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Field efficacy of novel fungicides against chickpea rust (*Uromyces ciceris-arietini*)

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Chickpea (*Cicer arietinum* L.) is the third most important pulse crop after bean (*Phaseolus vulgaris* L.) and pea (*Pisum sativum* L.), which is grown in over 50 countries under rainfed conditions thus, providing income to subsistence farmers (Gaur *et al.* 2014). It serves as an important source of dietary protein and essential micronutrients and thus plays a pivotal role in human and animal nutrition (Jukanti *et al.* 2012). It also plays crucial role in improving soil fertility by biological nitrogen fixation (Jhoda and Subbarao 1987). In India, chickpea contributes over 40% of the country's total pulse production which accounts for 75% of world chickpea production. It occupies an area of 9.63 million ha with production of 9.38 million tonnes and average productivity of 974 kg/ha (Anonymous 2021) which is lesser than global average. The low productivity of chickpea is due to many biotic and abiotic stresses. Among the biotic stresses, chickpea rust caused by *Uromyces ciceris-arietini* (Grogn.) Jacz. and G. Boyer, 1894 is one of the major limiting factor affecting the chickpea production and productivity in Peninsular India. Earlier it was a minor disease limited to certain parts of Peninsular India but more recently it is emerging as a major destructive disease. Symptoms are more conspicuous on the leaves with small, round, or ellipsoidal, cinnamon-brown or reddish-brown raised pustules or sori and are sometimes observed in small concentric circles. Under favourable conditions, severe rust infection leads to premature defoliation, fewer pods, and possible loss of the entire plant. The disease is more prevalent in many parts of the globe namely, India, East Africa, the Mediterranean region, South-eastern Europe, and Southern Asia (Rubiales *et al.* 2001). Chickpea rust appears at the reproductive stage of the crop when the weather is moderately warm (30–35°C). In northern Karnataka, chickpea rust reported to appear frequently causing significant losses in yield (Nargund *et al.* 2011, Rahul *et al.* 2023).

Currently, there are no known rust-resistant chickpea cultivars available against chickpea rust. Hence, application of fungicides to control chickpea rust is the only available first-line option, but there is limited information on fungicides that could be used against chickpea rust in India. Earlier studies on rusts of various legume crops proved that triazole, or combination with strobilurins was found effective (Miles 2007, Bal 2011). Thus, the present study was carried out to assess the efficacy of different triazole and strobilurin fungicides either alone or in combination along with neem, benzimidazole and thiourea fungicides in controlling chickpea rust.

A field experiment was conducted during the winter (*rabi*) seasons of 2019–20 and 2020–21 at Regional Research Station, ICAR-Indian Institute of Pulses Research, Dharwad (15.49°N and 74.98°E, at an elevation of 750 m), Karnataka. The experimental soil was shallow black cotton soil with a *p*H of 7.5–8.0 and annual rainfall of 864 mm/year. The popular cultivar of chickpea in Peninsular India, JG11 was used and all the standard agronomic practices were followed except for plant protection measures. The experiment was conducted in a completely randomized block design (CRBD) with 3 replications comprised of 8 treatments, viz. T_1, Inhibitors of DNA biosynthesis (benzimidazole fungicides-Bavistin® 50 WP, Crystal, India); T_2, Microtubule assembly inhibitors (thiourea fungicide-Melvin™ 70 WP, Nichino, India); T_3 and T_4, Inhibitors of sterol biosynthesis (triazole fungicides- Tilt® 25 EC and Score® 25 EC, Syngenta, India); T_5 and T_6, Inhibitors of QoI and sterol biosynthesis (strobilurin plus triazole fungicides-Amistar® Top Syngenta, India and Nativo® Bayer, India); T_7, Neem oil 5000 ppm (Future Biotech, India); and T_8, Farmers practice (control). Treatments were imposed soon after the disease appearance and the same set of treatments were repeated after 15 days. Data on disease severity was recorded by using a 0–9 scale (Mayee and Datar 1986) after 15 days of the second spray (Table 1).

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Table 1 Rating scale for the assessment of chickpea rust severity on chickpea leaves

Rating scale	Disease incidence (%)	Reaction
0	Free from disease	Immune
1	Uredosori covering ≥1% of the leaf area	Resistant
3	Uredosori covering 1–10% of the leaf area	Moderately resistant
5	Uredosori covering 11–25% for leaf area	Moderately susceptible
7	Uredosori covering 26–50% of leaf area	Susceptible
9	Uredosori covering ≤51% of leaf area	Highly susceptible

The percent disease index (PDI) was calculated as (Wheeler 1969):

$$\text{PDI} = \frac{\text{Sum of numerical disease ratings} \times 100}{\text{Maximum disease rating} \times \text{Total number of plants observed}}$$

Statistical analysis: The data on disease severity was subjected to log transformation (Gomez and Gomez 1984) to make error variance homogeneous. Analysis of variance (ANOVA) was calculated using software developed by Sheoran *et al.* (1998) and economics were calculated by considering the cost of cultivation, cost of treatment, gross returns, and net returns.

In the present study, treatments were imposed immediately after the appearance of the first symptoms of rust which was on the 46th day after sowing. The rust disease pressure in the experiment was high enough to evaluate the fungicidal efficacy. The imposition of different treatments at the proper time provided a visible reduction in rust disease severity compared to untreated control with disease severity ranging from 17.8–97.5%. The results indicated that the rust disease severity was high and uniform in untreated control plots with 100 and 97.8% during 2019–20 and 2020–21, respectively; whereas, disease was lower than 29.1% in T_4 (difenoconazole 25% EC), T_5 (tebuconazole 50% + trifloxystrobin 25% w/w WG) and T_6 (azoxystrobin 18.2% + difenoconazole11.4% SC) treatments during both years of investigation. The per cent disease severity of chickpea rust disease in T_6 was 21.5% during 2019–20 being significantly superior over other treatments, whereas during 2020–21 disease severity was 23.3% being at par with T_4 (17.8%) and T_5 (24.4%) treatments. Pooled data from two years of experiment also showed that azoxystrobin 18.2% + difenoconazole 11.4% SC (T_6) was the most effective treatment amongst different treatments resulting in lowest per cent disease severity (22.4%), followed by difenoconazole 25% EC (T_4) with 23.5% and tebuconazole 50% + trifloxystrobin 25% w/w WG (T_5) with 25.7% disease severity. While, T_1 (carbendazim 50% WP), T_2 (thiophanate methyl 70% WP), and T_7 (neem oil) treatments had consistently high rust severity with no significant difference in both the year of investigation (Table 2). The results demonstrated that efficacy of fungicides remained consistent in both the years.

The comparative efficacy of various fungicides and demonstrated that the triazole fungicides were suitable for management of rust diseases of various crops (Kuck *et al.* 1995). Further, combination of triazoles and strobilurins group of fungicides were also reported to be effective against rust diseases of many other crops (Du Preez and Caldwell 2004, Miles *et al.* 2007). Similarly, Shirasangi *et al.* (2012) reported propiconazole as a most effective fungicide against chickpea rust disease among various triazole fungicides. The result of Kumbar *et al.* (2021) concur with our results, who reported that combi fungicide tebuconazole 50% + trifloxystrobin 25% w/w WG as most effective against chickpea rust disease than triazoles alone.

Table 2 Chickpea rust severity and seed yield from foliar application of fungicides

Active ingredient	Rate (%)	Per cent disease index			Seed yield (kg/ha)			Pooled yield loss reduction (%)
		2019–20	2020–21	Pooled	2019–20	2020–21	Pooled	
T_1	0.2	93.1(74.7)e	83.3(66.2)c	88.2(70.5)	827a	1016a	922	8.2
T_2	0.2	97.5(82.6)efg	90.4(72.2)cd	94.0(77.4)	755a	998a	877	2.9
T_3	0.1	48.9(44.4)d	65.9(54.4)b	57.4(49.4)	1151b	1083b	1117	31.1
T_4	0.1	29.1(32.6)bc	17.8(24.9)a	23.5(28.7)	1280b	1331c	1306	53.2
T_5	0.1	26.9(31.2)b	24.4(29.4)a	25.7(30.3)	1327b	1310c	1319	54.8
T_6	0.1	21.5(27.6)a	23.3(28.5)a	22.4(28.0)	1331b	1419c	1375	61.3
T_7	0.3	93.6(75.4)ef	92.6(74.8)cd	93.1(75.1)	855a	1046a	951	11.6
T_8	-	100.0(90.0)g	97.8(85.0)d	98.9(87.5)	753a	950a	852	
CD (P=0.05)		4.80	10.48		220.9	128.3		
SEm+		1.57	3.42		72.1	41.9		

*Data in the parenthesis are angular transformed values. Refer to the methodology for Treatment details.

Table 3 Economic returns from foliar application of fungicides to control chickpea rust

Active ingredient (Product)	Cost of cultivation			Gross returns			Net returns			Benefit cots ratio		
	2019–20	2020–21	Pooled	2019–20	2020–21	Pooled	2019–20	2020–21	Pooled	2019–20	2020–21	Pooled
Carbendazim (Bavistin® 50 WP)	23170	24329	23749	35975	48768	42371	12805	24440	18622	1.55	2.00	1.78
Thiophanate methyl (Melvin™ 70 WP)	22840	23982	23411	32843	47904	40373	10003	23922	16962	1.44	2.00	1.72
Propinonozole (Tilt® 25 EC)	23250	24413	23831	50025	51984	51005	26775	27572	27173	2.15	2.13	2.14
Difenconozole (Score® 25 EC)	26090	27395	26742	55680	63888	59784	29590	36494	33042	2.13	2.33	2.23
Tebuconozole + Trifloxystrobin (Nativo® 75 WG)	25658	26941	26299	57725	62880	60302	32067	35939	34003	2.25	2.33	2.29
Neem oil 5000 ppm	23040	24192	23616	37193	50208	43700	14153	26016	20084	1.61	2.08	1.84
Azoxystrobin + Difenconozole (Amistar® Top 32.5 EC)	27040	28392	27716	57855	68112	62984	30815	39720	35268	2.19	2.45	2.32
Control	21890	22985	22437	32756	45600	39178	10866	22616	16741	1.50	1.98	1.74

* All costs are calculated in ₹.

The performance of different fungicides against chickpea rust simultaneously had a positive impact on the seed yield of chickpea. Accordingly, spraying of azoxystrobin 18.2% + difenoconazole 11.4% SC gave the highest yield of 1331 kg/ha in 2019–20 and 1419 kg/ha in 2020–21, though not superior significantly to T_4 and T_5 treatments in both years of study. Pooled data on average seed yield revealed highest seed yield in T_6 (1375 kg/ha) followed by T_5 (1319 kg/ha) and T_4 (1306 kg/ha). The untreated control provided a lowest average grain yield of 852 kg/ha in two seasons (Table 2). Our results were similar to findings of Lokesh *et al.* (2020) who reported significantly higher grain yield of chickpea in the combi fungicide tebuconazole 50%+ trifloxystrobin 25% w/w WG (1236 kg/ha) as compared to solo fungicides. However, among solo triazole fungicides, Shirasangi *et al.* (2012) reported that the propiconazole (1222 kg/ha) was recorded maximum grain yield followed by difenoconazole (1133 kg/ha) and hexaconazole (1111 kg/ha). Thus, the application of modern fungicides gave a noticeable impact on the net income and benefit cost ratio in both years of experimentation. The T_6 (azoxystrobin18.2% + difenoconazole11.4% SC) treatment provided a higher benefit cost ratio of 2.32 followed by T_5 (2.29), T_4 (2.23) and T_3 (2.13); while T_2 had a lowest benefit cost ratio of 1.72 (Table 3). A previous study conducted by Kumbar *et al.* (2021) also reported higher benefit-cost ratio for combi fungicides compared to fungicides used alone.

SUMMARY

The host resistance in present-day chickpea cultivars against rust disease is lacking thus, the present study was carried out during the winter (*rabi*) seasons of 2019–20 and 2020–21 at Regional Research Station, ICAR-Indian Institute of Pulses Research, Dharwad, Karnataka to explore effective fungicides for the management of chickpea rust. All fungicides found to reduce chickpea rust severity, but differences in efficacy were observed throughout the study. Present studies revealed that two sprays of 0.1% azoxystrobin 18.2% + difenoconazole 11.4% SC fungicide at 15 days interval minimizes the rust severity to the tune of >77% and achieved a benefit cost (B:C) ratio of 2.32 i.e. in terms of monetary value farmers could get a net income of ₹35268/ha. Thus, timely spraying of identified modern fungicide combination can be taken advantage for better control of chickpea rust.

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