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(Original Article)

Toxicological Evaluation of certain Fungicides on the Pathogens of Tomato Spot Disease Under Laboratory Conditions

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Abstract

Fungicides play an important role in controlling fungal diseases. Therefore, this study was conducted with the aim of evaluating the toxicity of fungicides on tomato spot disease pathogens under laboratory conditions. Nine chemical fungicides: Azoxystrobin + Difenoconazole, Copper Oxychloride, Chlorothalonil + Metalaxyl-M, Mancozeb, Dimethomorph + Pyraclostrobin, Tebuconazole, Azoxystrobin + Propiconazole, Chlorothalonil, and Metalaxyl-M were compared to one bio-fungicide Jojoba Oil on *Alternaria alternata*, *Curvularia pseudobrachyspora,* and *Curvularia hawaiiensis* using the poisoned food technique. Among the tested fungicides, tebuconazole demonstrated the highest potency *in vitro* inhibition (%) on *C. hawaiiensis* with an IC50 value of 0.8 ppm, while (Azoxystrobin + Difenoconazole) revealed the highest inhibition (%) on the growth of *A. alternata* and *C. pseudobrachyspora* with IC50 values of 0.83 and 1.88 ppm, respectively. The least inhibition was seen when copper oxychloride was used, with IC50 values of 4152.61, 3585.18, and 4755.95 for *A. alternata*, *C. pseudobrachyspora*, and *C. hawaiiensis*, respectively. A significant number of the tested fungicides are illustrated to be significantly effective in inhibiting the microorganisms that cause tomato spot disease, according to the overall results.

Keywords: *Alternaria alternata, Fungicides, Poisoned food technique.*

Introduction

Tomatoes are a good source of phytochemicals and nutrients such as lycopene, potassium, iron, folate, and vitamin C (Collins *et al.,* 2022)**.** In addition to lycopene and vitamin C, tomatoes also include phenolic substances such as flavonoids, hydroxycinnamic acid, chlorogenic acid, homovanillic acid, and ferulic acid, as well as additional antioxidants like beta-carotene. Tomatoes can be eaten raw or cooked and still retain their nutritional value, making them a valuable addition to a balanced diet. More than 80 percent of all tomatoes farmed for commercial purposes are used to make processed foods like ketchup, soup, and juice. It is well known that eating a lot of tomatoes and tomato-based products has various health benefits, many of which are linked to their antioxidant content (Collins *et al.,* 2022).

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Tomatoes typically have a dry matter content of 5% to 10%. Three-quarters of the dry matter in mature tomatoes is composed of solids, primarily pectin (about 7%), organic acids (more than 10%), minerals (8%), and sugars (almost 50%). The main sugars found are glucose and fructose, while trace amounts of raffinose, arabinose, xylose, galactose, and the sugar alcohol myoinositol have also been recorded (Wu *et al.,* 2022).

The first known fungus appeared around a billion years ago (Loron *et al*., 2019) There are over 120,000 species of fungi recognized, and between 1500 and 2000 new species are found each year, with 60% of these coming from Europe and Asia (Willis, 2018, and Knogge, 1996). Phytopathogenic fungi are a comparatively small subset among them, accounting for less than 10% and primarily belonging to the Ascomycetes and the Basidiomycetes classifications (Doehlemann *et al*., 2017).

Plant diseases are a major source of decreased product yield, quality, and safety, and as such, they are of great economic significance for forestry and agriculture sectors. Globally, annual crop losses due to pests and plant diseases are estimated to be 20–40% of total crop production, valued at $220 billion (Reddy *et al.,* 2009, and FAO, 2020). Microbial illnesses caused 16% of the world's harvest to be lost in 2006; fungi were responsible for 70–80% of these losses (Oerke, 2006). After six years, fungal pathogens wiped out more than 30% of the world's food crops (Fisher *et al*., 2012).

Fungal species are commonly found worldwide. Some of these species are pathogenic, and humans have been fighting to reduce production losses ever since organized agriculture began. A lot of progress has been made in this fight with the introduction of fungicides, which have significantly increased agricultural productivity. However, overuse of fungicides has been linked to negative effects on human health and the environment. Many plant pathogens can impact tomato plants, including the fungus *Alternaria* spp. which is thought to be one of the most significant ones that causes leaf spot, stem necrosis, and black mold on tomato fruit, as well as *Curvularia* spp. (Fayyadh and Yousif, 2019).

Since there were multiple reports of this tomato spot pathogen developing new races resistant to fungicides, it is highly recommended that fungicides be sprayed at the field-level using need-based methods and at the correct dosages. Therefore, before applying fungicides in the field level, it is essential to evaluate them first under laboratory conditions against the pathogen at different concentrations (Peerzada *et al*., 2020). The current study aimed to assess the effects of several systemic/translaminar and contact fungicides at different concentrations on mycelial growth.

Materials and Methods

Fungicides

Fungicides were obtained from pesticide and fertilizer sales stores in Assiut Governorate. Ten fungicides were tested, nine of them were chemical fungicides: Azoxystrobin 12.5 + Difenoconazole 20 SC, Copper Oxychloride 85 WP, Chlorothalonil 50 + Metalaxyl-M 3.75 SC, Mancozeb 80 WP, Dimethomorph 12

+ Pyraclostrobin 6.7 WG, Tebuconazole 25 EW, Azoxystrobin 20 + Propiconazole 12 SC, Chlorothalonil 75 WP, and Metalaxyl-M 48 EC. They belong to seven different chemical classes and show seven different modes of action (Table 1). In addition, one bio-fungicide, Jojoba Oil 60 EC, was also tested against tomato spot pathogens *Alternaria alternata*, *Curvularia pseudobrachyspora* and *Curvularia hawaiiensis.* Fungicides were selected as the most applied by farmers to control tomato spot disease (Table 1).

Table 1. Fungicides used in this study

Commercial Name	Active Ingredient	Chemical Group*	Mode of Action*
Dicore	Azoxystrobin + Difenoconazole	Strobilurin / Triazole	Breathing complex 3: ubiquinol oxidase, local Qo / Demethylation of C-14 in sterol biosynthesis
Newcooper	Copper Oxychloride	Inorganic	Enzyme inhibitor
Winner gold	Chlorothalonil + Metalaxyl-M	Chloronitriles / Acylalanine	Multi-site contact activity / Inhibiting the synthesis of proteins and nucleic acids
Tricam	Mancozeb	Ethylene bis dithiocarbamate	Multi-site contact activity
Maven	Dimethomorph + Pyroclostrobin	Carboxylic acid amides / Strobilurin	Affect the cellulose synthase, which interfere in the cell wall biosynthesis / Breathing complex 3: ubiquinol oxidase, local Qo
Sassco	Tebuconazole	Triazole	Demethylation of C-14 in sterol biosynthesis
Root Do-Plus	Azoxystrobin + Propiconazole	Strobilurin / Triazole	Breathing complex 3: ubiquinol oxidase, local Qo / Demethylation of C-14 in sterol biosynthesis
Chlorocal	Chlorothalonil	Chloronitriles	Multi-site contact activity
Delta Gold	Metalaxyl-M	Acylalanine	Inhibiting the synthesis of proteins and nucleic acids

* Information from Fungicide Resistance Action Committee (FRAC), available at www.FRAC.info

Toxicity Bioassay

Fungicides were evaluated in the laboratory for their efficacy in inhibiting the mycelial growth of the test pathogens using poisoned food technique (Nene and Thapilyal, 1979). Before the experiment was set up, the pathogen was cultured on Potato Dextrose Agar medium (PDA) for ten days. The PDA medium was prepared and melted. The fungicidal suspension was added to the melted medium to obtain the required concentration. Sterilized petri plate, 9 cm-diameter, was filled with 20 mL of the poisoned medium. control dishes were maintained without adding fungicide. A 5 mm diameter fungal disc was taken from the periphery of a 10-day-old colony and was placed at the center of the poisoned plates and incubated at 27±1 ˚C and radial growth of the pathogen was measured when growth is complete in control dishes. Four replications were maintained for each treatment. The percentage growth inhibition (PGI) of the pathogen over control was worked out using the formula given by (Arora and Dwivedi, 1979).

$$\mathbf{PGI}= \frac{100\ (\mathrm{DC}\ -\ \ \mathrm{DT})}{\mathrm{DC}}$$

Where

PGI: Percentage (%) of growth inhibition.

DC: Average diameter of mycelial growth in control plates.

DT: Average diameter of mycelial growth in treated plates.

A wide range of fungicide concentrations were tested on *A. alternata*, *C. pseudobrachyspora* and *C. hawaiiensis*. Concentrations that caused 10-90% inhibition were selected (Table 2).

Then the value of IC50 (Concentration that inhibits 50% of fungal growth) and the slope were determined using the regression analysis program Probit and the toxicity index and Relatives Potency calculated according to Sun equations (Sun, 1950):

$$\mathbf{Toxicity\ Index}\ = \left[\left(\frac{\mathrm{IC50\ of\ the\ most\ tested\ fungicide}}{\mathrm{IC50\ of\ the\ tested\ fungicide}}\right)\times 100\right]$$

$$\mathbf{Relatives\ Potency}\ = \frac{\mathrm{Toxicity\ index\ of\ the\ most\ tested\ fungicide}}{\mathrm{Toxicity\ index\ of\ the\ tested\ fungicide}}$$

Table 2. Concentrations tested against tomato spot pathogens

treatments	Concentrations (PPM)		
	A. alternata	*C. pseudobrachyspora*	*C. hawaiiensis*
Chlorothalonil	100, 1000, 5000, 10000, 13000 and 17000	100, 1000, 2000, 5000, 10000, 15000 and 19000	100, 1000, 5000, 10000, 13000 and17000
Metalaxyl-M	100, 300, 600, 1000, 3000 and 6000	10, 100, 300, 600, 1000, 3000 and 6000	10, 100, 300, 600, 1000, 3000 and 6000
Chlorothalonil + Metalaxyl-M	1, 10, 100, 400, 1000, 10000 and 15000	1, 5, 10, 100, 1000, 10000 and 16000	0.1, 10, 100, 500, 1000 and 10000
Azoxystrobin + Difenoconazole	0.05, 0.1, 1, 10 and 40	0.05, 0.1, 1, 10 and 100	0.05, 0.1, 1, 10 and 100
Dimethomorph + Pyraclostrobin	.01, 0.1, 5, 10, 100, 1000 and 4000	.01, 0.1, 1, 10, 100, 1000 and 4000	.01, 0.1, 1, 10, 100 and 1000
Tebuconazole	0.04, .4, 1, 10 and 30	0.1, 1, 5, 10, 30 and 50	0.01, 0.03, 0.07, 0.1, 1, 10 and 20
Azoxystrobin + Propiconazole	0.01, 0.1, 1, 5, 10, 40 and 60	0.01, 1, 5, 10, 40 and 60	0.01, 0.1, 1, 10 and 20
Mancozeb	0.01, 0.1, 1, 5, 10, 40 and 70	1, 5, 10, 30, 60 and 90	0.01, 0.1, 10, 100 and 130
Copper Oxychloride	500, 1000, 5000, 10000, 20000 and 30000	500, 1000, 5000, 10000, 20000 and 30000	500, 1000, 5000, 10000, 20000 and 30000
Jojoba Oil	100, 500, 1000, 5000, 10000 and 15000	100, 500, 1000, 5000, 10000 and 15000	100, 500, 1000, 5000, 10000 and 15000

Statistical analysis

A Probit analysis was carried out on the data using SPSS software version 26 to ascertain the fungicide's IC50, IC90, 95% confidence limits, and slope values in accordance with Finney (1971). Sigma Plot version 15 was used to generate the toxicity lines.

Results and Discussion

Results

Pathogens were cultivated on PDA medium contaminated with various fungicide concentrations, and after 10 days of incubation, the inhibition of fungal growth was assessed. All fungicides considerably decreased the growth of tomato spot infections, according to the findings *A. alternata*, *C. pseudobrachyspora* and *C. hawaiiensis* were among the pathogens tested.

The data in Table 3 and Fig 1. show the toxicity of the tested fungicides on *A. alternata*. Azoxystrobin + Difenoconazole was the most toxic compound with an IC50 value of 0.83 ppm, IC90 of 34.64 ppm and toxicity index was 100. Tebuconazole followed with an IC50 of 1.30 ppm, IC90 of 25.41 ppm and the toxicity index was 64.18. Azoxystrobin + Propiconazole had an IC50 of 2.12 ppm, IC90 of 139.90 ppm and the toxicity index was 39.40. Copper oxychloride was the least toxic fungicide that inhibited *A. alternata* growth, with an IC50 value of 4152.61 ppm, IC90 of 43350.77 ppm and a toxicity index of 0.02.

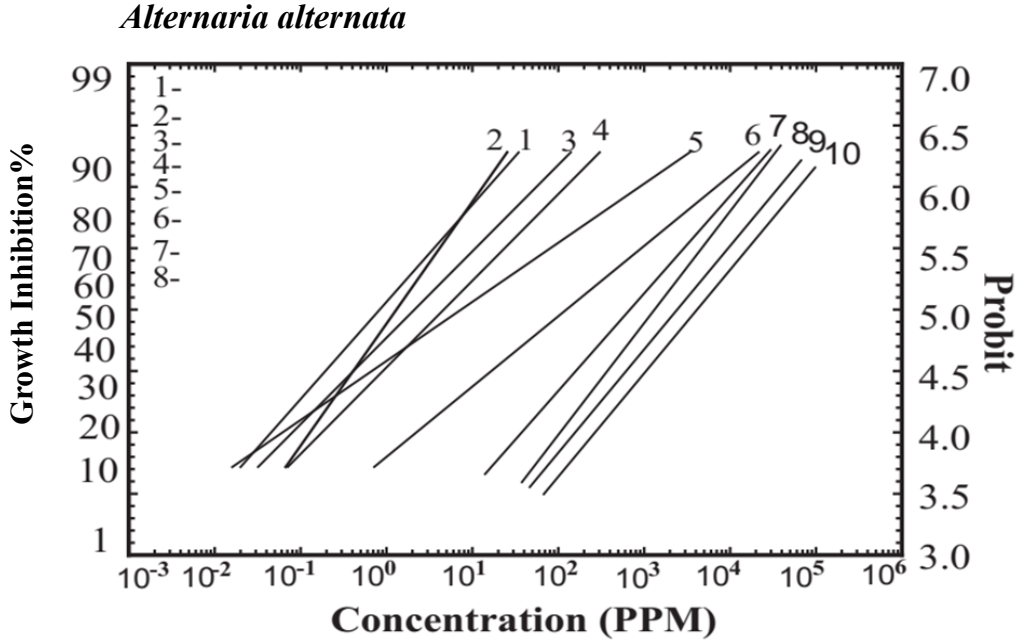

Fig 1. Toxicity lines of ten fungicides against *A. alternata* under laboratory conditions. 1. Azoxystrobin + Difenoconazole, 2. Tebuconazole, 3. Azoxystrobin + Propiconazole, 4. Mancozeb, 5. Dimethomorph + Pyraclostrobin, 6. Chlorothalonil + Metalaxyl-M, 7. Metalaxyl-M, 8. Jojoba Oil, 9. Chlorothalonil and 10. Copper Oxychloride.

Table 3. Values of IC50, slope, toxicity index and 95% lower and upper confidence limits for some fungicides on *A. alternata.*

Treatments	IC50	95% Confidence Limits		Toxicity Index*	Relatives Potency*	IC90	95% Confidence Limits		Slope ± SE
		Lower	Upper				Lower	Upper	
Azoxystrobin + Difenoconazole	0.83	(0.26 - 2.57) a		100	1	34.64	(8.43 - 768.52) a		0.79 ± 0.06
Tebuconazole	1.30	(0.51 - 3.27) a		64.18	1.6	25.41	(8.20 - 275.26) a		0.99 ± 0.07
Azoxystrobin + Propiconazole	2.12	(0.88 - 4.77) ab		39.40	2.5	139.90	(43.37 - 1066.41) a		0.70 ± 0.04
Mancozeb	4.64	(1.53 - 15.31) b		18.02	5.5	304.51	(62.75 - 10326.11) a		0.70 ± 0.05
Dimethomorph + Pyraclostrobin	7.47	(4.42 - 12.42) b		11.20	8.9	3391.40	(1482.74 - 9552.47) b		0.48 ± 0.03
Chlorothalonil + Metalaxyl-M	124.32	(79.83 - 189.17) c		0.67	149.3	21480.31	(10731.96 - 51932.59) c		0.57 ± 0.04
Metalaxyl-M	985.16	(822.99 - 1185.14) d		0.08	1250	7447.79	(5388.34 - 7447.79) b		1.45 ± 0.11
Jojoba Oil	1202.87	(723.90 - 1897.32) d		0.06	1666.7	9524.05	(5328.53 - 24204.30) bc		1.42 ± 0.09
Chlorothalonil	2394.14	(666.19 - 5903.35) d		0.03	3333.3	46769.36	(14892.60 - 1189836.60) cd		0.99 ± 0.08
Copper Oxychloride	4152.61	(2592.53 - 6383.73) d		0.02	5000	43350.77	(23144.38 - 125975.14) cd		1.25 ± 0.09

*Toxicity index = [(IC50 of the most efficient tested fungicide / IC50 of the tested fungicide) x 100]. *Relatives Potency = toxicity index of the most efficient tested fungicide / toxicity index of the tested fungicide. IC50 and IC90 values having different letters are significantly different (95% Confidence limits did not overlap).

Table 4. Values of IC50, slope, toxicity index and 95% lower and upper confidence limits for some fungicides on *C. pseudobrachyspora.*

Treatments	IC50	95% Confidence Limits		Toxicity Index*	Relatives Potency*	IC90	95% Confidence Limits		Slope ± SE
		Lower	Upper				Lower	Upper	
Azoxystrobin + Difenoconazole	1.88	(0.63 - 6.40) a		100	1	202.30	(37.35 - 7139.87) a		0.63±0.05
Dimethomorph + Pyraclostrobin	3.54	(2.05 - 5.97) a		53.27	1.9	1876.31	(815.18 - 5300.96) a		0.47±0.03
Tebuconazole	4.35	(1.96 - 8.72) ab		43.37	2.3	73.29	(28.97 - 466.61) a		1.04±0.07
Azoxystrobin + Propiconazole	4.51	(0.41 - 24.52) b		41.79	2.4	176.35	(29.97 - 503815.52) a		0.80 ± 0.06
Mancozeb	15.26	(9.96 - 22.94) b		12.36	8.1	122.66	(68.49 - 328.72) a		1.41±0.10
Chlorothalonil + Metalaxyl-M	183.16	(67.87 - 518.58) c		1.03	97.1	52508.18	(10632.65 - 795767.38) bc		0.52±0.03
Metalaxyl-M	668.39	(550.66 - 806.56) d		0.28	357.1	5670.59	(4110.63 - 8629.45) ab		1.38±0.10
Jojoba Oil	1681.92	(724.49 - 3623.06) d		0.11	909.1	17566.72	(6986.42 - 141174.25) ab		1.25±0.08
Chlorothalonil	2876.17	(1185.77 - 5899.90) de		0.06	1666.7	32211.22	(12957.48 - 302458.49) bc		1.22±0.08
Copper Oxychloride	3585.18	(2162.66 - 5585.72) de		0.05	1666.7	39750.83	(20968.69 - 119475.46) bc		1.22±0.09

*Toxicity index = [(IC50 of the most efficient tested fungicide / IC50 of the tested fungicide) x 100]. *Relatives Potency = toxicity index of the most efficient tested fungicide / toxicity index of the tested fungicide. IC50 and IC90 values having different letters are significantly different (95% Confidence limits did not overlap).

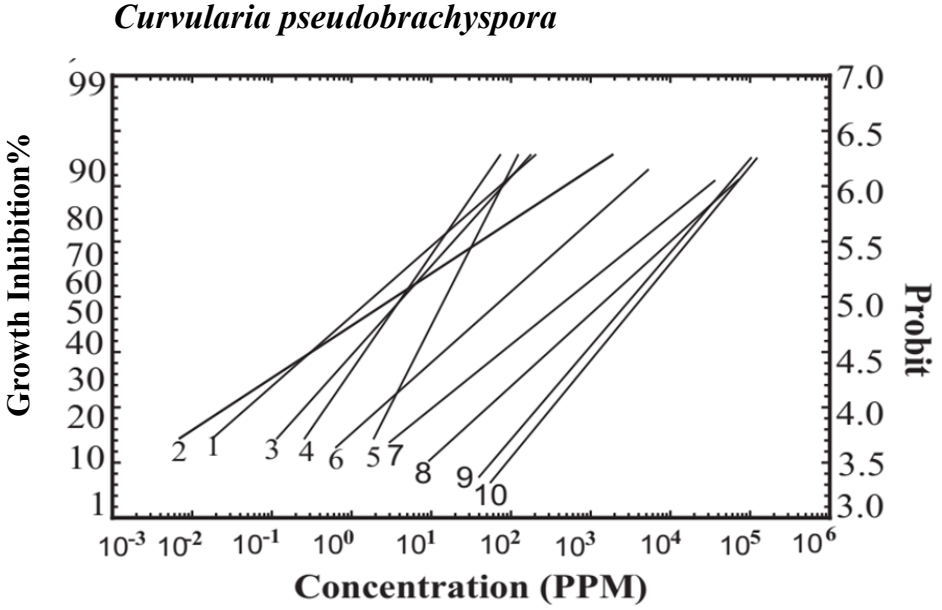

Fig 2. Toxicity lines of ten fungicides against *C. pseudobrachyspora* under laboratory conditions. 1. Azoxystrobin + Difenoconazole, 2. Dimethomorph + Pyraclostrobin, 3. Tebuconazole, 4. Azoxystrobin + Propiconazole, 5. Mancozeb, 6. Chlorothalonil + Metalaxyl-M, 7. Metalaxyl-M, 8. Jojoba Oil, 9. Chlorothalonil and 10. Copper Oxychloride.

The IC50, IC90 values and toxicity index of fungicides against the mycelial growth of *C. pseudobrachyspora* are presented in Table 4 and Fig 2. (Azoxystrobin + Difenoconazole) exhibited the best fungicidal activity against the tomato spot pathogen *C. pseudobrachyspora*, with an IC50 value of 1.88 ppm, IC90 202.30 ppm and the toxicity index was 100 followed by (Dimethomorph + Pyraclostrobin) with IC50 3.54 ppm, IC90 1876.31 ppm and the toxicity index was 53.27. Chlorothalonil and Copper Oxychloride fungicides are the least toxic compounds on *C. pseudobrachyspora* compared to other tested fungicides, with an IC50 value of 2876.17, 3585.18 ppm, IC90 32211.22, 39750.83 ppm and the toxicity index was 0.06, 0.05 respectively.

The IC50 and IC90 values as well as the toxicity index of fungicides against the mycelial growth of *C. hawaiiensis* are shown in Table 5 and Fig 3. Tebuconazole exhibited the best fungicidal activity against the tomato spot pathogen *C. hawaiiensis*, with an IC50 value of 0.28 ppm, IC90 8.65 ppm and a toxicity index of 100. This was followed by (Azoxystrobin + Propiconazole) with an IC50 of 0.40 ppm, IC90 10.85 ppm and a toxicity index of 71.18. However, Chlorothalonil and Copper Oxychloride did not exhibit significant toxicity in terms of inhibiting *C. hawaiiensis* growth, as their IC50 and IC90 values were high compared to other tested compounds.

Table 5. Values of IC50, slope, toxicity index and 95% lower and upper confidence limits for some fungicides on *C. hawaiiensis*.

Treatments	IC50	95% Confidence Limits		Toxicity Index*	Relatives Potency*	IC90	95% Confidence Limits		Slope ± SE
		Lower	Upper				Lower	Upper	
Tebuconazole	0.28	(0.16 - 0.50) a		100	1	8.65	(3.76 - 29.73) a		0.86 ± 0.05
Azoxystrobin + Propiconazole	0.40	(0.28 - 0.57) a		71.18	1.4	10.85	(6.66 - 19.88) a		0.89 ± 0.06
Azoxystrobin + Difenoconazole	0.98	(0.67 - 1.44) b		29.34	3.4	44.14	(23.72 - 98.49) b		0.77 ± 0.06
Dimethomorph+ Pyraclostrobin	1.25	(0.75 - 2.05) b		22.99	4.3	271.77	(126.37 - 715.09) bc		0.54 ± 0.04
Mancozeb	2.94	(0.28 - 24.26) a		9.82	10.2	499.49	(49.43 - 256563.99) c		0.57 ± 0.04
Chlorothalonil + Metalaxyl-M	79.37	(5.76 - 638.02) ac		0.36	277.8	10762.08	(1112.50 - 23618802.94) c		0.60 ± 0.04
Metalaxyl-M	850.51	(516.83 - 1415.78) c		0.03	3333.3	6505.74	(3222.04 - 27133.75) c		1.45 ± 0.11
Jojoba Oil	1202.86	(652.86 - 2047.25) c		0.02	5000	14431.63	(7077.37 - 14431.63) c		1.18 ± 0.08
Chlorothalonil	1898.99	(269.83 - 5805.94) ac		0.01	10000	36464.52	(10182.80 - 3761958.56) c		0.99 ± 0.08
Copper Oxychloride	4755.95	(2867.17 - 7654.95) cd		0.006	16666.7	48329.46	(24375.71 - 166554.62) cd		1.27 ± 0.09

*Toxicity index = [(IC50 of the most efficient tested fungicide / IC50 of the tested fungicide) x 100]. *Relatives Potency = toxicity index of the most efficient tested fungicide / toxicity index of the tested fungicide. IC50 and IC90 values having different letters are significantly different (95% Confidence limits did not overlap).

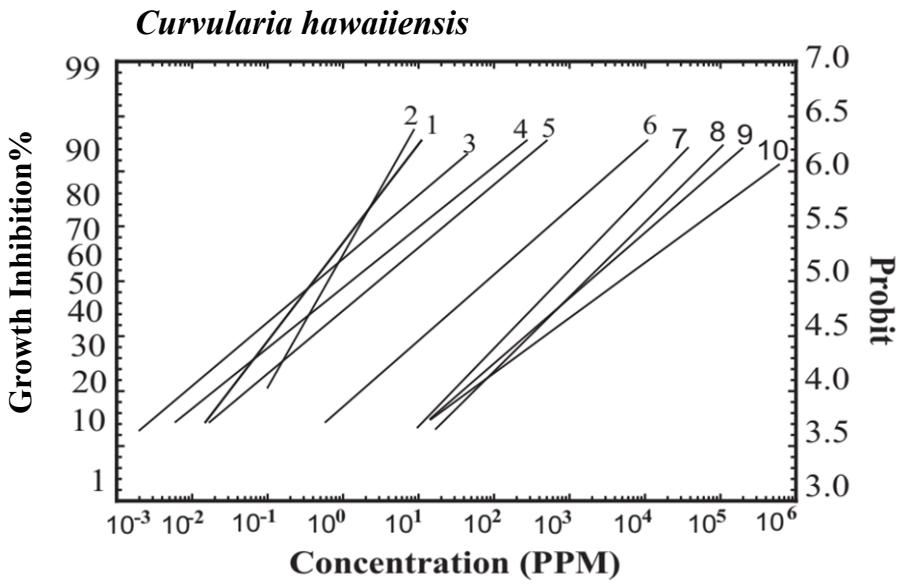

Fig 3. Toxicity lines of ten fungicides against *C. hawaiiensis* under laboratory conditions. 1. Tebuconazole, 2. Azoxystrobin + Propiconazole, 3. Azoxystrobin + Difenoconazole, 4. Dimethomorph + Pyraclostrobin, 5. Mancozeb, 6. Chlorothalonil + Metalaxyl-M, 7. Metalaxyl-M, 8. Jojoba Oil, 9. Chlorothalonil and 10. Copper Oxychloride.

In general, the highest fungicide toxicity was observed with Azoxystrobin + Difenoconazole on *A. alternata*, with values of 1.6, 2.5, 5.5, 8.9, 149.3, 1250, 1666.7, 3333.3 and 5000 higher than Tebuconazole, Azoxystrobin + Propiconazole, Mancozeb, Dimethomorph + Pyroclostrobin, Chlorothalonil + Metalaxyl-M, Metalaxyl-M, Jojoba Oil, Chlorothalonil and Copper Oxychloride, respectively.

Azoxystrobin + Difenoconazole also showed high toxicity on *C. pseudobrachyspora*, with value 1.9, 2.3, 2.4, 8.1, 97.1, 357.1, 909.1, 1666.7 and 1666.7 higher than from Dimethomorph + Pyroclostrobin, Tebuconazole, Azoxystrobin + PropiconazoleMancozeb, Chlorothalonil + Metalaxyl-M, Metalaxyl-M, Jojoba Oil, Chlorothalonil and Copper Oxychloride, respectively. Tebuconazole exhibited high toxicity on *C. hawaiiensis*, with value 1.4, 3.4, 4.3, 10.2, 277.8, 3333.3, 5000, 10000 and 16666.7 higher than from Azoxystrobin + Propiconazole, Azoxystrobin + Difenoconazole, Dimethomorph+ Pyroclostrobin, Mancozeb, Chlorothalonil + Metalaxyl-M, Metalaxyl-M, Jojoba Oil Chlorothalonil and Copper Oxychloride, respectively.

Discussion

The effect of ten fungicides were tested under laboratory conditions for their inhibitory effect on the linear growth of *A. alternata*, *C. pseudobrachyspora*, and *C. hawaiiensis* the causative agents of tomato spot. The results showed that all the tested compounds significantly reduced the growth, however the compounds that were most effective at inhibiting growth were Azoxystrobin + Difenoconazole, Dimethomorph + Pyraclostrobin, Tebuconazole, and Azoxystrobin + Propiconazole. According to the current results, fungicides from the triazole

family, such as tebuconazole, Difenoconazole and Propiconazole, had a high effect on inhibiting the growth of fungal spores, which is consistent with the study conducted by Ginoya and Gohel (2015). Previous studies conducted by Singh and Singh (2006) and Gohel and Solanky (2012) revealed that the use of Difenoconazole, Propiconazole and Hexaconazole on *Alternaria alternata* fungus had a high inhibition rate. The effectiveness of azoxystrobin and pyraclostrobin was high in inhibiting the three fungi, but the high toxicity was due to the presence of triazole family and Dimethomorph (Monteiro *et al.,* 2021). The results of Mancozeb were largely satisfactory and consistent with the results reached by (Lal *et al*., 2015 and Naik *et al*., 2010), Mancozeb is a multi-site fungicide and therefore its increased toxicity may be due to its ability to affect different sites in the fungal cell (Monteiro *et al.,* 2021). In a study conducted on the use of copper oxychloride, mancozeb, and azoxystrobin, the study found that copper oxychloride had the lowest inhibition rate for fungal spores, which is consistent with the results we conducted by (Kaur *et al.,* 2020).

Conclusion

To manage tomato spot disease, fungicides must be used after testing in the laboratory. Consequently, the current study determined the most significant fungicides that were both very toxic and efficient against the causes of tomato spot disease. The half-toxic concentrations of each pesticide were determined. The biocide jojoba oil was found to be superior to two of the tested chemical substances, copper oxychloride and chlorothalonil beside having health and environmental benefits.

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تقييم سمية بعض المبيدات الفطرية على مسببات مرض تبقع الطماطم تحت ظروف المختبر

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الملخص

تلعب مبيدات الفطريات دوراً هاماً في مكافحة الأمراض الفطرية، لذلك أجريت هذه الدراسة بهدف تقييم سـمية مبيدات الفطريات على مسـببات مرض تبقع الطماطم تحت ظروف المختبر. تم استخدام تسع مبيدات فطرية كيميائية: أزوكسيستروبين + ديفينوكونازول، أوكسي كلوريد النحاس، كلوروثالونيل + ميتالاكسـيل-م، مانكوزيب، ديميثومورف + بيراكلوسـتروبين، تبوكونازول، أزوكسيستروبين + بروبيكونازول، كلوروثالونيل وميتالاكسيل-م بالمقارنة مع مبيد فطري حيوي واحـد زيـت جوجوبـا علـى *Alternaria alternata*، *Curvularia pseudobrachyspora* ، *Curvularia hawaiiensis*والتي تم تقييمها باسـتخدام تقنية الغذاء المسـموم. من بين مبيدات الفطريات التي تم اختبارها، أظهر تيبوكونازول أعلى فعالية في التثبيط المختبري (%) على *C. hawaiiensis*بقيمـة IC50 تبلغ 0.8 جزء في المليون، بينمـا أظهر (أزوكسـيسـتروبين + ديفينوكونازول) أعلى تثبيط (%) على *A.alternata* ، *C. pseudobrachyspora* بقيم IC50 تبلغ 0.83 ، 1.88 جزء في المليون على التوالي. مع قيمIC50 البـالغـة 4152.61 ،3585.18 ، 4755.95 *A. alternata* ، *C. pseudobrachyspora* ، *C. hawaiiensis* على التوالي، لوحظ أقل تثبيط عند اسـتخدام أوكسـي كلوريد النحاس. وفقًا للنتائج الإجمالية، فقد ثبت أن عددًا كبيرًا من مبيدات الفطريات المختبرة فعالة بشـكل كبير في تثبيط الكائنات الحية الدقيقة التي تسـبب مرض بقعة الطماطم.

الكلمات المفتاحية: المبيدات الفطرية، تكنيك الأغذية المسمومة، مرض تبقع الطماطم.