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Research Paper

Comparative efficacy of different chemical fungicides against S*clerotium rolfsii* (sacc.) causing collar rot of chickpea (*Cicer arietinum* L.)

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ABSTRACT

Present investigation was undertaken for efficacy of fungicides like *i.e.*, carboxin 37.5% + thiram 37.5% WS (vitavax), pyraclostrobin 100 g/L CS, propiconazole 25% EC, hexaconazole 5% EC, thiophanate methyl 70% WP, carbendazim 50% WP, mancozeb 75% WP, chlorothalonil 75% WP and captan 70% + hexaconazole 5% WP were evaluated *in-vitro* at three concentrations *viz.*, 100, 125 and 200 ppm concentration against *S. rolfsii* on PDA by poisoned food technique. The result revealed that increase in concentration of the fungicides caused increased inhibition of mycelial growth of pathogen. Among these, carboxin 37.5% + thiram 37.5% WS (vitavax) was completely inhibited mycelial growth of pathogen at 100 ppm, 125 ppm & 200 ppm. Followed by hexaconazole 5% EC in mycelial growth inhibition of 95.44, 97.22 and 100% at 100, 125 and 200 ppm, respectively. At 200 ppm both hexaconazole 5% EC and carboxin 37.5% + thiram 37.5% WS (vitavax) is statistically at par in growth inhibition. While, mancozeb 75% WP was found least effective at all concentrations against *S. rolfsii*. Most effective *in-vitro* evaluate fungicides tested for their efficacy against disease under pot experiment along with treatment application methods *viz.*, pre-emergence drenching, seed treatment and integration of both seed treatment and post emergence seedling drenching at 7 days after germination (7 DAG) against collar rot disease of chickpea in pot experiment. All the treatments proved significantly superior when compared with inoculated control. Maximum percent reduction in PESR (100.00%) was recorded in vitavax power applied through seed treatment followed by hexaconazole recorded (90.91%) reduction in PESR. Maximum percent reduction in PESM (62.50%) was recorded in hexaconazole applied through integration of seed treatment & post emergence seedling drenching at 7 DAG. Which, was followed by vitavax power observed (50.00%) reduction in PESM. Seed treatment alone reduced PESR while, integration of seed treatment and post emergence seedling drenching at 7 DAG also reduced PESM. Among treated pots highest grain yield recorded (45.90 g/pot) in hexaconazole applied through integration of integration of seed treatment and post emergence seedling drenching at 7 DAG followed by vitavax power (43.33 g/pot).

Key words: Collar rot, Fungicides, Poisoned food technique, *Sclerotium rolfsii*, Seed treatment

INTRODUCTION

Chickpea is known in this country since ancient times. It is said to be one of the oldest pulses known and cultivated in Asia and Europe. According to Aykroyd and Doughty (1964), the center of origin of chickpea is stated to be eastern Mediterranean, but it's probable place of origin lies in south western Asia, *i.e.,* countries lying to north-west of India such as Afghanistan and Persia. Globally, chickpea ranked 3rd after common bean (*Phaseolus vulgaris* L.) and dry pea (*Pisum sativum* L.). Chickpea is not only good for human health but also for soil health. It meets 80% of its nitrogen (N) requirement from symbiotic *Rhizobial* interactions, which enables the crop to fix up to 140 kg N/ha from atmosphere (Saraf *et al*. 1998). It leaves substantial amount of residual nitrogen behind for subsequent crops and adds much needed organic matter to maintain and improve soil health, long-term fertility and sustainability of the ecosystems and is a boon to the resource-poor marginal farmers in the tropics.

India ranks first in conditions of chickpea production and consumption in the world. In India, area under chickpea was 9.85 m ha with a production of 11.99 mt and productivity of 1217 kg/ha. Whereas, in Rajasthan chickpea is an important winter legume crop, grown principally both in irrigated and rain-fed areas. It occupies an area 2.11 m ha with a production of 2.32 mt and productivity of 1099 kg/ha during 2020-21 (Anonymous 2021).

Despite the high total production and more nutritive value, yields of chickpea are low due to many biotic and abiotic constraints. Among the biotic causes collar rot caused by *Sclerotium rolfsii* Sacc. is an important disease in areas where seedling is exposed to high temperature and high moisture in the soil, affected seedlings turn yellow, which can be easily pulled out. The fungus placed in the form of genus *Sclerotium rolfsii* by Saccardo (1913) as it forms differentiated sclerotia and sterile mycelia. Lower portion of stem of herbaceous plants decay with development of white mat of mycelium at the lesion site. This often spreads out on to the near-by soil surface. Shortly after the mycelial mat develops, small (0.5-1mm), white round, fuzzy mycelial bodies begin to appear. These further developed into mustard grain sized light to dark brown structures known as sclerotia, serve as over wintering bodies and may be seen in the mycelium, on diseased tissues above or below ground, on soil surface, or in soil crevices. The characteristic white mycelial mats and sclerotia also develop at the infection sites near the crown under favorable conditions. Foliage wilting and die-back develop as a consequence of rolling of the lower trunk or crown tissue. *S. rolfsii* is a ubiquitous and aerobic pathogen. The drying of plants in chickpea field is observed due to wilt and root/collar rot complex. Out of these diseases, collar rot caused by *Sclerotium rolfsii* Sacc. is becoming more serious at a seedling stage especially in the area where paddy or soybean-based cropping system is followed.

Collar rot of chickpea caused by *Sclerotium rolfsii* is an important soil borne and fast spreading fungal pathogen, which causes considerable damage to the plant stand. Seedling mortality in chickpea due to *S. rolfsii* has been reported to vary from 54.7 to 95.00 per cent (Shrivastava *et al*. 1984). Under field conditions, *S. rolfsii* has been reported to cause 22 to 50 per cent reduction in yield of chickpea. Ghosh *et al*. (2013) surveyed four chickpea growing states of India *i.e.*, Andhra Pradesh, Karnataka, Madhya Pradesh, and Chhattisgarh and reported that losses from collar rot disease ranged from 7.1 to 10.5%. This disease is more problematic for chickpea farmer in the *Hadoti* region of Rajasthan. *S. rolfsii* control has met with very limited success. This may be due to the prolific growth, extensive host range of the pathogen and having the ability to produce large number of sclerotia that may persist in the soil for several years (Sennoi *et al.* 2013). There are no substantial levels of host plant resistance for collar rot in chickpea but the disease can be minimized by fungicides and appropriate crop rotation (Kumar *et al.* 1997, Azhar *et al.* 2006). The present study was carried out to assess antifungal potential of fungicides against *S. rolfsii in-vitro* and *in-vivo* management of collar rot of chickpea.

MATERIALS AND METHODS

Present investigation was carried out in the laboratory as well as under pot experiments at cage house of Department of Plant Pathology, College of Agriculture, Kota (Raj.) during *Rabi* 2019-20.

Collection, isolation, pathogenicity and identification of S. rolfsii

Infected plants which showing typical collar rot symptoms were collected during month of October to December, 2018 from the chickpea fields of Agriculture Research Station, Ummedganj (Kota) brings to laboratory for further studies. Isolation of fungus was carried through standard tissue isolation through infected plant parts and the pure culture of fungus was obtained by following hyphal tip culture under aseptic conditions was maintained on PDA slants at 4±1°C for further studies. Pathogenicity was proved through soil inoculation. Basis on culture characteristics fungus identified as *S. rolfsii*. Further, the identification of pathogen was confirmed from Indian Type of Culture Collection, Division of Plant Pathology, IARI, New Delhi (Ref. No. PP/3260; Date- 25/03/2019).

Efficacy of chemical fungicides against the pathogen under in-vitro condition

Various fungicides as listed in Table 1 at different concentrations were evaluated for their effectiveness against pathogen by Poisoned food technique as suggested by Nene and Thapliyal (2018) following FRCD design with 3 replications.

Above listed nine fungicides were tested *in-vitro* against *Sclerotium rolfsii*. Poisoned food technique (Nene and Thapliyal 2018) was employed for evaluation of different fungicides in the laboratory. Stock solution of 10000 ppm standard

Table 1. Treatment details for bioefficacy of fungicides under in-vitro condition

S.N.	Technical ingredient	Trade name	Chemical Name	Concentrations (ppm)
1.	Carboxin 37.5% + Thiram 37.5% WS	Vitavax Power	5,6 dihydro 2 methyl 1, 4 oxathin 3 carboxaniline + Tetramethyl thiram disulphide	100, 125, 200
2.	Pyraclostrobin 100 g/L CS	Seltima	Methyl *N*-[2-[[1-(4-chlorophenyl) pyrazol-3-yl] oxy methyl] phenyl]-*N*-methoxy carbamate	100, 125, 200
3.	Propiconazole 25% EC	Tilt	1-2-(2-chloro-4-(4-dichlorophenoxy))-4-propyl -1, 3-dioxolan-2 yl methyl)- 1H-1, 2, 4-triazole	100, 125, 200
4.	Hexaconazole 5% EC	Conquer	(RS)-2-(2,4-dichlorophenyl)-1-(1H-1, 2, 4-triazol-1yl) hexane -2-01	100, 125, 200
5.	Thiophanate Methyl 70% WP	Roko	1,2-bis (3-methoxy carbonyl -2-thiouredo) benzene	100, 125, 200
6.	Carbendazim 50% WP	Bavistin	Methyl -2-benzimidazole carbamate	100, 125, 200
7.	Mancozeb 75% WP	Diathane M-45	Zinc; Manganese (2+); *N*- [2- (sulfido carbothioyl amino) ethyl] carbamo dithioate	100, 125, 200
8.	Chlorothalonil 75% WP	Kavach	2,4,5,6-tetrachloroisophthalo nitrile	100, 125, 200
9.	Captan 70% + Hexaconazole 5% WP	Taqat	2-(trichloromethylsulfanyl)-3*a*,4,7,7*a*-tetrahydroisoindole-1,3-dione + (RS)-2-(2,4-dichlorophenyl)-1-(1H-1, 2, 4-triazol-1yl) hexane -2-01	100, 125, 200
10.	Control			

solution of fungicides in the 10 ml distilled water by dissolving adequate quantity of fungicides. 100 ml potato dextrose agar medium was sterilized in conical flask of 250 ml capacity. The required amount of stock solution of fungicides separately incorporated aseptically in molten Luke worm PDA to make 100, 125 and 200 ppm concentration. To avoid bacterial contamination little pinch amount of streptomycin antibiotics was added in each flask before pouring in petri dish. The amended medium was then poured in sterilized petri plates. Medium without any chemical incorporated medium plate served as control. A 6 mm mycelial disc of test fungus was cut with the help of sterilized cork borer from the margin of 3 days old culture and then placed centrally in petri plates. The disc was placed in inverted position to allow the contact of fungus with medium. Three replications were maintained for each treatment. The inoculated petri plates were incubated in the BOD incubator at 25±1^{o}C till growth of colony touched periphery in the control plate and the colony diameter of the pathogen was measured with the help of scale in mm, percent growth inhibition under the influence of different fungicides were calculated by using the formula given by Vincent (1947). The data were analysed statistically.

$$I = \frac{C-T}{C} X100$$

Where, I = per cent inhibition, C = growth in control, T = growth in treatment.

Efficacy of chemical fungicides against disease under pot experiment

For pot study the soil was sterilized by using formaldehyde by the following procedure. For this raised soil bed was prepared and watered the soil up to saturation level and left undisturbed for two days. After two days the soil was moistened by 4% formaldehyde solution (40 ml formaldehyde per liter of water) up to saturation level and covered by polythene sheet and kept undisturbed for five days. Polythene sheet was removed after five days and soil was exposed to open for seven days to remove the traces of formaldehyde present in soil. This soil was filled to the disinfected pots to carry out further studies.

The sterilized soil was mixed with *Sclerotium rolfsii* which was isolated from diseased plants or mass cultured on Sand Sorghum Medium. 10 g mass culture of *S. rolfsii* grown on sorghum seeds was added to upper 15 cm layer of soil in pots and mixed thoroughly. The mixed soil was placed in cemented pots. Ten seeds were placed in one cemented pot after 24 hrs. of inoculation. Three replications were maintained for each treatment. These pots were kept in a net house. Moisture content in the soil was maintained to field capacity by adding required amount of water periodically. Proper isolation was maintained to avoid other pathogens. Observations on germination, pre and post emergence mortality were recorded. No soil inoculated with test fungus was treated as control.

To find out effective chemical fungicides for management of collar rot of chickpea, the three-fungicide performed best *in-vitro* experiment were used on collar rot disease incidence at recommended dose, under pot experiment applied through seed treatment and drenching (Table 2). The experiment was conducted under CRD with 3 replications.

Table 2. Treatment details of experiment under pot experiment

Symbol	Treatment
T1	Pre-emergence drenching (PED) with vitavax at 48 hrs. after sowing @ 0.2% @ 50ml/pots.
T2	Pre-emergence drenching (PED) with hexaconazole 5% EC at 48 hrs. after sowing @ 0.1% @ 50ml/pots.
T3	Pre-emergence drenching (PED) with propiconazole 25% EC at 48 hrs. after sowing @ 0.1% @ 50ml/pots.
T4	Seed treatment (ST) with vitavax @ 0.2% /kg of seeds.
T5	Seed treatment with hexaconazole 5% EC @ 0.1% / kg of seeds.
T6	Seed treatment with propiconazole 25% EC @ 0.1% / kg of seeds.
T7	T_4 + Post emergence seedlings drenching (PESD) in root zone 0.2% concentration of vitavax @ 50 ml/pots at 7 days after germination (DAG)
T8	T_5 + Post emergence seedlings drenching in root zone 0.1% concentration of hexaconazole 5% @ 50 ml/ pots, at 7 days after germination (DAG).
T9	T_6 + Post emergence seedlings drenching in root zone 0.1% concentration of Propiconazole 25% EC @ 50 ml/pots at 7 days after germination (DAG).
T10	Inoculated control
T11	Un-inoculated control

Statistical analysis

Analysis and interpretation of the experimental data was done by using completely randomized design (CRD) for both as well as laboratory and pot experiments as suggested by Panse and Sukathme (1985).

Observations recorded

The percentage seed germination, pre-emergence seed rot and post-emergence seedling mortality were calculated by the formulae.

a) Germination (%) =

$$\frac{\text{Number of seed germinated}}{\text{Total number of seed sown}} X100$$

b) Pre-emergence seed rotting % (PESR) =

$$\frac{\text{Number of seed not germinated}}{\text{Total number of seed sown}} X100$$

c) Post-emergence seedling mortality % (PESM)

$$= \frac{\text{Number of seedling died}}{\text{Total number of seedling}} X100$$

d) Reduction (%) in PESR & PESM

$$= \frac{C-T}{C} X100$$

Where, C= Percent seed rot/mortality in inoculated control pots,

T = Percent rot/mortality in treated pots.

RESULTS AND DISSCUSSION

In-vitro effect of chemical fungicides on mycelial growth inhibition of the S. rolfsii on PDA by poisoned food technique

The efficacy of fungicides like *viz.*, carboxin 37.5% + thiram 37.5% WS (vitavax), pyraclostrobin 100 g/L CS, propiconazole 25% EC, hexaconazole 5% EC, thiophanate methyl 70% WP, carbendazim 50% WP, mancozeb 75% WP, chlorothalonil 75% WP and captan 70% + hexaconazole 5% WP were evaluated *in-vitro* at three concentrations *viz.*, 100, 125 and 200 ppm concentration against *S. rolfsii*

Plate 1. *In-vitro* efficacy of different chemical fungicides on growth inhibition of *S. rolfsii*, 96 hrs. after inoculation (T_1: Vitavax (Carboxin 37.5% + Thiram 37.5% WS), T_2: Pyraclostrobin 100 g/L CS, T_3: Propiconazole 25% EC, T_4: Hexaconazole 5% EC, T_5: Thiophanate Methyl 70% WP, T_6: Carbendazim 50% WP, T_7: Mancozeb 75% WP, T_8: Chlorothalonil 75% WP, T_9: Captan 70% + Hexaconazole 5% WP, T_{10}: Control)

Table 3. *In-vitro* efficacy of chemical fungicides on mycelial growth inhibition of *S. rolfsii* by poisoned food technique at different concentrations (96 hrs after inoculation) at 25±1°C

Treatment / Fungicides	Percent mycelial growth inhibition of *S. rolfsii.* *			
	100 ppm	125 ppm	200 ppm	Mean
T_1: Vitavax (Carboxin 37.5% + Thiram 37.5% WS)	100.00 * (90.00) **	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
T_2: Pyraclostrobin 100 g/L CS	28.89 (32.49)	34.44 (35.93)	53.33 (46.91)	38.89 (38.44)
T_3: Propiconazole 25% EC	64.44 (53.41)	68.33 (55.77)	71.11 (57.49)	67.96 (55.56)
T_4: Hexaconazole 5% EC	94.44 (76.41)	97.22 (80.60)	100.00 (90.00)	97.22 (82.34)
T_5: Thiophanate Methyl 70% WP	2.22 (8.38)	6.67 (14.93)	8.89 (17.29)	5.93 (13.53)
T_6: Carbendazim 50% WP	0.00 (0.00)	3.33 (10.42)	5.56 (13.59)	2.96 (8.00)
T_7: Mancozeb 75% WP	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
T_8: Chlorothalonil 75% WP	0.00 (0.00)	6.67 (14.93)	8.89 (17.02)	5.19 (10.65)
T_9: Captan 70% + Hexaconazole 5% WP	4.44 (12.11)	13.33 (21.32)	24.44 (29.60)	14.07 (21.01)
T_{10}: Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Concentration Mean	29.44 (27.28)	33.00 (32.39)	37.22 (36.19)	33.22 (31.95)
	Treatment	**Concentration**		**T x C**
S Em±	**0.53**	**0.29**		**0.91**
C.D. at 0.05% =	**1.49**	**0.81**		**2.58**

*Average of three replications; **Figures in parentheses are Arc sine transformed values.

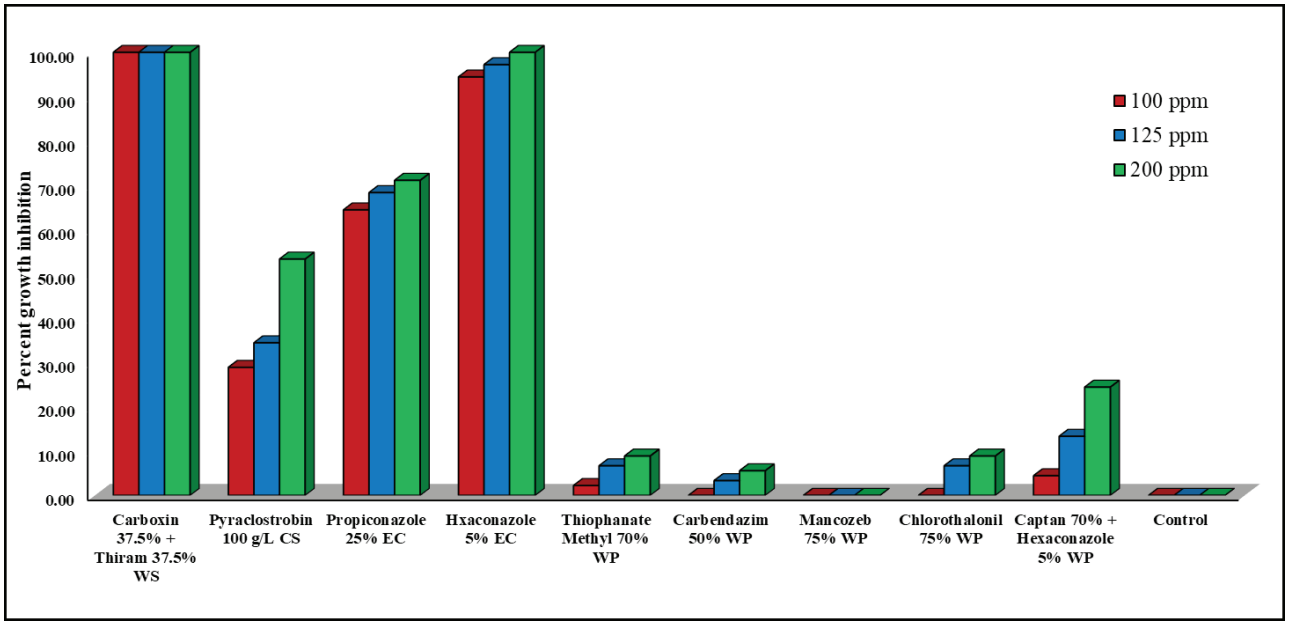

Fig. 1. *In-vitro* efficacy of chemical fungicides on mycelial growth inhibition of *S. rolfsii,* by poisoned food technique @ different concentrations (96 hrs. after inoculation)

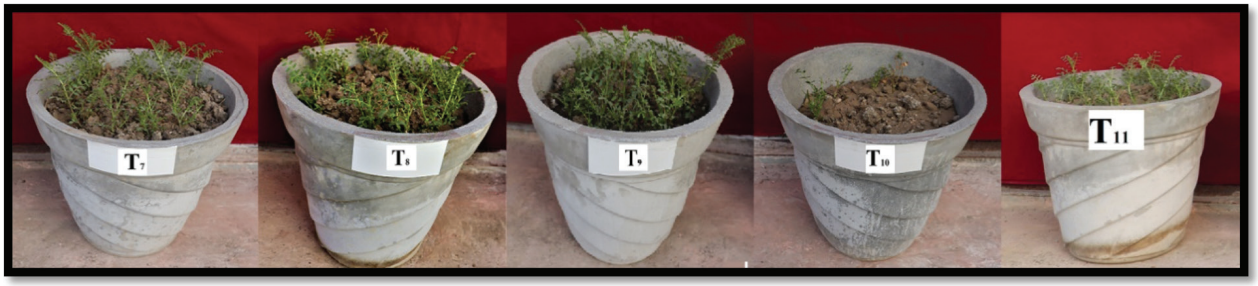

Plate 2. Best performed chemical fungicides along with application method under pot experiment
T_7 = T_4 + Post emergence seedlings drenching (PESD) in root zone 0.2% conc. of Vitavax @ 50 ml/pots at 7 DAG, T_8 = T_5 + PESD in root zone 0.1% conc. of Hexaconazole 5% @ 50 ml/pots, at 7 DAG, T_9 = T_6 + PESD in root zone 0.1% conc. of Propiconazole 25% EC @ 50 ml/pots at 7 DAG. T_{10} = Inoculated control, T_{11} = Un-inoculated control.

on PDA by poisoned food technique. The data suggested (Table 3, Fig. 1 and Plate 1) that increase in concentration of the fungicides caused increased inhibition of mycelial growth of pathogen. Among these, carboxin 37.5% + thiram 37.5% WS (vitavax) was inhibit completely mycelial growth of pathogen at all concentrations tested. This was followed by hexaconazole 5% EC in with inhibition of 95.44, 97.22 and 100 % at 100, 125 and 200 ppm, respectively. mancozeb 75% WP was found least effective at all concentrations against *S. rolfsii*. Thiophanate methyl 70% WP and chlorothalonil 75% WP were at par at all concentrations respectively. Thiophanate methyl 70% WP, carbendazim 50% WP, mancozeb 75% WP and chlorothalonil 75% WP at 100 ppm were found at par with each other with 2.22, 0.00, 0.00 and 0.00% mycelial growth inhibition, respectively. Whereas, captan 70% + hexaconazole 5% WP and thiophanate methyl 70% WP at 100 ppm were found at par with each other with 4.44% and 2.22% mycelial growth inhibition. Arunasri *et al.* (2011) reported that triazoles (hexaconazole, propiconazole, difenconazole) were highly effective to inhibit growth of *S. rolfsii*. Further, Manu *et al.* (2012) reported that systemic fungicides, difenconazole, hexaconazole, propiconazole @ 25, 50, 100, 150,

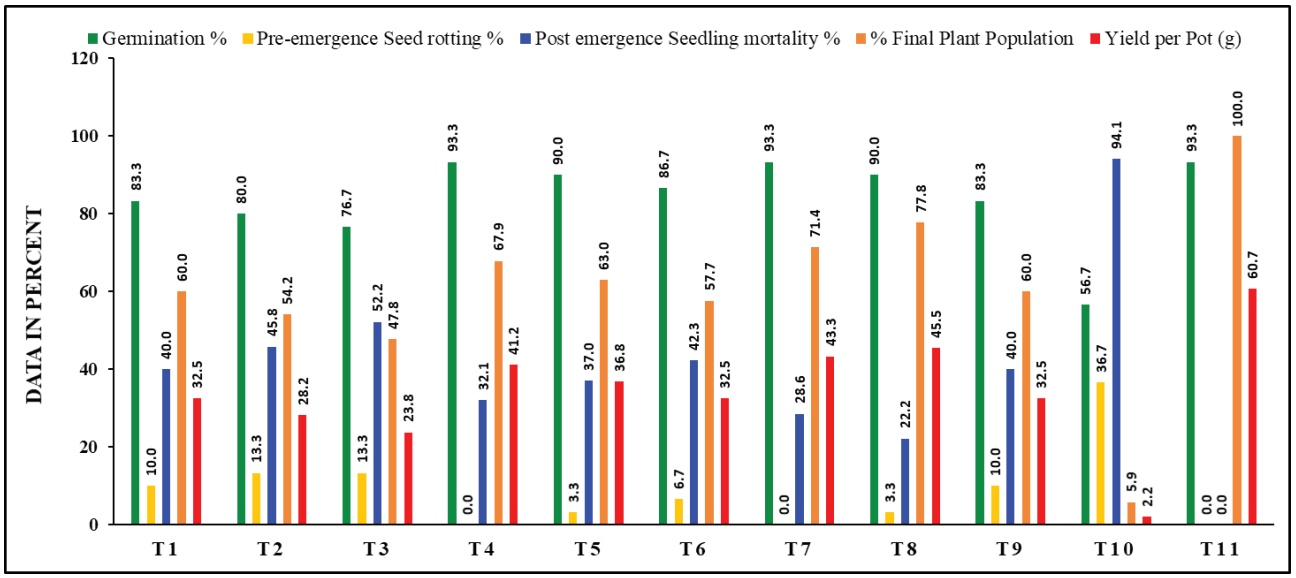

Fig. 2. Efficacy of best *in-vitro* evaluate chemical fungicides against disease under pot experiment

T_1 = Pre-emergence drenching (PED) with vitavax at 48 hrs. after sowing @ 0.2%, T_2 = PED with hexaconazole 5% EC at 48 hrs. after sowing @ 0.1%, T_3 = PED with Propiconazole 25% EC at 48 hrs. after sowing @ 0.1%., T_4 = Seed treatment (ST) with vitavax @ 0.2% /kg of seeds. T_5 = ST with Hexaconazole 5% EC @ 0.1% /kg of seeds., T_6 = ST with Propiconazole 25% EC @ 0.1% /kg of seeds., T_7 = T_4 + Post emergence seedlings drenching (PESD) in root zone 0.2% conc. of Vitavax @ 50 ml/pots at 7 DAG, T_8 = T_5 + PESD in root zone 0.1% conc. of Hexaconazole 5% @ 50 ml/pots, at 7 DAG, T_9 = T_6 + PESD in root zone 0.1% conc. of Propiconazole 25% EC @ 50 ml/pots at 7 DAG. T_{10} = Inoculated control, T_{11} = Un-inoculated control.

Table 4. Efficacy of best *in-vitro* evaluate chemical fungicides against disease under pot experiment.

Treat Ment	No. of Plant Emerge	Germination (%)	No. of Seed pre-emerge Rotting	Pre-emergence Seed rotting %	% Reduction in PESR	No. of Seedling post emerge died	Post emergence Seedling mortality %	% Reduction in PESM	No. of Final Plant stand	% Final Plant Population	Yield per Pot (g)
T_1	8.33 *	83.33	1.00	10.00	72.73	3.33	40.00	37.50	5.00	60.00	32.50
		(65.91) **		(18.43)	(58.52)		(39.23)	(37.76)		(50.77)	
T_2	8.00	80.00	1.33	13.33	63.64	3.67	45.83	31.25	4.33	54.17	28.17
		(63.43)		(21.42)	(52.91)		(42.61)	(33.99)		(47.39)	
T_3	7.67	76.67	1.33	13.33	63.64	4.00	52.17	25.00	3.67	47.83	23.83
		(61.12)		(21.42)	(52.91)		(46.25)	(30.00)		(43.75)	
T_4	9.33	93.33	0.00	0.00	100.00	3.00	32.14	43.75	6.33	67.86	41.17
		(75.04)		(0.00)	(90.00)		(34.54)	(41.41)		(55.46)	
T_5	9.00	90.00	0.33	3.33	90.91	3.33	37.04	37.50	5.67	62.96	36.83
		(71.57)		(10.52)	(72.45)		(37.49)	(37.76)		(52.51)	
T_6	8.67	86.67	0.67	6.67	81.82	3.67	42.31	31.25	5.00	57.69	32.50
		(68.58)		(14.96)	(64.76)		(40.58)	(33.99)		(49.42)	
T_7	9.33	93.33	0.00	0.00	100.00	2.67	28.57	50.00	6.67	71.43	43.33
		(75.04)		(0.00)	(90.00)		(32.31)	(45.00)		(57.69)	
T_8	9.00	90.00	0.33	3.33	90.91	2.00	22.22	62.50	7.00	77.78	45.50
		(71.57)		(10.52)	(72.45)		(28.13)	(52.24)		(61.87)	
T_9	8.33	83.33	1.00	10.00	72.73	3.33	40.00	37.50	5.00	60.00	32.50
		(65.91)		(18.43)	(58.52)		(39.23)	(37.76)		(50.77)	
T_{10}	5.67	56.67	3.67	36.67	0.00	5.33	94.12	0.00	0.33	5.88	2.17
		(48.83)		(37.27)	(0.00)		(75.96)	(0.00)		(14.04)	
T_{11}	9.33	93.33	_	_	_	_	_	_	9.33	100.00	60.67
		(75.04)								(90.00)	
		Germination	**Pre-emergence Seed rotting**		**Post emergence Seedling mortality**			**Final Plant Stand**		**Yield per Pot**	
S Em±		**0.46**	**1.07**		**0.66**			**1.06**		**4.13**	
C.D. at 0.05% =		**1.36**	**3.13**		**1.94**			**3.11**		**12.12**	

*Average of three replications; **Figures in parentheses are Arc sine transformed values.

T_1 = Pre-emergence drenching (PED) with vitavax at 48 hrs. after sowing @ 0.2%, **T_2 =** PED with hexaconazole 5% EC at 48 hrs. after sowing @ 0.1%, **T_3 =** PED with Propiconazole 25% EC at 48 hrs. after sowing @ 0.1%, **T_4 =** Seed treatment (ST) with vitavax @ 0.2% /kg of seeds. **T_5 =** ST with Hexaconazole 5% EC @ 0.1% /kg of seeds, **T_6 =** ST with Propiconazole 25% EC @ 0.1% /kg of seeds, **T_7 =** T_4 + Post emergence seedlings drenching (PESD) in root zone 0.2% conc. of Vitavax @ 50 ml/pots at 7 DAG, **T_8 =** T_5 + PESD in root zone 0.1% conc. of Hexaconazole 5% @ 50 ml/pots at 7 DAG, **T_9 =** T_6 + PESD in root zone 0.1% conc. of Propiconazole 25% EC @ 50 ml/pots at 7 DAG. **T_{10} =** Inoculated control, **T_{11} =** Un-inoculated control.

200, 250 ppm, combi products, *viz*., avatar, nativo and vitavax power @ 125, 250, 500, 750, 1000 ppm and contact fungicide, mancozeb was found to be effective only at higher concentrations at 1000 ppm were found effective against *S. rolfsii*. Ahsan *et al.* (2018) found propiconazole, hexaconazole and vitavax completely inhibited the growth of *S. rolfsii*, *in-vitro* while, bavistin and topsin M showed 79.52 and 71.78% growth inhibition respectively at 500 ppm. Shirsole *et al.* (2019) also reported that systemic fungicides like, hexaconazole 5% EC, propiconazole 25% EC and combo products tebuconzole 50% + trifloxystrobin 25% WG, captan 70% + hexaconazole 5% WP, propiconazole 13% + difenconazole and carboxin 37.5% + thiram 37.5% showed complete inhibition of the pathogen at 20, 50, 100, 200 and 500 ppm tested. Whereas, the non-systemic fungicide mancozeb 75%WP, thiram 75% WS and propineb 70% WP was found inhibitive only at higher concentrations (100 ppm) against *S. rolfsii* under *in-vitro* condition.

Efficacy of best in-vitro evaluate chemical fungicides against disease under pot experiment

Results are presented in Table 4, Fig. 2 and Plate 2 revealed that the treatment application method *viz*., pre-emergence drenching, seed treatment and integration of both seed treatment and post emergence seedling drenching at 7 days after germination (7 DAG) of each chemical fungicide against collar rot disease of chickpea under pot experiments. All the treatments proved significantly superior when compared with inoculated control. Maximum percent reduction in PSER (100.00%) was recorded in vitavax power applied through seed treatment followed by hexaconazole recorded (90.91%) reduction in PESR. Maximum percent reduction in PESM (62.50%) was recorded in hexaconazole applied through integration of seed treatment and post emergence seedling drenching at 7 DAG, which was followed by vitavax power observed (50.00%) reduction in PESM. Seed treatment alone reduced PESR while,

integration of seed treatment & post emergence seedling drenching at 7 DAG also reduced PESM. Maximum percent final plant population (77.78%) were observed in hexaconazole applied through integration of seed treatment and post emergence seedling drenching at 7 DAG followed by vitavax power (71.43%). Among treated pots highest grain yield recorded (45.90 g/pot) in hexaconazole applied through integration of integration of seed treatment and post emergence seedling drenching at 7 DAG followed by vitavax power (43.33 g/pot). While, in un-inoculated control grain yield recorded were (60.67 g/Pot). These observations are correlated with the findings of Sab *et al.* (2018) who reported vitavax power as most effective with 9% infection of collar rot. Ahsan *et al.* (2018) reported that seed treatment with fungicides significantly reduced the mortality of chickpea seedlings when compared with control. The seeds treated with carboxin (vitavax) 2 g/kg proved most effective and showed 66.70 % disease control followed by propiconazole 2 g/kg seed. Dabbas and Kumar (2016) revealed that seed treatment with taqat and hexaconazole were found most effective in seed germination (92.8 and 87.5%, respectively) and minimum in disease incidence (5.3 and 7.1%, respectively). Madhavi and Bhattiprolu (2011) reported that hexaconazole, propiconazole, difenconazole showed 100 percent inhibition of mycelial growth at 1000, 2000 and 3000 ppm at both depths followed by carbendazim + mancozeb, propineb and benomyl recorded 100 percent inhibition with 2000 and 3000 ppm at 10 cm and 15cm depths proved effective in controlling the pathogen. Integration of different treatments including seedling dip with carbendazim + mancozeb, addition of vermicompost, drenching with fungicide and application of *Trichoderma harzianum* (7%) were found to be effective in management of dry root rot disease of chilli caused by *Sclerotium rolfsii* (Sacc.) in comparison with individual treatments.

CONCLUSION

Out of nine chemical fungicides used against *S. rolfsii* on PDA by poisoned food technique, carboxin 37.5% + thiram 37.5% WS (vitavax) completely inhibited the mycelial growth of pathogen at all concentrations. This was followed by hexaconazole 5% EC in with inhibition of 95.44, 97.22 and 100% at 100, 125 and 200 ppm, respectively. Mancozeb 75% WP was found least effective at all concentrations against *S. rolfsii*. The three-fungicide performed best in *in-vitro* experiment were used on collar rot disease incidence at recommended dose, under pot experiment applied through seed treatment and drenching. Chemical fungicides applied as seed treatment alone reduced pre-emergence seed rotting while, integration of seed treatment and post emergence seedling drenching at 7 DAG reduced both PESR and PESM. Maximum percent final plant population (77.78%) and yield (45.90 g/pot) were observed in hexaconazole applied through integration of seed treatment and post-emergence seedling drenching at 7 DAG.

CONFLICT OF INTEREST

All the authors declare no conflict of interest.

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