Effect of repeated sulfur applications to emerging and developing leaves, panicles and open flowers of lychee (*Litchi chinensis* L.) trees in south Florida

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Background. The lychee erinose mite (*Aceria litchii*; LEM) is native to Asia where it is a severe pest of lychee (*Litchi chinensis* L.). Unfortunately, LEM has spread to Hawaii, Australia and Brazil where it can be the most limiting mite pest on commercial production. Crop losses of at least 80% have been reported in Brazil.

Florida is the leading lychee producing state in the U.S. with a conservative estimate of 700 acres distributed in at least eight counties (Miami-Dade, Palm Beach, Lee, Indian River, Broward, Martin, St. Lucie, Highlands, Brevard, Collier and Sarasota) (Crane, et al., 2018). The crop is valued at an estimate $11.2 million annually (F. Ballen, personal communication). Lychee is also grown on a small scale in Puerto Rico, Hawaii, and California.

LEM attacks emerging and immature leaves, shoots and panicles (thyrses), flowers and fruit. LEM causes leaf malformation (distortion and curling), blisters on the upper surface, and a reddish-brown erinea (felt-like proliferation of trichomes produced by the plant in reaction to the mites feeding) on the underside of leaves (Photo 1). Young trees and mature trees that are vegetatively and reproductively flushing are susceptible to attack (colonization) by this mite. The mite spreads on air currents, honey bees, and by the movement of infested plants or plant parts.

Photo-1. Erineum and leaf distortion caused by LEM infestation (Photo credits Daniel Carrillo and Chris Phang Sang).

Chemical control. Several pesticides have been evaluated for control efficacy of the erinose mite. However, most of them are not registered for use on lychee and recent research demonstrated abamectin does not control LEM inside the erinae and only partially protects the new flush from LEM infestations. Wettable sulfur sprays have been effective in preventing infestation of emerging and developing vegetative and reproductive structures (e.g., leaves, panicles). However, its use is not registered for mite control in lychee production in the U.S. (Azevedo et al., 2013; Sharma and Thakur, 1992; Nishida and Holdway, 1955).

There is some concern that repeated sulfur applications may be phytotoxic to emerging and developing leaves, panicles, flowers and open flowers of lychee. The purpose of this investigation was to evaluate elemental sulfur for any potential phytotoxicity on emerging and developing leaves and panicles and flower buds and open flowers of lychee under south Florida field condition during winter and spring/summer.

Materials and methods

Two trials were conducted. Both trials were in a 2.5-acre lychee (*Litchi chinensis*) planting at the UF/IFAS Tropical Research and Education Center, Homestead, FL. Trial-1 was conducted during the fall-winter period from Nov. 12 through Dec. 18th, 2018 (65 days). Environmental conditions during this period were dry and moderately warm (Fig. 1). Overall average temperature was 74.4°F with a maximum of 89.3°F. Total rainfall was 3.5 inches and average wind speed was 5.6 mph (range, 0.02 mph to 24.4 mph).

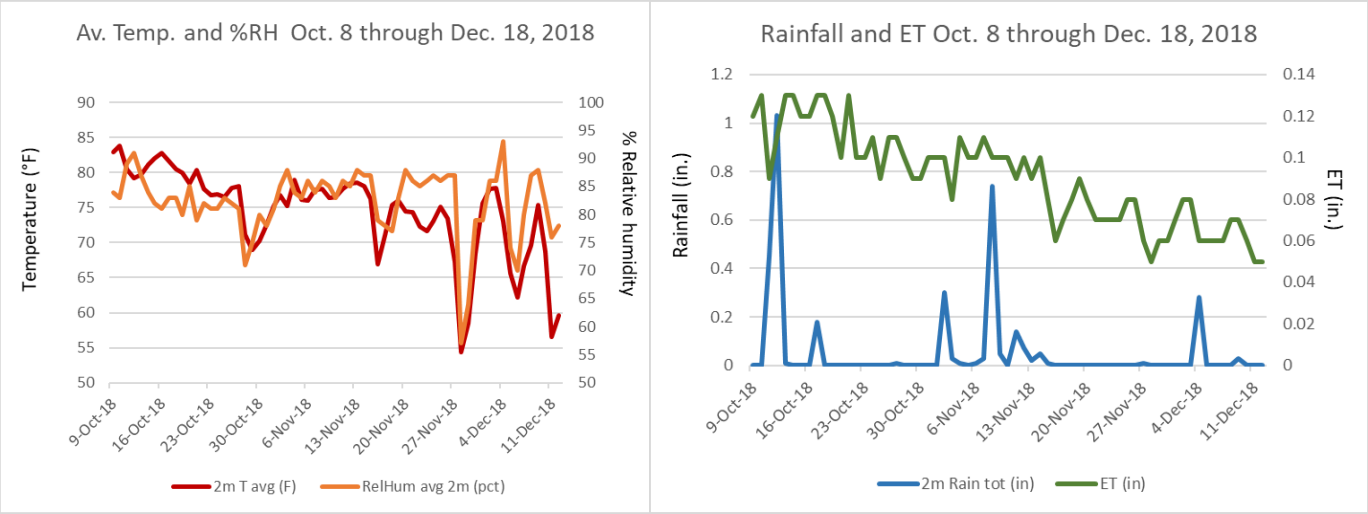

Fig. 1. Environmental conditions from 8 Oct. through 12 Dec. 2018 at TREC, Homestead, FL.

Trial-2 was conducted during panicle and flower emergence through fruit set (spring) from Feb. 4th through March 24th, 2018 (65 days) (Photo 3, 4, 5 and 6). Environmental

conditions during this period were moderately dry and warm (Fig. 2). Overall average temperature was 71.8°F with a maximum of 88.0°F. Total rainfall was 3.3 inches and average wind speed was 6.3 mph (range, 0.01 mph to 26.8 mph).

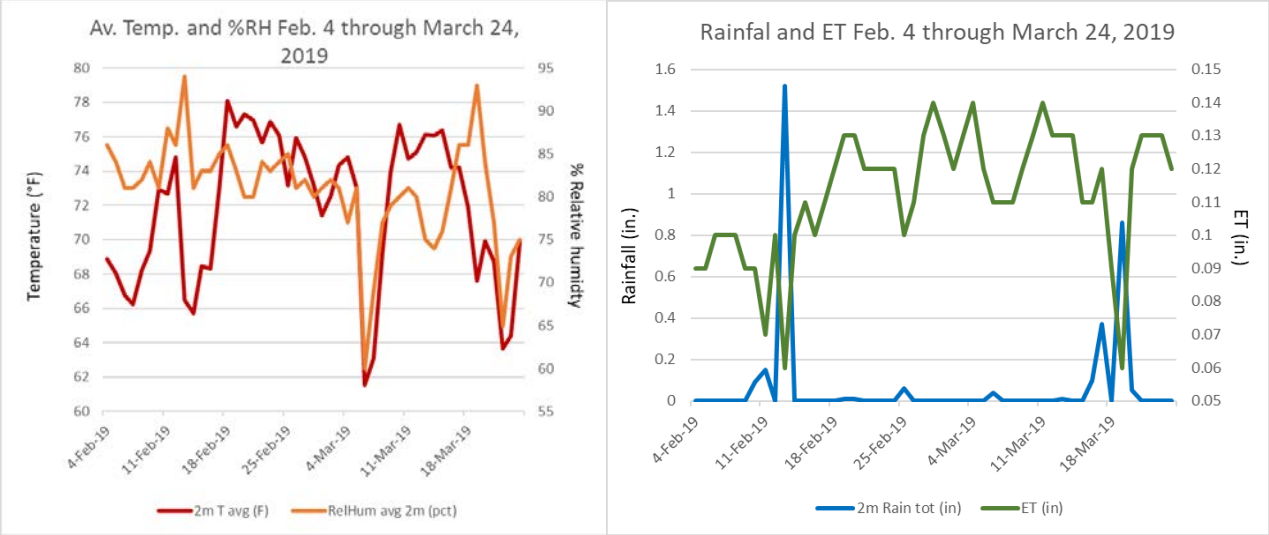

Fig. 2. Environmental conditions from 4 Feb. through 24 March 2019 at TREC, Homestead, FL.

Trial-1. Four commercially available elemental sulfur compounds plus a water-control were sprayed onto emerging flush (new shoots and leaves) five times at a seven-day interval (Table 1). Products were mixed at one and two times the highest labelled rates in 750 ml water, constantly agitated and sprayed onto the developing tissue. A new batch of product was used for each application date (Table 1 and 2). All ten treatments were applied to selected limbs of six, 10-year-old 'Mauritius' lychee trees.

Table 1. Sulfur products and rates applied to 'Mauritius' lychee flush at TREC.

Trt	Products	% elemental sulfur	Rate per acre*	Rate per 750 ml
1	Suffa 1x	52	5 gal/acre	25 ml
2	Suffa 2x	52	10 gal/acre	50 ml
3	Tracite sulfur 1x	52	5 pts/acre	3.1 ml (~3.0 ml)
4	Tracite sulfur 2x	52	10 pts/acre	6.2 ml (~6.0 ml)
5	Yellow Jacket 1x	90	30 lbs/acre	17.97 g (18 g)
6	Yellow Jacket 2x	90	60 lbs/acre	35.95 g (36 g)
7	Kolla sulfur 1x	52	4 pts/acre	39.9 ml (~40 ml)
8	Kolla sulfur 2x	52	8 pts/acre	79.9 ml (~80 ml)
9	Non-treated[y]	NA	NA	NA
10	Non-treated[y]	NA	NA	NA
y, non-treated trees were sprayed with water.				

*, assume 150 gallons of material (sulfur plus water) per acre.

Table 2. Trial-1 sulfur application and new flush evaluation dates of ‘Sweetheart’ lychee at TREC from Nov. 12 to Dec. 18, 2018.

Date		
Application of sulfur	Evaluation of flush	Comments
Nov. 12, 2018	Nov. 12, 2018	Pre-spray evaluation
	Nov. 13, 2018	1-day post spray
Nov. 19, 2019	Nov. 19, 2018	7-days post spray
Nov. 26, 2019	Nov. 26, 2018	7-days post spray
Dec. 3, 2019	Dec. 3, 2018	7-days post spray
Dec. 11, 2019	Dec. 10, 2018	7-days post spray
	Dec. 18, 2018	7-days post spray

Trial-2. Four commercially available elemental sulfur compounds plus a water-control were sprayed onto emerging panicles, flower-buds and open flowers six times at a six to eight-day interval (Table 1) (Photo 3, 4, 5 and 6). Products were mixed at one and two times the highest labelled rates in 750 ml water, constantly agitated and sprayed onto the developing tissue. A new batch of product was used for each application date (Table 3). All ten treatments were applied to selected limbs of seven, 7-year-old ‘Sweetheart’ lychee trees.

Table 3. Trial-2 sulfur application and new flush evaluation dates of ‘Sweetheart’ lychee at TREC from Feb. 4 to March 24, 2019.

Date		
Application of sulfur	Evaluation of panicles and flowers	Comments
Feb. 4, 2019	Feb. 4, 2019	Pre-spray evaluation
Feb. 5, 2019	Feb. 5, 2019	1-day post spray
Feb. 11, 2019	Feb. 10, 2019	5-days post spray
Feb. 18, 2019	Feb. 17, 2019	6-days post spray
Feb. 25, 2019	Feb. 24, 2019	6-days post spray
March 5, 2019	March 3, 2019	6-days post spray
March 11, 2019	March 10, 2019	5-days post spray
	March 17, 2019	6-days post spray
	March 24, 2019	13-days post spray (fruit set)

Damage assessments. Emerging and developing vegetative and reproductive flushes were evaluated as they emerged, developed and matured. Tissue damage assessments were made pre-application, one-day post application and then continuously at a 5 to 7-day interval, unless otherwise noted (Table 4, 5, and 6).

Table 4. Damage rating for emerging and developing leaves and stems.

1	no visible leaf or stem damage
2	small areas of marginal and/or tip leaf necrosis

3	moderate areas of marginal and/or tip leaf necrosis
4	severe marginal and/or tip leaf necrosis
5	leaves dead and/or abscission

Table 5. Damage rating for emerging and developing panicles and unopened flowers.

1	no visible bud or emerging panicle damage
2	slight bud or emerging panicle damage or distortion
3	moderate bud or emerging panicle damage or distortion
4	sever bud or emerging panicle damage or distortion
5	bud dead and/or abscised

Table 6. Damage rating for open flowers.

1	no visible flower damage
2	slight flower necrosis and/or distortion (damage)
3	moderate flower necrosis and/or distortion (damage)
4	severe flower necrosis and/or distortion (damage)
5	flowers necrotic and/or abscised

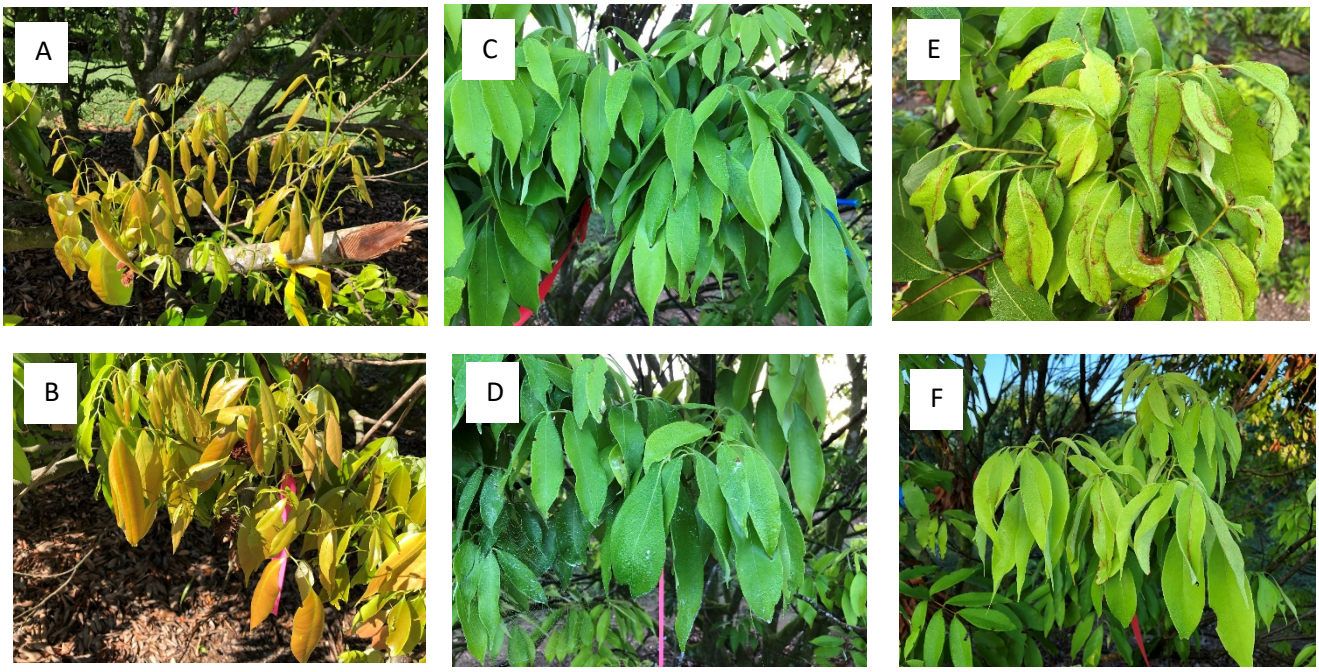

Photo-2. A and B, emerging and developing ‘Mauritius’ lychee flush just prior to foliar sulfur applications; C and D, developed foliage after four sulfur applications and; E, non-treated/water control with moderate areas of marginal and/or tip leaf necrosis and F, (sulfur treated), examples of with small areas of vein, marginal and/or tip leaf necrosis after four sulfur applications. (Photo credits Photo 2-6: JHCrane©)

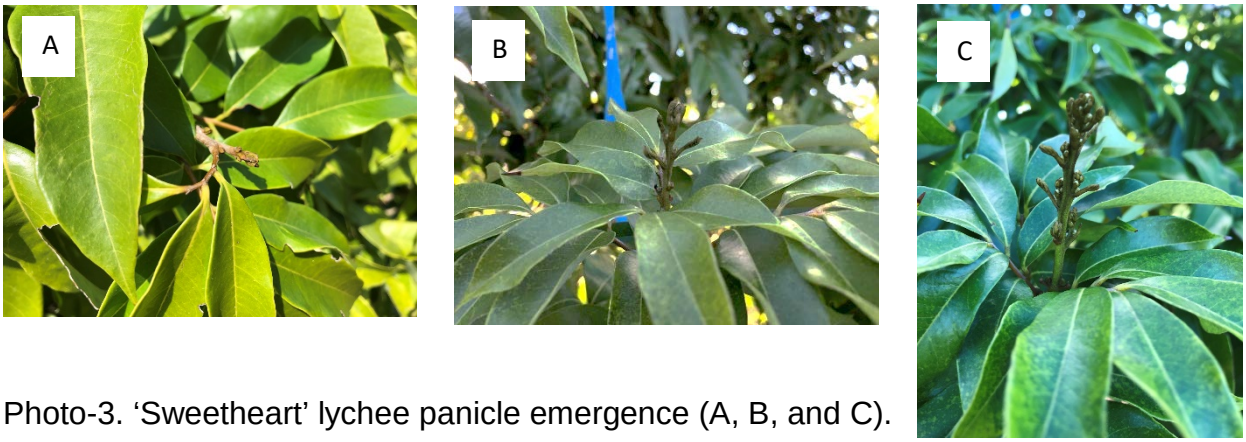

Photo-3. ‘Sweetheart’ lychee panicle emergence (A, B, and C).

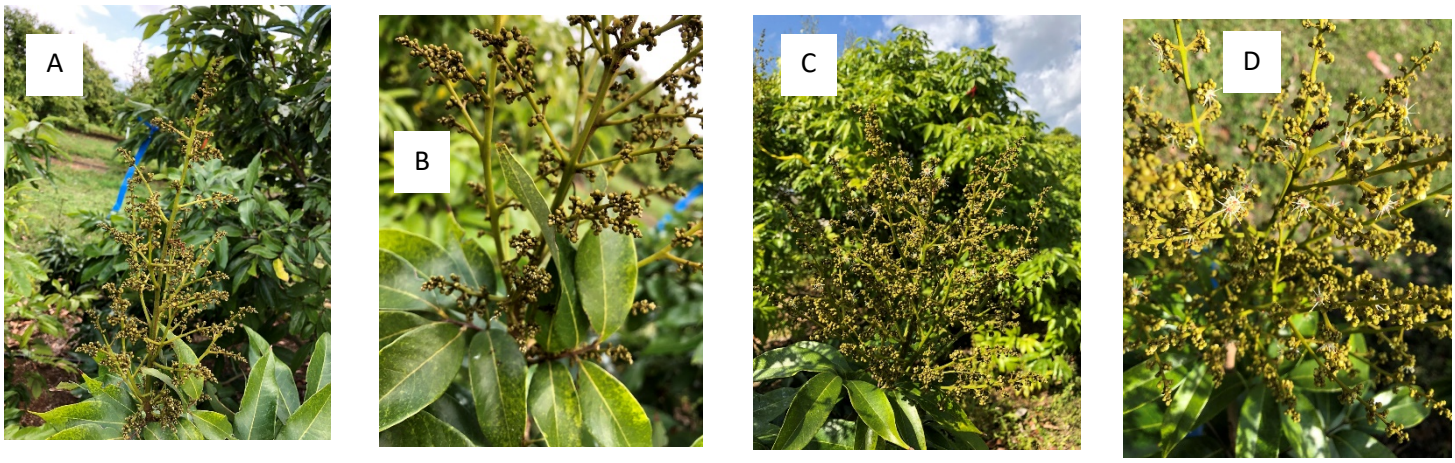

Photo-4: A, ‘Sweetheart’ panicle emerged; B, closeup of developed flowers; C and D, first opening of some male (M1) flowers.

Photo-5. A, ‘Sweetheart’ flowering; B, dead old male flowers and female flowers as waves of flowering normally progresses; C, healthy male and female flowers and; C, normally dying male flowers and fruit set female flowers.

Fruit set. To assess what effect if any, repeated sulfur sprays had on fruit set in Trial-2, the number of fruits on each panicle was counted thirteen-days after the last sulfur application.

Data analysis. Data for single time point measures were analyzed using the Kruskal-Wallis Test and Multiple Date Measurements were analyzed using Linear Mixed Model and differences in means were compared using the Tukey Multiple Comparison procedure. Damage was analyzed over dates and also averaged over dates to compute a single damage score for the whole experiment.

Results and discussion

Trial-1. There was a significant difference in ratings by date but no significant difference in damage to emerging, developing and developed leaves of 'Mauritius' lychee flush among sulfur treatments. The overall damage rating mean for each treatment was 1.5 or less (Table 7). Non-treated controls and sulfur treatments had similar damage ratings. A damage rating of 1.5 was defined as no visible leaf or stem damage (a zero) to small areas of marginal and/or tip leaf necrosis (a rating of 2) (Photos 2C, D, E and F).

Although damage ratings by date were significant, there was no trend for increased damage rating scores with time; i.e., increased damage with increased time (data not shown). Furthermore, damage ratings were all at or below 1.5.

Table 7. Overall damage rating for sulfur treatment to emerging, developing and developed leaves of 'Mauritius' lychee.

Sulfur treatments	Mean damage rating	Std Dev
Suffa 1x	1.4	0.4
Suffa 2x	1.5	0.4
Tracite sulfur 1x	1.6	0.5
Tracite sulfur 2x	1.4	0.5
Yellow Jacket 1x	1.5	0.4
Yellow Jacket 2x	1.5	0.5
Kolla sulfur 1x	1.3	0.4
Kolla sulfur 2x	1.2	0.3
Non-treated	1.4	0.5
Non-treated	1.5	0.5

Trial-2. Again, there was a significant difference in damage ratings by date but no significant difference in damage to emerging, developing and developed panicles and flowers of 'Sweetheart' lychee among sulfur treatments. The overall damage rating means for each treatment ranged from 1.3 to 1.5 (Table 8). There was no trend for an

increase or decrease in damage rating scores with time (data not shown). Non-treated controls and sulfur treatments had similar damage ratings. A damage rating of 1.5 was defined as no visible leaf, stem, panicle, and flower damage to small areas of marginal and/or tip leaf necrosis and/or slight flower necrosis or distortion (Photos 2E and 2F).

As with Trial-1, although damage ratings by date were significant in Trial-2, there was no trend for increased damage rating scores with time; i.e., increased damage with increased time (data not shown). Furthermore, damage ratings were all at or below 1.5.

Table 8. Overall damage rating for sulfur treatment to emerging, developing and developed panicles and flowers of 'Sweetheart' lychee.

Sulfur treatments	Mean damage rating	Std Dev
Suffa 1x	1.5	0.2
Suffa 2x	1.4	0.3
Tracite sulfur 1x	1.3	0.2
Tracite sulfur 2x	1.3	0.2
Yellow Jacket 1x	1.4	0.1
Yellow Jacket 2x	1.4	0.2
Kolla sulfur 1x	1.3	0.2
Kolla sulfur 2x	1.3	0.1
Non-treated	1.3	0.2
Non-treated	1.3	0.2

There was no significant difference in the number of fruit set per panicle 13-days after the last sulfur application (Table 9). All set fruit appeared normal for this early stage of fruit development.

Table 9. Mean number of fruit set per panicle treated with sulfur.

Sulfur treatments	Mean number of fruit set	Std Dev
Suffa 1x	6.9	8.4
Suffa 2x	6.8	11.8
Tracite sulfur 1x	13.5	18.5
Tracite sulfur 2x	16.3	17.6
Yellow Jacket 1x	7.0	9.4
Yellow Jacket 2x	5.8	8.4
Kolla sulfur 1x	7.1	12.3
Kolla sulfur 2x	8.1	10.4
Non-treated	7.9	8.9
Non-treated	14.3	17.6

Additional observations. Prior to sulfur applications circular sections of the leaf margins of a few leaves were missing which is evidence of Sri Lankan weevil (*Myllocerus*

undecimpustulatus undatus) feeding (Neal, 2017) (Photo 6A). Leaf spots caused by uneven distribution of minor element foliar sprays, leaf iron deficiency (chlorosis/yellow color between green veins) and zinc (small leaf size) deficiency were observed on some shoots (Photo 6B). During Trial-2 lychee webworm damage was noted and very small leaf bracts subtending the tertiary and quaternary axes abscised on the panicles of all treatments (Photo 6C and 6D). For Trial-2, eleven percent of the terminals tagged had delayed or did not emerge panicles. This occurred on a few terminals in sulfur- and non-treated treatments.

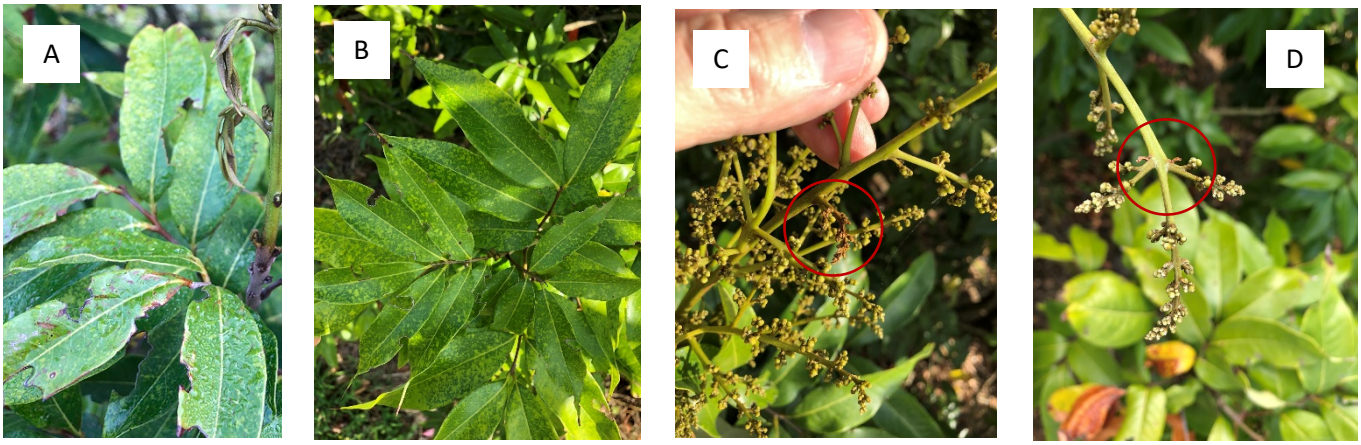

Fig. 6. A, marginal necrosis caused by Sri Lankan weevil; B, nutrient spray spots; C, evidence of lychee webworm (*Crocidosema* sp.) damage and D, leaf bract necrosis.

Conclusions

Average ambient temperatures during these field trials ranged from 74.4°F during Nov.-Dec. and 71.8°F during Feb.-March; maximum temperatures were 89.3°F and 88.0°F, respectively. The elemental sulfur content of test substances tested ranged from 52 to 90%. At the sulfur rates tested, five to seven applications of sulfur at a seven-day interval did not cause damage to emerging and developing vegetative and reproductive flushes. Rates used for each product were based on the highest rates mentioned on their labels. Slight marginal and tip leaf necrosis occurred in all sulfur treatments and water-controls.

Literature cited

Azevedo, L.H. and G.J. Moraes, P.T. Yamamoto, and O.Z. Zanardi. 2013. Development of a methodology and evaluation of pesticides against *Aceria litchi* and its predator *Phytoseius intermedius* (Acari: Eriophyidae, Phytoseiidae). J. Econ. Entomology 106(5):2183-2189.

Carrillo D., S. Revynthi, J.H. Crane, and J. Wasielewski. 2019. Control recommendations for the lychee erinose mite LEM. UF/IFAS TREC and UF/IFAS Miami-Dade County Extension Handout, June 12, 2019.pdf

Crane, J.H. 2018. Tropical Fruit Production in Florida, Trials, Tribulations and Opportunities. Proc. Fla. State Hort. Soc. 131:ix-xii.

Nakata, M., N. Sugiyama, and T. Pankasemsuk. 2005. Morphology study of the structure and development of longan inflorescence. J. Amer. Soc. Hort. Sci. 130:793-797.

Neal, A. 2017. Sri Lankan Weevil. Featured Creatures, Entom. and Nematology Dept. – Univ. of Fla./IFAS and Fla. Dept. Agric. and Consumer Services – Div. of Plant Industry. (Accessed 7-14-19) [http://entnemdept.ufl.edu/creatures/orn/sri_lankan_weevil.htm].

Nishida, T., and Holdaway, F.G. 1955. The Erinose mite of Lychee. Hawaii Agricultural Experiment Station, Circular 48: 1-10.

Robbertse, H., J. Fivaz, and C. Menzel. 1995. A reevaluation of tree model, inflorescence morphology, and sex ration in lychee (*Litchi chinensis* Sonn.). J. Amer. Soc. Hort. Sci. 120:914-920.

(u://IR4/efficacy/crane/2019/sulfur phytotoxicity report JHCrane.doc)