Title	**Efficacy Trial Terminal Report: BC-TECT *(Citric Acid and Plant Extracts)* as an Effective Organic Bio-Control Agent (OBCA) against Crown Mold and Crown Rot of Cavendish Banana**

Introduction

Banana (*Musa* spp.cv Cavendish) of the AAA cultivar is one of the most important crops in the Philippines, as the leading imported product. However, this particular cultivar is susceptible from the field to postharvest diseases such as anthracnose, crown rot and crown mold. Moreover, banana fruits' susceptibility to these diseases escalates once it is predisposed to Sigatoka disease. It compromises quality and significantly reduces shelf life. Losses could reach up to 50% depending on disease severity (Ploetz 2001; Cook et.al. 2021).

Crown rot and Crown mold are diseases largely caused by *Colletotrichum musae*, *Fusarium* spp., *Lasiodiplodia* spp., *Verticillium* and *Curvularia* spp. Some of these opportunistic pathogens are found in debris, dispersed by wind and untreated water, insects and rodents. Infection would start at the fresh wounds at the crown, the severed portion from the stalk. A rotting symptom would appear at the crown and more often would advance, penetrating deeply into the crown and the feeder-line of the fingers. Poor cultural management in the farm, inferior packing house sanitation, and fluctuating temperature are some of the factors that enhance disease development. It may intensify rapidly during fruit ripening due to starch breakdown to simple sugars (Nelson, 2008; Lassois and de Lapeyre de Bellaire, 2014; Mann et al., 2017). Break of cold chain also enhances infection (Kusumaningrum et al., 2015; Fernando et al., 2019; Pathare and Al-Dairi, 2022).

Postharvest diseases have been a recurrent issue in the entire banana industry. In addition, health impacts of postharvest fungicides are alarming and sensitivity of the registered postharvest fungicides, except lately for Prochloraz (Trevorrow, 2018) are declining. Furthermore, imposed country restrictions on compound residues on fruits and vegetables limits the use of synthetic postharvest products. Therefore, the use of biological control is being considered. Several reports on the efficacy of endophytes in the family of *Fusarium* species and *Musicillium theobromae* have been noted. Another promising postharvest control product for climacteric fruits is potassium silicate (Nikagolla, N.G.D.N, et al., 2019) However, consistency is another issue (Trevorrow, 2018). Mitigating measures however can be done including proper sanitation, wash water treatment and proper cold storage.

Recently, the use of Citric Acid for the control of crown rot and crown mold in bananas have been known (Reeves and Meadows, 2022). Introducing BC-TECT, a liquid formulation fungicide based on citric acid and vegetable extracts, is used as postharvest control. Residue is not an issue due to its natural organic characteristics. It has a broad-spectrum activity that has been effective against postharvest pathogens such as

	Botrytis, *Alternaria*, *Penicillium*, and *Fusarium*. It is effective at modifying pH by secreting organic acids to achieve tissue acidification (Jiao, et al., 2022). Thus, by lowering pH, the pathogen's DNA, proteins and extracellular membranes will be damaged leading to microbial death. This leads us to explore the potential of this product as postharvest control against crown rot and mold.
Objective	The general objective of efficacy trials was to generate efficacy data of BC – TECT to support product registration with DA-BAFS. Specifically, this trial aimed to: 1. determine the efficacy of BC – TECT against crown mold and crown rot on cavendish banana; and, 2. determine the effective dose of BC – TECT against crown mold and crown rot on cavendish banana.
Methodology	1. **Time and location of study** The study was conducted in Pindasan, Mabini, Davao de Oro from March 2023 to June 2023. 2. **Target Pests** Crown mold and crown rot (fungal complex – *Colletotrichum musae*, *Fusarium* spp., *Lasiodiplodia* spp., *Verticulum* and *Curvularia* spp.) - Infection of fresh cut wound at the crown of cavendish banana. 3. **Target Crop** Banana (Musa spp.cv Cavendish) of the AAA cultivar is one of the most important crops in the Philippines as the leading imported product. However, this particular cultivar is susceptible from the field to postharvest diseases such as anthracnose, crown rot and crown mold. 4. **Experimental Design and layout** The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments at four replications. The boxes were arranged inside a reefer container as shown in Figure 1. There are two sample boxes per treatment, with a total of 48 boxes. Table 1 shows the treatment description, rates, and frequency.

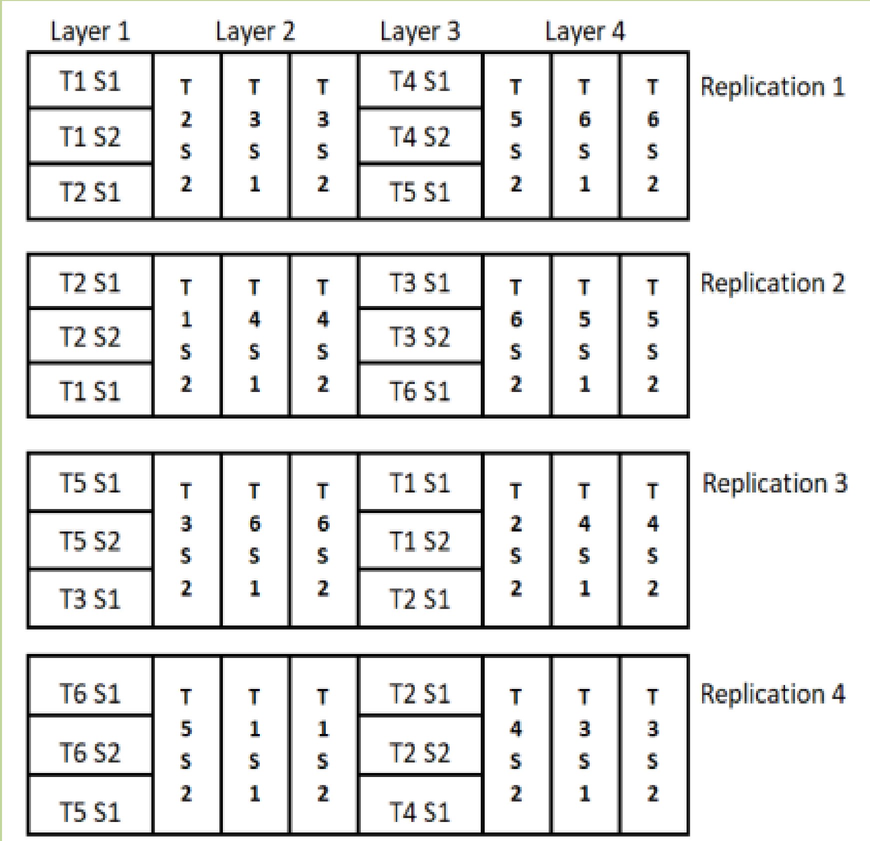

Figure 1. Treatment and box arrangement per pallet or replication.

Table 1. Treatment Application Rates and Frequency

Treatment	Dosage (g or ml/L of water)	Frequency and Schedule (Crown spraying)
T1	Untreated	1 treatment application, prior boxing of and voyage simulation
T2	BC-TECT (Recommended Rate-RR) - 0.4	
T3	BC-TECT - 0.5	
T4	BC-TECT- 0.6	
T5	Hi-Chlon (Calcium hypochlorite) 70G – 0.14	
T6	Omega 45 EW (Prochloraz) - 1	

5. **Cultural Management Practices**
   Preparation of materials. Fruits from a healthy plant were harvested. These fruits were unloaded to the wash tank to remove dirt and debris from harvesting. Good fruits were selected, and damaged fingers were removed using a sharp selector's knife. It was clustered based on the packing specification. Once the desired number of clusters were reached, it was arranged in a tray and then weighed at 13.5 kilos per tray (Figure 2).

Figure 2. Standardization of cavendish banana fruits (A) dehanding, (B) fruits unloaded to wash tanks, (C) arranged, clustered weighted fruits.

Treatment Applications. Treatment sequences were in chronological order (T1 to T6) to avoid treatment contamination (Figure 3). Packing operations and standard protocol were followed, except for the postharvest application. The fruits were packed after the liquid or excess moisture had dried out so as not to promote latex flow, which also hastens the growth of pathogens. Packing followed the pattern for cluster pack (crown down), and the number of clusters per box was achieved.

Figure 3. (A) Treatment application and (B) treated banana fruits.

Packaging materials were according to specifications. The boxes were labeled accordingly. After packing, the boxes were stored in a reefer container to simulate transit for 30 days maintaining the temperature of 13 – 140 Celsius. The boxes were arranged randomly, and distributed evenly inside a 40-footer container. This is to encourage uniformity of airflow, and cool temperature in each box. Data logger was installed inside the container to monitor the temperature for the entire 30 days of storage. It was automatically saved and recorded.

Data to be Gathered	1. **Disease incidence (DI)**. The DI rating was calculated using formula below: $$\%DI = \frac{\text{Total of infected cluster hands}}{\text{Total number of samples}} \times 100$$ 2. **Disease Severity (DS).** The DS percentage for Crown rot and Crown Mold was calculated using the formula below: $$\%DS = \frac{\Sigma(n(0)+n(1)+n(3)+n(5)}{N(5)} \times 100$$ The ratings scales for crown rot and crown mold are shown in Tables 2 and 3:

Table 2. Crown Rot

Scale	Crown rot rating
0	None, no rotting
1	Slight, rotting up to 2mm
3	Moderate, 50% of the crown is infected
5	Severe, rotting has expanded from neck to finger

Table 3. Crown Mold

Scale	Crown mold rating
0	None, no mold growth
1	Slight, mold growth <25%
3	Moderate, mold growth 26 to 50% of the crown
5	Severe, mold growth >50% of the crown

Results & Discussion	The product, BC – TECT met the acceptable standard efficacy against the crown mold and crown rot of banana on the following parameters: Note: 30 Days After Treatment 2 (DAT2) results were the simulation on the actual transit time and inspection in distant markets such as the Middle East or New Zealand. The set-up was not disturbed during the period. 1. **Mean percent reduction on crown mold incidence.** The average percent reduction on crown mold incidence is shown in Table 4. The applications of BC – TECT at 0.4ml/L, 0.5ml/L and 0.6 ml/L were effective against reduction of crown mold incidence. Further, BC – TECT at 0.5 ml/L had the highest percent efficacy results from the 30DAT2 simulated voyage.

Table 4. Mean percent reduction on crown mold incidence.

Treatment	Mean from Data Gathering	30 DAT2
T2-BBC – TECT (RR) at 0.4 ml/L	82.50 %	44.00 %
T3-BC – TECT at 0.5 ml/L	86.40 %	65.50 %
T4-BC – TECT at 0.6 ml/L	80.20 %	29.20 %

2. **Mean percent reduction on crown mold severity.** The average percent reduction on crown mold severity is shown in table 5. The applications of BC – TECT at 0.4ml/L, 0.5ml/L and 0.6 ml/L were effective against reduction of crown mold severity based on the results of mean from data gathering and data from 30 DAT2 simulation of voyage.

Table 5. Mean percent reduction on crown mold severity

Treatment	Mean from Data Gathering	30 DAT2
T2-BBC – TECT (RR) at 0.4 ml/L	80.40%	71.90%
T3-BC – TECT at 0.5 ml/L	89.70%	82.70%
T4-BC – TECT at 0.6 ml/L	75.90 %	64.50%

3. **Mean percent reduction on crown rot incidence.** The average percent reduction on crown rot incidence is shown in table 6. The applications of BC – TECT at 0.4ml/L, 0.5ml/L and 0.6 ml/L were effective against reduction of crown rot incidence based on the results of mean from data gathering. Further, BC – TECT at 0.4ml/L and 0.5ml/L is effective in reduction of the disease incidence based on data from 30 DAT2 simulation of voyage.

Table 6. Mean percent reduction on crown rot incidence

Treatment	Mean from Data Gathering	30 DAT2
T2-BC– TECT (RR) at 0.4 ml/L	94.30%	57.30%
T3-BC – TECT at 0.5 ml/L	95.60%	72.20%
T4-BC – TECT at 0.6 ml/L	94.90 %	47.10%

4. **Mean percent reduction on crown rot severity.** The average percent reduction on crown rot severity is shown in table 7. The applications of BC – TECT at 0.4ml/L, 0.5ml/L and 0.6 ml/L were effective against reduction of crown rot severity based on the results of mean from data gathering and data from 30 DAT2 simulation of voyage.

Table 7. Mean percent reduction on crown rot severity

Treatment	Mean from Data Gathering	30 DAT2
T2-BC – TECT (RR) at 0.4 ml/L	89.70%	57.80%
T3-BC – TECT at 0.5 ml/L	88.10%	76.80%
T4-BC – TECT at 0.6 ml/L	82.50%	59.10%

Conclusion and Recommendation	1. The product BC – TECT was able to reduce the disease incidence and severity of crown mold and crown rot of post – harvest cavendish banana. 2. BC – TECT was able to meet the percent efficacy standard, ≥50 percent in the PNS/BAFS 182:2016. 3. BC – TECT at 0.4 to 0.6 ml/Liter of water was effective against crown mold and crown rot of post – harvest cavendish banana.
Researcher and Company Profile	 **LOVE VINE C. LAVADOR, PhD** Vine's Phytolab and Agricultural Consultancy D-2, 2/F, KS Business Center, J. Abad Santos, Magugpo Poblacion, Tagum City DA-BAFS Certified Researcher DA Special Order No. 065 series 2022 **COMPETITIVE ELECTRONICS ZONE CORPORATION** Unit 302 Relta Bldg., Rodeo Drive, Laguna Bel Air 2, Sta. Rosa City, Laguna
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Annex

-Photo Documentation

Figure 4. (A) Selecting of sample clusters; and (B) Weighing of samples.

Figure 5. (A)Preparation of treatment; and (B) Application.

Figure 6. (A) Packing of treated sample clusters; and
(B) Placing data logger inside the box for each replicate.


Figure 7. Packed treated Banana fruits stored in a reefer container.

Figure 8. Treated Cavendish banana fruits at 30 days of treatment (DAT). (A) T1: Untreated Control; (B) T2: BC-Tect (RR) at 0.4 ml/L; (C) T3: BC-Tect at 0.5 ml/L; (D) T4: BC-Tect at 0.6 ml/L; (E) T5: Hi Chlon *(Calcium hypochlorite)* 70G at 0.14 g/L; and (F) T6: Omega *(Prochloraz)* 45 EW at 1.0 ml/L.