Int.J.Curr.Microbiol.App.Sci (2017) *6*(10): 2387-2404

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 10 (2017) pp. 2387-2404**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.610.282

Management of Seed-Borne Diseases of Sesame through Novel Seed Dressing Fungicides, Botanicals and Bio-Agents

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Keywords

Sesame, Seed borne fungi, Seed dressing fungicides, Botanicals and bio-agents.

Article Info

Accepted:
21 September 2017
Available Online:
10 October 2017

A B S T R A C T

Sesame is as an important oilseed crop and the diseases are taking heavy toll of the productivity. The seed borne organisms not only reduce the quality but also have an effect on germination. In view of these, understanding of seed borne mycoflora, their detection and management are important. The present investigation on management of seed-borne diseases of sesame through novel seed dressing fungicides, botanicals and bio-agents is undertaken during 20012-13 at Department of Plant Pathology, College of Agriculture, Bijapur, UAS, Dharwad. Among nine seed dressing fungicides evaluated against *A. sesami* by poisoned food technique, hexaconazole was found statistically superior over other treatments. Among the six plant extracts tested against *A. sesami*, maximum inhibition of mycelial growth was noticed in *Allium sativum* L. at 5%. However, at 10 per cent concentration, *Zingiber officinal.* Among the six bio-agents, maximum reduction in colony growth of *A. sesami* was observed in *T. harzianum* and was superior to all the other bioagents tested. Among the nine treatments of fungicides, botanicals and bio-agent by rolled towel method, the hexaconazole exhibited least per cent seed infection.

Introduction

Sesamum or otherwise called as sesame, (*Sesamum indicum* L.) locally called as *til*, belongs to family Pedaliaceae, originated from East Africa. Sesame oil is known for its excellent nutritional, medicinal, cosmetic and cooking qualities for which it is considered as 'the queen of oils' in the West and in Tamil as '*nallennai*' meaning good oil.

A large proportion of sesame is used for producing edible oil, while purely white sesame seeds are in demand on conventional markets due to their higher oil content. Sesamum oil is used for manufacturing perfumed oils and for medicinal purposes.

Sesamum cake is a rich source of protein, carbohydrates and mineral nutrients such as calcium and phosphorous. It is also a valuable and nutritious feed for milch cattle.

Due to the presence of potent antioxidants (sesamolin and sesamol) which makes the oil to be one of the most stable oils in the world and the sesame. Seeds are called as 'the seeds of immortality'. Sesame is known as "Queen of oil seeds" because seeds have high quality poly unsaturated stable fatty acids (PuFA). Moreover, seeds are rich source of edible oil (48-55%) and protein (20-28%) consisting both methionine and tryptophan, vitamin

(niacine) and minerals (calcium and phosphorus) (Bedigian *et al.*, 1985).

According to Ayurveda, the sesame seeds have aphrodisiac, demulcent, diuretic, emmenagogue, emollient, galactogogue, laxative, rejuvinative and tonic action. It is useful for treating amenorrhea, burns, cholera, constipation, cough, dysentery, dysmenorrheal, gonorrhea, hemorrhoids, scalds, ulcers, wounds, etc.

In Karnataka and Maharashtra during Makar Sankranti festival, people exchange pieces of sugarcane, a mixer of fried til (sesame seeds), pieces of dry coconut, peanuts and fried gram or muticoloured tilguls made from til seeds and sugar and greet with the words '*ellu bella thindu, olle maathu aaduva*' (Kannada - eat sesame seeds and speak only good); '*til-gul ghya, god bola'* (marathi- accept these tilguls and speak sweet words). This signifies the cultural attachment of people with sesame in India.

Sesame is the sixth important oil seed crop in the world with an area of 7.78 m ha and a total production of 3.15 m t and an average yield of 405 kg per ha. Sesame is extensively cultivated in India, China, Myanmar, Sudan, Nigeria, Mexico, and to a small extent in Ethiopia, Uganda, Venezuela and Turkey (Anon., 2005).

In India, sesame occupies an area of about 1834.5 m ha with a production of 7.70 m t with a productivity of 303 kg per ha. Sesame is cultivated in marginal and submarginal areas as a rainfed crop throughout the country. Mainly grown in the states of Rajasthan, Gujarat, West Bengal, Madhya Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, Uttar Pradesh and Orissa.

In Karnataka, sesame is grown over an area of 67 ha with a production of 31,000 tonnes with a productivity of 407 kg per ha. The acreage and production of sesame is declining in the traditional sesame growing areas due to several yield limiting factors like biotic and abiotic stresses (Anon., 2011).

Sesame is resistant to drought and tolerant to insect pests but it is susceptible to diseases like *Alternaria* and *Cercospora* leaf spots, powdery mildew and phyllody due to phytoplasma etc. Seed borne mycoflora are carried over by infected seeds and they cause deterioration in seed, in soil affecting germination, causing seedling mortality and further infection of foliage is observed at adult stage. Fungi including *Alternaria*, *Curvularia*, *Fusarium*, *Helminthosporium*, *Penicillium*, *Mommoniella* and *Rhizophus* sp. have been found associated with sesame seeds (ISTA, 1999).

Among these, *Alternaria* is the most destructive pathogen of sesame; as it produces small brown spots on leaf ranging from 1-8 mm in diameter.

It reduces the viability of seeds and the seed borne pathogens are the most disastrous as they reduce the seed vigour and weaken the plant at the initial growth.

In view of the seed borne pathogens, causing substantial damage and to study the different aspects of the fungal pathogens and their effects on seed the following objectives were formulated.

Materials and Methods

The present investigations were carried out in the plant pathology laboratory of College of Agriculture, Bijapur of University of Agricultural sciences, Dharwad during 2012-13. The details of materials used and the methodology followed in conducting the experiments are presented here under.

General laboratory procedure

Glassware cleaning

Borosil and Corning glassware were used for all the laboratory experimental studies. They were kept for a day in the cleaning solution containing 60 g potassium dichromate, 60 ml of concentrated sulphuric acid, in one liter of water. Then they were cleaned by washing with detergent solution followed by rinsing several times in tap water and finally with distilled water.

Sterilization

All glassware used in the studies were sterilized in autoclave at 1.1 kg/cm pressure for 20 min and kept in hot air oven at 60º C for one hour. Both solid and liquid media were sterilized at 1.1 kg /cm pressure for 15 min.

Management strategies to overcome seed borne fungal infections of sesame

Evaluation of seed dressing fungicides

This study was carried out to know the efficacy of different seed dressing fungicides in eliminating the seed-borne fungal infections in the infected seed sample of sesame (variety E -8). The fungicides were tested initially under *in vitro* condition by following using poisoned food technique (Nene and Thapliyal, 1973) and rolled towel method.

The trade name and common name of fungicides used in the experiment are given below.

In vitro evaluation of fungicides against *A. sesami* by poisoned food technique

All the systemic fungicides were tested at 0.025, 0.05 and 0.1 per cent and combi products were tested 0.05, 0.1, 0.2 per cent concentration by adopting poisoned food technique. In this technique the fungus *A. sesami* was grown on potato dextrose agar medium in Petriplates for seven days prior to setting up of experiment. The fungicidal suspension was added to the melted potato dextrose agar medium to obtain the desired concentration on the basis of active ingredients present in the chemical. Twenty ml of poisoned medium was poured in each sterilized Petri plates. Suitable checks were maintained without addition of fungicides. Five mm mycelial disc taken from the periphery of seven days old colony was placed in the centre and incubated at 25 ± 2ºC for full growth of the fungus. Four replications were maintained for each treatment, the diameter of the colony growth was measured in two directions after seven days of inoculation at which maximum growth was observed in control and average was recorded. Per cent inhibition was calculated by using the following formula given by Vincent (1947).

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

Where,

I = Per cent inhibition
C = Growth in control
T = Growth in treatment

Evaluation of plant extracts

This study was carried out to know the efficacy of different plant extracts in eliminating the seed-borne fungal infections in infected seed sample, of sesame cultivar E-8. Six commonly available plants parts as mentioned below were collected and used for extraction. The plant extracts were tested initially under *in vitro* condition by following poisoned food technique.

In vitro evaluation of plant extracts against *A. sesami* by poisoned food technique

Preparation of cold aqueous extract

Fresh plant materials were collected and washed first in tap water and then in distilled water. One hundred grams of fresh sample was chopped and then crushed in a surface sterilized pestle and mortar by adding 100 ml sterile water (1:1 w/v). The extract was filtered through two layers of muslin cloth and was used as stock solution.

To study the antifungal mechanism of plant extract, the poisoned food technique was followed (Nene and Thapliyal, 1973). Five and ten ml of stock solution was mixed with 95 and 90 ml of sterilized molten PDA media, respectively so as to get 5 and 10 per cent concentration. The medium was thoroughly shaken for uniform mixing of extract Twenty ml of medium was poured into sterile Petri plates.

Mycelium of 5 mm size disc from periphery of actively growing culture were cut out by sterile cork borer and one such disc was placed on the centre of each agar plate. Control was also maintained by growing the pathogen on PDA plates. Each treatment was replicated thrice and plates were incubated at 25 ± 2ºC till control plates reached the radial growth of 90 mm. The per cent inhibition over control was calculated according to the formula given by Vincent (1947).

In vitro evaluation of bio-agents against *A. sesami* by dual culture technique

The antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., *Bacillus subtilis* Cohn. were evaluated for their antagonistic effect under *in vitro* condition against *A. sesami* by dual culture technique. The cultures of antagonistic microorganisms used in the present study were obtained from the National Bureau of Agriculturally Important Insects (NBAII), Bangalore, Karnataka.

In dual culture, 20 ml of sterilized and cooled potato dextrose agar was poured in to sterile Petri plates and allowed to solidify. Fungal antagonist was evaluated by inoculating the pathogen at one side of Petri plate and the antagonist was inoculated at exactly opposite side of the pathogen by leaving 3-4 cm gap. For this actively growing cultures were used.

In case of evaluation of bacterial antagonist, two mycelial discs of the pathogens were inoculated and bacterial antagonist was streaked in the centre of the plate. Each treatment was replicated three times. After required period of incubation *i.e.*, after control plates reached 90 mm diameter, the radial growth of pathogen was measured. Per cent inhibition over control was worked out according to formula given by Vincent (1947) (Fig. 4).

In vitro evaluation of fungicides, botanicals and bio-agent by rolled towel method.

Seeds were treated with fungicides by following wet seed treatment with 0.2 per cent concentration of the fungicidal solution. Seeds were soaked in the fungicidal solution for two hrs. Then the seeds were dried under shade. Four replications of 100 seeds per treatment were tested in moist paper towel (rolled towel) method as described earlier and then incubated in BOD incubator at 25 ± 2ºC for six days under 12 hrs of light and 12 hrs of darkness. The untreated samples served as control. The per cent germination and per cent infection were recorded after six days of incubation. Vigour index was calculated as stated earlier.

In each treatment, 20 g seeds of sesame variety E - 8 were soaked in 100 ml of 5 &10 per cent concentration plant extract for two hours and dried in shade for two hours. Seeds soaked in sterile distilled water served as control.

The treated seeds were tested in four replications of 100 seeds by employing rolled paper towel method and then incubated at 25 ± 2ºC for six days under 12 hrs light and 12 hrs darkness. Per cent infection and per cent germination were recorded after six days of incubation. Seedling vigour was also calculated as stated earlier.

The powder formulations of antagonists *viz*., *T. viride*, *T. harzianum* and *P. fluorescens* were taken for seed treatment to test their efficacy in overcoming seed-borne fungal infections of sesame under *in vitro* condition by rolled towel method. Seeds of sesame variety E -8 were treated with different bio-agent at the rate of one per cent concentration. The seeds were shaken along with bio-agent for 20 min in mechanical shaker for uniform application and then stored in separate boxes for two hrs.

The treated seeds were tested in four replications of 100 seeds by employing rolled paper towel method. Seeds without treatment served as control. These paper towel were incubated at 25±2 ºC for six days under 12 hrs light and 12 hrs darkness. After six days of incubation, per cent germination, per cent infections were recorded and seedling vigor was calculated as stated earlier.

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Results and Discussion

Management strategies for overcoming seed borne infections of sesame

Evaluation of fungicides

In vitro evaluation of fungicides by poisoned food technique

Efficacy of nine seed dressing fungicides were tested against *A. sesami* at three concentrations by employing poisoned food technique as explained under 'Material and Methods'. Observations on colony diameter of the fungus was recorded when the growth in after seven days of incubation. The per cent inhibition of the growth of fungus at three concentrations over control was calculated and the results are presented in Tables 1 and 2.

The results indicated that, the meximum inhibition of the mycelial growth of the pathogen was observed in hexaconazole at 0.025 per cent (85.18%) which was statistically superior over other treatments and was followed by propiconazole (81.85%). Least inhibition of mycelial growth was observed in diffenconazole at 0.025 per cent

(77.03%). The mean values were also calculated for 0.025, 0.05 and 0.1%, accordingly, again hexaconazole was found statistically superior (86.90 %) over other treatments. Propiconazole was found as the next best fungicide (85.20%) (Fig. 1).

Management strategies

Evaluation of fungicides

In the absence of resistant variety, use of fungicides is an alternate practice to control the disease. Seed treatment with fungicide gives maximum protection against seed borne disease like Alternaria leaf spot of sesame, which can spread through infected seed allowing establishment of pathogen in pathogen free area. *In vitro* evaluation of new synthetic molecules of seed dressing fungicides is very much necessary before they are taken to field testing. In the present study, nine seed dressing fungicides were tested for their efficacy in overcoming seed-borne infection of *A. sesami* along with other seed contaminants both by poisoned food technique and rolled towel method.

In vitro evaluation of fungicides by poisoned food technique

Among the different systemic fungicides, the meximum inhibition of the mycelial growth of the pathogen was observed in hexaconazole at 0.025 per cent (85.18%) which was statistically superior over other treatments and was followed by propiconazole (81.85%).

Least inhibition of mycelial growth was observed in diffenconazole at 0.025 per cent (77.03%). The mean values were also calculated for 0.025, 0.05 and 0.1%, accordingly, again hexaconazole was found statistically superior (86.90 %) over other treatments. Propiconazole was found as the next best fungicide (85.20%). Similar studies have been reported other workers also as Mallikarjun (1996), Arunkumar (2006), and Patel and Choudhary (2010) reported the effectiveness of triazoles in inhibiting mycelial growth *A. solani* of tomato.

Among the different concentration of combi products tested against *A. sesami*, avtar at 0.2 per cent (88.88%) was very effective in inhibition of mycelial growth and was statistically superior over other treatments. The next best fungicides were quintal and saaf with an inhibition of 85.92 % and were on par. and Least inhibition of mycelial growth of pathogen was observed in taqat (70.74%) at 0.2 per cent concentration.

The mean values also indicated that avtar was superior with a per cent inhibition of 84.31 followed by saaf and these two fungicides were on par. The next best fungicides were quintal and cabritop with the per cent inhibition of 77.90 and 76.17 respectively. Taqat was least in inhibition of 62.34 per cent. Similar results have been reported by Arunkumar (2008) and Sharma and Gaur (2009) that combi products were effective for seed borne pathogens (Fig. 2).

Evaluation of plant extracts

Generally, synthetic fungicides are used against phytopathogenic fungi. The continuous use of chemical fungicides in the management of plant disease has become a major threat to mankind which often imposes various undesirable side effects (Fig. 3).

Hence, in recent years there has been increased awareness on toxic hazards of chemicals to crops, consumer and environment due to residual phytotoxicity and pollution effect. So screening of plant products for their effective antifungal activity against the pathogen as an alternative is essential to minimize the use of fungicides.

Table.1 Effect of different seed dressing systemic fungicides on the mycelial growth of *A. sesame*

Fungicides	Per cent inhibition at			
	0.025%	**0.05%**	**0.10%**	**Mean**
Hexaconazole 5% EC	85.18 (67.34)*	86.66 (68.55)*	88.88 (70.49)*	86.90 (68.79)*
Difenconazole 25% EC	77.03 (61.34)	81.48 (64.49)	84.44 (66.75)	80.98 (64.19)
Tebuconazole 25% EC	77.77 (61.85)	81.11 (64.21)	84.44 (66.75)	81.10 (64.27)
Propiconazole 25% EC	81.85 (64.77)	86.37 (66.46)	87.40 (69.18)	85.20 (66.80)
Mean	80.45 (63.82)	83.90 (65.92)	86.29 (68.29)	83.55 (66.01)
	Fungicides (F)	**Concentration (C)**		**F × C**
S.Em±	0.91	0.79		1.58
CD at 1 %	2.54	2.21		5.6

*Arcsine transformed values

Table.2 Evaluation of plant extracts against the mycelial growth of *A. sesame*

SI. No.	Botanicals	Plant Part used	Per cent inhibition at		Mean
			5%	10%	
1.	*Azardirachta indica*	Leaf	16.65 (8.36)*	13.74 (5.65)*	15.35 (7.00)*
2.	*Allium sativum*	Clove	27.16 (21.76)	29.17 (27.03)	29.61 (24.39)
3.	*Ocimum sanctum*	Leaf	18.46 (10.23)	21.43 (13.34)	20.08 (11.78)
4.	*Zingiber officinalis*	Rhizome	26.64 (20.76)	24.74 (17.26)	25.69 (19.01)
5.	*Capsicum annum*	Fruit	22.40 (14.73)	24.68 (17.62)	23.72 (16.17)
6.	*Allium cepa* L.	Bulb	24.33 (17.56)	22.13 (15.20)	23.89 (16.38)
		Mean	22.77 (14.97)	28.37 (22.55)	
		Botanicals(B)	**Concentrations(C)**	**B X C**	
	S. Em±	**2.88**	**1.44**	**4.08**	
	CD at 1%	**11.16**	**5.58**	**15.78**	

* Arcsine transformed values

Table.3 Evaluation of antagonists in dual culture against *A. sesame*

Bioagents	**Per cent inhibition**
Trichoderma harzianum	77.50 (61.66)*
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

Table.4 Effect of seed-borne fungal infection on seed quality parameters of sesame

SI. No.	Treatments	Percent seed Infection	Percent seed germination	Vigour index
1.	Garlic	30.33 (33.43)*	70.00 (56.82)	517
2.	Ginger	26.67 (31.11)	74.33 (59.59)	591
3.	Hexaconazole	13.33 (21.42)	89.33 (70.97)	1208
4.	Tebuconazole	30.67 (33.65)	72.00 (58.08)	697
5.	Propiconazole	26.33 (30.89)	74.00 (59.37)	729
6.	*T. harzianum*	21.33 (27.52)	80.67 (63.95)	515
7.	*P. fluoroscencs*	25.00 (30.00)	75.33 (60.03)	828
8.	Avatar72WP (Hexazconazole 4% + Zineb 68%)	14.00 (21.89)	87.67 (69.48)	1027
9.	Taqat 75WP (Captan 70 + Hexaconazole 5%)	25.00 (30.00)	78.33 (62.34)	429
10	Control (untreated seeds)	42.00 (40.41)	57.33 (49.24)	318
	S.Em±	**0.46**	**0.78**	**13.95**
	CD at 1 %	**2.16**	**3.71**	**69.38**

* Arcsine transformed values

Systemic fungicides

Sl.No.	Common Name	Trade name
1.	Hexaconazole	Contaf 5EC
2.	Propiconazole	Tilt 25EC
3.	Difenconazole	Score 25EC
4.	Tebuconazole	Folicur 25EC

Combiproducts

1.	Captan70% +Hexaconazole 5%	Taqat 75 WP
2.	Hexzconazole 4% + Zineb 68%	Avtar 72 WP
3.	Carbendazim 25%+ Iprodione 25%	Quintal 50 WP
4.	Carbendazim 12% +Mancozeb 63%	Saaf 75 WP
5.	Pyraclostrobin 5% + Metiram 55%	Cabriotop 60WG

Evaluation of plant extracts

SI. No.	Botanical name	Common name	Family	Plant part Used
1.	*Azardirachta indica*	Neem	Meliaceae	Leaf
2.	*Ocimum sanctum*	Tulsi	Labiateceae	Leaf
3.	*Allium cepa*	Onion	Liliaceae	Bulb
4.	*Allium sativum*	Garlic	Liliaceae	Clove
5.	*Zingiber officinalis*	Ginger	Zingiberaceae	Rhizome
6.	*Capsicum annuum*	Chilli	Solanaceae	Fruit

Fig.1 Effect of different seed dressing systemic fungicides on the mycelial growth of *A. sesami*

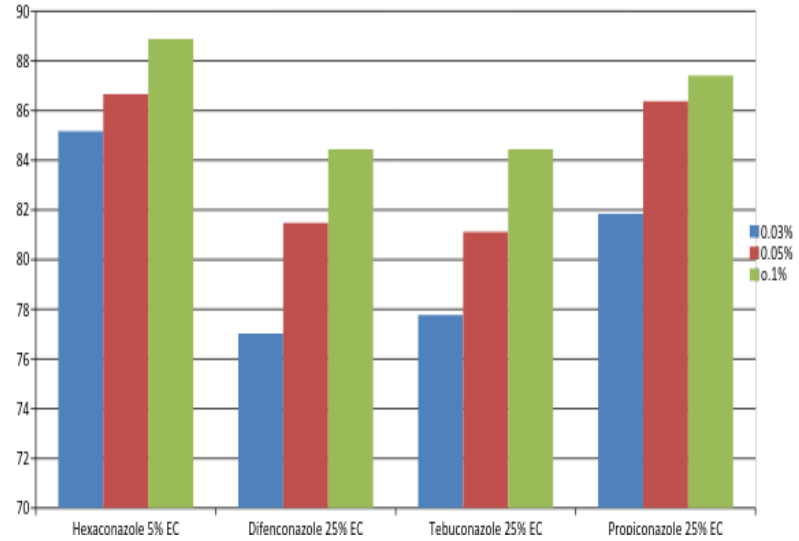


Fig.2 *In vitro* evaluation of combi produts agsainst *A. sesame*

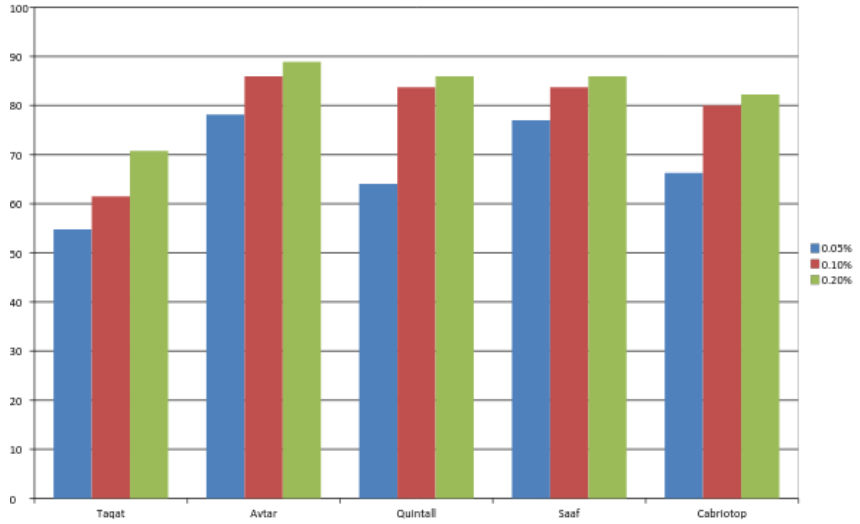


Fig.3 Evaluation of plant extracts against mycelial growth of *A. sesami*

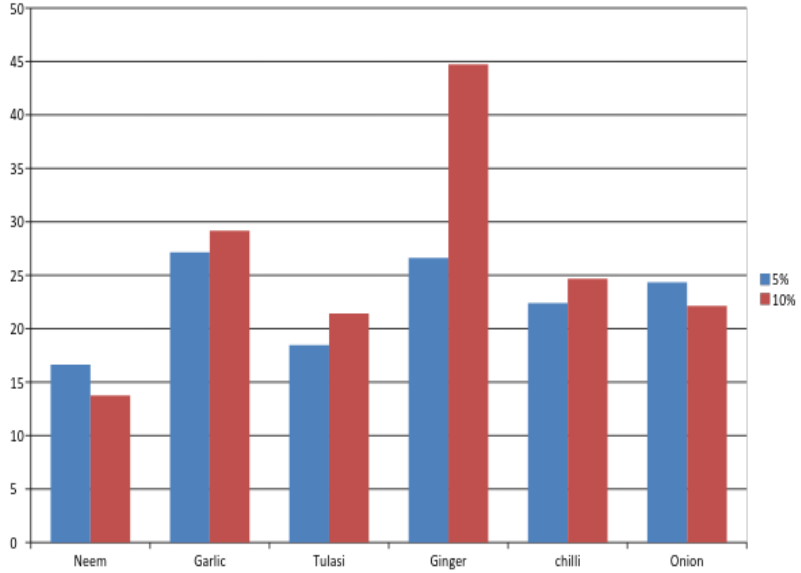


Fig.4 Evaluation of antogonist in dual culture against *A. sesami*

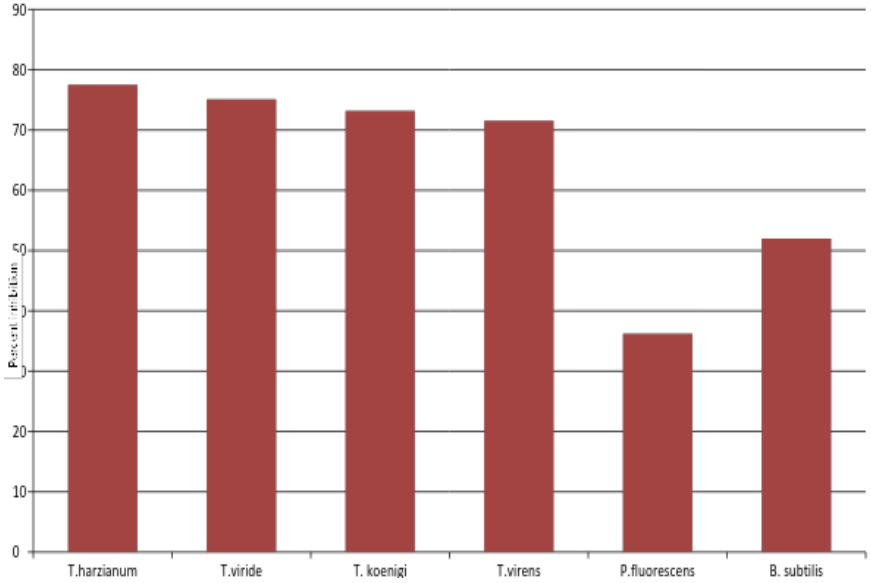


Fig.5 Effect of seed-borne fungal infections on seed quality parameters of sesame

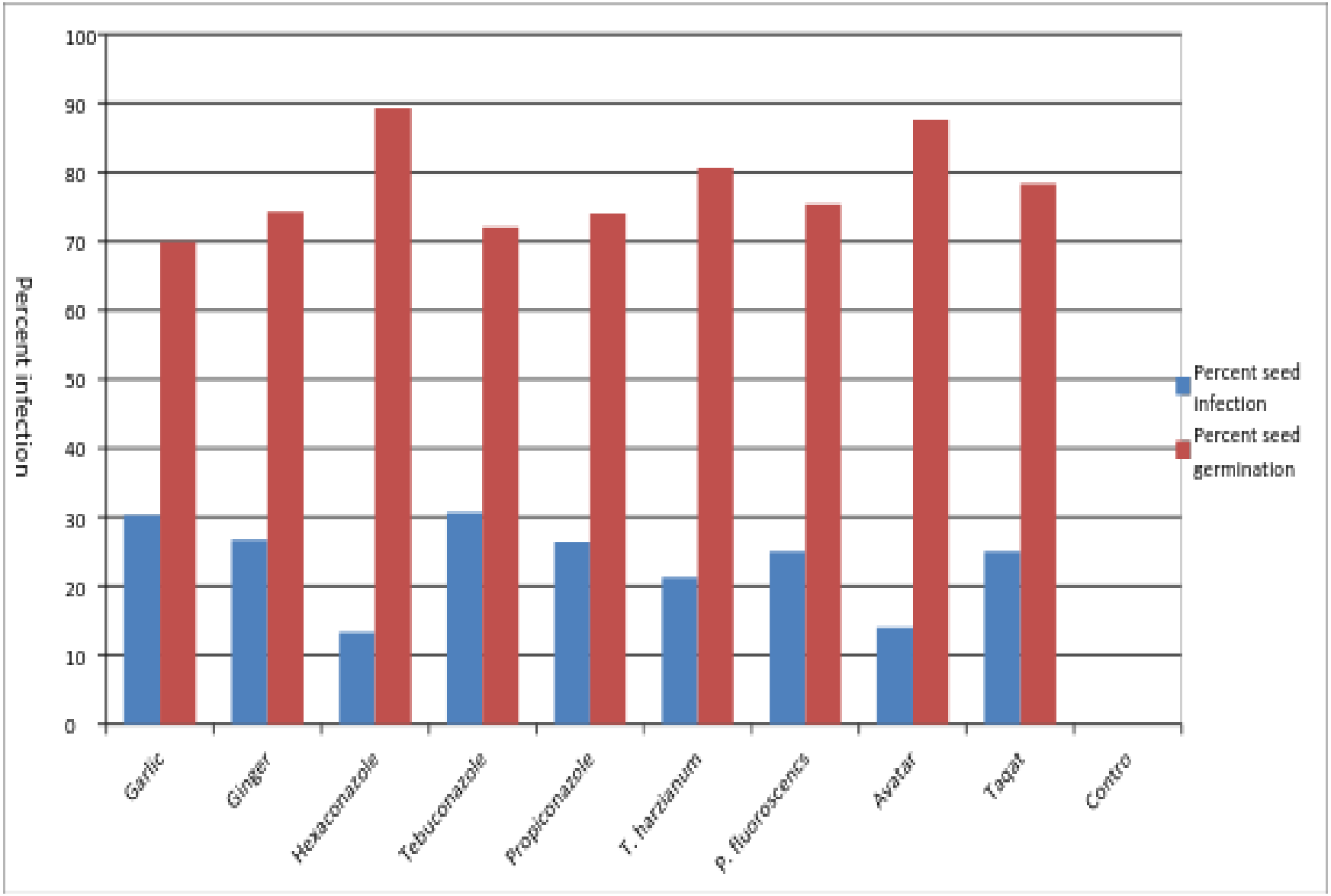


Plate.1 *In vitro* evaluation of seed dressing systemic fungicides on the mycelial growth of *A. sesami.*

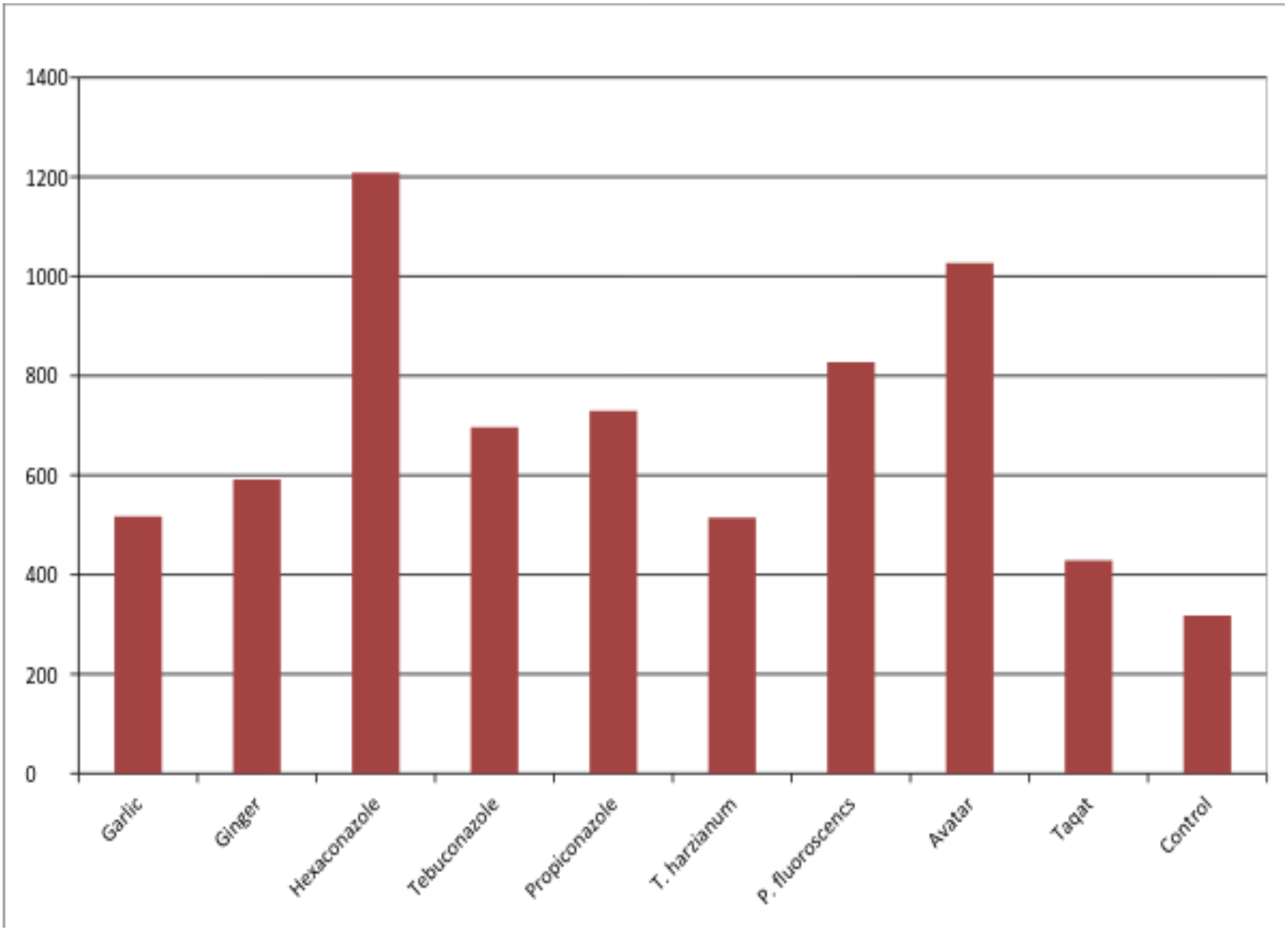


Plate.2 *In vitro* evaluation of combi products against *A. sesami*

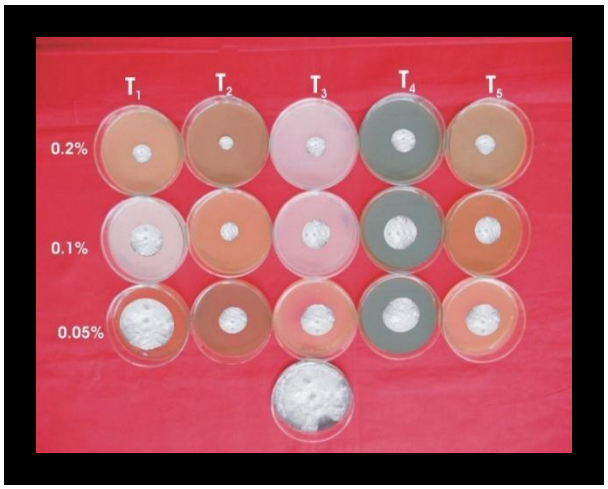
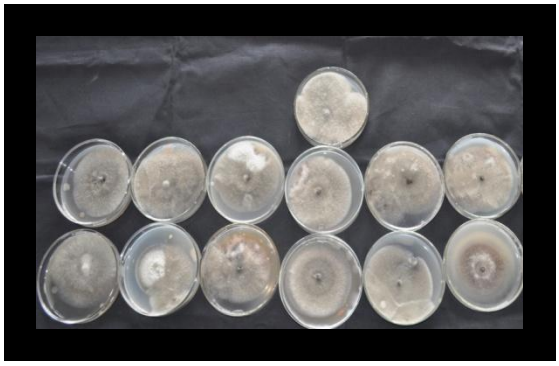
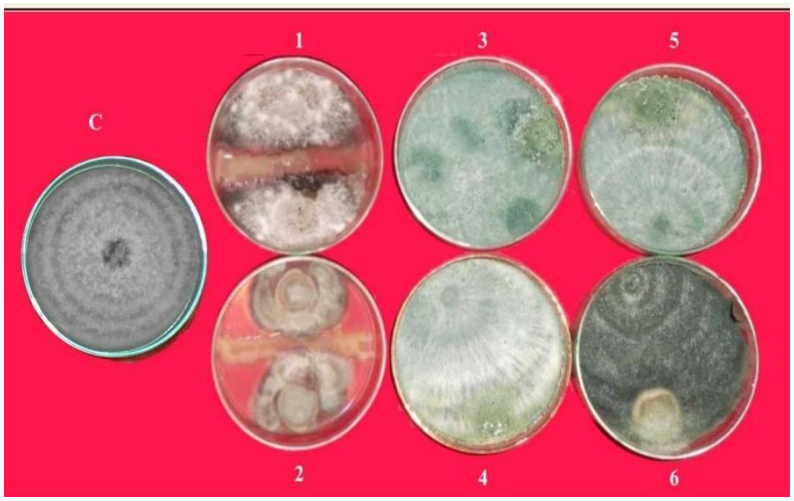


Plate.3 Evaluation of plant extracts against mycelial growth of *A. sesami*



T_1 – Neem,T_2 – Tulasi,T_3 - Onion, T_4 – Garlic, T_5 – Ginger, T_6 – Chilli, C- Control

Plate.4 Evaluation of antagonists in dual culture against *A. sesami*



T_1 – *Bacillus subtilis*, T_2 – *Pseudomonas fluorescens*,T_3 - *Trichoderma koenigii*, T_4 – *Trichoderma harzianum*,T_5 – *Trichoderma viride*,T_6 – *Trichoderma virens*, C- Control

Plate.5 *In vitro* evaluation of fungicides, botanicals and bio-agents against *A. sesami* in sesame

Hexaconazole at 0.2%

Hexazconazole 4% + Zineb 68% at 0.3%

Captan70+Hexaconazole 5% at 0.3%

Garlic at 5%

Control

In the present investigation, different plant species evaluated the for the possible presence of fungal toxic substances against *A. sesami* by using poisoned food technique and rolled towel method under *in vitro* condition for the management of *Alternaria* leaf spot in sesame.

In vitro evaluation of plant extracts by poisoned food technique

Efficacy of six plant extracts was tested against *A. sesami* at two concentrations by poisoned food technique as explained in 'Material and Methods'. Observation on diameter of mycelial growth of the fungus was recorded after seven days of incubation. The per cent inhibition of the growth of the fungus at two concentrations over control was calculated and presented in Table 3. Among the six plant extracts tested against *A. sesami*, maximum inhibition of mycelial growth was noticed in *Allium sativum* L. (27.16 %) followed by *Zingiber officinalis* (26.64%) and they were found statistically significant and on par at 5% concentration. However, at 10 per cent concentration, *Zingiber officinalis* showed 24.74 % inhibiton. *Azardirachta indica* showed least inhibition of mycelial growth at both concentration used i.e., 5% and 10% as 16.65 % and 13.74% respectively.

Among the mean values, *Zingiber officinalis* exhibited 25.69s % inhibition and was statistically superiour over other treatments followed by *Allium sativum* with an inhibition of 29.61 %. *Azardirachta indica* was least effective with an inhibition of 15.35 %.

Muhsin *et al.,* (2001) also recorded a high reduction (or) inhibition of enzymatic activities for fungi (isolated from rhizospheric soil and rhizoplane samples of three plant crops) treated with garlic extract compared with untreated fungal cultures and the growth of the fungal species was remarkably reduced by the garlic extract. The toxicity of *Azadirachta indica* and *Allium cepa* have been tested against *C. capsici* and are found to be effective (Gupta *et al.*, 1981; Mesta, 2006;

Shivapuri *et al.,* 1997; Singh *et al.,* 1997 and Hegde *et al.,* 2002).

Evaluation of bio-agents

Control of seed-borne plant pathogens by application of fungicides often gives viable success with the high cost involvement. Hence, there is a need to search for alternative methods of disese control. Biological control through introduction of microorganisms antagonistic to plant pathogens is one of the important strategy in the management of seed-borne plant pathogens too.

In the present investigation, studies were conducted to know the antagonistic activity of six bio-agents on *A. sesami.*

Among the six bio-agents, maximum reduction in colony growth of *A. sesami* was observed in *Trichoderma harzianum* which gave the highest growth inhibition (77.50%) followed by *T. viride* (75.14%), *T. koningii* (73.19%) and *T. virens* (71.53%) and were found statistically on par. The least growth inhibition of the fungus was observed in *B. subtilis* (52.02%) and *P. fluorescens* (36.22%) and were differed significantly each other.

In general, species of *Trichoderma, viz*. *T. harzianum*, *T. koningii*, *T. viride* and *T. virens* showed more mycelial inhibition of the pathogen compared to bacterial antagonists. This could be obviously attributed to several possibilities of existence of microbial interactions such as higher competitive ability, stimulation and antibiosis by these *Trichoderma* isolates over the test pathogen.

Similar results wherein efficacy of *Trichoderma* spp. against *Alternaria* species have been reported by Deshmukh and Raut (1992), Leifort *et al.,* (1992), Amaresh (2000), Martinez and Solano (1995), Babu *et al.,* (2000a), Kota (2003), Mesta (2006), Rao (2006) and Dalpati *et al.,* (2010).

In vitro evaluation of fungicides, botanicals and bio-agents by rolled towel method.

Among nine treatments, hexaconazole exhibited least per cent infection (13.33%) and was on par with avtar (14.00%). The next best treatment was *T. harzianum* (21.33%) followed by taqat (25.00%), *P. fluorescens* (25.00%) and were on par with each other. Highest per cent infection was recorded in garlic (30.33%) which was on par with ginger (26.67%), propiconazole (26.33%), tebuconazole (30.67%), compared to untreated seeds (42.00%). The hexaconazole (89.33%) and avatar (87.67%) exhibited highest germination and the results were statistically superior over others and were on par. The per cent germination in untreated seeds was 57.33% rest of the other treatments were statistically superior over untreated control and were on par. The seedlings from such treated seeds i.e., hexaconazole and avatar exhibited higher vigour index 1208 and 1027 respectively compared to seedlings from untreated seeds (318). Hexaconazole and avatar were found as the best treatments with respect to their low per cent seed infection, high per cent seed germination and high vigour index and these two treatments were found statistically superior and are on par with each other.

Seed treatment with *P. fluorescens* showed least seed infection of 14.11 per cent with maximum per cent germination of 98.22 and vigour index of 2660.81, followed by *Trichoderma harzianum* with per cent seed infection, per cent germination and vigour index of 14.67, 94.89 and 2385.6, respectively.

Similar results were obtained by Sathyaprasanth (2004), Ehteshamul-Haque *et al.,* (2007), Lokesha and Benagi (2007) and Sharma *et al.,* (2007). Ramamoorthy and Samiyappan (2001), Hegde *et al.,* (2002), Ekbote (2005).

In vitro evaluation of fungicides, botanicals and bio-agent by rolled towel method.

Efficacy of fungicides, botanicals and bio-agents were tested against seed borne fungal infections of sesame (variety E-8) by employing rolled towel method as explained in 'Material and Methods' and results are presented in Table 3. Among the nine treatments, hexaconazole exhibited least per cent seed infection (13.33%) and was on par with avtar (14.00%). The next best treatment was *T. harzianum* (21.33%) followed by taqat (25.00%), *P. fluorescens* (25.00%) and were on par with each other. Highest per cent infection was recorded in garlic (30.33%) which was on par with ginger (26.67%), propiconazole (26.33%), tebuconazole (30.67%), compared to untreated seeds (42.00%) (Fig. 5).

The results with respect to the per cent germination were significantly influenced by botanicals, bio-agents and fungicides (Table 3 and Plate 13). The hexaconazole (89.33%) and avatar (87.67%) exhibited highest germination and the results were statistically superior over others and were on par. The per cent germination in untreated seeds was 57.33% rest of the other treatments was statistically superior over untreated control and was on par.

The seedlings from such treated seeds i.e., hexaconazole and avatar exhibited higher vigour index 1208 and 1027 respectively compared to seedlings from untreated seeds (318). Hexaconazole and avatar were found as the best treatments with respect to their low per cent seed infection, high per cent seed germination and high vigour index and these two treatments were found statistically on par with each other.

Among nine seed dressing fungicides evaluated against *A. sesami* by poisoned food technique, hexaconazole was found statistically superior over other treatments. Among the six plant extracts tested against *A. sesami*, maximum inhibition of mycelial growth was noticed in *Allium sativum* L. Among the six bio-agents, maximum reduction in colony growth of *A. sesami* was observed in *T. harzianum.*In general, species of *Trichoderma* showed more mycelial inhibition of the pathogen compared to bacterial antagonists. Among the nine treatments of fungicides, botanicals and bio-agent by rolled towel method, the hexaconazole exhibited least per cent seed infection. Among all the treatments tested, hexaconazole seed treatement (2ml/kg) was found to be superior followed by combi product avtar 72WP (hexazconazole 4% + zineb 68%) 2 ml/kg for *A. sesame*

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How to cite this article:

Radha, P.L. and Chattannavar, S.N. 2017. Management of Seed-Borne Diseases of Sesame through Novel Seed Dressing Fungicides, Botanicals and Bio-Agents. *Int.J.Curr.Microbiol.App.Sci.* 6(10): 2387-2404. doi: https://doi.org/10.20546/ijcmas.2017.610.282