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Management of Banana (Musa Paradisiaca 1 L) Fruit Rot Diseases using Fungicides

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Abstract

Banana suffers from several diseases at all the stages of its life. Finger rot and fruit rot caused by the fungus *Lasiodiplodia theobromae* (Pat.) Griffth and Maubl are the most important diseases in field as well as post-harvest of banana fruits. In this study, the antifungal activity of total seven fungicides was tested under *in-vitro* condition against *L. theobromae* and under *in-vivo* condition. The results of present study showed that six fungicides at all tested concentrations were a significantly check the fungal growth. At lowest tested concentration (250 ppm) carbendazim and propiconazole were completely inhibited fungal growth. Copper oxychloride at all tested three concentration were stimulated the mycelia growth of *L.theobromae*. Results of field experiment showed that carbendazim @0.5 gL^{-1} 17 and propiconazole @1mlL^{-1} 18 were completely reduced the percent disease index (PDI) and gave cent percent reduction of the finger rot disease followed by SAAF (97.36%). One hand containing ten fruits were selected from each treated bunch brought to laboratory, kept for ripening under natural Condition up to eating ripening stage the results showed that propiconazole @1mlL^{-1} 21 was highly reduction of PDI (1.50%) and gave highest reduction of fruit rot disease (98.20%) followed by carbendazim (4.005) with increased shelf life of banana fruits. Fruits were dipped in fungicides solution for 2 minutes and kept for ripening results showed that minimum PDI was observed in propicanazole and SAAF (1.00%) treated fruits with 25 maximum reduction of fruit rot disease (98.76%) followed by carbendazim (2.50%) with 96.79 percent reduced fruit rot disease.

Keywords: Banana; Fruit rot; Finger rot; Pathogen; Fungicides; *L. theobromae*

Introduction

Banana (*Musa paradisiaca L.),* fruit is one of the most important commercial fruit and vegetable crops grown all over the world in the tropical and subtropical areas. It is the second largest fruit crop, belongs to family *Musaceae* in order *Scitamineae.* It can be grown round the year and it is widely adopted in India. Apart from this it is considered as potential 'Dollar Earning crop'. Major banana producing countries are India, China, Philippines, Brazil, Ecuador, Indonesia, Costa Rica, Mexico, Thailand and Colombia. It is cultivated on an area of 4.81 Mha with an average production of 100.9 MT. in world, India produced 25.6% of total banana production of the world during 2012-13 (FAO) [1]. It shared 32.6 percent of total national fruit production during 2012-13 [2]. It ranks third in terms of area and first in production with a second in productivity of 34.2 mt/ha [2]. Gujarat share 17.1% of total national banana production with highest productivity (62.3t/ha.). Bananas are highly perishable commodities with post-harvest losses estimated to 25-30% [3]. Banana fruit suffers from many serious diseases such as fruit rot, crown rot, finger rot, cigar-end rot and pitting disease. The current postharvest problems of bananas are mainly concerned with storage and marketing. It is necessary to identify the most prevalent pathogen causing above said diseases and ultimately to reduce the yield loss as well as post-harvest loss of the banana fruit. The aim of this study was to evaluate the common and easily available fungicides in the markets for determine minimum inhibitory concentration (MIC) values of different level to find out the most suitable for field and post-harvest applications to reduced yield and post-harvest losses due to fruit rot of banana.

Materials and Methods

Isolation, identification and proving pathogenicity 50 of banana fruit rot pathogens

Diseased samples of banana fruit (cv. Grand naine) with pulp rot, crown rot, tip end rot, red spots, peeling injury/bruising and finger rot were collected from fruit markets, fruit stalls and domestic store-rooms of South Gujarat (viz., Navsari, Gandevi, Surat, Bardoli and Vyara) and field of soil and water management project, department of plant pathology and fruit research station Gandevi and brought to laboratory, examined visually and microscopically. The symptoms were observed were up to complete rotting of banana fruits. Repeated isolations were carried out from the crown portion, rotted pulp, reddish spot on pericarp and dried tip end rot, after washing thoroughly with tap water. The infected tissue were cut into small bits, surface sterilized with 2% sodium hypochlorite solution for 30 second followed by three subsequent washings with sterilized distilled water and then transferred aseptically on potato dextrose agar (PDA) medium in petriplates. The petriplates were incubated at room temperature for development of fungus growth. The plates were observed daily, the initial growth observed was picked up aseptically and it was transferred to PDA slants. The pure culture thus obtained was further purified by aerial mycelia tip technique. The pure cultures of isolated fungi were stored in slants in the refrigerator at 4^0C and used for further investigations.

Identification of isolates

The pure culture isolates obtained from the diseased banana fruits were used for the purpose of identification. Each isolate was subjected

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to colony and microscopic examinations during which their structural features were observed. After purification, each fungus was allowed to sporulate. The sporulating cultures were identified on the basis of morphological characters of somatic and reproductive structures including spores/conidia. This was followed by a slide mount of each isolate under the lacto phenol cotton blue stain. The characteristics observed were matched with those available in manuals of Barnett and Hunters [4]. They were then identified accordingly.

Pathogenicity test

To prove the Koch's postulate, mature and semi ripen healthy banana fruits (cv. *Grandnaine*) were collected from field as well as from fruit market of Navsari and brought to the laboratory. The fruits were then surface sterilized by 2% sodium hypo chlorite solution for 2 minute followed by three washings with sterilized water and air dried then separately inoculated with each of the isolated fungus by Pin- Pricking method. Five fruits were separately inoculated with each of the isolated fungus. The inoculated as well as inoculated fruits were placed in sterilized, loosely tied polythene bags. A piece of sterilized wet absorbent cotton was placed inside each bag and the bag was kept at room temperature (24-28^{0}C) in an incubation room for symptoms development, inoculated fruits were observed regularly. Reisolation of pathogenic fungi from the diseased fruits was done. Morphological as well as cultural characters of reisolated fungi were compared with those of previously isolated from diseased banana fruits.

Management of Banana fruit rot diseases

The antifungal activity of seven different systemic, non-systemic and combination product (systemic+non systemic) fungicides at three different concentrations were evaluated against *L. theobromae* under in vitro and *in vivo* condition.

In vitro evaluation of fungicides against *L. theobromae*

The aim of this objective was to determine minimum inhibitory concentration (MIC) values of different fungicides to find out the most suitable fungicide with minimum concentration for field as well as post-harvest application to reduce yield and post-harvest losses due to *L.theobromae*. The antifungal activity of seven different fungicides evaluated, in these, three non-systemic (viz., mancozeb, copper oxychloride, chlorothalonil) @1500, 2000, 2500 ppm, three systemic (viz., carbendazim, propiconazole, hexaconazole) @ 250, 500, 1000 ppm and one combination (carbendazim 12 %+mancozeb 63 %, SAAF 75 WP) @1500, 2000, 2500 ppm were carried out against most frequently isolated fungus pathogen viz., *L.theobhomae in vitro* by poisoned food technique method described by Nene and Thapliya, [5]. The measured quantities of fungicides were incorporated in the melted sterilized PDA medium aseptically to obtain desired concentration (minimum inhibitory concentrations, MICs; 250 to 2500 ppm) of different fungicides at the time of pouring into borosil glass petri plates ($^{\varnothing}$90 mm). The 60 ml medium with fungicide was shaken well to give uniform dispersal of fungicides. Than the 20 ml medium with fungicides were poured in each of the Petri plates. After solidification, 5 mm discs of 7 days old culture of *L.theobromae* was placed in the center of test plates and arranged in completely randomized design with three repetitions. The plates were

Incubated at 25 ± 2^{o}C temperature. The plates without fungicides served as control. After 48 and 72 hr of incubation, diameter of fungal growth was measured in each case, by averaging two diameter of fungal colony at right angle to one another and the percent inhibition was calculated by using the formula given by Bliss, [6].

Field evaluation

The field experiments were carried out at a commercial banana field "Soil and Water Management Project", situated at Navsari Agricultural University, Navsari, district Navsari of the Gujarat. Mancozeb, carbendazim, propicanazole, mancozeb+carbendazim (SAAF) that gave the best inhibition of *L.theobromae in vitro* were further evaluated in the field conditions. Efficacy of the fungicides namely mancozeb @ 3.33 gL^{-1}, carbendazim @ 0.5 gL^{-1}, propicanazole @ 1mL^{-1} and mancozeb+carbendazim (SAAF) @ 2gL^{-1} were dissolved in water to get a final concentration of 2500, 250, 250 and 250 ppm respectively which were used for field and post-harvest treatment. Experiment was laid out in randomized block design (RBD) with five treatments in four replications. Variety Grand naine was used for experimentation. The plants were thoroughly sprayed two times, first at bunch emergence and second spray before 15 days of harvest. Before the first spray the plants were tagged and all dead leaves were removed by cutting. Fertilizer application was done as per the recommended dose @ 200:90:200 NPK g/ plants. Irrigation was given as and when required with tube well water. Isolation was done from the bunches of treated and control plants before each spray to determine the infection on each plant. The effect of fungicides on banana bunch was also evaluated by assessing the percent disease index before and after treatment. Percent disease index was evaluated with the help of a model given by Rose [7]. Percent disease index (PDI) was recorded as procedure followed. Percent disease index was evaluated before the harvesting and 10 days after 2nd spray of each fungicide. Disease severity was recorded on the basis of percent fruit area infected under following assessment key (Figures 1 and 2).

Percent disease index (PDI) was calculated using to the formula [7].

$$\text{Percent disease index} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of fruit examined} \times \text{maximum rating}} \times 100$$

One hand containing ten fruits were selected from each treated bunch brought to laboratory, kept for ripening under natural condition at room temperature up to eating ripening stage. Untreated fruits from each untreated bunch served as control. Each treatment was repeated four times, containing forty fruits. All treatments of the uninoculated fruits as well as untreated fruits were packed in sterilized polythene bags and stored at 25-28°C and 90-95% RH. After 12 days, PDI was calculated at eating ripening stage for all treatments as mentioned above. Efficacy (E) of each chemical treatment was calculated as under

$$E = \frac{\text{PDI of control fruits - PDI of treated fruits}}{\text{PDI of control fruits}} \times 100$$

Mancozeb @ 3.33 g/lit., carbendazim @ 0.5 g/lit., propicanazole @ 1ml/litre and mancozeb+carbendazim (SAAF) @ 2 g/lit. Were dissolved in water to get a final concentration of 2500, 250, 250 and 1500 ppm respectively which were used for the post-harvest dips treatments. Banana (c. v. Grand naine) fruits were harvested at uniform maturity stage and were treated by dipping for 2 minutes in the respective fungicides solutions. Before treatments, fruits were surface sterilized with 2% sodium hypochlorite solution for 2 minutes then 3 times rinsed with sterilized water. A randomized complete block design with four replicates considering one hand as one replication having $10^{-1}2$ healthy fruits. The fruit samples were subjected to the above treatments and placed in tray for natural ripening at ambient temperature (25-

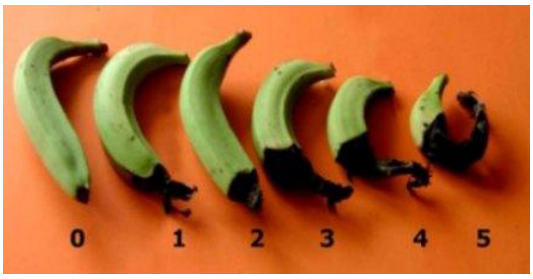


Figure 1: Assessment key for banana finger rot disease.

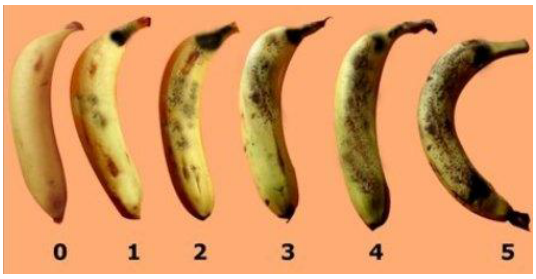
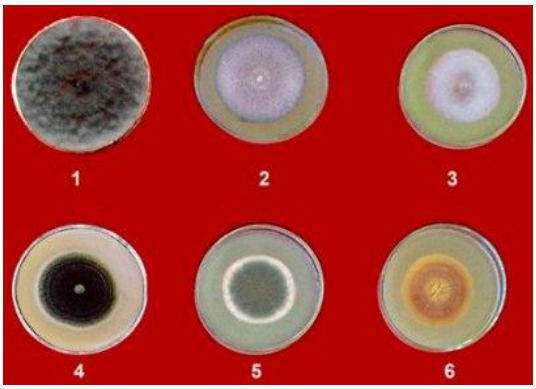


Figure 2: Assessment key for banana fruit rot (ripe) disease.

28^{0}C) up to full ripening stage. Percent disease index (PDI) was worked out as above mentioned procedure.

Results

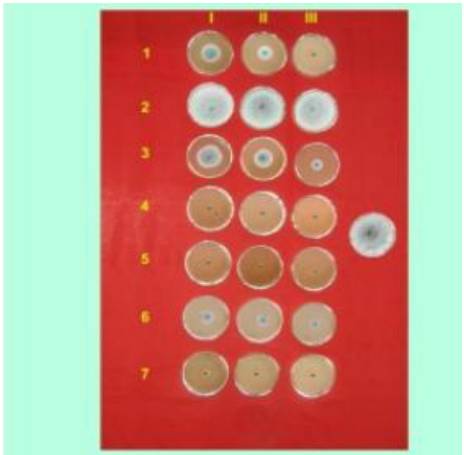
Isolation, identification and proving pathogenicity of banana fruit rot pathogens. Different fungi were successfully isolated from different banana fruit rots included, crown portion, rotted pulp, reddish spot on pericarp and dried tip end rot. The mixed infection of *L. theobromae* Pat., *F. moniliformae* Shield, *Fusarium* sp., *A. niger* VanTiegh., *Acremonium* sp. And *Curvularia* sp. at different stages of field, market and storage was observed of all the isolated fungi *L. theobromae* pat and *F. moniliformae* Sheld. Were predominantly infected banana fruits with *L. theobromae* being the most virulent, exhibiting dried tip end rot and pulp rot Cultural and morphological characters of isolated fungus were studied on PDA medium. On the basis of cultural and morphological characters, the isolates were identified as *L. theobromae* Pat., *F. moniliformae* Sheld, *Fusarium* sp., *A. niger*, *Acremonium* sp. and *Curvularia* sp. (Figure 3) with the help of illustrated genera of imperfect fungi [4]. Among these isolates, *L. theobromae* Pat and *F.monniliformae* were frequently isolated and well responsible for finger rot, crown rot and fruit rot disease in field as well as storage condition. However, for detail identification the purified cultures were confirmed at Agharkar Research Institute, Pune (No.3/426-2008). Immature healthy banana fingers were inoculated with seven days old culture of *L. theobromae* and left for symptom development. Results observed that Symptoms usually begin at the lower-end of the finger at the inoculated site. The decay spreaded uniformly causing black brownish discolaration of the peel and softening of the pulp. The affected area of the peel becomes wrinkled and encrusted with pycnidia. The pulp was reduced to a soft, rotten mass and a dark-grey mold grew on the peel surface under high humidity. The rate of disease development increased with maturity and spreaded to adjacent fingers. Infected clusters tend to ripe prematurely and fully mature fruits are most susceptible to infection. The infection occurred through tissues at the flower-end of the fingers and wounds were created by the insects. Thus, results of our study corroborate with previous workers reported by Goos et al. [8]. They found association of *Botryodiplodia theobromae* (Pat.) with finger rot disease and reported that infection occurs through tissues at the flower-end of the fingers and wounds. Slabaugh [9] found that finger rot disease caused by *Botryodiplodia theobromae* has been reported from Central and South America, the Caribbean Islands, India, Taiwan, and the Philippines. Symptoms produced at the lower-end of the finger or at the wound site resulted in to black- brownish discolaration of the peel and a softening of the pulp and peel becomes wrinkled. The *L. theobromae* was inoculated on healthy banana (var. Grand naine) fruits, produced brownish- black discolaration on the peel and a softening of the pulp on unripe banana fruits. On the ripe fruits water–soaked brownish discoloration observed in the infected area. Under moist conditions white to light grey cottony mycelium covered the infected tissues. Pycnidiospore formation takes place rather late (Figure 4). Water soaked brown discolaration that appeared later turned to dark brown and pulp got rotted slowly, rotting was fast in high humid condition due to *F. moniliformae* (Figure 5). *A. niger* produced light brown discoloration on peel and rotted pulp when fruits were over riped. *Curvularia* sp. produced minute pinkish spots when fruits fully ripened, or at over ripen stage, it extended in size, gone up to pericarp, but not infected pulp. *Acremonium* sp. produced brownish internal rotting at blossom end portion of fruits. The pathogenicity test showed that *Lasiodiplodia theobromae* as the most virulent pathogen, and in culture, it was in the most abundant. This suggests that *L.*



1. Lasiodiplodia theobromae
2. Fusarium moniliformae
3. Fusarium sp. 4. Aspergillus niger 5. Acremonium sp. 6. Curvularia sp.

Figure 3: Fungi associated with banana fruit rot.

Figure 4: Symptoms of banana pulp rot.**I1-**Banana pulp rotted due to *L. theobromae* (Pat.) Griffth and Maubl. **I2**- Banana pulp rotted due to *F. moniliformae* Sheld **C**- healthy banana pulp.



Sr No.	Fungicides	Concentration I	II	III
1.	Mancozab	1500	2000	2500
2.	Copper oxycloride	1500	2000	2500
3.	Chlorothalonil	1500	2000	2500
4.	Carbondazim	250	500	1000
5.	Propiconazole	250	500	1000
6.	Hexaconazole	250	500	1000
7.	SAAF-75WP	1500	2000	2500
8.	Control	-	-	-

Figure 5: In vitro efficacy of fungicides against *L. theobromae*.

theobromae Pat. Could be the leading cause of postharvest fruit rot in banana especially in South Gujarat from where all the samples were obtained. Crown rot disease was the major post-harvest disease due to fungal pathogens viz ; *L. heobromae, F. moniliformae* and *A. niger* the frequency of occurrence of these pathogens was 72% on ripe banana fruits of Grand Naine variety. The next fruit rot disease was due to *L. theobromae* and *F. moniliformae* with 10% fréquency occurrence. *L. theobromae* was the most frequently (43%) isolated in both the diseases followed by *F. moniliformae* (21.5%) from both Navsari and Surat market places. This is suggested that *L. theobromae* could be the leading cause of finger rot as well as post-harvest fruit rot in banana especially here in South Gujarat from where all the samples were obtained.

Management of banana fruit rot diseases

***In vitro* evaluation of fungicides:** Efficacy of seven fungicides at three different concentrations was evaluated for their comparative efficacy against mycelial growth of *L. theobramae* through "Poisoned Food Technique"under *in vitro* condition. All the evaluated fungicides exhibited varying level of efficacy against *L. theobramae.* The perusal of results presented in Table 1 revealed that all the fungicides tried were inhibitory to the fungal growth except coper oxychloride. Among these system fungicide at low concentration (250 ppm) carbendazim and propiconazole, while hexaconazole at 500 ppm inhibited cent percent fungus growth. In non-systemic fungicide, mancozeb and chlothalonil at highest concentration (2500 ppm) completely inhibited the fungal growth. In case of carbendazim 12% +mancozeb 63% (SAAF, 75 WP) completely inhibited growth at lowest (1500 ppm) concentration after 48 hrs of incubation. Copper oxychloride at lowest (1500 ppm) stimulated (12.40%) the fungus growth and stimulation of growth was increased with increased concentration. After 72 hrs of incubation the fungus growth was observed that systemic fungicides, carbendazim and propiconazile at lowest concentration completely inhibited the fungus growth, while hexaconazole at 500 ppm can't completely inhibited the fungus growth that's why the effect of hexaconazole was reduced after 48 hrs of incubation. In non-systemic fungicide, mancozeb at higher concentration (2500 ppm) completely inhibited the growth of fungus followed by chlorothalonil (87.59%), while in case of copper oxychloride the fungus over grew the petri plates i.e., growth was stimulated. SAAF retained their fungitoxicity up to 72 hrs petri plats incubated gave cent percent inhibition. These were four fungicides namely; carbendazin and propiconazole at 250 ppm concentration and mancozeb at 2500 ppm and SAAF at 1500 ppm were found superior in cent percent growth inhibition and proved statistically superior over the rest of fungicides tested. But in case of all tests concentrations for copper oxychloride the pathogen over grew the petri plates i.e., growth was stimulated.

Field evaluation: Out of evaluated fungicides, mancozeb @ 3.33 gL^{-1}, carbendazim @ 0.5 gL^{-1}251 , propiconazole @ 1mlL^{-1}, and SAAF @ 2gL^{-1} dissolved in tap water to make final concentration at 2500 ppm, 250, 250 and 1500 ppm respectively were selected as field and post-harvest treatments on the basis of their inhibitory effects under *in vitro* condition. The result presented in Table 2 revealed that PDI of finger rot was in these treatments ranged between 0.0 to 0.22 as compared to control (2.23%). PDI in banana finger rot was completely checked by carbendazim @ 0.5 gL^{-1} and propicinazole @ 1mlL^{-1}, followed by SAAF (0.08%) @ 2 gL^{-1} amd mancozeb (0.22.) @ 3.33 gL^{-1}. The overall finger rot disease reduction ranged from 91.48 to 100.00% in treated bunches as compared to control. Cent percent reduction of finger rot disease was in propiconazole and carbendazim treated bunches followed by SAAF and mancozeb by 97.36% and 91.48% respectively. All the tested fungicides were significantly reduced finger rot disease under field condition up to harvesting of banana bunches. Propiconazole treated bunches takes 3-5 days more for fruit maturity and increased 5-8% bunch weight as compaired to other tested fungicides as well as untreated bunch.

Storage condition: One hand containing ten fruits were selected from each treated bunch brought to laboratory, kept for ripening under natural condition up to eating ripening stage the results showed that PDI of fruit rot was in these treatments ranged between 1.50 to 11.50 % (Table 3). A minimum PDI of 1.50% was recorded in carbendazim @ 0.5 gL^{-1} followed by 4.0 % inpropiconazole @1mlL^{-1}treated banana bunches. While, 5.50 % and 11.50% PDI was observed in SAAF@ 2 gL^{-1} and mancozeb 3.33 gL^{-1} treated bunches as compared to control (83.00%). In term of percent disease reduction, the overall disease reduction was observed ranged from 86.12% to 98.20%. Maximum reduction of fruit rot disease was observed in propiconazole (98.20%) followed by carbendazim (95.16%) and SAAF (93.45%) treated bunches. While mancozeb was found moderate reduction of banana fruit rot disease as compared to control. Present study also indicated that propiconazole treated fruits take 2-3 day more time to eating ripe stage as compared to other treatments and pulp rotting was rare when stored up to 16 days after harvesting. The present results suggested that propiconazole and carbendazim were the best fungicide to control the field as well as storage disease and also increased shelf life of banana fruits upto16 days after harvest. The post-harvest application result presented in Table 4 all tested fungicides showed the greatest activity with significantly PDI reduction. Minimum PDI was observed in propiconazole and SAAF (1.0%) treated fruits and maximum PDI (4.0%) was observed in mancozeb treated fruits as compared to controlled (76.50%) up to eating ripened stage and16 days of storage. Maximum fruit rot disease reduction was observed in propiconazole and SAAF (98.76%) treated fruits followed by carbendazim (96.79%). Mancozeb and carbendazim produced brownish discoloration on fruit skin after 4-6 days of storage, but there was no effect on pulp. Overall,

Sr.No.	Fungicides	Conc. (ppm)	Growth after 48hrs of incubation		Growth after 72hrs of incubation	
			Growth (mm) *	Growth inhibition (%)	Growth (mm)	Growth inhibition (%)
1.	Mancozeb (Dithane M-45 75%WP)	1500	16.00* (4.06) **	60.49 (10.99) ***	32.33 (5.73) **	64.07 (8.03)
		2000	6.67 (2.68)	83.54 (12.00)	20.67 (4.60)	77.04 (8.80)
		2500	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
2.	Copper oxychloride (Blue copper 50 WP)	1500	45.50 (6.78)	-12.40 (6.94)	90.00 (9.51)	0.00 (0.71)
		2000	51.83 (7.23)	-28.00 (5.69)	90.00 (9.51)	0.00 (0.71)
		2500	61.67 (7.88)	-52.30 (2.84)	90.00 (9.51)	0.00 (0.71)
3.	Chlorothalonil (Kavach 75 WP)	1500	19.33 (4.45)	52.27 (10.62)	41.17 (6.45)	54.26 (7.40)
		2000	9.33 (3.13)	76.97 (11.72)	25.67 (5.09)	71.48 (8.48)
		2500	0.00 (0.71)	100.00 (12.67)	11.17 (3.41)	87.59 (9.39)
4.	Carbendazim (Bavistin 50 WP)	250	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
		500	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
		1000	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
5.	Propiconazole (Tilt 25 % EC)	250	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
		500	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
		1000	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
6.	Hexaconazole (Contaf 5 % EC)	250	7.83 (2.88)	80.65 (11.88)	18.67 (4.38)	79.26 (8.93)
		500	0.00 (0.71)	100.00 (12.67)	12.33 (3.58)	86.30 (9.31)
		1000	0.00 (0.71)	100.00 (12.67)	9.33 (3.13)	89.63 (9.49)
7.	Carbendazim 12 % + Mancozeb 63 % (SAAF 75 WP)	1500	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
		2000	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
		2500	0.00 (0.71)	100.00 (12.67)	0.00 (0.71)	100.00 (10.02)
8.	Control	-	40.50 (6.40)		90.00 (9.51)	
S.Em.±		0.036		0.08	0.079	0.05
C.D. at 5%		0.10		0.22	.22	0.15
C.V. %		2.49		1.20	3.68	1.17

Table 1: Efficacy of fungicides on growth of *L. theobromae* under *in vitro* condition. * Average of three repetition. ** Figures are $\sqrt{X}$ + 0.5 transformed values *** Figures are $\sqrt{X}$ + 60 transformed values.

Sr. No.	Fungicides (ppm)	Per cent disease index (PDI)**	Disease reduction (%)
1.	Mancozeb (Dithane M-45 75%WP) (2500)	0.22** (4.86)*	91.48** (73.55)*
2.	Carbendazim (Bavistin 50 WP) (250)	0.00 (4.05)	100.00 (90.00)
3.	Propiconazole (Tilt 25 % EC) (250)	0.00 (4.05)	100.00 (90.00)
4.	Carbendazim 12 % + Mancozeb 63 % (SAAF 75 WP) (1500)	0.08 (4.36)	97.36 (81.59)
5.	Control	2.23 (9.51)	0.00 (4.05)
S.Em.±		0.042	0.12
C.D. at 5 %		.013	0.37
C.V.%		9.09	3.01

* Figures in the parentheses are angular transformed (X+0.5) values.
** Average of four replication.

Table 2: Effect of fungicides on banana fruit (finger) rot disease development under field Conditions.

the carbendazim @ 0.5 gL^{-1} and propicinazole @ 1mlL^{-1} were found to control the finger rot as well as post-harvest diseases of banana when plants were spayed two times, first just after bunch emergence and second spray before 15days of harvest.

Discussion

Finger rot and fruit rot caused by the fungus *Lasiodiplodia theobromae* (Pat.) Griffth and Maubl. are the most important diseases in field as well as post-harvest of banana fruits in south Gujarat condition. *In vitro* results showed that carbendazim, propiconazole, hexaconazole, carbendazim 12% +mancozeb 63% (SAAF, 75 WP) at lowest tested concentration and mancozeb at highest tested concentration (2500 ppm) were completely inhibited the fungal growth and proved statistically superior over the rest of fungicides tested. Copper oxychloride was found to stimulate the growth of *L.theobromae*. The present results are in agreement with the finding of several studies (Sabalpara, [10]; Thakore, [11]; Godara, [12]) showed that bavistin (0.025%) and dithane M-45 (0.05%) were effective against B. *theobromae* under *in vitro* condition. Ahmad et al. revealed that carbendazim (0.1%) and mancozeb (0.25%) were highly fungitoxic to *L. theobromae* in both solid and liquid media. Banik et. al. [13] observed the complete inhibition of mycelial growth of *B. theobromae* causing mango fruit rot by carbendazim (400 ppm), followed by captan (450 ppm), thiophanate methyl (450 ppm), ziram (600 ppm) and chlorothalonil (650 ppm). Yadav and Majumdar [14] reported effectiveness of carbendazim and mancozeb against *L. theobromae* (Guava isolate). Copper oxychloride at lowest (1500 ppm) stimulated (12.40%) the *L. theobromae* growth and stimulation of growth was increased with increased concentration. Muhammad et. al. [15] also reported that carbendazim and thiophanate methyl when used @ 1 ppm a.i. or more significant inhibition of mycelial growth of *L. theobromae*. Whereas, copxykil, cuprocaffaro and thiovit failed to inhibit the mycelial growth of *L. theobromae*. The results of field experiment showed that the spraying of carbendazim and propiconazole were completely reduced PDI of finger rot disease of banana over the rest fungicide treatment as compared to control (2.23%). Maximum percent reduction of finger rot disease was found in carbendazim 0.5 gL^{-1} and propiconazole @ 1 mlL^{-1} spraying bunches followed by SAAF (97.36%) and mancozeb as compared to control. All the tested

Sr. No	Fungicides (ppm)	Per cent disease index (PDI)	Disease reduction (%)
1	Mancozeb (Dithane M-45 75%WP) (2500)	11.50* (20.27)**	86.12* (68.55)**
2	Carbendazim (Bavistin 50 WP) (250)	4.00 (12.25)	95.16 (77.98)
3	Propiconazole (Tilt 25 % EC) (250)	1.50 (8.13)	98.20 (83.45)
4	Carbendazim 12 % + Mancozeb 63 % (SAAF 75 WP) (1500)	5.50 (14.18)	93.45 (75.76)
5	Control	83.00 (67.62)	0.00 (4.05)
S.Em.±		1.52	1.39
C.D. at 5 %		4.57	4.29
C.V.%		13.05	9.68

Table 3: Effect of pre-harvest application of fungicides on banana fruit rot disease development under storage conditions.

Sr. No.	Fungicides (ppm)	Per cent disease index (PDI)	Disease reduction (%)
1	Mancozeb (Dithane M-45 75%WP) (2500)	4.00* (11.53)**	94.70* (77.34)**
2	Carbendazim (Bavistin 50 WP) (250)	2.50 (9.97)	96.79 (80.52)
3	Propiconazole (Tilt 25 % EC) (250)	1.00 (7.03)	98.76 (85.06)
4	Carbendazim 12 % + Mancozeb 63 % (SAAF 75 WP) (1500)	1.00 (7.03)	98.76 (85.06)
5	Control	76.50 (61.34)	0.00 (4.05)
S.Em.±		1.83	1.03
C.D. at 5 %		5.51	3.11
C.V.%		20.22	9.95

Table 4: Effect of post-harvest application of fungicides on banana fruit rot disease development under storage conditions * Figures in the parentheses are angular transformed (X+0.5) values. ** Average of four replication Fruit assessment was done at the "eating" stage.

fungicides were significantly controlled finger rot disease as compared to control. Similar results were reported from the control of mango die-back caused by *L.theobromae* by spraying with carbendazim @ 0.1% at fortnight interval [16]. Fruits harvested from treated plant, which were kept for natural ripening at room temperature. Minimum PDI was observed in propicinazole (1.50%) followed by carbendazim (4.00%) over the rest fungicides as compared to control (83.00%). Maximum per cent reduction (98.76%) of fruit rot was observed in propiconazole treated fruits followed by SAAF (98.67%) and carbandzim (95.64%) under storage condition up to eating ripe stage. No thytotoxic effect found in any treatment. In post-harvest treatment the results showed that minimum PDI (1.00%) was observed in propiconazole and SAAF treated fruits fillowed by carbendazim (2.50%). Maximum percent disease reduction (98.20%) was observed in propiconazole followed by SAAF and carbendazim treated fruits. Mancozeb and carbendazim showed phytotoxic effect producing brownish discoloration after 4-6 days of storage, but there was no effect on pulp. From these post-harvest experiment suggested that propiconazole was best fungicide to reducing post-harvest loss, while carbendazim and macozeb were other best fungicide if its applied as 10-15 days before the harvest. The present results are more or less in agreement with the results obtained by Khanna and Chandra [17] who reported benomyl and aretan were highly toxic as they completely checked the banana (Var. Harichal) fruits rot pathogen viz., *F. moniliformae* and *F. roseum* as pre and post inoculation treatment up to 8 days. Ved Ram and Dharam vir [18] got complete control of banana fruit rot decay caused by *A. flavus* and *A. fumigatus* by treating the fruits with thiophanate methyl, benlate, thiobendazole, bavistin, propionic acid and sodium metabisulphite at 2000 ppm up to 8 days of storage. Treatments of banana frui ts at three di fferent concent rat ion of thiophanate-methyl and benomyl which inhibi ted the di fferent rot in bananan frui ts range from 89.6 to 100.0% also reported by Latchmeah and Santchurn [19]. The results of field and post-harvest treatment suggested that most common and easily available fungicide i.e., propiconazole @1mlL^{-1} was completely reduced the finger rot disease in field and fruit rot disease in post-harvest disease is considered to be very important in the present day situation because both disease caused by *L. theobromae*. Similarly to the *in vitro* efficacy, the outcome of the field and post-harvest evaluation was highly encouraging propiconazole significantly reduced the post-harvest disease.

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