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J. Mycopathol, Res, 57(2) : 95-99, 2019*;*
ISSN 0971-3719

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J. Mycopathol. Res. **57(2) :** 95-99, 2019; (ISSN 0971-3719)

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Received : 17.05.2019 Accepted : 29.05.2019 Published : 29.07.2019

Black rot of coffee caused by the fungus *Koleroga noxia* Donk. is one of the major disease which causes yield loss up to 20-30% and infects both arabica and robusta coffee cultivars. Presently carbendazim 50% WP @ 0.6% was recommended for management of black rot as an alternative to this fungicide is required to avoid the development of fungicide resistance by the pathogen. Hence, different fungicide molecules *viz*., carbendazim 50% WP, tebuconazole 25% EC, hexaconazole 75% WG, propiconazole 25% EC, pyraclostrobin 133 g/l + epoxiconazole 50 g/l, propineb 70% WP, copper oxychloride 50% WP, carbendazim 12% + mancozeb 63% WP, zineb 68% + hexaconazole 4% WP at the concentrations of 0.05%, 0.10% and 0.15% and Bordeaux mixture @ 0.5%, 1.0% and 1.5% were tested under laboratory condition against *Koleroga noxia* by adopting food poisoning technique. Among the tested fungicides, carbendazim 50% WP, tebuconazole 25 % EC and carbendazim 12% + mancozeb 63% WP recorded 100% inhibition of the mycelial growth at all the concentrations tested over control. The fungicide pyraclostrobin 133 g/l + epoxiconazole 50 g/l could completely inhibit the mycelial growth at 0.1% and 0.15% and copper oxychloride 50 % WP was least effective against the pathogen and could inhibit the mycelial growth only up to 52.59% at the highest concentration tested. The results of the experiment indicated that the fungicides carbendazim 50% WP, tebuconazole 25% EC and carbendazim 12% + mancozeb 63% WP were found effective in arresting the growth of *Koleroga noxia*.

Key words: Black rot, coffee, *in vitro* evaluation, *Koleroga noxia*

INTRODUCTION

Among the diseases of coffee, Black rot disease is considered to be second important disease next to leaf rust in India. The disease is caused by the fungus *Koleroga noxia* Donk. The pathogen infects both the commercially cultivated species of *Coffea.* This fungus is also called in different names as *Corticium koleroga (*Cke*.), Ceratobasidium anceps* and *Pellicularia koleroga* which are the synonyms of the black rot fungus. It is a seasonal disease mainly confined to rainy season. Continuous rains during monsoon without a long dry spell, saturated atmosphere with 95 to 100% relative humidity, hanging mist, thick over head shade, plants sheltered from sunlight and wind in the valley areas, favours the black rot disease development. The pathogen infects leaves, developing berries and tender shoots. The disease is characterized by blackening and rotting of the infected leaves, developing berries and young twigs. Affected leaves get detached from branches and hang down by means of slimy fungal strands. On green berries the characteristic blackening starts from one side and spreads gradually in a narrow band. Close examination reveals the presence of characteristic mycelial strands running along the twig, petioles and spreading mostly on the lower surface of the leaves. Affected leaves and berries show a white web consisting of closely interwoven mycelia when surface moisture is drained (Fig.1 , 2). Defoliation and berry drop from the infected branches occur in advanced stage of disease (Fig. 3).

In India, this disease has been reported from almost all coffee growing regions of Karnataka, Kerala and Tamil Nadu coming under the influence of heavy South-West monsoon. Damage caused by this disease varies from place to place and season to season. However, in severely affected

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areas, a loss of 10 - 20 % of the crop for the whole estate and 70 - 80 % or even more on an individual bush has been recorded. Further, indirect crop loss due to foliage loss by the disease which leads to severe die-back and destruction of wood may also be taken into account while estimating the crop loss. Besides India, black rot disease is reported from 34 coffee cultivating countries of Asia, Africa, Australia, Oceania, North America, Central America, West Indies and South America . Apart from India, in Trindad and Tobego also black rot is an important disease of coffee (Belachew *et al.* 2015). During 2014, coffee black rot outbreak is recorded at major coffee growing areas of South-West, West and South Ethiopia which reveales that mean incidence and severity are 58.44 and 32.59 % respectively, resulting in considerable damages which implicated on arabica coffee production in Ethiopia (Belachew *et al.* 2015).

The aim of the present study has been desigued to compare the effect of some fungicides on *Koleroga noxia* mycelial growth *in vitro* and identify the concentration of fungicide having fungicidal properties for better management of this disease.

MATERIALS AND METHODS

The present study was conducted at Central Coffee Research Institute (CCRI), Balehonnuru to assess the efficacy of newer fungicides on black rot pathogen of coffee under *in vitro* conditions. The pathogen *Koleroga noxia* Donk was isolated from the infected coffee leaf samples collected from the CCRI farm. Aseptic and axenic culture of the fungus was derived from the original isolation and maintained at Plant Pathology Division of CCRI, Balehonnuru. The stock cultures were maintained by periodic transfer and stored in the refrigerator at 4°C. The fungus culture maintained in the Institute was used as the test fungus for the present study. The fungicides *viz.*, carbendazim 50% WP, tebuconazole 25% EC, hexaconazole 75% WG, propiconazole 25% EC, pyraclostrobin 133 g/l + epoxiconazole 50 g/l, propineb 70% WP, copper oxychloride 50% WP, carbendazim 12% + mancozeb 63% WP, zineb 68% + hexaconazole 4% WP at the concentrations of 0.05%, 0.10% and 0.15% and Bordeaux mixture @ 0.5%, 1.0% and 1.5% were tested under laboratory conditions. Efficacy of fungicides was evaluated under *in vitro* conditions by adopting poisoned food technique as described by Nene and Thapliyal (1979). Fungicidal suspensions of different concentrations were prepared in flasks by dissolving requisite quantities of each fungicide in warm Potato Dextrose Agar (PDA) medium before pouring and mixed well under aseptic condition. About 20 ml of the melted poisoned PDA medium was poured into the sterilized 90 mm diameter Petri plates and allowed for solidification. For each concentration of the test fungicide, three replications were maintained. The PDA medium without fungicide served as control. The Petri plates containing the fungicide poisoned PDA medium were then inoculated aseptically with 5 mm diameter discs of actively growing seven days old culture of the fungus grown on PDA. The discs were placed in the center of the Petri plates in an inverted position to have direct contact with poisoned medium. All the Petri plates were incubated at 24ºC ± 1ºC.

Observation on the growth of the fungus was recorded after seven days of incubation period. Colony growth was measured (mm) in two directions from the back side perpendicular to each other, taking the value of growth as the mean of two measures.

Per cent inhibition of radial growth of mycelia was computed based on colony diameter on control plate adopting the following formula.

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

where; I = Per cent inhibition of the fungal mycelia
C = Growth of fungal mycelia (mm) in control
T = Growth of fungal mycelia (mm) in treatments

RESULTS AND DISCUSSION

Four systemic, three contact and three combi-product fungicides were tested at three concentrations in the laboratory for their efficacy against *Koleroga noxia.* The results obtained during the present investigation are presented in Table 1 and Fig. 4.

The results revealed that there is significant difference in efficacy between the fungicides tested. The efficacy was found to increase in all the fungicides when concentration increased. Among the various chemicals evaluated *in vitro* by poisoned food technique, carbendazim 50% WP, tebuconazole 25% EC and carbendazim 12%

Table 1: Efficacy of fungicides against *Koleroga noxia* at different concentrations

Treatments	Per cent mycelial inhibition over control concentration (in %)		
	0.05	0.10	0.15
T_1 - Carbendazim 50% WP	100.00 (90.04)*	100.00 (90.04)*	100.00 (90.04)*
T_2 - Tebuconazole 25% EC	100.00 (90.04)	100.00 (90.04)	100.00 (90.04)
T_3 - Hexaconazole 75% WG	75.37 (60.28)	76.48 (61.03)	78.52 (62.42)
T_4 - Propiconazole 25% EC	82.04 (64.98)	83.15 (65.84)	84.44 (66.81)
T_5 - Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l	86.11 (68.17)	100.00 (90.04)	100.00 (90.04)
T_6 - Propineb 70% WP	80.00 (63.55)	84.26 (66.66)	88.33 (70.10)
T_7 - Bordeaux mixture @ 0.50%, 1.00% & 1.50%	57.59 (49.84)	77.04 (61.56)	85.19 (67.48)
T_8 - Copper oxychloride 50% WP	12.78 (12.76)	46.85 (43.21)	52.59 (46.52)
T_9 - Carbendazim 12% + Mancozeb 63% WP	100.00 (90.04)	100.00 (90.04)	100.00 (90.04)
T_{10} - Zineb 68% + Hexaconazole 4% WP	71.48 (57.75)	72.78 (58.58)	74.07 (59.40)
T_{11} - Control	0.00	0.00	0.00
CD @ 1% Factor 'A'		4.25	
CD @ 1% Factor 'B'		2.22	
CD @ 1% Factor 'A × B'		7.37	

*Figures in parentheses are arc sine transformed values

+ mancozeb 63% WP recorded 100% inhibition of the mycelial growth at all the concentrations tested over control (Fig. 5). The fungicide pyraclostrobin 133 g/l + epoxiconazole 50 g/l could completely inhibit the mycelial growth at 0.1% and 0.15%. However, fungicide copper oxychloride 50 % WP was less effective against the pathogen and could inhibit the mycelial growth only up to 52.59% at the highest concentration tested.

Besides eradicative action, chemicals also provide a chemical toxic barrier against pathogens and are thus unavoidable means of controlling many plant diseases. Efficacy of carbendazim against black rot has been well documented in different literatures. Carbendazim alone or in combination with mancozeb was found to be most effective at all concentrations and caused complete mycelial inhibition. Among the triazole fungicides, tebuconazole 25% EC caused complete inhibition of mycelia growth at all the concentrations. Triazole compounds are known to inhibit the sterol bio-synthesis in the target fungus. These results corroborate the findings of Prashad (2013) that among the various chemicals evaluated *in vitro* against pink canker in apple caused by *Corticium salmonicolor* where the chemicals difenaconazole, hexaconazole and flusilazol at 50, 100, 150 and 200 µl l^{-1} and combi-products like, carbendazim + mancozeb, zineb + hexaconazole and captan + hexaconazole at 250, 500, 750 and 1000 µl l^{-1} exhibited complete mycelium inhibition followed by carbendazim (97.72%), propiconazole (97.31%) and pyraclostrobin + metiram (86.05%), respectively. Further, the investigations of Prashad also revealed that carbendazim alone or in combination with mancozeb or iprodione was found to be most effective at all concentrations and caused complete conidial germination inhibition followed by difenaconazole (3.97%) and azoxystrobin (4.27%), while pyraclostrobin + metiram and captan + hexaconazole was least effective as compared to control (84.56%).

In light of present investigation, apart from carbendazim 50% WP the efficacy of which was proven in the field condition long ago, the fungicides like, tebuconazole 25% EC and carbendazim 12% + mancozeb 63% WP may serve as an alternative fungicides in control of black rot disease of coffee incited by *Koleroga noxia*.

Fig. 1 : White mycelial growth of the pathogen on the lower surface of the infected leaf

Fig. 2 : White mycelial growth of pathogen covering the infected berries

Fig. 3 : Defoliated branch with rotted berries

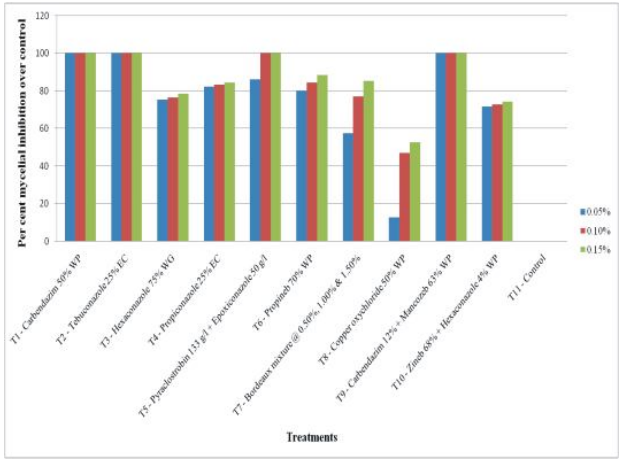

Fig. 4 : Efficacy of fungicides against *Koleroga noxia* at different concentrations

Fig. 5 : Efficacy of fungicides against *Koleroga noxia* at different concentrations

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