

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(4): 1076-1087
www.biochemjournal.com
Received: 02-03-2025
Accepted: 03-04-2025

Alex Khalkho
Department of Plant
Pathology, College of
Agriculture, GB Pant
University of Agriculture and
Technology, Pantnagar
Uttarakhand, India

AK Jain
Department of Plant
Pathology, Jawaharlal Nehru
Krishi Vishwa Vidyalaya,
Jabalpur, Madhya Pradesh,
India

Jayant Bhatt
Department of Plant
Pathology, Jawaharlal Nehru
Krishi Vishwa Vidyalaya,
Jabalpur, Madhya Pradesh,
India

Manisha Shyam
RARS, AICRP on Small
Millets, Dindori, Madhya
Pradesh, India

Sanjay Kharte
Abhyuday University,
Khargone, Madhya Pradesh,
India

Corresponding Author:
Alex Khalkho
Department of Plant
Pathology, College of
Agriculture, GB Pant
University of Agriculture and
Technology, Pantnagar
Uttarakhand, India

In-vitro efficacy of plant extracts and fungicides on *Alternaria tenuissima* inciting leaf blight of Kodo millet (*Paspalum scrobiculatum* L.) and their effect on conidial characters

Alex Khalkho, AK Jain, Jayant Bhatt, Manisha Shyam and Sanjay Kharte

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i4m.4247>

Abstract

Kodo millet (*Paspalum scrobiculatum* L.) is an important ancient millet crop, which is believed to originate from African subcontinent and was domesticated in India approximately 3000 years ago. It belongs to family *Poaceae*, is self-pollinating crop and has chromosome no. $2n = 4x = 40$. It is hardy, small seeded, climate resilient crop, which thrives well in different ecological conditions. *Kodo* is infected by a number of pathogens which includes fungi, bacteria, viruses, etc. Leaf blight is becoming a major concern these days, which is caused by *Alternaria* spp. and *Helminthosporium* spp. (*Bipolaris* spp.). *Alternaria tenuissima*, which is responsible for causing leaf blight of kodo millet have gained immense importance these days as the disease is becoming a major concern now. In our experiment, eight plant extracts were used viz., garlic, ginger, Aloe vera, marigold, turmeric, neem, congress grass and Calotropis along with control were used at 5% and 10% concentrations. The garlic extract gave the best inhibition at both 5% and 10% of 45.5% and 51.1% with poor and with no conidial production, respectively. Among fungicides, single and combo fungicides namely, *Tebuconazole* 5.36%, *Metalaxyl* 35% WS, *Carbendazim* 50% WP, *Carboxin* 37.5% + *Thiram* 37.5% DS, *Carbendazim* 12% + *Mancozeb* 63% WP, *Metalaxyl* 8% + *Mancozeb* 64% WP and *Difenoconazole* 25% EC along with control were used at 100, 250 and 500 ppm. *Difenoconazole* 25% gave best results all 3 concentrations of 69.5% 71.9% and 84.7% with no conidial production.

Keywords: Kodo millet, leaf blight, *Alternaria tenuissima*, plant extracts, fungicides, inhibition, management

Introduction

Kodo millet (*Paspalum scrobiculatum* L.) is a very ancient crop which is believed to be originated in Africa and was domesticated in India 3000 years' ago and is distributed widely, grown by farmers of low income group, it is resource poor soil under the traditional agriculture systems [1]. Kodo millet is a principal member of millet, is a self-pollinating, C_4 crop, has chromosome number $2n = 4x = 40$ and belongs to family *Poaceae*. Besides India, the crop is extensively grown in tropical and sub-tropical regions which include countries viz., Indonesia, Philippines, Thailand, Vietnam, Bangladesh, Myanmar and western part of Africa. In India, crop is extensively grown in states of Madhya Pradesh, Chhattisgarh, Tamil Nadu, Telangana, Maharashtra, Gujarat, Karnataka, Uttar Pradesh and Jharkhand [2]. Kodo millet is a small seeded, low water demanding, hardy, climate resilience crop, fertilizer responsive, which can be grown in various cropping systems under different ecological situations. Being C_4 plant it has high efficacy of using CO_2 .

Kodo has gained a lot of attention these days due to its nutritional value which is very rich in numerous health benefits and agronomic practices with low maintenance. Presence of good amount of proteins, carbohydrate, minerals and vitamins makes it very famous. Grains of kodo also contain high amount of lecithin, an important factor for enriching the nervous system with very less or negligible gluten content. Kodo millet increases the insulin sensitivity for people who are suffering from diabetes. Low glycaemic index, rich in antioxidants like polyphenols are unique properties of the kodo grains. Consumption of kodo

reduces the problems of constipation, stomach cramping, bloating, flatulence and lowers the problems of cardiovascular diseases [3, 4, 5].

Different types of pathogens have been reported in kodo millet viz., fungi, bacteria, nematodes, viruses, some partial root parasites, etc. which limits the production of kodo [6]. Leaf blight caused by *Alternaria* spp. and *Helminthosporium* spp. were reported long time ago in kodo millet as a minor disease but now leaf blight is becoming an emerging problem in kodo millet [7] very few studies were undertaken regarding characterization of the pathogen, identification of the resistant sources and management of the disease, hence needs more studies on different aspects of pathogen as well as disease.

Materials and Methods

An experiment was carried out in the laboratory of the plant pathology department, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India. In this experiment, a total of eight available plants (Table 1) were collected from the locality and was tested against the fungus using poisoned food technique [8]. One hundred grams of the plant was taken and washed with NaOCl and water to surface sterilize (2 to 3 times) and was allowed to dry at room temperature for some time. Plant parts (100g) were crushed in 100 ml of sterilized water in sterilized pestle and mortar, then the extract was filtered with double layered muslin cloth under aseptic conditions. The stock solutions of 5% and 10% were prepared and mixed with 95 and 90 ml of potato dextrose agar medium (PDA) to get 5% and 10% of the concentrations respectively. PDA supplemented with different types of plant extracts was poured in Petri plates of 90mm at rate of 10ml per plate and the plates were allowed to solidify. Disc of 5mm from the test fungi (10 day old) was taken with the help of cork borer and forceps and placed in the center of the plate. For comparison, a separate plate was maintained without any extract (control). All the treatments were replicated thrice in completely randomized design (CRD). Plates were placed in Biological Oxygen Demand (BOD) incubator (25 ± 2 °C); the readings were taken after 48 hours (hrs.) of inoculation at the interval of 24 hrs. Inhibition of the tested fungus was measured in (mm) and was calculated by the formula given by (Vincent 1947) [9];

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

Where,

I = Per cent inhibition (%).

C = Radial growth of the fungus in control (in mm).

T = Radial growth of the fungus in treatment (in mm).

After 264 hrs. of incubation, the conidia per microscopic field (100 X) were counted and length, width of the conidia was measured. Number of longitudinal and transverse septa in 25 conidia was recorded. Micrometry of the pathogen was done to ensure proper details regarding length and width of the pathogen in the treatments which showed spore count with microscope (Leica company) and software (Leica Application Suite) at 100X.

In order to check the efficacy of the fungicides the experiment was carried out in the same laboratory mentioned above. Seven available fungicides namely,

Tebuconazole 5.36%, Metalaxyl 35% WS, Carbendazim 50% WP, Carboxin 37.5% + Thiram 37.5% DS, Carbendazim 12% + Mancozeb 63% WP, Metalaxyl 8% + Mancozeb 64% WP and Difenconazole 25% EC along with control were used. These fungicides were tested against the test fungus using poisoned food technique [8] at 100, 250 and 500 ppm. Different types of fungicides are listed in Table 2. Different concentrations which were required were taken in sterilized flask containing sterilized water to make stock solution then required amount of fungicide was poured into the PDA flask. Then flask having PDA was agitated lightly to mix solution properly and for the uniform distribution of fungicides into the medium. About 10ml of PDA was poured into 90mm Petri plates and was allowed to solidify. Test fungus from seven days old was taken from cork borer and forceps. Then was placed at the center of plate under aseptic conditions. All the treatments were replicated thrice in completely randomized design (CRD). Separate control was maintained without any fungicide for comparison. Inoculated plates were kept in BOD (25 ± 2 °C). Readings were taken after 48 hrs. of incubation at 24 hrs. of interval. The inhibition percent and micrometry was done as in above experiment of plant extracts.

Scale of sporulation

- (++++)= Excellent (>60 conidia per microscopic view).
- (+++)= Good (41-60 conidia per microscopic view).
- (++)= Fair (21-40 conidia per microscopic view).
- (+)= Poor (Less than 20 conidia per microscopic view).
- (-)= No sporulation.

Statistical Analysis

Data obtained was analyzed using OPSTAT online software at 5% level of significance and is presented as the mean of the triplicates.

Results

Observations on the radial growth and conidial characteristics as influenced by different aqueous extracts (Table 3; figure 1; plate 1) were tested against *Alternaria tenuissima* (in-vitro) at two different concentrations, i.e., 5% and 10% by poisoned technique.

Among eight plant extracts used best inhibition was shown by garlic (46.3mm with inhibition of 45.5%) followed by ginger (76.8mm with inhibition of 9.6%) whereas minimum was shown by *Aloe vera* extract (83.3 with inhibition of 2.0%) when compared to control (85.0mm) after 216 hours of incubation at 5% concentration. Excellent sporulation was noted in control, good in *Aloe vera*, marigold and turmeric fair in *Calotropis* whereas poor sporulation in garlic, ginger, neem and *Parthenium* (table 3). Mean length and width recorded were; 28.34 µm and 9.42 µm in garlic, 16.81 µm and 9.84 µm in ginger, 33.05 µm and 12.54 µm in *Aloe vera*, 22.38 µm and 9.26 µm in marigold, 34.82 µm and 10.80 µm in turmeric, 36.39 µm and 11.79 µm in neem, 28.90 µm and 10.95 µm in *Parthenium*, 28.75 µm and 10.41 µm in *Calotropis* and 30.83 µm and 11.21 µm in control. Range of longitudinal septa seen was 1-4 in garlic, marigold and turmeric, 2-4 in *Aloe vera* and control, 2-3 in ginger, 0-3 in neem, 3-5 in *Parthenium* and 3-6 in *Calotropis*. Regarding transverse septa it was 1-2 in ginger and *Aloe vera*, 0-1 in garlic, turmeric, control and 0-2 in marigold, neem, *Parthenium* and *Calotropis* (table 4; plate 2).

At 10% concentration (table 3; figure 2; plate 1), best inhibition was observed in aqueous extract of clove of garlic (41.5mm with inhibition of 51.1%) followed by neem (59.7mm with inhibition of 29.7%) while minimum was seen in marigold (80.0mm with inhibition of 5.8%) after 216 hours of incubation. No sporulation was seen in garlic, ginger, turmeric, neem and *Parthenium*. Good sporulation was seen in marigold while fair in *Aloe vera*. On other hand,

it was excellent in control. In *Aloe vera*, mean length and width of conidia was 11.66 μm and 4.34 μm , 35.17 μm and 12.81 μm in *Calotropis* and 28.29 μm and 8.60 μm in control respectively. Range of longitudinal septa found were 2-4 in control and *Calotropis* while 3-5 in *Aloe vera* while range of transverse septa was 0-2 in control and *Aloe vera* respectively (table 5; plate 3).

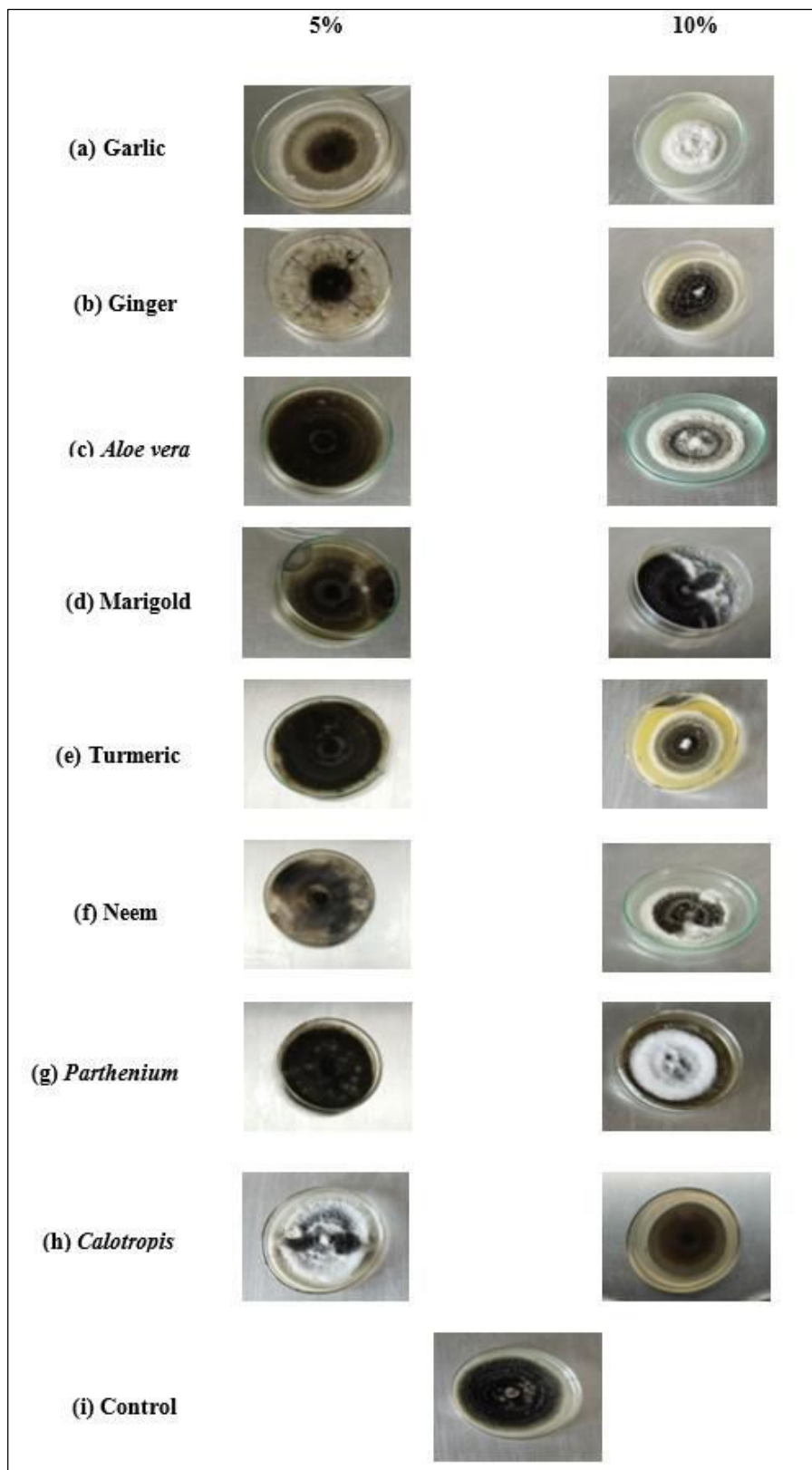


Plate 1: Effect of plant extracts (5% and 10%) on mycelial growth of *A. tenuissima*

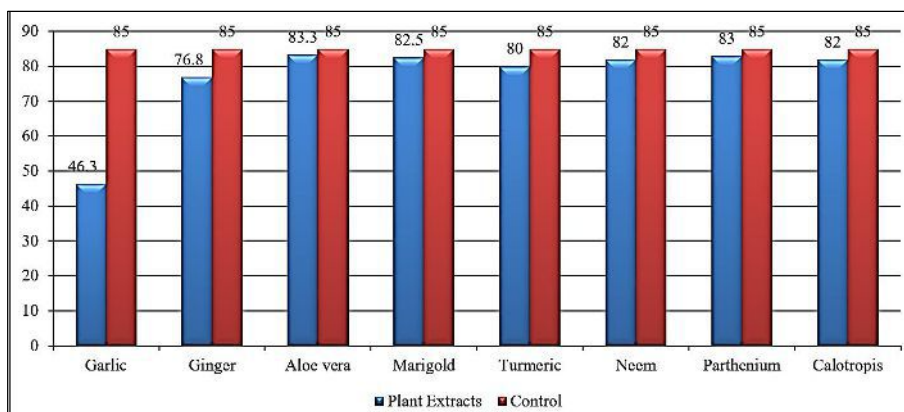


Fig 1: Effect of plant extracts (5%) on mycelial growth of *A. tenuissima*

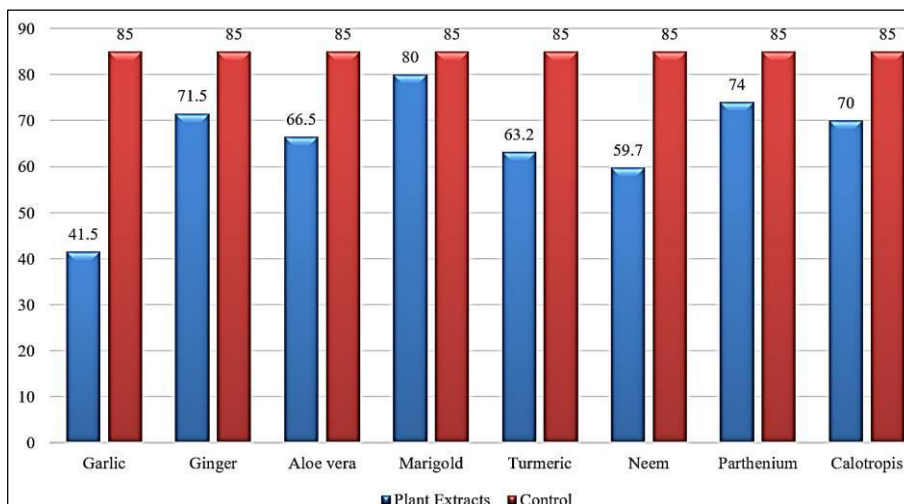


Fig 2: Effect of plant extracts (10%) on mycelial growth of *A. tenuissima*

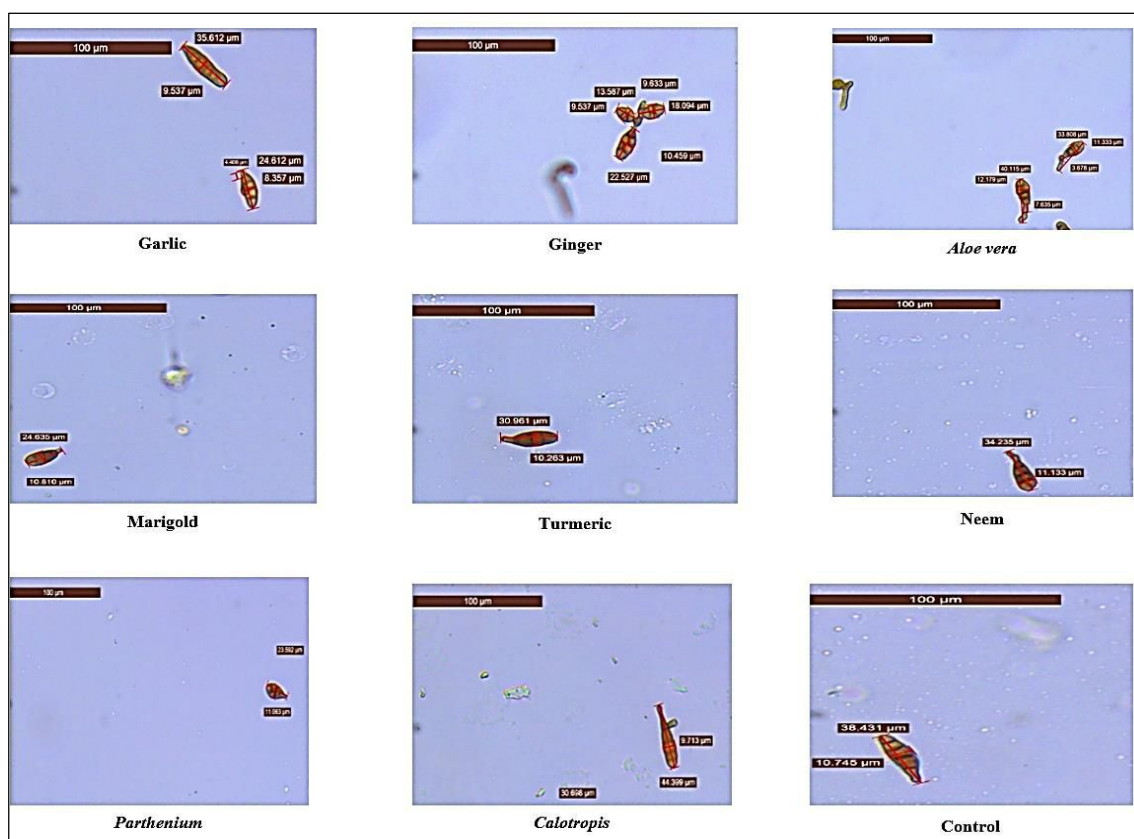


Plate 2: Conidial characterization of *A. tenuissima* as influenced by (5%) of plant extracts (10 x 10 X)

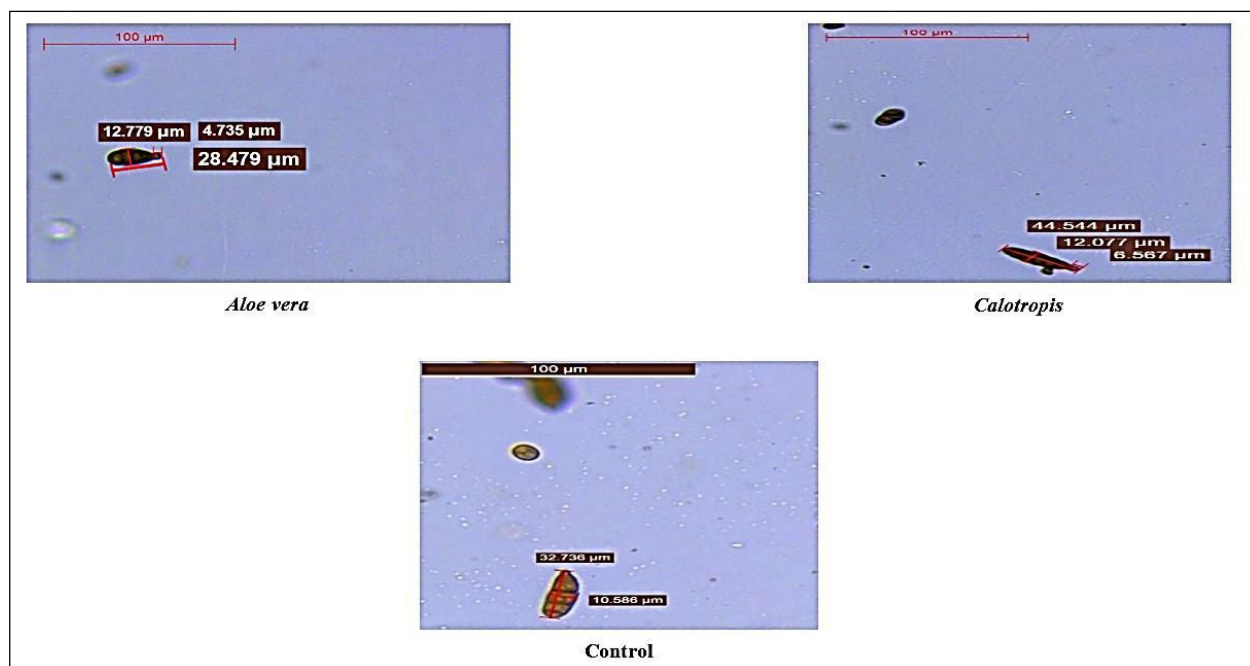


Plate 3: Conidial characterization of *A. tenuissima* as influenced by plant extracts (10%) (10 x10 X)

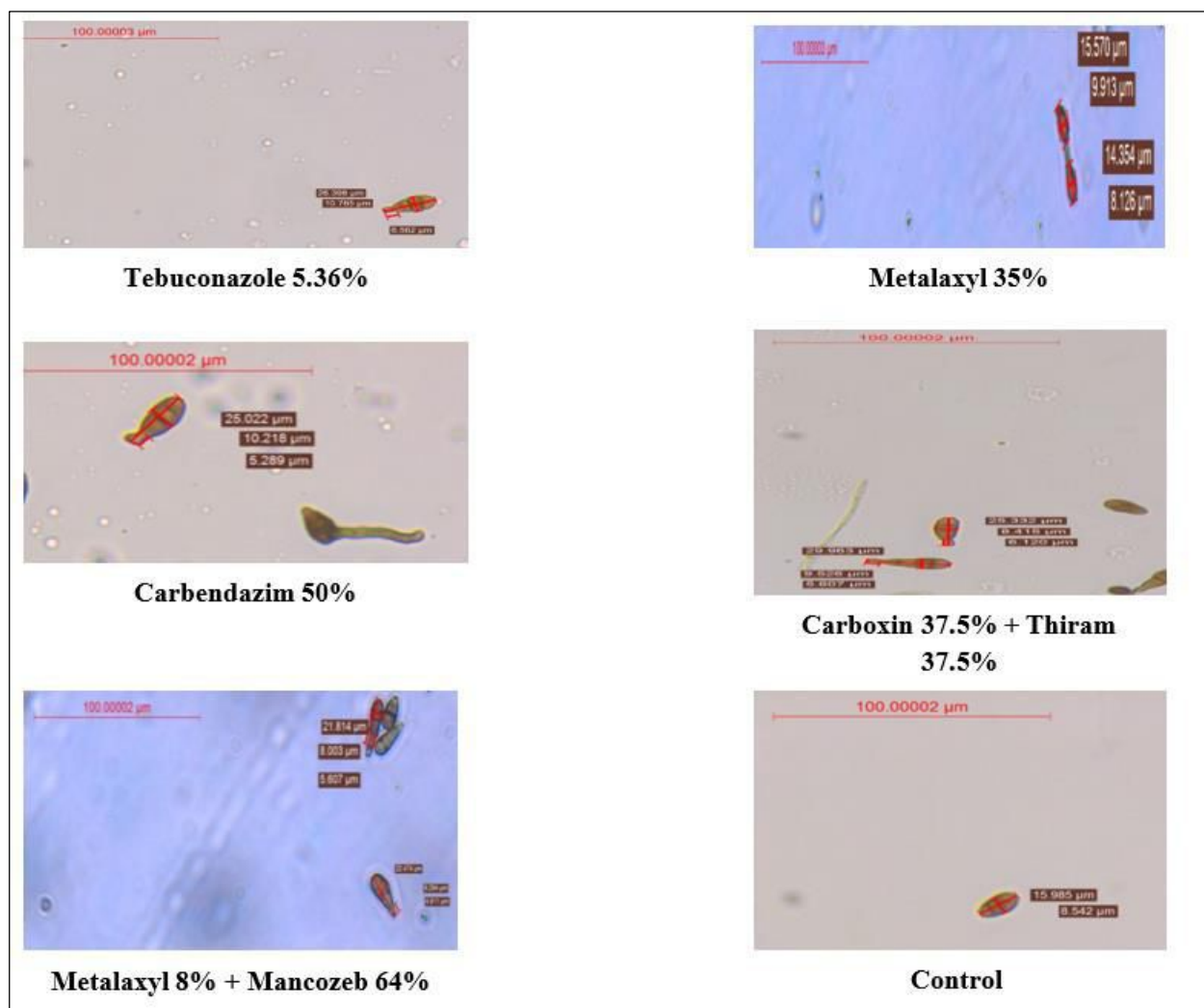


Plate 5: Conidial characterization of *A. tenuissima* as influenced by 100 ppm of fungicides (10 x10 X)

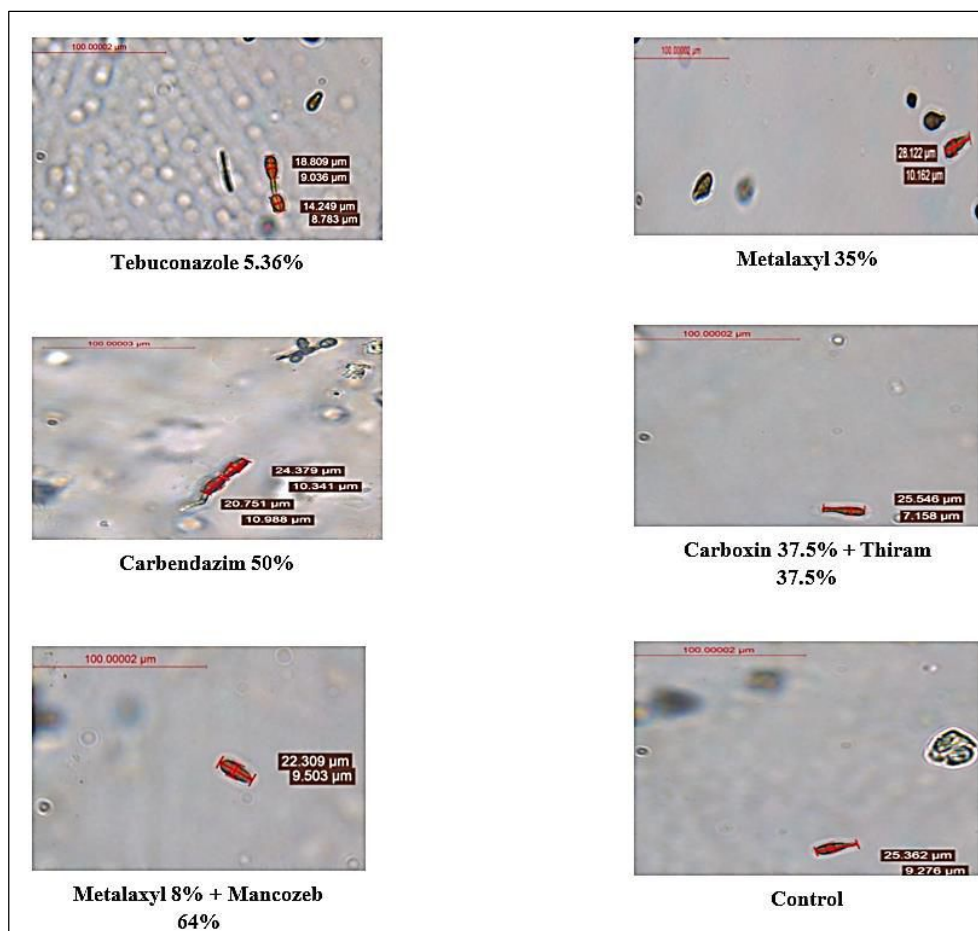


Plate 6: Conidial characterization of *A. tenuissima* as influenced by 250 ppm of fungicides (10 x 10 X)

To evaluate the different fungicides at (table 2) 100, 250 and 500 ppm. Data depicted in table 6 presents the growth and inhibition of the fungus at all the three different concentrations. Difenconazole 25% was most effective in suppressing mycelial growth and showing inhibition with mean of 25.6mm with inhibition of 69.5%, 23.8mm with inhibition of 71.9% and 13.3mm with inhibition of 84.7% when compared to control (84.1mm, 84.9mm and 85.0mm) at 100, 250 and 500 ppm respectively after 192 hours of incubation. This was followed by Tebuconazole 5.36% (45.8 with inhibition of 45.5%, 27.3mm with inhibition of 67.8% and 26.0mm with inhibition of 69.4%) when compared to control (84.1mm, 84.9mm and 85.0mm) at 100, 250 and 500 ppm respectively after 192 hours of incubation. On other hand, least inhibition and maximum growth of pathogen was observed in Metalaxyl 35% and Carbendazim 50% (77.3mm with inhibition of 8.08%) at 100 ppm when compared to control (84.1mm) after 192 hours of incubation (table 6; figure 3; plate 4). At 250 ppm, Carbendazim 12% + Mancozeb 63% showed least inhibition (71.1mm with 16.2% inhibition) when compared to control (84.9mm), whereas Carbendazim 50% (68.6mm with inhibition of 19.2%) closely followed by Carbendazim 12% + Mancozeb 63% (67.3mm with inhibition of 20.7%) at 250 ppm when compared to control after 192 hours of incubation respectively. Treatments of Carbendazim 12% + Mancozeb 63% and Difenconazole 25% did not showed any sporulation. Poor sporulation was observed in Metalaxyl 35%, Carbendazim 50% and Metalaxyl 8% + Mancozeb 64%. Fair sporulation was in Tebuconazole 5.36%, whereas good sporulation in Carboxin 37.5% + Thiram 37.5% and excellent sporulation was observed in control at 100 ppm.

Treatments of Tebuconazole 5.36%, Metalaxyl 35%, Carbendazim 50%, and Metalaxyl 8% + Mancozeb 64% resulted in poor sporulation. Whereas good sporulation was shown by Carboxin 37.5% + Thiram 37.5% and excellent sporulation in control. No sporulation was recorded in the treatments of Carbendazim 12% + Mancozeb 63% and Difenconazole 25% at 250 ppm (table 6; figure 4; plate 4). At 500 ppm, sporulation was completely inhibited in all the fungicidal treatments at 500 ppm and excellent sporulation was recorded in control (table 6; figure 5; plate 4).

Regarding conidial characterization at 100 ppm revealed that there is plenty of variations in size of conidia and the septations. Average length of conidia was 21.76 μm , 12.81, 27.51, 22.64, 20.13 and 20.42 μm in Tebuconazole 5.36%, Metalaxyl 35%, Carbendazim 50%, Carboxin 37.5% + Thiram 37.5%, Metalaxyl 8% + Mancozeb 64% and control, respectively. Whereas, average conidial width was 8.89, 7.34, 10.08, 9.78, 8.47 and 9.03 in the same treatments. Slight variation in longitudinal septa varied from 1 to 3, 1 to 2, 2 to 3, 1 to 3, 1 to 3 and 2 to 3 was noted in the treatments of Tebuconazole 5.36%, Metalaxyl 35%, Carbendazim 50%, Carboxin 37.5% + Thiram 37.5%, Metalaxyl 8% + Mancozeb 64% and control, respectively. Number of transverse septa varied from 0 to 2 was recorded in the different treatments (table 7; plate 5).

At 250 ppm, average conidial length was recorded in Tebuconazole 5.36% (16.27 μm), Metalaxyl 35% (22.26 μm), Carbendazim 50% (23.77 μm), Carboxin 37.5% + Thiram 37.5% (24.17 μm), Metalaxyl 8% + Mancozeb 64% (24.90 μm) and 26.54 μm in control. Average conidial width was maximum in Carbendazim 50% (11.19 μm) followed by Tebuconazole 5.36% (10.18 μm), Metalaxyl 35% (9.67

μm), Metalaxyl 8% + Mancozeb 64% (8.80 μm) and in control width was 8.25 μm . Whereas minimum conidial width was in Carboxin 37.5% + Thiram 37.5% (7.70 μm). Number of longitudinal septa were 1 to 2 in Tebuconazole 5.36%, 1 to 3 in control and 2 to 3 in Metalaxyl 35%, Carbendazim 50%, Carboxin 37.5% + Thiram 37.5% and Metalaxyl 8% + Mancozeb 64%. Transverse septa ranging

from 0 to 1 were recorded only in the treatments of Metalaxyl 35%, Carbendazim 50%, Carboxin 37.5% + Thiram 37.5% and Metalaxyl 8% + Mancozeb 64% (table 8 and plate 7).

At 500 ppm, mean length and width of conidia were 23.34 μm and 9.48 μm respectively with 2-3 longitudinal septa and 0-2 transverse septa (table 9).

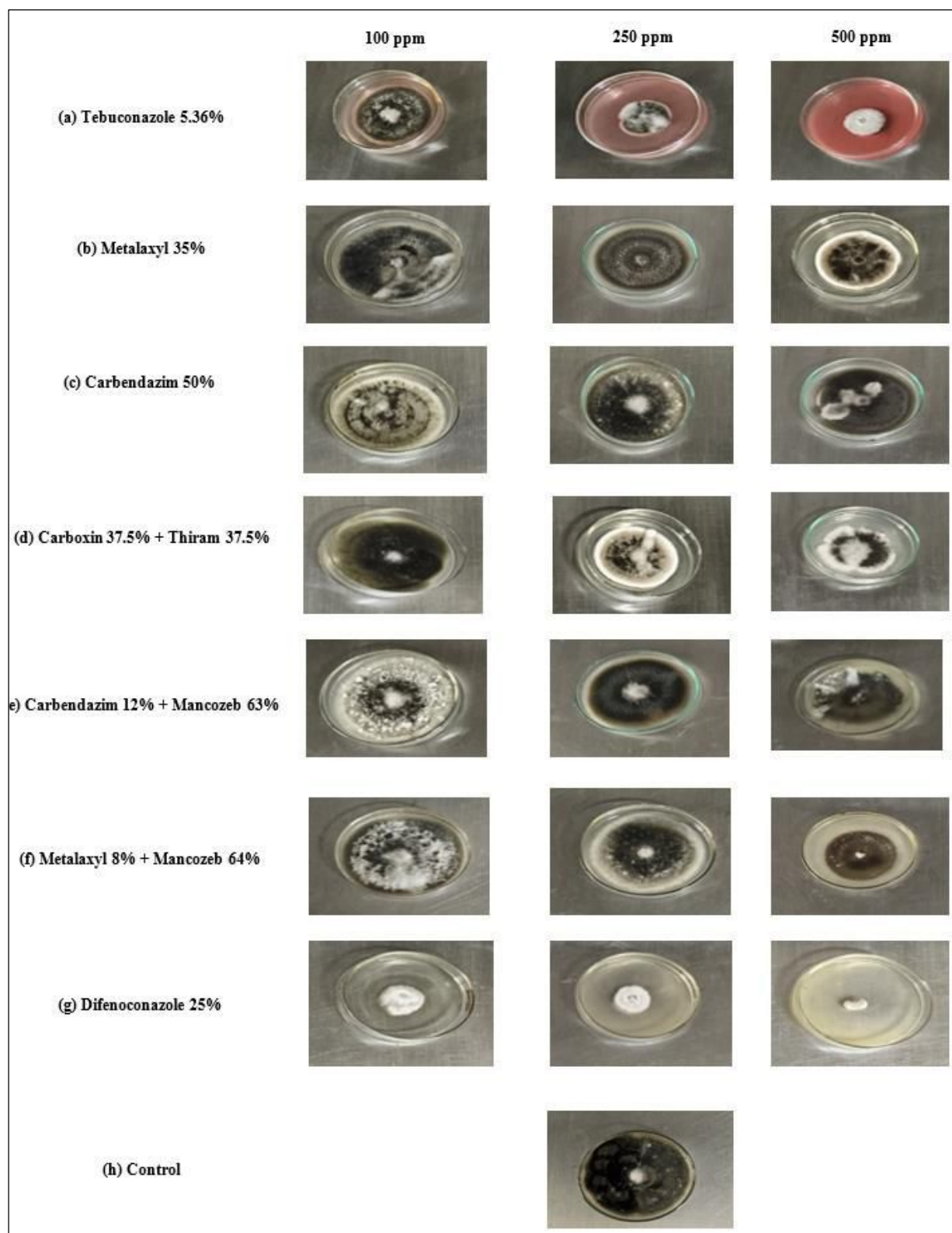


Plate 4: Effect of fungicides (100, 250 and 500 ppm) on mycelial growth of *A. tenuissima*

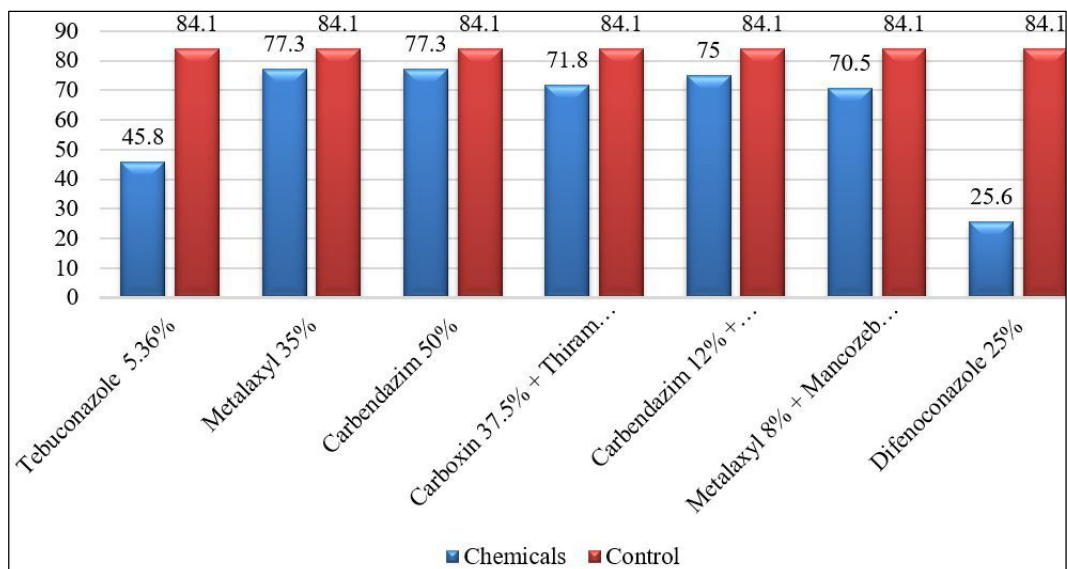


Figure 3: Effect of fungicides (100 ppm) on mycelial growth of *A. tenuissima*

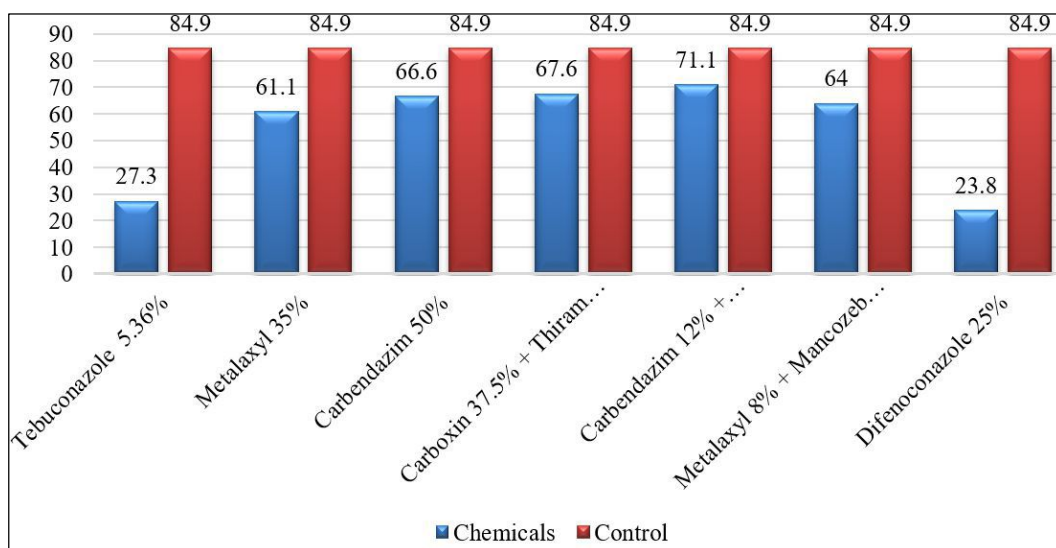


Figure 4: Effect of fungicides (250 ppm) on mycelial growth of *A. tenuissima*

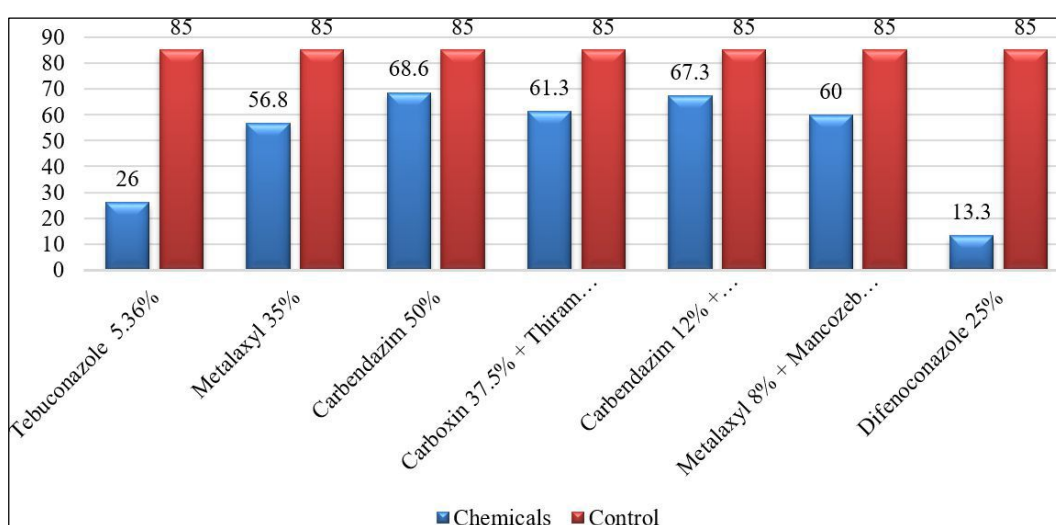


Figure 5: Effect of fungicides (500 ppm) on mycelial growth of *A. tenuissima*

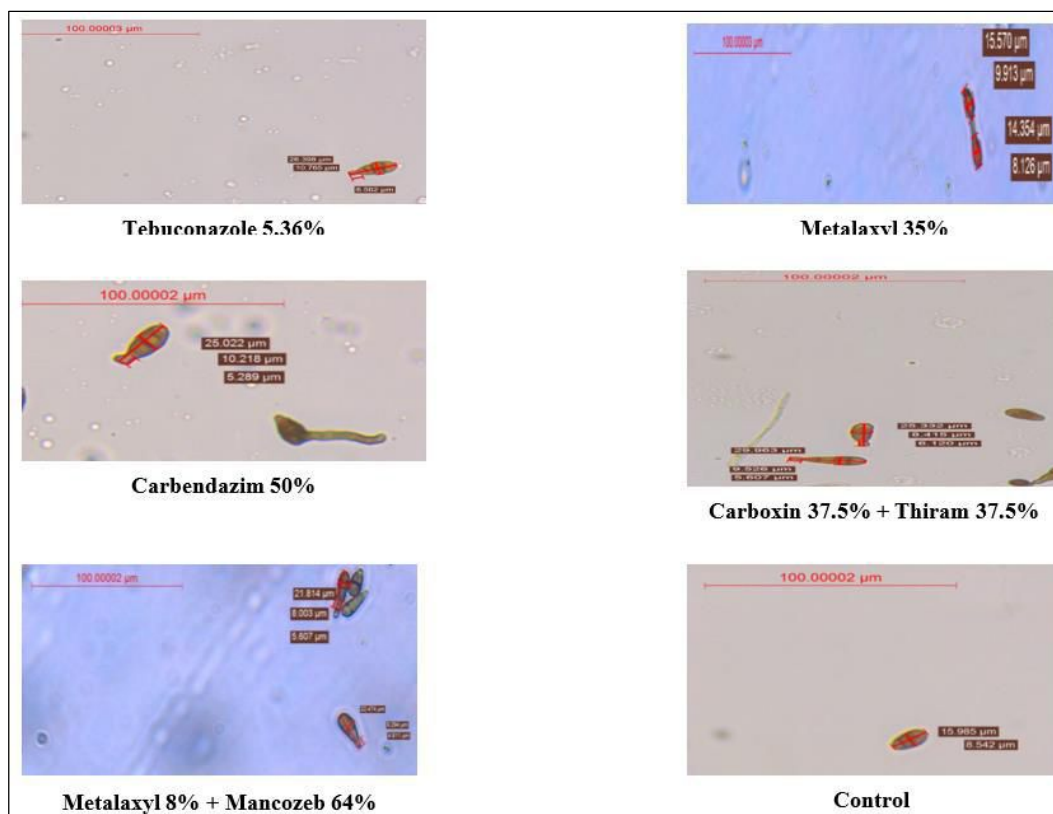


Plate 5: Conidial characterization of *A. tenuissima* as influenced by 100 ppm of fungicides (10 x 10 X)

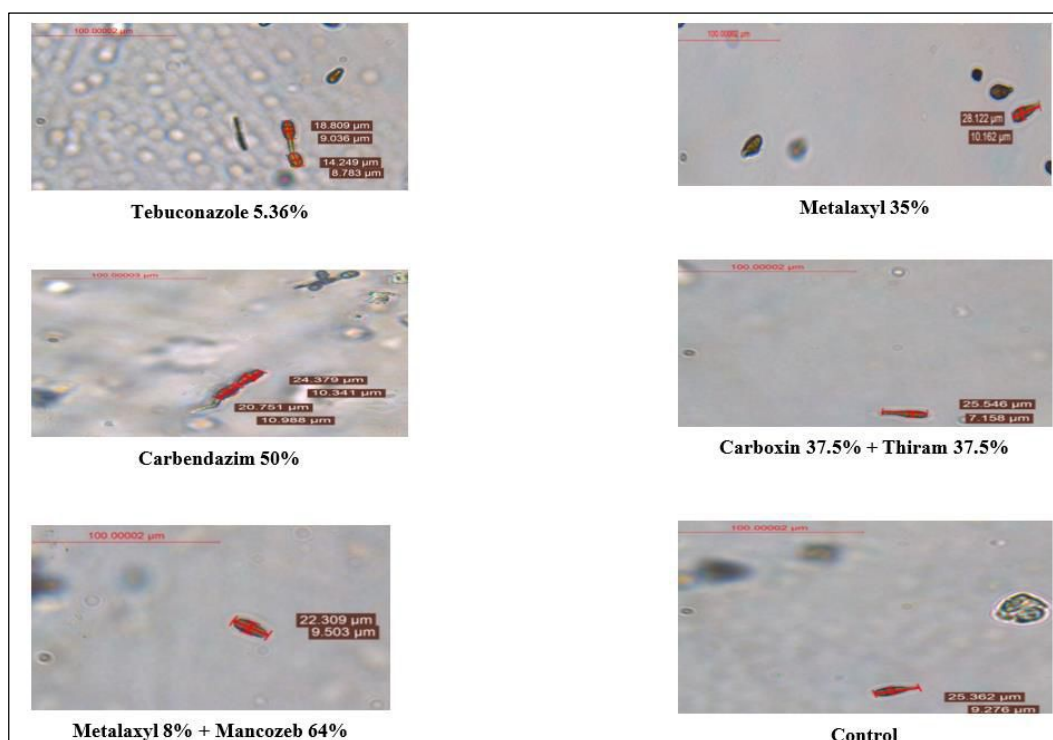


Plate 6: Conidial characterization of *A. tenuissima* as influenced by 250 ppm of fungicides (10 x 10 X)

Discussion: Eight different available plant extracts viz., garlic (*Allium sativum*), ginger (*Zingiber officinale*), Aloe vera, Marigold (*Tegetes erecta*), turmeric (*Curcuma longa*), Neem (*Azadiracta indica*), Congress grass (*Parthenium hysterophorus*) and Aak (*Calotropis procera*) were tested against the pathogen, i.e., *A. tenuissima* check their antifungal activity at 5% and 10% concentrations. Among these botanicals tested garlic (*Allium sativum*) showed the

best inhibition at both the concentrations. Garlic exhibits a notable antifungal activity against fungi, perhaps due to the presence of different sulfur compounds such as alliin and allicin, vinylthiines, sallycysteine, ajoene, and others. In addition, there are minerals like selenium and enzymes like myrosinase, peroxidases and allinase. Similar activity of garlic has been reported by some authors regarding anti-fungal activity [10, 11, 12, 13]. In order to evaluate the effective

fungicide against leaf blight causing pathogen, different fungicides were tested viz., Tebuconazole 5.36%, Metalaxyl 35% WS, Carbendazim 50% WP, Carboxin 37.5% + Thiram 37.5% DS, Carbendazim 12% + Mancozeb 63% WP, Metalaxyl 8% + Mancozeb 64% WP and Difenconazole

25% EC. These were tested at 100, 250 and 500 ppm, among them Difenconazole 25% EC gave the best results 69.5%, 71.9%, and 84.7% at 100, 250 and 500 ppm respectively. Same findings were given by some researchers [14, 15, 16].

Table 1: Name of plants tested, plant part, their doses and formulations

Treatment Code	Treatments		Part Used	Concentration
	Common Name	Botanical Name		
T ₁	Garlic	<i>Allium sativum</i>	Clove	5%, 10%
T ₂	Ginger	<i>Zingiber officinale</i>	Rhizome	5%, 10%
T ₃	<i>Aloe vera</i>	<i>Aloe vera</i>	Leaves	5%, 10%
T ₄	Marigold	<i>Tagetes erecta</i>	Leaves	5%, 10%
T ₅	Turmeric	<i>Curcuma longa</i>	Rhizome	5%, 10%
T ₆	Neem	<i>Azadiracta indica</i>	Leaves	5%, 10%
T ₇	Congress grass	<i>Parthenium hysterophorus</i>	Leaves and flowers	5%, 10%
T ₈	<i>Calotropis</i>	<i>Calotropis procera</i>	Leaves	5%, 10%
T ₉	Control	-	-	-

Table 2: Name of fungicides, their doses and formulation

Treatment Code	Treatments	Concentration (in ppm)
	Fungicides Used	
T ₁	Tebuconazole 5.36%	100, 250, 500
T ₂	Metalaxyl 35% WS	100, 250, 500
T ₃	Carbendazim 50% WP	100, 250, 500
T ₄	Carboxin 37.5% + Thiram 37.5% DS	100, 250, 500
T ₅	Carbendazim 12% + Mancozeb 63% WP	100, 250, 500
T ₆	Metalaxyl 8% + Mancozeb 64% WP	100, 250, 500
T ₇	Difenconazole 25% EC	100, 250, 500
T ₈	Control	-

Table 3: Effect of plant extracts (5% and 10%) on mycelial growth of *Alternaria tenuissima*

S. No.	Botanicals	5%			10%		
		Radial growth (mm) after (hrs)	Per cent Inhibition	Sporulation Index	Radial growth (mm) after (hrs)	Per cent Inhibition	Sporulation Index
		216 (hrs)			216 (hrs)		
1.	Garlic	46.3	45.5%	+	41.5	51.1%	-
2.	Ginger	76.8	9.6%	+	71.5	15.8%	-
3.	<i>Aloe vera</i>	83.3	2.0%	+++	66.5	21.7%	+
4.	Marigold	82.5	2.9%	+++	80.0	5.8%	+++
5.	Turmeric	80.0	5.8%	+++	63.2	25.6%	-
6.	Neem	82.0	3.5%	+	59.7	29.7%	-
7.	<i>Parthenium</i>	83.0	2.3%	+	74.0	12.4%	-
8.	<i>Calotropis</i>	82.0	3.2%	++	70.0	17.5%	+
9.	Control	85.0	-	++++	85.0	-	++++
	SEm±	0.870	-		0.868		
	CD (5%)	2.610	-		2.599		

Table 4: Conidial characteristics of *Alternaria tenuissima* as influenced by (5%) of plant extracts

S. No.	Botanicals	Length of conidia		Width of conidia		Range of longitudinal septa	Range of transverse septa
		Range	Mean	Range	Mean		
1	Garlic	17.43-44.39	28.34	8.33-12.09	9.42	1-4	0-1
2	Ginger	13.58-22.52	16.81	9.53-10.59	9.84	2-3	1-2
3	<i>Aloe vera</i>	21.60-40.11	33.05	9.75-16.87	12.54	2-4	1-2
4	Marigold	16.77-30.26	22.38	6.49-10.98	9.26	1-4	0-2
5	Turmeric	28.73-43.37	34.82	8.96-13.55	10.80	1-4	0-1
6	Neem	21.86-34.23	26.39	11.13-12.29	11.79	0-3	0-2
7	<i>Parthenium</i>	23.59-42.33	28.90	9.70-11.80	10.95	3-5	0-2
8	<i>Calotropis</i>	24.07-35.61	28.75	8.35-11.59	10.41	3-6	0-2
9	Control	18.29-38.43	30.83	10.58-11.72	11.21	2-4	0-1

Table 5: Conidial characteristics of *Alternaria tenuissima* as influenced by (10%) of plant extracts

S. No.	Botanicals	Length of conidia		Width of conidia		Range of longitudinal septa	Range of transverse septa
		Range	Mean	Range	Mean		
1	Garlic	-	-	-	-	-	-
2	Ginger	-	-	-	-	-	-
3	<i>Aloe vera</i>	10.60-12.84	11.66	3.14-5.14	4.34	3-5	0-2
4	Marigold	-	-	-	-	-	-
5	Turmeric	-	-	-	-	-	-
6	Neem	-	-	-	-	-	-
7	<i>Parthenium</i>	-	-	-	-	-	-
8	<i>Calotropis</i>	26.52-44.54	35.17	11.15-14.97	12.81	2-4	-
9	Control	23.10-34.23	28.29	5.25-10.72	8.60	2-4	0-2

Table 6: Effect of fungicides (100, 250 and 500 ppm) on mycelial growth of *Alternaria tenuissima*

S. No.	Fungicides	100 ppm			250 ppm			500 ppm		
		Radial growth (mm) after (hrs)	Per cent Inhibition	Sporulation Index	Radial growth (mm) after (hrs)	Per cent Inhibition	Sporulation Index	Radial growth (mm) after (hrs)	Per cent Inhibition	Sporulation Index
		192 (hrs)			192 (hrs)			192 (hrs)		
1.	Tebuconazole 5.36%	45.8	45.5%	++	27.3	67.8%	+	26.0	69.4%	-
2.	Metalaxyl 35%	77.3	8.08%	+	61.1	28.0%	+	56.8	33.1%	-
3.	Carbendazim 50%	77.3	8.08%	+	66.6	21.5%	+	68.6	19.2%	-
4.	Carboxin 37.5% + Thiram 37.5%	71.8	14.6%	+++	67.6	20.3%	+++	61.3	27.8%	-
5.	Carbendazim 12% + Mancozeb 63%	75.0	10.8%	-	71.1	16.2%	-	67.3	20.7%	-
6.	Metalaxyl 8% + Mancozeb 64%	70.5	16.1%	+	64.0	24.6%	+	60.0	29.4%	-
7.	Difenoconazole 25%	25.6	69.5%	-	23.8	71.9%	-	13.3	84.7%	-
8.	Control	84.1	-	++++	84.9	-	++++	85.0	-	++++
	SEM±	1.347			0.812			1.113		
	CD (5%)	4.072			2.456			3.364		

Table 7: Conidial characteristics of *Alternaria tenuissima* as influenced by (100 ppm) of fungicides

S. No.	Fungicides	Length of conidia		Width of conidia		Range of longitudinal septa	Range of transverse septa
		Range	Mean	Range	Mean		
1	Tebuconazole 5.36%	17.33-26.39	21.76	6.97-10.76	8.89	1-3	0-1
2	Metalaxyl 35%	10.65-15.57	12.81	4.12-9.91	7.34	1-2	-
3	Carbendazim 50%	24.51-29.96	27.51	8.41-13.16	10.08	2-3	0-1
4	Carboxin 37.5% + Thiram 37.5%	13.77-25.86	22.64	8.22-10.94	9.78	1-3	0-2
5	Carbendazim 12% + Mancozeb 63%	-	-	-	-	-	-
6	Metalaxyl 8% + Mancozeb 64%	11.09-28.09	20.13	7.04-9.29	8.47	1-3	0-1
7	Difenoconazole 25%	-	-	-	-	-	-
8	Control	15.98-21.89	20.42	8.54-9.44	9.03	2-3	-

Table 8: Conidial characteristics of *Alternaria tenuissima* as influenced by (250 ppm) of fungicides

S. No.	Fungicides	Length of conidia		Width of conidia		Range of longitudinal septa	Range of transverse septa
		Range	Mean	Range	Mean		
1	Tebuconazole 5.36%	12.28-18.80	16.27	8.78-12.20	10.08	1-2	-
2	Metalaxyl 35%	17.00-28.122	22.26	8.50-10.55	9.67	2-3	0-1
3	Carbendazim 50%	20.751-26.53	23.77	9.02-14.53	11.19	2-3	0-1
4	Carboxin 37.5% + Thiram 37.5%	19.58-28.00	24.17	6.35-9.56	7.70	2-3	0-1
5	Carbendazim 12% + Mancozeb 63%	-	-	-	-	-	-
6	Metalaxyl 8% + Mancozeb 64%	18.74-32.55	24.90	7.15-9.50	8.80	2-3	0-1
7	Difenoconazole 25%	-	-	-	-	-	-
8	Control	19.87-31.00	26.54	7.28-9.54	8.25	1-3	-

Table 9: Conidial characteristics of *Alternaria tenuissima* as influenced by (500 ppm) of fungicides

S. No.	Fungicides	Length of conidia		Width of conidia		Range of longitudinal septa	Range of transverse septa
		Range	Mean	Range	Mean		
1	Tebuconazole 5.36%	-	-	-	-	-	-
2	Metalaxyl 35%	-	-	-	-	-	-

3	Carbendazim 50%	-	-	-	-	-	-
4	Carboxin 37.5% + Thiram 37.5%	-	-	-	-	-	-
5	Carbendazim 12% + Mancozeb 63%	-	-	-	-	-	-
6	Metalaxyl 8% + Mancozeb 64%	-	-	-	-	-	-
7	Difenoconazole 25%	-	-	-	-	-	-
8	Control	18.60-27.31	23.34	8.50-10.03	9.48	2-3	0-2

Conclusion

Eight plants extracts-garlic, ginger, *Aloe vera*, marigold, turmeric, neem, congress grass and *Calotropis* as well as a control were included in our experiment at 5% and 10% concentrations respectively. The best inhibition was obtained by the aqueous extract of garlic at 5% and 10%, 45.5% and 51.1%, respectively, with low and no conidial production. The following fungicides were also applied and tested against *A. tenuissima* at 100, 250, and 500 ppm: Tebuconazole 5.36%, Metalaxyl 35% WS, Carbendazim 50% WP, Carboxin 37.5% + Thiram 37.5% DS, Carbendazim 12% + Mancozeb 63% WP, Metalaxyl 8% + Mancozeb 64% WP and Difenoconazole 25% EC. With no conidial generation, the best outcomes were obtained with dose of Difenoconazole 25% EC with inhibition of 69.5%, 71.9%, and 84.7% at 100, 250 and 500 ppm.

Acknowledgements

The authors thank College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur – 482004, India for supporting the research.

References

- De Wet JM, Prasad Rao KP, Mangesha MH, Brink DE. Diversity in Kodo Millet, *Paspalum scrobiculatum*. Economic Botany. 1983; 37(2):159-163. ISSN 0013-0001. <http://dx.doi.org/10.1007/BF02858779>.
- Hariprasanna K. Small millets in India: Current scenario and way forward. Indian farming. 2023; 73(1):38-41. <https://epubs.icar.org.in/index.php/IndFarm/article/view/132568>.
- NAAS. Role of millets in nutritional security of India. Policy paper No. 66. National Academy of Agricultural Sciences, New Delhi. 2013; 16p.
- Rajalakshmi P, Devanathan R, Sahayam SC. Special medicinal implications of navadhyanyam. International Journal of Pharmaceutical and Clinical Research. 2014; 6(1):54-62.
- Sharma S, Saxena J. *Paspalum scrobiculatum* as nutraceutical, its health benefits and phytochemistry: A review. Inventi Rapid: Nutraceuticals. 2014; 2015(1):1-3.
- Nagaraja A, Kumar J, Jain AK, Narasimhudu Y, Raghuchander T, Kumar B, Hanumanthe Gowda B. Compendium of small millets diseases. Project Coordinator (Small Millets), P.C. Cell, All India Coordinated Small Millets Improvement Project, ICAR, GKVK Campus, Bangalore –560 065, India. 2007; Pp 1-76.
- Nagaraja A, Kumar B, Jain AK, Sabalpara AN. Emerging diseases: Need for focused research in small millets. Journal of Mycopathological Research. 2016; 54(1):1-9.
- Nene YL, Thaplial PN. Fungicides in Plant Disease Control (3rd Edition). Oxford & IBH Publishing Company Pvt. Ltd., Calcutta. pp. 1993; 144-146. ISBN: 9781881570226, 1881570223.
- Vincent JM. Distortion of fungal hyphae in the presence of certain inhibitors. Nature. 1947; 159:850.
- Raja P. Fungitoxic properties of plant extracts against *Alternaria tenuissima*: new sp. infecting eggplant in India. Indian Phytopathology. 2010; 63(1):45-46. <https://epubs.icar.org.in/index.php/IPPJ/article/view/11042>.
- Roopa P, Fugro PA, Kadam JJ. Symptomatology, host range study and management by botanicals against *Alternaria alternata* of *Canna indica* (Fr.) Keissler. International Journal of Life Sciences Biotechnology and Pharma Research. 2014; 3(2):116-120.
- Rani N, Lal HC, Kumar P, Ekka S and Kumar N. *In-vitro* evaluation of fungicides, bioagents and plant extracts against *Alternaria* sp. infecting pigeonpea. International Journal of Current Microbiology and Applied Sciences. 2018; 7:5112-5118.
- Chaudhary S, Singh HK. *In-vitro* evaluation of different botanicals against *Alternaria alternata* causing Alternaria leaf spot of ber (*Zizyphus mauritiana* Lamk.). International Journal of Economic Plants. 2021; 8(1):40-44. <http://dx.doi.org/10.23910/2/2021.0407>.
- Kantwa SL, Tatarwal JP, Shekhawat KS. *In vitro* effect of fungicides and phyto-extracts against *Alternaria alternata* causing leaf blight of groundnut. IOSR Journal of Agriculture and Veterinary Science. 2014; 7(6):28-31. <http://www.iosrjournals.org/>.
- Parmar KA, Pathak DM. *In vitro* evaluation of fungicides and phytoextracts against *Alternaria tenuissima*-an incitant of pigeonpea [*Cajanus cajan* (L.) Millsp.] leaf blight. International Journal of Plant Protection. 2019; 12 (2): 94-97. DOI:10.15740/HAS/IJPP/12.2/94-97.
- Kumar D, Singh HK, Maurya MK. Inhibitory effect of phytoextracts and fungicides against *Alternaria alternata* causing Alternaria leaf spot of ber. Environment and Ecology. 2022; 40(2B): 716-720.