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Assessment of Efficacy of Potential Fungicides and Biocontrol agents for Efficient Management of *Phoma* sp., causing Leaf Spot of Pigeonpea

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ABSTRACT: Though an effective disease management starts with cultural, mechanical and physical methods but practically the chemicals and use of biocontrol agents are important to reduce the outbreak of diseases. The efficacy of new fungicides at different concentrations pave the way for new recommendations with the replacement of old chemicals. To know the efficacy of any fungicide, there is need to test chemicals under laboratory conditions which provide primary information regarding efficacy of fungicides against pathogen within a shortest period of time. An experiment was conducted to evaluate the efficacy of fungicides and bioagents against *Phoma* sp., causing leaf spot in pigeonpea at Department of Plant Pathology, UAS Raichur. Among the bio-agents tested, *T. hamatum* (NAIMCC-F-04088) was found to be more effective and statistically significant over other bio-control agents in inhibiting the test fungus. Among, all the tested non-systemic, systemic and combi fungicides, mancozeb, propineb, hexaconazole, propiconazole and all the tested combi fungicides were effective with 100 per cent inhibition at all the concentrations tested, respectively.

Keywords: Bioagents, Fungicides, Pigeonpea, *Phoma* sp.,

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] (2n=2x=22) belongs to the genus *Cajanus*, subtribe *Cajaninae*, tribe *Phaseoleae* and family *Fabaceae*. The word *Cajanus* is derived from a Malay word '*Katschang*' or '*Katjang*' meaning pod or bean. Several authors considered that Eastern Africa to be the center of origin of pigeonpea, as it occurs in the wild form (Zeven and Hukovsky, 1975). However, De (1974) and Vernon (1976) reviewed the pigeonpea origin and agreed in favour of India and concluded that India is the primary center and Africa is the secondary center of origin. Pigeonpea is predominantly grown in *the Kharif* season both as a sole and intercrop under a wide range of agro-ecological situations. The deep root system of pigeonpea helps in extracting the nutrients and moisture from deeper soil layers and making it suitable for rainfed conditions and enables in breaking of the plough pans. Besides this, it fixes atmospheric nitrogen and thereby increases soil fertility (Reddy, 1990; Smita *et al*., 2015) and improves the soil structure hence it is called 'Biological Plough'.

The global pigeonpea production scenario accounts for an area of 6.99 m. ha. with the production of 5.96 m. t. and productivity of 852 kg/ha (Anon., 2018). In India, the total area coverage, production and productivity accounts for 4.78 m. ha., 3.59 m. t. and 751 kg/ha, respectively. The state-wise trend showed that, Maharashtra ranks first both in area and production (29.19 % and 29.68 %) followed by Karnataka (19.23 % and 15.96 %). The protein content of commonly cultivated pigeonpea varieties ranges between 17.9 and 24.3 g/100 g sample (Salunkhe *et al*., 1986) in whole grain samples and 21.1 to 28.1 g/100 g sample in the split seed samples. The wild species of pigeonpea are used to develop several high-protein genotypes with protein content as high as 32.5 per cent (Singh *et al*., 1990). The pigeonpea seeds contain about 57.3 to 58.7 per cent carbohydrate, 1.2 to 8.1 per cent crude fiber and 0.6 to 3.8 per cent lipids (Sinha, 1977).

Even though pigeonpea is accounting for about 90 per cent of the world area and production, there are constraints in productivity over the years. This might be due to abiotic and biotic factors. Among the biotic factors, the crop is known to be affected by more than 200 pathogens among which 83 are fungi (Nene *et al*., 1989) and few are economically important and widespread causing heavy losses. More recently *Phoma* leaf spot caused by *Phoma* sp., becoming a serious menace in parts of North-Eastern Karnataka due to

mono-cropping, but cursory literature is available on management.

Nevertheless, an effective disease management programme would be designed with the incorporation of chemical protection along with other methods of disease control. Assessments of efficacy of new fungicides at different concentrations pave the way for new recommendations with the replacement of old chemicals. Further, exploring the possibility of findings and usage of effective bio-control agents would be of immense help in managing the disease through eco-friendly approaches.

MATERIAL AND METHODS

A. Efficacy of bio-agents and fungicides against Phoma sp., under in vitro

Bioagents obtained indigenously and exogenously *viz.*, *P. fluorescens* (BGREB73), *T. viride* (Tv-B), *T. harzianum* (TUREF59), *T. asperellum* (Ta-1), *T. hamatum* (NAIMCC-F-04088), *B. subtilis* (NAIMCC-B-00750), *B. subtilis* (SE76) and *B. amyloliquifaciens* (NAIMCC-B-00754) were evaluated for their efficacy under *in vitro* using dual culture technique against *Phoma* sp. The mechanism of inhibition of pathogen by the bioagents was studied to identify the efficient bio-agent against *Phoma* sp.

Dual culture test. Bio-agents were evaluated for their efficacy through dual culture technique, the fungal bio-agents and the test pathogen were inoculated in the periphery in an opposite direction of the single Petri plate containing solidified PDA medium. Whereas, the bacterial bio-agents were streaked one day prior to the pathogen inoculation. Three replications were maintained and one control by maintaining pathogen and bio-agent alone and incubated for nine days. The colony diameter of both the bio-agents and the pathogen was measured in both directions and the average was recorded. Per cent inhibition growth of the test pathogen was calculated by using the formula given below by Vincent (1947). The sources of bio-agents are listed in table 1.

$$I = \frac{C-T}{C} \times 100$$

Where,

I = Per cent inhibition

C = Growth in control

T = Growth in treatment

Table 1: List of bioagents used against *Phoma* sp., in dual culture technique.

Sr. No.	Bio agents	Source
1.	*Trichoderma viride* (Tv-B)	Biocontrol Laboratory, Department of Plant Pathology, UAS, Raichur
2.	*T. harzianum* (TUREF59)	
3.	*T. asperellum* (Ta-1)	
4.	*T. hamatum* (NAIMCC-F-04088)	ICAR – National Bureau of Agriculturally Important Microorganisms, Mau (UP)
5.	*Pseudomonas fluorescens* (BGREB73)	Biocontrol Laboratory, Department of Plant Pathology, UAS, Raichur
6.	*Bacillus subtilis* (SE76)	Biocontrol laboratory, Department of Plant Pathology, UAS, Raichur
7.	*B. subtilis* (NAIMCC-B-00750)	ICAR – National Bureau of Agriculturally Important Microorganisms, Mau (UP)
8.	*B. amyloliquifaciens* (NAIMCC-B-00754)	

B. Efficacy of systemic, non-systemic and combi-fungicides on the mycelial growth of Phoma sp.

The experiment was carried out in a completely randomized design and the details of treatments for *in vitro* evaluation of fungicides are listed in table 2 and 3. Twenty ml of PDA medium was initially mixed with the required quantity of fungicides calculated based on the active ingredient listed below and were poured into 90 mm diameter Petri dishes. After solidification, 5 mm discs of *Phoma* pathogen were placed at the center of the plate and suitable checks were maintained without poisoning the media. Each set of experiments was replicated three times and plates were incubated at 25 ± 2 ˚C until the control culture reached the periphery of the plates.

Table 2: List of systemic and non-systemic fungicides used against *Phoma* sp.

Sr. No.	Common name	Trade name
Non-systemic fungicides		
1	Copper hydroxide 53.8 W/W	Kocide
2	Copper oxychloride 50 %WP	Blitox
3	Chlorothalonil 75 % WP	Kavach
4	Propineb 70 % WP	Antracol
5	Mancozeb 75 % WP	Dithane M-45
Systemic fungicides		
1	Azoxystrobin 23% SC	Amistar
2	Carbendazim 50 % WP	Bavistin
3	Difenconazole 25 % EC	Indream
4	Hexaconazole 5 % EC	Contaf
5	Myclobutanil 10 % WP	Myclowin
6	Tricyclozole 75 % WP	Beam
7	Propiconazole 25 % EC	Tilt
8	Tebuconazole 25.9 % EC	Folicur
9	Kitazin 48 % EC	Kitazin
10	Thiophanate methyl 70 % WP	Roko

Table 3: List of combi fungicides used against *Phoma* sp.

Sr. No.	Common name	Trade name
1.	Azaoxystrobin 11 % + Tebuconozole 18.3 % EC	Custodia
2.	Carbendazim 12 % + Mancozeb 63 % WP	SAAF
3.	Fluopyram17.7 % + Tebuconazole 17.7 % w/w SC	Luna experience
4.	Hexaconazole 4 % + Zineb 68 % WP	Avatar
5.	Trifloxystrobin 25 % + Tebuconazole 50 % WG	Nativo
6.	Pyraclostrobin 13.3 % + Epoxyconazole 50 % SE	Opera
7.	Metiram 55% + Pyraclostrobin 5% WG	Cabriotop
8.	Tricyclozole-45% +Hexaconazole-10% WG	Impression
9.	Iprovalicarb 5.5% + Propineb 61.25% WP	Melody Duo

Observations were taken for the growth of the pathogen in treated plates such as colony diameter and per cent inhibition of growth was calculated using the formula (Vincent, 1947). The data were analyzed statistically.

RESULTS AND DISCUSSION

A. Efficacy of bioagents and fungicides against Phoma sp., under In vitro

Efficacy of fungal and bacterial bio-agents against *Phoma* sp. under dual culture. Chemicals are spectacular, impressive, quick and convincing even to an uneducated farmer, but there is an intensified worldwide concern about environmental pollution due to escalated use of hazardous pesticides including fungicides also. A multitude of microbes has been implicated to be biocontrol agents of the plant pathogen, sometimes with excellent documentation. Hence studies were conducted to find out an effective biocontrol agent against *Phoma* sp., and to develop a biocontrol technique as a feasible component in the present day integrated disease management (IDM) strategy.

In the present investigations, eight bio-agents were tested for the ability on the inhibition of colony diameter of *Phoma* sp., through dual culture (Table 4 and Plate 1). Among the bio-agents tested, *T. hamatum* (NAIMCC-F-04088) was found to be more effective and statistically significant over other bio-control agents in inhibiting the colony diameter (75.93 %) which was followed by *T. asperellum* (73.70 %). However, the minimum mycelial inhibition was recorded in *B. subtilis* (SE76) (47.04 %). Mechanisms for bio-control of plant pathogens by *Trichoderma* are through antibiosis, competition and mycoparasitism. In the present study, both *T. hamatum* and *T. asperellum* suppressed the growth of *Phoma* sp., and that might be due to the mutual intermingling of antagonistic isolate with the test pathogen.

Table 4: Efficacy of bio-agents against the growth of *Phoma* sp., under dual culture.

Sr. No.	Bio-agents	Per cent inhibition*
1	*Trichoderma viride* (Tv-B)	72.59 (58.43)[b]
2	*T. harzianum* (TUREF59)	69.26 (56.33)[c]
3	*T. asperellum* (Ta-1)	73.70 (59.15)[b]
4	*T. hamatum* (NAIMCC-F-04088)	75.93 (60.62)[a]
5	*Pseudomonas fluorescens* (BGREB73)	55.93 (48.40)[d]
6	*Bacillus subtilis* (SE76)	47.04 (43.30)[f]
7	*B. subtilis* (NAIMCC-B-00750)	47.41 (43.51)[f]
8	*B. amyloliquifaciens* (NAIMCC-B-00754)	49.26 (44.58)[e]

*Mean of three replications and values in the column followed by common letters are non-significant at p = 0.01 as per DMRT (Duncan, 1955)

Figures in parenthesis are arc sine values

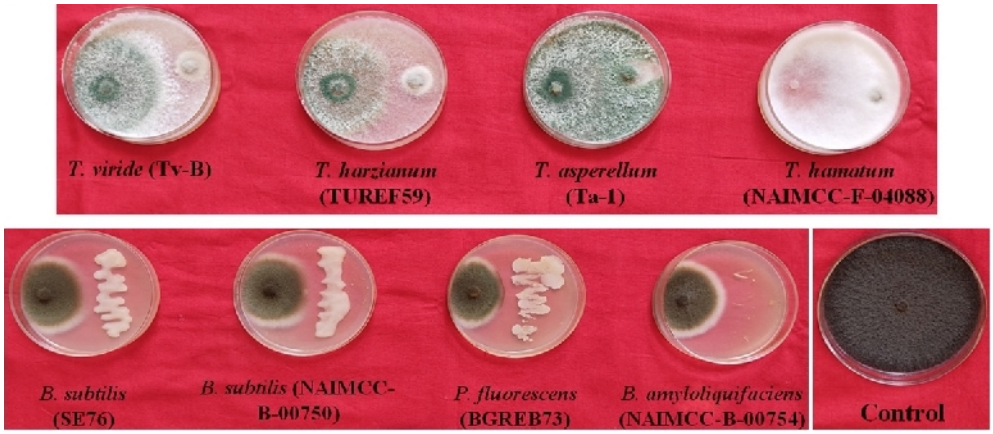


Plate 1. Bio-efficacy of fungal and bacterial bio-agents against *Phoma* sp., under dual culture.

Among bacterial antagonists, *P. fluorescens* showed maximum inhibition. The mechanism involved in the inhibition of growth might be due to the agglutination potential of *P. fluorescens* and also antibiotics *viz*., siderophore, HCN, pyrrolnitrin, phenazine and 2, 4-diacetyl phloroglucinol and lytic enzymes by *P. fluorescens* might have inhibited the mycelial growth of *Phoma* sp. Similar work was done by Hammoudi *et al*. (2012) revealed that *Gliocladium catenulatum* was most effective in inhibiting the colony diameter of *P. lingam* with very strong inhibition zones (>10 mm). However, *Bacillus subtilis* was failed to inhibit the pathogen and *P. fluorescens* (E9) caused the weak inhibition zone (<5 mm) since it produced antifungal metabolites (phenazine-1-carboximide) and exhibited chitinase and glucanase activity. Imen *et al*. (2012) revealed that the *B. subtilis* L194 strain appeared highly effective in the control of *P. medicaginis* because the disease suppression by *B. subtilis* is the net result of plant growth promotion, antibiosis, competition for space and nutrients, lysis of pathogen hyphae and induced systemic resistance.

Various species of *Trichoderma*, *Pseudomonas* and *Bacillus* are the most commercially exploited bio-agents/antagonists to combat several seed-borne and soil-borne plant pathogens. Fungicidal/ fungistatic effects of these bio-agents have been attributed to various mechanisms exerted such as antibiosis, lysis, mycoparasitism, competition, production of volatile/non-volatile compounds, *etc*. In the present study, different species of *Trichoderma* and *Pseudomonas* were found as an efficient antagonist against *Phoma* infecting pigeonpea.

Efficacy of systemic, non-systemic and combi-fungicides on the mycelial growth of *Phoma* sp. Even though plant disease management starts with the basic principles of management practices like exclusion and eradication, the chemical method would be a rapid method for the management of disease in crops. Disease management by means of chemical usage is the most predominant practice. It has become inevitable to go for the management of *Phoma* leaf spot through fungicides. The fungicides, their concentration and mode of action were considered as factors for inhibiting the growth of the fungus. To identify a suitable fungicide and its effective concentration, non-systemic, systemic and combi-fungicides were evaluated for their efficacy against *Phoma* sp., under laboratory conditions by following poison food technique and the results are discussed below.

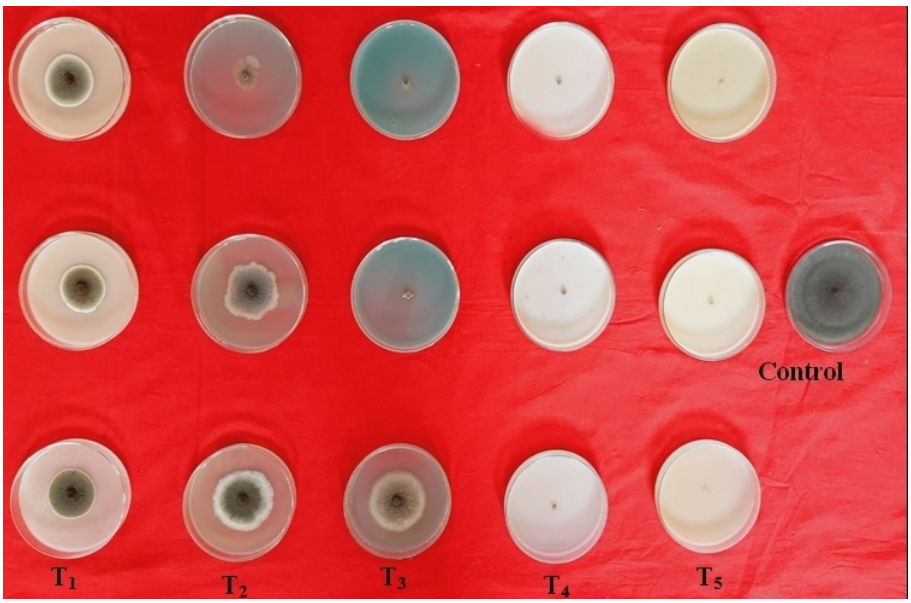
Efficacy of non-systemic fungicides on the mycelial growth of *Phoma* sp. The efficacy of five contact fungicides was tested against *Phoma* sp., by poison food technique (Table 5 and Plate 2).

Table 5: Efficacy of non-systemic fungicides on the mycelial growth of *Phoma* sp.

Sr. No.	Fungicides	Per cent inhibition*			
	Concentration (%)	0.10	0.20	0.30	Mean
1.	Copper hydroxide 53.8 W/W	47.04 (43.30)^{h}	91.85 (73.42)^{c}	92.96 (74.63)^{b}	77.28 (61.53)^{b}
2.	Copper oxychloride 50WP	48.15 (43.94)^{h}	56.3 (48.62)^{f}	82.96 (65.62)^{b}	62.47 (52.22)^{c}
3.	Chlorothalonil 75WP	52.96 (46.70)^{g}	57.04 (49.05)^{f}	58.52 (49.90)^{e}	56.17 (48.54)^{c}
4.	Propineb 70 WP	100 (90.00)^{a}	100 (90.00)^{a}	100 (90.00)^{a}	100 (90.00)^{a}
5.	Mancozeb 75 WP	100 (90.00)^{a}	100 (90.00)^{a}	100 (90.00)^{a}	100 (90.00)^{a}
Mean		62.79 (52.41)^{a}	70.22 (56.93)^{a}	74.03 (59.36)^{a}	

*Mean of three replications and values in the column followed by common letters are non-significant at p = 0.01 as per DMRT (Duncan, 1955)

Figures in parenthesis are arc sine values



T_1: Chlorothalonil 75 % WP; T_2: Copper oxychloride 50 %WP; T_3: Copper hydroxide 53.8 W/W; T_4: Propineb 70 % WP; T_5: Mancozeb 75 % WP.

Plate 2. Efficacy of non-systemic fungicides on the mycelial growth of *Phoma* sp.

Among contact fungicides tested at different concentrations, mancozeb and propineb recorded 100 per cent mean mycelial inhibition, which is significantly superior followed by copper hydroxide (77.28 %) and the mean minimum inhibition was recorded in chlorothalonil (56.17 %). Among the different concentrations, 0.30 per cent showed maximum mycelial inhibition (74.03 %) followed by 0.20 (70.22 %) which was statistically on par with 0.30 per cent. The interaction between fungicides and concentration tested revealed that the mancozeb and propineb were significantly superior over others at all the tested concentrations followed by copper hydroxide (92.96 %) at 0.30 per cent and the minimum inhibition was observed by copper hydroxide (47.04 %) at 0.10 per cent concentration followed copper oxychloride (48.15 %) at 0.10 per cent concentration.

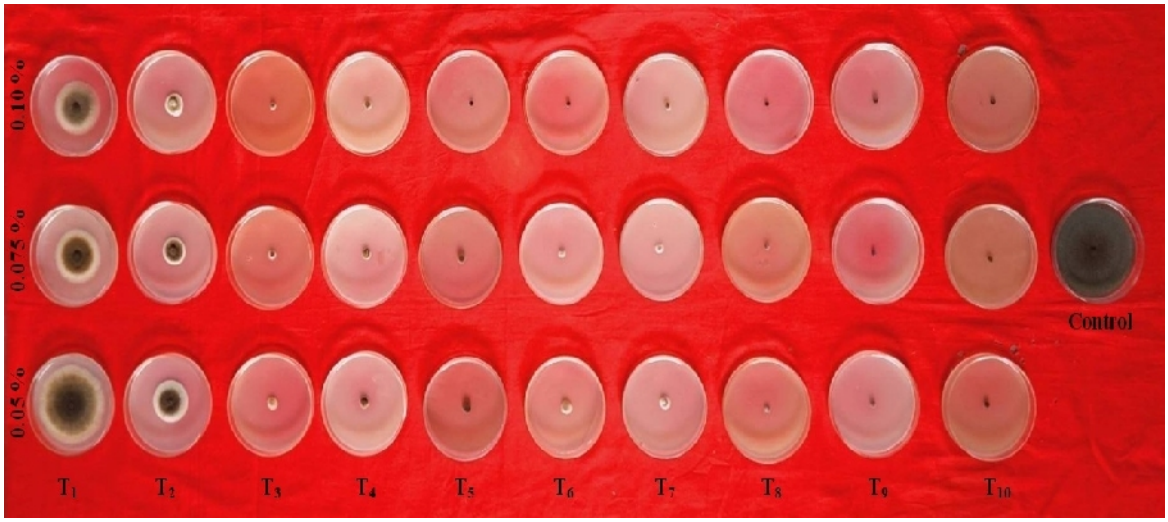
Efficacy of systemic fungicides on the mycelial growth of *Phoma* sp. The efficacy of 10 systemic fungicides was tested against *Phoma* sp, by poison food technique (Table 6 and Plate 3). Among the systemic fungicides tested, hexaconazole and propiconazole were significantly superior over other fungicides in inhibiting mycelial growth followed by tebuconazole (95.43 %) and the mean minimum inhibition was recorded in azoxystrobin (39.63 %) followed by kitazin (75.43 %). Among the different concentrations, 0.10 per cent showed significantly superior mean mycelial inhibition (78.23 %) followed by 0.075 (72.87 %) and 0.05 (69.03 %) per cent concentration which was statistically on par with 0.10 per cent. The interaction between fungicides and concentrations showed that the hexaconazole and propiconazole were inhibited 100 per cent at all the tested concentrations and myclobutanil and tebuconazole showed 100 per cent inhibition at 0.10 per cent concentration, followed by difenconazole (95.56 %) at 0.10 per cent.

Efficacy of combi-fungicides on the mycelial growth of *Phoma* sp. The efficacy of nine combi fungicides was tested against colony diameter of *Phoma* sp., by poison food technique (Table 7 and Plate 4). Among the different combi fungicides tested, except hexaconazole 4% + zineb 68% and metiram 55% + pyraclostrobin 5%, all other fungicides were significantly superior and the minimum inhibition was recorded in metiram 55% + pyraclostrobin 5% (90.86 %).

Table 6: Efficacy of systemic fungicides on the mycelial growth of *Phoma* sp.

Sr. No.	Fungicides	Per cent inhibition*			
	Concentration (%)	0.05	0.075	0.10	Mean
1.	Azoxystrobin 23% SC	17.41(24.66)^{h}	49.26(44.58)^{g}	52.22(46.27)^{g}	39.63(39.01)^{d}
2.	Carbendazim 50 WP	89.63(71.22)^{cd}	91.85(73.42)^{c}	92.96(74.63)^{bc}	91.48(73.03)^{b}
3.	Difenconazole 25 EC	88.89(70.54)^{cd}	92.96(74.63)^{bc}	95.56(80.02)^{b}	92.47(74.07)^{b}
4.	Hexaconazole 5 EC	100(90.00)^{a}	100(90.00)^{a}	100(90.00)^{a}	100(90.00)^{a}
5.	Myclobutanil 10 WP	90.74(72.29)^{cd}	91.85(73.42)^{c}	100(90.00)^{a}	94.20(76.06)^{b}
6.	Tricyclozole 75 WP	90.37(71.93)^{cd}	91.85(73.42)^{c}	95.56(80.02)^{b}	92.59(74.21)^{b}
7.	Propiconazole 25 EC	100(90.00)^{a}	100(90.00)^{a}	100(90.00)^{a}	100(90.00)^{a}
8.	Tebuconazole 250 EC	92.96(74.63)^{bc}	93.33(75.04)^{bc}	100(90.00)^{a}	95.43(77.66)^{b}
9.	Kitazin 48% EC	65.19(53.84)^{f}	76.67(61.12)^{e}	84.44(66.78)^{d}	75.43(60.29)^{c}
10.	Thiophanate methyl	89.63(71.22)^{cd}	91.48(73.04)^{c}	92.96(74.63)^{bc}	91.36(72.90)^{b}
Mean		69.03(56.19)^{a}	72.87(58.61)^{a}	78.23(62.19)^{a}	

*Mean of three replications and values in the column followed by common letters are non-significant at p = 0.01 as per DMRT (Duncan, 1955)



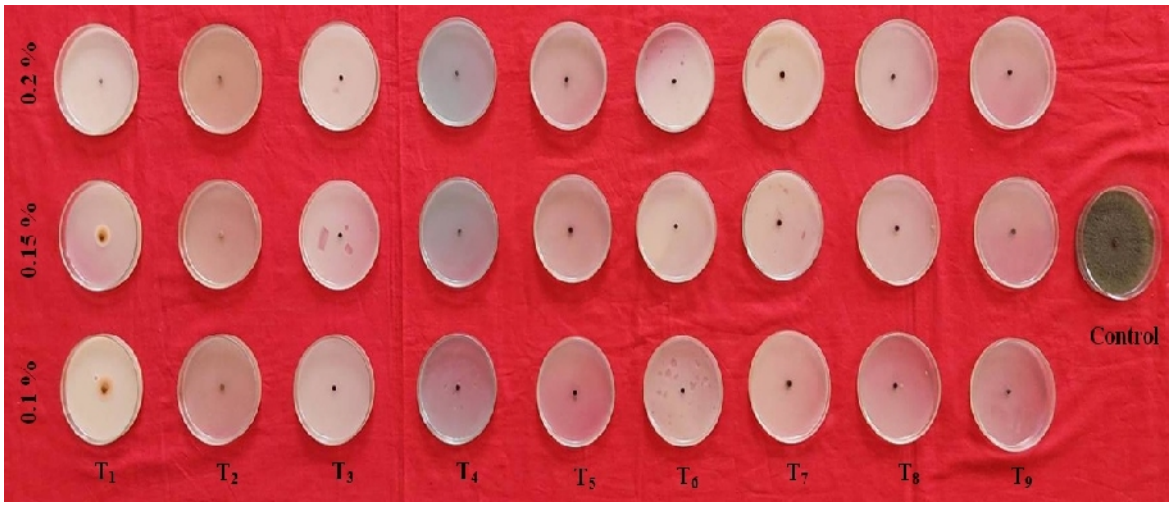
T_1: Azoxystrobin 23% SC; T_2: Kitazin 48 % EC; T_3: Tricyclazole 75 % WP; T_4: Thiophanate methyl 70 % WP; T_5: Myclobutanil 10 % WP; T_6: Difenconazole 25 % EC; T_7: Carbendazim 50 % WP; T_8: Tebuconazole 25.9 % EC; T_9: Propiconazole 25 % EC; T_{10}: Hexaconazole 5 % EC.

Plate 3. Efficacy of systemic fungicides on the mycelial growth of *Phoma* sp.

Table 7: Efficacy of combi fungicides on the mycelial growth of *Phoma* sp.

Sr. No.	Fungicides	Per cent inhibition*			
	Concentration (%)	**0.10**	**0.15**	**0.20**	**Mean**
1.	Azaoxystrobin 11 % + Tebuconozole 18.3%	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
2.	Carbendazim 12 % + Mancozeb 63 % WP	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
3.	Fluopyram17.7 % + Tebuconazole 17.7 % w/w SC	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
4.	Hexaconazole 4 % + Zineb 68 % WP	91.85(73.42)[c]	100(90.00)[b]	100(90.00)[a]	97.28(82.46)[a]
5.	Trifloxystrobin 25 % + Tebuconazole 50 %	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
6.	Pyraclostrobin 133g/I + Epoxyconazole 50g/l w/v (SE)	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
7.	Metiram 55% + Pyraclostrobin 5%	84.07(66.48)[e]	88.52(70.20)[d]	100(90.00)[a]	90.86(72.41)[b]
8.	Tricyclozole-45% +Hexaconazole-10% WG	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
9.	Iprovalicarb 5.5% + Propineb 61.25% WP	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]	100(90.00)[a]
Mean		97.33(80.60)[a]	98.72(83.50)[a]	100(90.00)[a]	

*Mean of three replications and values in the column followed by common letters are non-significant at p = 0.01 as per DMRT (Duncan, 1955)
Figures in parenthesis are arc sine values



T_1: Metiram 55% + Pyraclostrobin 5% WG; T_2: Tricyclazole 45% + Hexaconazole 10% WG; T_3: Trifloxystrobin 25 % + Tebuconazole 50 % WG; T_4: Carbendazim 12 % + Mancozeb 63 % WP; T_5: Iprovalicarb 5.5% + Propineb 61.25% WP; T_6: Fluopyram 17.7 % + Tebuconazole 17.7 % w/w SC; T_7: Hexaconazole 4 % + Zineb 68 % WP; T_8: Azoxystrobin 11 % + Tebuconazole 18.3 % EC; T_9: Pyraclostrobin 13.3 % + Epoxyconazole 50 % SE.

Plate 4. Efficacy of combi-fungicides on the mycelial growth of *Phoma* sp.

Among different concentrations, 0.20 per cent showed mean maximum mycelial inhibition (100 %) followed by 0.15 (98.72 %) and 0.10 (97.33 %) per cent concentration which was statistically on par with 0.20 per cent. The interaction between fungicides and concentration showed that except hexaconazole 4% + zineb 68% at 0.10 per cent concentration all other fungicides were significantly superior at all tested concentrations.

In vitro evaluation of fungicides provides useful preliminary information regarding its efficacy against a pathogen within the shortest period of time and therefore serves as a guide for further testing. Non-systemic fungicides directly have contact with the diseased part of the plant and they are mostly multi-site inhibitors and are not absorbed by the plant and only stick to plant surfaces. These fungicides provide a barrier and that prevents the fungus from entering and damaging the plant tissues. Systemic fungicides translocate to plant parts and they are not covered by the application and protect the plant from inside. They are effective in smaller amounts and these fungicides are less prone to rain wash or photodegradation. The combi-fungicides are the combination of two fungicides with low risk and having multi-site action on the pathogen which will contribute to the avoidance of resistance development. The different fungicides in the mixture must be active against the target fungi so that subgroups that are resistant to one mode of action are controlled by the fungicide partner with a different mode of action.

The effectiveness of the triazoles fungicides in a combi form may be attributed to their interference with the biosynthesis of fungal sterols and inhibits biosynthesis of ergosterol. In many fungi, ergosterol is essential to the structure of the cell wall and its absence causes irreparable damage to the cell wall leading to the death of the fungal cell. A similar study was reported for the effectiveness of triazoles, which inhibit the biosynthesis pathway in fungi.

The present findings are in accordance with the reports made by previous researchers. Smith and Cole (1991) revealed that chlorothalonil and fenpropimorph were the most effective for inhibiting spore germination and colony diameter of *P. clematidina* due to complex formation, partitioning, or steric hindrance at the site of action, dichlofluanid, captafol, prochloraz and propiconazole were useful for alternative sprays. Cerkauskas and McGarvey (1988) revealed that fungicides such as chlorothalonil, maneb, mancozeb, fixed copper and iprodione were effective in inhibiting conidial germination of *P. complanata* under *in vitro*.

Pethybridge and Hay (2001) found that the prochloraz, tebuconazole, difenoconazole and cyproconazole produced the most significant reduction in colony diameter of *Phoma ligulicola* due to emethylation inhibition, which acts by inhibiting the C-14 demethylation of 24-methylene dihydrolanosterol, a precursor of fungal sterol biosynthesis. Azoxystrobin, a QoI inhibitor, was especially effective at reducing the germination of conidia at low concentrations *in vitro* and mancozeb and chlorothalonil were also effective in reducing the colony growth.

Saju *et al*. (2011) revealed that carbendazim 50WP was significantly effective against *Phoma* leaf spot of large cardamom at all concentrations (0.05% - 0.15%) tested followed by carbendazim + mancozeb 75WP (0.1% - 0.4%). Hembram and Baskey (2015) revealed that carbendazim and mancozeb have great potentiality in comparison to copper oxychloride and zineb in the management of *Phoma* leaf spot disease of betel vine.

CONCLUSION

From the present study it was concluded that, Among the bio-agents tested, *T. hamatum* (NAIMCC-F-04088) was found to be more effective and statistically significant over other bio-control agents in inhibiting the fungu. Among all the tested non-systemic fungicides, systemic and combi fungicides, Mancozeb 75 % WP and Propineb 70 % WP, Hexaconazole 5 % EC and Propiconazole 25 % EC and all the tested combi fungicides were effective with 100 per cent inhibition at all the concentrations tested, respectively.

FUTURE SCOPE

(i) Surveillance of the pathogen has to be undertaken to observe the rhythmic changes in disease.

(ii) Field management of *Phoma* sp., infecting pigeonpea through integrated approach.

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