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Research Article

Efficacy of organic formulations and biocontrol agents against leaf spots of strawberry

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ABSTRACT: Strawberries are important delicious fruit famed for their sweetness, distinct flavour and colour. The crop is grown throughout tropical conditions in Kerala and is infested by a number of leaf spot diseases. Four leaf diseases caused by *Alternaria, Phoma* and two by *Colletotrichum* were serious during the study. As frequent use of chemical fungicides has serious impacts, the efficacy of organic formulations viz., neem oil, calphomil, panchagavya and baking powder + vegetable oil and bio-agents like *Trichoderma asperellum* and *P. fluorescens* were evaluated against the pathogens. *In vitro* evaluation showed that calphomil was effective in reducing mycelial growth up to 60 per cent. The other three formulations were least effective, reducing the growth only by 16 to 30 per cent. Bioagents when evaluated by dual culture exhibited a good control. *Trichoderma asperellum* overgrew the pathogen showing 100 per cent inhibition and *P. fluorescens* was 70.55 and 66.57 per cent effective against two *C. gloeosporiodes* pathogens and *Alternaria* and *Phoma* were restricted to 56.67 and 45.61 per cent. This work aims to find out the best organic practices to be followed in managing leaf diseases in strawberries.

KEYWORDS: *Alternaria*, bioagents, *Colletotrichum*, *Phoma*, strawberry

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INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.), is a significant and highly valuable fruit crop. China is the largest producer of strawberries accounting for 3.8 million tonnes being produced every year followed by the United States which holds only half of the production by China. In India, Maharashtra holds 85 per cent of the total production of our country producing many leading varieties. Idukki and Wayanad districts in Kerala are becoming strawberry hubs. But, strawberry production is rigorously hampered by diseases among which fungal diseases are the most. Leaf spots caused by Colletotrichum (Denoyes & Baudry, 1995, Freeman *et al.* 2001, Han *et al.,* 2016; Wang *et al.* 2022) Alternaria (Nishikawa *et al*., 2019, Fu *et al*., 2020; Sun *et al*., 2023) Phomopsis (Turechek, 1999, Milicevic *et al.* 2006, Ertek *et al.* 2018; Abd-El-Kareem *et al.* 2019) has seriously hampered strawberry production.

Synthetic fungicides like carbendazim, triazole and strobilurins are in great use in agriculture. On an average these fungicides cost up to Rs. 400 to 800 per litre and application costs range up to Rs. 700 to 1000 per acre. When compared to organic products, neem oil, calphomil and biocontrol agents 250-550, 350-400 and 250-300 Rs per hectare. Organic compounds enhance the number of beneficial soil microbes, enhance soil structure, help in more water retention and avoid chemical buildup that harms beneficial organisms and reduces soil fertility over time. Moreover, organic treatments stimulate resistance in plants and reduce their dependency on chemicals. Organic treatments play a crucial role in preventing water pollution, decreasing carbon footprints, and fostering biodiversity, establishing them as a foundation for sustainable agriculture.

Our present study envisages in finding an organic alternative against chemical fungicides in managing leaf spot diseases of strawberry using biocontrol agents and organic formulations.

MATERIALS AND METHODS

The study was carried out by isolating the pathogens from collected samples and bringing them into pure culture with subsequent re-inoculation every 15 days to maintain virulence. Four pathogens were used for the study. Two isolates were identified as *Colletotrichum gloeosporiodes* and named Cg1 and Cg2. The second and third isolates were identified as *Alternaria alternata* and *Phoma exigua*.

This work was carried out at the Plant Pathology Laboratory, College of Agriculture, Vellanikkara, Thrissur, Kerala. The organic formulations were purchased from local shops and bio-agents were used which was maintained by the Department.

In vitro evaluation of organic formulation

Four organic formulations and two bioagents were evaluated for their effectiveness against pathogens in sterile circumstances using the food poisoning method (Zentmyer, 1955). The trial was conducted in a Completely Randomised Design (CRD) replicated three times. Control media does not contain any organic formulation. Following this, the plates were incubated at ambient temperature (26–1°C). To prevent contamination, organic formulations were pre-treated for one hour under UV light before being mixed with PDA medium. To guarantee optimal neem oil-medium mixing, a non-ionic surfactant called Tween 20 was added at a rate of 0.2% to the PDA and neem oil mixture (Neves *et al*., 2001). After mixing the medium with the necessary amount of each formulation, the mixture was plated. Until the cultures on the control plates reached full growth, daily observations were made documenting the fungal pathogen's growth rate. The per cent mycelial growth inhibition was computed for each treatment using the formula proposed by Vincent (1947).

$$\text{Per cent inhibition of growth} = \frac{C-T}{C} \times 100$$

where,

C= Growth of fungus in control (mm)

T= Growth of fungus in treatment (mm)

In vitro evaluation of bioagents

Reference cultures of bacterial (*Pseudomonas fluorescens*) and fungal (*Trichoderma asperellum*) biocontrol agents from Kerala Agricultural University (KAU) were sub-cultured and maintained regularly and were evaluated against the pathogens by dual culture approach (Dennis & Webstar, 1971). Control plates of each of the pathogen and bio-agents were maintained separately. Culture bits of *T. asperellum* and test pathogen were placed 2cm away from the sides of Petri dishes at opposite ends and incubated. The bacterial biocontrol agent was streaked on both sides similarly 2cm away from the periphery. The per cent inhibition of mycelial growth in each treatment was calculated using the formula suggested by Vincent (1947).

RESULTS

In the case of Cg1, Calphomil at different concentrations recorded a zero per cent inhibition (Figure 1a). Neem oil, baking powder + vegetable oil and panchagavya at all concentrations could inhibit the growth of the pathogen below 30 per cent only (Figure 2a), (Figure 4a) and (Figure 3a). Leaf spot pathogen Cg2 recorded 56.67, 69.11 and 75.33 per cent inhibition with Calphomil at 0.2, 0.25 and 0.3 per cent (Figure 1b). Neem oil showed an inhibition of less than 20.11 per cent at all concentrations (Figure 2b). Panchagavya and baking powder + vegetable oil showed below 30 per cent inhibition at various concentrations tested (Figure 3b) and (Figure 4b). Calphomil showed 58.33, 66.11 and 67.77 per cent efficiency against *A. alternata* at 0.2, 0.25 and 0.3 per cent, respectively (Figure 1c). Neem oil exhibited an inhibition of below 51 per cent efficacy against the pathogen (Figure 2c). Panchagavya and bakinThe antifungal activity of neem g powder + vegetable oil mixture showed comparatively less inhibition of below 43 and 31 per cent (Figure 3c) and (Figure 4c). *In vitro* evaluation of neem oil against *P. exigua* recorded below 10 percent inhibition (Figure 2d). However, it was noticed that Calphomil at various concentrations recorded above 40 per cent inhibition (Figure 1d). Moreover, baking powder + vegetable oil mixture and panchagavya could restrict the growth of the pathogen below 25.4 per cent only (Figures 3d and 4d) (Table 1).

The isolates of *Colletotrichum gloeosporioides* (Cg1 and Cg2) were evaluated against *T. asperellum* by dual culture assay and it was noticed that *T. asperellum* exhibited better control by overgrowing on the pathogen and restricting its growth by cent per cent (Figure 5a, b). However, the bacterial antagonist, *P. fluorescens* could restrict the mycelial growth of the pathogen ranging from 65-70 per cent only (Figure 6a, b). Response of *Trichoderma asperellum* against the fungal pathogen, *A. alternata* showed better control by the overgrowth mechanism of inhibition. *T. asperellum*

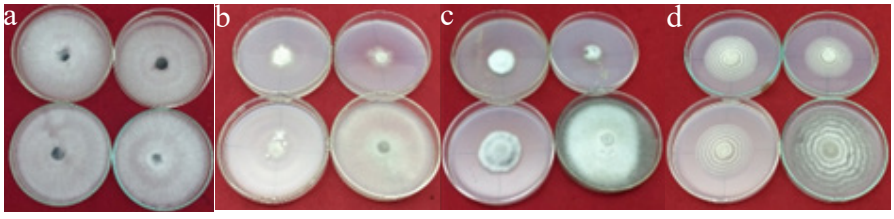


Figure 1. Effect of Calphomil against leaf spot pathogens of strawberry. **(a).** *C. gloeosporioides* 1; **(b).** *C. gloeosporioides* 2; **(c).** *A. alternata;* **(d).** *P. exigua.*

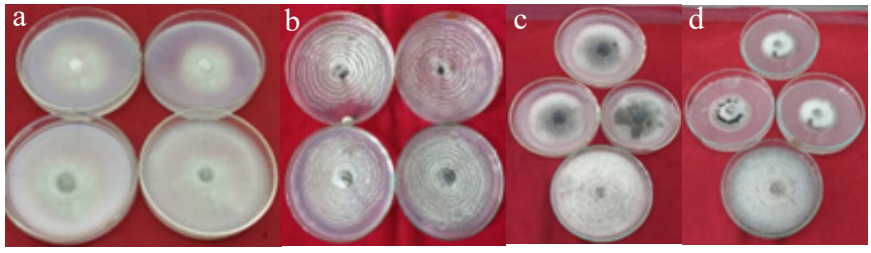


Figure 2. Effect of neem oil against leaf spot pathogens of strawberry. **(a).** *C. gloeosporioides* 1; **(b).** *C. gloeosporioides* 2; **(c).** *A. alternata;* **(d).** *P. exigua.*

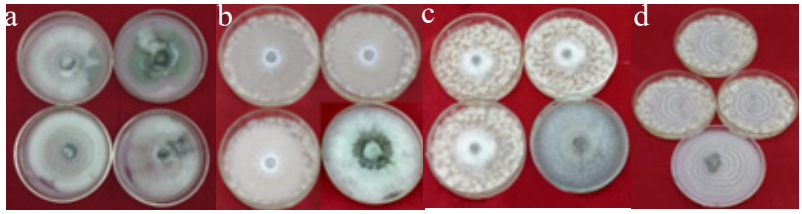


Figure 3. Effect of panchagavya against leaf spot pathogens of strawberry. **(a).** *C. gloeosporioides* 1; **(b).** *C. gloeosporioides* 2; **(c).** *A. alternata;* **(d).** *P. exigua.*

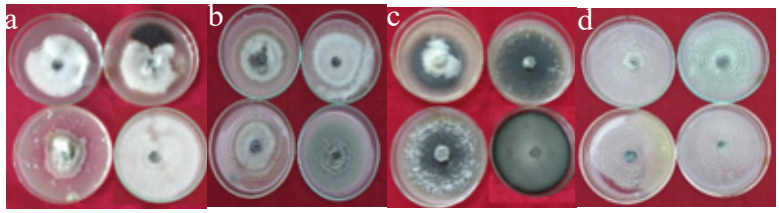


Figure 4. Effect of Baking powder + vegetable oil against leaf spot pathogens of strawberry. **(a).** *C. gloeosporioides* 1; **(b).** *C. gloeosporioides* 2; **(c).** *A. alternata;* **(d).** *P. exigua.*

Table 1. Percent inhibition of leaf spots of strawberries against various organic formulations

S. No.	Formulation	Conc (%)	Per cent inhibition over control			
			***Colletotrichum gloeosporioides* (Cg1)**	***Colletotrichum gloeosporioides* (Cg2)**	***Alternaria alternata***	***Phoma exigua***
1	Calphomil	0.2	0	56.67(7.53)	58.33(7.64)^{c}	44.44(6.66)^{c}
		0.25	0	69.11(8.32)	66.11(8.13)^{b}	47.44(6.88)^{b}
		0.3	0	75.33(8.66)	67.77(8.22)^{a}	53.88(7.3)^{a}
2	Neem oil	0.15	16.67(4.15)^{g}	16.67(4.09)	48.80(5.36)^{h}	5.55(2.3)^{k}
		0.2	18.16(4.33)^{f}	18.48(4.31)	49.30(5.42)^{g}	6.67(2.6)^{j}
		0.25	20.1(4.5)^{e}	20.0(4.4)	51.00(5.59)^{e}	9.93(3.14)^{i}
3	Panchagavya	2.0	23.67(4.8)^{d}	22.22(4.7)	38.50(5.33)^{hi}	21.30(5.6)^{f}
		3.0	26.33(5.2)^{ab}	23.33(4.83)	40.10(5.49)^{f}	23.90(5.8)^{e}
		4.0	27.10(5.26)^{a}	25.10(5.02)	42.40(5.72)^{d}	25.40(5.98)^{d}
4	Baking powder + Vegetable oil	0.2	20.10(4.55)^{e}	26.60(5.16)	27.20(5.22)^{j}	21.0(4.59)^{h}
		0.25	24.20(4.97)^{c}	27.90(5.26)	28.30(5.32)^{i}	26.10(5.12)^{g}
		0.3	26.11(5.16)^{b}	30.00(5.48)	30.20(5.50)^{f}	33.80(5.8)^{e}
	CD (0.05)		0.088	0.019	0.029	0.021

*Mean of three replications; Values in the parenthesis are arc-sine transformed; Treatments with the same alphabets in the superscript, do not differ significantly.

Table 2. Percent inhibition of fungal pathogens by *T. asperellum*

S. No.	Pathogen	Per cent inhibition of pathogen	
		T. asperellum	***P. fluorescens***
1	*Colletotrichum gloeosporioides* (LSI-1)	100	70.55
2	*Colletotrichum gloeosporioides* (LSM-1)	100	66.67
3	*Alternaria alternata* (LSI-2)	100	56.67
4	*Phoma exigua* (LBI-1)	100	45.61

*Mean of three replications

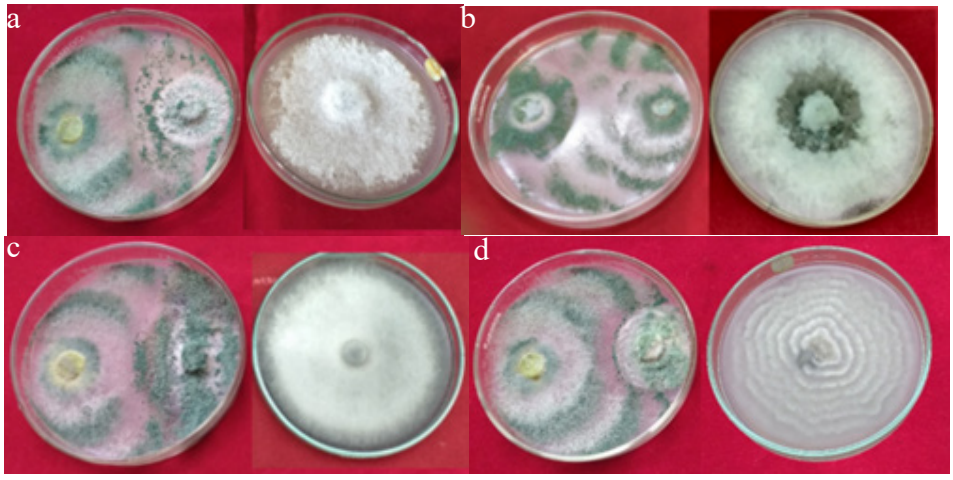


Figure 5. Effect of *T. asperellum* against leaf spot pathogens of strawberry. **(a).** *C. gloeosporioides* 1; **(b).** *C. gloeosporioides* 2; **(c).** *A. alternata;* **(d).** *P. exigua.*

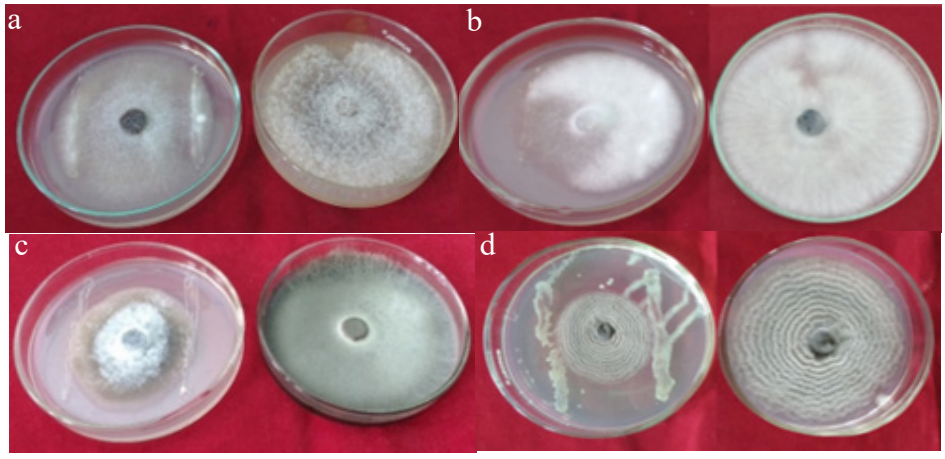


Figure 6. Effect of *P. fluorescens* against leaf spot pathogens of strawberry. **(a).** *C. gloeosporioides* 1; **(b).** *C. gloeosporioides* 2; **(c).** *A. alternata;* **(d).** *P. exigua.*

inhibited the pathogen by 100 per cent (Figure 5c). Contrary to this, the bacterial bioagent could inhibit the pathogen only by 56.67 per cent (Figure 6c). *Trichoderma asperellum* and *Pseudomonas fluorescens* when tested against the fungal pathogen, *P. exigua,* it was noticed that *T. asperellum* was a better antagonist restricting the mycelial growth by 100 per cent where *T. asperellum* overgrew the pathogen (Figure 5d). However, the pathogen was inhibited by *P. fluorescens* only by 45.61 per cent (Figure 6d) (Table 2).

DISCUSSION

Various organic preparations and formulations like Calphomil, panchagavya, neem oil and baking powder + vegetable oil mixture were evaluated for their efficacy

against the isolated pathogens. Calphomil, a biofungicide, is found to eradicate fungal diseases and is manufactured from the actinomycetes strains *viz*., *Streptomyces griseus* CBCC 2786 and *Streptomyces violaceus* CBCC 2788. Likewise, several researchers worldwide have elucidated the antifungal activity of baking soda and vegetable oil in controlling plant pathogenic fungi which are often used as a preventive measure and not as a curative one (Williams & Williams, 1993; Elmer & Farandino, 1997; Anon, 1998) where the fungicidal effect of bicarbonate might be due to the bicarbonate compounds of salts present in it (Hang & Woodams, 2003). Moreover, Govindachari *et al.* (1998) proved the antifungal activity of neem oil which is due to the presence of triterpenoids. Jarvis *et al.* (1999) reported the presence of limonoids in azadirachtin and various other compounds like salanin, nimbin etc. Similarly, according to Vallimayil and Shekar (2012), panchagavya acts as a growth promoter and immunity booster and also restricts the growth of many common fungal diseases. Hence an *in vitro* study was carried out to evaluate the aforesaid formulations against the isolated fungal pathogens.

Leaf spot caused by *Colletotrichum gloeosporioides* when treated against Calphomil at all these concentrations showed less than 21 per cent inhibition over control. However, neem oil could restrict the mycelial growth of Cg1 and Cg2 only up to 25 per cent and baking powder + vegetable oil as well as panchagavya exhibited an inhibition of up to 35 per cent. Similarly, Calphomil evaluated against LSI-1 and LSM-1 at different concentrations recorded zero per cent and up to 75 per cent inhibition, whereas, neem oil and baking powder + vegetable oil mixture and panchagavya inhibited the pathogen up to 30 per cent. Deviating from the above observations, Muthukumar and Ranganathan (2012) observed a cent per cent control at 0.1 per cent of neem oil against *Colletotrichum musae* in banana. The antifungal activity of neem oil was also described by Sagoua *et al*. (2008) in banana infected with *Colletotrichum* sp. Ashlesha and Paul (2014) observed 89.47 per cent inhibition with panchagavya against *Colletotrichum capsici* in chilli. The ineffectiveness of Calphomil may be attributed to the fact that the biofungicide is reported to be effective against the fungi belonging to Oomycetes like *Pythium*, *Phytophthora* and downy mildew. Contrary to the present findings, Anon (1998), reported that the bicarbonate products are found effective against many fungal diseases which includes the anthracnose caused by *Colletotrichum* sp.

Data revealed that Calphomil showed 55 to 70 per cent efficiency against *Alternaria alternata,* whereas, neem oil exhibited only 51 per cent efficacy over the pathogen. Conversely, Chethana *et al*. (2013) reviewed 76.94 per cent control over *Alternaria porri* in onion with neem oil. In the present study, panchagavya and baking powder + vegetable oil mixture showed comparatively less inhibition ranging up to 43 and 30.20 per cent. According to Joseph and Sankarganesh (2011) and Sahu and Verma (2015) a higher antifungal activity of 53.7 per cent reduction over control was noticed with panchagavya against *Alternaria helianthi* and *Alternaria sesame* in sesamum. The above findings are not validated with Abd-El-Kareem and Abd-El-Latif (2012) and Zaker (2014) where they observed cent per cent efficacy of bicarbonate with *Alternaria alternata* and *Alternaria solani* of tomato under *in vitro* conditions. However, Fagundes *et al*. (2013) reported that inorganic salts of carbonate and bicarbonate were not effective against *Alternaria* black rot of cherry tomatoes caused by *Alternaria alternata* which is in agreement with the present study.

In the present study, *Phoma exigua* when subjected to *in vitro* testing with different formulations revealed only nine per cent efficiency when neem oil was used, which is in congruence with the findings of Somda *et al*. (2007) in *Phoma sorghina* in lemongrass. More than 40 per cent control was recorded with Calphomil at various concentrations, while, panchagavya restricted the mycelial growth only up to 35 per cent. Baking powder + vegetable oil mixture was also found to the less effective against the pathogen which is found contradictory to the findings of Anon (1998) where they observed the effectiveness of potassium bicarbonate against *Phoma* sp.

Trichoderma asperellum was found cent per cent effective against *Alternaria alternata* and 56.67 per cent with *Pseudomonas fluorescens*. Chethana *et al*. (2013) and Roopa *et al*. (2014) recorded up to 71.53 to 79.5 per cent inhibition with *T. harzianum* and *T. viride* and 36.22 per cent with *P. fluorescens a*gainst *Alternaria* sp. of tomato and onion. Tapwal *et al*. (2015) recorded up to 34 per cent control over *Alternaria alternata* with *T. viride* and *T. harzianum*. Mishra and Gupta (2012) observed *P. fluorescens* recording 19.20 per cent control over *Alternaria porri* in onion. Ngoc *et al*. (2013) tested several isolates of *Trichoderma* with the pathogen recording maximum efficacy over *Alternaria solani*. Rahman *et al*. (2015) noticed maximum control with *T. viride* and *T. harzianum* over *Alternaria porri* in onion. Taware *et al*. (2014) reported the efficacy of *Trichoderma viride* and *Pseudomonas fluorescens* against *Alternaria carthami* in safflower.

While studying the antagonistic effect of *Trichoderma asperellum* and *Pseudomonas fluorescens* tested against *Phoma exigua*, the former recorded 100 per cent and the latter 45.61 per cent control over the pathogen. Different from the results of the *in vitro* experiment, Parizi *et al.* (2012) and Mokhtar and Dehimat (2015) reported 71.16 and 39.58

per cent inhibition with *Trichoderma viride* against *Phoma exigua* in rosselle and tomato, respectively.

Two reference cultures from KAU were evaluated against the isolated pathogens. It was observed that *Trichoderma asperellum* when evaluated against Cg1 and Cg2 pathogen incited by *Colletotrichum gloeosporioides*, the isolates exhibited an overgrowth mechanism of antagonism showing cent per cent inhibition. However, *Pseudomonas fluorescens* could inhibit the pathogen only by 67.7 to 70 per cent. Conversely, Tasiwal *et al*. (2009), Ramani *et al*. (2015) and Tapwal *et al*. (2015) pointed out only less than 61 per cent control with *Trichoderma viride* and 42.87 per cent using *Pseudomonas fluorescens* with *Colletotrichum gloeosporioides* infecting papaya and banana, whereas, Patil *et al*. (2009) recorded 70.42 per cent and 20.72 per cent inhibition of *Colletotrichum gloeosporioides* with *Trichoderma viride* and *P. fluorescens* in long pepper. In congruence with the present results, Dev *et al*. (2016) observed 100 per cent efficacy with several isolates of *Trichoderma viride* and 47.6 per cent with *Pseudomonas fluorescens* in pomegranate infected with *Colletotrichum gloeosporioides.*

CONCLUSION

The present study revealed that calphomil and biocontrol agent, *T. asperellum* are efficient in inhibiting the mycelial growth of fungal pathogens causing leaf spots in strawberries. The use of these organic practices enhances plant health and helps to reduce the application of synthetic fungicides.

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REFERENCES

Abd-El-Kareem, F., and Abd-El-Latif, F. 2012. Using bicarbonates for controlling late blight disease of potato plants under field conditions. *Life Sci J,* **9**(4): 2080-2085.

Abd-El-Kareem, F., Elshahawy, I. E., and Abd-Elgawad, M. M. 2019. Management of strawberry leaf blight disease caused by *Phomopsis obscurans* using silicate salts under field conditions. *Bull Natl Res Cent,* **43**(1): 1-6. https://doi.org/10.1186/s42269-018-0041-2

Anon. 1998. Powdery mildew fungicide. The Grower.

Ashlesha, and Paul, Y. S. 2014. Antifungal Bioefficacy of Organic inputs against fungal pathogens of Bell Pepper. *Indian J Res*, **3**(6): 4-6.

Chethana, B. S., Ganeshan, G., Rao, A. S., and Bellishree, K. 2013. *In vitro* evaluation of plant extracts, bioagents and fungicides against *Alternaria* porri (Ellis) Cif. causing purple blotch disease of onion. *Pest Manag Hortic Ecosyst,* **18**(2): 194-198.

Dennis, C., and Webster, J. 1971. Antagonistic properties of species groups of Trichoderma: III. Hyphal interaction. *Trans British Mycol Soc,* **57**(3): 363-369. https://doi.org/10.1016/S0007-1536(71)80050-5

Denoyes, B., and Baudry, A. 1995. Species identification and pathogenicity study of French Colletotrichum strains isolated from strawberry using morphological and cultural characteristics. *Phytopathol*, **85**(1): 53-57. https://doi.org/10.1094/Phyto-85-53

Dev, D., Konda, S., Puneeth, M. E., Tanuj, N., Singh, P., and Narendrappa. T. 2016. *In vitro* evaluation of bioagents and botanicals against *Colletotrichum gloeosporioides* (Penz.) Penz & Sacc. causing anthracnose of Pomegranate. *Eco Env Cons*, **22**(3): 1229-1232.

Elmer, W. H., and Farandino, F. J. 1997. Managing powdery mildew of cucurbits. *The Natural Farmer Summer*, **26**.

Ertek, T. S., katircioğlu, Y. Z., and Maden, S. 2018. Fungal diseases of strawberry grown in Duzce province of Turkey. *Plant Protec Bull,* **58**(3): 123-129. https://doi.org/10.16955/bitkorb.449140

Fagundes, C., Perez-Gago, M. B., Monteiro, A. R., and Palou, L. 2013. Antifungal activity of food additives *in vitro* and as ingredients of hydroxypropyl methylcellulose-lipid edible coatings against *Botrytis cinerea* and *Alternaria alternata* on cherry tomato fruit. *Int J Food Microbiol*, **166**(3): 391-398. https://doi.org/10.1016/j.ijfoodmicro.2013.08.001 PMid:24026010

Freeman, S., Horowitz, S., and Sharon, A. 2001. Pathogenic and nonpathogenic lifestyles in *Colletotrichum acutatum* from strawberry and other plants. *Phytopathol*, **91**(10): 986-992. https://doi.org/10.1094/PHYTO.2001.91.10.986 PMid:18944126

Fu, Y., Zhang, X., Liu, S., Hu, K., and Wu, X. 2020. Characterization of Alternaria species associated with black spot of strawberry in Beijing municipality of China. *Canadian J Plant Pathol*, **42**(2):235-242. https://doi.org/10.1080/07060661.2019.1662851

Govindachari, T. R., Suresh, G., Gopalakrishnan, G., Banumathy, B., and Masilamani, S. 1998. Identification of antifungal compounds from the seed oil of

Azadirachta indica. *Phytoparasitica*, **26**(2): 109-116. https://doi.org/10.1007/BF02980677

Han, Y. C., Zeng, X. G., Xiang, F. Y., Ren, L., Chen, F. Y., and Gu, Y. C. 2016. Distribution and characteristics of *Colletotrichum* spp. associated with anthracnose of strawberry in Hubei, China. *Plant Dis*, **100**(5): 996-1006. https://doi.org/10.1094/PDIS-09-15-1016-RE PMid:30686149

Hang, Y. D., and Woodams, E. E. 2003. Control of *Fusarium oxysporum* by baking soda. *LWT-Food Sci Technol,* **36**(8): 803-805. https://doi.org/10.1016/S0023-6438(03)00095-1

Jarvis, A. P., Morgan, E. D., and Edwards, C. 1999. Rapid separation of triterpenoids from neem seed extracts. *Phytochemical Anal*, **10**(1): 39-43. https://doi.org/10.1002/(SICI)1099-1565(199901/02)10:1<39::AID-PCA426>3.0.CO;2-L

Joseph, B., and Sankarganesh, P. 2011. Antifungal efficacy of panchagavya. *Int J Pharm Tech Res*, **3**(1): 585-588.

Milicevic, T., Ivic, D., Cvjetkovic, B., and Duralija, B. 2006. Possibilities of strawberry integrated disease management in different cultivation system. *Agric Conspec Sci*, **71**(4): 129-134.

Mishra, R. K., and Gupta, R. P. 2012. *In vitro* evaluation of plant extracts, bio-agents and fungicides against Purple blotch and *Stemphylium* blight of onion. *J Med Plants Res*, **6**(48): 5840-5843.

Mokhtar, H., and Dehimat, L. 2015. *In vitro* and *in vivo* efficiency of *Trichoderma harzianum* against *Phoma* and *Glocladium* soft rot occurred on tomato fruits (*Lycopersicon esculentum*). *Int J Curr Microbiol App Sci*, **4**(8): 141-147.

Muthukumar, A., and Ranganatahan, P. 2012. *In vitro* and *in vivo* evaluation of plant oils against anthracnose pathogen *Colletotrichum musea* and *Botryodiplodia theobromae*. *Indian J Plant Prot*, **40**(2): 91-94.

Neves, P., Hirose, E., Tchujo, P. T., and Moino, A. 2001. Compatibility of entomopathogenic fungi with neonicotinoid insecticides. *Neotropical Entomol*, **30**: 263-268.

Ngoc, N. K., Narendrappa, T., and Chaudhary, M. 2013. Management of tomato early blight disease (*Alternaria solani* (Elis and Martin) Jones and Grout) through biological and chemical methods. *Mysore J Agric Sci*, **47**(2): 241-245.

Nishikawa, J., and Nakashima, C. 2019. Morphological and molecular characterization of the strawberry black leaf spot pathogen referred to as the strawberry pathotype of *Alternaria alternata*. *Mycosci*, **60**(1): 1-9. https://doi.org/10.1016/j.myc.2018.05.003

Parizi, T. E., Ansari, M., and Elaminejad, T. 2012. Evaluation of the potential of *Trichoderma viride* in the control of fungal pathogens of Roselle (*Hibiscus sabdariffa* L.) *in vitro*. *Microb Pathog*, **52**(4): 201-205. https://doi.org/10.1016/j.micpath.2012.01.001 PMid:22261114

Patil, C. U., Zape, A. S., and Wathore, S. D. 2009. Efficacy of fungicides and bioagents against *Colletotrichum gloeosporioides* causing blight in *Piper longum*. *Int J Plant Prot*, **2**(1): 63-66.

Rahman, S. M., Muniruzzaman, S. M., Nusrat, S., and Khair, A. 2015. *In vitro* evaluation of botanical extract, bioagents and fungicides against purple blotch diseases of bunch onion in Bangladesh. *Advan Zool Bot*, **3**: 179-183. https://doi.org/10.13189/azb.2015.030403

Ramani, V. N., Davara, D. K., Anadani, V. P., and Detroja, A. M. 2015. Evaluation of fungicides, botanicals and biocontrol agents against banana anthracnose disease under *in vitro* condition. *Int J Plant Prot*, **8**(2): 228-233. https://doi.org/10.15740/HAS/IJPP/8.2/228-233

Roopa, R. S., Yadahalli, K. B., and Kavyashree, M. C. 2014. Evaluation of natural plant extracts, antagonists and fungicides against early blight caused by *Alternaria solani in vitro*. *Bioscan*, **9**(3): 1309-1312.

Sagoua, W., Ducamp, M. N., and Loiseau, G., 2008. *In vitro* antifungal activity of Neem oil against banana pathogens. IV International Symposium on Tropical and Subtropical Fruits. https://doi.org/10.17660/ActaHortic.2013.975.21

Sahu, U., and Verma, K. P. 2015. *In vitro* efficacy of oil cakes and cow byproducts against leaf spot of Sesame. *Ann Plant Prot Sci,* **23**(2): 409-410.

Somda, I., Leth, V., and Sereme, P. 2007. Antifungal effect of *Cymbopogon citratus*, *Eucalyptus camaldulensis* and *Azadirachta indica* oil extracts on sorghum seed-borne fungi. *Asian J Plant Sci,* **6**(8): 1182-1187. https://doi.org/10.3923/ajps.2007.1182.1189

Sun, X., Wang, C., Gao, X., Wu, X., and Fu, Y. 2023. Characterization of alternaria species associated with black spot of strawberry in Dandong,

China. *Agronomy*, **13**(4): 1014-1021. https://doi.org/10.3390/agronomy13041014

Tapwal, A., Thakur, G., Chandra, S., Tyagi, A., 2015. *In-vitro* evaluation of *Trichoderma* species against seed borne pathogens. *Int J Pharma Biosci*, **1**(10): 14-19.

Tasiwal, V., Benagi, V. I., Hegde, Y. R., Kamanna, B. C., and Naik, K. R. 2009. *In vitro* evaluation of botanicals, bioagents and fungicides against anthracnose of papaya caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. *Karnataka J Agric Sci,* **22**(4): 803-806.

Taware, M. R., Gholve, V. M., and Dey, U. 2014. Bio-efficacy of fungicides, bioagents and plant extracts/ botanicals against *Alternaria carthami*, the causal agent of *Alternaria* blight of Safflower (*Carthamus tinctorius* L.). *African J Microbiol Res*, **8**(13): 1400-1412. https://doi.org/10.5897/AJMR2013.6335

Turechek II, W.W. 1999. Spatial characteristics of phomopsis leaf blight and leaf spot of strawberry: Pattern, association, and scale. The Ohio State University.

Vallimayil, J., and Sekar, R. 2012. Investigation on the effect of panchagavya on Southern Sunnhemp Mosaic Virus (SSMV) infected plant systems. *Glob J Environ Res*, **6**(2): 75-79.

Vincent, J. M. 1947. Distortion of fungal hyphae in the presence of certain inhibitors. *Nature*, 159(4051): 850. https://doi.org/10.1038/159850b0 PMid:20343980

Wang, C., Tang, Y., Qiao, N., Zhang, D., Chi, W., Liu, J., Pan, H., and Li, J. 2022. First report of Colletotrichum black leaf spot on strawberry caused by *Colletotrichum siamense* in China. *J Phytopathol*, 170(5): 279-281. https://doi.org/10.1111/jph.13080

Williams, G., and Williams, P. 1993. Baking soda and horticultural oil vs. powdery mildew. HortIdeas. May. p. 51.

Zaker, M. 2014. Antifungal evaluation of some inorganic salts against three phytopathogenic fungi. *Int J Agric Crop Sci*, **7**(14): Article 1352.

Zentmyer, G. A. 1955. Diseases of the avocado. California Avocado Society Yearbook.