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Uptake, Distribution and Persistence of Systemic Fungicides in Large Palms

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Introduction

Palm trees add unique features to landscapes due to their plant architecture. Their use continues to expand as they become dominant elements in the landscape throughout the southern continental U.S. Increasingly, the health and survival of palms in the landscape is being challenged by new insect pests and diseases, and a resurgence of established pests and diseases. Unfortunately, palms that are properly managed to reduce environmental stresses appear to be just as vulnerable to the lethal diseases as improperly managed palms, which limits the use of cultural methods as a means to manage these diseases.

Large palms (those with more than 5 to 6 feet of clear trunk) in the landscape (commercial, homeowner and municipal landscapes) present special problems for pest control. Foliar application of pesticides is impractical due to palm height and canopy spread, their location within landscapes (inaccessible without a bucket truck or lift), and environmental and human health risks caused by spray drift.

Only two diseases of mature, large palms have been successfully managed with systemic pesticides. Phytophthora bud rot control in coconuts, caused by *Phytophthora palmivora*, has been achieved in Africa and Asia using trunk injections of fosetyl-Al (e.g., Aliette) or phosphite as preventive treatments. In Africa, two or three trunk injection applications per year appear to be necessary for adequate disease control, but is still not economical for this crop. Distribution of the phosphite compound in palms has not been determined, but we do know that phosphite is translocated via phloem and xylem tissue, a unique characteristic for fungicides.

In the U.S., the only palm disease for which a successful management plan using a pesticide has been developed is lethal yellowing (LY) caused by a phytoplasma, a phloem-limited, unculturable bacterium. The pesticide used is the antibiotic oxytetracycline HCl (OTC). Various methods of applying the antibiotic to mature coconut palms were tested in the 1970s, and it was determined that only a liquid trunk injection (one injection site per palm) was effective in moving this material into the phloem tissue of the palm canopy. Soil drenches, foliar sprays and trunk implantation of solid tablets were ineffective. It was also determined that repeat applications (2-6.5 ml per palm, depending on size) were necessary every 4 months for disease management because foliar concentrations slowly declined. This is in contrast to the use of

tetracycline in dicot trees for similar diseases, where multiple injection sites per application are necessary (dicot vs. monocot morphology) and treatments are only necessary once a year.

In contrast, virtually no research has been conducted on these same topics (uptake, distribution and efficacy) for xylem-mobile fungicides that may have applicability for management of fungal palm diseases in the landscape. Some of our questions include: Are these fungicides taken up by roots? Can these fungicides be injected or infused into the trunk? Where do these fungicides accumulate in the palm? How long does the fungicide persist in the appropriate palm tissue? After all, the fungicide must accumulate and persist in the palm tissue the pathogen infects in order to be effective.

Objectives

The overall objective of this research project was to determine the uptake, distribution and persistence of selected xylem-mobile fungicides in large palms (mature palms with trunks) over a defined time period.

Materials and Methods

- **Palm material**

Coconut palms (*Cocos nucifera*) with at least 15 feet of clear trunk located at the University of Florida's Fort Lauderdale Research and Education Center were used for this experiment. These palms are growing in a uniform Margate fine sand soil and had not been subjected to pesticide treatments prior to this experiment. When this proposal was first submitted (October 2009), shorter coconut palms were our intended research material, as they could be sampled using orchard ladders. However, the long, cool winter of 2009-2010 severely damaged this group of coconut palms, so larger (i.e., taller) coconut palms were used. It was not feasible to move a bucket truck efficiently in this grove for sampling, and a lift was rented to access the palm canopies.

All palms had at least 13 leaves. Leaves used for sampling were numbered by starting with the newest growth at the time the fungicides were applied. The emerging spear leaf is leaf 0, the next oldest leaf (fully emerged and expanded) is leaf 1, and so on down through the canopy to the oldest leaf. Leaves that emerge after the start of the experiment are labeled as -1, and so on up through the new growth emerging in the canopy.

The diameter at breast height (DBH) for the 20 palms in the experiment ranged from 7.50 to 12.50 inches. The mean DBH (inches) was 9.76 $\pm$ 1.50 (SD). Because canopy size and height are not related to DBH in palms, a 10 inch DBH was used to standardize and simplify calculations.

- **Systemic fungicides and application methods**

Fungicides were applied on August 16, 2010. Fungicides used in the study included propiconazole (Alamo), tebuconazole (Tebuject 16), thiabendazole (Arbotect 20-S) and thiophanate methyl (3336). Thiabendazole and thiophanate methyl belong to the same class of fungicides, benzimidazoles. Thiophanate methyl is labeled for soil-root drench or foliar spray applications; the other three fungicides are labeled for trunk injections. There were four palms per fungicide treatment, and four palms for the untreated control treatment.

Since the grant protocol is designed to look at commercial feasibility of products on or soon to be on the market, exceeding legal labeled rates of fungicides was not desirable. But, there are no established fungicide rates for mature palms, so the following rates for dicot trees or plants were selected. For 3336, the highest labeled soil drench rate is 16 fluid ounces per 100 gallons with 3 ptints of mixed fungicide per square foot. For Alamo, the dominant labeled rate is 10 ml per inch DBH. For Tebuject 16, the highest labeled rate for any disease is one 6-ml capsule multiplied by DBH/2. For Arbotect 20-S, the highest labeled 1-year therapeutic rate for Dutch elm disease of 4 fluid ounces per 5 inches DBH was selected. In a preliminary experiment using half this rate, the active ingredient in Arbotect 20-S (thiabendazole) was detected, but detection had been relatively low and inconsistent throughout the canopy and among replicate palms. The actual amount of active ingredient and formulated product per palm is provided in Table 1.

Table 1. Fungicides (chemical name, trade name) and amount used in experiment.

Chemical name	Trade name	lbs. a.i./gal.	a.i. per palm	Formulated amount per palm
Propiconazole	Alamo	1.3	0.55 oz.	100 ml (3.4 fl. oz.)
Tebuconazole	Tebuject 16	1.4	0.18 oz.	30 ml (1.0 fl. oz.)
Thiabendazole	Arbotect 20-S	1.84	1.84 oz.	240 ml (8.1 fl. oz.)
Thiophanate methyl	3336	4.0	0.75 oz.	44 ml (1.5 fl. oz.)

In contrast to the antibiotic injections for lethal yellowing where no more than 5.0 ml of liquid material is injected into a coconut palm, the amount of fungicide needed to be injected for this experiment ranged from 30 ml to 240 ml. Preliminary studies with the fungicide Arbotect 20-S (thiabendazole) demonstrated an infusion technique was a better method for fungicide uptake by palms when compared to a trunk injection under low pressure. Infusion allows for passive uptake of the fungicides into the palm. Therefore, pine tree infusers provided by Rainbow Treecare Scientific Advancements (see this web page for photo of infuser: http://www.treecarescience.com/arborceuticals/equipment/pine-infuser-system) were used to apply propiconazole (Alamo), tebuconazole (Tebuject 16) and thiabendazole (Arbotect 20-S). Two holes on opposite sides of the trunk at breast height were drilled 2.5 inches deep using a 5/64 inch drill bit. The infuser nozzle was tapped into trunk with rubber mallet to a 1-inch depth, and the tube attached to the nozzle was tied upright to the trunk with flagging tape. Each tube held about 40 ml liquid. These three fungicides were added undiluted to the infuser tubes. For propiconazole and thiabendazole, multiple additions of fungicide were required to the infuser tubes. Problems regarding formulation are discussed in the Results section.

For thiophanate methyl (3336), formulated material was mixed with tap water and 75 pints of fungicide mixture were poured over a 25 square foot area around each of four replicate palms. This area had been treated with glyphosate (Round-up) herbicide to eliminate any other plant growth (grass and dicot weeds) that might interfere with fungicide uptake. It had rained the evening prior to fungicide applications, and the ground was moist which prevented any soil

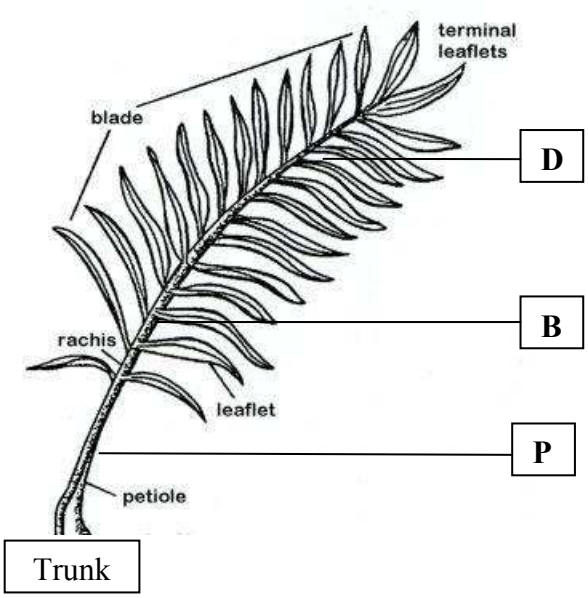
water repellency to the fungicide mixture. A light rain (approximately 0.25 in.) occurred about 4 hours after the fungicide was applied.

- **Fungicide detection in leaf tissue using a biological assay**

A bioassay method was used to detect fungicides in the leaf tissue sampled. This bioassay uses *Fusarium oxysporum* f. sp. *palmarum*, a palm pathogen, and a *Penicillium* sp., a non-pathogen. The latter is more sensitive to the fungicides than the *Fusarium* pathogen. For each fungus, spore suspensions are prepared in sterile deionized water, diluted to 10^4 spores per ml and added to sterile water agar. A thin layer of this agar-spore suspension is spread on the surface of potato dextrose agar amended with 300 $\mu g\ ml^{-1}$ streptomycin sulfate to inhibit bacterial growth. The fungal-seeded media is used immediately. After leaf tissue or paper discs are placed on the media, plates are incubated at 25°C. Zones of fungal inhibition are measured in two directions and the average recorded. This is done at 24 hours for *Fusarium* and 40 hours for *Penicillium*.

Standard inhibition curves were developed using sterile filter paper discs (6-mm diameter) saturated with a range of known concentrations applicable for each fungicide active ingredient. After drying, discs are placed on fungal seeded media, incubated and inhibition zones measured. Standard curves were developed at the same time the leaf assays were conducted, so a new standard curve was developed for each sampling time.

For sampling leaflet tissue, 4 basal leaflets and 4 distal leaflets (2 from each side of the rachis) were cut from the rachis, washed and blotted thoroughly dry. Leaflet tissue discs (6-mm diameter) were cut out of the leaflets (8 discs per leaflet) using a paper hole punch and placed on the fungal seeded media.



The petiole is the term used for the leaf "stem" between the trunk and the beginning point of the leaflets. The rachis is the continuation of the petiole into the blade.

Figure 1. Diagram of typical pinnate palm leaf, explaining location of petiole and rachis tissue sampled.

For sampling petiole and rachis tissue, three 4-inch sections were obtained from each leaf: a) petiole section (P), located half way between the trunk and rachis, b) basal section of the rachis,

located about 24 inches from beginning of rachis (B), and c) distal section of the rachis, located about 24 inches from leaf tip (D). The epidermis of each section was removed and a cross-section selected and cut into 5-mm by 5-mm pieces of ~2-mm thickness. There were 4 sub-sections from each of the 3 sections placed on each of the fungal seeded media. Note that sampling the petiole and rachis is destructive sampling since the leaf is removed from the canopy. On each sample date, one of the oldest (=low) leaves, a mid-canopy leaf (=middle), and the youngest, fully expanded leaf (=high) was sampled from each palm.

Dates when palms were sampled are shown Table 2. Fungicides were applied on August 16, 2010. Only leaflets were sampled 1 week (August 23) after fungicides were applied. Leaflets and petiole/rachis tissue were sampled at 4 weeks (September 13) and 8 weeks (October 12) post-application. Thereafter, only petiole/rachis tissue was sampled as no fungicides were detected in the leaflet tissue on the October 12 sample date. No samples were obtained from lower leaves on March 3 and from lower and middle leaves on April 12 as all such leaves had been removed from the palm by that time. The coconut palms grew normally (about one new leaf every 4 to 5 weeks) until the end of November when we experienced a near freezing temperature event. At that time, new leaves either did not emerge or were emerging extremely slowly. There was no fully emerged new leaf to sample until early March (leaf -3). Only one leaf was sampled on April 12 (leaf -4), as all older leaves had been removed for sampling by this date.

Table 2. Sample dates and location within canopy of coconut leaf tissue sampled.

Tissue sampled	Specific leaf number sampled						
	2010					2011	
	Aug. 23	Sept. 13	Oct. 12	Nov. 8	Dec. 6	Mar. 3	Apr. 12
Leaflets only	0	0	-1	-2	-3	NS	NS
Leaflets, petiole, basal rachis, distal rachis							
Low[y]	NS[z]	10	9	8	7	NS	NS
Middle	NS	5	4	3	2	6	NS
High	NS	1	0	-1	-2	-3	-4

[y] General position within canopy
[z] NS=not sampled

Results

Fungicide formulation and uptake of the fungicides using the infusers requires comment before results on fungicide detection in leaf tissue are presented.

Thiabendazole (Arbotect 20-S)

The treatment amount was 240 ml and each infuser only held 40 ml. With two infusers per palm, only 80 ml of thiabendazole could be added at a time. As palm uptake of the fungicides emptied the infusers, the next 80 ml would be added. Thus, 80 ml was added to the infusers at 8 AM on August 16, another 80 ml was added at 4 PM on the same day (when infusers for all thiabendazole-treated palms were empty), and a third 80-ml amount was added at 8 AM on August 17 for a total of 240 ml. By 4 PM on August 17 (32 hours after infusion began), all 240 ml of the thiabendazole had been taken up by the palm. When this formulation of thiabendazole mixes with water, it remains a clear liquid.

Propiconazole (Alamo)

Twenty-four (24) hours after infusion was initiated, approximately 50% of the fungicide (50 ml) had been taken up by each palm. In contrast, 160 ml of Arbotect 20-S (thiabendazole) had been taken up by palms after the same amount of time. After 32 hours, all the Alamo fungicide (100 ml) had been taken up by each palm. This formulation of propiconazole does form a somewhat cloudy, but apparently stable, emulsion when mixed with water. The mixture is not a clear liquid like Arbotect 20-S is when mixed with water, but it is certainly not as cloudy as the Tebuject 16-water mixture described below.

Tebuconazole (Tebuject 16)

Forty-eight (48) hours after infusion was initiated, only 15 ml of the 30 ml of fungicide added to the infusers (15 ml into each infuser per palm; 2 infusers per palm) had been taken up by each of the tebuconazole-treated palms. This formulation of tebuconazole forms a very milky, but apparently stable, emulsion when mixed with water. There had been some palm sap back flow into the infusion tube during the second night of the experiment as the bottom inch of material in the infusion tube was milky when examined at 48 hours post application. At 48 hours, the infusion tubes were removed and fungicide remaining discarded. In an attempt to place a total of 30 ml Tebuject 16 into each palm, Arborjet's QUIK-jet injection system was used. Three new holes, equidistant around the trunk at DBH, were drilled into the trunk with a 9/32 inch drill bit at a 2-inch depth and arborplugs inserted. With great difficulty, 5-ml of Tebuject 16 was injected into each hole for a total of 15 ml per palm (30 ml per palm as infusion plus injection).

On all seven sampling dates, leaf tissue samples were obtained from the four control (untreated) palms that were equivalent to leaf tissue samples from the fungicide treated palms. For all dates, there was no inhibition of either fungus (*Fusarium* or *Penicillium*) by any leaflet, petiole or rachis tissue, indicating there was nothing naturally present in the palm tissue that inhibited these fungi. Thus, any inhibition of these fungi by tissue obtained from fungicide treated palms described below is assumed to be due to an applied fungicide.

The level of fungicide (active ingredient) detected in each tissue piece on each sampling date was based on the results obtained with the fungicide saturated sterile paper discs for that

particular sampling date. Examples of standard curves developed are shown in the figures below for the September 13, 2010 sampling date.

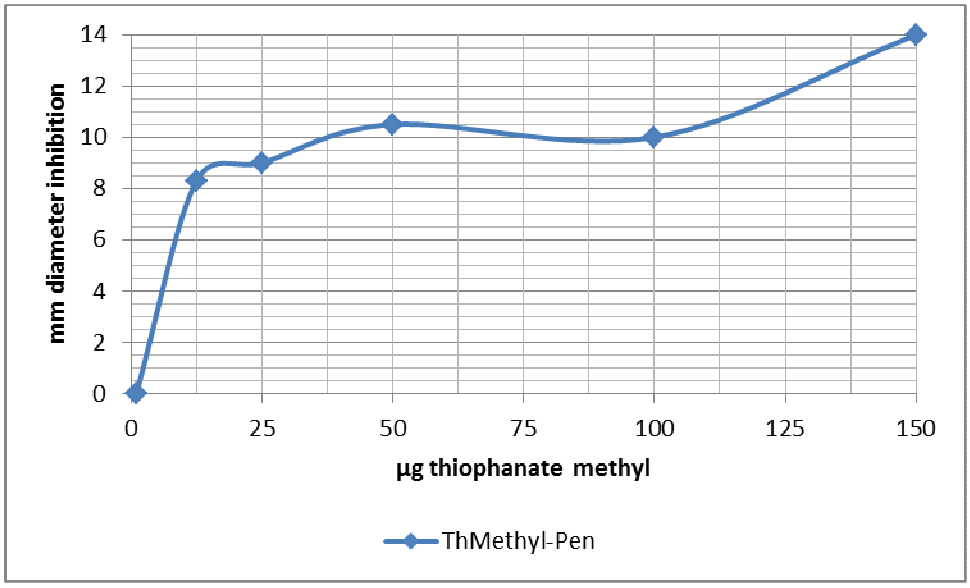


Figure 2. This figure shows *Penicillium* inhibition only as *Fusarium oxysporum* f. sp. *palmarum* was not inhibited by this formulation of thiophanate methyl.

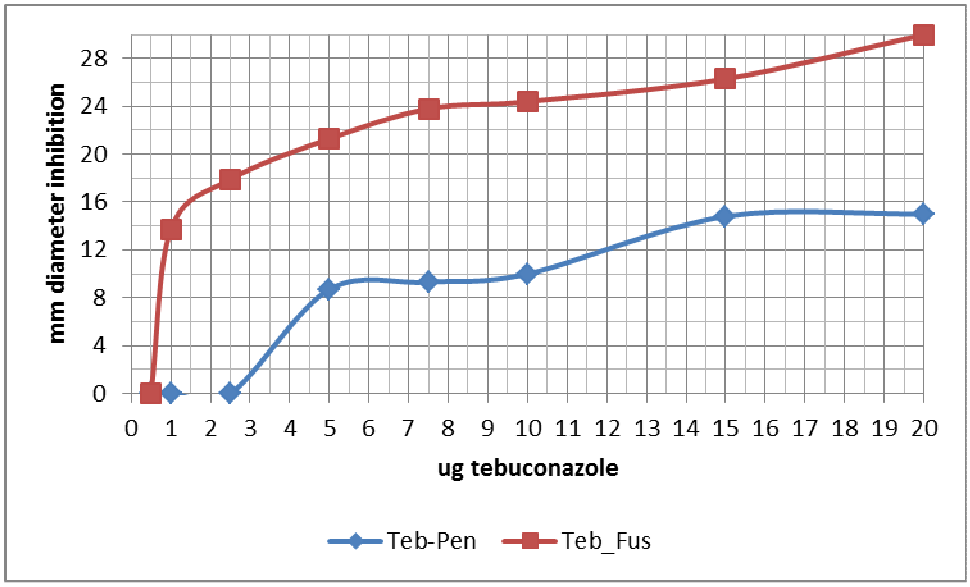


Figure 3. Inhibition of *Penicillium* (Pen) and *Fusarium oxysporum* f. sp. *palmarum* (Fus) by tebuconazole.

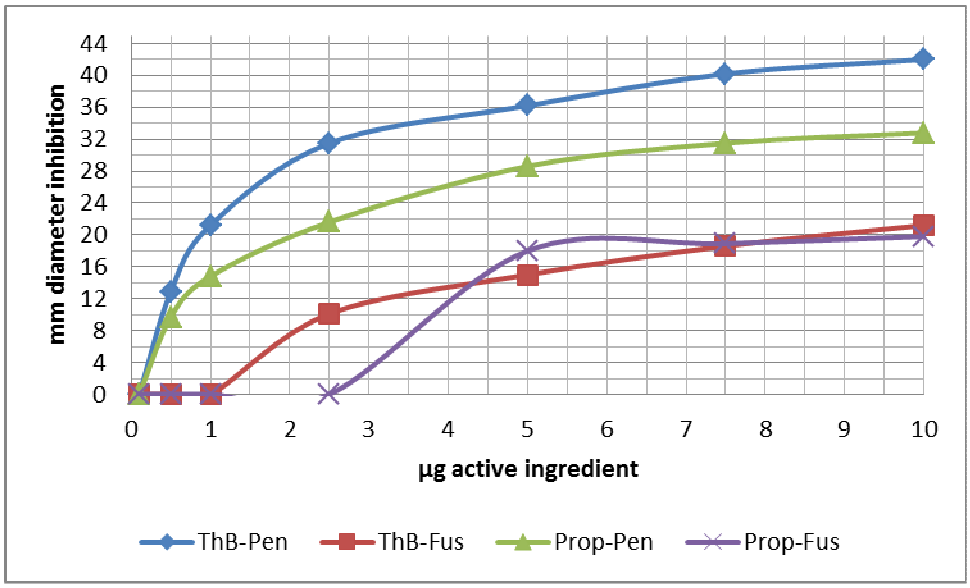


Figure 4. Inhibition of *Penicillium* (Pen) and *Fusarium oxysporum* f. sp. *palmarum* (Fus) by thiabendazole (ThB) and propiconazole (Prop).

The consistency of inhibition among sampling dates was good. Results with thiabendazole, which was detected for all sampling dates with *Penicillium* as the bioassay fungus, is provided as an example below. The December 6 standard curve was the least consistent, at least at the lower levels.

Table 3. Mean and standard deviation for each level of thiabendazole across seven sampling dates.

Thiabendazole level	Inhibition (mm) of *Penicillium* [z]	SD
10.0 µg	43.5	4.1
7.5 µg	41.5	3.4
5.0 µg	37.8	2.9
2.5 µg	30.9	2.1
1.0 µg	20.2	2.4
0.5 µg	11.6	2.8
0.1 µg	0	0

[z]Mean of 35 replicates (6 replicates x 7 sample dates).

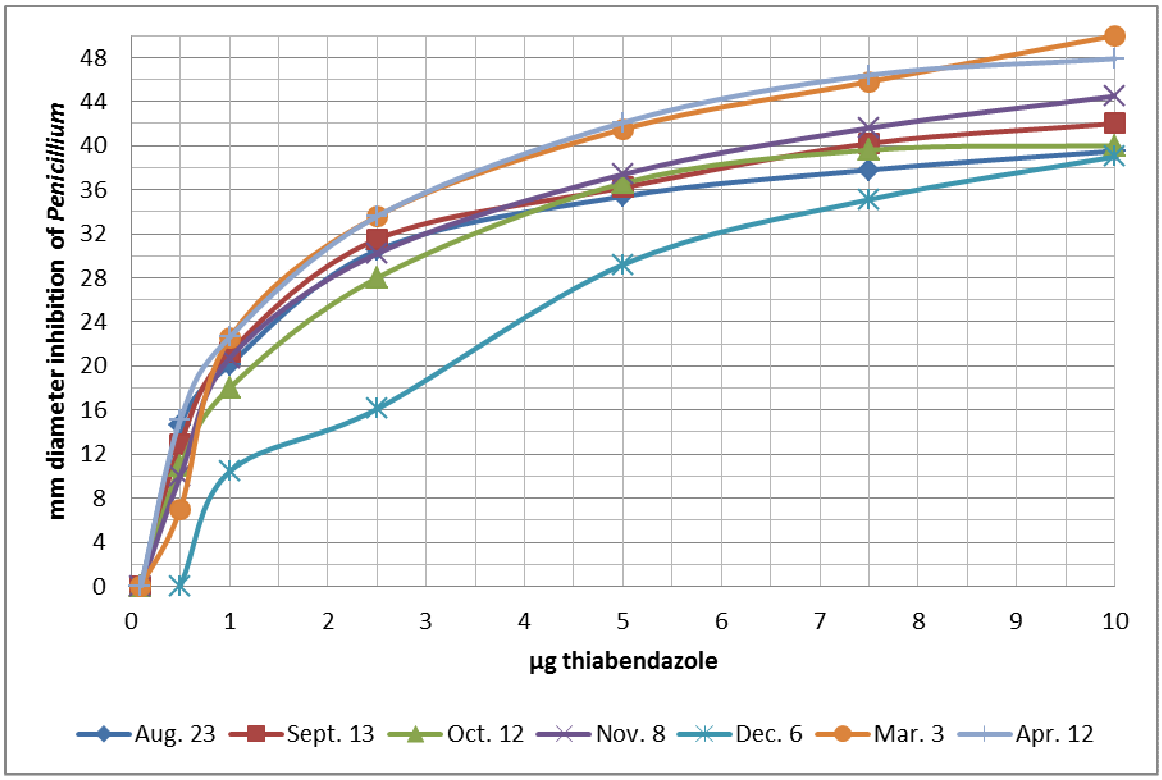


Figure 5. Inhibition of *Penicillium* by thiabendazole on seven different sampling dates.

Thiophanate methyl (3336) and tebuconazole (Tebuject 16) **were not detected** from any leaf tissue sample (leaflets, petiole and rachis) on any of the five dates that samples were obtained from treated palms (August 23 through December 6).

Detection of thiabendazole (Arbotect-20S) and propiconazole (Alamo) in **leaflet tissue** was inconsistent on August 23, September 13 and October 12, and neither was detected on November 8 and December 6. On August 23, only thiabendazole was detected and only in leaf 1 of one replicate palm (Rep III). On September 13, propiconazole was detected only in leaf 1 of one replicate palm (Rep III); thiabendazole was detected in leaves 0, 5 and 10 of Rep IV, but was not detected in Rep III. On October 12, propiconazole was detected in leaves 0 and -1 of Rep III; thiabendazole was detected only in leaf 0 of Rep IV. In all cases, <0.5 µg active ingredient was detected.

Detection of thiabendazole (Arbotect-20S) in **petiole and rachis tissue** is shown in Table 4 (end of document). In general, the fungicide was detected in at least one of three locations of each leaf sampled during the first three sampling dates. It was always the distal portion of the rachis of the lowest (oldest) or middle leaves in the canopy where the fungicide was not detected on these dates. On December 6, the fungicide was detected primarily in the middle and highest (youngest) leaves in the canopy, but never in the distal portion of these leaves. On March 3, thiabendazole was detected only in the petiole of the youngest leaf of Rep I. On April 12, it was detected in the youngest leaf of Rep I and Rep IV, albeit at very low concentrations.

In general, the greatest amount of thiabendazole detected in the palm canopy was present 8 weeks (October 12) after fungicide infusion, after which the level declined. The highest level of thiabendazole detected was 1.2 µg (October 12), 2.5 µg (October 12), 1.4 µg (October 12) and 4.6 µg (November 8) in replicate palms I, II, III and IV, respectively.

Detection of propiconazole (Alamo) in **petiole and rachis tissue** is shown in Table 5 (end of document). The fungicide was only detected in 2 of 4 replicate palms. Even in these two palms, the detection level was $\leq$1.2 µg for the first two sampling dates (September 3 and October 12) and $\leq$ 0.7 µg for the next two sampling dates (November 8 and December 6). The fungicide was not detected in any palm in March or April. Even though the amount detected was low, the same general trend was observed – highest levels at the 4 and 8 weeks post-application sampling dates, following by a decline.

It should be noted that no phytotoxicity was observed with any of the four fungicides, despite using undiluted material.

Discussion

The first problem encountered was formulation. While passive uptake of a fungicide may not be commercially feasible, we believe if the palm is unable to take-up the fungicide passively then even low-pressure injection is not likely to succeed. For the three "injectable fungicides", thiabendazole (Arbotect 20-S) is the only product that remains a clear liquid when mixed with water. It was also taken up the fastest by coconut palms. After 24 hours, coconut palms had taken up 160 ml Arbotect 20-S (thiabendazole), 50 ml of Alamo (propiconazole) and none of the Tebuject 16 (tebuconazole).

While a soil drench or quick trunk injection of these fungicides would be desirable, it remains to be determined if soil drenches are an effective means of moving a fungicide into the canopy and how much fungicide it is physically possible to inject into a palm trunk, even under low pressure. As a reminder, various methods of applying the antibiotic oxytetracylcine HCl (OTC) to mature coconut palms were tested in the 1970s, and it was determined that only a liquid trunk injection (one injection site per palm) was effective in moving this material into the canopy. Soil drenches, foliar sprays and trunk implantation of solid tablets were ineffective. Furthermore, even today, the amount of the most commonly used formulated OTC material (TreeSaver) being injected is never more than 6.5 ml per palm.

In our experiment, the lowest amount of fungicide infused into the palm trunks was 30 ml (Tebuject 16). The active ingredient in this fungicide (tebuconazole) was never detected in the canopy. While this is likely due to the incompatible formulation, it is also possible that the highest labeled rate is too low to be detected. Note that the maximum labeled rate was being used for this product. Tebuject 16 is designed to be used in injectable capsules that contain a premeasured amount of product. Only 0.18 ounces tebuconazole was used, as compared to 0.55 ounces propiconazole (Alamo) and 1.84 ounces thiabendazole (Arobtect 20-S). While this is a workable solution for hardwood (dicot) trees, it is not workable for monocot palms where wounds are permanent and where it is highly probable that multiple applications will be required each year (to be discussed later). To inject 30 ml into a coconut palm with a 10 inch DBH would require drilling a minimum of 5 holes into the trunk for <u>each</u> application. To increase the amount

of active ingredient injected into a palm would require more holes. With the most commonly used OTC material and technique used in Florida (TreeSaver), the injection site is actually used twice before a new hole is drilled.

Propiconazole (Alamo) was detected at very low levels and only in two palms. Doubling the rate of Alamo from 10 ml to 20 ml per inch DBH (0.55 ounces to 1.1 ounces propiconazole) might increase the amount detected and the consistency of detection. The label does allow for the 20 rate under "very high disease pressure". The frequency of this rate is a bit vague, but can be implied to be every 12 months. It is important to note that propiconazole was detected in leaves that had not emerged at the time of the application – i.e., leaves -1 and -2, indicating the potential for movement into new leaves.

A flowable formulation of thiophanate methyl (3336) was used in this experiment as a soil drench. Despite being used at the highest labeled rate for soil drenches, this active ingredient was never detected. It is possible that if the highest labeled rate for a soil drench was used every 21-28 days, thiophanate methyl might accumulate in the canopy. However, both *Fusarium oxysporum* and *Penicillium* are considerably more sensitive to thiabendazole (a.i. in Arbotect 20-S) than to thiophanate methyl, even though both active ingredients are benzimidazole fungicides. Plus, given a choice of applying a product once a month vs. every 3 to 4 months would probably also give an edge to the use of Arbotect 20-S. Interestingly, the use of a thiophanate methyl soil drench is a standard practice for palms in Florida, and, to our knowledge, there is no data to support this practice.

Thiabendazole (Arbotect 20-S) was consistently detected in all four replicate palms. This is likely a reflection of the compatibility of the formulation (soluble in water) and the amount of active ingredient, which is three times greater than the propiconazole amount applied. The thiabendazole rate used in this experiment is twice as much as used in a preliminary experiment, where consistency in detection was problematic. Just like propiconazole, thiabendazole was detected in leaves that had not emerged at the time of the application - i.e., leaves -1 and -2. More importantly, the level of thiabendazole in these newly developed and emerged leaves was equivalent to levels in leaves present at the time of the application indicating that the fungicide is moving into new growth. While not consistent, there was a general trend to find less fungicide in the lowest (=oldest) leaves as compared to the highest (=youngest) leaves in the canopy over the initial four-month period. Thiabendazole levels appear to decline over time, which would be similar to oxytetracycline HCl (OTC) used to manage phytoplasma diseases of palms. This indicates there would be a need to treat palms more than once a year.

It also appears that it might take time for thiabendazole to move into the canopy, as the highest level of detection was 8 weeks after application. This might explain why another benzimidazole fungicide, carbendazin phosphate (Lignasan is the former trade name), was not detected in palm leaf tissue in a California study in the 1970s. In that study, researchers trunk injected carbendazim phosphate into a *Phoenix canariensis* (Canary Island date palm) with about 15 feet of trunk. After 48 hours, palms were felled, and trunk, bud and leaf tissue were bioassayed for the fungicide, which was detected in the trunk and bud tissue but never in the leaf tissue.

However, another explanation for not detecting carbendazin phosphate in the leaf tissue might be the type of leaf tissue assayed, which is not clear in the California study. In our study reported, a very limited amount of thiabendazole was detected in leaflet tissue and it was detected in only a few leaves during the first two sampling dates. This is in stark contrast to the consistent detection of thiabendazole in the petiole and rachis tissue of the same leaf. We do not believe this is a methodology issue. If detached coconut leaves are placed in a 20 µg/ml solution of thiabendazole for 24 hours (as if in a vase), we can easily detect thiabendazole in the leaflet tissue using the sampling method and assay described. Therefore, even higher rates of thiabendazole may be necessary if the target zone for disease control is the leaflet tissue.

Conclusion

We have clearly demonstrated that it is possible for xylem-mobile fungicides to move passively into the palm canopy (via trunk infusion) and persist for at least 120 days if the formulation is compatible with palm uptake and a sufficient quantity of fungicide is applied. Furthermore, the fungicides are moving into leaf tissue that was in development (not yet emerged) at the time of the fungicide application. Issues with formulation and application method still need to be resolved, and it still needs to be determined if the fungicides would be efficacious against specific palm diseases. However, simply knowing that these fungicides are present in palm tissue provides the first step in developing fungicide management programs.

Table 4. Quantity of thiabendazole detected in tissue after coconut palms were infused with Arbotect 20-S on August 16, 2010.

		µg thiobendazole																	
	Location in	September 3			October 12			November 8			December 6			March 3			April 12		
Rep	Canopy	P[x]	B	D	P	B	D	P	B	D	P	B	D	P	B	D	P	B	D
I	Low[y]	0.5[z]	0.6	0	1.1	1.2	0.4	0.4	0.7	0	0	0	0	NS	NS	NS	NS	NS	NS
	Middle	0.5	0.4	0	0.5	1.1	0	0.5	0.6	0	0.4	0.4	0	0	0	0	NS	NS	NS
	High	0.8	0.8	0.8	0.6	1.0	1.2	0.6	0.7	0.7	0.7	0.9	0	0.6	0	0	0.2	0.2	0
II	Low	0.6	0.3	0.4	0.5	0.4	0	0.6	0.5	0	0	0.4	0	NS	NS	NS	NS	NS	NS
	Middle	0.7	0.9	0	0.7	1.8	0	0.7	0.9	0	0.5	0.6	0	0	0	0	NS	NS	NS
	High	1.1	1.0	0.2	1.1	2.5	0.7	1.4	1.4	0.6	0	1.2	0	0	0	0	0	0	0
III	Low	0.3	0.4	0.1	0.3	0.4	0	0.2	0.3	0	0	0	0	NS	NS	NS	NS	NS	NS
	Middle	0.4	0.5	0.3	0.6	1.4	0.6	0.7	0.8	0	0.3	0.3	0	0	0	0	NS	NS	NS
	High	0.7	0.6	0.6	0.6	1.0	1.0	0.7	1.1	0.6	0.6	0.7	0	0	0	0	0	0	0
IV	Low	0.9	1.4	1.1	2.1	2.1	1.2	1.2	2.2	0.8	1.1	1.0	0	NS	NS	NS	NS	NS	NS
	Middle	1.3	1.2	0.7	1.8	2.4	1.2	1.2	2.2	0.8	0.7	1.8	0	0	0	0	NS	NS	NS
	High	1.2	1.5	1.2	3.0	1.8	2.4	1.6	4.6	1.2	1.1	1.5	0	0	0	0	0.3	0	0
Mean																			
	Low	0.6	0.7	0.4	1.0	1.0	0.4	0.6	0.9	0.2	0.3	0.4	0						
	Middle	0.7	0.8	0.3	0.9	1.7	0.4	0.8	1.1	0.2	0.5	0.8	0	0	0	0			
	High	1.0	1.0	0.7	1.3	1.6	1.3	1.1	2.0	0.8	0.4	1.1	0	0.2	0	0	0.2	<0.1	0

[x]P=petiole (leaf base); B=basal portion of rachis; D=distal portion of rachis

[y]Low=lower, older leaf (leaves 10 to 7); Middle= mid-canopy leaf (leaves 6 to 2); High=highest, youngest leaf (leaves 1 to -4)

[z]Values are mean of four sub-samples per tissue piece sampled. NS=not sampled

Table 5. Quantity of propiconazole detected in tissue after coconut palms were infused with Alamo on August 16, 2010.

		µg propiconazole											
	Location in	September 3			October 12			November 8			December 6		
Rep	Canopy	P[x]	B	D	P	B	D	P	B	D	P	B	D
I	Low[y]	0.5[z]	0.5	0.3	0.3	0.5	0.5	0.3	0.5	0	0.4	0.2	0
	Middle	0.1	0	0	0.5	1.1	0	0.1	0	0	0.1	0	0
	High	0.5	0.5	0	0.6	1.0	1.2	0.5	0.5	0	0.4	0.4	0
II	Low	0	0	0	0	0	0	0	0	0	0	0	0
	Middle	0	0	0	0	0	0	0	0	0	0	0	0
	High	0	0	0	0	0	0	0	0	0	0	0	0
III	Low	0.7	1.0	0.5	0.6	0.7	0.5	0.6	0.7	0.4	0.6	0.3	NS
	Middle	0.7	1.0	0.3	0.7	0.9	0.5	0.6	0.5	0.4	0.5	0.5	0.5
	High	0.6	0.8	1.0	0.9	0.8	0.9	0.4	0.4	0.3	NS	0.5	0
IV	Low	0	0	0	0	0	0	0	0	0	0	0	0
	Middle	0	0	0	0	0	0	0	0	0	0	0	0
	High	0	0	0	0	0	0	0	0	0	0	0	0

[x]P=petiole (leaf base); B=basal portion of rachis; D=distal portion of rachis

[y]Low=lower or older leaf (leaves 10 to 7); Middle= mid-canopy leaf (leaves 6 to 2); High=upper or youngest leaf (leaves 1 to -4)

[z] Values are mean of four sub-samples per tissue piece sampled. NS=not sampled