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KB Shinde
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra. India

Dr. RA Chavan
Associate Professor, Department of Plant Pathology, College of Agriculture Amabajogai, Maharashtra, India

Dr. SJ Magar
Assistant Professor, Department of Plant Pathology, College of Agriculture, Latur, Maharashtra India

AN Kavale
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra India

OJ Jadhav
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra India

Corresponding Author:
KB Shinde
Department of Plant Pathology, College of Agriculture, Latur, Maharashtra India

Efficacy of fungicides against *Fusarium oxysporum* f. sp. *udum* associated with wilt of pigeonpea

KB Shinde, Dr. RA Chavan, Dr. SJ Magar, AN Kavale and OJ Jadhav

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Abstract
In vitro efficacy of fungicides was tested against *Fusarium oxysporum* f. sp. *udum* causing wilt of pigeonpea using Poision Food Technique. All seven systemic fungicides tested at 500 and 1000 ppm were significant in recording minimum mycelial growth and maximum inhibition of *Fusarium oxysporum* f. sp. *udum* over the control. Among systemic fungicides, Carbendazim 50% WP achieved the highest inhibition of mycelial growth of *Fusarium*. followed by Tebuconazole 25.9% EC, Propiconazole 25% EC, Thiophanate Methyl 70% WP, Difenoconazole 25% EC, Hexaconazole 5% EC and Azoxystrobin 23% SC. Seven contact and combi fungicides were also found effective over control in recording least mycelial growth and maximum inhibition. Among combi fungicides, Carbendazim 12% + Mancozeb 63% WP provided the highest inhibition followed by Tebuconazole 50% + Tryfloxystrobin 25% WDG, Captan 70% + Hexaconazole 5% WP, Captan 50% WP, Chlorothalonil 75% WP, Mancozeb 75% WP and Copper oxychloride 50% WP.

Keywords: *Fusarium oxysporum*, *In vitro*, fungicides, poison food technique, inhibition

Introduction
Pigeonpea [*Cajanus cajan* (L.) Mill. sp.] belongs to family Fabaceae is an important legume of rainfed agriculture and cultivated as a sole crop, inter or mixed with cereals. It is good source of crude fibre, iron, sulphur, calcium, manganese, and water-soluble vitamins especially thiamine, riboflavin, and niacin. Pigeonpea is susceptible to over 100 pathogens, including fungi, bacteria, viruses, nematodes and phytoplasmas. Among various diseases, *Fusarium* wilt is a significant soil-borne disease affecting pigeonpea in India, causing yield losses of up to 67% at maturity and potentially 100% if the infection occurs at the pre-pod development stage (Kannaiyan and Nene, 1981) [6]. Hence experiment to find out effective fungicide against *Fusarium oxysporum* f. sp. *udum* was conducted under *In vitro* condition.

Materials and Methods
Efficacy of seven systemic fungicides and seven contact/combi fungicides were evaluated using the Poisoned Food Technique, as outlined by Nene and Thapliyal (1993) [7]. The systemic fungicides (referenced in Table 1) were tested at concentrations of 500 ppm and 1000 ppm, while the contact and combi fungicides listed in (Table 2) were tested at 2000 ppm and 2500 ppm. PDA medium, containing the appropriate amount of fungicide, was poured aseptically into 90 mm Petri dishes, where it solidified at room temperature. Each dish was inoculated aseptically with a 5 mm culture disc taken from an actively growing pure culture of a pathogen, placing the disc in the centre of the Petri dish on PDA. The plates were then incubated at 27 ± 2 °C. Three replicates of each fungicide concentration were prepared. Petri dishes with plain PDA (without any fungicides) and the pathogen culture disc were maintained as untreated controls.

Table 1: List of systemic fungicides

Tr. No.	Treatments	Tr. No.	Treatments
T_1	Carbendazim 50% WP	T_5	Difenoconazole 25% EC
T_2	Azoxystrobin 23% SC	T_6	Tebuconazole 25.9% EC
T_3	Propiconazole 25% EC	T_7	Hexaconazole 5% EC
T_4	Thiophanate methyl 70% WP	T_8	Control (untreated)

Table 2: List of contact and combi-fungicides

Tr. No.	Treatments	Tr. No.	Treatments
T_1	Copper Oxychloride 50% WP	T_5	Carbendazim 12% + Mancozeb 63% WP
T_2	Mancozeb 75% WP	T_6	Tebuconazole 50% + Tryfloxystrobin 25% WDG
T_3	Chlorothalonil 75% WP	T_7	Captan 70% + Hexaconazole 5% WP
T_4	Captan 50% WP	T_8	Control (untreated)

Observations on radial mycelial growth was recorded after seven days of incubation in all the replicated treatments. Percent inhibition of the test pathogen was calculated by applying the formula given by Arora and Upadhay (1978) [1] as follows,

$$\text{Percent growth inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,
C = Growth (mm) of test fungus in untreated control plate.
T = Growth (mm) of test fungus in treated plates.

Results

Effect of systemic fungicides on mycelial growth

The results indicate that all treatments of systemic fungicides at each concentration significantly reduced the mycelial growth of *Fusarium oxysporum* compared to the control. The fungus treated with Carbendazim 50% WP showed no mycelial growth. Tebuconazole 25.9% EC was the second most effective treatment, showing minimum mycelial growth compared to the control, followed by Propiconazole 25% EC, Thiophanate methyl, 70% WP, Difenoconazole 25% EC, Hexaconazole 5% EC and Azoxystrobin 23% SC. A similar pattern of mycelial growth inhibition was observed at the 1000 ppm concentration for all tested systemic fungicides. Results (Table 3, Fig 1) shows that all the treatments at all concentration were significant over the control in inhibiting the growth of test pathogen. At all concentration same trend of systemic fungicide were recorded in inhibition of mycelial growth. Carbendazim showed maximum inhibition of mycelial growth to the tune of 100% followed by Propiconazole, Thiophanate methyl, Difenoconazole, Hexaconazole and Azoxystrobin. The results of present investigation resembled with the finding of earlier records of many workers *viz*., Raju *et al.* (2008) [10] tested *In vitro* efficacy of five fungicides carbendazim, captan, dithane Z-78, thiophanate methyl, thiram against *Fusarium oxysporum* f. sp. *udum* and observed complete inhibition of mycelial growth of pathogen with carbendazim at all concentrations (100, 250, 500 ppm). These results were also supported by the observations of Mehta *et al.* (2010) [5], Gupta *et al.* (2014) [4], Patil *et al.* (2015) [9] and Arsia *et al.* (2018) [2].

Table 3: *In vitro* efficacy of systemic fungicides against *Fusarium oxysporum* f. sp. *Udum*

Tr. No.	Treatments	*Colony Diameter (mm)		Avg.	% Inhibition		Avg
		500 ppm	1000 Ppm		500 ppm	1000 ppm	
T_1	Carbendazim 50% WP	00.00	00.00	00.00	100.00 (90)**	100.00 (90)	100.00 (90)
T_2	Azoxystrobin 23% SC	46.00	40.00	43.00	48.88 (44.35)	55.55 (48.18)	52.22 (46.27)
T_3	Propiconazole 25% EC	12.00	10.00	11.00	86.66 (68.57)	88.88 (70.52)	87.77 (69.53)
T_4	Thiophanate Methyl 70% WP	16.00	14.00	15.00	82.22 (65.06)	84.44 (66.76)	83.33 (65.90)
T_5	Difenoconazole 25% EC	22.00	19.50	20.75	75.55 (60.36)	78.33 (62.25)	76.94 (61.30)
T_6	Tebuconazole 25.9% EC	8.00	6.00	7.00	91.11 (72.65)	93.33 (75.03)	92.22 (73.80)
T_7	Hexaconazole 5% EC	23.50	20.00	21.75	73.78 (59.19)	77.77 (61.86)	75.83 (60.55)
T_8	Control (untreated)	90.00	90.00	90.00	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)
S.E±		0.50	0.53	0.46	0.49	0.47	
CD at 1%		2.06	2.21	1.90	2.08	2.01	

*Colony diameter = Average of *three* replications **Figures in parenthesis are arcsine transformation value

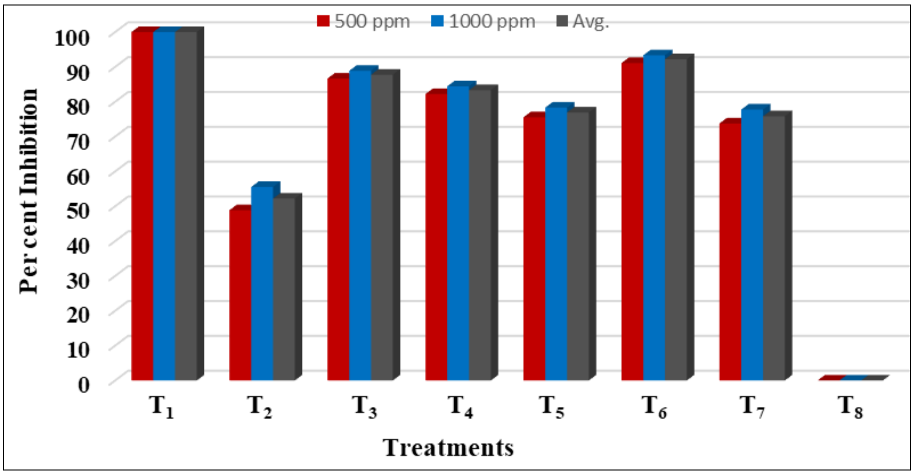

Fig 1: *In vitro* efficacy of systemic fungicides against *Fusarium oxysporum* f. sp. *udum*

In vitro evaluation of non-systemic and combi fungicides against *Fusarium oxysporum* f. sp. *udum*

Results (Table 4, Fig 2) shows that all the treatments were significant over the control and showed similar trend at all concentration in recording minimum mycelial growth and maximum inhibition over control. The least mycelial growth and maximum inhibition was recorded in Carbendazim 12% + Mancozeb 63% WP at both concentrations. whereas Tebuconazole 50% + Tryfloxystrobin 25% WDG was the second-best treatment in recording least mycelial growth and percent inhibition. followed by, Captan 70% + Hexaconazole 5% WP, Captan 50% WP, Chlorothalonil 75% WP, Mancozeb 75% WP and Copper oxychloride 50% WP. The results of the present investigation have resembled the finding of earlier records of scientist, Chaudhary *et al.* (2019) [3] evaluated eight fungicides *viz*., Captan, Blue copper, Carbendazim, Carbendazim + Mancozeb, Mancozeb, Fipronil, Thiophanate Methyl and Pyraclostrobin against wilt of pigeonpea. The broad-spectrum combination of Carbendazim + Mancozeb, Thiophanate Methyl and Carbendazim was found best fungicide which completely inhibited the growth of test pathogen. Patel *et al*. (2021) [8] evaluated eight solo fungicides *viz*., Carbendazim, Mancozeb, Propineb, Thiophanate methyl, Azoxystrobin, Difenoconazole, Tebuconazole and seven combi fungicides *viz*., Carboxin + Thiram, Carbendazim + Mancozeb, Tebuconazole + Trifloxystrobin, Mancozeb + Thiophanate methyl, Fluopyram + Tebuconazole, Azoxystrobin +Tebuconazole, Azoxystrobin + Difenoconazole *In vitro* against *Fusarium udum*, causal agent of wilt of pigeonpea, where Carbendazim (0.1%) and Tebuconazole (0.1%) were found best solo fungicides and Carboxin + Thiram (0.25%), Carbendazim + Mancozeb (0.2%) and Azoxystrobin + Difenoconazole (0.1%) were best combi fungicides which completely inhibited the radial growth and sporulation of *Fusarium udum*.

Table 4: *In vitro* efficacy of contact and combi fungicides against *Fusarium oxysporum* f. sp. *udum*

Tr. No.	Treatments	*Colony diameter (mm)		Avg.	% Inhibition		Avg.
		2000 ppm	2500 ppm		2000 ppm	2500 ppm	
T_1	Copper oxychloride 50% WP	45.00	38.00	41.50	50.00 (45) **	57.77 (49.47)	53.88 (47.22)
T_2	Mancozeb 75% WP	42.00	33.00	37.50	53.33 (46.90)	63.33 (52.73)	58.33 (49.79)
T_3	Chlorothalonil 75% WP	22.00	18.00	20.00	75.55 (60.36)	80.00 (63.43)	77.77 (61.86)
T_4	Captan 50% WP	20.00	15.00	17.50	77.77 (61.86)	83.33 (65.90)	80.55 (63.83)
T_5	Carbendazim 12% + Mancozeb 63% WP	00.00	00.00	00.00	100.00 (90)	100.00 (90)	100.00 (90)
T_6	Tebuconazole 50%+ Tryfloxystrobin 25% WDG	9.00	7.50	8.25	90.00 (71.56)	91.66 (73.21)	90.83 (72.37)
T_7	Captan 70% + Hexaconazole 5% WP	16.00	11.00	13.50	82.22 (65.06)	87.77 (69.53)	85.00 (67.21)
T_8	Control (untreated)	90.00	90.00	90.00	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)
S.E ±		0.48	0.51	0.48	0.47	0.50	
C.D. (P=0.01)		2.02	2.12	2.01	2.00	2.10	

*Average of three replications. **Figures in parenthesis are arc sine transformation value.

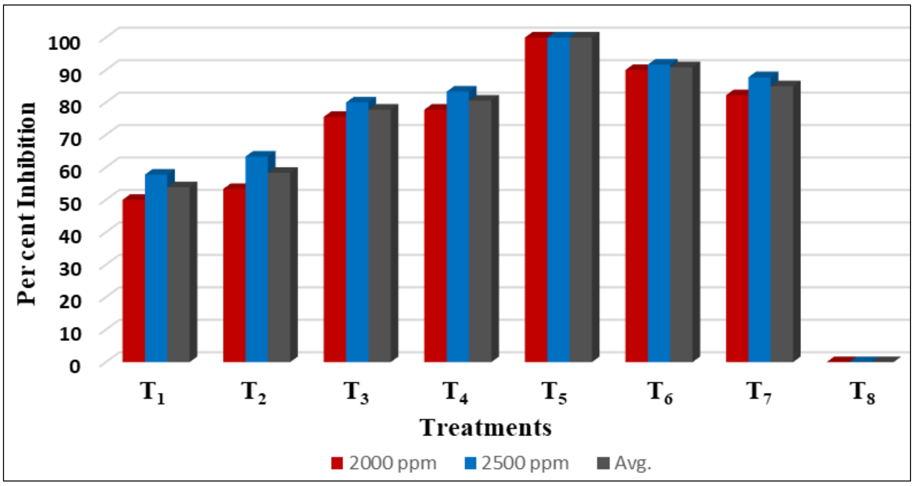

Fig 2: *In vitro* efficacy of contact and combi fungicides against *Fusarium oxysporum* f. sp. *udum.*

Conclusion

The results of the conducted experiment documented that, all tested systemic, contact and combi- product fungicide significantly inhibited the growth of the test pathogen compared to the untreated control in *In vitro*. However, among the systemic fungicides, Carbendazim 50% WP, Tebuconazole 25.9% EC, Propiconazole 25% EC and were most effective at both 500 ppm and 1000 ppm concentrations. In contact and combi-product fungicides *viz*., Carbendazim 12% + Mancozeb 63% WP and Tebuconazole 50% + Trifloxystrobin 25% WG combinations effectively inhibited the growth of *Fusarium oxysporum* f. sp. *udum* under *In vitro* experimental conditions.

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