Int.J.Curr.Microbiol.App.Sci (2020) *9*(5): 779-786

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 9 Number 5 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.905.086

Post-Harvest Problem of the Ripe Banana and its Management

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Keywords

Colletotrichum spp, Plant extract, Bio control agent and chemical management

Article Info

Accepted:
05 April 2020
Available Online:
10 May 2020

A B S T R A C T

The post-harvest problem in ripe banana *Musa* Spp. is a great problem in banana mostly during transport and storage. Among different problem the rotting of ripe banana after harvest due to *Colletotrichum* spp. is very important. To get some solution about the rotting problem an experiment was conducted in the Dept. of plant pathology, Institute of Agricultural Science, SOADU, BBSR. To avoid the post-harvest loss due to *Colletotrichum* spp different plant extract, Bio control agent and some chemical control was tried in the lab condition. Among plant extract, Onion (*Allium cepa*), Garlic (*Allium sativum*), Sadabahar (*Vinca rosea*), Begunia (*Vitex negundo*) plant extracts inhibited 100% radial growth of *C. musae*. All plant extracts inhibited 100% radial growth in 20% concentration except Bael (*Aegle marmelos*) and Morning glory (*Ipomea* sp). The Bio control agent *Trichoderma hamatum* inhibited 65.26% radial growth of causal fungus followed by *Trichoderma harzianum* (63.68%) and *Trichoderma viride* (61.41%). *Pseudomonas fluorescens* was found to be best inhibiting 100% mycelial growth. The 100% growth inhibition of *Colletotrichum* spp was observed by Propiconazole 25% EC, Tebuconazole 25.9% EC, Carbendazim 50% WP, Hexaconazole 5% SC, Carbendazim12% WP + Mancozeb 63% WP. But use of Plant extract and bio control agents is safe to use over ripe banana.

Introduction

Banana (*Musa paradisiaca* L.) is the most popular fresh fruit used all over the world and its name came from the Arabic word 'banan', which means finger. The scientific name of Banana is *Musa acuminata* and *Musa balbisiana*. But the old scientific names of banana are *Musa sapientum* and *Musa paradisiaca*. It belongs to family *Musaceae*in order *Scitamineae*. It is a large herbaceous, perennial, monocotyledonous and monocarpic fruit crop. It is also known as 'Apple of Paradise' poor man fruit and Adam's Figure (Bose and Mitra, 2001), originated in the tropical region of South-East Asia. India is considered to be one of the centres of origin of banana *Musa balbisiana*. It can be grown round the year and it is widely adopted in India.

Global production of bananas grew at a compound annual rate of 3.7 per cent, reaching a record of 117.9 million tons in 2015, from 68.2 million tons in 2000. India produced 29 million tons average banana per year followed by China 11 million tons per year during 2010 to 2015 (FAOSTAT). In India it is cultivated in an area of 830.5 thousand ha and total production is around 29,779.91 thousand tons. It accounts for 31.7% of total fruit production. Main banana growing states are Tamil Nadu, Maharashtra, Gujarat, Andhra Pradesh and Karnataka. In Odisha condition it is produced in a total area of 24700 ha of which approximate production is 2.80 lakh M.T.

Crown rot of banana once caused a serious problem for post-harvest fruits during transit (Greene &Goos, 1963 and Papaisri Pitakpaivan, 1986). Fungi associated with crown rot were isolated and identified from fruits obtained from Mexico, Guatemala, and Costa-Rica & Educator in October and November, 1993. *Fusarium semitectum* Berk &Rav and *Penicillium* spp. were isolated more frequently. After inoculation of crowns *Fusarium moniliforme* Scheld and *Fusarium semitectum* Berk and Rav caused the greatest amount of rot (Martin *et al*., 1996). Anthracnose of banana caused by *Colletotrichum musae* (Berk & Curt) Arx. (Smoot *et al*., 1971; Bilgrami *et al*., 1979 and 1981) has been reported mainly on fruit. It is a serious problem in transit. Two distinct kinds of anthracnose are found on fruits. Green fruits are infected first which become severe during ripening. The pulp of the fruit is affected. High temperature favours the disease. Brown rot is one of the most important diseases of ripe banana caused by *Botryodiplodia theobromae* Sacc. This disease is noted in storage as well as in transit and markets (Wardlaw, 1972). In India this disease has been recorded from UP, Delhi, Maharashtra, AP and West Bengal (Srivastava *et al*., 1964).This disease is also known from West Indies (Beeze, 1993). The fungus *Colletotrichum* spp. has been the most notorious fungal pathogen, which causes severe rots deteriorating rapidly fruit quality and rendering the fruit completely to a rotten with sticky mass tickling from the infected pulpy banana.

Materials and Methods

For managing the fruit rot of banana caused by *Colletotrichum* spp. at ripening stage i.e. post-harvest rotting during storage and transit various methods were followed to have an integrated management practice.

In vitro evaluation of plant extracts

Preparation of crude extracts

The fresh plant parts were washed with tap water followed by distilled water. The plant parts were dried for few minutes. 100 g of each plant part was weighed and ground using grinder with addition of equal volume (w/v) of ethanol. These extracts were then filtered through double layered muslin cloth and kept in 100 ml conical flasks. The content was mixed thoroughly and centrifuged at 5500 rpm for 10 minutes and the supernatant was filtered through Whatman filter paper no.1 and after filtration the contents were used for further study (Shamsi, 2016).

The bio-efficacy of plant extracts were evaluated by poisoned food technique (Nene and Thaplial, 1973) in two different concentrations i.e. 10% and 20%. Required amount of crude extracts were mixed with 90 and 80 ml of sterilized molten potato dextrose agar medium so as to get 10% and 20% concentration respectively in laminar airflow chamber. A control set was maintained without any plant extracts. 20 ml of media was poured into petri dishes and allowed to

solidify; 8 mm culture disc was put on the middle of the solidified petri dishes. All the plates were incubated at room temperature. Mycelia growth measurement was taken when maximum growth was observed in control plate. The growth of mycelium on other plates was compared with the control plate. The efficacy of plant extracts was expressed as percentage inhibition of mycelia growth over control. The per cent inhibition over control was calculated according to formula given by Vincent (1947) as follows.

I = (C – T)/C ×100
I = Per cent inhibition
C = Mean Radial growth in control
T = Mean Radial growth in treatment

The following plant extracts were used for management study

Sl. No.	Common name	Plant parts used	Concentrations used
1	Tulsi	Leaf	10% and 20%
2	Onion	Bulb	10% and 20%
3	Basanga	Leaf	10% and 20%
4	Morning glory	Leaf	10% and 20%
5	Garlic	Clove	10% and 20%
6	Neem	Leaf	10% and 20%
7	Arakha	Leaf	10% and 20%
8	Karanj	Leaf	10% and 20%
9	Big-sage	Leaf	10% and 20%
10	Custard apple	Leaf	10% and 20%
11	Bael	Leaf	10% and 20%
12	Sadabahar	Leaf	10% and 20%
13	Begunia	Leaf	10% and 20%

In vitro evaluation of bio-control agents

Dual culture technique

About 20 ml of potato dextrose media was poured into petri dishes and allowed to cool down. The fungal mycelial disc (8mm) was transferred to one end of the plate and fungal antagonist culture disc placed opposite to it leaving 5-6 mm distance from the periphery of the plates.

In case of bacterial antagonist, spore suspension of bacteria was mixed in the molten media and thoroughly mixed and plated immediately. Eight mm fungal disc was put in the centre after solidification and cooling. The radial growth of the fungus was measured indicate the efficacy of bacterial bio agent. Fungal disc was also put in the petri plate without bacterial suspension as control. Each treatment was replicated four times. The inoculated plates were incubated at room temperature. After five days, observations were taken. The efficacy of bio-control agents were expressed as percentage inhibition of mycelia growth over control. The Per cent inhibition over control was calculated according to formula given by Vincent (1947) as follows.

I = (C –T)/C×100
I = Per cent inhibition
C = Mean Radial growth in control
T = Mean Radial growth in treatment

Trichoderma viride, Trichoderma harzianum, Trichoderma hamatum, Pseudomonas fluorescens, Bacillus subtilis bio control are used against the *colletotrichum* sp.

In vitro evaluation of fungicides

The fungicides were tested initially under *in vitro* conditions by using poisoned food technique (Nene and Thapliyal, 1973) at desired concentration. The concentration of chemicals in the medium was as per recommended dose.

Then 20ml of potato dextrose media was poured into sterilized petri dishes. Mycelia disc of eight mm from actively growing zone of ten days old culture were inoculated in to

each plate and placed at the centre of petri plate inverted manner. Control was maintained without adding any fungicide. Each treatment was taken with four replications. The plates were incubated at 27 ± 1^{0C} temperature and radial growth of fungal mycelium was measured from both direction and radial growth was calculated. The data were analysed statistically and efficacies of fungicides were expressed as percentage of inhibition of mycelia growth over control. The Per cent inhibition over control was calculated according to formula given by Vincent (1947) as follows.

I = (C-T)/C ×100
I = Per cent inhibition
C = Mean Radial growth in control
T = Mean Radial growth in treatment

List of fungicides used in management of the causal fungus

Sl. No.	Chemical name	Dose (%)	Concentration (g or ml/litre)
1	Tricyclazole 75% wp	0.3%	3g/litre
2	Propiconazole 25% Ec	0.2%	2ml/litre
3	Tebuconazole 25.9% EC	0.15%	1.5ml/litre
4	Azoxystrobin 23% SC	0.1%	1g/litre
5	Carbendazim 50% WP	0.1%	1g/litre
6	Metalyxl 4%w/w + mancozeb 64% w/w	0.35%	3.5g/litre
7	Hexaconazole 5% sc	0.2%	2ml/litre
8	Copper oxychloride 50% wp	0.3%	3g/litre
9	Carbendazim 12% wp + Mancozeb 63% wp	0.15%	1.5g/litre

Results and Discussion

Bio-efficacy of certain plant extracts against *C. musae*

The plant extracts were evaluated in two different concentrations (10% and 20%) against the *C. musae*. The result revealed significant difference among plant extracts in reducing the radial growth of *Colletotrichum musae* in both the concentration. Onion, Garlic, Sadabahar and Begunia extracts completely stopped the growth of causal pathogen in 10% concentration. Neem, Karanja and custard apple leaf extracts reduced more than 90% radial growth of *Colletotrichum musae*(Table 1, a-b) .

Tulsi, Onion, Basanga, Garlic, Neem, Arakha, Karanj, Big sage, Custard apple, Sadabahar and Begunia plant extracts completely inhibited the radial growth of causal fungus (100%) in 20% concentration (Table 2,a-b). Similar observation was reported by Bagwan (2001) evaluated ten plant extracts against the anthracnose of banana fruit caused by *Gloeosporium musarum (C. musae)* and reported that neem extract was found most effective found most effective in comparison to other plant extract. Different plant extracts prove effective in controlling *Colletotrichum musae in vitro* conditions (Win *et al.*, (2007), Bazie *et al.*, (2014).

Bio-efficacy of fungal and bacterial bio-agents against radial growth of *C. musae*

The causal pathogen *Colletotrichum musae* was evaluated against three fungal bio agents namely *Trichoderma viride*, *Trichoderma harzianum*, *Trichoderma hamatum* in dual culture. It was found that *Trichoderma hamatum* reduced (65.26%) radial growth of causal pathogen followed by *Trichoderma harzianum* (63.68%) and *Trichoderma viride* (61.41%).

Table.1 Inhibition of radial growth of *Colletotrichum musae* by 10% concentrations of plant extracts (Treatment part: a)

Treatment	Plant extracts	Plant part used	Mean radial growth (mm) 10% concentration	Percent inhibition over control
T_1	Tulsi*(Ocimum sanctum)*	Leaf	3.71	94.55
T_2	Onion (*Allium Cepa*)	Bulb	0.00	100
T_3	Basanga (*Adhatoda vasica*)	Leaf	4.43	93.48
T_4	Morning glory (*Ipomea* sp.)	Leaf	4.67	93.12
T_5	Garlic (*Allium sativum*)	Clove	0.00	100
T_6	Neem (*Azadirachta indica*)	Leaf	3.06	95.49
T_7	Arakha (*Calotropis gigantea*)	Leaf	7.69	88.72
T_8	Control		68.20	
	SE(m)±		0.38	
	CD @ 5%		0.93	

Treatment part: b

Treatment	Plant extracts	Plant part used	Mean radial growth (mm) 10% concentration	Percent inhibition over control
T_9	Karanj(*Pongamia pinnata*)	Leaf	4.06	94.00
T_{10}	Big-sage (*Lantana camara*)	Leaf	9.17	86.52
T_{11}	Custard apple (*Annona reticulate*)	Leaf	5.72	91.57
T_{12}	Bael (*Aegle marmelos*)	Leaf	21.58	68.13
T_{13}	Sadabahar*(Vinca rosea)*	Leaf	0.00	100
T_{14}	Begunia (*Vitex negundo*)	Leaf	0.00	100
T_{15}	Control		67.95	
	SE(m)±		0.99	
	CD @ 5%		2.42	

Table.2 Inhibition of radial growth of *Colletotrichum musae* by 20% concentrations of plant extracts (Treatment part: a)

Treatment	Plant extracts	Plant part used	Mean radial growth (mm) 20% concentration	Percent inhibition over control
T_1	Tulsi*(Ocimum sanctum)*	Leaf	0	100
T_2	Onion (*Allium Cepa*)	Bulb	0	100
T_3	Basanga (*Adhatoda vasica*)	Leaf	0	100
T_4	Morning glory (*Ipomea* sp.)	Leaf	3.67	94.78
T_5	Garlic (*Allium sativum*)	Clove	0	100
T_6	Neem (*Azadirachta indica*)	Leaf	0	100
T_7	Arakha (*Calotropis gigantea*)	Leaf	0	100
T_8	Control		70.44	
	SE(m)±		0.12	
	CD @ 5%		0.29	

Treatment part: b

Treatment	Plant extracts	Plant part used	Mean radial growth (mm) 20% concentration	Per cent inhibition over control
T_9	Karanj(*Pongamia pinnata*)	Leaf	0	100
T_{10}	Big-sage (*Lantana camara*)	Leaf	0	100
T_{11}	Custard apple (*Annona reticulate*)	Leaf	0	100
T_{12}	Bael (*Aegle marmelos*)	Leaf	3.45	95.05
T_{13}	Sadabahar*(Vinca rosea)*	Leaf	0	100
T_{14}	Begunia (*Vitex negundo*)	Leaf	0	100
T_{15}	Control		69.99	
	SE(m)±		0.23	
	CD @ 5%		0.57	

Table.3 Antagonistic effect of some fungal and bacterial bio-agent against radial growth of *Colletotrichum musae*

Sl. No.	Bio agents	Mean radial growth (mm)	Per cent inhibition over control
T_1	*Trichoderma viride*	23.57	61.41
T_2	*T. harzianum*	22.2	63.68
T_3	*T. hamatum*	21.23	65.26
T_4	*Pseudomonas fluorescens*	0.00	100
T_5	*Bacillus subtilis*	17.28	71.74
T_6	Control	61.08	
	SE(m)±	0.94	
	CD @ 5%	2.33	

Table.4 Efficacy of different chemicals against radial growth of *Colletotrichum musae in vitro* (mm)

Treatments	Chemicals	Trade name	Dose	Mean Colony diameter (mm)	Per cent inhibition on control
T_1	Tricyclazole 75% WP	Blastin	0.3%	10.8	83.75
T_2	Propiconazole 25% EC	Dhanuka	0.2%	0.00	100
T_3	Tebuconazole 25.9% EC	Folicur	0.15%	0.00	100
T_4	Azoxystrobin 23% SC	Amistar	0.1%	22.13	66.72
T_5	Carbendazim 50% WP	Zim50	0.1%	0.00	100
T_6	Metalyxl 4% w/w + Mancozeb 64% w/w	Ridomil gold	0.35%	15.76	76.3
T_7	Hexaconazole 5% SC	Trigger pro	0.2%	0.00	100
T_8	Copper oxychloride 50% WP	Nag copper	0.3%	21.38	67.84
T_9	Carbendazim12% WP + Mancozeb 63% WP	Sixer	0.15%	0.00	100
T_{10}	Control			66.5	
	SE(m) ±			0.91	
	CD at 5%			2.19	

Pseudomonas fluorescens and *Bacillus subtilis* were also evaluated in spore suspension method as per material methods. *Pseudomonas fluorescens* caused 100% inhibition of test pathogen followed by *Bacillus subtilis* (71.74%) (Table3). In support of our findings, Shirshikar (2002) repoted that *Trichoderma viride* to be more effective in inhibiting the mycelial growth of *Botryodiplodia theobromae* and *Colletotrichum gloeosporioides* under field condition.

Similarly, Xiao *et al.*, (2007) showed the antagonist effect of *T. harzianum* against *Rhizoctonia solani, Fusarium moniliforme, Colletotrichum capsici and Sclerotium rolfsii*. The colonies of pathogen were either overgrown or invaded by *Trichoderma* spp., leading to inhibition of growth, along with debasement and reduction in spore concentration.

Efficacy of various chemicals against radial growth (mm) of *C. Musae*

Nine fungicides were evaluated against the growth *Colletotrichum musae* in laboratory condition and the percent inhibition over control was calculated. Propiconazole(0.2%), Tebuconazole (0.15%), Carbendazim(0.1%), Hexaconazole (0.2%) and Carbendazim + Mancozeb (0.15%) recorded 100% growth inhibition of the fungus. It was also observed that Azoxystrobin (0.1%) and Copper oxychloride (0.3%) recorded similar control habit against the pathogen with colony diameter 22.13 mm and 21.38 mm respectively (Table 4).

Similar finding also reported by Das *et al.*, (1998) that Propiconazole and Epoxiconazole (50 ppm), Carbendazim, Metalaxyl + Mancozeb (250 ppm) and Calixin (500 ppm) effectively checked the total growth of *C. gloeosporioides* under *in vitro* condition. Patel and Joshi (2002) studied the efficacy of Carbendazim (Bavistin 50% WP), Thiophanate methyl (Topsin-M 75% WP), Propiconazole (Tilt 25% EC) at 250, 500 and 1000 ppm, Hexaconazole (Contaf 5% EC) at 750, 1000 and 1500 ppm and Tricyclazole (Beam 75% EC) at 500 and 1000 ppm and found cent per cent inhibition of *Colletotrichum gloeosporioides* causing leaf spot of turmeric under *in vitro* condition.

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How to cite this article:

Manasranjan Rout, Shubhendu Kumar Behera, K. C. Sahu and Shreeza Nanda. 2020. Post-Harvest Problem of the Ripe Banana and its Management. *Int.J.Curr.Microbiol.App.Sci.* 9(05): 779-786. doi: https://doi.org/10.20546/ijcmas.2020.905.086