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Evaluation of fungicides against *Aspergillus niger* van Tieghem causing collar rot of groundnut under laboratory and field condition

JG Piprotar, KK Kanzaria, RM Zankat and DS Kelaiya

Abstract
A study was conducted at the Department of Plant Pathology, College of Agriculture, JAU, Junagadh during 2020-21 to find out the efficacy of different fungicidal groups at different concentration against *A. niger* under *in vitro* and *in vivo* conditions. In laboratory study among non-systemic fungicides, copper oxychloride 50% WP exhibited cent percent mycelial growth inhibition at 1000, 1500 and 2000 ppm concentrations followed by mancozeb 75% WP at 2000 ppm. Whereas, among systemic fungicides, carbendazim 50% WP, fluxapyroxad 333 g/L, propiconazole 25% SC and tebuconazole 2% DS gave cent percent mycelial growth inhibition at 100, 250 and 500 ppm concentrations. While, among ready-mixed fungicides, carbendazim 25% + mancozeb 50% WS at 1000 ppm, carboxin 37.5% + thiram 37.5% DS at 750 and 1000 ppm and fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC at 1000 ppm concentrations found the most effective treatments in inhibiting the cent percent mycelial growth of *A. niger in vitro.* In field evaluation of fungicides against collar rot disease of groundnut, the seed treatment of carboxin 37.5% + thiram 37.5% DS at the rate of 3 g/kg kernel found the most effective treatment with minimum disease incidence of 3.96 percent and 91.76 percent disease control followed by fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC (7.46 and 84.13) and penflufen 13.28% + trifloxystrobin 13.28% FS (8.84 and 81.18), respectively both at the rate of 2 g/kg kernel with the corresponding pod and haulm yield (kg/ha) of (1766 and 2735), (1725 and 2666) and (1688 and 2584), respectivley.

Keywords: Groundnut**,** *Aspergillus niger,* collar rot, fungicides, pod and haulm yield

Introduction

Groundnut (*Arachis hypogaea* L.) is a leguminous oilseed crop belonging to the family *Fabaceae* and sub-family *Papillionaceae* (Hammons, 1982) [7]. It is one of the most important oilseeds *Kharif* crop in India and regarded as "King of oilseed crops". India ranks first in groundnut acreage and is the second largest producer of groundnut in the world with 101 lakh tonnes and productivity of 1816 kg per hectare in 2020-21 (Anon., 2022) [3]. In India, Gujarat is the highest groundnut producing state followed by Andhra Pradesh, Karnataka, Rajasthan and Tamil Nadu. In Gujarat, groundnut is cultivated in a 21.63 lakh hectare area with the production of 41.27 lakh metric tonnes and productivity of 1908 kg/ha in the year 2020-21 (Anon., 2021) [2]. In groundnut, Grover (1981) [6] listed more than fifty-five pathogens including viruses. Jochem (1926) [8] was the first to report *Aspergillus niger* on groundnut seedlings. Joshi (1969) [9] surveyed groundnut growing areas of Gujarat state and found as high as 50 percent seedling blight in some fields. Meena. (2019) [12] during five years survey observed the maximum collar rot incidence of 11.7 percent in 2015 and minimum (7.1 percent) in 2017 in Sikrai block of Dausa district of Rajasthan where groundnut is shown as rainfed crop. Collar rot caused by *A. niger* is a common constraint prevalent in groundnut growing regions especially during *Kharif* season. This disease is emerging as a major and widespread problem in the Saurashtra region since last few years causing pre-emergence seed rot and post-emergence seedling rot. Therefore, it is very necessary to have some information on the inhibitory effect of fungicides *in vitro* as well as to know effective fungicides for the management of the disease under field condition. Keeping in view the importance of groundnut and the severity of the disease, the present work was carried out to know the effective fungicides *in vitro* and *in vivo* and results so obtained were documented hereunder.

Materials and Methods

Efficacy of different fungicides against *Aspergillus niger* under *in vitro* condition

Efficacy of different fungicides were tested in the Laboratory of Department of Plant

Pathology, College of Agriculture, JAU, Junagadh using Completely Randomized Design with factorial concept with three repetition. Different non-systemic, systemic and ready-mixed fungicides were selected and evaluated against the test pathogen. Among them, seven non-systemic fungicides *viz*., wettable sulphur 80% WP, chlorothalonil 75% WP, copper oxychloride 50% WP, mancozeb 75% WP, propineb 70% WP, thiram 75% DS and zineb 75% WP with three concentrations (1000, 1500 and 2000 ppm), seven systemic fungicides *viz*., azoxystrobin 23% SC, carbendazim 50% WP, fluxapyroxad 333 g/L, fosetyl-Al 80% WP, propiconazole 25% SC, tebuconazole 2% DS and thiophanate methyl 70% WP with three concentrations (100, 250 and 500 ppm) and seven ready-mixed fungicides *viz*., carbendazim 25% + mancozeb 50% WS, carboxin 37.5% + thiram 37.5% DS, fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC, hexaconazole 4% + zineb 68% WP, metiram 55% + pyraclostrobin 5% WG, penflufen 13.28% + trifloxystrobin 13.28% FS and thiophanate methyl 45% + pyraclostrobin 5% FS with three concentrations (500, 750 and 1000 ppm) were evaluated against *A. niger* under laboratory condition. Mycelial growth inhibition activities of fungicides were tested against *Aspergillus niger in vitro* by employing the Poisoned Food Technique of Bagchi and Das (1968) [4] using potato dextrose agar (PDA) as a germinating medium. Appropriate quantity of each fungicides required were incorporated into autoclaved PDA medium before solidification using digital balance and micropipette for solid and liquid formulation of fungicide, respectively. After thoroughly shaking on vertex, the medium was poured into sterilized Petri plates (90 mm dia.) in equal quantity (20 ml per Petri plate) to form a uniform layer. An actively growing mycelial bit of 4 mm diameter cut with the help of sterilized cork borer were transferred under aseptic conditions in an inverted position over the solidified PDA medium containing Petri plates in the centre. Then Petri plates were incubated at 28$\pm$2°C till the control plate attains full growth and observations were recorded on linear mycelial growth in treated and control plates. Inoculated Petri plates containing PDA medium without fungicides were served as control.

The percent growth inhibition of the fungus in each treatment was calculated by using the following formula (Vincent, 1947) [21].

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

Where,

I = Percent inhibition of mycelial growth

C = Radial growth of fungus in control plate (mm)

T = Radial growth of fungus in treated plate (mm)

Efficacy of different fungicides against *Aspergillus niger* under field condition

A field trial was conducted at the Research Farm of the Department of Plant Pathology, Junagadh Agricultural University, Junagadh to study the efficacy of different fungicides for the management of collar rot of groundnut. The trial was arranged in Randomized Block Design with three replication. Certified seeds of groundnut variety 'GJG-22' was sown at the rate of 120 kg seeds per hectare on 10th June, 2021. Before sowing, seeds were treated with respective fungicides at specified rates and dried under shed condition. Inoculum load of *A. niger* culture isolated from the diseased plant parts were multiplied on half-cooked sorghum grain added in the soil at the rate of 100 kg/ha seven days before sowing in open furrows. The soil was gently planked after the sowing of the seeds. Thereafter, seeds were used for sowing at 60 x 10 cm distance in each of the gross plot size of 5.0 m x 3.6 m and net plot size of 4.0 m x 2.40 m in manually fertilized (12.5:25:00 NPK kg/ha) soil. All agronomical practices were followed as and when required except fungicidal treatments.

Ten fungicides *viz*., thiram 75% DS (3 g/kg kernel), mancozeb 75% WP (3 g/kg kernel), carbendazim 50% WP (2 g/kg kernel), tebuconazole 2% DS (1.25 g/kg kernel), fluxapyroxad 333 g/L (2 g/kg kernel), fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC (2 g/kg kernel), thiophanate methyl 45% + pyraclostrobin 5% FS (2 g/kg kernel), penflufen 13.28% + trifloxystrobin 13.28% FS (2 g/kg kernel), carboxin 37.5% + thiram 37.5% DS (3 g/kg kernel) and carbendazim 25% + mancozeb 50% WS (2 g/kg kernel) were evaluated through seed treatment against *Aspergillus niger* under field condition. Experiment was laid out with ten treatments along with control.

Observations on disease incidence of each treatment were recorded periodically. Pod and haulm yield were recorded after harvesting of the crop. The percent disease incidence was calculated using the formula given below.

$$\text{Percent disease incidence} = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

The percentage disease control and the percentage deviation in yield were calculated with the help of the following formula (Mathur. 1971) [11].

$$\text{Disease control (\%)} = \frac{\text{P.D.I. in check} - \text{P.D.I. in treatment}}{\text{P.D.I. in check}} \times 100$$

$$\text{Yield increase (\%)} = \frac{\text{Yield in treatment} - \text{Yield in check}}{\text{Yield in check}} \times 100$$

Results and Discussion

Efficacy of non-systemic fungicides against *Aspergillus niger* under *in vitro* condition

The efficacy of seven non-systemic fungicides were tested at 1000, 1500, 2000 ppm concentrations using Poisoned Food Technique. The observations on mycelial growth inhibition were recorded when control plate attains full growth. The results so obtained are communicated here under.

The data presented in Table 1 and Plate 1 indicated complete mean mycelial growth inhibition in copper oxychloride 50% WP. The next effective treatment was mancozeb 75% WP with mean mycelial growth inhibition of 95.34 percent. Thiram 75% WP and propineb 70% WP found equally effective with mean mycelial growth inhibition of 85.12 and 83.13 percent, respectively. Similarly, zineb 75% WP with 74.39 percent mean mycelial growth inhibition remained statistically at par with chlorothalonil 75% WP with 73.76 percent mean mycelial growth inhibition. While, minimum mean mycelial growth inhibition was found in wettable sulphur 80% WP with 6.14 percent.

All the three concentrations of non-systemic fungicides tested against *A. niger* found effective in inhibiting the mycelial growth of *A. niger* over control. As the concentration of fungicides increases, the mycelial growth inhibition also increases.

Among the concentrations, 2000 ppm concentration was found significantly superior with 77.02 percent mycelial growth inhibition, but it was remained statistically at par with 1500 ppm concentration with 74.22 percent mean mycelial growth inhibition.

Looking to the interaction effect of fungicides and various concentration, copper oxychloride 50% WP at all concentration found significantly superior followed by mancozeb 75 WP at 2000 ppm concentration with cent percent mycelial growth inhibition. The next effective treatments in order of merit was mancozeb 75% WP at 1500 ppm concentration with 96.34 percent growth inhibition. Whereas, thiram 75% DS and propineb 70% WP found equally effective with 87.83 and 86.72 percent mycelial growth inhibition. The next moderately effective treatment was zineb 75% WP at 2000 ppm concentration with 77.10 percent mycelial growth inhibition, but it was found statistically at par with chlorothalonil 75% WP at the same concentration with 77.08 percent mycelial growth inhibition. Whereas, wettable sulphur 80% WP found less effective as compared to other fungicides and had minimum mycelial growth inhibition of 2.13, 5.92 and 10.37 percent at 1000, 1500 and 2000 ppm concentration, respectively.

The results obtained were in accordance with the result of Lora and Begum (2019) [10]. They also observed complete mycelial growth inhibition in mancozeb 75% WP at 500 ppm concentration. Rohtas. (2016) [17] also reported effectiveness of captan and thiram with 81.11 and 72.77 percent mycelial growth inhibition, respectively at 1000 ppm concentration which support the results obtained in present study.

Table 1: Efficacy of non-systemic fungicides against *Aspergillus niger* under *in vitro* condition

Fungicides	Mycelial growth inhibition (%)			Mean mycelial growth inhibition (%)
	1000 ppm	**1500 ppm**	**2000 ppm**	
Wettable sulphur 80% WP	8.39 (2.13)	14.08 (5.92)	18.79 (10.37)	13.75 (6.14)
Chlorothalonil 75% WP	57.05 (70.42)	59.19 (73.76)	61.40 (77.08)	59.21 (73.76)
Copper oxychloride 50% WP	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)
Mancozeb 75% WP	71.26 (89.67)	78.97 (96.34)	90.05 (100.00)	80.09 (95.34)
Propineb 70% WP	63.47 (80.05)	66.52 (84.12)	68.63 (86.72)	66.21 (83.63)
Thiram 75% DS	64.83 (81.91)	67.71 (85.61)	69.58 (87.83)	67.37 (85.12)
Zineb 75% WP	58.24 (72.29)	59.19 (73.77)	61.41 (77.10)	59.61 (74.39)
Mean	59.04 (70.92)	62.24 (74.22)	62.33 (77.02)	-
	Fungicide (F)	Concentration (C)		F x C
S. Em. ±	0.32	0.21		0.55
C. D. at 5%	0.91	0.59		1.58
C. V.%	1.54			

Note: Data outside the parentheses are arcsine transformed, whereas inside are re-transformed values.

Efficacy of systemic fungicides against *Aspergillus niger* under *in vitro* condition

The efficacy of seven systemic fungicides were tested at 100, 250 and 500 ppm concentrations using Poisoned Food Technique. The observations on mycelial growth inhibition were recorded when control plate attains full growth. The results so obtained are communicated here under.

The data presented in Table 2 and Plate 2 indicated cent percent mean mycelial growth inhibition in carbendazim 50% WP followed by fluxapyroxad 333 g/L, propiconazole 25% SC and tebuconazole 2% DS among different systemic fungicides tested *in vitro*. Fosetyl-Al 80% WP and azoxystrobin 23% SC remained moderately effective fungicides with mean mycelial growth inhibition of 50.29 and 34.57, respectively. While, minimum mean mycelial growth inhibition was found in thiophanate methyl 70% WP with 15.14 percent.

All the three concentrations of systemic fungicides tested against *A. niger* found effective in inhibiting the mycelial growth of *A. niger* over control. As the concentration of fungicides increases, the mycelial growth inhibition also increases.

Table 2: Efficacy of systemic fungicides against *Aspergillus niger* under *in vitro* condition

Fungicides	Mycelial growth inhibition (%)			Mean mycelial growth inhibition (%)
	100 ppm	**250 ppm**	**500 ppm**	
Azoxystrobin 23% SC	30.82 (26.25)	33.67 (30.74)	43.11 (46.70)	35.87 (34.57)
Carbendazim 50% WP	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)
Fluxapyroxad 333 g/L	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)
Fosetyl-Al 80% WP	40.33 (41.88)	46.72 (53.01)	48.43 (55.97)	45.16 (50.29)
Propiconazole 25% SC	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)
Tebuconazole 2% DS	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)	90.05 (100.00)
Thiophanate methyl 70% WP	12.15 (4.43)	21.69 (13.66)	31.52 (27.33)	21.79 (15.14)
Mean	63.35 (67.51)	66.04 (71.06)	69.03 (75.72)	-
	Fungicide (F)	Concentration (C)		F x C
S. Em. ±	0.53	0.34		0.91
C. D. at 5%	1.50	0.98		2.60
C.V.%	2.39			

Note: Data outside the parentheses are arcsine transformed, whereas inside are re-transformed values.

Among the three concentrations, 500 ppm concentration was found significantly superior over rest of the concentrations with 75.72 percent mycelial growth inhibition.

Looking to the interaction effect, carbendazim 50% WP, fluxapyroxad 333 g/L, propiconazole 25% SC and tebuconazole 2% DS at all concentration completely inhibited the mycelial growth and proved significantly superior over rest of the treatments. Fosetyl-Al 80% WP found next effective treatment in order of efficacy at 500 ppm concentration and gave 55.97 percent mycelial growth inhibition, but it was found statistically at par with same fungicides at 250 ppm concentration with 53.01 percent mycelial growth inhibition. However, thiophanate methyl 70% WP found less effective as compared to other fungicides and had minimum mycelial growth inhibition of 4.43, 13.66 and 27.33 percent at 100, 250 and 500 ppm concentration, respectively followed by azoxystrobin 23% SC with mycelial growth inhibition of 26.25 percent at 100 ppm concentration.

The present findings are in close conformity with the results of Nathawat and Partap (2014) [14]. They reported cent percent mycelial growth inhibition of *A niger* using tebuconazole and propiconazole at 100 to 1000 ppm concentration followed by carbendazim and difenoconazole at 750 and 1000 ppm concentration, respectively. Rani. (2017) [16] and Sekhon. (2019) [19] also revealed complete inhibition of mycelial growth of *A. niger* using tebuconazole.

Efficacy of ready-mixed fungicides against *Aspergillus niger* under *in vitro* condition

Development of resistance in many pathogens to fungicides with single point action has lead way to development of new fungicides where chemicals with two different mode of action, which showed synergistic effect for the control of pathogens. So, an effort made to evaluate different ready-mixed fungicides against *A. niger in vitro.*

Seven ready-mixed fungicides were tested against *A. niger in vitro* at three different concentrations (500, 750 and 1000 ppm) along with control by employing Poisoned Food Technique. Observations on mycelial growth inhibition were recorded when control plate attains full growth. The results so obtained are communicated here under.

The data presented in Table 3 and Plate 3 showed that among different ready-mixed fungicides tested *in vitro*, carbendazim 25% + mancozeb 50% WS recorded maximum mycelial growth inhibition with 95.70 percent but it was remained at par with carboxin 37.5% + thiram 37.5% DS with 94.46 percent mean mycelial growth inhibition. The next effective treatment was fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC with 90.12 percent mean mycelial growth inhibition. Penflufen 13.28% + trifloxystrobin 13.28% FS found moderately effective fungicides with 79.72 percent mean mycelial growth inhibition, but it was remained at par with thiophanate methyl 45% + pyraclostrobin 5% FS with 77.48 percent mean mycelial growth inhibition. While, minimum mean mycelial growth inhibition was recorded in metiram 55% + pyraclostrobin 5% WG with 44.10 percent.

All the three concentrations of ready-mixed fungicides tested against *A. niger* found effective in inhibiting the mycelial growth of *A. niger* over control. As the concentration of fungicides increase, the mycelial growth inhibition also increases.

Among the three concentrations, 1000 ppm concentration was found significantly superior over rest of the concentrations with 88.99 percent mycelial growth inhibition.

Table 3: Efficacy of ready-mixed fungicides against *Aspergillus niger* under *in vitro* condition

Fungicides	Mycelial growth inhibition (%)			Mean mycelial growth inhibition (%)
	500 ppm	750 ppm	1000 ppm	
Carbendazim 25% + Mancozeb 50% WS	74.09 (92.49)	76.59 (94.62)	90.05 (100.00)	80.24 (95.70)
Carboxin 37.5% + Thiram 37.5% DS	65.95 (83.39)	90.05 (100.00)	90.05 (100.00)	82.01 (94.46)
Fluxapyroxad 167 g/L + Pyraclostrobin 333 g/L SC	66.14 (83.63)	68.63 (86.72)	90.05 (100.00)	74.94 (90.12)
Hexaconazole 4% + Zineb 68% WP	60.94 (76.40)	67.79 (85.71)	70.97 (89.37)	66.56 (83.82)
Metiram 55% + Pyraclostrobin 5% WG	32.46 (28.81)	40.54 (42.25)	51.50 (61.25)	41.50 (44.10)
Penflufen 13.28% + Trifloxystrobin 13.28% FS	57.56 (71.23)	63.52 (80.11)	69.58 (87.83)	63.55 (79.72)
Thiophanate methyl 45% + Pyraclostrobin 5% FS	53.44 (64.51)	65.97 (83.42	66.81 (84.50)	62.07 (77.48)
Mean	58.65 (71.49)	67.58 (81.83)	75.57 (88.99)	-
	Fungicide (F)	Concentration (C)		F x C
S. Em. ±	0.86	0.56		1.50
C. D. at 5%	2.47	1.61		4.28
C. V. %	3.86			

Note: Data outside the parentheses are arcsine transformed, whereas inside are re- transformed values.

Looking to the interaction effect between the different fungicides and concentrations, carboxin 37.5% + thiram 37.5% DS at 750 and 1000 ppm concentration, carbendazim 25% + mancozeb 50% WS and fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC both at 1000 ppm concentration completely inhibited the mycelial growth of *A. niger in vitro* and proved significantly superior over rest of the treatments. Hexaconazole 4% + zineb 68% WP found next effective treatment in order of efficacy at 1000 ppm and gave 89.37 percent growth inhibition, but it was found at par with penflufen 13.28% + trifloxystrobin 13.28% FS at same concentration with 87.83 percent mycelial growth inhibition and hexaconazole 4% + zineb 68% WP at 750 ppm concentration with 85.71 percent mycelial growth inhibition. Whereas, metiram 55% + pyraclostrobin 5% WG found less effective as compared to other fungicides and had minimum mycelial growth inhibition of 28.81, 42.25 and 61.25 percent at 500, 750 and 1000 ppm concentration, respectively.

More or less similar kind of trend was also reported by Andge. (2017) [1] and Saran. (2022) [18] while working with the efficacy of ready-mixed fungicides against *A. niger* under laboratory condition with varied inhibition of mycelial growth at different concentration.

Field evaluation of fungicides for the management of collar rot of groundnut

In field experiment, total ten fungicides were tested against the collar rot of groundnut along with control at Research Farm of the Department of Plant Pathology, JAU, Junagadh. Observations on percent disease incidence (PDI), pod and haulm yield (kg/ha) were recorded and results obtained are communicated hereunder.

Observations on disease incidence of each treatment were recorded periodically and percent disease incidence (PDI) calculated accordingly. Pod and haulm yield was recorded after harvesting of the crop.

The data presented in Table 4 revealed that seed treatment with carboxin 37.5% + thiram 37.5% DS gave minimum percent disease incidence of 3.96 with maximum disease control (91.76 percent). But, it was remained statistically at par with fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC with percent disease incidence and disease control of 7.46 and 84.13, respectively. The next effective treatment found was penflufen 13.28 + trifloxystrobin 13.28 FS with 8.84 percent disease incidence and 81.18 percent disease control. Seed treatment with tebuconazole 2% DS gave reduced percent disease incidence of 16.13 with disease control of 65.67 percent. But, it was found statistically at par with fluxapyroxad 333 g/L, mancozeb 75% WP and thiophanate methyl 45% + pyraclostrobin 5% FS with percent disease incidence and disease control of (17.26 and 63.27), (20.87 and 55.59) and (21.16 and 54.97), respectively. The fungicides with moderately effective action were carbendazim 25% + mancozeb 50% WS, but it was found at par with carbendazim 50% WP with PDI of 22.65 and 23.23, respectively. Whereas, the least effective treatment was thiram 75% DS with percent disease incidence of 34.59 as against 47.00 in control treatment.

Looking to the pod yield, the seed treatment with carboxin 37.5% + thiram 37.5% DS gave maximum pod yield of 1766 kg/ha with percent pod yield increase of 52.27 percent over control. But, it was remain statistically at par with fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC (1725 kg/ha), penflufen 13.28% + trifloxystrobin 13.28% FS (1688 kg/ha), tebuconazole 2% DS (1578 kg/ha), fluxapyroxad 333 g/L (1543 kg/ha), mancozeb 75% WP (1537 kg/ha), thiophanate methyl 45% + pyraclostrobin 5% FS (1532 kg/ha) and carbendazim 25% + mancozeb 50% WS (1486 kg/ha) with pod yield increase over control of 48.70, 45.54, 36.09, 33.04, 32.52, 32.06 and 28.13 percent, respectively.

Table 4: Efficacy of fungicides for the management of collar rot of groundnut under field condition

Fungicide	Percent disease incidence (%)	Disease Control (%)	Pod yield (kg/ha)	Pod yield increase (%)	Haulm yield (kg/ha)	Haulm yield increase (%)
Thiram 75% DS	36.02 (34.59)	26.40	1285	10.83	1866	13.75
Mancozeb 75% WP	27.18 (20.87)	55.59	1537	32.52	2403	46.46
Carbendazim 50% WP	28.82 (23.23)	50.56	1436	23.85	2135	30.13
Tebuconazole 2% DS	23.68 (16.13)	65.67	1578	36.09	2480	51.15
Fluxapyroxad 333 G/L	24.55 (17.26)	63.27	1543	33.04	2476	50.93
Fluxapyroxad 167 g/l + Pyraclostrobin 333 g/l SC	15.85 (7.46)	84.13	1725	48.70	2666	62.49
Thiophanate methyl 45% + Pyraclostrobin 5% FC	27.39 (21.16)	54.97	1532	32.06	2346	43.01
Penflufen 13.28% + Trifloxystrobin 13.28% fs	17.30 (8.84)	81.18	1688	45.54	2584	57.49
Carboxin 37.5% + Thiram 37.5% Ds	11.48 (3.96)	91.76	1766	52.27	2735	66.74
Carbendazim 25% + Mancozeb 50% WS	28.42 (22.65)	51.79	1486	28.13	2170	32.26
Control	43.28 (47.00)		1160		1640	
S. Em. ±	1.69		101.41		191	
C.D at 5%	4.98		297		562	
C.V.%	11.32		11.54		14.34	

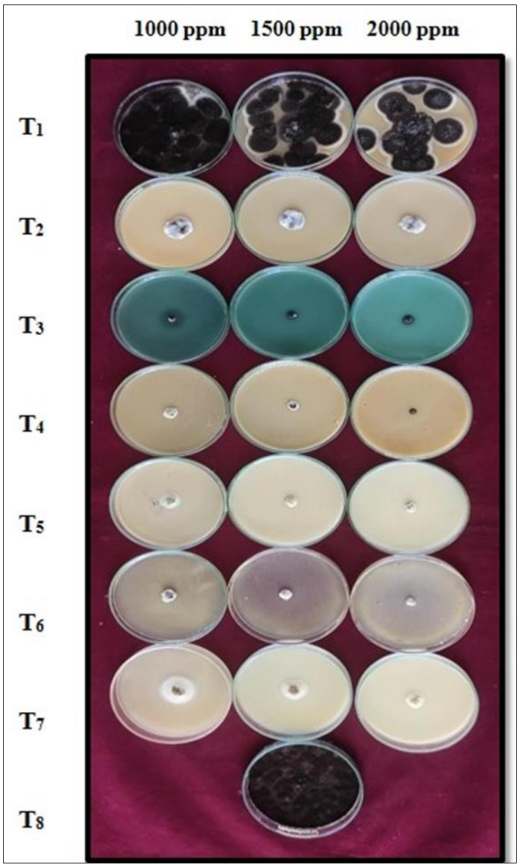
Note: Data outside the parentheses are arcsine transformed, whereas inside are re-transformed values.

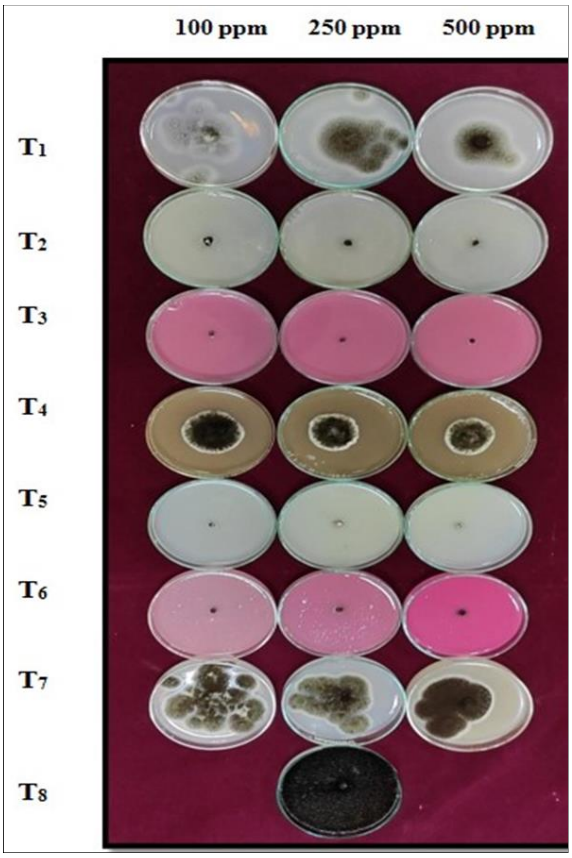
The control treatment recorded minimum pod yield of 1160 kg/ha. But, it was remained statistically at par with thiram 75% DS and carbendazim 50% WP with pod yield of 1285 and 1436 kg/ha with pod yield increase over control of 10.83 and 23.85, respectively.

Looking to the haulm yield, seed treatment with carboxin 37.5% + thiram 37.5% DS gave maximum haulm yield 2735 kg/ha with percent haulm yield increase of 66.74 percent over control. But, it was remained statistically at par with fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC (2666 kg/ha), penflufen 13.28% + trifloxystrobin 13.28% FS (2584 kg/ha), tebuconazole 2% DS (2480 kg/ha), fluxapyroxad 333 g/L (2476 kg/ha), mancozeb 75% WP (2403 kg/ha) and thiophanate methyl 45% + pyraclostrobin 5% FS (2346 kg/ha) with haulm yield increase over control of 62.49, 57.49, 51.15, 50.93, 46.46 and 43.01 percent, respectively.

The control treatment recorded minimum haulm yield of 1640 kg/ha. But, it was remained statistically at par with carbendazim 25% + mancozeb 50% WS and thiram 75% DS with haulm yield of 2170 and 1866 kg/ha with haulm yield increase over control of 32.26 and 13.75 percent, respectively.

More or less similar type of results were also reported by Shivpuri. (2011) [20]. They reported carboxin 37.5% + thiram 37.5% WP as highly effective fungicide against collar rot of groundnut. Mohapatra and Beher (2012) [13], Rakholiya. (2012) [15] and Bajaya. (2022) [5] were also demonstrated the effective nature of chemical fungicides against collar rot disease under field condition.



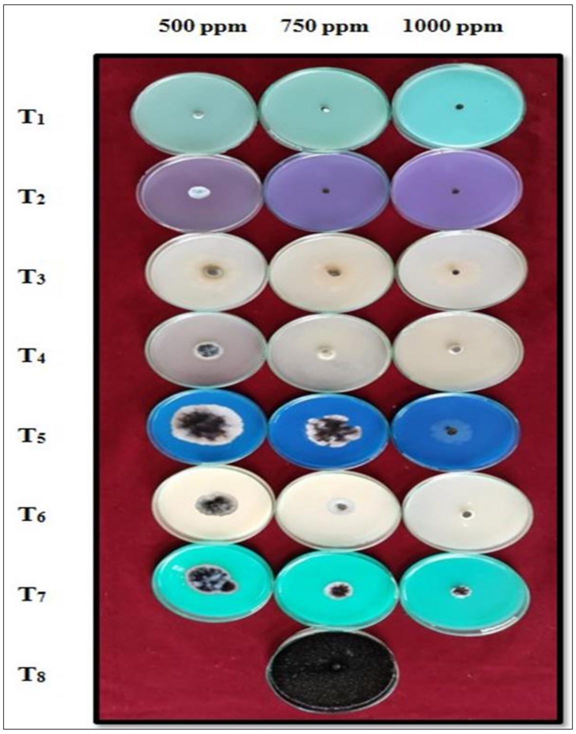


Non: systemic fungicides
T_1: Wettable sulphur 80% WP
T_2: Chlorothalonil 75% WP
T_3: Copper oxychloride 50% WP
T_4: Mancozeb 75% WP
T_5: Propineb 70% WP
T_6: Thiram 75% DS
T_7: Zineb 75 % WP
T_8: Control

Systemic ftiugi Cides
T_1: Azoxystrobin 23% SC
T_2: Carbendazim 50% WP
T_3: Fluxapyroxad 333 g/l
T_4: FosetyL-AI 80% WP
T_5: Propaccmazole 25% SC
T_6: Tebuconazole 2% DS
T_7: Thiophanate methyl 70°O WP
T_8: Control

Plate 1: Efficacy of non-systemic fungicides against *Aspergillus niger* under *in vitro* condition

Plate 2: Efficacy of systemic fungicides against *Aspergilius niger* under in vitro condition



Ready-mixed fungicides

T_1: Carbendazim 25%- Mancozeb 50% WS	**T_2:** Casboxin 37.5% - Thiram 37.5% DS	**T_3:** fluxapyroxad 167 g/L + Pyraclosetrobin 333 g/l SC	**T_4:** Hexaeonazole 4% + Zineb 68% WP	**T_5:** Metiram 55% Pyraclostrobin 5% WG
T_6: Penflufen 13.28% + Trifloxystrobin 13.28% FS	**T_7:** Thiophanate methyl 45% + Pyraclostrobin 5% FS	**T_8:** Control		

Plate 3: Efficacy of ready-mixed fungicides against *Aspergillus niger* under in vitro condition

Conclusion
The present study indicated that all the fungicides under *in vitro* and *in vivo* conditions remain effective in inhibition of mycelial growth of *A. niger* and reducing the disease incidence, respectively. Under *in vitro* condition the cent percent mycelial growth inhibition was found in copper oxychloride 50% WP and mancozeb 75% WP among non-systemic fungicides; carbendazim 50% WP, fluxapyroxad 333 g/L, propiconazole 25% SC and tebuconazole 2% DS among systemic fungicide; carbendazim 25% + mancozeb 50% WS, carboxin 37.5% + thiram 37.5% DS and fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC among ready-mixed fungicides. Whereas, in field evaluation of fungicides, the seed treatment of carboxin 37.5% + thiram 37.5% DS (3 g/kg kernel), fluxapyroxad 167 g/L + pyraclostrobin 333 g/L SC and penflufen 13.28% + trifloxystrobin 13.28% FS fungicides both at the rate of 2 g/kg kernel found effective under field condition and exhibited minimum percent disease incidence (3.96, 7.46 and 8.84 percent) with maximum pod and haulm yield (kg/ha) of (1766 and 2735), (1725 and 2666) and (1688 and 2584), respectively.

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