.82%) and the lowest yield (1596 kg/ha). Residue analysis confirmed hexaconazole residues well below permissible limits, while economic evaluation revealed the highest ICBR (13.82) with Tf. Thus, foliar application of hexaconazole 5 SC at 0.0063% proved most effective, safe, and economical for managing powdery mildew in fenugreek.

Keywords: *Erysiphe polygini*, Economics, Fenugreek, Fungicides, Powdery mildew, Residues

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual leguminous crop belonging to the family Fabaceae, cultivated worldwide as a multipurpose plant valued for its leaves and seeds. Globally, it is grown across Asia, Africa, the Mediterranean region and parts of Europe for its culinary, medicinal and industrial applications. The seeds are a rich source of protein, fibre, saponins and alkaloids and are widely used in functional foods and traditional medicine for their hypoglycaemic and hypocholesterolemic properties. Major fenugreek-producing countries include India, Egypt, Morocco and China, together

contributing significantly to global spice trade and pharmaceutical industries.

In India, fenugreek holds a prominent position as the third-largest seed spice crop, extensively cultivated in Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh. It serves as an important component of smallholder farming systems, contributing to household income and nutritional security. However, fenugreek productivity is severely constrained by several fungal, bacterial and viral diseases that adversely affect yield and quality. Among the fungal diseases, powdery mildew, downy mildew, root rot and wilt are predominant, with powdery mildew caused by *Erysiphe polygini*

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being one of the most widespread and destructive. The disease typically appears during the late vegetative to pod formation stages, covering leaves, stems and pods with white powdery growth, leading to premature leaf senescence, reduced photosynthetic efficiency and yield losses up to 25-70 per cent under severe infection.

Although several management approaches, including cultural and biological methods, have been explored, their effectiveness remains inconsistent under field conditions. Hence, optimizing fungicidal management using safe and economical formulations suited to local agro-climatic conditions is essential. Therefore, the present investigation was undertaken to evaluate the efficacy of different concentrations of hexaconazole and wettable sulphur for sustainable management of powdery mildew in fenugreek under field conditions at the Seed Spices Research Station, SDAU, Jagudan.

MATERIAL AND METHODS

Experiment site and Duration

A comprehensive field experiment was undertaken in a randomized block design with three replications during the Rabi seasons of 2018-19, 2019-20, 2020-21 and 2021-22 at Seed Spices Research Station, Jagudan.

Crop and Variety

The Fenugreek cv. Gujarat Methi-2 (GM-2) was meticulously sown in the month of November, with a well-maintained row spacing of 45 cm and a seed rate of 15 kg per hectare.

Treatments and Fungicidal applications

To ascertain the effectiveness of disease management, two distinct fungicides, hexaconazole 5 SC (0.0050%) and wettable sulphur 80 WP (0.20%), each with three prefixed concentrations, were systematically

compared to an untreated control group. The efficacy of these fungicides was meticulously evaluated against the untreated control through the application of two sprays, adhering to the predetermined concentrations. The first spray was diligently administered at the onset of the disease, followed by a second spray after a lapse of 15 days from the initial application.

Calculation of Percent Disease Index

Intricate observations on the intensity of the powdery mildew disease were meticulously recorded from 20 randomly selected plants from each plot, employing a precise 0-4 scale, as elaborated below:

0.0: No incidence/Healthy

1.0: Whitish small spots on the leaf

2.0: Whitish growth covering the entire leaf

3.0: Whitish growth on leaf and stem

4.0: Whitish growth on leaf, stem, and pod

The percent disease index (PDI) was meticulously calculated based on the observations, employing the well-established formula. Additionally, the percent disease intensity (PDI) was further evaluated using the formula proposed by Datar and Mayee (1981) to provide a comprehensive assessment of the disease management strategies employed in the study.

$$\text{PDI} = \left[\frac{\text{Total grade}}{\text{Maximum grade}} \times 100 \right] / \text{No. of plants scored}$$

Pesticide Residue Analysis method

Modified QuEChERS multiresidue method was adopted for the extraction and clean-up of various pesticide residues from seed spices. A representative portion ground seed (20 g) was moistened with water followed by addition of acetonitrile. The extract was treated with sodium chloride for separation of acetonitrile layer which was then subjected to dispersive SPE clean-up using PSA, MgSO₄

Treatment details

Sr.No.	Treatments	Conc. (%)	Dose(ml or g/ 10 L)
T ₁	Hexaconazole 5 SC	0.0038	7.6
T ₂	Hexaconazole 5 SC	0.0050	10.0
T ₃	Hexaconazole 5 SC	0.0063	12.6
T ₄	Wettable sulphur 80 WP	0.15	18.75
T ₅	Wettable sulphur 80 WP	0.20	25.0
T ₆	Wettable sulphur 80 WP	0.25	31.25
T ₇	Untreated control	-	-

Note: First spray at initiation of disease and second spray after 15 days of first spray

and C18. The residues were determined using GC-MS/MS and/or LC-MS/MS.

RESULTS AND DISCUSSION**Percent disease intensity (PDI)**

Upon examining the data, it is evident that there was a noteworthy disparity in the percent disease intensity throughout all the experimental years, as well as in the overall pooled results (refer to Table 1). The application of T₃, specifically hexaconazole at a concentration of 0.0063%, resulted in the lowest percent disease intensity values across all the years of experimentation (2018-19, 2019-20, 2020-21, and 2021-22), as well as in the pooled results, exhibiting values of 12.78, 8.97, 10.42, 13.47, and 11.34, respectively. In the *Rabi* season of 2018-19, the treatment T₃, which utilized hexaconazole at a concentration of 0.0063%, exhibited at par results with T₂ (hexaconazole 0.005%) and T₆ (wettable sulphur 0.25%) treatments. Similarly, during the *Rabi* season of 2019-20, T₃ remained on par with T₆ (wettable sulphur 0.25%), T₅ (wettable sulphur 0.2%), and T₂ (hexaconazole 0.005%) treatments.

Furthermore, in the *Rabi* season of 2020-21, the superior treatment T₃ (hexaconazole 0.0063%) demonstrated comparable efficacy with T₆ (wettable sulphur 0.25%) and T₂

(hexaconazole 0.005%) treatments. In the *Rabi* season of 2021-22, the most effective treatment, T₃ (hexaconazole 0.0063%), exhibited at par results with T₆ (wettable sulphur 0.25%) and T₂ (hexaconazole 0.005%) treatments.

Similarly, in the pooled results, T₃ demonstrated similar efficacy when compared to T₆ (wettable sulphur 0.25%), T₂ (hexaconazole 0.005%), and T₅ (wettable sulphur 0.2%) treatments. However, it is noteworthy that the untreated control exhibited the highest percent disease intensity values of 40.80, 47.63, 28.51, 38.80, and 38.82 during all four years of experimentation, as well as in the pooled results.

Seed yield

The analysis of the data has unveiled a significant variation in fenugreek seed yield across all the years of experimentation (Table 2). Remarkably high seed yields of 2770, 2017, 1927, 2521, and 2309 kg/ha were consistently observed with T₃, employing hexaconazole at 0.0063% concentration, during the entirety of the experimental period (2018-19, 2019-20, 2020-21, and 2021-22), as well as in the pooled results.

In the *Rabi* season of 2018-19, T₃, utilizing hexaconazole at 0.0063%

Table 1. Effect of different treatments on Percent disease intensity of Powdery mildew

Sr.No.	Treatments	Percent disease intensity				
		2018-19	2019-20	2020-21	2021-22	Pooled
T ₁	Hexaconazole 5	*23.30 ^{bc}	*22.48 ^b	*22.41 ^{bc}	*24.01 ^{bc}	*23.05 ^b
	SC 0.0038 %	(15.65)	(14.62)	(14.53)	(16.56)	(15.33)
T ₂	Hexaconazole 5	21.88 ^{cd}	19.35 ^{cd}	20.30 ^{de}	22.35 ^{cd}	20.97 ^{bc}
	SC 0.0050 %	(13.89)	(10.98)	(12.04)	(14.46)	(12.81)
T ₃	Hexaconazole 5	20.95 ^d	17.43 ^d	18.83 ^e	21.53 ^d	19.68 ^c
	SC 0.0063 %	(12.78)	(8.97)	(10.42)	(13.47)	(11.34)
T ₄	Wettable sulphur	24.96 ^b	20.55 ^{bc}	23.33 ^b	25.64 ^b	23.62 ^b
	80 WP 0.15 %	(17.81)	(12.32)	(15.68)	(18.72)	(16.05)
T ₅	Wettable sulphur	23.17 ^{bcd}	19.02 ^{cd}	21.00 ^{cd}	23.69 ^{bcd}	21.72 ^{bc}
	80 WP 0.20 %	(15.48)	(10.62)	(12.84)	(16.14)	(13.70)
T ₆	Wettable sulphur	22.09 ^{cd}	17.78 ^d	19.26 ^{de}	22.77 ^{cd}	20.47 ^{bc}
	80 WP 0.25 %	(14.14)	(9.32)	(10.88)	(14.98)	(12.23)
T ₇	Untreated	39.70 ^a	43.64 ^a	32.27 ^a	38.53 ^a	38.54 ^a
	control	(40.80)	(47.63)	(28.51)	(38.80)	(38.82)
	S.Em	0.67	0.66	0.65	0.65	1.061
	C.D at 5%	2.08	2.03	2.01	2.01	3.15
	C.V%	4.64	4.98	5.01	4.42	4.75
	Y X T					1.87

Figures in the parenthesis are retransformed values

Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

concentration, exhibited comparable seed yields when compared to several treatments, namely T₂ (hexaconazole 0.005%), T₆ (wettable sulphur 0.25%), T₅ (wettable sulphur 0.2%), T₁ (hexaconazole 0.0038%) and T₄ (wettable sulphur 0.15%). These treatments yielded 2667, 2657, 2570, 2526, and 2505 kg/ha of seeds, respectively.

The results suggest that the application of T₃, utilizing hexaconazole at a concentration of 0.0063%, exhibited superior efficacy in significantly enhancing fenugreek seed yield over multiple years of experimentation. These findings offer valuable insights into the

potential of this treatment for optimizing seed production in fenugreek cultivation.

During the *Rabi* season of 2019-20, T₃ displayed comparable seed yields with treatments T₆ (wettable sulphur 0.25%), T₅ (wettable sulphur 0.2%), and T₂ (hexaconazole 0.005%), which recorded seed yields of 1963 kg/ha and 1910 kg/ha, respectively. Similarly, in the *Rabi* season of 2020-21, the superior treatment T₃ (hexaconazole 0.0063%) showed comparable performance with T₂ (hexaconazole 0.005%), T₆ (wettable sulphur 0.25%), and T₅ (wettable sulphur 0.2%), which recorded seed yields of 1894 kg/ha, 1862 kg/ha, and 1790 kg/ha, respectively.

Table 2. Effect of different treatments on seed yield

Sr.No.	Treatments	Seed yield (Kg/ha)				
		2018-19	2019-20	2020-21	2021-22	Pooled
T ₁	Hexaconazole 5 SC 0.0038 %	2526 ^a	1724 ^a	1773 ^a	2250 ^a	2068 ^b
T ₂	Hexaconazole 5 SC 0.0050 %	2667 ^a	1910 ^a	1894 ^a	2390 ^a	2215 ^{ab}
T ₃	Hexaconazole 5 SC 0.0063 %	2770 ^a	2017 ^a	1927 ^a	2521 ^a	2309 ^a
T ₄	Wettable sulphur 80 WP 0.15 %	2505 ^a	1869 ^a	1761 ^a	2229 ^a	2091 ^b
T ₅	Wettable sulphur 80 WP 0.20 %	2570 ^a	1910 ^a	1790 ^a	2292 ^a	2141 ^{ab}
T ₆	Wettable sulphur 80 WP 0.25 %	2657 ^a	1963 ^a	1862 ^a	2381 ^a	2216 ^{ab}
T ₇	Untreated control	1943 ^b	1339 ^b	1440 ^b	1663 ^b	1596 ^c
	S.Em	145	107	83	159	56
	C.D at 5%	446	331	255	489	159
	C.V%	9.94	10.22	8.06	12.24	10.52
	Y X T					NS

Treatments means with the letter (s) in common are not significant by DNMRT at 5% level of significance

Table 3. Effect of different treatments on 1000 seed wt.(g)

SrNo.	Treatments	Mean 1000 seed weight (g)
T ₁	Hexaconazole 5 SC 0.0038 %	15.3
T ₂	Hexaconazole 5 SC 0.0050 %	15.7
T ₃	Hexaconazole 5 SC 0.0063 %	16.1
T ₄	Wettable sulphur 80 WP 0.15 %	15.4
T ₅	Wettable sulphur 80 WP 0.20 %	15.6
T ₆	Wettable sulphur 80 WP 0.25 %	16.1
T ₇	Untreated control	14.9

Notably, in the pooled results, the differences between treatments were non-significant. However, T₃ consistently exhibited the maximum seed yield of 2309 kg/ha and was at par with T₆ (wetable sulphur 0.25%), T₂ (hexaconazole 0.005%), and T₅ (wetable sulphur 0.2%).

In contrast, the untreated control consistently showed the lowest seed yields of 1943 kg/ha, 1339 kg/ha, 1440 kg/ha, 1663 kg/ha, and 1596 kg/ha during all four years of experimentation, as well as in the pooled results.

These findings contribute valuable knowledge for practitioners aiming to improve fenugreek seed production and underscore the effectiveness of T₃ with hexaconazole 0.0063% for achieving optimal yields in fenugreek cultivation.

1000 seed weight

The maximum seed weight was observed in T₃, utilizing hexaconazole at a concentration of 0.0063%, and T₆, employing wettable sulphur 80 WP at a concentration of 0.25%. The decline in percent disease intensity (PDI) could potentially augment plant growth and development, consequently influencing seed size and weight (Table 3).

These findings suggest that treatments T₃ and T₆ hold promise for promoting favourable seed weight in the context of disease management, thereby contributing to improved crop yield and quality.

Pesticide Residue Analysis

In this investigation, the residue levels of the crop treated with hexaconazole 5 SC at a concentration of 0.0063%, administered both at the disease onset and 15 days after the first application, were determined to be well below the critical limit set by various regulatory agencies (Table 5).

These results indicate that the application of hexaconazole at the specified concentration and timing adheres to the established safety guidelines, ensuring that the residue levels remain within acceptable limits. This finding holds significance for the safe and responsible use of the fungicide, minimizing potential risks to human health and the environment while effectively managing the target disease.

Economics

Based on the economic evaluation of various treatments, plots treated with hexaconazole 5 SC at a concentration of 0.0063% demonstrated the highest additional income, net realization, and Incremental Cost-Benefit Ratio (ICBR: 13.82). Following closely, hexaconazole 5 SC at 0.0050% concentration exhibited a favourable ICBR of 12.60.

The findings are well supported by the result of Kumawat and Shekhawat (2015) evaluated different nine fungicides against powdery mildew of fenugreek under field condition. Among these fungicides, hexaconazole at 0.005 per cent recorded (9.60%) per cent disease intensity with maximum (84.68%) per cent disease control.

The results are in closed agreement with the study conducted by Dhruj *et al.* (2000) conducted field experiments to determine the efficacy of eight fungicides for the control of powdery mildew of fenugreek in Gujarat. The test fungicides included propiconazole at 0.025 percent, penconazole at 0.01 percent, hexaconazole at 0.005 percent, triadimefon at 0.025 per cent, tridemorph at 0.08 per cent, dinocap at 0.048 percent, sulphur WP at 0.2 percent and sulfur dust at 20 kg/ha. All the fungicides significantly reduced disease incidence in comparison with the control and increased seed yield. The minimum disease intensity (19.38%) and the highest yield (2132

Table 4. Protection Cost Benefit Ratio (PCBR)

Trt. No.	Quantity of materials (Kg or L/ha)	Cost of materials (₹ /ha)	Labour charges (₹ /ha)	Total cost of treatment (₹ /ha)	Yield (Kg/ha)	Gross realization (₹ /ha)	Net realization (₹ /ha)	Net gain (₹ /ha)	PCBR
T ₁	0.760	304.00	1420.00	1724.00	2068	82720.00	18880.00	17156.00	9.95
T ₂	1.000	400.00	1420.00	1820.00	2215	88600.00	24760.00	22940.00	12.60
T ₃	1.260	504.00	1420.00	1924.00	2309	92360.00	28520.00	26596.00	13.82
T ₄	1.875	468.75	1420.00	1888.75	2091	83640.00	19800.00	17911.25	9.48
T ₅	2.500	625.00	1420.00	2045.00	2141	85640.00	21800.00	19755.00	9.66
T ₆	3.125	781.25	1420.00	2201.25	2216	88640.00	24800.00	22598.75	10.27
T ₇	0.000	0.00	0	0.00	1596	63840.00	0.00	0.00	

Cost of Inputs

Particular	Price (₹ /kg or L.)
Average Fenugreek Seed	40.00
Hexaconazole 5 SC	400.00
Wettable sulphur 80 WP	250.00
Labour/spray/ha	355.00

Table 5. Pesticide residue analysis

TrNo	Treatments	Results (ppm)	LoD (ppm)	LoQ (ppm)	Maximum Residue Limit (ppm)		
					EU	CODEX	Japan
T ₂	Hexaconazole 5 SC 0.0050 %	0.067	0.2	0.5	0.1	0.2	0.1
T ₇	Untreated Control	BDL					

BDL-Below detection limit

kg/ha) were recorded with penconazole but this fungicide treatment did not differ significantly from hexaconazole, which recorded 21.34 percent disease intensity and 2023 kg/ha seed yield.

These findings are well supported by the result of Kumawat *et al.* (2016) evaluated different nine fungicides against powdery mildew of fenugreek under field condition. Among these fungicides, hexaconazole recorded seed yield (24.61 q/ha) by increasing 63.08 percent seed yield.

According to Singh (2006) six fungicides were evaluated for control of powdery mildew disease of coriander (*Coriandrum-sativum*), caused by *Erysiphe polygoni*. All the fungicides reduced the disease severity significantly, over control, with maximum reduction in hexaconazole (0.1%) that was on par with propiconazole (0.1%) and wettable sulphur (0.3%). Yield of coriander was higher 2.54, 2.00 and 2.20 times, over control, in hexaconazole (0.1%), propiconazole (0.1%) and wettable sulphur (0.3%), respectively.

The present research findings corroborate well with the results of Patel *et al.* (2017), who reported that two sprays of hexaconazole 5 EC (0.05%) were most effective in managing powdery mildew of coriander caused by *Erysiphe polygoni* DC, recording a disease intensity of 22.53 and a 67.01 per cent reduction over control. The treatment was found statistically at par with wettable sulphur 80 WP (0.30%) and dinocap 48 EC (0.10%), which recorded 24.17 and 29.83 per cent disease intensity, respectively.

The present research aligns with the findings of Pawar *et al.* (2020), who studied the effect of fungicide sprays on powdery mildew of cowpea incited by *Erysiphe polygoni* (DC) and reported that hexaconazole 5 EC (0.05%) and triadimefon 25 WP (0.1%) were significantly effective and statistically at par, recording disease intensities of 18.18 and 19.33 per cent, respectively. These results are comparable to the present investigation, where hexaconazole effectively reduced disease intensity and improved seed yield and quality parameters in fenugreek.

Similarly, Undhad *et al.* (2022) evaluated different fungicides against *Erysiphe cichoracearum* causing powdery mildew of sesame and concluded that propiconazole 25 EC (0.025%) was the most effective, recording the minimum disease intensity (6.48%) with higher seed yield (699 kg/ha), followed by azoxystrobin 18.2 + difenoconazole 11.4 SC (0.030%) with 10.92 per cent disease intensity and 688 kg/ha seed yield.

The present research findings corroborate with the findings of Pansuriya (2022), who reported that among various fungicides evaluated under field conditions, hexaconazole 5 EC (0.05%) was the most effective treatment in reducing powdery mildew intensity (21.67%), resulting in the highest seed

yield (1534 kg/ha), 1000-seed weight (13.73 g) and volatile oil content (0.41%) in fenugreek. Similar trends were observed in the present investigation, where hexaconazole significantly minimized disease severity and enhanced yield and quality parameters.

The study showed that hexaconazole 0.005% was highly effective in managing fenugreek powdery mildew, consistently recording the lowest disease intensity and higher seed yield across all seasons. These results align with finding by Patel *et al.* (2024) who reported that total six fungicides, along with treated and untreated control were evaluated for their efficacy to control the powdery mildew disease of fenugreek. All the fungicides were significantly effective in reducing the powdery mildew disease intensity over control. Among these fungicides, at maturity the minimum per cent disease intensity 29.25 was recorded with the spray of hexaconazole (0.005%) @ 1 ml/l. The highest net returns were recorded with hexaconazole 5% EC (Rs. 20,198/ha) and an ICBR of 1:6.23.

CONCLUSION

This multi-season field evaluation, conducted over four consecutive Rabi seasons at SDAU, Jagudan, represents the first comprehensive study combining yield, economic and residue analyses for the management of powdery mildew in fenugreek. Foliar application of hexaconazole 5 SC at 0.0063% consistently recorded the lowest disease intensity (pooled mean 11.34%) and the highest seed yield (2309 kg/ha), while maintaining residue levels well below permissible limits and the highest benefit–cost ratio (ICBR 13.82). These results establish hexaconazole 5 SC at 0.0063% as an effective, safe, and economically viable option for sustainable management of powdery mildew in fenugreek under Gujarat conditions.

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