EVALUATION OF SOME PESTICIDES ON MYCELIAL GROWTH AND SPORULATION OF *FUSARIUM OXYSPORUM* F. SP. *STRIGAE,* A BIOCONTROL AGENT FOR MANAGING *STRIGA HERMONTHICA*

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SUMMARY

Studies were carried out to determine the ability of growth enhancement by five (0.0x, 0.5x, 1.0x, 1.5x and 2.0x) rates of benomyl, carbendazim, mancozeb, hexaconazole, carbendazim + mancozeb, imidacloprid + metalaxyl-M + tebuconazole (IMT) and metsulfuron methyl on *Fusarium oxysporum* f. sp. *strigae,* a biocontrol agent of *Striga hermonthica*. The chemicals were incorporated into molten potato dextrose agar to determine growth and sporulation of PSM 197 and Foxy 2, which were isolates of *F. oxysporum* f. sp. *strigae* used against *S. hermonthica*. Two hundred and eighty Petri dishes containing amended and un-amended media were inoculated with 14-day-old cultures of PSM 197 and Foxy 2 using flame-sterile 5 mm cork borer. Petri dishes were arranged on laboratory bench in a Completely Randomized Design (CRD) and observations taken at 24 hours interval. Mycelial growth and development of conidia were completely inhibited in media amended with benomyl, carbendazim, and carbendazim + mancozeb. Increasing mancozeb rate from 18 to 24 g/L resulted in complete inhibition of mycelia and conidia for PSM 197 and Foxy 2. Fourteen days after incubation, mycelial diameter of both isolates was low on media amended with highest rates of hexaconazole (1 ml/L), metsulfuron methyl (4.6 g/L) and (IMT) (8 g/L). With respect to all parameters considered, (IMT) had the highest percent variations than hexaconazole, mancozeb and metsulfuron methyl. The study therefore shows that metsulfuron methyl at 2.3 g/L promoted growth and sporulation of PSM 197 and Foxy 2 and should be used in the management of *S. hermonthica*.

Key words: Pesticide, sporulation, isolates, mycelia, conidia, metsulfuron methyl

Parasitic weeds of the genus Striga (Orobanchaceae) pose a major threat to cereal production in the African savannahs. To this effect, these weeds are important limitations to the attainment of regional food security (20). Marley and Shebayan (15) and Ejeta (9) reported independently, that *S. hermonthica* (Del.) Benth is the most economically important parasitic weed of cereals, especially maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench) in the African Savannah, causing 40 – 100 % grain yield losses.

Management approaches for Striga control in Nigeria are generally based on cultural practices such as land preparation, hand pulling, hoe weeding, use of trap and catch-crops, seed treatment, application of appropriate rate of nitrogen fertilizer, herbicide spray, use of biological control and host plant resistance (16). Control of *S. hermonthica* is particularly difficult due to its biology and intimate physiological interaction with its hosts. The parasite attaches its roots to the host, thereby withdrawing water, mineral nutrients, carbohydrates and amino-acids for its growth and development. These consequently cause stunted shoot growth, leaf chlorosis and reduced photosynthesis in the host (10). Damage is done to the host before parasite shoots emerge above soil level. So far, effective control of Striga has not been achieved through any single measure, and therefore, the integrated approach of which bio-control is a crucial component, is the most promising strategy for reducing *S. hermonthica* infestations. The potential of using fungi for biological control of Striga was proposed by (18) and has since generated research interest. Adeoti (3) and Weber *et al*. (24) showed that *Fusarium* spp., *Cercospora* spp., *Phoma* spp., *Alternaria* spp. and *Macrophomina* spp. were associated with *Striga* spp. Abbasher *et al.* (1) first reported *Fusarium oxysporum* f. sp. *strigae* as pathogenic on *Striga* spp. This fungus infects Striga at all developmental stages from seeds to flowering (12). From diseased *S. hermonthica* in northern Ghana, *F. oxysporum* (Foxy 2) was isolated (2). Elzein *et al.* (11) reported between 75 and 81 % reduction of healthy emerged Striga shoots when Sorghum seeds were coated with Foxy 2 using 40 % gum Arabic. *F. oxysporum* (PSM 197) isolated from diseased *S. hermonthica* plants in northern Nigeria, is an aggressive isolate which reduce *S. hermonthica* emergence by 89.1 and 100 % through foliar application and soil incorporation of the fungus respectively (16).

The application of biocontrol agent (*F. oxysporum* f. sp. *strigae*) coated

with maize seeds has been found effective in controlling *S. hermonthica* (7, 19). However, many farmers use imidacloprid + metalaxyl-M + tebuconazole, benomyl dressed seeds to manage seedling diseases, metsulfuron methyl to manage weeds and application of carbendazim, mancozeb and hexaconazole for managing fungal diseases. The efficacy of PSM 197 and Foxy 2 as a biological control agent (BCA) can be promoted by pesticides usage. Therefore, the need to test some of these pesticides on growth and conidia production of *F. oxysporum* isolates obtained in West Africa *in vitro* became imperative.

This study was conducted to evaluate the efficacy of pesticides on the two *F. oxysporum* f. sp. *strigae* isolates and to determine the most appropriate rate of pesticides for enhancing growth and sporulation of *F. oxysporum* f. sp. *strigae* isolates towards promoting its biocontrol attributes against *S. hermonthica*.

MATERIALS AND METHODS

Preparation of Potato Dextrose Agar (PDA)

Two hundred grams of peeled and diced potato was boiled in one litre of tap water for 30 minutes and filtered through double layer muslin cloth. Dextrose (20 g) and agar powder (15 g) were dissolved in the filtrate. The volume was made up to one litre and autoclaved at 121 ^{o}C and 1.1 kg cm^{-2} for 15 minutes. Five millilitre streptomycin sulphate was added after cooling to a temperature of 40 ^{o}C.

Determination of the effects of pesticides on isolates of *Fusarium oxysporum*

Three factors: fungal isolates (2), pesticides (7) and their rates (5) were studied using a factorial experiment with 4 replicates was carried out. Seven pesticides: Benomyl, Carbendazim, Mancozeb, Carbendazim + Mancozeb, Hexaconazole, Imidacloprid + Metalaxyl-M + Tebuconazole and Metsulfuron methyl at 0.0x, 0.5x, 1.0x, 1.5x and 2.0x where x is the manufacturer's recommended rate and 0.0x is control. The pesticides manufacturer's recommended rates are: Benomyl (2.50 g/L), Carbendazim (7.50 g/L), Mancozeb (12.00 g/L), Carbendazim + Mancozeb (6.25 g/L), Hexaconazole (0.50 ml/L), Imidacloprid + Metalaxyl-M + Tebuconazole (4.00 g/L) and Metsulfuron methyl (2.30 g/L). These were incorporated into freshly prepared Potato Dextrose Agar (PDA) with Streptomycin (PDAs). Required quantities of each pesticide for each rate were dissolved

in 20 ml sterile distilled water (SDW) in 250 ml conical flasks and the volume made up to 200 ml with molten PDAs. Two isolates of *F. oxysporum*: PSM 197 and Foxy 2 were used. The isolates were obtained from the culture room of Department of Crop Protection, Ahmadu Bello University, Zaria and cultured in PDAs for 14 days at room temperature (28 ± 2 ^{o}C) and transferred using 5 mm flame-sterile cork borer to the centre of amended and control PDAs. The experiment was laid out in completely randomized design (CRD) with four replicates on laboratory bench.

Data collection

Mycelial growth measurement

Colony formation and colour of *F. oxysporum* isolates PSM 197 and Foxy 2 on PDAs was observed visually. Mycelial diameter was measured at 24 hours interval for fourteen days, starting from 2 days after inoculation (DAI) along two perpendicular lines drawn at bottom of the Petri dishes. Mycelial diameter measurement was terminated at 14 DAI. Percent inhibition (PI) of mycelial diameter for each treatment was calculated using the formula described by (4)

$$PI = \frac{A - B}{A} \; x \; 100$$

where, A = mycelial diameter in control plate and B = mycelial diameter in treated plate.

Sporulation

At 14 days after incubation, mycelia were harvested from 4 Petri dishes per treatment into 250 ml beakers using scalpel, macerated in 80 ml SDW, using Binatone Turbo blender (Model No. HM-350S), filtered through sterile double layer muslin cloth. Conidia suspension obtained was homogenized, divided into four portions each representing a replicate. Micro and macro-conidia were counted using haemocytometer under electrically powered binocular microscope at x400 magnification. The values obtained were substituted into the formula below as described by (14) to calculate the number of conidia per millilitre (ml) of each replicate

$$C = \frac{n}{256} 4 \; x \; 10^{6}$$

where, C = number of conidia/ml, n = number of conidia counted/ chamber and 256 = constant (16 x 16 square grids)

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using (21) software version 9 and means were separated using Student-

Newman-Keuls (SNK) test at 5 % level of significance.

RESULTS

Effect of pesticides on morphological characteristics of *Fusarium oxysporum* isolates

The reactions of Foxy 2 and PSM 197 isolates of *F. oxysporum* to the tested pesticides were not significantly ($P \leq 0.05$) different from each other in respect of percent mycelial growth inhibition (Table 1). Isolate PSM 197 produced significantly ($P \leq 0.05$) higher number of micro and macro-conidia than Foxy 2. There was significant ($P \leq 0.05$) difference among the pesticide's treatment on mycelial growth and conidia count of *F. oxysporum.* The fungicides Benomyl, Carbendazim, Carbendazim + Mancozeb completely inhibited mycelial growth while Metsulfuron methy1 recorded the lowest 19.65 % inhibition. Highest number of micro-conidia was obtained from Metsulfuron methyl treated media compared to other pesticides. For macro-conidia, isolates cultured on hexaconazole incorporated media yielded the highest number compared with other pesticides treatment. This was followed by Metsulfuron methyl, while Mancozeb and IMT did not differ significantly ($P \leq 0.05$).

The effect of pesticide rates was significantly ($P \leq 0.05$) different on mycelial growth and conidia of *F. oxysporum*. Mycelial growth inhibition in *F. oxysporum* increased proportionally with increased rates of pesticides used. Highest (81.44 %) inhibition was observed at twice recommended rate used. The number of micro-conidia produced was higher on an un-amended media, whereas the amount of macro-conidia recorded on un-amended media was significantly ($P \leq 0.05$) higher than any pesticide rates in amended media. There was no significant ($P \leq 0.05$) difference in macro-conidia count between half and recommended rate as well as one and half and twice rate respectively.

A significant interaction was observed on mycelial growth, between isolate and pesticide, isolate and rate, pesticide and rate, as well as isolate and pesticide and rate. Similarly, interaction between isolate and rate, pesticide and rate was significant on conidia count. On macro conidia count, there was significant interaction between pesticide and rate.

The isolates PSM 197 and Foxy 2 cultured on Benomyl, Carbendazim, Carbendazim + Mancozeb, IMT and Hexaconazole did not interact significantly ($P \leq 0.05$) on mycelial growth except Mancozeb and Metsulfuron methyl (Table 2). Under Mancozeb, mycelial growth inhibition in Foxy 2 was significantly ($P \leq 0.05$) higher than in PSM 197. However, mycelial growth inhibition with Metsulfuron methyl in PSM 197 was significantly higher than in Foxy 2. Lower mycelial growth inhibition was observed in Foxy 2 with Metsulfuron methyl. There was no

significant ($P \leq 0.05$) difference of pesticides effects across the isolates except Mancozeb, Hexaconazole and Metsulfuron methyl (Table 3). The isolate PSM 197 significantly ($P \leq 0.05$) produced higher number of micro-conidia when cultured on Hexaconazole and Metsulfuron methyl amended media than Foxy 2. Highest number of micro-conidia was observed in PSM 197 cultured on Metsulfuron methyl.

Comparing the isolates across different rates, at 0.0x, 0.5x and 1.0x, mycelial growth inhibition did not differ significantly except at 1.5x and 2.0x. At 1.5x, mycelia inhibition in PSM 197 was significantly ($P \leq 0.05$) higher than Foxy 2 (Table 4). However, when pesticide rate was increased to 2.0x, mycelial growth inhibition was higher in Foxy 2 than in PSM 197. Highest mycelial growth inhibition was recorded at 2.0x with Foxy 2 (Table 4).

There was significant ($P \leq 0.05$) interaction between pesticide and rate on mycelia growth of *F. oxysporum* (Table 5). Mycelial growth inhibition at 0.0x for all the pesticides did not differ significantly ($P \leq 0.05$). Highest mycelial growth inhibition was recorded when fungicide rates of benomyl, carbendazim and carbendazim + mancozeb were increased from 0.5x to 2.0x and did not differ significantly ($P \leq 0.05$) from each other. However, when pesticide rates of IMT, Mancozeb, Hexaconazole and Metsulfuron methyl were increased from 0.5x to 2.0x, it was observed that mycelial growth inhibition was also increased except for IMT and Mancozeb. Mycelial growth did not differ significantly ($P \leq 0.05$) when rates of IMT and Mancozeb were increased from 1.5x to 2.0x. Lower mycelial growth inhibition was recorded with Metsulfuron methyl at 0.5x (Table 5).

There was no significant ($P \leq 0.05$) difference among the pesticides at 0.0x with respect to number of micro-conidia produced but was higher than all the pesticide rates tested (Table 6). IMT at all rates did not differ significantly ($P \leq 0.05$) from one another but were similar to those produced on Mancozeb at 1.0x. It was observed that, when rates of Hexaconazole and Metsulfuron methyl were increased from 0.5x to 2.0x, there was decreased number of micro-conidia produced.

There was no significant ($P \leq 0.05$) difference observe at 0.0x though was higher than any pesticide rates used (Table 7). Similarly, Benomyl, Carbendazim, Carbendazim + Mancozeb, IMT and Mancozeb at all their rates did not differ significantly ($P \leq 0.05$) from one another in macro-conidia number. In every increase in rate of Hexaconazole and Metsulfuron methyl from 0.5x to 2.0x, there was decreased number of macro-conidia produced. However, macro-conidia produced on Hexaconazole at 2.0x and Metsulfuron methyl at 0.5x rates are similar (Table 7).

Table 1: Effect of pesticides and rates on morphological characteristics and conidia germination of *Fusarium oxysporum* isolates in Zaria, Nigeria.

Treatment	Mycelial growth inhibition (%)	Conidial count ($x10^5$) Micro-conidia	Macro-conidia
Isolate (I)			
PSM 197	73.48^{NS}	$2,947.59^{a}$	78.64^{a}
Foxy 2	73.45^{NS}	$2,719.71^{b}$	76.39^{b}
S. E. ±	0.106	2.803	0.691
Pesticide (P)			
Benomyl	100.00^{a}	0.00^{e}	0.00^{d}
Carbendazim	100.00^{a}	0.00^{e}	0.00^{d}
Carbendazim+Mancozeb	100.00^{a}	0.00^{e}	0.00^{d}
IMT	85.51^{b}	112.06^{d}	3.30^{c}
Mancozeb	82.06^{c}	305.87^{c}	6.34^{c}
Hexaconazole	45.42^{d}	$3,021.65^{b}$	137.31^{a}
Metsulfuron methyl	19.65^{e}	$5,248.56^{a}$	87.94^{b}
S. E. ±	0.189	39.059	1.565
Rates (R) g/L			
0.0x	0.00^{e}	$8,363.91^{a}$	235.85^{a}
0.5x	68.46^{d}	$2,944.84^{b}$	73.28^{b}
1.0x	74.93^{c}	$2,281.53^{c}$	70.28^{b}
1.5x	79.55^{b}	$2,363.02^{c}$	62.13^{c}
2.0x	81.44^{a}	$2,048.77^{d}$	58.12^{c}
S. E.±	0.143	39.059	1.565
Interaction			
I*P	**	**	Ns
I*R	*	Ns	Ns
P*R	**	**	**
I*P*R	**	Ns	Ns

Means with the same superscript in each column under each factor are not significantly different at $P \leq 0.05$, using the Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid+Metalaxyl-M+Tebuconazole, x = manufacturer's recommended rate [Benomyl (2.50 g/L), Carbendazim (7.50 g/L), Mancozeb (12.00 g/L), Carbendazim + Mancozeb (6.25 g/L), Hexaconazole (0.50 ml/L), Imidacloprid + Metalaxyl-M + Tebuconazole (4.00 g/L) and Metsulfuron methyl (2.30 g/L)], Ns = not significant at 0.05 % level of significance, * = significant at 0.05 % and ** = highly significant at 0.05 % level of significance

Table 2: Interaction between isolate and pesticide on mycelia growth of *Fusarium oxysporum* in Zaria, Nigeria.

Pesticide	Mycelial growth inhibition (%)	
	Isolate	
	PSM 197	Foxy 2
Benomyl	100.00[a]	100.00[a]
Carbendazim	100.00[a]	100.00[a]
Carbendazim + Mancozeb	100.00[a]	100.00[a]
IMT	85.77[b]	85.24[b]
Mancozeb	81.04[d]	83.09[c]
Hexaconazole	45.36[e]	45.49[e]
Metsulfuron methyl	20.58[f]	18.73[g]
S. E. ±	0.267	0.267

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

Table 3: Interaction between isolate and pesticide on micro-conidia number of *Fusarium oxysporum* in Zaria, Nigeria.

Pesticide	Micro-conidia count ($x10^5$)	
	Isolate	
	PSM 197	Foxy 2
Benomyl	0.00[f]	0.00[f]
Carbendazim	0.00[f]	0.00[f]
Carbendazim + Mancozeb	0.00[f]	0.00[f]
IMT	109.46[f]	114.65[f]
Mancozeb	318.31[e]	293.44[c]
Hexaconazole	3,165.23[c]	2,878.07[d]
Metsulfuron methyl	5,520.75[a]	4,976.37[b]
S. E. ±	55.238	55.238

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

Table 4: Interaction between isolate and rate on mycelia growth of *Fusarium oxysporum* in Zaria, Nigeria.

Isolate	Pesticide rate (g/L)				
	0.0x	0.5x	1.0x	1.5x	2.0x
Foxy 2	0.00g	68.38f	74.81e	79.24d	81.88a
PSM 197	0.00g	68.53f	75.06e	79.85c	80.99b
S. E. ±	0.184	0.184	0.184	0.184	0.184

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test.

Table 5: Interaction between pesticide and rate on mycelial growth of *Fusarium oxysporum* in Zaria, Nigeria.

Pesticide	Mycelial growth inhibition (%)				
	Pesticide rate (g/L)				
	0.0x	0.5x	1.0x	1.5x	2.0x
Benomyl	0.00^{o}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Carbendazim	0.00^{o}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Carbendazim+Mancozeb	0.00^{o}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
IMT	0.00^{o}	80.35^{d}	85.61^{c}	87.96^{b}	88.11^{b}
Mancozeb	0.00^{o}	49.31^{g}	78.94^{e}	100.00^{a}	100.00^{a}
Hexaconazole	0.00^{o}	37.93^{j}	42.39^{i}	48.22^{h}	53.16^{f}
Metsulfuron methyl	0.00^{o}	11.60^{n}	17.59^{m}	20.63^{l}	28.79^{k}
S. E. ±	0.344	0.344	0.344	0.344	0.344

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

Table 6: Interaction between pesticide and rate on micro-conidia number of *Fusarium oxysporum* in Zaria, Nigeria.

Pesticide	Micro-conidia count ($x10^6$)				
	Pesticide rate (g/L)				
	0.0x	0.5x	1.0x	1.5x	2.0x
Benomyl	836.39^{a}	0.00^{l}	0.00^{l}	0.00^{l}	0.00^{l}
Carbendazim	836.39^{a}	0.00^{l}	0.00^{l}	0.00^{l}	0.00^{l}
Carbendazim+Mancozeb	836.39^{a}	0.00^{l}	0.00^{l}	0.00^{l}	0.00^{l}
IMT	836.39^{a}	23.99^{jk}	9.50^{kl}	6.47^{kl}	4.87^{kl}
Mancozeb	836.39^{a}	37.99^{j}	23.19^{jk}	0.00^{l}	0.00^{l}
Hexaconazole	836.39^{a}	433.52^{e}	335.03^{g}	235.71^{h}	204.4^{i}
Metsulfuron methyl	836.39^{a}	682.44^{b}	544.90^{c}	466.73^{d}	405.36^{f}
S. E. ±	7.393	7.393	7.393	7.393	7.393

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

Table 7: Interaction between pesticide and rate on macro-conidia number of *Fusarium oxysporum* in Zaria, Nigeria.

Treatments	Macro-conidia count ($x10^6$)				
	Pesticide rates (g/L)				
Pesticides	0.0x	0.5x	1.0x	1.5x	2.0x
Benomyl	235.85^{a}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}
Carbendazim	235.85^{a}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}
Carbendazim+Mancozeb	235.85^{a}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}
IMT	235.85^{a}	4.70^{i}	4.11^{i}	2.59^{i}	1.81^{i}
Mancozeb	235.85^{a}	7.73^{i}	4.94^{i}	0.00^{i}	0.00^{i}
Hexaconazole	235.85^{a}	172.48^{b}	145.47^{c}	124.65^{d}	106.64^{e}
Metsulfuron methyl	235.85^{a}	108.22^{e}	93.98^{f}	83.61^{g}	65.92^{h}
S. E. ±	3.628	3.628	3.628	3.628	3.628

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

When the pesticides rates were increased, at 0.0x, there was no mycelial growth inhibition observed (Table 8 and 9). When the rates of Benomyl, Carbendazim and Carbendazim + Mancozeb were

increased at 0.5x to 2.0x, they exhibited the same effect. However, mycelial growth of the isolates (PSM 197 and Foxy 2) were completely inhibited. Mycelial growth was reduced significantly ($P \leq 0.05$) when IMT at 0.5x was increased to 1.0x, while further increase at 1.5x to 2.0x gave no significant ($P \leq 0.05$) difference in the two isolates (Table 8 and 9).

Table 8: Mycelia inhibition of PSM 197 by different pesticides at varying rates

Pesticide	Mycelial growth inhibition (%)				
	Pesticide rate (g/L)				
	0.0x	0.5x	1.0x	1.5x	2.0x
Benomyl	0.00^{n}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Carbendazim	0.00^{n}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Carbendazim+Mancozeb	0.00^{n}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
IMT	0.00^{n}	80.27^{d}	86.15^{c}	88.25^{b}	88.40^{b}
Mancozeb	0.00^{n}	47.14^{h}	77.01^{e}	100.00^{a}	100.00^{a}
Hexaconazole	0.00^{n}	37.56^{j}	42.64^{i}	49.75^{g}	51.49^{f}
Metsulfuron methyl	0.00^{n}	14.72^{m}	19.59^{l}	20.96^{l}	27.05^{k}
S. E. ±	0.566	0. 566	0. 566	0. 566	0. 566

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

Table 9: Mycelia inhibition of Foxy 2 by different pesticides at varying rates

Pesticide	Mycelial growth inhibition (%)				
	Pesticide rate (g/L)				
	0.0x	0.5x	1.0x	1.5x	2.0x
Benomyl	0.00^{n}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Carbendazim	0.00^{n}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Carbendazim+Mancozeb	0.00^{n}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
IMT	0.00^{n}	80.43^{d}	85.06^{c}	87.67^{b}	87.82^{b}
Mancozeb	0.00^{n}	51.48^{f}	80.86^{d}	100.00^{a}	100.00^{a}
Hexaconazole	0.00^{n}	38.29^{i}	42.13^{h}	46.70^{g}	54.82^{e}
Metsulfuron methyl	0.00^{n}	8.49^{m}	15.59^{l}	20.30^{k}	30.53^{j}
S. E. ±	0.501	0. 501	0. 501	0. 501	0. 501

Means with same superscript in each column are not significantly different at ($P \leq 0.05$) using Student-Newman-Keuls (SNK) Test. IMT = Imidacloprid + Metalaxyl-M + Tebuconazole

PSM 197 cultured on Mancozeb amended media at 0.5x and 1.0x recorded lower reduction of mycelial growth than in Foxy 2 but, at 1.5x and 2.0x the growth of both isolates was completely inhibited. Mycelial growth inhibition in PSM 197 and Foxy 2 cultured on Hexaconazole amended media at 0.5x and 1.0x did not differ significantly ($P \leq 0.05$) from each other. Hexaconazole at 1.5x significantly ($P \leq 0.05$) recorded higher reduction of mycelial growth in PSM 197 than in Foxy 2. However, further increase in rate to 2.0x, showed that, mycelial growth in Foxy 2 was inhibited more than PSM 197. Mycelial growth in Foxy 2 on Metsulfuron methyl was lower than PSM 197 except at 2.0x, PSM 197 was least inhibited (Table 8 and 9).

DISCUSSION

The result of this study has shown that, *F. oxysporum* isolates (PSM 197 and Foxy 2) did not differ significantly from each other in their response to the different pesticides in term of mycelial growth inhibition. This could probably be because they are of the same genera and species. PSM 197 was isolated from diseased *S. hermonthica* in northern Nigeria (16) and Foxy 2 in northern Ghana (2).

The effects of seven pesticides, Benomyl, Carbendazim, Carbendazim + Mancozeb, Mancozeb, Imidacloprid + Metalaxyl-M + Tebuconazole, Hexaconazole and Metsulfuron methyl on PSM 197 and Foxy 2 isolates of *F. oxysporum* was studied *in vitro*. The result showed that benomyl, carbendazim and carbendazim + mancozeb completely inhibited mycelial growth and sporulation of *F. oxysporum* isolates PSM 197 and Foxy 2. Similar inhibitory effect of fungicides on another *Fusarium* spp. both *in vitro* and *in vivo* has been reported. Sultana and Ghaffar (23) reported complete inhibition of *F. solani* by Benomyl and Carbendazim *in vitro*. Similarly, Chavan *et al*. (6) reported that carbendazim and carbendazim + mancozeb resulted in 100 % inhibition of *F. solani* mycelia. The observed effect of benomyl on both PSM 197 and Foxy 2 isolates of the biocontrol agents against *S. hermonthica* could be due to inhibition of cell division and transport of molecules in the two isolates as reported by Yang *et al.* (25).

In this study, inhibitory effect of pesticides on mycelial growth and sporulation increased significantly with increase in pesticide from 0.5x to 2.0x rates. Mamza *et al.* (13) reported mycelial growth inhibition of *F. pallidoroseum* with benomyl used at

the rate of 2.25, 1.5 and 0.75 g/L. The effect of pesticides observed in this study due to increased pesticide rates could be due to increase in toxicity of the pesticides chemicals.

This study showed that, Mancozeb, Imidacloprid + Metalaxyl-M + Tebuconazole (IMT), Hexaconazole and Metsulfuron methyl at all rates tested supported sporulation of the two *F. oxysporum* f. sp. *strigae* isolates (PSM 197 and Foxy 2). Growth inhibition increased proportionally as rate of mancozeb, IMT, Hexaconazole and Metsulfuron methyl was increased from 0.5x to 2.0x indicating a positive dosage response curve relationship. With mancozeb alone, however, mycelial growth inhibition and sporulation recorded at 1.5x and 2.0x (18.0 and 24.0 g/L) was 100 %. In a report by Cycon *et al.* (8), mancozeb was found to inhibit energy production within *F. oxysporum* and inactivated the – SH groups in amino acids, proteins and enzymes. Similarly, the effect of mancozeb observed in this study could be attributed to the depletion of energy production and protein utilization in *F. oxysporum* isolates.

Also, this study revealed that, IMT at all rates had high inhibitory effect on mycelial growth and sporulation of the two isolates PSM 197 and Foxy 2. Buchenauer (5) reported that, Metalaxyl-M inhibited nucleic acids synthesis on fungal growth. The poor mycelial growth and conidia produced could be attributed to the effect of Metalaxyl-M inhibiting nucleic acids synthesis in both PSM 197 and Foxy 2 isolates. Singh *et al*. (22) also reported the use of tebuconazole at recommended rates supported mycelial growth of *Paenibacillus* sp. *in vitro*.

The study could also infer that, Metsulfuron methyl, an herbicide against *S. hermonthica* supported highest mycelial growth and sporulation of both isolates at 0.5x (1.15 g/L) and at 1.0x (2.30 g/L). Milhomme and Bastide (17) reported that, Metsulfuron methyl inhibited cellular division in meristem in higher plants and hence, stopped growth. *F. oxysporum* f. sp. *strigae* isolates PSM 197 and Foxy 2 are heterotrophic organisms which have the ability of growth and sporulation better on Metsulfuron methyl.

CONCLUSION

Based on the findings of this study, the fungicides Benomyl at 0.5x (1.25 g/L), Carbendazim at 0.5x (3.75 g/L) and Carbendazim + Mancozeb at 0.5x (3.13 g/L) did not allow any form of mycelial growth and sporulation of *F. oxysporum* f. sp. *strigae* isolates *in vitro*. Therefore, these fungicides should not be used in situations where

either PSM 197 or Foxy 2 is part of *S. hermonthica* management options. Metsulfuron methyl at 1.0x (2.3 g/L) and *F. oxysporum* f. sp. *strigae* isolates may be combined and be formulated as seed dressing technology against *S. hermonthica*. In addition, the different formulations can be applied together at the same time.

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