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# **CARIBBEAN FOOD CROPS SOCIETY**

**50**

**Fiftieth  
Annual Meeting 2014**

**St. Thomas, United States Virgin Islands  
Volume L**

PROCEEDINGS  
OF THE  
50<sup>TH</sup> ANNUAL MEETING

Caribbean Food Crops Society  
50<sup>TH</sup> Annual Meeting  
July 7 – July 11, 2014

Sugar Bay Resort and Spa Hotel  
St. Thomas, United States Virgin Islands

Edited by  
Thomas W. Zimmermerman, Stafford M.A. Crossman,  
Errol Chichester and Wilfredo Colón

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**Caribbean Food Crops Society**

**50<sup>th</sup> Annual Meeting**

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**St. Thomas, United States Virgin Islands**

**“Enhancing Family Farms Through Sustainable Energy, Research and  
Technology”**

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## Message from the CFCS President

**Kwame N. Garcia, Sr., State Director, Cooperative Extension Service, University of the Virgin Islands**

The 50<sup>th</sup> Annual Meeting of the Caribbean Food Crops Society is now history, but our gratitude to all sponsors, participants, and presenters will be continuous. Without their contributions in various forms, we would not have had such an engaging conference. I would like to express my sincere gratitude to those on whom I have been calling and who have always responded positively to my call. To the Virgin Islands Department of Tourism, the Virgin Islands Port Authority, the Virgin Islands Department of Agriculture, the Virgin Islands Lottery, the Caribbean Agro-Economic Society, the Association of 1890 Research Directors, and to all other supporters, I extend special kudos for always being available and supportive of our programs and endeavors. We also thank those individuals who attended or conveyed welcoming remarks such as Governor John P. de Jongh, Jr., and UVI President, Dr. David Hall.

From the very beginning of the conference, we were guided by our theme: “Enhancing Family Farms through Sustainable Energy, Research and Technology,” which is very evident in the papers presented and our entire focus. Those who attended will always remember the passion with which our presenters delivered on their topics. That is so very important because our theme highlights an essential component that requires our attention if we are going to survive as a people. The present economic and other global issues seem to have a greater impact on us in the Caribbean because of our geographic location and our great dependence on the elements for our existence. We, therefore, need to tap into the available resources that we can identify through research and technology.

The included articles in this volume will remind us all of the various facets at our disposal that can be applied for our sustainability. For those who could not have attended, we hope that you will benefit from the many points presented through application and research. The following are some of the topics presented at the conference: “Technology Transfer in Smallholder Rice Farms in Guyana: The Success Story of the Six Improved Practice”, “Commercial Status of Breadfruit and Breadnut Production in Trinidad and Tobago”, “Nitrous Oxide Production in Tropical Soils under Different Moisture Regimes and N-Application”, “Effect of Temperature and Relative Humidity on *Nephapis bicolor*, A Predator of *Aleurodicis spp*”, “Food Security in the French Caribbean Islands and Public Action: What is at Stake?” and “Influence of Storage on Sweetpotato Sugar Content.” These are only a small number of the papers presented throughout the conference, but they should be enough to whet your appetite for more.

We could not have had such a productive and successful conference without our sponsors, presenters, and all those who participated in planning and executing the conference. I thank everyone, and encourage our readers to read the complete presentations and implement as much as you possibly can.



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**Oral Presentations**  
**Production and Management of Vegetables/Root Crops**

**CHARACTERIZATION OF THE SWEET POTATO VIRUS DISEASE COMPLEX IN BARBADOS**

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**Abstract:** Sweet potato viruses are a major biotic constraint on global production of sweet potato (*Ipomoea batatas* (L.) Lam). In 2000-2003, a decline in yields by more than 50% was observed in some sweet potato fields in Barbados. The Sweet Potato Feathery Mottle Virus (SPFMV) which has been associated with the Sweet Potato Virus Disease (SPVD) was identified as the possible agent. SPVD is a virus complex which is vectored by aphids and whiteflies. It comprises several viruses in addition to SPFMV. This study sought to characterize the other viruses in the SPVD complex affecting sweet potato in Barbados. Total RNA was extracted from diseased leaves, followed by reverse transcriptase PCR using specific PCR primers designed for SPFMV; Sweet potato Virus G (SPVG), Sweet potato Virus 2 (SPV2) and Sweet potato Chlorotic Stunt Virus (SPCSV). PCR primers designed to target the coat protein of SPCSV and SPV 2 were not able to amplify these viruses in infected leaves; however primers designed against SPFMV and SPVG Viral RNA sequences were able identify the presence of these viruses in infected tissues. This study confirmed the continued presence of the SPVD complex in Barbados and identified the presence of viruses other than SPFMV in SPVD in Barbados.

**Keywords:** Sweet potato, SPVD

## **GINGER PRODUCTION AND STORAGE IN THE VIRGIN ISLANDS**

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**Abstract:** Ginger is widely utilized in the Virgin Islands but seldom grown. The objective was to determine the production potential, in-row plant spacing, length of postharvest storage and develop value added products of these spicy rhizomes. Ginger was planted at eight and twelve inches in-row spacing in February. The high pH calcareous soils caused chlorosis which was controlled through the use of supplemental iron (Fe-EDDHA). Harvest was over a three month period starting in December by mechanical means. No significant difference was obtained in the production between in-row spacing for either total yield or marketable yield. Harvested ginger was stored at 40, 60 or 80°F over 75 days. Ginger at 40 °F exhibited chilling injury after two weeks of storage. The ambient temperature, 80 °F, resulted in desiccation and sprouting of the ginger within 40 days. Refrigeration at 60 °F provided the best storage for ginger after 75 days. Ginger was also processed by slicing at 2 or 4 mm, dried and ground into powder. The 2 mm ginger resulted in a finer powder. Finally, the peeled and sliced Ginger was candied to provide long-term storage where the 4 mm slices worked best. Ginger was found to successfully grow in the Virgin Islands at 8” or 1’ in-row spacing and best stored postharvest at 60 °F. This project was developed through grant funding by the USDA-NIFA- Specialty Crops Block Grant administered by the VI Department of Agriculture.

**Keywords:** In-row spacing, postharvest storage, temperature, calcareous soil

## **INTRODUCTION**

Ginger (*Zingiber officinale* Rosc.) originated in South Asia and is grown for its pungent rhizomes. The rhizomes are utilized for culinary and medicinal purposes. Ginger is used to alleviate nausea, vomiting, morning sickness and motion sickness. Ginger is reported to promote digestion, blood circulation, lower blood sugar and lower blood pressure (Singletary, 2010). Though ginger is widely used, it is seldom grown in the US Virgin Islands. The objectives were to determine the optimum in-row plant spacing for the U.S. Virgin Islands, define the postharvest storage temperature for these spicy rhizomes and extend shelf-life with value-added products.

## **MATERIALS AND METHODS**

Ginger rhizomes were obtained in December and stored at 75°F for a month prior to cutting into 5-7 cm pieces. Soil was prepared in banks 5 ft apart to allow for mechanical harvest and drip irrigation installed. Pre-emergent herbicide was applied prior to planting for weed control during establishment. Rhizomes were planted at either 8” or 12 in-row spacing. The 8” spacing required 4.6 Kg seed pieces per 75 ft row while the 12” spacing required 3.4 Kg. Ginger was grown in calcareous soils with pH 8.5 and iron in the form of Fe-EDDHA was applied in the fertilizer to control chlorosis. Due to the one year growing cycle, the banks needed to be reformed twice after heavy rains. Harvest, with a one row 3 ft potato digger, occurred over three month period starting

in December. After harvest the ginger was cleaned and put in three storage temperatures 40, 60 or 80°F and the marketable storage weight determined over time. Other harvested ginger was peeled, sliced at 2 or 4 mm, dried and ground to powder.

## RESULTS AND DISCUSSION

Germination was slow and some pieces took two months to germinate. Fe-EDDHA was able to control chlorosis in the pH 8.5 calcareous soils when applied through drip irrigation. Harvest began in December when the plants started to senesce (Figure 1). The small potato digger did an excellent job separating the soil from the large ginger clusters. The late January and early February harvest had a greater fresh weight per 75 ft of row at both the 8” and 12” spacing than the December and early January harvest (Figure 2). Marketable yield of over 85 lbs per 75 ft of row were greatest and obtained with the 12” in-row spacing. A trend indicated that 12” spacing results in a greater fresh weight and marketable yield than the 8” in-row spacing. The 12” spacing requires less seed pieces per row but outperforms the higher 8” spacing density.



Fig. 1. Ginger plants at maturity in December.

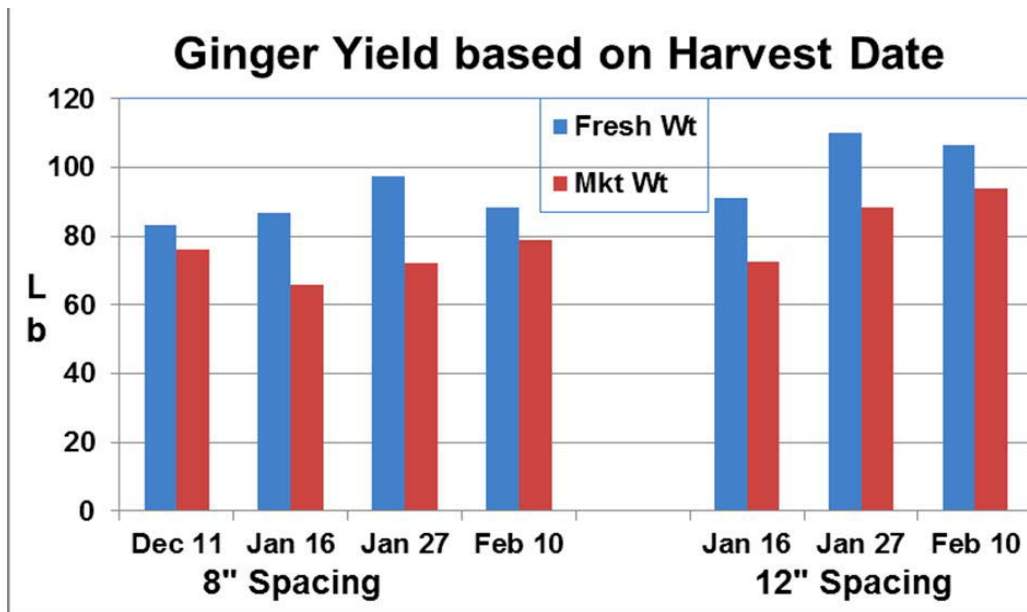


Fig. 2. Fresh and marketable yield of ginger plated at 8” or 12” spacing harvested over time.

Ginger is influenced by the postharvest storage temperature. Ginger kept at 80°F dried up over time and began to sprout after 40 days (Figure 3). Storing ginger at 40°F resulted in chilling injury of this tropical crop. The best of these three storage temperatures to extend the fresh use of ginger was 60°F but is only recommended for 60 days. To extend ginger for over two months, it is recommended to slice and dry the fresh ginger. Ginger sliced at 2 mm dried quicker than ginger sliced at 4 mm. Once the ginger is dried it can be stored as dried slices or ground into a powder for convenient use (Figure 4). The 2 mm sliced ground ginger resulted in a fine powder than the 4mm slices.

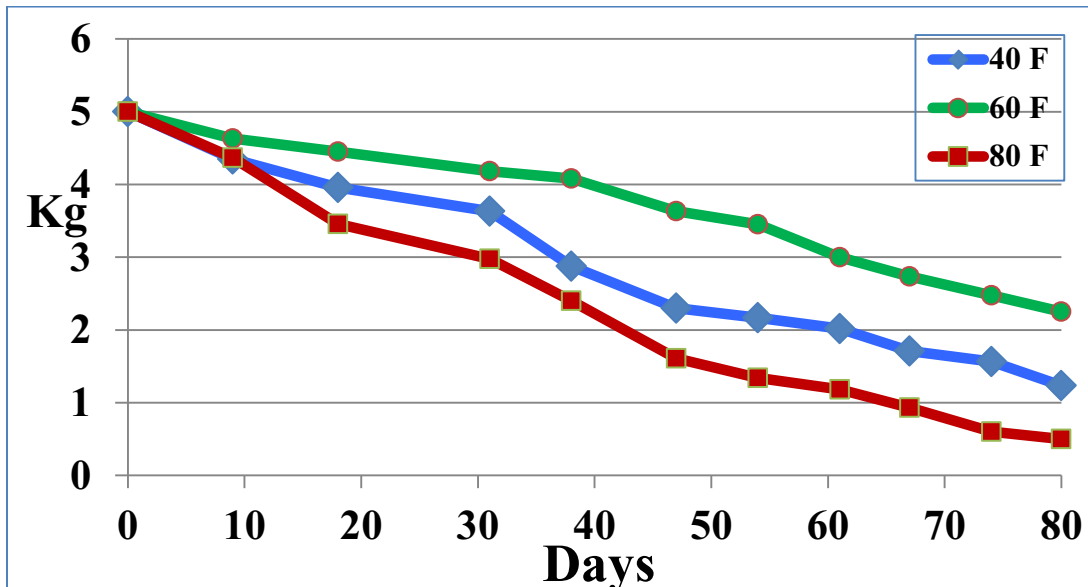


Fig. 3. Marketable ginger weight following postharvest storage at 40, 60 or 80 °F over time.

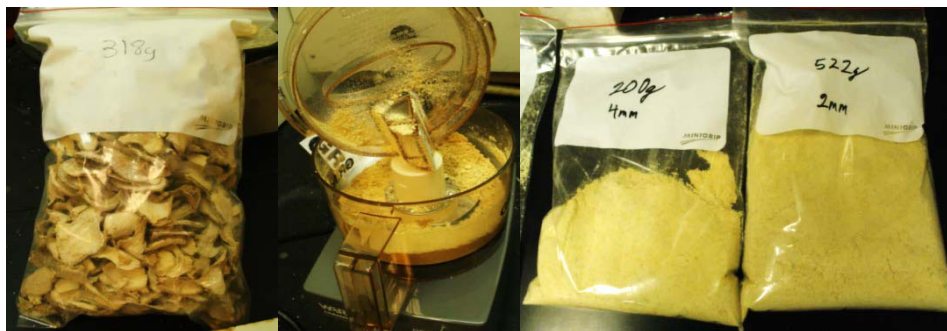


Fig. 4. Sliced dried ginger ground into powder.

## CONCLUSIONS

Ginger can be successfully grown in the US Virgin Islands on high pH calcareous soils when Fe-EDDHA is used to control chlorosis. No significant difference in production was observed between 8” or 12” in-row spacing for either total yield or marketable yield on a 75 ft row. A trend was indicated with greater marketable yield with later harvests. Ginger stored at 40°F exhibited chilling injury after two weeks in storage but storage at ambient temperature of 80°F

resulted in desiccation over time and sprouting after 40 days. Ginger refrigerated at 60°F provided the best postharvest storage for up to 80 days. Value added dried ginger can extend marketing beyond the fresh storage limit.

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DISSEMINATION OF RHIZOBIUM INOCULANTS IN HAITI

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**Abstract:** Common beans (*Phaseolus vulgaris*) are widely grown in Haiti, with 120,000 hectares planted during the March, July and December growing seasons. Average yields are 700 Kg/ha although increased use of disease resistant cultivars and improved soil fertility would increase production. The use of inoculation with efficient Rhizobium strains can significantly increase biomass and seed yield. Common beans can nodulate and fix nitrogen with the Rhizobium species *R. tropici*, *R. leguminosarum* *bv. phaseoli* and *R. etli*. During 2011-2014, Rhizobium inoculants were produced with a mixture of *Rhizobium tropici* CIAT 899, Haiti 1 and *Rhizobium etli* CIAT 632 strains. Inoculants and 2.3 Kg bags of bean cultivar DPC-40 were distributed to small-scale farmers in Haiti. The inoculants were produced at the laboratory of the Juana Diaz Substation in 25 g bags with a pasteurized peat carrier "American Peat Technology". The Rhizobium strains were multiplied in yeast-mannitol-broth (YMB) to a final concentration of 10<sup>9</sup> rhizobia cells per gram of peat. Inoculants were distributed to 16,000 growers in Ouest, Centre, Artibonite, Nord'Est, Grande Anse, Nord'Ouest, Nippes, Sud-Est and Sud Cayes in a total of 54 municipalities. The nodulation of common beans in 20 fields ranging 0.1 to 0.25 ha. was evaluated. In ten fields in Savanette, Haiti the nodulation at the R1 growth stage ranged between 10 to 48 nodules/plant. In 2014 additional fields were visited in Leogane, Haiti where nodulation ranged between 10 to 42 nodules/plant. The characteristics of the nodules formed were round with internal red color, medium size located in the upper part and lateral roots. In low fertility and degraded soils in Haiti the symbiotic relationship with Rhizobium is an important source of Nitrogen for common beans cultivated without the application of nitrogen fertilizer.

**Keywords:** Inoculants, Rhizobium, common beans

**EVALUATION OF DIFFERENT CROP MANAGEMENT SYSTEMS ON GROWTH AND PRODUCTIVITY OF THREE PUMPKIN VARIETIES**

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**Abstract:** Yield, fruit size and shape are important deterministic characteristics for marketing pumpkin locally and internationally. An evaluation of new and improved varieties with export quality characteristics was conducted at the UFS on a River Estate series using different crop management systems including the Ministry of Food Production, Mafas Ltd. and Caribbean Chemicals Ltd. cultivation guides. Growth and reproductive data were collected monthly, while yield and fruit quality measurements were made after eight weeks. Interaction effects of variety×system significantly affected vine diameter, number of flowers, fruit diameter and length. Stem diameter increased with time, whilst the number of flowers fluctuated across both variety and system. Pumpkin yield varied across system and variety but the differences were non-significant. CES Star produced the pumpkins with highest individual fresh weights with dimensions similar to cv. Boodles Globe but significantly different from cv. Future NP999. Cultivation system did not influence fruit quality properties. Local variety CES Star cultivated using the MFP guidelines produced significantly better pumpkin quality attributes.

**Keywords;** pumpkin variety, cultivation guide, fruit quality



**Tropical Fruits**

**COMMERCIAL STATUS OF BREADFRUIT AND BREADNUT PRODUCTION IN TRINIDAD AND TOBAGO**

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**Abstract:** Breadfruit is grown throughout the Caribbean where its traditional importance as a starchy food is well-known but has declined, and several efforts have been made to increase production and utilization in the thrust towards food and nutrition security. The success of its use for substitution of imported foods will depend largely on the viability of commercial production but little information to make this assessment is available. In Trinidad and Tobago, breadnut (chataigne) is also commonly grown and consumed, but even less information is available. The findings of a survey among 83 breadfruit and breadnut farmers in Trinidad and Tobago showed that while these crops were important for home consumption, more than 60% of the farmers also grew them for income. The majority of farmers thought that consumer acceptance for these crops was high to very high and that demand had increased. Most fruit was marketed locally at the farm-gate and at the public markets and prices differed seasonally. The estimated mean annual revenue for breadfruit and breadnut, respectively, was \$US 1,153 and \$US 637 per farmer. The results indicated that the importance of these crops as cash crops is likely to increase with greater levels of consumption.

**Keywords:** farmers' perspectives; consumer acceptance; demand; markets; prices; revenue

## **SORREL HYBRIDS: FRUIT SIZE EVALUATION**

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**Abstract:** Sorrel (*Hibiscus sabdariffa*) also known as Roselle, is in the malvaceae family and popular in the Caribbean as a seasonal beverage. The objective of the research was to compare sorrel F<sub>1</sub> and F<sub>4</sub> hybrids as it relates to calyx length, width and spur size. The deep colored fleshy calyces were collected and evaluated from KxT F<sub>1</sub> and TxK F<sub>1</sub> and F<sub>4</sub> lines that were field established in June. Overall the TxK hybrids had darker fruit than the KxT lines. Varieties TxK F<sub>1</sub> and KxT F<sub>1</sub> had the same fruit length which was significantly longer than the hybrid TxK F<sub>4</sub> line. The calyx width among these hybrids was not statistically different. The epicalyx or spur length for the KxT F<sub>1</sub> line was significantly longer than the TxK lines. Hybrid vigor was evident in the F<sub>1</sub> lines for fruit length but is diluted by the F<sub>4</sub> generation. This research was supported by USDA-Hatch and USDA-NIFA-Insular Tropical Grant funds.

**Keywords:** Roselle, *Hibiscus sabdariffa*, Breeding

## **INTRODUCTION**

Sorrel, *Hibiscus sabdariffa* also known as Roselle, Red sorrel, Jamaican sorrel, Indian sorrel, Guinea sorrel, sour-sour, Jelly okra, Lemon bush, Karkade, Florida cranberry, etc. (James, 2012) is a fruit in the hibiscus family commonly used to make juices and teas as well as jams, jellies and several other items around the world. Sorrel is high in calcium, potassium and vitamin A and C (Martinez, 2011). The flowers, fruits and leaves of the sorrel are edible. The most common sorrel is the red that produces during the short day length. Prior to the initiation of a breeding program for sorrel, the extent of out crossing in this species in the western hemisphere was unknown. In addition, there was no information on possible natural cross-pollination between local Jamaican varieties grown adjacent to one another in small plots, although foraging by honey bees and other insects had been observed in fields planted with sorrel (Vaidya, 2000). Akpan (2000) reported an outcrossing rate of <1% in sorrel based on experiments conducted adjacent to breeding nurseries. The objective of the research was to compare sorrel F<sub>1</sub> and F<sub>4</sub> hybrids as it relates to calyx length, width and epicalix size.

## **MATERIALS AND METHODS:**

In June 2013, the AES's Biotechnology program planted the sorrel seeds. The F<sub>1</sub> and F<sub>4</sub> sorrel hybrids were transplanted to the field July, 2013. A variety of tools and factors were used to conduct the research. A greenhouse was used to house the plants in their fragile adolescence, providing a safer and growth friendly environment. At the height of 6 cm, (two weeks from seed germination) they were transplanted to the field at 0.67m by 1m. Drip tape was used to water the plants regularly. At two week intervals, the fruits were harvested, counted and the calyx length, width and spur (epicalyx) length recorded. The field was weeded frequently, and fertigation was used to supply required nutrients. Fertigation is a combination of fertilizer and irrigation water.

## RESULTS AND DISCUSSION

The size of calyces from the F<sub>1</sub> sorrel hybrid KxT are shown in Figure 1. As seen in the graph, most of the plants yielded calyx averages that had a length of, or over 60 mm with the exception of 4 plants. KxT-4 had the highest average length of about 70 mm. In Fig 2. TxK F<sub>1</sub> is shown. Most of the calyx lengths for this hybrid were just below 50, but 3 plants did exceptionally well with lengths ranging from 65 to 75 mm. Fig. 3 shows the TxK F<sub>4</sub> hybrid; the lengths are roughly 60 mm. Overall the TxK hybrids had darker fruit than the KxT lines. As seen in Fig. 4, the varieties TxK F<sub>1</sub> and KxT F<sub>4</sub> had the same average calyx length which was significantly longer than the hybrid TxK F<sub>1</sub> line. The calyx width among these hybrids was not statistically different. The epicalyx or spur length for the KxT F<sub>1</sub> line was significantly longer than the TxK lines. Fig 5. shows employees of biotechnology, Henry Harris and Carlos Montilla harvesting the sorrel, as well as a close up of a sorrel calyx.

## CONCLUSION

The F<sub>1</sub> hybrid KxT and the selected F<sub>4</sub> TxK sorrel calyces had longer calyces than F<sub>1</sub> TxK. Selection in successive generations can fix the characteristic of calyx length. Continued research is needed to determine hybrid combinations that will be more vigorous and productive to combine and set desirable characteristics.

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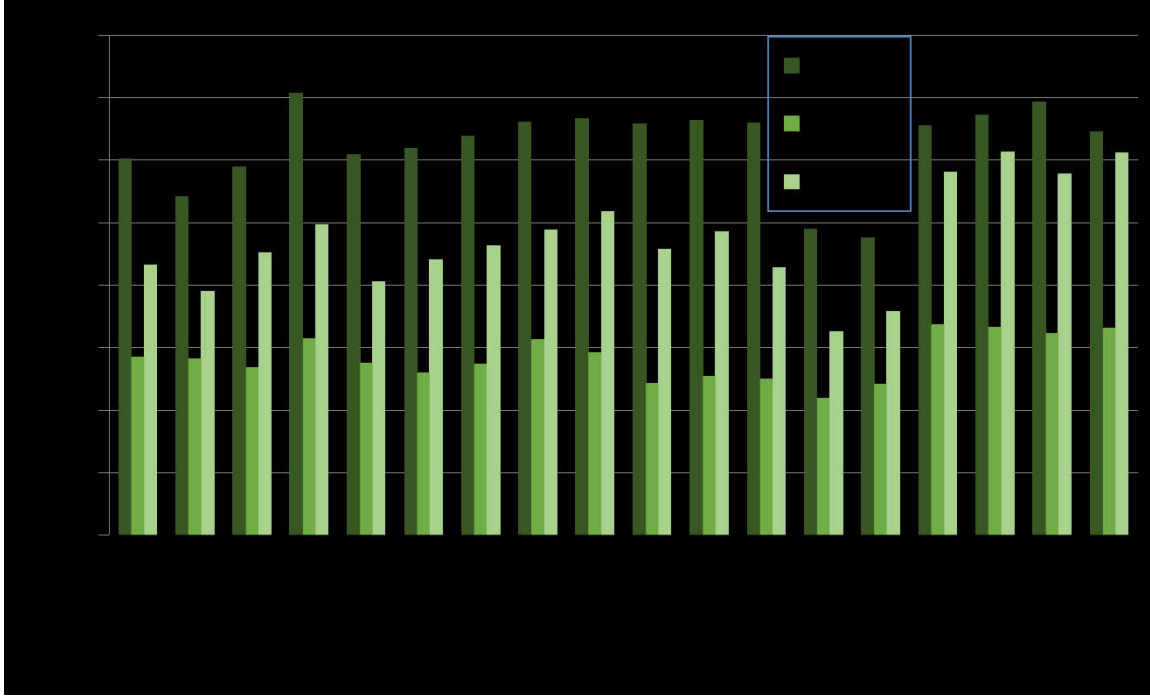


Fig. 1. Calyx measurements of Sorrel K x T F<sub>1</sub> hybrids.

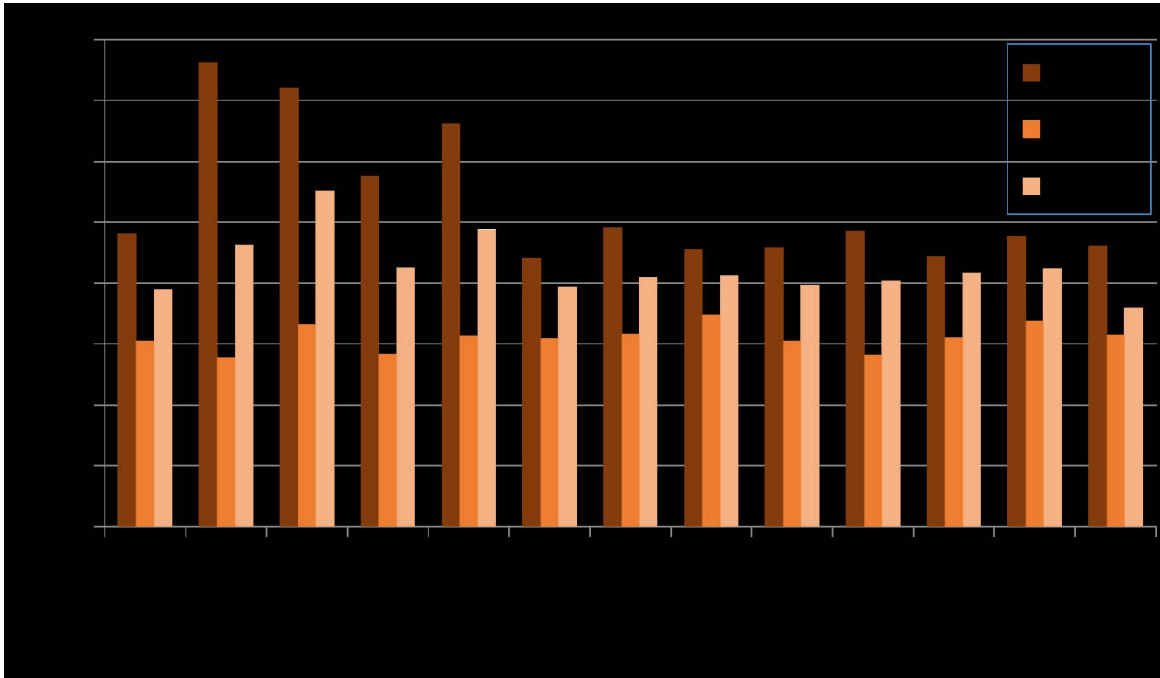


Fig. 2. Calyx measurements of Sorrel T x K F<sub>1</sub> hybrids.

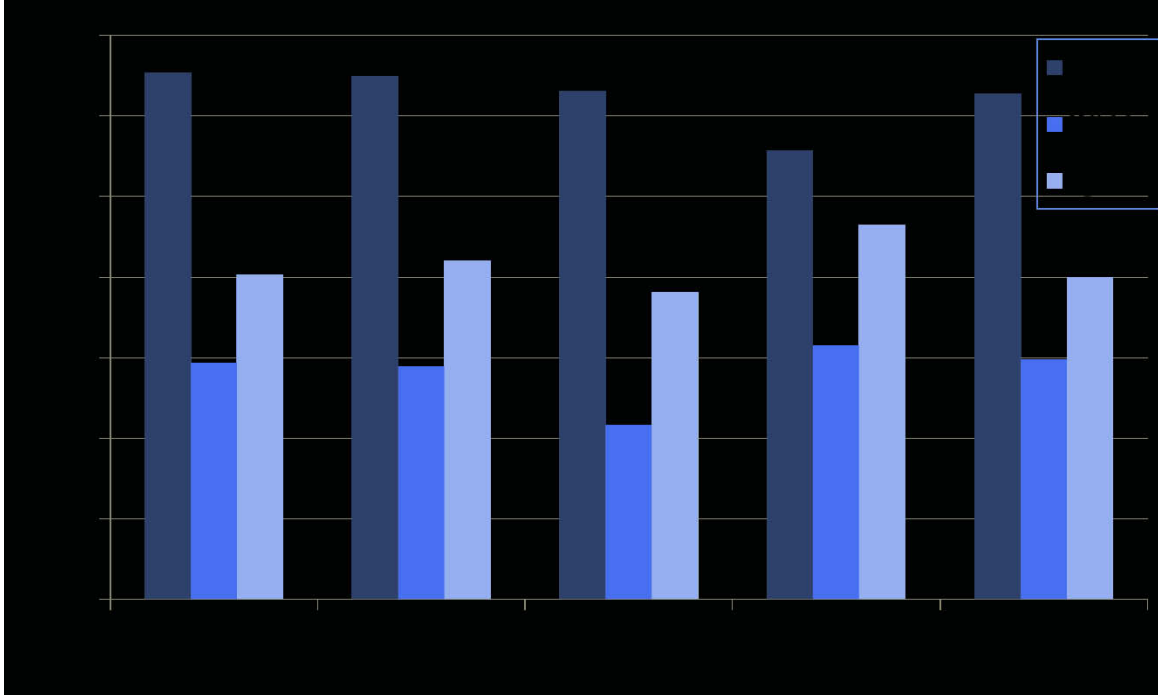


Fig. 3. Calyx measurements of Sorrel T x K F<sub>4</sub> hybrids.

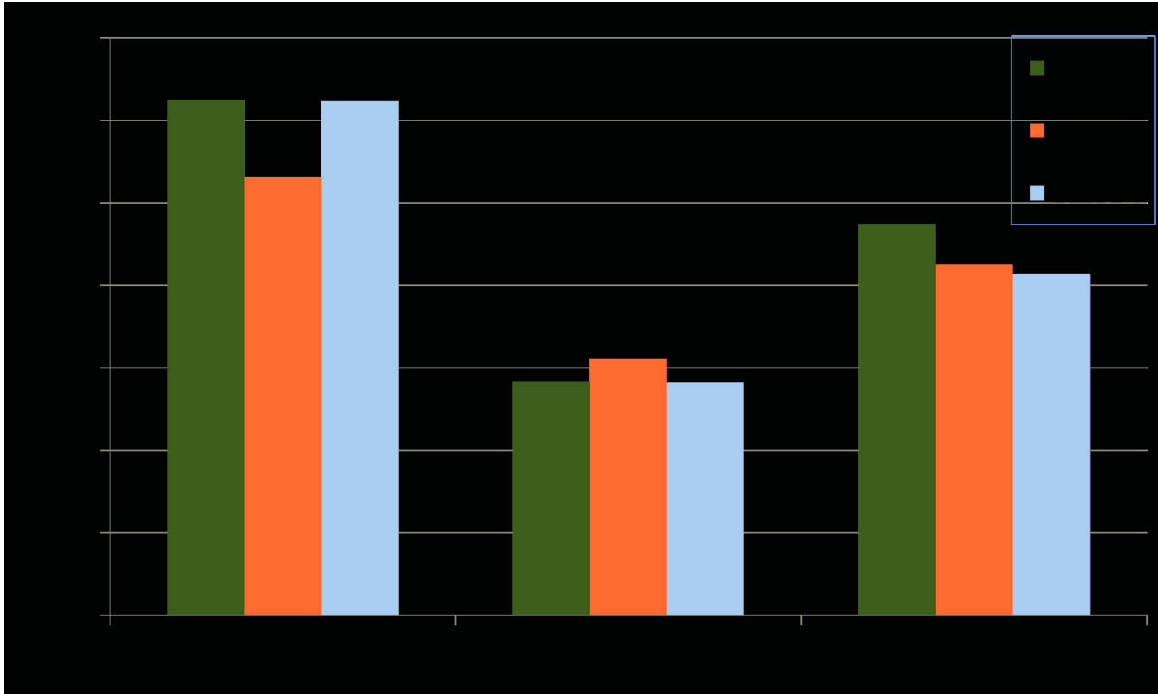


Fig. 4. Average Sorrel calyx sizes for the hybrids.



Fig. 6. Hybrid Sorrel harvest left and closeup of sorrel calyx and spur shaped epicalyx.

## TWO YEAR EVALUATION OF 25 PITAYA VARIETIES IN THE VIRGIN ISLANDS

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**Abstract:** Pitaya or Dragon Fruit, is a cactus, closely related to the Caribbean night blooming cereus, with a large succulent fruit. Twenty-five Pitaya varieties were established in a former grape trellis wire system. Plants were set in a replicated trial at either 2 ft or 4 ft intervals. Pitaya were established and proved able to grow to the top of a six foot trellis wire and flower within a year. Plant growth and flowering were monitored monthly and data recorded. Ripe fruit were harvested and data collected on weight, length, width, fruit flesh color and soluble sugar content. After two years of growth all varieties flowered and set fruit. All flowers were naturally pollinated at night by bats and moths so no hand pollination was required. Six pitaya varieties were selected and recommended based on production, fruit size and sweetness. These varieties are 'Dark Star', 'Makisupa', 'Physical Graffiti', 'Purple Haze', 'Halley's Comet' and 'Delight'. 'Natural Mystic' though productive, is susceptible to scale. Pitaya has potential for production in the Virgin Islands. This research was supported by USDA-Multistate Hatch and USDA-SCBG administered through the Virgin Islands Department of Agriculture.

**Keywords:** Dragon Fruit Production, Trellis, *Hylocereus* spp

### INTRODUCTION

Pitaya is a cactus, closely related to the native night blooming cereus found growing wild on trees, with a large succulent pink, red or yellow fruit. Pitaya varieties are made from three main species *Hylocereus polyrhizus*, *H. undatus*, *H. guatemalensis* and hybrids between species (Crane and Balerdi, 2005). These fast growing cacti are epiphytic or climbing vines with a 3-sided green, fleshy, jointed, many branched stems (Crane and Balerdi, 2009). Each stem segment has 3 flat wavy wings (ribs) with margins and 1-3 small spines or spineless and form aerial roots to adhere or climb. The stem may reach over 20 ft and have a lifespan of 20-30 years (Mizrahi, 1997). The large white flowers are open during the night and pollinated by bats and



moths. Pitaya has characteristics that enhance its prospects as a suitable and viable commercial crop. These features include ease of propagation; low crop maintenance; the short turnaround time between planting and harvesting; and high yield potential, ranging from about 20 to 60 pounds per plant (Gunasena et al., 2006). I first learned of pitaya as a succulent fruit while visiting the Fengshan Tropical Horticulture Experiment Station of the Taiwan Agricultural Research Institute in 2005. Five years later, a source of pitaya varieties was found in Miami, Florida to obtain material for a

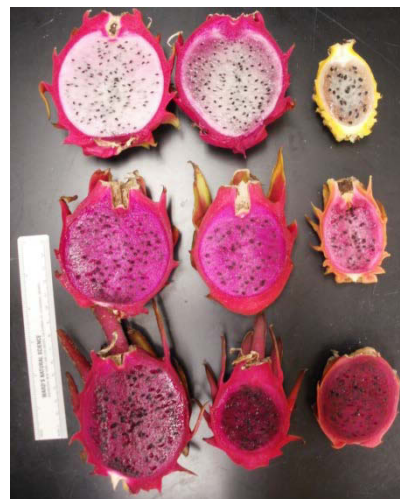
U.S. Virgin Islands trial on St Croix (Zimmerman, et al., 2013). A native Pitaya can be found growing wild in the U.S. Virgin Islands especially on Blue Mountain, elevation 350 meters. Though the wild native pitaya has good fruit size, the flavor and soluble sugar content is poor.

## MATERIALS AND METHODS



Twenty-five Pitaya varieties were obtained from Pine Island Nursery in Miami, Florida. Stem cuttings were rooted in 1 gallon pots for two months then established in a former grape wire trellis system. Plants were set in a replicated trial at either 2 ft or 4 ft intervals in a 6 row plot. Drip irrigation, with 2 ft emitters, was used for watering every other week. Fertilization was applied via an injector three times at a rate of 12.5 lbs of soluble 20-20-20 fertilizer during the trial. Iron was applied in the form of FeEDDHA due to

the high pH calcareous soils. Six-foot bamboo sticks were used as support for the pitaya. Plants were tied with tape every month to train them until they reached the top of the trellis. Malathion and Sevin were applied to control ants which were found to feed on the fleshy pitaya stems and fruit. Plants were mistreated when staff cut grass around the base with weed-eater but basal protection was installed to halt further damage to the succulent stem. Side branches were removed to promote one stem to the top of the trellis. Six fruit characteristics were recorded from the mature pitaya: days to maturity, fruit weight, length, width, sugar content and flesh color.



## RESULTS AND DISCUSSION

Few Pitaya varieties flowered and set fruit during the first year but grew vigorously on high pH calcareous soil to reach the six foot top of the trellis. However, the wire of the trellis was found to cut into the fleshy stems. During the first year, fruit were not attacked by birds. However, during the second and third year, birds developed a taste for pitaya fruit and caused damage. Being a cactus, pitaya can survive the extended dry season and still be productive during late spring when rains occur. Most Pitaya flowered and set fruit during the second year from late May through September. After a year and a half of field establishment, 97% of the varieties flowered and set fruit. All flowers were naturally pollinated at night, so no hand pollination was required. Lower fruit set occurred on





varieties that are self-incompatible and require cross-pollination which included ‘Alice’, ‘American Beauty’, ‘Cosmic Charlie’, ‘LA Woman’ and ‘Rixford’ (Table 1). Fruit matured 30 to 52 days after flowering (Table 1). The smallest fruits were on ‘Costa Rica’, ‘Pink’, ‘Voodoo’ and ‘Yellow’. Six varieties were selected to be recommended to local growers based on size, production and color. The six varieties were ‘Dark Star’, ‘Delight’, Halley’s Comet’, ‘Physical Graffiti’ and ‘Purple Haze’ (Table 2). One variety, ‘Natural Mystic’, was found to be most susceptible to stem rot under U.S. Virgin Islands environment.

Table 1. Average Pitaya fruit harvested, days to harvest, length, width and fruit weight over two years. Bold font indicates varieties recommended for growing in the U.S. Virgin Islands.

Variety	Fruits Harvested	Days to Harvest	Length mm	Width mm	Weight g
Alice	7	30	126	61	255
American Beauty	5	35	208	68	115
Bloody Mary	36	32	76	53	177
Cosmic Charlie	5	34	195	65	74
Costa Rica	20	36	70	51	97
<b>Dark Star</b>	<b>41</b>	<b>34</b>	<b>136</b>	<b>68</b>	<b>185</b>
David Bowie	20	34	84	57	237
<b>Delight</b>	<b>32</b>	<b>33</b>	<b>91</b>	<b>67</b>	<b>221</b>
<b>Halley’s Comet</b>	<b>32</b>	<b>34</b>	<b>105</b>	<b>91</b>	<b>217</b>
L A Woman	6	35	90	65	242
Lake Atitlan	29	34	69	59	185
<b>Makisupa</b>	<b>49</b>	<b>34</b>	<b>71</b>	<b>59</b>	<b>181</b>
Natural Mystic	27	34	88	76	318
<b>Physical Graffiti</b>	<b>53</b>	<b>34</b>	<b>80</b>	<b>60</b>	<b>224</b>
Pink	17	34	74	51	102
<b>Purple Haze</b>	<b>38</b>	<b>33</b>	<b>73</b>	<b>69</b>	<b>234</b>
RGHP	8	34	123	55	70
Rixford	9	40	142	66	170
Seoul Kitchen	29	33	62	58	138
Thompson	17	36	89	58	242
Tissue Culture	17	38	73	56	129
UVI	14	34	80	80	224
Voodoo	25	39	70	48	113
Yellow	12	52	70	41	101
Zamorano	24	49	68	54	122

Table 2. Average Pitaya fruit soluble sugar content (% Brix), flesh color and production determined after two years of production.

Variety	Brix %	Flesh Color	Yield lbs
Alice	16	White	3.9
American Beauty	20	pink	1.3
Bloody Mary	15	Red	14.0
Cosmic Charlie	16	Pink	0.8
Costa Rica	16	Red	4.3
<b>Dark Star</b>	<b>18</b>	<b>Pink</b>	<b>16.7</b>
David Bowie	16	White	10.4
<b>Delight</b>	<b>20</b>	<b>White</b>	<b>15.6</b>
<b>Halley's Comet</b>	<b>19</b>	<b>Pink</b>	<b>15.3</b>
LA Woman	17	red	3.2
Lake Atitlan	19	white	11.8
<b>Makisupa</b>	<b>19</b>	<b>Red</b>	<b>19.5</b>
Natural Mystic	16	Pink	18.9
<b>Physical Graffiti</b>	<b>18</b>	<b>Pink</b>	<b>26.2</b>
Pink	18	Pink	3.8
<b>Purple Haze</b>	<b>18</b>	<b>Red</b>	<b>19.6</b>
RGHP	18	Red	1.2
Rixford	19	Purple	3.4
Seoul Kitchen	16	White	8.8
Thompson	17	White	9.1
Tissue Culture	16	Red	4.8
UVI	18	Pink	6.9
Voodoo	19	Red	6.2
Yellow	22	White	2.7
Zamorano	16	Red	6.4

## CONCLUSION

Pitaya is a new tropical fruit for the Virgin Islands which has potential for commercial growers or back yard gardeners. After two years of evaluating 25 varieties, six varieties are recommended based on production, fruit size, color and sweetness. Six varieties selected have fruit color from white, pink to deep red. Self-pollinating varieties are recommended to ensure fruit set. One variety, 'Natural Mystic', was found to be susceptible to a stem rust disease. Pitaya grew well and can tolerate the high pH 8.5 calcareous soils found on the island of St. Croix, USVI.

## ACKNOWLEDGEMENT

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Integrated Pest Management/Crop Protection

**SIMULTANEOUS DETECTION AND DIFFERENTIATION OF TWO CYTOPLASMIC CITRUS LEPROSIS VIRUSES USING BI-DIRECTIONAL REVERSE TRANSCRIPTION POLYMERASE CHAIN REACTION**

Ronald Brlansky, University of Florida

**Abstract:** *Citrus leprosis* is the most destructive virus disease of citrus in Colombia. Three different viruses, cytoplasmic *Citrus leprosis virus C* (CiLV-C), *Citrus leprosis virus C2* (CiLV-C2) and nuclear *Citrus leprosis virus* (CiLV-N), have been reported causing similar symptoms. CiLV-C and CiLV-C2 comprise the genus *Cilevirus* whereas CiLV-N belongs to the unassigned genus *Dichorhavirus*. It is difficult to identify and differentiate the two cytoplasmic CiLVs based on symptoms. To detect and distinguish the two cytoplasmic CiLVs from citrus and *Brevipalpus* mite vectors a bi-directional reverse transcription polymerase chain reaction (BD-RT-PCR) assay was developed. In BD-RT-PCR two generic (forward and reverse) and two inner species-specific (either forward or reverse) primers are required. We successfully designed BD-RT-PCR primers based on CiLV-C and -C2 RNA1 sequences and standardized them. In single infections, a generic cytoplasmic CiLVs amplicon (666 nt) and an amplicon specific to either CiLV-C (455 or 237 nt) or CiLV-C2 (456 or 239 nt) were amplified whereas in mixed leprosis infections, all three amplicons (666, 455 and 239 nts or 666, 456 and 237 nts) were amplified. Fifty CiLVs infected citrus samples were collected from Belize, Colombia, Costa Rica, Mexico and Panama and tested by BD-RT-PCR. In addition, mites were tested from citrus orchards and experimental plants in Colombia. CiLV-C was exclusively detected in all of the leprosis samples except those from Colombia. Interestingly, both CiLV-C and -C2 were only detected in mites in Colombia. For further confirmation, results of the BD-RT-PCR were compared with conventional RT-PCR followed by sequence analysis. Simultaneous detection will not only save time and labor but also establish the distribution of these two cytoplasmic CiLVs. BD-RT-PCR for identification of CiLVs will also aid certification programs by preventing the dissemination of infected materials.

**HISTORY OF *CITRUS LEPROSIS VIRUS* RECORDED IN HERBARIUM SPECIMENS**

John Hartung, USDA ARS

**Abstract:** Leprosis is the common name of a virus disease of citrus, in which necrotic local lesions are produced on citrus and the virus is transmitted by mites in the genus, *Brevipalpus*. This disease is at the same time an emerging, a current and a historical disease problem. For some time researchers have understood that the *Citrus leprosis virus* (CiLV) occurs in two distinct forms, one that produces particles only in the nucleus of infected cells (CiLV-N; *Dichoravirus*) and another, much more widespread type that produces particles in the cytoplasm of infected plant cells (CiLV-C, *Cilevirus*). Both forms produce bacilliform particles with bipartite, single stranded, RNA genomes. CiLV-C is widespread in South America and as far north as parts of Mexico. The distribution of CiLV-N is much more restricted, having been reported only in Brazil, Panama, Mexico and very recently in Colombia. Neither form of the virus occurs in the USA today, although leprosis disease was a problem for Florida citrus prior to the mid 1960's, at which time the disease disappeared for reasons that are not well understood. We have recently used degradome sequencing to show that there is great diversity within both the CiLV-N and CiLV-C viruses. The USDA ARS maintains a collection of disease samples from citrus that were taken to document interception of restricted pathogens at border inspection stations. This includes more than 50 samples identified at the inspection stations 50 or more years ago. We have applied NGS degradome sequencing to some of these samples identified as Citrus leprosis. We have obtained near full length genome sequences of both a typical CiLV-C strain intercepted from Argentina in 1967 and another CiLV-N strain obtained in Florida in 1948. The latter is a completely novel form of CiLV-N, not known to exist anywhere in the world today.

**EVALUATION OF *Phaeoisariopsis griseola* ON COMMON BEAN *Phaseolus vulgaris* IN PUERTO RICO**

Consuelo Estevez De Jensen, University of Puerto Rico

**Abstract:** Angular leaf spot (ALS), caused by *Phaeoisariopsis griseola* (Sacc.) Ferraris sin. *Pseudocercospora griseola* (Sacc.) Crous & U. Braun., is an important disease in common bean (*Phaseolus vulgaris* L.) in the Caribbean and Central America. The wide pathogen variability makes it necessary to continuously monitor virulence patterns when breeding common bean for resistance. A greenhouse and field experiments were carried out to determine the reaction of 12 ALS differentials, 19 genotypes, and local check 'Verano' to the pathogen in Juana Diaz, on the southern coast. Prevalent warm and wet conditions in the months of March and April were ideal for disease development. In the greenhouse, the experiment was arranged in a completely randomized design replicated four times and inoculated with isolate ISA-1-2010 (10<sup>5</sup> conidia ml<sup>-1</sup>). In the field trial, the 20 genotypes were arranged in a randomized complete block design with three repetitions and the differential lines were included in a single row with 10 plants each. In the field, genotypes were evaluated with natural ALS infection. The evaluation was carried out 12 days after inoculation in the greenhouse and at the R2 growth stage in the field, using the CIAT scale where: 1 to 3 = resistant, 4 to 6 = moderately resistant, and 7 to 9 = susceptible. Under field conditions disease severity was higher than in the greenhouse. Lines G11796, G-5686, "Flor de Mayo" and "Montcalm" were susceptible to *P. griseola*. Amendoin, Bolón Bayo, Don Timoteo, Amendoin, Verano, Mexico 54, Cornell 49242, Pan 72 and G2858 were moderately resistant. BAT 332 was resistant. Lines ADP-010, ADP-132, ADP-143, ADP-158, ADP-160, ADP-161 and ADP-429 were resistant to *P. griseola*. Moderately resistant lines were ADP-106, ADP-154, ADP-006, ADP-213, ADP-225 and "Verano". In the greenhouse, the isolate ISA-1-2010 produced similar results with the Mesoamerican and Andean genotypes.

**NUTMEG WILT AND MORTALITY IN GRENADA AND ITS CONNECTION TO ENDEMIC *Phytophthora* species**

Yilmaz Balci Psl, University of Maryland

**Abstract:** A survey of *Phytophthora* was initiated during March 2011 in the Island of Grenada. In total 16 streams were selected across the island. Foliage of tropical forest trees in the Grand Etang National Park was also surveyed to discover foliar Phytophthoras. In addition, three nutmeg sites were surveyed for involvement of *Phytophthora* spp. with nutmeg wilt and mortality. To isolate *Phytophthora* from streams, 1-2 month old mango leaves were deployed using mesh bags and collected two days later. One-week-old mango leaves were used as bait when isolation was attempted from soils that were collected underneath wilted nutmegs. Isolation from tree foliage was attempted by selecting leaves with dark necrotic lesions that have recently dropped or still were attached to the plant. For all isolations, 1-3 mm sections of necrotic tissue were cut and dried using filter papers and plated on V8 Juice based PARPNH selective media. Outgrowing colonies subcultured after two days and were identified by combination of morphological features and molecular classification. In total, 678 isolates (449 *Phytophthora* and 229 *Pythium*) were obtained. These included *P. capsici*, *P. hevea*, *P. macrochlamydospora*, *P. nicotiana*, *P. palmivora*, *P. tropicalis* and nine hitherto unknown species. *P. palmivora* and an unknown species closely related to *P. katsurae* (99.1 % sequence match) was isolated from stem and root lesions of wilted nutmeg trees. *P. macrochlamydospora* was isolated from soil of two trees at one location. While all known and unknown species were recovered from streams, foliar Phytophthoras included only *P. hevea*, *P. palmivora*, *P. tropicalis* and four of the unknown species. *P. palmivora* was reported to cause seedling mortality and trunk canker on nutmegs, however its involvement along with the new species found in this survey should be evaluated to reveal the primary pathogen involved with common nutmeg wilt in Grenada.

**A REAL-TIME PCR ASSAY TO DETECT AND QUANTIFY 16SrIII-L AND 16SrI PHYTOPLASMAS ASSOCIATED WITH CASSAVA FROGSKIN DISEASE IN COSTA RICA AND PARAGUAY**

Juan Pardo, CIAT, Cali, Columbia

**Abstract:** Cassava has the ability to grow on marginal lands, tolerates drought, and grows in low-fertility soil. Several diseases, including cassava frogskin disease (CFSD), threaten the sustainability of cassava production. Recently, this disease was discovered to be associated with infection by phytoplasmas of groups 16SrIII-L and 16SrI. The disease is exponentially propagated through asexual seed, creating a demand for disease-free planting materials. Two TaqMan® probes were designed for the microorganisms, based on the rp gene (16SrIII-L phytoplasma) and 16S rRNA gene (16SrI phytoplasma). We used qPCR to obtain a sensitivity that was 100- and 1,000-fold higher than that obtained from nested PCR. In Paraguay, phytoplasma belonging to groups 16SrIII-L and 16SrI was detected in the localities of Caaguazú, Isla Sola, and Barrientos Cue. In Costa Rica, phytoplasma from group 16SrIII-L was detected in the localities of Aguas Zarcas, Pital, Los Lagos, La Merced, Los Chiles, Alajuela, Fortuna, and Guápiles. The CFSD symptoms observed in Paraguay were less severe than those observed in Costa Rica, where phytoplasma group 16SrIII-L showed greater disease severity. With the qPCR technique, both phytoplasmas could be detected and cassava planting certified disease-free, thus allowing germplasm exchange.



**MANAGEMENT STRATEGIES, ASSOCIATED FUNGI AND INTENSITY OF GUAVA SPECK IN MICHOACÁN, MEXICO**

Angel Rebollar-Alviter, Universidad Autonoma Chapingo, Mexico

**Abstract:** Guava speck is a major disease of guava fruits in Michoacan, Mexico. This disease has been associated with nutritional deficiencies and fungi. The objectives of this research were to evaluate different disease management strategies based on chemical and biorational fungicides, identify the associated fungi and to determine the losses associated with the disease in three producing regions in the state of Michoacán. In 2011 and 2012, 3 and 2 experiments were established respectively in commercial orchards of guava. Fungicides were applied every 14 days from green to ripe fruits. In 2011, strategies were based on benomyl, azoxystrobin, pyraclostrobin, thiophanate-methyl and thiabendazole in blocks alternated with captan and copper oxychloride, quaternary ammonium salts and *Bacillus subtilis*. In 2012 13 strategies similar to the previous year were evaluated including plant resistance inducers Glutathione-oligosaccharins and potassium phosphite. The results in each season showed significant differences between treatments ( $P < 0.0001$ ). The programs beginning with pyraclostrobin or azoxystrobin alternated with captan and / or copper oxychloride in blocks of 2 applications of the same active ingredient reduced the incidence and severity of guava speck significantly in relation to the control. Glutathione-Oligosaccharins, potassium phosphite, showed intermediate levels of control. *B. subtilis* and strategies based on quaternary ammonium salts and hydrogen dioxide showed no significant difference with the control. The associated fungi based on PCR amplification and sequencing of the ITS region indicated 99 to 100 % similarity with sequences deposited in the Genbank corresponding with *Pantospora guazumae* and *Mycosphaerella aurantia*. The data indicated yield losses of more than 11% associated to the disease. The results show a significant effect of management strategies in the intensity of guava speck, which could be associated with fungi. Although the pathogenicity tests have not been completed until now, treatments have contributed significantly to the reduction of production losses.

## ROSE ROSETTE DISEASE ALERT

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**Abstract:** Rose Rosette Disease (RRD) is a devastating plant infection that threatens Florida's rose (*Rosa* spp.) nursery industry as well as retail sales and landscape use. In late 2013, the disease was diagnosed on a rose sample submitted to the Florida Extension Plant Diagnostic Clinic at the UF/IFAS North Florida Research and Education Center in Quincy, FL. Researchers at the plant diagnostic clinic confirmed the presence of RRD by applying a molecular biology technique known as Reverse Transcription Polymerase Chain Reaction to detect RNA expression levels. Since then, RRD has been found in two other Florida counties. RRD is a virus vectored by a tiny Eriophyid mite, *Phyllocoptes fructiphilus* Keifer, however the mite has not yet been found in Florida. RRD may have been introduced through plant shipments to Florida. Currently, there is no cure for RRD. Infected plant warning signs include proliferation of shoots, distortion of shoots and leaves, elongated reddened leaves, distorted flower buds and the overabundance of thorns. Ultimately, the disease weakens the plant causing it to decline and die. Early recognition of RRD plant symptoms is a key component to containing the spread of the disease. UF/IFAS Extension and the Florida Department of Agriculture and Consumer Services, Division of Plant Industry are working together to provide commercial growers, professional landscape personnel, professional scouts and county Extension faculty with Rose Rosette Virus and Eriophyid mites information and scouting training.

**Keywords:** Rose, Rose Rosette, RRD, RRV, Eriophyid mite

**ECONOMICS OF EARLY DETECTION AND SUPPRESSION OF LAUREL WILT DISEASE**

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**Abstract:** Laurel wilt (LW), caused by *Raffaelea lauricola*, is an invasive, lethal disease of members of the Lauraceae plant family in the southeastern USA. Since 2003, it has killed millions of native forest trees and currently impacts commercial avocado production in South Florida. Given the destructive nature of this disease, there are major concerns over the future of the Florida avocado industry. Cost-effective management of LW remains an elusive goal, and current recommendations rely heavily on the early detection and destruction of affected trees (sanitation). This study assesses the potential net benefit of area-wide management of the Laurel wilt disease in the commercial avocado production area based on sanitation program.

**IR-4'S EFFORTS TO HELP COMBAT 'LAUREL WILT,' A THREAT TO THE FL AVOCADO INDUSTRY**

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**Abstract:** Laurel wilt is a disease of avocado (*Persea americana*), redbay (*P. borbonia*) and other members of the Laurecea family that is currently threatening the avocado industry in South Florida, affecting both residential and commercial plantings. It is caused by a fungus (*Raffaelea* spp.) that grows and reproduces in the xylem of the host tree, causing the tree to wilt. The fungus is vectored by the redbay ambrosia beetle (*Xyleborus glabratus*), a non-native pest which introduces it into trees while feeding and boring galleries into the host sapwood. This pest/disease is a major threat to the Florida avocado industry and research is being prioritized to get this situation under control. A number of fungicides were screened for efficacy against the pathogen and Propiconazole was identified as being highly efficacious against the laurel wilt pathogen. The IR-4 project is aiding in efforts to get this compound registered by conducting MRL residue studies of Propiconazole in avocado in EPA crop production region XIII. Residue field trials (conducted under US Environmental Protection Agency (EPA) mandated Good Laboratory Practices (GLPs)] were initiated in 2013 and will continue in 2014 in Florida, California and Puerto Rico at the IR-4 field research centers at the University of Florida, University of California-Davis and the University of Puerto Rico, Mayaguez. This talk will highlight efforts being made to procure the registration of this compound so that growers will have access to this material to help combat this problem. Novel application methods including root flair infusion and trunk injections are being utilized in the studies and will be described.

**Keywords:** Laurel wilt, Redbay ambrosia beetle, Avocado, IR-4

**NEW INSECTICIDES IN MANAGING AMERICAN SERPENTINE LEAFMINER, *Liriomyza trifolii* (BURGESS) (DIPTERA: AGROMYZIDAE) IN SOUTH FLORIDA**

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**Abstract:** The American serpentine leafminer, *Liriomyza trifolii* (Burgess) is a polyphagous insect. It is an economic pest of all vegetable crops grown in south Florida, USA. Recently, we evaluated insecticides of various chemical classes to manage leafminer on bean. In the first study, six insecticide treatments belonging to dimaide, neonicotinoid, pyrazole, and spinosyn were used once as a soil application. All insecticides effectively suppressed leafminer infested leaves on beans. In the second study, two insecticides belonging to diamide class at different rates applied at planting as a soil drench significantly controlled leafminers on beans. In the third study, foliar formulations of diamide insecticide similarly controlled leafminers. In the fourth study, pyrethroids alone or in combination with diamide or neonicotinoid provided season long control of leafminers where insecticide treatments were applied weekly for four weeks. This study generated some valuable information for controlling American serpentine leafminers on bean. This information can be used for controlling leafminers on other vegetable crops.

**Keywords.** Leafminer, insecticide, application method, management

## INTRODUCTION

The American serpentine leafminer, *Liriomyza trifolii* (Burgess) is a major concern of vegetable growers in south Florida for its unique tropical environment for leafminers' rapid multiplication (Seal et al. 2002, Stegmaier 1966; Spencer 1965). Host crops including vegetable, ornamental and fruit are grown all year round which also facilitate continuous reproduction of leafminer populations. It has been speculated that leafminer has originated in Florida (Spencer 1965), and subsequently moved to Caribbean and Canada. With the increase of floral traffic, *L. trifolii* dispersed to different parts of the world (Minkenberg and Van Lenteren 1986, Parella 1987, Minkenberg 1988). Specifically, *L. trifolii* is abundant in tropical and subtropical regions around the world (Capinera 2001). *L. trifolii* has gained worldwide distribution.

It attacks a diverse group of plants comprising of 400 plants in 25 families (Parella 1987). The economically important crops attacked by *L. trifolii* include bean, celery, chrysanthemum, cotton, lettuce, pepper, potato and tomato, onions and cotton (Seal et al. 2002; Parrella et al. 1985; Leibe, 1984).

*L. trifolii* causes damage to host plants by the action of feeding and oviposition which result in stippled appearance on the leaves (Parella et al. 1985). However the major damage is caused by larval feeding resulting in long mines. The mines become distinctly visible in three to four days after egg-laying. Mines length increases as larvae grow older feeding on leaf tissues. It has been observed that occurrence of full grown three mines per tomato leaf may account for yield loss (Levins et al. 1975, Schuster et al. 1976). Larval mining and stippling greatly reduce ability of

photosynthesis and affect crop yield. The mines and stipples also serve as entry points for bacterial and fungal diseases which can be devastating to the host crops.

Insecticides of various modes of action are most commonly used tool for managing leafminers in commercial agriculture (Ferguson 2004, Cox et al. 1995). During the period of 1946 to 1957, insecticides belonging to carbamates, organochlorine and organophates were frequently used to control leafminers and other insect pests on potato and tomato (Wolfenbarger 1954, Wolfenbarger and Wolfenbarger 1966). Due to extensive use of these insecticides, leafminers developed resistance against most of the known insecticides in two years (Ferguson 2004; Leibe 1984). As a result it was impossible to control leafminers in Florida (Leibe and Capinera 1995, Poe and Strandberg 1979).

In 1982 use of cyromazine gave some relief to growers of celery in Florida as *L. trifolii* populations came under control by the use of this insecticide. But in 1989, some problems of resistance with cyromazine were reported from Everglades, Florida. It was reported that *L. trifolii* larval mortality was very hard to achieve even at the highest dose (Leibe and Capinera 1995). After 1982, many research studies showed the efficacy of abamectin to control *L. trifolii* (Cox et al. 1995; Leibe 1984; Parrella et al. 1985). Seal et al. (2002) reported that abamectin and spinosad provided better control of *L. trifolii*. SpinTor<sup>®</sup> and Proclaim<sup>®</sup> were reported to be effective in controlling *L. trifolii* and were relatively benign to natural enemies (Webb 2002). Ferguson (2004) reported abamectin, cyromazine and Spinosad to be effective against *L. trifolii* and suggested that cyromazine resistance was limited to only one place in Florida in celery.

The objectives of this study were to evaluate new insecticides alone or in rotation to control leafminers. Different methods of application for better efficacy were also tested.

## **MATERIALS AND METHODS**

Three studies were conducted in Tropical Research and Education Center (TREC), University of Florida-IFAS, Homestead, Florida research plots. The soil type of the study area was a Rockdale which consists of about 33% soil and 67% pebbles (>2mm). The pH of this calcareous soil ranged from 7.4 – 8.4. Raised beds, 6 inches high 28 inches wide, were formed. The beds were open without any mulch cover. Sandea, a preplant herbicide, was broadcast over the bed at the rate of 0.71 oz/acre three weeks before planting to prevent weeds. At the time of bed formation, granular fertilizer (N:P:K = 8:16:16) at 1600 lbs./acre was broadcast on the surface of each bed to fertilize plants. For irrigating plants, beds were provided with two parallel lines of drip Tape (T-systems, Drip Works, Inc., 190 Sanhedrin Circle, Willits, CA 95490) having 5 inch emitter spacing to supply 1500 gallons of water/acre/day. The T-tapes were placed 12 inches apart on both sides of the center of each bed to irrigate and fertigate tomato plants. 'Pod Squad' beans were directly seeded on 18 July at a depth of 2.5 cm. on the center of the bed with 6 inch spacing within the row and 36 inches spacing in between the center of two adjacent rows. Addition liquid nitrogen fertilizer (4:0:8) was injected through irrigation drip line at the rate of 0.5 lbs. per acre /day starting four weeks after planting and continued weekly for four times.

Various treatments evaluated in three trials were arranged in a randomized complete block design with four replications. Treatment plots in each study consisted of 30 ft long two beds

each 3 ft wide. Treatments evaluated in the first study includes: 1. Cyantraniliprole (20 oz/acre, Verimark<sup>®</sup> 20 SC, IRAC # 28, DuPont); 2. spinetoram (8.0 oz/acre, Radiant<sup>®</sup> SC, IRAC #5, Dow); 3. sulfoxaflor (5.0 oz/acre, Closure<sup>®</sup>, IRAC # 4C, Dow); 4. chlorantraniliprole (5.0 oz/acre, Coragen<sup>®</sup>, IRAC # 28, Dupont); 5. Tolfenpyrad (21 oz/acre, Torac<sup>®</sup> 15 EC, IRAC # 21A, Nichino); 6. clothianidin (6.0 oz/acre, Belay<sup>®</sup>, IRAC # 4A, Valent); and 7. a nontreated control.

In the second study, cyantraniliprole (Verimark<sup>®</sup>) and chlorantraniliprole (Coragen<sup>®</sup>) were applied once as a soil drench to control leafminers on beans. Three rates of cyantraniliprole (10, 15 and 20 oz/acre) and three rates of chlorantraniliprole (3, 4 and 5 oz/acre) were drenched by using a backpack sprayer without any nozzle delivering a volume of 150 gpa at 30 psi.

In the third study, foliar formulations of cyantraniliprole and chlorantraniliprole were sprayed once to compare their residual efficacy in controlling leafminers. Various rates used for each insecticide were as described above. Treatments were applied using a backpack sprayer provided with two nozzles/bed delivering 70 GPA at 30 psi.

In the fourth study five insecticide treatments and a control were used to control leafminers on beans. The treatments evaluated in the study were: 1. Lambda-cyhalothrin (5.5 oz/acre, Warrior<sup>®</sup> II, IRAC # 3, Syngenta); 2. Lambda cyhalothrin + thiamethoxam (5.12 oz/acre, Endigo<sup>®</sup> ZC =Warrior<sup>®</sup> + Actara<sup>®</sup>; IRAC # 3A+4A), Syngenta); 3. Thiamethoxam (9.0 oz/acre, Actara<sup>®</sup> 25 WG, IRAC # 4A, Syngenta); 4. Lambda cyhalothrin + chlorantraniliprole (5.0 oz/acre, Warrior<sup>®</sup> + Coragen<sup>®</sup>; IRAC # 3A + 28, Syngenta); 5. Bifenthrin (2.5 oz/acre, Brigade<sup>®</sup> 2 EC, IRAC # 3A, FMC).

All treatments in the above studies were applied on foliage by using a backpack sprayer with two nozzles/row. Volume used for spraying each treatment measured 50 – 70 GPA which was delivered by using 30 psi. Efficacy of each treatment was evaluated by collecting 10 full grown young leaves from randomly selected 10 plants, one leaf/plant, from each treatment plot. All leaves from a plot were placed in a zip-lock bag and marked with date, treatment name and treatment plot. The bags were then transported to the IPM laboratory, TREC, UF at Homestead, FL. Leaves were checked carefully for leafminers mines. In some trials, all plants in a treatment plot were checked carefully for leafmines and counted by treatment and treatment plot.

### **Statistical analysis**

Data were transformed using square-root ( $x + .25$ ) before analysis of variance. The transformed data were analyzed with one-way analysis of variance (SAS, 1989). Means were then separated by Duncan's (1955) multiple range test when significant ( $P < 0.05$ ) values were found in the analysis of variance (ANOVA).

### **RESULTS AND DISCUSSION**

In the first study, all insecticides were drenched once in soil at planting. On the first sampling date, mean numbers of leafminer infested leaves/treatment was significantly fewer when bean plants were treated with Verimark<sup>®</sup>, Radiant<sup>®</sup>, Coragen<sup>®</sup> and Torac<sup>®</sup> than the nontreated control (Table 1). Sulfoxaflor and Belay<sup>®</sup> did not differ from nontreated control in the numbers of

leafminers infested leaves. On the second sampling date, 7 d after the first sampling date, Verimark<sup>®</sup>, Radiant<sup>®</sup> and Coragen<sup>®</sup> were effective in significantly reducing leafminer infested leaves when compared with the nontreated control. Sulfoxaflor, Torac<sup>®</sup> and Belay<sup>®</sup> did not differ from nontreated control. On the third and fourth sampling date, only Verimark<sup>®</sup> and Coragen<sup>®</sup> significantly reduced leafminer. Other treatments did not differ from the nontreated control. Effectiveness of Radiant in controlling American serpentine leafminer was reported by Seal (2002). Spintor<sup>®</sup>, a same chemical group of Radiant<sup>®</sup>, is also effective in controlling leafminers which is also benign to natural enemies (Webb 2002, Ferguson 2004). Seal et al (2002) reported that abamectin and spinosad provided better control of *L. trifolii*. SpinTor<sup>®</sup> and Proclaim<sup>®</sup> were reported to be effective in controlling *L. trifolii* and were relatively benign to natural enemies (Webb 2002). Diamide insecticides (Verimark<sup>®</sup> and Coragen<sup>®</sup>) were found effective in controlling leafminers in our various studies using beans, squash and cucumber (Seal 2014, unpublished reports).

Drench application of Verimark<sup>®</sup> and Coragen<sup>®</sup> provided significant reduction of leafminers infested bean leaves (Table 2). All rates of Verimark<sup>®</sup> (10, 15 and 20 oz/acre) and Coragen<sup>®</sup> (3, 4 and 5 oz/acre) provided suppression of leafminers up to third sampling date. On the fourth sampling date, two higher rates of Verimark<sup>®</sup> (15 and 20 oz/acre) were effective in reducing leafminer infested leaves on beans when compared with the nontreated control. Other treatments did not differ from the nontreated control.

In the third study, Exirel<sup>®</sup> (10, 15 and 20 oz/acre) and Coragen<sup>®</sup> (3, 4 and 5 oz/acre) were sprayed once on foliage one week after planting (Table 3). All rates of both insecticides, except Coragen<sup>®</sup> at 10 oz/acre, significantly reduced leafmines on bean leaves on the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> sampling dates as compared to the nontreated control. On the fourth sampling date, only Exirel<sup>®</sup> treated plants at 15 and 20 oz/acre had significantly fewer leafmines/leaf than the nontreated control. Other treatments did not differ from the nontreated control. However, mean numbers of mines/plot on the fourth sampling date showed increasing numbers irrespective of the treatment rates of both insecticides. Exirel belong to the same active ingredient as Verimark, and is similarly effective in controlling leafminers. Verimark is applied in soil and Exirel is sprayed on foliage. Irrespective of the application methods, both products showed potentiality in managing American serpentine leaf miners.

In the fourth study, we used two pyrethroid treatments (Warrior<sup>®</sup> and Brigade<sup>®</sup>), two premixed insecticides (Endigo<sup>®</sup> and Besiege<sup>®</sup>) and Actara alone. All insecticide treatments significantly reduced leafminers mines/bean leaf when compared with the nontreated control (Table 4). Both Endigo<sup>®</sup> and Besiege<sup>®</sup> are premixed products consisting two insecticides belonging to two modes of action. Endigo<sup>®</sup>, consisting of Warrior<sup>®</sup> and Actara<sup>®</sup>, is effective in controlling leafminers like its two components which are equally effective when applied individually. Similarly, Besiege<sup>®</sup> is a combination of Warrior<sup>®</sup> and Coragen<sup>®</sup> where Besiege<sup>®</sup> is as effective as two of its components when applied alone. It has been speculated that two effective insecticides when applied as a premixed might delay in development of resistance.

The results of this study are valuable to the commercial growers in controlling leafminers and other pests of vegetable. This information can be used to develop an insecticide based



management program to delay insecticide resistance in American serpentine leafminers and in other associated insect pests of vegetable crops.

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Table 1. Mean numbers of leafminers (LM) infested bean leaves per plot treated with various insecticides at planting as a soil drench.

Treatments	Rate [oz]/acre	Mean numbers of leafminers infested leaves/plot			
		2 Aug	9 Aug	16 Aug	26 Aug
Control		29.00a	76.00a	12.50ab	61.25a
Verimark	20.00	0.00c	0.00d	1.25c	3.75c
Radiant	8.00	0.00c	17.00bc	11.75ab	31.50ab
Sulfoxaflor	5.00	28.00a	67.25a	14.50ab	49.25a
Coragen	5.00	0.25c	0.50cd	5.25bc	8.75bc
Torac	21.00	7.75b	51.00ab	16.75a	23.25a-c
Belay	6.00	20.00a	54.25ab	13.50ab	28.50a-c

Means within the column followed by the same letter or no letter do not differ significantly ( $P > 0.5$ ; DMRT).

Table 2. Mean numbers of leafminers infested bean leaves/plant treated once with various rates of two diamide insecticides at planting as a soil drench.

Mean numbers of leafminers infested leaves/plant

Treatments	Rate [oz]/acre	22 Aug	29 Aug	7 Sept	14 Sept
Control		9.00a	36.25a	14.00a	57.50a
Verimark	20.00	0.75b	2.50b	0.50b	12.00c
Verimark	15.00	0.25b	6.25b	1.50b	24.50b
Verimark	10.00	0.00b	5.25b	2.50b	30.00 a-c
Coragen	5.00	0.00b	5.25b	2.50b	30.00 a-c
Coragen	4.00	0.00b	2.25b	2.00b	30.00 a-c
Coragen	3.00	0.00bc	11.25b	4.50b	42.25ab

Means within the column followed by the same letter or no letter do not differ significantly ( $P > 0.5$ ; DMRT).

Table 3. Mean numbers of leafminers infested bean leaves/plant sprayed once with various rates of two diamide insecticides at planting.

Treatments	Rate [oz]/acre	Mean numbers of leafminers infested leaves/plant			
		22 Aug	29 Aug	7 Sept	14 Sept
Control		8.25a	28.25a	33.00a	52.25a
Exirel	20.00	0.00b	0.00b	0.25b	15.00c
Exirel	15.00	0.00b	4.25b	0.50b	17.50c
Exirel	10.00	0.00b	3.25b	1.25b	34.00 a-c
Coragen	5.00	0.00b	3.25b	1.50b	29.00 a-c
Coragen	4.00	0.00b	4.25b	3.00b	27.00 a-c
Coragen	3.00	0.00bc	7.25b	5.50b	39.25ab

Means within the column followed by the same letter or no letter do not differ significantly ( $P > 0.5$ ; DMRT).

Table 4. Mean numbers of leafminers mines/bean leaf sprayed weekly with various insecticides.

Treatments	Rate [oz]/acre	Mean number of mines/leaf			
		5 May	12 May	17 May	29 May
Control		1.75b	5.00a	10.00a	14.00a
Warrior II	5.50	4.25a	2.50b	2.75b	4.00b
Endigo ZC	5.12	0.25c	0.00c	0.00c	0.00c
Actara 25 WG	9.00	0.00c	0.00c	0.00c	0.00c
Besiege	4.50	0.00c	0.00b	0.00c	0.25c
Brigade 2 EC	5.92	0.25c	1.75c	4.00b	4.75b

Means within the column followed by the same letter or no letter do not differ significantly ( $P > 0.5$ ; DMRT).

**ENHANCEMENT OF FAMILY FARMS PRODUCTIVITY AND PROFITABILITY USING IPM STRATEGIES**

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**Abstract:** Insect pests pose serious challenges to successful production of specialty crops in family farms settings in North Florida. To provide necessary skills and hands-on training to family farm stakeholders and clientele, the College of Agriculture and Food Sciences, Florida A&M University initiated an extension IPM project in 2010 to implement integrated pest management (IPM) strategies in specialty crops (vegetables and fruits) and communities (schools and community gardens). Since then, we have organized several workshops, field days and on-site demonstrations with a view to manage pests using IPM strategies. These commodity-wise strategies include regular scouting or monitoring for pest problems, identifying pests & beneficial species, and their life stages, keeping good records of pests, use of proven best management practices, use of plant-mediated pest management tactics, practicing good sanitation, conservation of biological controls agents, and application of minimum use of selective pesticides. Every year, seasonal vegetables were cultivated and training & demonstrations were carried out and underserved communities were served. In case of selective fruit cultivars under North Florida climatic conditions for small farms adaptability, evaluation were carried out and certain promising results were obtained. Indeed, by adapting IPM strategies, participating growers in the target counties including Leon, Wakulla, Gadsden, and Jefferson were able to produce various vegetable crops successfully. Our stakeholders include small scale growers, students, extension agents, pesticide applicators, hobbyists, community gardeners, and school gardeners. Major aim of extension activities focused on two components of the national roadmap of IPM, i) Implementation of IPM in specialty crops, and ii) Implementation of IPM in communities. These participatory approaches were proven very successful in promoting up-to-date knowledge and necessary skills to stakeholders and clientele. In addition, these tools were found very useful in training small scale growers and to our student recruitment initiatives in the College of Agriculture and Food Sciences.

**Keywords:** Specialty Crops, Implementation of IPM, Conservation of Beneficial Species

## FAO'S SUPPORT TOWARDS THE SUSTAINABLE MANAGEMENT OF BEET ARMYWORM (*Spodoptera exigua*) IN JAMAICA

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**Abstract:** Jamaica's agricultural sector, largely dominated by small farmer families, plays an important role in contributing to National Food Security. Small farmers in the 'breadbasket' parish of St. Elizabeth, in particular, are important producers of scallion, onion and other crops. Recent advances in onion production are significant elements leading to improvements in their livelihoods. However, these improvements have been threatened by increasingly frequent and serious outbreaks of the Beet Armyworm (BAW) (*Spodoptera exigua* Hübner) infestations. Despite efforts by the farmers and government agencies to control the outbreaks in 2009-2012, the devastation has continued to erode the progress made and the livelihoods of the farmers (J\$140 million/US\$1.4 million). This is largely due to an inability to provide appropriate production practices and management options to farmers. In response to a request from the Government of Jamaica to the Food and Agriculture Organization (FAO), the project *Strengthening a National Beet Armyworm Management Programme* (TCP-JAM-3401) was formulated and approved in 2012. Activities, which began in January 2013 include consultative and participatory processes among national, international experts and farming communities, towards the development of a strategy to adopt area-wide, integrated and comprehensive approaches to management of the BAW infestations. These are expected to contribute significantly to improved and sustained production. FAO assistance includes the development of a forecasting tool (FT) to assist farmers in making effective management decisions based on climatic conditions, as well as support to undertake an extensive Farmer Field School (FFS) programme, training both national Extension personnel and farmers in Training of Trainers workshops. It is anticipated that this approach would enable more timely and appropriate responses to BAW infestations and an improved/effective management of the BAW, as well as facilitate the institutionalization of FFS for direct empowerment of farmer communities and groups. The paper reports on progress made over the past 18 months, highlighting achievements under each component of the project.

## INTRODUCTION

Jamaica's agricultural sector plays an important role in contributing to National Food Security and economic development, employing about 22 % of the labour force ( $\approx$  250,000 persons) and supports 150,000 small farm ( $\leq$  2.02 ha) families. Its contribution, including both fresh produce and agro-processed goods, to GDP in 2000 was 16%. In Jamaica, agriculture is closely linked to rural development and has a multiplier effect on the economy as it impacts on other service

industries such as transportation, marketing, tourism, export and local commerce. It also maintains social stability, thus reducing the problem of rural-urban migration.

Jamaica spent three times more on imports than it earned through exports from January to August 2010. In order to stem this imbalance, the Ministry of Agriculture and Fisheries (MOAF) initiated the Productivity Improvement Programme, aimed at increasing production and productivity of vegetable crops (also onions), not only as a mitigation strategy for the economic down-turns, nutritional deficits and natural disasters (floods, droughts and hurricanes) but also for import substitution in the retail, tourism and agro-processing industries. This required expanding production in major agricultural producing areas such as St. Elizabeth, the “bread basket parish”. It is a major agricultural producing area in Jamaica with over 30,000 ha under farming, the main source of employment for many self-employed small farmers. In 2007, St. Elizabeth recorded 22,230 farmers or 14% of all registered farmers island-wide and, therefore, the parish is a major contributor to agricultural production. Onion has a long history of cultivation and tremendous growth potential in St. Elizabeth. The Marketing and Agriculture for Jamaican Improved Competitiveness (MAJIC) project, funded by USAID (United States Agency for International Development), was implemented by the Rural Agricultural Development Authority (RADA) in St. Elizabeth to address production, productivity and marketing. This resulted in 300% increase in onion production (2011-2012), with St. Elizabeth accounting for 75 % of onion and scallion production island-wide.

Since the 1990s, agricultural production in St. Elizabeth has suffered from major outbreaks of beet armyworm (*Spodoptera exigua*) (BAW) which have increased in frequency and severity and thereby threatening the progress achieved by the initiatives for improving productivity. BAW is a pest of agricultural crops worldwide, known for its resilience and its ability to survive harsh environmental conditions as well as to develop resistance to conventional insecticides. Adult moths tend to migrate in large numbers and oviposit on existing host crops. Larvae spend most of their life inside the onion (*Allium cepa*) and scallion (*Allium fistulosum*) leaf, being well-protected from the reach of natural enemies and insecticides, making their management even more challenging. In addition, very few effective pesticide chemistries are currently available to control this pest once it enters the leaf. Farmers, suddenly faced with heavy infestations, tend to increase usage of pesticides which negatively impacts the natural enemy balance and results in escalation of production costs and threats to food safety.

Traditional scallion production in St. Elizabeth involves a continuous crop system (up to 20 years) which creates highly favourable conditions for the feeding and breeding of BAW. Climate change factors such as increase in average temperatures and more prolonged droughts favour rapid growth of the pest population. With the onset of the rainy season triggering active crop growth, the pest population explodes and with poor pest management and the absence of sufficient natural enemies and over-reliance on use of conventional insecticides, the farmers are faced with a dilemma. The need therefore exists for a comprehensive monitoring system for the pest population and the employment of a forecasting system to predict possible outbreaks.

Several interventions, based on internationally recommended best-practices for sustainable management of BAW, have been made by the extension and research agencies. Despite these, outbreaks and/or pest flare ups continue annually due to poor uptake and adaptation of the



technologies by many farmers. Further strengthening of the current management programme is needed to improve mitigation efforts to reduce the impact of future BAW outbreaks.

The Government of Jamaica requested technical assistance from the Food and Agriculture Organization (FAO) to support the demonstration of improved productivity and sustainable management of onion /scallion production, with emphasis on comprehensive and integrated pest management (IPM) and crop management (ICM) approaches, seeking to provide optimal strategy for BAW management, minimal and safe use of pesticides during the life of the crop and prevention of BAW outbreaks. This would further broaden and strengthen the current management programme and improve adaptation by farmers of the various recommended management practices. The project *Strengthening a National Beet Armyworm Management Programme* was formulated in response to this request under FAO's Technical Cooperation Programme (TCP).

## **PROJECT DETAILS**

The two-year project was approved at the end of 2012 and was implemented by the Plant Protection Unit, Bodles Research Station of the MOAF in close collaboration with RADA.

The main project beneficiaries were the farmers of St. Elizabeth. Early in the implementation, the project entered into a partnership with ACIDI/VOCA<sup>1</sup>, which was in the process of implementing complementary activities in several areas of Jamaica. The project's impact and outcome were '*Jamaica's national food security and economic development strengthened by promoting the sustainable production of onion and scallion in the 'bread basket' parish of St. Elizabeth*' and '*Improved and sustained vegetable crop production through economically effective and sustainable management of beet armyworm populations*', respectively.

Three key outputs anticipated from the project were:

1. On-farm crop/pest management practices strengthened
2. Monitoring and surveillance programme for BAW strengthened and a monitoring tool established and institutionalized in appropriate agencies and supported by farmers
3. National crop/pest management programme broadened and strengthened

## **PROJECT ACTIVITIES**

In the project document, a number of activities were proposed in order to achieve the anticipated outputs. Progress on the implementation of these activities to date is outlined below, together with the next steps.

### **Output 1: Monitoring and surveillance programme for BAW strengthened and a monitoring tool established and institutionalized**

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<sup>1</sup> ACIDI/VOCA received a 4-year, \$14 million award from USAID to implement the Jamaica Rural Economy and Ecosystems Adapting to Climate Change (Ja-REEACH) program (formerly MAJIC program that focused on transforming Jamaica's agriculture sector into a market-driven, competitive industry)

<http://www.acdivoca.org/site/ID/jamaica-ja-reeach>

A key component of managing pests includes understanding the population dynamics of the target species. An ability to understand when and where an outbreak is likely to occur allows for better focused and increasingly rational management operations. The project aimed to establish the foundation for an integrated and improved management of BAW, specifically to create a forecast system by using geographic information system (GIS) technology to manage BAW populations in Jamaica. Four activities were to be carried out towards this end:

1. Evaluation and improvement of data collection and analysis programme
2. Formulation of a forecasting tool (FT) including an assessment of requirements for a global information system (GIS)
3. Review of institutional arrangements for operating the FT
4. Training of ten personnel from key agencies in Jamaica to maintain the tool

An expert Consultant (Yu Takeuchi) was recruited to develop the FT, which would be based on an analysis of weather patterns in Jamaica, development of a Degree-day Model and pest population dynamics. It was anticipated that the consultant would carry out the activities in three missions, the first of which took place over a two-week period from 22 April to 3 May 2013. The goals for this Mission were (1) to investigate the current situation of BAW in St. Elizabeth, (2) to understand current studies and researches done on BAW in Jamaica, (3) to understand the use of GIS in MOAF, (4) to gather necessary information for a forecast system, and (5) to design a forecast system for BAW.

During several site visits, severe BAW outbreaks were observed in the scallion/onion fields. Farmers tended to rely on insecticides and often over-sprayed the crops. Current efforts were focused on providing alternative management measures and appropriate information to farmers. Life cycle and population fluctuations of BAW had not yet been studied in Jamaica. Basic biological information, such as development time required for each stage, and population at each insect stage, were necessary for the forecast system. Therefore, laboratory and field experiments were proposed to MOAF.

GIS was not commonly used by the MOAF, and its usage was limited to categorizing land cover and soil types in Jamaica. While there were some persons with GIS skills, the limitation was the budget for the purchase of GIS software. The Meteorological Services Division had some weather data, which they were already providing. However, accessing some of the data was not easy, and it was anticipated that getting data could take some time to complete, especially to render paper-based records into digital form. The forecast system for BAW required weather data and duration of BAW development at different temperatures. Phenological models (using heat unit accumulations or degree-days) are commonly used models to predict the timing of the events.

Based on the above, the following were some of the recommendations made by the consultant:

1. The biology of BAW needed to be understood in the Jamaican environment. Population dynamics and insect development experiments were proposed.

2. The Research and Development (R&D) Unit of the MOAF should be responsible for laboratory experiments, while RADA should be responsible for field experiments.
3. MOAF needed to set up pheromone traps in scallion/onion fields to monitor population fluctuations throughout at least one year.
4. ArcGIS should be purchased and maintained by either R&D or RADA. For compatibility with newer software version, ArcGIS 10.1 was recommended.
5. MOAF needed to determine who managed weather data and a forecast system. The database to maintain historical weather data was necessary for BAW and many other species. Also, MOAF needed to identify a person to collect weekly weather data from meteorological services and run a forecast system.

Over the next few weeks, insurmountable challenges were experienced with the purchase and maintenance of ArcGIS software. Therefore, the project team recommended that an evaluation of available alternate options be carried out. Accordingly, the consultant evaluated several free-ware GIS packages, including GRASS, OpenJump, MapWindow and SAGA and compared them with the functions in ESRI ArcMap (as a baseline reference product). GRASS GIS was recommended as a viable, low cost solution that would allow most of the envisioned functionality for the BAW Management system.

## **Output 2 - On-farm crop/pest management practices strengthened**

Two Letters of Agreement (LOAs) were signed with RADA, aimed at building capacity to manage and coordinate Farmer Field Schools (FFSs). Activities to be carried out under the LOA were:

- Conduct (1) a baseline assessment (survey) of current status and (2) post-project impact survey (the survey tool captured farmer profile, practices, knowledge of pest/IPM etc.)
- Conduct intensive one-week residential training course on participatory knowledge transfer to 20 Extension personnel and other key persons
- Establish two demonstration plots to facilitate an eight-week FFS Training of trainers (TOT) for 20 lead farmers
- Train 150 farmers by facilitating 10 FFS (run by the 20 TOT farmers with support of extension staff)
- Produce educational material and best practices Manual

A National FFS Expert (Mr Dean Passard, an ACIDI/VOCA Associate) as well as a National Consultant in Entomology (Dr Kathy Dalip) were recruited to support RADA with the activities. It was anticipated that the activities would provide the following results:

- Trained Extension personnel continue utilizing Farmer Participatory (FP) methods in delivery of services
- Farmer groups continue to work together for mutual benefits (sharing knowledge / experiences, marketing)

Activities carried out by RADA to date under the LoA are summarized below:

Activities	Progress to date (June 2014)
Baseline pre-assessment of farmer practices	Both pre- and post-assessments completed. Data

to ID gaps; Post-assessment to gauge learning / knowledge gained through FFS	currently being analyzed
Workshops for Extension personnel (training) and for engagement of farmers and staff	Completed – capacity of Extension personnel enhanced; Farmers and RADA staff fully engaged
Establishment of two demonstration plots for eight-week long FFS-TOT for 20 farmers; Training 150 farmers in FFSs (by 20 TOT farmers, with Extension support)	11 farmers graduated as FFS facilitators. A total of 8 FFSs facilitated and 181 farmers exposed to participatory learning and knowledge sharing as part of the area-wide management of BAW
Production of Instructional video and placement on RADA website	Completed - <a href="http://www.rada.gov.jm">www.rada.gov.jm</a> Available on YouTube: <a href="https://www.youtube.com/watch?v=oTzQpzo4QBo">https://www.youtube.com/watch?v=oTzQpzo4QBo</a>
Manual on Best Practices	Draft compiled
Stakeholder Consultation meeting held	Project status and achievements were presented to farmers and other stakeholders. Feedback obtained
Public Awareness	Project achievements were highlighted during the two major agricultural shows (Denbigh Agricultural and Industrial Shows/ 2013 & 2014; Outdoor broadcast with Northern Caribbean University radio station, with coverage in St. Elizabeth and Manchester

### Lessons learnt from the FFS

The following summary on lessons learnt from the FFS is based on observations made during the FFS sessions and testimonials of farmers during training sessions and graduation ceremony (Young, 2013):

- FFS approach is well accepted by farmers and extension officers
- Some farmers, who usually did not attend formal training sessions organized by RADA, were regular attendants at the FFS
- All participants (farmers and facilitators) were very comfortable in sharing information
- Linkages among farmers, extension staff, research officers and other stakeholders were strengthened (farmers actually provided suggestions on what is to be researched further!).
- Farmers indicated that they learnt new information and/or better appreciated information that was already known, through a better understanding of the pest and the crop:
  - Usefulness and importance of an agro-ecological assessment of the field and the surrounding environment (AESAs)
  - Knowledge of the BAW life cycle for timely interventions e.g. identify and target early instars of BAW for control before they enter the leaves as they are easier to manage than older instars.

- Better understanding and appreciation of the BAW complexity and its adaptability and resilience. Role play of ‘Olympic race’ between the BAW, and thrips pests was performed by a group of farmers to highlight their understanding of ability of pest to damage the crop and its economic importance.
- Proper use of pheromone traps and interpretation of trap catch data for planning pest interventions.
- Proper scientific terminology of pest name, life cycle stages and names of natural enemies. This assisted with ability to understand pesticide labels and better relate to common pest names.
- Proper pest scouting and importance of record keeping
- Real impact of field sanitation measures on reduction of pest population (weed management, removal of infested leaves, proper disposal of infested plant residues etc.). Weeds now seen not only as crop competitor for water and nutrients, but a source of pests and diseases.
- Wider use and reliance on mechanical BAW control methods by farmers: hand picking of egg sacks from scallion leaves, removal (clipping) of leaves infested with the beet armyworm larvae to allow access by natural enemies such as paper wasps, spiders and birds)
- Innovations:
  - ✓ Farmers were introduced to innovation by Mr Buchannan, a farmer from Gillards, who designed a compost drum. Plant residues from scallion field are used to generate organic compost used as fertiliser.
  - ✓ Self-made light traps powered with mobile phone battery was innovated by a young farmer from Manchester
  - ✓ Use of thyme for intercropping of scallion as repellent for the beet armyworm adults was well taken by farmers.
- Use of pesticides did not result in expected reduction of pest in demonstration field unless it was done in combination with field sanitation practices.
- Better understanding of pesticide modes of action, timeliness of applications, proper protection of body from pesticide exposure and proper fitting of protective gears.
- Real benefits of soil analysis. Analysis results had helped to apply needed grade of fertilizer resulting in good response from crop and reduction in overreliance on a high nitrogen formulas.
- Appreciation of role of ‘farmer friends’ -natural enemies (spiders, paper wasps, ants, birds, etc.). Farmer(s) with heavily reliance of insecticides had seen importance of other methods of management and the role of natural enemies
- It is expected that farmers are better equipped to manage the pest and to reduce use of insecticides in their scallion fields. This might have a positive effect on reduction in cost of crop production and cleaner environment. Impact assessment should be able to capture such information.
- Farmers had expressed more appreciation for work done by extension staff and their role. Relations had improved noticeably.
- Community was well aware about FFS. Great interest was generated and other farmers in the community were willing to participate in the next set of FFSs.
- Farmers were more aware about the impact of markets on the beet armyworm population.

- Two new FFS modules were added to the curriculum: Marketing Linkages and Climate Smart Agriculture.
- All TOT farmers can provide advice and suggestions for the BAW management to other farmers in community.
- Farmers were more comfortable to make oral presentations individually or in the group setting.
- Farmers expressed great pride and sense of achievement in graduation FFS.
- Project achievement were backed with support from the Government of Jamaica (GOJ)/ Jamaica Social Investment Fund funded project, where farmers in St. Elizabeth were trained in areas of Good Agricultural Practices, Food Safety and Safe Use of Pesticides (17 training sessions were delivered to date by RADA, benefiting 446 farmers).

### **Challenges**

- Sessions tended to have a longer duration than scheduled due to a number of concerns and issues brought by farmers to the discussion.
- Group recommendations for needed interventions in the fields (weeding and spraying) were not followed by a farmer / field owner, resulting in pest build up. The large size of the field and lack of financial resources prevented timely arrest of BAW population.
- Non availability of water for irrigation acted as limiting factor for crop and pest management in Comma Pen.
- Some FFS sessions had to be postponed due to farmer active involvement with crop planting after ending of prolonged and severe drought, which affected Jamaica in 2013-2014
- Challenges to identify funding support for continuation of FFSs beyond the project
- FFS is not yet fully institutionalized in RADA

### **Output 3 - National Crop / pest management programme broadened and strengthened**

Two key components that were expected to contribute to the achievement of this output were:

1. Development of a comprehensive, integrated crop management programme to promote multi-agency management and response mechanism
2. Identification of appropriate local or foreign biological control agent(s) and evaluate the feasibility of establishing a rearing and releasing programme

The field component of integrated crop management programme involved the implementation of tried and tested area-wide IPM strategies:

- The use of area-wide monitoring of BAW populations with pheromone traps as a tool for decision-making on the management method(s)
- Adjustment of planting season:
  - No late planting of onion, particularly from February to March
  - Delay planting of new fields to the period April-June
  - Harvest mature scallion, onion during April-June period
  - Practice appropriate crop rotation – e.g. rotate with crops belonging to other crop families and / or those which are not attacked by BAW
- Employment of cultural practices: intercropping, crop rotation and removal of grass hosts as well as postharvest materials from onion / scallion as sources of BAW
- Safe use of effective pesticides (including biological control)

The project had a specific component on biological control – the identification and preparation of protocols for rearing / mass production and release techniques for at least two biocontrol agents. The natural enemies of the beet armyworm include predators, parasitoids, entomopathogenic nematodes, fungi and viruses. Available literature indicates that the efficacy of natural enemies in suppressing BAW populations ranges widely, with field parasitism levels of < 1% to 90% (Sertakaya *et al.* 2004, Ruberson *et al.* 1994). Thus, while previous attempts at finding natural enemies had not been successful (Diedrick *et al.*, 2011), it was anticipated that at least a parasitoid or an entomopathogen would have been found, the presence of which could have contributed significantly to the overall management efforts of the BAW. During the FFSs and on several other occasions, field visits were made to scallion and onion farms. The immediate environs of the fields were scouted for BAW larvae. Observations were made on sightings of BAW and any natural enemies observed feeding on the larvae as well as from larvae collected from the field. Generalist predators, namely white egret birds, wasps (*Polistes* spp.), spiders and ants were recorded preying on BAW larvae; none of the field-collected larvae showed outward signs of possible parasitization/infection. *Polistes* sp. were observed cutting open the leaves to remove BAW larvae. It soon became apparent that the heavy reliance on insecticide control of the BAW had decimated most of the natural enemy population.

## **NEXT STEPS**

### Forecasting tool

It is necessary evaluate and improve data collection and analysis programme and the monitoring protocol developed by the consultant: implementation strategies were being developed by the Technical working group using 10 Farmer Field school farmer groups in tandem with RADA and R&D. Eight agencies are involved in the implementation of the forecasting tool, and it is necessary to formalize institutional arrangements via a Memorandum of Understanding (MOU). Furthermore, a national policy is needed with regard to the use forecasting tools as a part of the Ministry's way forward to address issues of climate change including pest outbreaks and for funds to be allocated to support the associated activities.

The consultant is currently preparing a Manual to be used to train personnel from the Ministry and partner agencies. This training is to be carried out during the second mission. The third and final mission would take place in 2015, with the objective of testing and fine-tuning of the selected forecasting tool. In terms of the establishment of BAW forecasting tool (FT): it would be necessary to (1) ensure that FT is widely and easily accessible to all users – this would fall under the responsibility of the MOAF and RADA, and (2) incorporate updating of weather and BAW population data into RADA's annual work plan to ensure continuity and sustainability. Collaboration is being sought with established Climate Change group headed by RADA and continued research to improve system through the local Universities. *Development of the pest forecasting system has enriched local capacity for the development of similar systems for important pests on priority crops on the island.*

### **FFS, including biological control**

A comprehensive Manual on BAW Management is being prepared for use by Extension personnel in farmer training.

While the initial evaluation of the FFS was generally very favourable, it is necessary to carry out a comprehensive evaluation of (1) the overall impact of the FFS over a period of time and (2) the use of farmer participatory methods for knowledge transfer and learning among farmers. Based on the evaluation, a Formal Policy can be developed to support the utilization of FP methods for the provision of agricultural extension services to farmers and to the farming communities. Through FAO's support, a linkage has been created with CABI and a Concept Note submitted to CABI to support the development of a biological control programme for BAW.

## **Sustainability**

From the outset, it was recognized that the project was not stand-alone, but was to add value to the on-going national programme on BAW management. The following measures that were put in place to ensure the success and sustainability of the project took this into consideration:

1. The Government-appointed National Project Coordinator (Ms Michelle Sherwood, Senior Research Director, MOAF), was the focal point for the execution of the project. She was guided by the Technical Working Group (TWG), comprising representatives from the agencies involved in its implementation: R&D-MOAF, the Agricultural Land Management Division (ALMD) of MOAF (with GIS capability), Director General and Information and Communication Technology (ICT) Unit of MOAF, RADA, The Meteorology Service Division of Jamaica, ACDI/VOCA and National Caribbean University (NCU). The TWG met regularly to review progress and make plans for the next few weeks. This ensured that the agencies were kept abreast of developments and in turn provided the necessary support at each stage.
2. The project supported the development of the forecasting tool as the basis for an early-warning system, a critical gap in the current management programme. It also supported and fostered the cooperation and collaboration that was necessary with several new agencies. The forecasting tool will remain within the MOAF and RADA: it will support and strengthen the early-warning system for BAW in the first instance and for other pests in the long term.
3. At the start of the project, RADA and R&D personnel were trained as FFS facilitators and in the integrated management of BAW. Furthermore, FAO consultants (FFS Expert and Entomologist) supported the newly-trained FFS facilitators in conducting the Training of Trainers for lead farmers. Thus, a cadre of well-trained FFS facilitators as well as lead farmers now exists in Jamaica. It is anticipated that the FFS facilitators will continue to use the skills acquired during the TOT/FFS in their interactions with farmers.
4. Baseline surveys were conducted and sensitization sessions held with farmers prior to the start of the activities in order to establish a baseline of current status of BAW management and farmer perceptions: the information was used in planning the various interventions that were tested in the FFS. Furthermore, farmers were the main focus and subject of the FFS, which empowered them to make evidence-based decisions in crop management not only for BAW on scallions and onions but also for other crops.



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Animal Science and Agronomy/Soil

**NITROGEN MINERALIZATION OF AGOUTI (*Dasyprocta leporina*) MANURE APPLIED TO FOUR TROPICAL SOILS**

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**Abstract:** Assessing nitrogen (N) mineralization potential of manure is an important precursor for ensuring nutrient use efficiency. N mineralization of agouti and cattle manure was assessed after application to four contrasting soils, incubated for 35 days. Total Kjeldahl nitrogen (TKN) fluctuated over the incubation period and was affected by both soil and manure type. Mineralization was greater in agouti versus cattle manure, with the latter showing immobilization between sampling days 3 and 14. TKN was greatest in Princes Town soil. Ammonium ( $\text{NH}_4^+$ ) content fluctuated similarly to TKN. Values were significantly higher in the strongly acid soils. Nitrate ( $\text{NO}_3^-$ ) content decreased with time, stabilising at values just below 50 mg/kg. For the first two sampling times, agouti manure contained significantly higher values compared to cattle manure. Agouti manure can be applied as a soil amendment with consideration of the N supplying potential.

**INTRODUCTION**

The regional livestock industry is under increasing pressure to improve the management of waste and increase the efficiency of nutrient use. Soil application of manures has remained an important traditional control point that not only increases soil organic matter content and quality (Burger and Venterea, 2008) but also reduces soil degradation and environmental pollution when applied at appropriate rates related to crop requirements. This practice has increased with greater concern over the misuse of inorganic fertilisers and trends towards improving soil quality through sustainable practices (Hartz et al., 2000). Application rates of animal manures have been generalized based on decay rates (mineralization models) based on trials conducted mostly in temperate regions and rarely are nitrogen (N) content of the manures determined and mineralization assessed under humid, hot conditions. Burger and Venterea (2007) indicated that accurate estimates of plant available N and phosphorus (P) are needed to maximise the benefit to the crop and minimize undesirable losses of these nutrients. Eghball (2000) stated that N mineralization increased with increasing temperature under conditions found in agricultural soils. This is important in the tropics as at present rates, greater amounts of available N may be present over the growing season due to increase mineralization.

Whilst ammonium ( $\text{NH}_4^+$ ) and nitrate ( $\text{NO}_3^-$ ) are readily available for plant uptake from manures, mineralization determines the time dependent continual release of these inorganic N forms. Manures vary widely in nutrient quality, depending on animal species, age, feed and feeding pattern, management system and sex (Azeez et al., 2009). Differences in manure composition influences N transformation processes when applied to soil. Eghball et al. (2002) showed a range from 18-55 % of organic N mineralized within one year after application for composted manure

and poultry manure respectively. The wide range in potential N availability necessitates assessment of specific animal manures in lieu of soil application. The Agouti (*Dasyprocta leporina*) is a neotropical rodent. Locally, the high demand for its meat has directed research efforts towards domestication. Intensive rearing of these animals must include appropriate systems of waste management. It is germane that N mineralization potential be assessed to allow for proper use and disposal of this manure through soil application. Although practical constraints limit scaling up results from laboratory incubation-based mineralization studies to field application, such studies are important for comparison and understanding of the mechanisms and factors affecting N mineralization.

In addition to animal related factors matrix effects also determine the rate of release of inorganic N from applied manure. Van Kessel and Reeves III (2002) reported that a series of studies showed a range from 0-60 % organic N mineralized from cow manure. Chae and Tabatabai (1998) concluded that net N mineralized from manure depended on soil chemical and physical properties, but failed to elucidate the associated properties. Limited research has reported on the effects of soil properties on N mineralization. Burger and Venterea (2007) stated that declines in inorganic N occurring immediately after manure application to soil have been attributed to N loss processes. Nitrogen losses as high as 39% of manure N via denitrification have been reported (Calderon et al., 2005). The diverse nature of the soils of Trinidad (Roopnarine et al., 2012) will compound any generalization of application rates for animal manures. The main objectives of this study were to determine the mineralization rate of Agouti manure applied to contrasting soils and further to comparatively evaluate N mineralization from agouti relative to cattle manure.

## **MATERIALS AND METHODS**

### **Manures and Soils**

Laboratory incubations were performed comparing two manure types. Cattle manure was collected from storage areas where animal were confined with straw bedding assessable to the cattle. Agouti manure was collected from storage pits below animal confinement cages. Surface samples (0-30cm) were collected for four contrasting soils series; Piarco, River Estate, Princes Town and Talparo. Soils and manures were prepared by air drying, followed by crushing to pass a 2 mm sieve. Subsamples were analysed for pH, EC, TKN, total organic carbon (TOC), available P, K and particle size distribution for the soils. TKN was determined by acid digestion of 0.3 g and 1.05 g of dried milled manure and soil samples respectively, followed by Kjeldahl steam distillation (Bremner, 1966). TOC was tested using (Nelson and Sommers, 1996) loss on ignition and Walkley and Black wet oxidation for manure and soils respectively. Available P was extracted using NaHCO<sub>3</sub> following the Ascorbic Acid method (Kuo, 1996) and determined using a UV Mini 1240 (Shimadzu Corporation, Japan), while K was determined on the Digital Flame Model 2655-00 (Cole Parmer Instrument Company, USA) after NH<sub>4</sub>OAc extraction (Helmke and Sparks, 1996). Electric conductivity (EC) was measured using a hand held conductivity/ TDS/ Temperature/ RS232C meter and pH using the IQ 150 pH meter at a solid to water ratio of 1:1 and 2.5: 1. Soil available N (NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup>) was extracted with 2M KCl (Mulvaney, 1996) followed by steam distillation utilizing Rapidstill II Labconco distillation unit. Clay content of soil samples was determined by the hydrometer method following Gee and Or (2002).

## Soil Incubation

Triplicate samples of 4.5 kg of soil were mixed with either manure at a rate equivalent to 25 t/ha and then transferred into 3.78 L perforated plastic containers. Samples were watered to field capacity, covered and incubated in a closed ventilated room at 30°C for 35 days. A total of 24 experimental units were used for the incubation. Samples for all treatments were taken using a core auger capable of sampling the entire depth of the container, at different times (i.e. 1, 2, 3, 7, 14, 21, 28 and 35 days). Samples were analysed for nitrate ( $\text{NO}_3^-$ ),  $\text{NH}_4^+$  and TKN, as described previously.

## Analysis

All data were subjected to repeated measures analysis of variance (ANOVA) using Genstat statistical software. Significant treatment means were separated using least significant differences (LSDs) values at 5 % level of probability.

## RESULTS AND DISCUSSION

The soil series showed a wide variability in physical and chemical characteristics. Clay content ranged from 11.2 for Piarco to 75.7 % for Talparo (Table 1). Talparo and Princes Town series have been classified as Vertisols with expanding mineralogy, whilst Piarco and River Estate are classified as an Ultisol and Inceptisol respectively (Smith, 1983). The soils ranged from strongly acid to neutral, with the neutral soil having the highest TOC and TKN contents. Inorganic N was similar across all soils, values typical of tropical soils (Eudoxie, 2010) and indicative of quick N turnover and transformations. Wide variation in soil properties was important for elucidating the properties affecting N mineralization from manures.

Chemical characteristics of the manures differed, supporting the claim that manure quality varies in relation to animal type, age, diet and management (Chadwick et al., 2000). Cattle manure had a lower pH (alkaline) but higher EC compared to agouti manure (Table 1). TOC and TKN were lower in cattle manure, whilst the C:N ratios were similar. The C:N ratios (>25) suggest that mineralization would be slow and dependent on availability of native soil and manure inorganic N. Azeez et al., (2010) stated that immobilization of applied nutrients was likely from cattle and goat manures with C:N ratios of 10.3 and 11.3 respectively. This implies that immobilization would be the dominant N process in this study. However, the decomposition of organic substrates is also conditioned by the content of labile C and inorganic N.

## Manure Mineralization in Soils

Figure 1 shows the combinatory effects of soil series and manure type on TKN. Variation in TKN is reflective of changes in organic N and inversely related to mineralization. For both manures across all soils TKN content fluctuated over the incubation period. Patterns were similar among cattle amended soils, whilst greater variability was observed in soils receiving agouti manure. TKN increased and decreased at different times among the soils. Princes Town recorded significantly higher TKN contents at days 3 and 7, whilst Talparo had a significantly lower content at day 21. The fluctuating trend suggests equilibrium shifts between mineralization and

immobilization, with periods of increased TKN representative of immobilization. This is interesting as immobilization occurred immediately after application for cattle manure across all soils, whilst it took 21 days before immobilization was observed in agouti amended soils with the exception of Princes Town, which showed immobilization at day 3. The C:N ratios were similar for both manures but the content of C and N was greater in agouti manure. Agouti manure was able to supply available N for an extended period indicating the potential for use in cropping systems. Similar fluctuating trends were noted by Azeez et al. (2010) who attributed it to microbial population and C:N ratio. Notably the C:N ratios across the three manures used in their study was very similar and in the low range (10). It is suggested that C:N ratio plays a secondary role as values in our study were three times greater, in the range associated with immobilization. Availability of inorganic N and labile C moderates mineralization-immobilization dynamics. Abbasi et al. (2007) inferred that the higher C content of manures increases the energy and food supply to the microbes. This in turn stimulates their activity consuming more available N than the mineralization process releases.

Princes Town soil across both manures maintained the greater amount of organic N, implying lowest mineralization. Eudoxie (2010) reported highest immobilization for this soil among a similar range of tropical soils and alluded to the higher carbon content of this soil. Barret and Burke (2000) hypothesized that soils with higher organic matter content and wide soil C:N ratios may immobilize more N than soils with less SOM because of a limitation of reduced C substrate to microbial metabolism.

### **Inorganic N**

$\text{NH}_4^+$  content decreased over the incubation period, stabilising at about 15 mg/kg for both manures (Figure 2).  $\text{NH}_4^+$  content was significantly ( $P < 0.05$ ) higher for agouti compared to cattle manure for all sampling times except days 7 and 35.  $\text{NH}_4^+$  content was lowest after 28 DOI. Burger and Venterea (2007) reported similar results for incubation of four different manure types. Consistent with TKN trends, agouti manure sustained a greater amount of  $\text{NH}_4^+$ , indicating greater mineralization. Contrastingly, Piarco soil showed the greater content of  $\text{NH}_4^+$ . The corresponding low TKN values for this soil indicate greater mineralization. River Estate soil showed significantly lower  $\text{NH}_4^+$  content over time relative to Piarco although TKN values were similar. This may be related to greater nitrification of  $\text{NH}_4^+$  in the former soil associated probably with pH and enhanced microbial populations. Lower levels of microbial activity associated with low soil organic C, coarse texture and acidity allowed for a longer period of  $\text{NH}_4^+$  availability in Piarco soil.

Agouti manure significantly ( $P < 0.05$ ) increased the content of  $\text{NH}_4^+$  in Talparo soil relative to cattle manure (Figure 3). This value was also significantly greater than all other soil×manure interactions except agouti amended Piarco soil. Piarco and Talparo soils are strongly acid, which could affect microbial activity. Eudoxie (2010) showed lowest nitrification and immobilization in these soils, which is also supported by the TKN data. Curtin et al. (1998) reported that liming of acid soils stimulated mineralization of C and N. Cheng et al., (2013) investigating gross mineralization in contrasting forest and grassland soils reported that the increase in soil pH significantly stimulated gross mineralization, while the opposite occurred for soil acidification.

Liming of acidic soils may stimulate N mineralization and subsequently nitrification, increasing the content and availability of inorganic N.

Nitrification was affected solely by manure type and varied significantly over the incubation period. After 1 DOI,  $\text{NO}_3^-$  content was 20 fold greater in agouti amended soils (Figure 4). The decreasing trend stabilized at values  $< 50$  mg/kg from day 3, indicating loss or utilization of  $\text{NO}_3^-$  from soils. The high content of  $\text{NO}_3^-$  in agouti treated soil is related to native inorganic N in the manure and greater gross N mineralization. The rapid decline in  $\text{NO}_3^-$  concentration after application is of concern as continued supply of inorganic N may be interrupted. Additionally, dependent on soil properties loss pathways such as leaching and denitrification may pose environmental concerns. Azeez et al. (2010) reported net decreases in nitrification within 30 DOI for goat, cattle and poultry manure, all with significantly lower C:N ratios than manures used in this study. However, the authors showed that at 40 DOI, net nitrification increased for all manures. The incubation duration for this study did not exceed 40 DOI, but a similar fate can be anticipated.

## CONCLUSION

Agouti manure differed in its physical and chemical properties compared to cattle manure and resulted in separate mineralization kinetics across different soils. Greater amounts of organic N were mineralized for agouti amended treatments, the extent modified by soil series. Princes Town series (pH 7.07) showed increased immobilization. Inorganic N forms ( $\text{NH}_4^+$  and  $\text{NO}_3^-$ ) generally decreased over time being affected by manure type. Agouti manure started with a greater content but at 35 DOI was similar to cattle manure. Use of agouti manure can follow similar recommendations to cattle manure with consideration for the higher content of organic and inorganic N and C.

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Table 1 Selected properties of manures and soils used in the study.

Property	Manure		Soil			
	Agouti	Cattle	Piarco	Princes Town	River Estate	Talparo
Clay (%)			11.2	61.8	32.3	75.7
pH	8.42	7.1	4.21	7.07	5.59	4.37
EC (dS/m)	5.33	7.91				
OC (%)	47.5	34.3	0.86	2.1	1.26	0.69
TKN (%)	1.63	1.08	0.08	0.22	0.14	0.1
C:N	29	32	11	10	9	7
NH4+ (mg/kg)			27.6	33	49.1	35.9

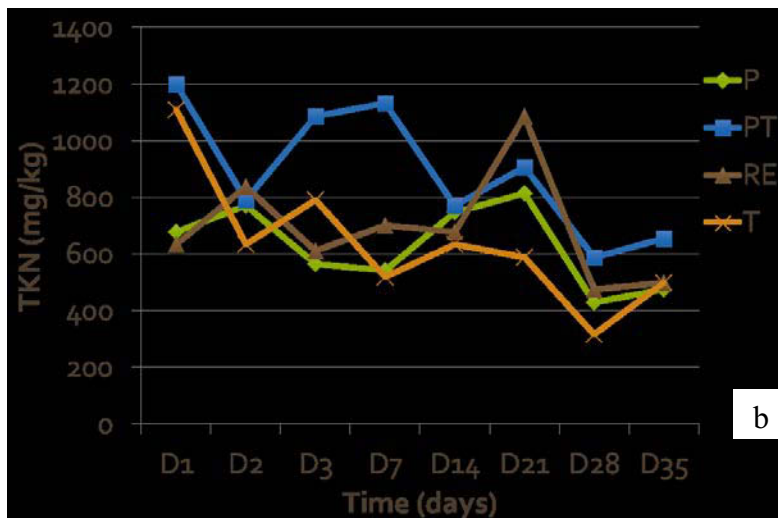
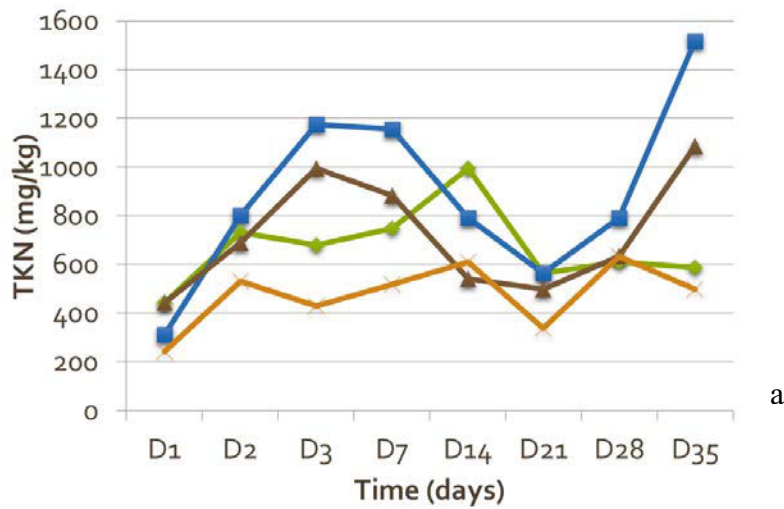


Figure 1 Combinatory effect of soil series and cattle (a) or agouti (b) manure on TKN content of samples incubated for 35 days



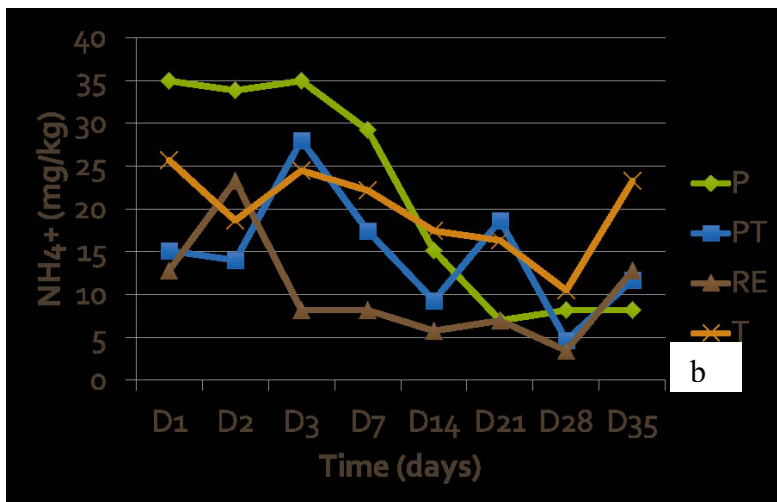
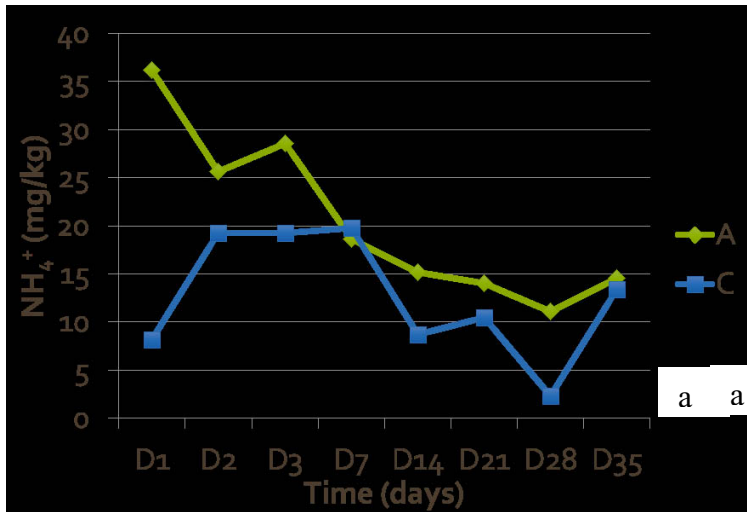


Figure 2 Main effects of manure type (a) and soil series (b) on NH<sub>4</sub>\* content of samples incubated for 35 days

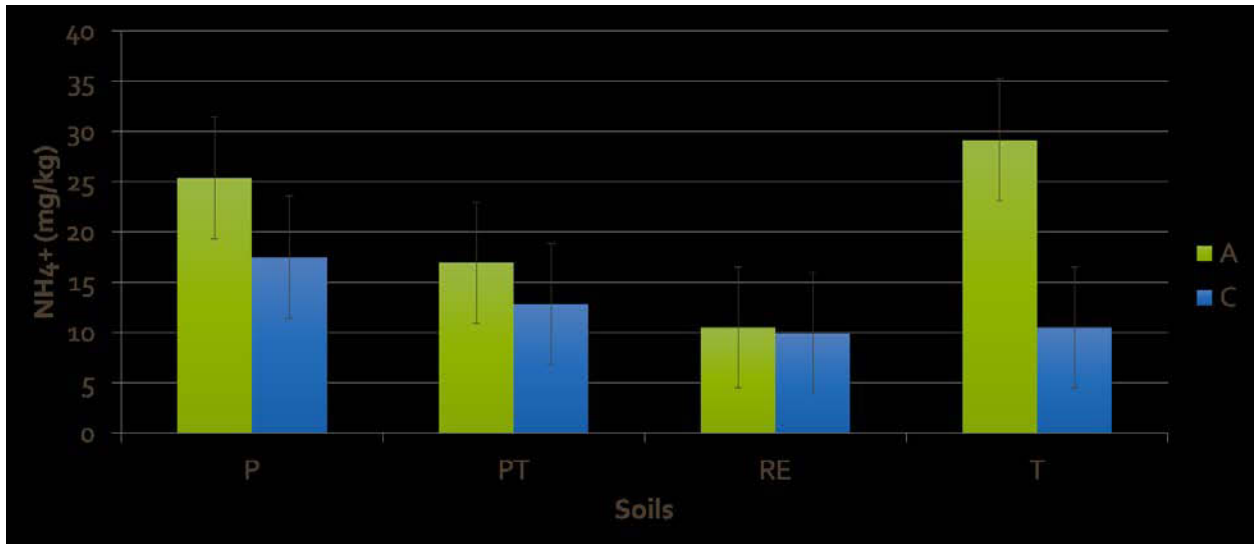


Figure 3 Interaction effect between manure type and soil series on  $\text{NH}_4^+$  content

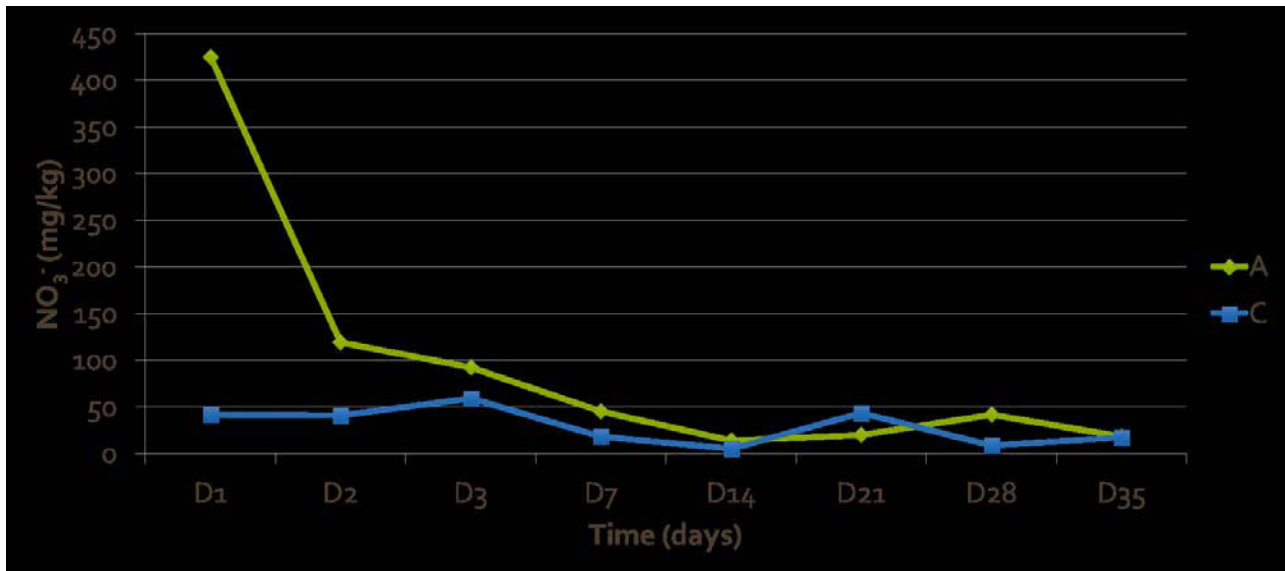


Figure 4 Main effect of manure type on  $\text{NO}_3^-$  content of samples incubated over 35 days.

**CENTRAL FLORIDA LIVESTOCK AGENTS GROUP (CFLAG) BEEF CATTLE REPRODUCTIVE MANAGEMENT SCHOOL WITH ARTIFICIAL INSEMINATION**

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**Abstract:** Efficient beef cattle reproductive management is critical to economic success of cattle operations. A beef cattle reproductive management school has been conducted, evaluated and modified meeting educational needs of large/small beef cattle businesses and livestock workers in excess of fifteen years with artificial insemination (A.I.) components added the last three years. Educational objectives are that participants (100%) would complete a 5-day intensive school gaining whole herd management knowledge and tactile competency in pregnancy determination by palpation, laboratory confirmation via “tail-bleeding” and artificial insemination directly incorporating to ranches. CFLAG coordinates the 5-day school between Extension (specialist and agents), teaching and research faculty and Deseret Ranch, the ranch providing facilities/cattle, Extension instructors, manuals, course content and participant nourishment. Annual participants include cattlemen/women, mature high school and college students plus 5 Deseret employees. Participation limited to thirty-five annually, maximizes instructor/student ratios, combining didactic and clinical experiences with combined attendance of more than 400 students over 15 years. Multi-disciplinary instructors include UF Extension agents, professors, graduate students, American Breeders Service (ABS) personnel and veterinarian. Participants pay \$300 with student discounts to encourage younger participant attendance. Held in August, it provides group and one-on-one teaching opportunities utilizing morning tactile labs held at 3-5 chutes with afternoon classroom sessions. Annual and a 6-year evaluation have been conducted indicating substantial knowledge gain and practice change. Seventy percent indicating management change from “some to a lot,” improved reproductive management, improved lower stress cattle handling methods, better understanding of nutritional programs and increased understanding and use of A.I. Producers state a variety of positive financial impacts ranging from \$500.00 to \$50,000.00 dollars. Of students, several have become large animal veterinarians, obtained animal science degrees and have taken knowledge to farms. Participants that historically didn’t attend Extension events, attend regularly, expanding knowledge.

## AN EVALUATION OF FACTORS AFFECTING THE CO<sub>2</sub>- C SINK STRENGTH OF AG-LIME ADDED TO TWO TRINIDAD ACID SOILS

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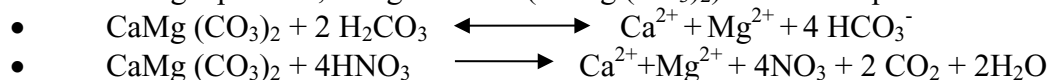
**Abstract:** The most recent Intergovernmental Panel on Climate Change (IPCC) greenhouse gas (GHG) inventory guidelines recognizes that CO<sub>2</sub> is not always the end product of ag-lime dissolution in soils and now allows countries to report on their own emission factors once it is supported by sound research findings. This study was therefore established to assess the effects of additions of organic amendments (biochar and poultry litter) and ammonium N on the magnitude of the CO<sub>2</sub> flux and the carbon sequestration potential of ag-lime when added to two diverse soils (a peaty clay and a sand). The soil treatments with the equivalent of 80g oven dry soil (ODS) were incubated in modified 500 mL mason jars. At each measurement, the alkali-trap attached to the cover was installed ensuring proper sealing of the jar opening and left for 24 hrs to absorb the CO<sub>2</sub> emitted from the soil. Fluxes were measured at days 1, 3, 6, 9, 10, 15, 18, 21, 24, 28 and, 31, and all soil treatments were initially brought to 100% field capacity and rewetted three times thereafter. Analysis of the data showed that soil type, organic matter and ag-lime additions had a significant effect ( $P < 0.05$ ) on CO<sub>2</sub> emissions. The effect of time was significant on the rates of CO<sub>2</sub> emissions, showing a decline in the emission rate from an overall mean of 33.8 mg CO<sub>2</sub>/kgODS/hr at day 1 down to 1.98 mg CO<sub>2</sub>/kgODS/hr. The peaty clay fluxes were consistently higher than those from the sand, and soils treated with poultry litter were also statistically ( $P < 0.05$ ) consistently higher than those with biochar and no organic matter additions. Given that ag-lime addition to soil is known to have a priming effect on organic matter decomposition, evidence for carbon sequestration was seen with both soils; whereby the increase in CO<sub>2</sub> emissions following the addition of ag-lime was much lower in the presence of poultry litter compared to soils with biochar and no organic matter addition.

**Keywords:** carbon dioxide (CO<sub>2</sub>), carbon sequestration, ag-lime, biochar, poultry litter, climate change, acid soils.

### INTRODUCTION

Liming agents such as agricultural lime (calcite and dolomite), are commonly applied in humid regions to raise the pH of the naturally acidic soils which are too acidic to facilitate the optimum growth of most crops (Brady and Weil, 2010; Dumale et al., 2011; West and Mc Bride, 2005). Periodic liming is also necessary to counteract soil acidification, which is commonly caused by the over use of nitrogenous and sulphur fertilizers (Fisher et al., 2003). The use of agricultural lime (ag-lime) has been identified as a contributor of carbon dioxide (CO<sub>2</sub>) emissions (Dumale et al., 2011; West and Mc Bride, 2005; IPCC, 2004). However, data on the magnitude to which ag-lime dissolution affects the flux of CO<sub>2</sub> from acid soils is limited, and it has also been noted that the flux of CO<sub>2</sub> from ag-lime is quite diverse (Dumale et al., 2011).

The revised 1996 Intergovernmental Panel on Climate Change (IPCC) on greenhouse gas inventories assumed that 100% of the carbon (C) stored in ag-lime is ultimately emitted as CO<sub>2</sub>. The most recently published 2006 guidelines on greenhouse gas inventories, however, recognizes that this is not the case and allows countries to report on their own emission factors once it is supported by sound research findings. This revision of the IPCC guidelines was as a consequence of findings by West and Mc Bride (2005), who estimated that only about 49% of the C in ag-lime is emitted as CO<sub>2</sub>. Contrary to these findings, results from a more recent study by Hamilton et al. (2007) suggest that ag-lime may actually serve both as a sequester or source of CO<sub>2</sub> depending on if its dissolution is influenced by weak acids, such as carbonic acid (H<sub>2</sub>CO<sub>3</sub>) that are released as result of root and microbial respiration, or strong acids such as nitric acid (HNO<sub>3</sub>) liberated from nitrification, respectively. These two biochemical pathways are summarized in the following equations, using dolomite (CaMg (CO<sub>3</sub>)<sub>2</sub>) as an example:



Based on results obtained from the analysis of leachate from limed agricultural plots on the Michigan State University Biological Station, Hamilton et al. (2007) proposed that ag-lime may sequester CO<sub>2</sub> equivalent to 25 percent to 50 percent of its C content in the case of H<sub>2</sub>CO<sub>3</sub> dissolution and emit CO<sub>2</sub> equivalent to as much as 60% of its C content when its dissolution is influenced by strong acids. As the estimates on the carbon sequestration potential of ag-lime made by Hamilton et al. (2007) were not based on measurement of the actual flux of CO<sub>2</sub>, this study was established to assess the effects of additions of organic amendments (biochar and poultry litter) and ammonium N on the magnitude of the CO<sub>2</sub> flux and the carbon sequestration potential of ag-lime when added to two diverse acids soils in Trinidad.

## **MATERIALS AND METHODOLOGY**

Two diverse acid soils (Nariva peaty clay and Piarco fine sand) of Trinidad were used in this experiment. Soil samples for both soil types were taken from farms that had a long history of vegetable production. Soils were prepared first by grounding with a metal pistol then sieving through a 2mm sieve. This procedure was repeated for the preparation of the poultry litter used in the experiment.

### **Soil and organic amendment and analyses pre-incubation**

Soil samples and organic amendments were characterized based on various physical and chemical properties using standard operating procedures (Sparks et al., 1996; Gee and Bauder, 1986). The results of these analyses are summarized in table 1. The potential of hydrogen (pH) was measured utilizing both calcium chloride (CaCl<sub>2</sub>) and water in a 1:1 soil: water/ CaCl<sub>2</sub> ratio. The electrical conductivity of the two soils was determined by means of the saturated paste method and dilution method, using the recommended 1:2 sample: water ratio in the case of dilution method (Sparks et al., 1996). Other analyses carried out on the two soil types included particle size distribution, using the hydrometer method; available P; and the lime requirement (Ca(OH)<sub>2</sub>) to raise the soil pH 6.5. The organic amendments were analyzed for pH in CaCl<sub>2</sub> and water using a 1:2.5 ratio; they were also analyzed based on the other parameters mentioned above for the characterisation of the two soils. The average percentage moisture and dry matter

(DM) content of the soils and organic amendments were also determined; however, these results are not presented in this paper.

### **Soil incubation and gas measurement**

A 3×2×2×2 factorial design with three levels of material (poultry litter and biochar at a rate of 5% of soil on an oven dried basis and no organic material); two levels of ag-lime (2000ppm and 0ppm of laboratory grade CaCO<sub>3</sub>); two soil types (80g ODS); and two levels of ammonium N (200ppm and 0ppm) was employed for this experiment. The treatments used in this experiment were the result of combination of these four factors and their levels. Soil treatments were incubated in modified 500mL mason jars in a laboratory at 22.3± 0.58°C for 33days. All soil treatments were initially brought up to 100% field capacity (FC) and rewetted at days 9, 19, and 26. Before each measurement, the alkali traps attached to the cover of the mason jars were filled with 5mL of 1M NaOH using a 5mL pipette. The traps were then carefully installed and properly sealed to avoid spillage and the escape of CO<sub>2</sub> from the jars and fluxes were measured 24hrs after by titrating the unreacted NaOH to a phenolphthalein end point with 1M HCL (Anderson, 1982). Fluxes were measured day 1, 3, 6, 9, 10, 15, 18, 21, 24, 28, and 31 of incubation.

### **Post-incubation analyses**

Analyses were carried out on the soil treatments at the end of the incubation period. pH was determined in water using a 1:1 ratio, while EC was determined using a 1:2 dilution. Available P was also determined.

### **Calculation of lime derived carbon (C)**

The total percentage lime derived C was calculated by first subtracting the total cumulative C of the un-limed treatments from their corresponding lime treatment. The difference was divided by the rate at which C was added in the ag-lime and then multiplied by a 100.

### **Statistical analysis**

Data were analysed using a factorial analysis of variance (ANOVA) by Gen Stat Discovery Edition statistical package. Where there were significant (P<0.05) effects of a particular treatment or their interaction, least significant differences (LSD) were used to discriminate among means.

## **RESULTS AND DISCUSSION**

The effect of soil type on the rate of CO<sub>2</sub> emissions was significant (P<0.05) at all eleven sampling times (table 2). The rate of emissions was consistently higher from the Nariva peaty clay than from the Piarco fine sand soil series. On average, the emission rates were 11.9 mg CO<sub>2</sub> kg/hr and 3.65 mg CO<sub>2</sub> kg/hr for the peaty clay and fine sand respectively. The significantly higher mean emission rate from the peaty clay as compared to the fine sand is expected. It is well understood that the rate of decomposition of indigenous carbon by soil microorganisms, which leads to the production of CO<sub>2</sub>, is higher in soils with high initial soil organic carbon (SOC)

levels than those with initially low levels (Dumale et al., 2011; Mann, 1986). Therefore, the difference in the mean emission rate is as a consequence of the higher organic carbon content in the peaty clay.

Table 1. Characterisation of soil and material pre-incubation.

EC- Electrical conductivity by dilution method							
Sample	pH H2O	pH CaCl <sub>2</sub>	EC (mS)	ECe (mS)	Av. P (ppm)	Lime Requirement (tons/ha)	Textural class
Piarco fine sand	4.43	4.05	0.2167	0.7933	51.164	1.716	Sandy loam
Nariva peaty clay	4.52	4.33	0.8000	2.085	30.167	6.543	Clay
Biochar	7.35	6.95	0.2353	NA	NA	NA	NA
Poultry litter	8.58	8.43	14.31	NA	NA	NA	NA

ECe- Saturated paste electrical conductivity

NA- Analysis not applicable

Av. P- Available phosphorus

Table 2. F probabilities as affected by individual factor treatments and their two-way interactions for CO<sub>2</sub> emission rates at various sampling times.

Source of variation	Df	n	Sampling Time (days)										
			1	3	6	9	10	15	18	21	24	28	31
Soil	1	12	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Mat	2	8		xxx	xxx	xxx	x	xxx	xxx	xxx	xxx	xxx	xxx
Lime	1	12	xxx	xx	x								
Amm	1	12										x	
Soil.Mat	2	4		xxx				x					xx
Soil.Lime	1	6	x		x								
Soil.Amm	1	6		x									
Mat.Lime	2	4	xx									x	
Mat.Amm	2	4											
Lime.Amm	1	6				x							
Residual	9												
Total	23												

x, xx and xxx represent statistical significance at P < 0.05, 0.01 and 0.001 respectively

Empty boxes represent no statistical significance with P > 0.05

The effect of time on the rates of emissions was very significant (P=0.001). The highest rates of emissions occurred in the early stages of incubation particularly within the first 24 hours,

decreasing progressively thereafter from 33.8 mg CO<sub>2</sub> kg/hr to 1.98 mg CO<sub>2</sub> kg/hr for the means of both soils combined (fig 1).

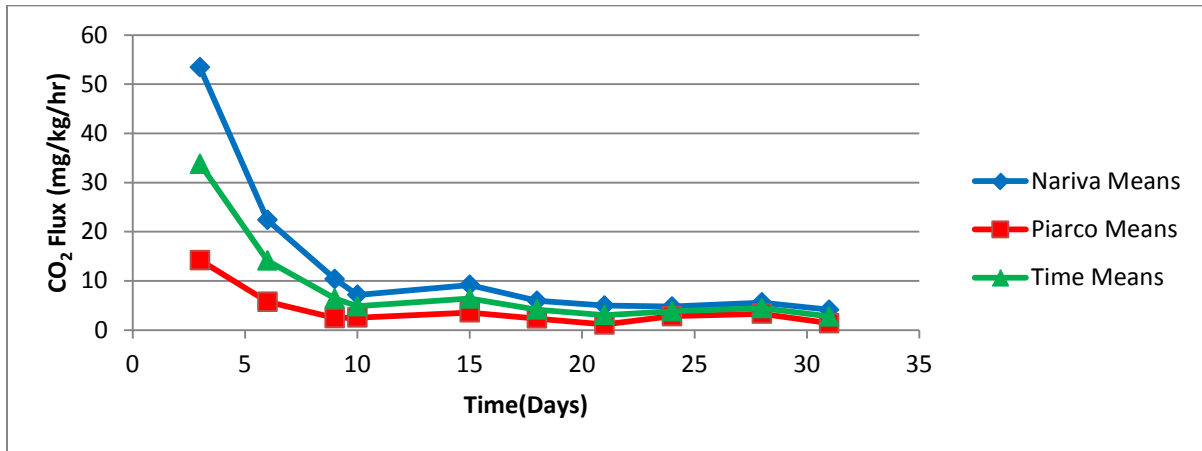


Figure 1. Temporal variation in rates of CO<sub>2</sub> emissions as affected by individual soils and their combined means.

Analysis of emissions data at the end of the experiment showed that the effect of lime was significant ( $P < 0.05$ ) on the rates of emissions. Higher mean rates of emissions were recorded from the lime treatments than the no-lime treatments. Notwithstanding this, analysis of the emissions data by days however indicated a significant ( $P < 0.05$ ) effect of ag-lime only in the first 6 days of incubation. This effect was seen to be most statistically significant ( $P < 0.001$ ) after the first day of incubation (table 2; fig 2). A similar experiment by Dumale et al. (2011) recorded a significant quantity of lime-CO<sub>2</sub> evolving within the first 24 hours of incubation.

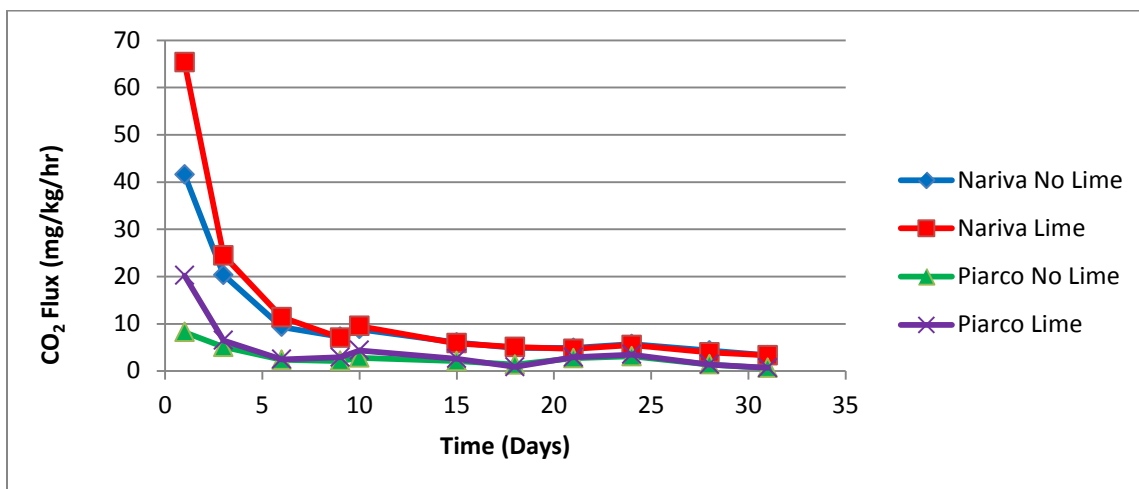


Figure 2. Interaction effect of time, soil and lime on the rates of CO<sub>2</sub> emissions

Organic material (OM) type had a significant ( $P < 0.05$ ) effect on the rates of emissions at all sampling times except day one (table 2). At day one, rates of 35.105, 31.855 and 34.565 mg CO<sub>2</sub>



Kg/ODS/hr were recorded for soils with no organic amendment and soils that were amended with biochar and poultry litter respectively. The higher fluxes from soils treated with poultry litter is expected, as the addition of readily decomposable organic material such as poultry litter, is known to significantly increase the rate of CO<sub>2</sub> emissions from soils (Hossain and Puteh, 2013). The lack of a statistically significant difference between the three organic matter treatments after the first day incubation in this study, however, may actually be an indication that the primary source of emissions from treatments without poultry litter, at least at this stage, may have been the ag-lime.

There was significant ( $P < 0.05$ ) interaction between organic material and lime—where in contrast to the no organic material amendment and biochar treatments, little difference was observed between the lime and un-limed treatments in the case of poultry litter addition (fig 3). Based on the assumption that the difference in emissions between the lime and un-lime treatments was as a result of ag-lime addition, these results suggest an enhancement of the carbon sequestration potential of ag-lime in the presence of poultry litter. Poultry litter, because of its high labile carbon content, greatly enhances microbial respiration through rapid decomposition of this labile carbon by these microorganisms (Hossain and Puteh, 2013). The addition of this amendment may have therefore led to the production of carbonic acid, which has been suggested by Hamilton et al. (2007) to enhance the carbon sequestration potential of ag-lime (equation 1 in introduction)

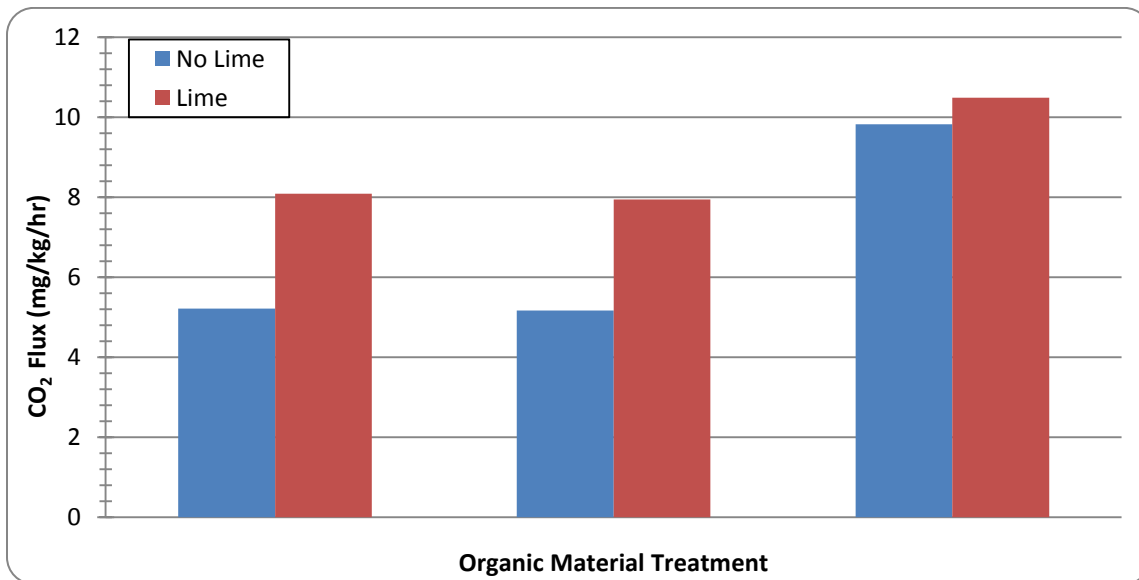


Figure 3. Interaction effect of organic material and lime on the rates of CO<sub>2</sub> emissions

$$LSD_{(0.05)} = 1.147$$

Calculations of the lime derived C showed average values as high 202% and 198% ,to as low 18% for treatments with no organic matter amendment, and biochar and poultry litter amendment respectively (fig 4a). It is important to note that the lime derived C may actually be lower than what was calculated in this experiment by the difference method, given that ag-lime addition is

known to have a positive priming effect on organic matter decomposition. The priming effect is described as a rapid turnover of soil organic matter subsequent to liming, and it results in an increase in CO<sub>2</sub> evolution from microbial respiration (Dumale et al., 2011). Lime derived C values of more than 100% in our experiment is an indication that there was some priming of SOC. With the limitations of this method of calculating lime emissions in mind, these results point to some evidence of a reduction in lime emissions when poultry litter is present. Moreover, results of the lime derived C from a second experiment, which investigated the effects of ag-lime and poultry litter rate on the CO<sub>2</sub> flux and the carbon sequestration potential of the Nariva peaty clay soil series corroborates the findings of this experiment. The results of this second experiment, presented in figure 4b, show a significant reduction in the recovery of C in the presence of poultry litter. This effect was especially prominent at the 1% poultry litter and 0.1% ag-lime combination.

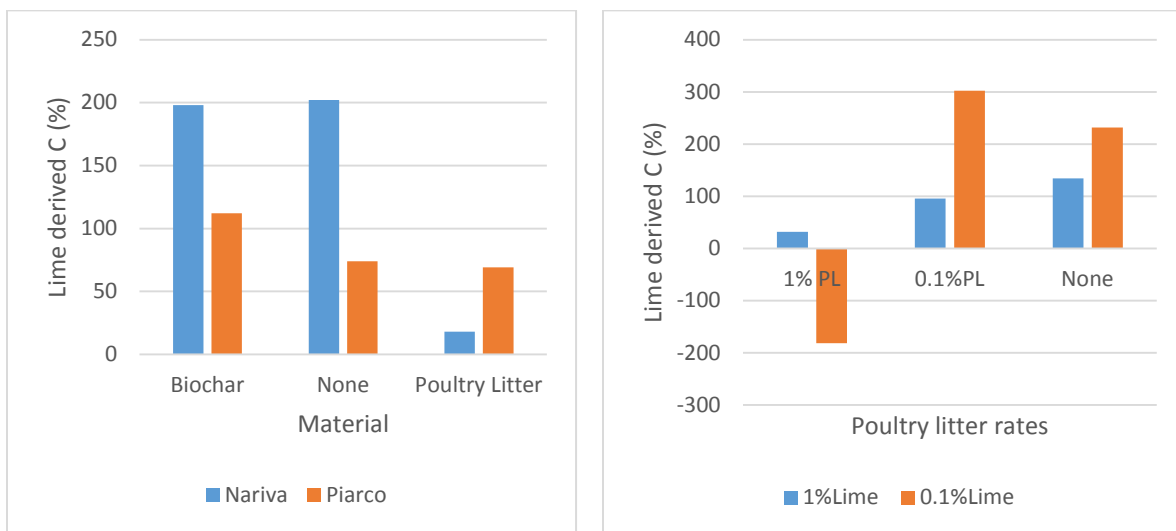


Figure 4a. Effect of OM and soil type on lime-C and Figure 4b. Effect poultry litter rates on lime-C.

Although a post incubation analysis of the soil treatments for NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub> was not carried out at the time of writing this paper to assess the extent to which the added ammonium- nitrogen (N) was nitrified, the significantly (P<0.05) lower pH observed for soils that were treated with ammonium- N compared to soils that were not (fig 5) may serve as an indication that a significant amount of the added N had been nitrified. Hamilton et al. (2007) observed that lime switched from a net sink to a source of CO<sub>2</sub> as the concentration of NO<sub>3</sub><sup>-</sup> in infiltration waters. This phenomenon is explained by the dissolution of HCO<sub>3</sub><sup>-</sup> by H<sup>+</sup> from HNO<sub>3</sub> that is liberated during nitrification. In this current study, however, there was a generally a lack of a statistically significant effect of ammonium addition on the flux from the lime treated soil. This may have been due to the low rate at which ammonium -N was added in comparison to ag-lime. From equation 2 in the introduction of this paper, it is seen that two moles of HNO<sub>3</sub> is required to dissolve one mole of ag-lime by strong acid dissolution.

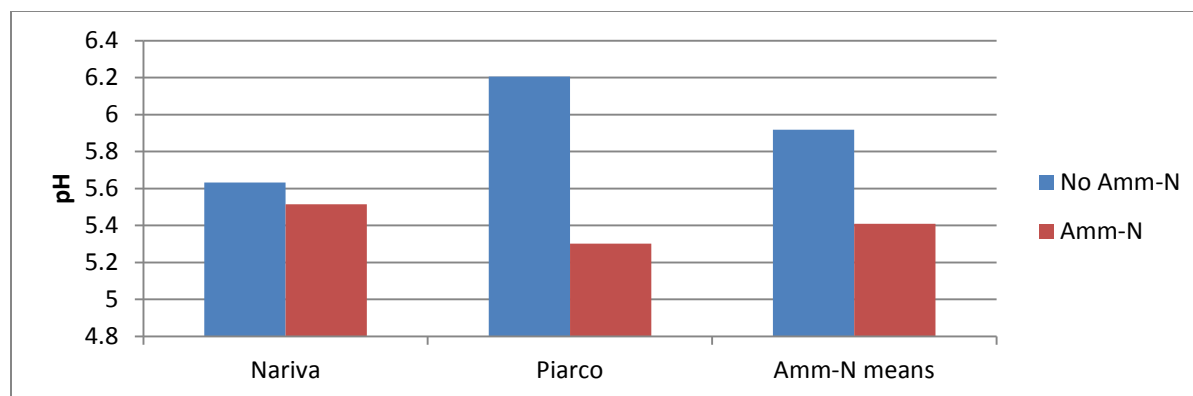


Figure 5. Interaction effect of soil and ammonium N on pH at the end of experiment one.

## CONCLUSIONS

In these studies, the addition of poultry litter in combination with ag-lime reduced lime emissions, especially for the Nariva peaty clay. This therefore suggests the need to further explore the climate change mitigation potential of ag-lime under a wider range of soils and management conditions. The use of more accurate techniques to estimate lime derived emissions is also recommended to better elucidate the mechanisms that control this phenomenon.

The application of ammonium-N and ag-lime at similar or equal rates should be considered in future experiments investigating the effect of addition of N fertilizers on the magnitude and flux of CO<sub>2</sub> from limed soils. Doing such may yield a more significant effect of ammonium N addition flux of CO<sub>2</sub> from these soils.

## ACKNOWLEDEMENTS

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**A FARM INVESTIGATION OF THE ASSOCIATION BETWEEN SOIL PHOSPHORUS (P) AND P IN GRASSES AND THE SERUM P OF DAIRY COWS**

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**Abstract:** Phosphorus is a macro mineral that can limit animal productivity in pregnant and lactating cattle. A study was therefore carried out to investigate whether a relationship existed between soil Phosphorous levels, levels of Phosphorous found in grasses and the serum of cows fed grasses at the Eastern Caribbean Institute of Agriculture and Forestry (ECIAF) farm. A total of 8 soil samples, 12 forage samples from two locations and 24 serum samples were collected from dairy cattle in 2013. Soil Phosphorous was determined by the Mechlich II extraction Method whereas forage and serum P levels were determined from the formation of the yellow complex formed by phosphor-vanado-molybdate method. Soil Phosphorous levels did not vary between two locations ( $P > 0.05$ ) and were found to be low (0.1 to 2.7 ppm). Phosphorus levels found in forages would neither supply maintenance nor production requirements for cattle. Forage P levels did not vary between two locations nor between pregnant and lactating cows studied ( $P > 0.05$ ). 54% of cows had serum P levels below 35 mg/L. Low P levels found in soils and grasses are supported by the low serum Phosphorous levels found in the serum of lactating and pregnant cows. In order to enhance productivity of the ECIAF dairy herd soil Phosphorous fertilization is recommended for ECIAF pastures. Also a phosphatic supplement such as Di calcium Phosphate should be included in the diet of the both dairy and pregnant cows.

## TURFGRASS GROWTH AND SOIL WATER STATUS IN RESPONSE TO BIOCHAR APPLICATION

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**Abstract:** Much research attention is currently focused on biochar (charcoal) as a soil amendment for enhancing plant growth while providing a mechanism for carbon sequestration. The extensive porous structure of charcoal can serve to increase mineral nutrient retention, microbial activity and water status in the soil medium for very long periods. Such effects can conceivably reduce the application frequency of fertilizers and irrigation water resulting in reduced costs along with environmental benefits. This is likely to be especially beneficial for turfgrass on rapid-draining sports fields, where maintenance costs can be considerable. Responses to the application of locally-sourced biochar (produced by traditional methods from local feedstock) were investigated for turfgrass (*Zoysia japonica* Steud., 'El Toro') grown in pots under field conditions. Observations on turf growth and soil water status were made for varying biochar application rates (0 - 20%, v/v of soil medium) using two types of biochar (plain, enriched), five application methods and three sand/soil potting mixtures. Enriched biochar was treated with compost tea from chicken manure during the production process. Enriched biochar enhanced turfgrass growth and soil moisture status when applied soon after product preparation but not after 6 months of dry storage. Effects of biochar application rates were observed only after 7 months of incubation in the soil medium, with increased turfgrass height at application rates of 4% or higher and optimum clippings dry mass production at 12% biochar. Soil incorporation appeared to work better than surface application of wet or dry biochar. Newly applied biochar had no significant effects on early turfgrass establishment in varying sand/soil potting mixtures. Biochar produced with traditional low-level technology appears to show potential as an organic input for sustainable production provided that there is an adequate soil incubation period.

**Keywords:** green cover, image analysis, greenness index.

## INTRODUCTION

Biochar refers to the carbon-rich material produced by the pyrolysis of organic material (feedstock) under low oxygen conditions for use as a soil amendment. This organic input can remain in the soil for very long periods influencing soil physical and chemical properties while sequestering carbon dioxide from the atmosphere (Schmidt et al. 2014). The physical and chemical properties of biochar are affected by the nature of the feedstock and the pyrolysis temperature used in the production process (Lei and Zhang 2013). Biochar application can improve soil microbial activity, soil water retention capacity and saturated hydraulic conductivity (Lei and Zhang 2013). Positive effects on soil nutrient retention and bioavailability can occur due to the high porosity of the biochar particles, which increases the surface area for adsorption of ions (Scholz et al. 2014). Yield responses tend to increase over time after biochar application and are generally greater with biochar application on poorer soils (Andrew et al. 2013).

Beneficial agronomic and environmental effects of biochar as a soil amendment have been demonstrated, however, results are not always positive and there are numerous knowledge gaps (Verheijen et al. 2009).

The turfgrass industry stands to benefit greatly from the use of Biochar due to the frequent heavy demands for irrigation water and fertilizers, which can be costly and may also pose a drain on foreign exchange reserves along with environmental risks. Biochar can be applied to the root zone soil before turf establishment and/or later as a top dressing. Biochar application was found to increase water retention and reduce nitrogen leaching for turfgrass in sand-based systems, but root growth was reduced at high application rates (Brockhoff et al. 2010). Soil phosphorus and potassium levels also increased as the biochar application rate increased from 0 to 25% (v/v), suggesting that essential nutrients can also be supplied by the biochar (Brockhoff et al. 2010).

There appears to be potential benefits for use of biochar as a soil amendment in turfgrass, however, further investigations are required on biochar preparation, optimum application rates and methods and effectiveness in different soil types. Biochar prepared by traditional (low technology) methods appeared to show consistent yield increases when applied to soil (Spokas et al. 2012). In the current work, biochar prepared from local feedstock using traditional (drum) technology was applied to potting mixture for *Zoysia* (*Zoysia japonica* Steud., 'El Toro') turfgrass growing in pots. Objectives of this study were to investigate the effects of biochar preparation (with and without compost tea), application rates and methods, and treatment effectiveness in different soil types.

## **MATERIALS AND METHODS**

Two types of biochar (plain and enriched) were produced for this study by a local company (Diceabed (Barbados) Ltd., Gibbons, Christ Church, Barbados). Plain biochar was produced by the pyrolysis of organic matter in a drum, using local green waste materials. The enriched biochar was produced by submerging plain biochar (prior to grinding) for three days in a container containing compost tea from chicken manure. The density of the plain and enriched biochar was 340 g L<sup>-1</sup> and 406 g L<sup>-1</sup>, respectively.

Three potted-plant experiments using *Zoysia* turfgrass were conducted under field conditions at the Cave Hill Campus of the University of the West Indies, Barbados during the period May 2013 to March 2014:

1. Experiment #1: Biochar types and application rates
2. Experiment #2: Biochar types and application methods
3. Experiment #3: Biochar application methods and soil types

In all studies, *Zoysia* turfgrass was planted using plugs (2.5 x 2.5cm) obtained from nursery grass established in trays. Soil (local black clay) used for the preparation of potting mixtures was obtained in the vicinity of the Cave Hill Campus. Plants received daily irrigation as needed and a fertilizer (3 g L<sup>-1</sup>, NPK 24-8-16, Scotts Miracle-Gro products, Inc., USA) solution was applied every 2-3 weeks. Clipping was done at weekly intervals with plants clipped back to the rim of the pot or to a height of 3.5cm from the rim on each occasion. Data were analyzed using statistical software (GenStat Discovery edition, VSN International Ltd., UK).

**Experiment #1:** This study was done in PVC tubes, 16.2 cm diameter and 45 cm depth, covered at one end with perforated caps to form planting pots. Thirty (30) tubes were filled with a 1:1 sand/soil mixture to a height of 35 cm from the covered base of each tube. The remaining 10 cm at the top of the tubes was filled with the same 1:1 sand/soil mixture containing varying mixtures of biochar as indicated in Table 1.

Mixing of the biochar with the sand/soil medium was done in an open tray and 1 g of Triple Super Phosphate (TSP) was added to the mixture for each pot. A completely randomized design was used in this study with 3 replications. Observations were made over a 9-month period.

**Experiment #2:** Plastic plant pots (4L, 17.9 cm average diameter) were used in this study. There were nine treatments, which consisted of two biochar types (plain and enriched), and four application methods and the control:

1. Control (no biochar application)
2. Incorporated (biochar mixed evenly into soil)
3. Plugs (biochar applied in two cylindrical plugs within potting mixture)
4. Spread (biochar spread on surface and covered by thin layer of soil)
5. Watered (biochar mixed with water and applied to surface of soil)

Table 1. Biochar treatments in Experiment #1

Treatment #	Type of Biochar	Biochar Application Rate v/v %
1	Control	0
2	Plain	4
3	Plain	8
4	Plain	12
5	Plain	16
6	Plain	20
7	Enriched*	4
8	Enriched	8
9	Enriched	12
10	Enriched	16

\* Enriched with compost tea from chicken manure

The application rate for biochar was standardized at 4% (v/v) for both biochar types in this study (experiment #2). For the ‘Plugs’ application method, biochar was added to two cylindrical holes created in the soil mixture with a syringe (13 cm long, 2.9 cm diameter) on opposite edges of the pot, 2 cm from the rim. Phosphate fertilizer (Triple Super Phosphate, TSP, 3 g per pot) was mixed into each soil mixture including the control. Pots were arranged in five randomized blocks. Observations were made over a 5-month period.



**Experiment #3:** This study was conducted in 4L plastic pots as for Experiment #2. Three biochar application methods (control, incorporated and watered) and three sand/soil mixtures (33, 50, and 67 % sand) were combined in a factorial design (nine treatments). Only the enriched biochar was used in this study, and this was applied at a rate of 4% (v/v). Phosphate fertilizer (Triple Super Phosphate, TSP, 3 g per pot) was mixed into each soil mixture as for Experiment #2. Pots were arranged in a randomized block design with four replications. Observations were made over a 2-month period.

## **Observations**

The following turfgrass growth and soil parameters were determined:

1. Green cover (%)
2. Chlorophyll index (dimensionless)
3. Grass height (mm)
4. Dry mass of clippings (g week<sup>-1</sup>)
5. Soil water content (% v/v), Soil temperature (°C), Soil electrical conductivity

## **Green Cover**

A digital Camera was used to capture images of the surface of each pot during the period 10:00am to 12:00 noon. Images were taken at a distance of 60cm from the pot at an angle of 70-80 degrees to the horizontal ensuring that the surface of the pot accounted for most of the area in the image. The photographs were all taken from the same side for each block, facing the direction of the sun to avoid any shadow of the camera on the grass. The images were processed using image analysis software (Assess 2.0, APS, USA) to determine the percentage green cover (%) of the area within each pot. Weeds and rocks were removed prior to taking images to reduce error. Observations were made at weekly intervals at one week after clipping.

## **Chlorophyll Index**

A chlorophyll meter (FieldScout CM1000, Spectrum Technologies Inc., USA) was used to monitor the chlorophyll index of the grass in each pot over time. The meter was aimed at the turf surface from 0.5 m above at an angle of 70-80 degrees from horizontal. Ten measurements were taken at random locations in each pot, being careful to avoid the bare soil surface and the rim of the pot. The chlorophyll meter automatically generated the average of these 10 readings and this measurement was recorded. It was ensured that the ambient light was equal to or more than the minimum recommended by the instrument manufacturer when the readings were taken. Observations were made at weekly intervals between 10:00 am and 12:00 noon at one week after clipping.

## **Turfgrass Height**

The height of the grass above the rim of the pot was measured using a modification of the rising disc technique (New Zealand Sports Turf Institute). The instrument consisted of a cylindrical rod (26 cm long, with mm measurement markings) placed through the center aperture of a compact disc (13.55g, 12 cm outer diameter, 1.5cm hole diameter). The cylindrical rod was threaded

vertically into the center of the turf to the level of the rim of the pot. The compact disc was then dropped from a height of 10 cm on to the turf guided by the cylindrical rod. Turf height was measured from the point where the disc rested on leaf blades to the rim of the pot. Observations were made at one week after clipping with one measurement made in each pot.

### Dry Mass of Clippings

Turf clippings were collected in brown paper bags and the dry mass was determined following drying in an oven at 80°C for four days. Samples were allowed to cool within sealed plastic bags for several hours before dry mass was measured.

### Soil Moisture, Soil Temperature and Soil Electrical Conductivity

Soil moisture, soil temperature and soil electrical conductivity were measured in the top 5cm of soil mixture using a multi-sensor probe (model 5TE, Decagon Devices Inc., USA). The three-prong probe was pushed into the soil at two locations in each pot and measurements were done 10:00 – 11:00 am and 5:00 – 6:00 pm.

## RESULTS AND DISCUSSION

In experiment #1, there were strong effects of biochar type on turfgrass growth, chlorophyll index and soil moisture content within the first three months after planting (Table 2). Ground cover, chlorophyll index, turf height and soil moisture content were all higher in the enriched biochar compared to the plain biochar treatments. There were no significant effects of the biochar rate or of factor interactions (biochar type/rate/time) during this initial period. The enriched biochar infused with compost tea from chicken manure was likely to contain higher levels of nutrients and/or biostimulants compared to the plain biochar. The use of biochar produced from the pyrolysis of chicken manure has been shown to increase both soil macro and micronutrients (Hass et al. 2012).

Table 2. Results of repeated-measures ANOVA (p values) for parameters determined within three months after planting of turfgrass in soil mixtures with varying application rates of two types of biochar.

Parameter	Source of variation		
	Biochar Type	Biochar Rate	Biochar Type.Rate
Ground Cover (%)	0.026	0.386	0.064
Chlorophyll Index	<0.001	0.492	0.205
Turf Height (mm)	<0.001	0.073	0.259
Soil Moisture (%)	0.018	0.164	0.128

After 8 months (236 and 255 days after planting) in experiment #1, turf height at one week after clipping was consistently increased by Biochar rates of 4% and higher (Figure 1). Earlier measurements indicated no consistently significant effects of biochar application rate on turf

height in conformity with results obtained during the first three months of growth (Table 2). These results suggest that a period of incubation in the soil is required after application of biochar before beneficial responses are observed. Biochar produced at relatively low temperatures (as used in this study) are likely to contain higher levels of plant oils that promote hydrophobicity in the short run but may serve to increase microbial activity and fertility over time (Verheijen et al. 2009). The observed effects of applied enriched biochar during the first three months may have been due primarily to the effects of compost tea from chicken manure on the soil medium. Significant effects of the enriched biochar were also observed at 7-8 months after planting in this study.

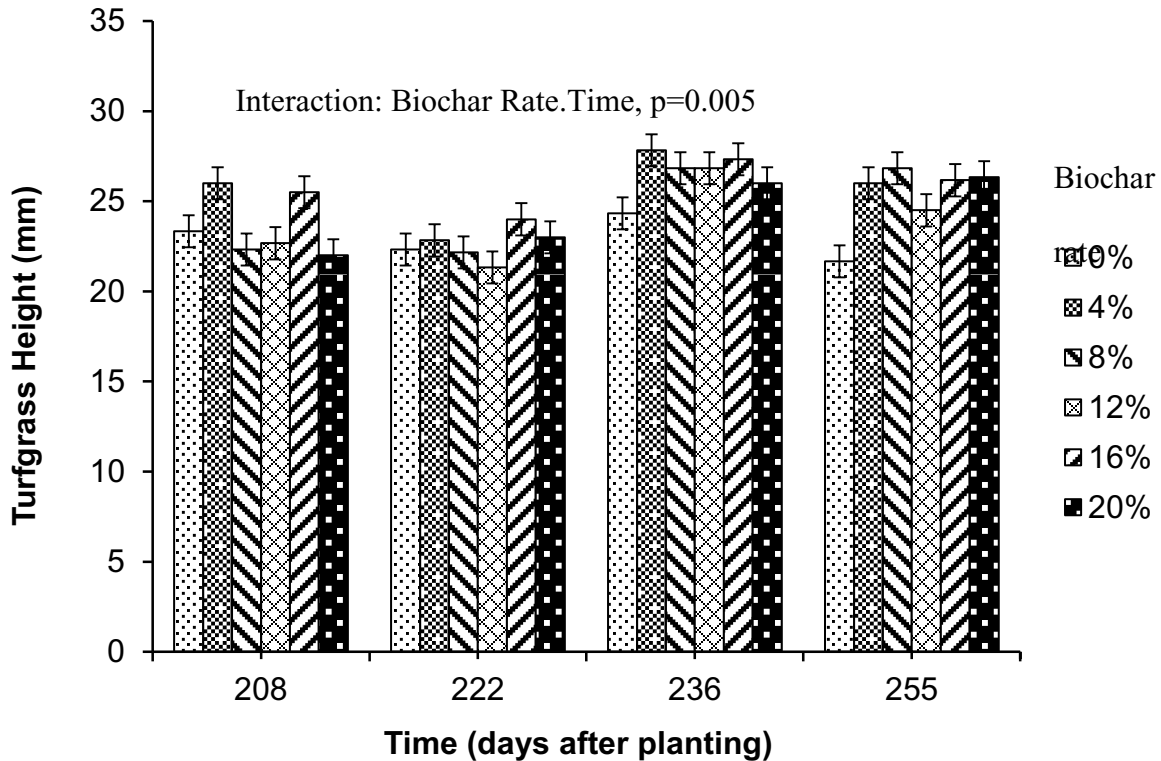


Figure 1. Effects of biochar application rate on turfgrass height (mean  $\pm$ SE, at 1 week after clipping) for observations at various times after biochar application and planting.

Dry mass of clippings obtained per week was affected by both the type and rate of biochar applied for observations at 7-8 months after biochar application (Figure 2). Dry mass of clippings was consistently higher with use of the enriched biochar compared to the plain biochar. A significant quadratic trend was observed as biochar application rate increased and the highest dry mass of clippings was obtained at a biochar application rate of 12% (v/v of soil) for both types of biochar (Figure 2). If this optimal rate is scaled up, the biochar required per unit land area works out to be about 40 t ha<sup>-1</sup> and 48 t ha<sup>-1</sup> for the plain and enriched biochar, respectively, assuming that biochar is incorporated to a depth of 10 cm. This high rate is not likely to be practical and a lower application rate (4% v/v) was selected for follow-up studies investigating the efficacy of different application methods.

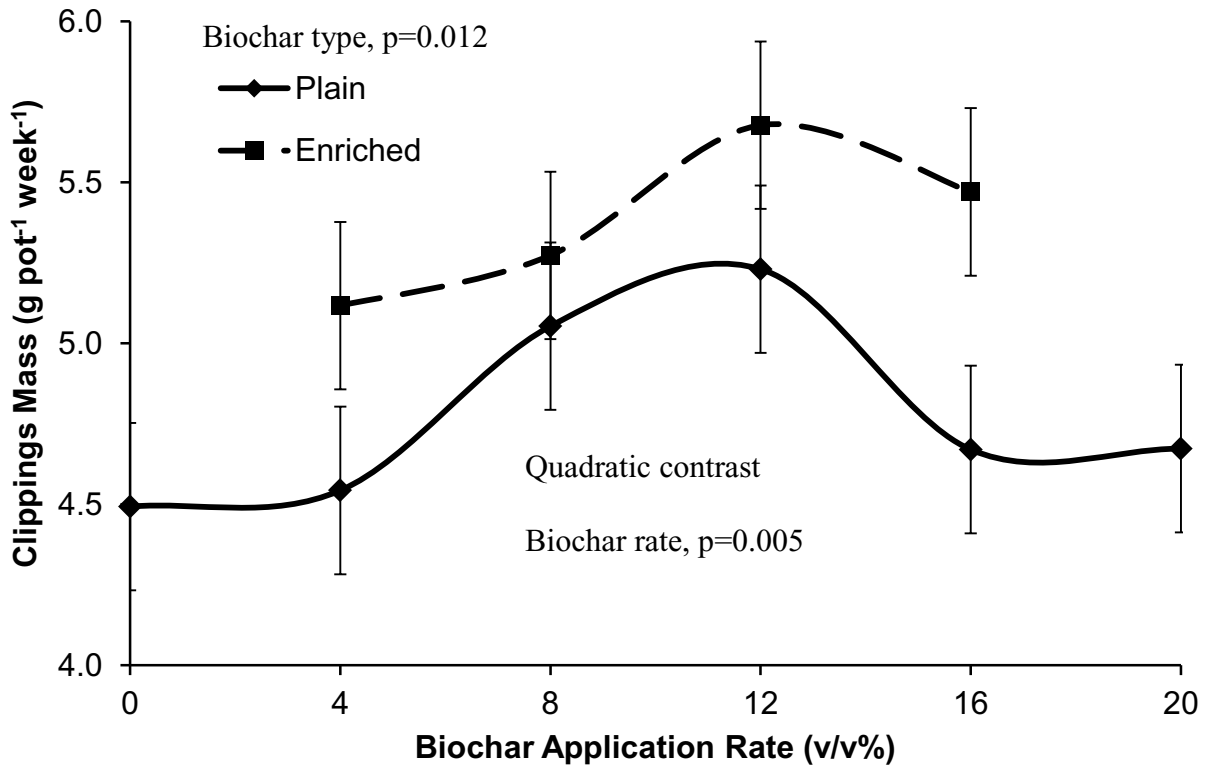


Figure 2. Effects of biochar type and application rate on dry mass of clippings (per week, means  $\pm$ SE) observed 7-8 months after biochar application at planting.

The effects of biochar application in experiment #2 were marginal. There were significant effects of the biochar application methods on chlorophyll index measured during the first 3 months of turfgrass growth (Figure 3). The application of biochar by mixing into the soil (incorporated) appeared to be more effective than dry (spread) or wet (watered) applications to the surface. However, chlorophyll index for each of the 4 application methods tested was not significantly different from that of the control (Figure 3). Similar responses were also observed for dry mass of clippings and turfgrass height (data not shown). No significant effects of biochar type (plain vs. enriched) were observed in experiment #2. Perhaps beneficial biostimulant agents that may have been originally in the enriched biochar (freshly prepared) did not survive the months of dry storage.

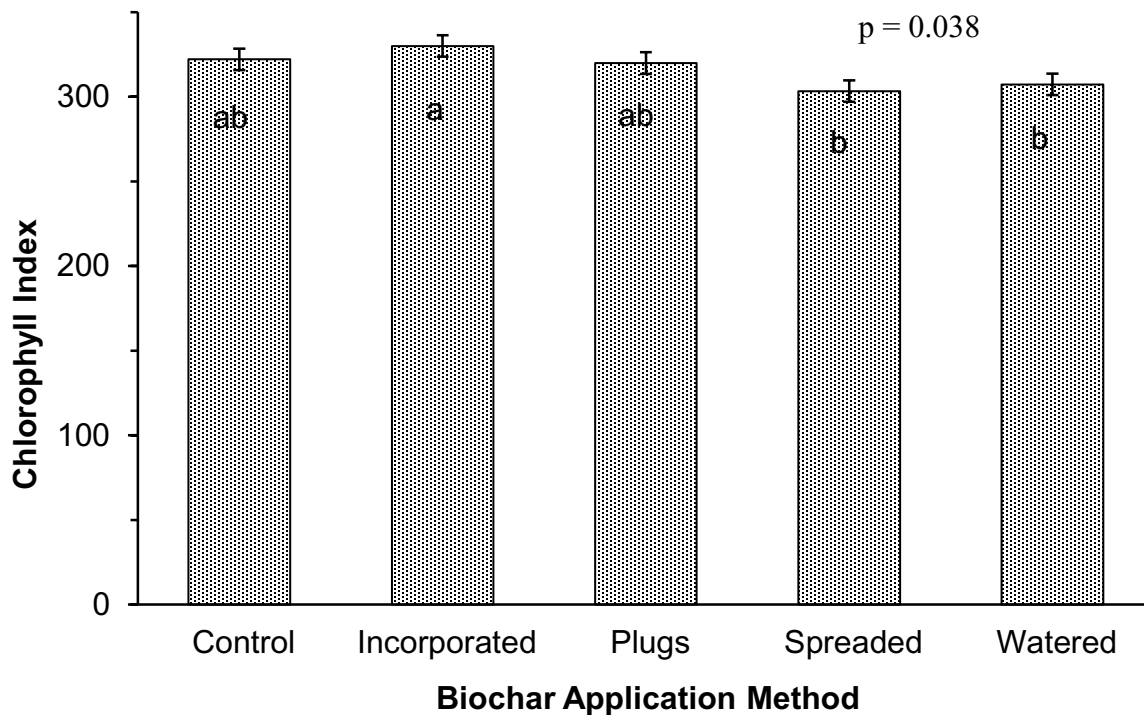


Figure 3. Effects of biochar application method on chlorophyll index of turfgrass measured over a 3-month period (data were pooled across time).

In experiment #3, turfgrass growth during the 3-month period after planting was reduced as the sand content was increased in the sand/soil mixture, however, there were no significant effects of biochar application (data not shown). Additional studies are needed to determine whether turfgrass establishment can be improved by biochar if planting is delayed for a few months after the biochar is applied to the soil.

## CONCLUSIONS

Beneficial effects of biochar on turfgrass growth were observed after an incubation (aging) period of 7-8 months in the soil. The optimum biochar application rate was 12% (v/v of soil). Earlier responses to applied biochar are likely to be obtained with the application of freshly-prepared biochar enriched by treatment with compost tea. Soil incorporation of biochar appeared to be marginally better than surface application (dry or wet) methods. For established turfgrass, biochar application to fill cylindrical holes (plugs) created by soil aeration tines may be preferred compared to surface application.

## ACKNOWLEDGEMENTS

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## EVALUATION OF THREE COVER CROPS TERMINATED WITH A ROLLER-CRIMPER ON COVER CROP RE-GROWTH AND WEED DEVELOPMENT UNDER TROPICAL CONDITIONS

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**Abstract:** Tropical farmers in low-external-input conditions rely upon non-intensive on-farm inputs such as cover crops (CC) to provide ecological and economical means for the management of soil quality, soil fertility, and pest management. Roller-crimper technologies for the termination of CC to produce residue based surface mulch were developed in temperate climates where seasonal changes impede CC re-growth. Information on the response of CC to termination with a roller-crimper and resulting weed suppression is limited or non-existent for tropical environments. The objective of this project is to; 1) evaluate three CC under tropical environmental conditions produced with zero external inputs, 2) to determine CC re-growth levels post termination with a roller crimper, and 3) to evaluate CC surface residue on weed development. Sunn hemp (SH; *Crotalaria juncea* (L.) cv IAC-1), lablab (LL; *Lablab purpureus* (L.) cv Rongai), and sorghum sudan (SS; *Sorghum bicolor* x *S. sudanense* L. cv Mega Green) were planted November 1, 2011 (Year 1) and again on October 4, 2012 (Year 2) by broadcast seeding. Cover crops were terminated with a roller-crimper 112 days after planting (DAP) in year 1 and 55 DAP in year 2. CC and weed biomass data was determined before termination and CC regrowth and weed biomass was determined post-termination. Sunn Hemp produced the highest level of CC biomass at 8,091 dry matter (DM) kg/ha which was greater than either the SS or LL at 5,182 or 4,382 DM kg/ha, respectively, in year 1 ( $p < 0.0001$ ). Year 2 resulted in lower CC biomass than in year 1 for both SH and SS at 3,589 and 4,424 DM kg/ha, respectively, ( $p < 0.0001$ ), with no difference in biomass between SH and SS within year 2. Lab lab failed to establish in year 2 from extensive army worm herbivory. Cover crop vegetative biomass yields in year 1 resulted in the contribution of 177 kg/ha nitrogen (N) from SH which was more than SS at 112 kg/ha N or LL at 89 kg/ha N ( $p < 0.05$ ). Due to similar CC biomass yields and plant tissue N content in year 2, there was no difference in N contribution to the farm system between SS and SH. In both years, weed biomass at CC termination was greatest for LL and similarly low for both SH and SS ( $p < 0.05$ ). Sunn hemp responded favorably to termination with a roller-crimper and SH had the lowest level of regrowth. This was supported by the high amount of both SS and LL re-growth harvested in year 1 and again in year 2 for SS ( $p \leq 0.0002$ ). However, SH regrowth was greater in year 2 compared to year 1 which could be attributed to differences in SH maturity and lower plant stem lignification. Both SH and SS were effective in suppressing graminaceous, broad leaf, and sedge weed classes following termination where LL was not. Sunn hemp performed well as a tropical cover crop producing high biomass levels and inhibiting weed development. Sorghum sudan performed well as a cover crop with excellent weed suppression, but was not effectively terminated with a roller crimper exhibiting a high regrowth potential. In comparison, SH did respond favorably to termination with a roller-crimper by exhibiting a high kill rate that produced surface mulch that inhibited weed development.

**Economics/Trade Policy/Food Security**

**POST EUROPEAN UNION/CARIFORUM EPA: EMERGING TRENDS IN TRADE BETWEEN THE EUROPEAN UNION AND CARIFORUM**

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**Abstract:** In 2008, the Economic Partnership Agreement (EPA) was signed by the European Union (EU) and the African, Caribbean, and Pacific (ACP) member states. This agreement was necessary to ensure the trading arrangements between the EU and the ACP adhered to the World Trade Organization's (WTO) regulations. The WTO's Economic Partnership Agreement (EPA) required the removal of the preferential treatment offered to the ACP. The Windward Islands (Dominica, Grenada, St. Lucia, and St. Vincent), a part of CARICOM, are very dependent on the EU market for their banana revenue with preferential treatment. Since the agreement, the CARIFORUM banana suppliers have experienced major shifts in their economic fortunes. This paper seeks to investigate the current status of agricultural imports into the EU to assess whether trade was created or diverted away from certain members of ACP under the WTO agreement. Various trade models were utilized to determine the impact of the WTO's EPA agreement on CARIFORUM. The findings of this study will provide policy makers with evidence of the impact of the trade agreements and can be used as a model in future planning.

**Keywords:** EU-ACP, Trade creation /Trade diversion, Gravity Model, RCA



**FOOD SECURITY IN THE FRENCH CARIBBEAN ISLANDS AND PUBLIC ACTION:  
WHAT IS AT STAKE?**

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**Abstract:** As part of France and Europe, the French Caribbean Islands belong to developed countries. Nevertheless, the recognition of their specificities makes them considered as Small Islands Developing States (Angeon 2011; Levratto, 2007). As SIDS, they are vulnerable, a fact which is partly attributable to the structural features of the agricultural sector (Atkins et al., 2000; United Nations, 2008; Guillaumont, 2010). In this article, we discuss the role of agriculture in the vulnerability of the French West Indies. We assume that agriculture can be a factor of resilience if it becomes twice efficient (i.e. productive and conservative). To achieve such an objective, two main conditions are required. First, agriculture has to respect or better exploit natural processes. Second, it has to insure food security for local populations. In other words, the agricultural sector has to manage important transformations qualified as “ecologization” of practices and public policies (Papy, 2013; Barbier & Goulet, 2013; Mzoughi & Napoléone, 2013; Mormont, 2013; Ollivier & Bellon, 2013). This calls for redesigning the actual socio-technical system (Marques et al., 2012). In this article, we show that a resilient agriculture must be based on agroecological principles which require management and governance renewals (1). We then critically analyze adaptive governance presented in the literature as a good process to accompany innovation and changes (2). By exploring the properties of the dominant socio-technical system existing in the French Caribbean islands (banana food chain), we discuss whether the transformation of agriculture in these territories is likely to occur (3).

**Keywords:** SIDS, Agriculture, Vulnerability, Food security, Agroecology, Ecologization, Public policy

**AN ECONOMIC ASSESSMENT OF THE IMPACT OF *Raoiella indica* ON THE NARIVA SWAMP, TRINIDAD AND TOBAGO**

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**Abstract:** The Red Palm Mite (*Raoiella indica*) is a great threat to terrestrial biodiversity, with particular interest in palm populations. In Trinidad and Tobago, the Coconut palm (*Cocos nucifera*) has been the most affected. The local Nariva Swamp, a designated Ramsar site, hosts large populations of various palm species. The impact of the Red Palm Mite on this ecosystem can be both direct and indirect. Its direct impacts include declining yields of coconuts and increased market prices. Indirect impacts of this invasion include the loss of non-market ecosystem goods and services such as the change to aesthetic values and demand for recreational services. The study was aimed at calculating the indirect costs of invasion, creating an awareness campaign and stating a case for the use of web-based surveys in local contingent studies. Contingent Valuation was used to estimate the non-market impacts. Data was collected for this study using both web-based surveys and interviewer administered questionnaires at the study site. The data was analyzed using mainly Logistic Regression, yielding a mean willingness to pay for the mite's removal of \$237.34. Respondents' view of the swamp and attitudes to environmental degradation significantly affected willingness to pay for conservation. No significant differences were found between survey modes.

**Keywords:** Red Palm Mite, Nariva Swamp, Contingent Valuation, Logistic Regression, Web-Based Surveys, Awareness Campaign, Trinidad and Tobago, Caribbean.

## TECHNOLOGY TRANSFER IN SMALLHOLDER RICE FARMS IN GUYANA: THE SUCCESS STORY OF THE SIX IMPROVED PRACTICES

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**Abstract:** Guyana's Agriculture Sector contributes 20% to the Gross Domestic product and is the source of livelihood for nearly 38 % of the population. This sector continues to grow being the main vehicle for poverty alleviation and overall economic development of the Country, while successfully keeping pace with the rising food demand of the country and the region as a whole. Rice (*Oryza sativa* L.) has been the pillar of the agriculture sector in Guyana. The production of this staple food has seen an increasing trend over the past decade, recording the highest production in history of 535,000 tons in 2013. Today more than ever, increased food production depends on judicious use of resources, if the environment is to be preserved. Additionally, issues such as climate change, climate variability, and its long-term impact on food security and environmental sustainability, have become increasingly important. Many factors such as weather, soil, genetics and management considerations affect the way the rice crop will responds to irrigation, fertilizer and other management practices. Determining appropriate crop management strategies under these uncertainties has major economic and environmental implications. The six improved practices promoted by the Guyana Rice Development Board have proven to be a successful management strategy in improving farmer's productivity. In this study we examine the use of the six improved practice as a tool of scientific agriculture production in selected rice growing regions. The study found that farmers who adopted the six improved practices recorded more than 25 % increase in yields when compared to their conventional practices, resulting in these farmers earning higher profits. The Guyana Rice Development Board will continue to promote the adoption of this technology for the continued enhancement of the social and economic development of the farm families of Guyana's rice industry.

**Keywords:** Climate Change, Adaptation, Guyana, Six Points Practice

### INTRODUCTION

Rice is the staple food in Guyana. The rice industry is currently the largest agricultural industry in the country. It is the bedrock of the Guyanese rural economy and over the last two years it became the main contributor to export earnings in the agriculture sector. Rice accounted for about 7% of GDP and 14 % of total exports in 2013 (MOA, 2013, p. 28). It is the greatest user of arable land with approximately 8,000 families directly and 150,000 indirectly associated with the industry. Two rice crops are cultivated annually.

The rice industry in Guyana experienced mixed fortunes over the years. Rice production averaged around 150,000 metric tons in the 1980s but by 1990 this figure declined to a mere 93,400 tons. It rebounded to 168,300 metric tons in 1992. In one of the better periods (1990's)

the annual growth of production averaged 13%, with the increase in area cultivated accounting for 75% of the gain in production. This period was short-lived as production contracted by 18% in the early 2000's, due mainly to stagnation of yields which averaged approximately 4 tons/ ha. This coupled with increasing costs made the business of growing marginally profitable with the resultant effect being farmers abandoning their lands or converting same to other uses. The strategy for improving rice production required a coherent and coordinated technology transfer effort to empower farmers on the various strategic management practices that, when applied in an integrated manner, will result in significant yield increases.

The Guyana Rice Development Board (GRDB) provides extension services for the rice farming sector. In 2007, the GRDB implemented a set of six improved management technologies (renamed “six points” in Guyana), practiced in other Latin American countries in Guyana. This study aims to analyze data collected from six points’ demonstrations across the country from 2007 to 2013 and determine its impact on small holder rice farms.

## METHODOLOGY OF IMPLEMENTATION

The Farmers’ Field School (FFS) approach was identified as a strategy to enhance farmers knowledge through demonstrations in farmers’ fields. This approach was result oriented, which served to compare and measure the indigenous practices carried out by the farmers against practices that targeted solving field problems. The main objective of FFS has been ‘learning by doing’, which placed much emphasis on informal meeting and group participation. The ‘six points’ became a part of the FFS programme in the spring crop of 2007 and continues to be the main technology for advancing farmers’ yields. Approximately twenty two (22) demonstrations were conducted in the first year (2007) which rose to ninety two (92) in 2013 (Table 1). In all, a total of 430 ‘six points’ demonstrations were conducted during the period 2007 to 2013.

Regions	Number of Demonstrations							
	2007	2008	2009	2010	2011	2012	2013	
2	5	19	22	7	12	11	9	
3	8	19	22	9	16	13	23	
4	2	3	2	3	7	9	11	
5	3	8	6	8	17	19	30	
6	4	13	15	17	22	17	19	
<b>Total</b>	<b>22</b>	<b>62</b>	<b>67</b>	<b>44</b>	<b>74</b>	<b>69</b>	<b>92</b>	<b>430</b>

Table 1. Demonstrations held in regions from 2007 to 2013

## Six point's technology

The six points are: time of sowing, seed rate, seed treatment, weed control, balanced nutrition and water management. This is further illustrated below:

### 1. Time of Sowing

Solar radiation has a significant impact on the yield of rice. Shading during the reproductive phase affects the number of spikelets per panicle. During ripening shading reduces grain yield due to a spurt in spikelets (Yashida, 1981). Adjusting the date of sowing so that the crop can receive the maximum solar radiation from the start of primordial stage to heading stage or flower emergence allows the varieties to fully express their yield potential.

### 2. Seed rate

The rice plant depends on solar radiation, moisture and soil fertility for growth and nutritional requirements. A thick population may have limitation in the maximum availability of these factors. High densities of plants produce weak plants, susceptible to lodging and attack of diseases, especially *piricularia* and *rhizoctonia*. It is therefore necessary to ensure that there is the optimum density of plant population per unit to produce healthy, strong plants and ultimately higher yields.

### 3. Treatment of seeds

Farmers apply pyrethroids base products for the control of early season pests, especially water weevil. The pyrethroids kill only the adult weevils, not the eggs or larvae and therefore require repeated applications. A healthier and more economic form to attack this problem is to treat the seeds with insecticides. Treated seeds provide control of the first larvae generation and inhibit population growth. In this way only the insects that affect the plant is controlled and those that are beneficiary are protected, returning the ambient balance in the crop.

### 4. Weed Control

Weeds compete with the crop for light, nutrients, and space. Ploughing, puddling and leveling although these operations reduce the incidence of weeds, they should be combined with other forms of control. The control of weeds is most effective when it is done at an early stage (1 – 3 leaves). The mixture of herbicides pre and post emergent applied at early post emergence permits a good control. The management of water allows better residual control preventing re-infestations and reducing costs.

### 5. Balanced Nutrition

The crop should depend on the adequate nutrients that allow it to take advantage of the ambient conditions and to express the genetic potential of the varieties. All fertilizer recommendations should be based on soil analysis. Phosphorus and potassium based fertilizers should be incorporated before planting or immediately after early draining or about (4-6 DAS) to give maximum results. In terms of nitrogen, precautions need to be taken to prevent great loss by the inadequate management of urea. The application of N is optimum if it is done in the field on dry soil and applied in the indicated phases of the crop, before permanent flooding. After the application on dry soil the farmers should

irrigate and establish a thin layer of constant water, preferably within five days of Nitrogen application. The flood incorporates the nitrogen fertilizer into the soil.

#### 6. Water Management

Water management is very critical in maximizing rice yields. It is necessary for weed control, preventing nitrogen loss and maximizing grain-filling. To achieve these results it is necessary to establish the layer of water as soon as possible. In leveled fields, water established for sowing should remain in the field until removal to allow for weed control and application of fertilizer. Re-flooding after fertilization of 22 DAS will prevent loss of nitrogen due to volatilization.

## RESULTS

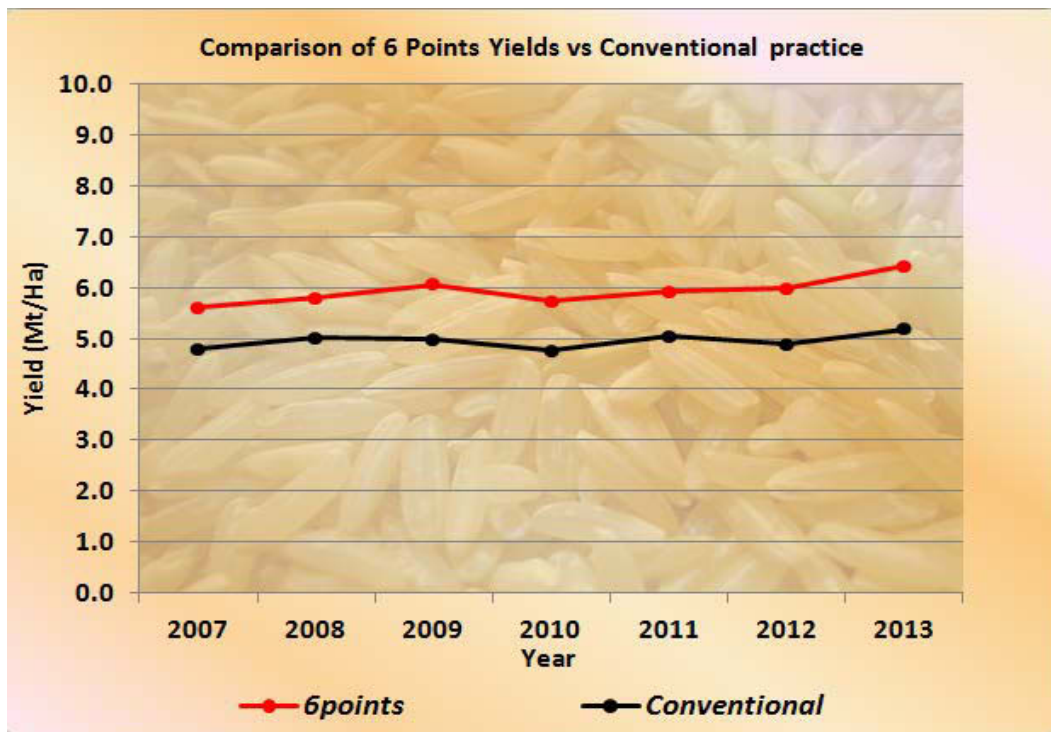


Fig.1 Comparison of Six points and Conventional Practice yield

It is seen in Fig.1, yields of the 'six points' and conventional practices increased over the period, however the yields of the 'six points' practices was consistently higher than the conventional practice. Farmer using the 'six points' technology obtained over 1.2 tons/hectare more than conventional farmers, Figure (2)

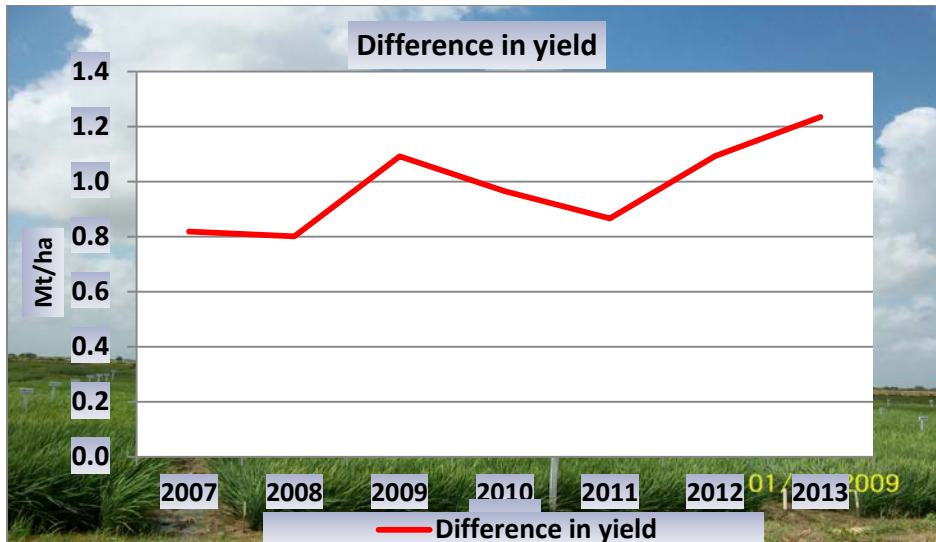


Fig.2 Difference in yield between Six Points and Conventional practice

The increased yield obtained by the farmers practicing the ‘six points’ resulted in increased income allowing their profit to be approximately 53% greater than those farmers who didn’t practice the six points’ (Fig.3).

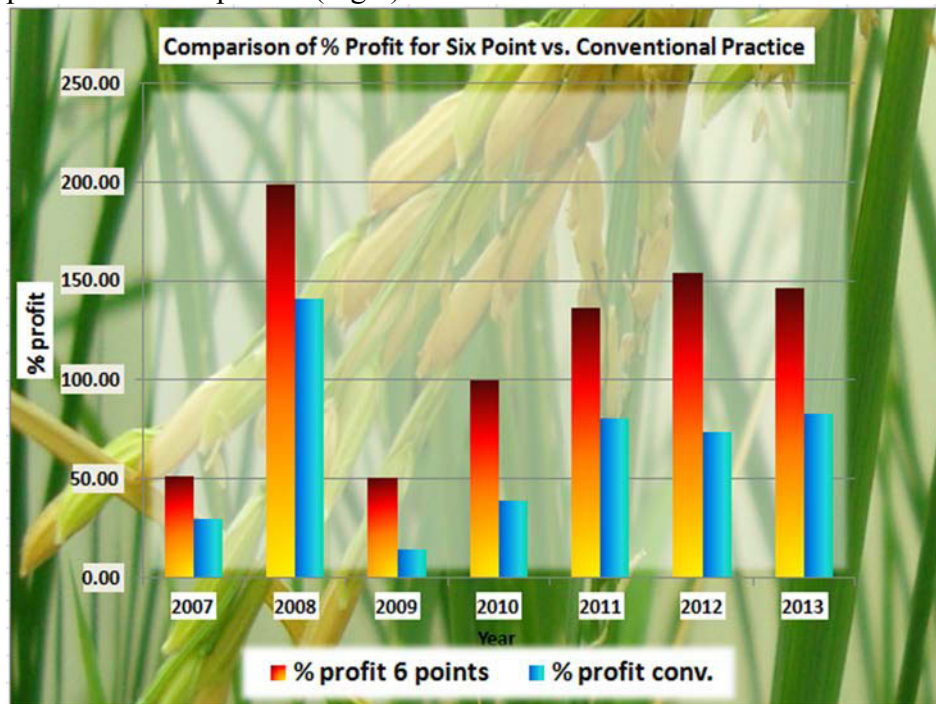


Fig.3 Comparison of Percentage Profit received with 6 points and Conventional Practice

## DISCUSSION

The ‘six points’ programme proved successful in increasing farmers’ yield and by extension their livelihoods through increased percentage profit. The considerable benefits that are gained from

'six points' encouraged the GRDB's Extension department to target a 90% adoption of the technology. However, for this goal to be achieved several challenges must be addressed.

Water is very critical for the success of the programme. Farmers are often prevented from releasing water from their fields to apply Nitrogen fertilizer since they are dissuaded by the uncertainty of the availability of water to reflood. This can be due to low water level in the reservoirs, blocked irrigation canals or lack of reservoirs in some areas. All agencies that are responsible for providing water to farmers inclusive of the Water Users Association (WUAs), National Drainage and Irrigation Authority (NDIA), Regional Democratic Councils (RDCs), should make a concerted effort to make water available on time. Greater collaboration among these agencies will definitely allow water to be provided on a timelier basis to farmers.

Sometimes factors that are extraneous to the Board's mandate can prevent farmers from applying the knowledge gained on the 'six points' technology in their fields. Low prices for paddy compounded by delayed payment by millers can result in these farmers not applying the required inputs and also on time if they do acquire it. Regulations are in place to ensure millers pay farmers on a timely basis however experience has proven that this is not enough and other methods must be looked at.

Generally fields are not entirely level for rice cultivation thus making the management of water very challenging. This can result in loss of nutrients; rapid growth of weeds and additional costs to flood fields since the low areas accumulates more water. Leveling fields requires sophisticated equipment, which is beyond the reach of the farmer. It is therefore recommended that the government embark on a program to assist farmers to level their field by providing the service of a fleet of machines.

It is expected adoption by all farmers should be achieved by the year 2017. This will require a collaborative and determined effort by all players to allow this to take place. The development of higher yielding varieties by the Rice Research Station, complimenting the 'six points' practice will ensure farmers achieve higher yields. The 'six points' technology could be further refined through more research making it a stronger technology for even greater yields in the future.

## **CONCLUSION**

The 'six points' technology package of practices without any doubt contributed to increased yield and profitability of the farmers further improving their standard of living. While the adoption of technologies are impacted by factors such as characteristics of the technology, the information accompanying it, the appropriateness of the technology and support in terms of research and policy, the role of extension cannot be overemphasized. Many gains have been made with the 'six points' technology; this needs to be built upon to make Guyanese rice farmers world class producers.

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Postharvest Technology/Biological Pest Control

INFLUENCE OF STORAGE ON SWEETPOTATO SUGAR CONTENT

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**Abstract:** Sweetpotato (*Ipomoea batatas*), is a tuberous root crop native to South America and cultivated by the ancient Incas in Peru. Sweetpotato is one of the ground provisions grown in the Caribbean. Consumers want their sweet potatoes to be sweet. Sweetpotatoes require a postharvest curing to set the skin prior to storage. The objective of this study was to determine the influence of time and temperature on the postharvest sugar content of ten sweetpotato varieties. Soluble sugar content was determined at harvest using a garlic press and refractometer. The tuberous roots were cured at room temperature for five days then placed at 40°F, 60°F and room temperature (~80°F). Nine varieties had a soluble sugar content of 4-6% Brix while 'VIP' was at 8.5% brix at harvest. The soluble sugar content more than doubled after two weeks of storage. There was only a small change in sugar content between the second and fourth weeks. While all three temperatures resulted in increased sugar content the room temperature and 60°F resulted in higher soluble sugars than 40°F. Postharvest storage of sweetpotato results in a significant increase in sugar content within two weeks. This research was supported by USDA-NIFA-Regional Hatch.

**Keywords:** *Ipomoea batatas*, Curing, Storage Temperature, Soluble Sugars

INTRODUCTION

Sweetpotato is a very important crop in the United States and the Caribbean. Where sweetpotatoes are produced in the USA, freshly harvested roots are referred to as "green" and are usually not as sweet as cured sweetpotatoes. Most roots are cured immediately after harvest to improve flavor and storage life. Curing is holding sweetpotatoes at warm temperatures for a week to heal cuts and reduce decay and shrinkage in storage. Curing also converts some starches to sugars and enhances flavor. The University of Virgin Islands at the Agricultural Experiment Station has selected nine sweetpotato varieties with weevil resistance. These varieties have early production with harvest between 90 – 120 days. However, the sugar content is low at harvest. The objective was to study the effect of curing and postharvest storage temperature on the soluble sugar content in sweetpotato over time.

MATERIALS AND METHODS

Nine sweetpotato varieties obtained from the USDA germplasm repository, Louisiana State University and local sources were grown and harvested under normal conditions. The nine sweetpotato varieties were 'Beauregard-14' (B-14), 'Liberty', 'Virgin Island Purple' (VIP), 'Francia', 'Toquecita', 'Murasaki', 'Mojave', 'Saint Kitts' (StK) and 'Pujol' were stored for 5 – 7

days at ambient temperature followed by storage at 40, 60 and 80°F for 28 days. Sugar content data were taken weekly from the center of three sweet potatoes weekly. The 2 cm<sup>3</sup> tissue section was placed in a garlic press and squeezed to extract a few drops of juice. The squeezed juice was collected on the surface of a refractometer to determine the soluble sugar content (%Brix). Data was collected weekly from harvest to 35 days.

## RESULTS AND DISCUSSION

Eight sweetpotato varieties had a low sugar content at harvest that range between 4.5 to 7% Brix (Fig. 1 - 3) except for ‘VIP’ which started at 11% Brix (Fig. 4). ‘VIP’ is a new sweetpotato with both purple skin and flesh indicating that it is high in bioflavonoids and antioxidants. ‘B-14’ is a variety with tan skin and orange flesh most often grown in the USA. ‘Liberty’ is a new red skin cream flesh variety developed for drought tolerance and weevil resistance. ‘St Kitts’ source is indicated in its name has irregular tuberous roots that with pink skin and light orange flesh.

## CONCLUSIONS

Sweetpotatoes require a postharvest curing to allow the skin to set but also to allow the after-ripening of the development of higher sugar content. All postharvest storage regimes resulted in an increase in soluble sugar content over time. Therefore, one doesn’t need refrigeration to obtain a sweeter sweetpotato following harvest. However, storing sweetpotatoes at 60°F resulted in the greatest increase in soluble sugar content over time for all varieties examined. Sweetpotato, being a tropical plant, may be susceptible to chilling injury at temperatures near 40°F. The storage temperature at 60° F is an excellent post-harvest technique that farmers and backyard gardeners of the US Virgin Islands can produce early weevil-free sweetpotatoes and get the sugar content required for commercial sales that consumers expect.

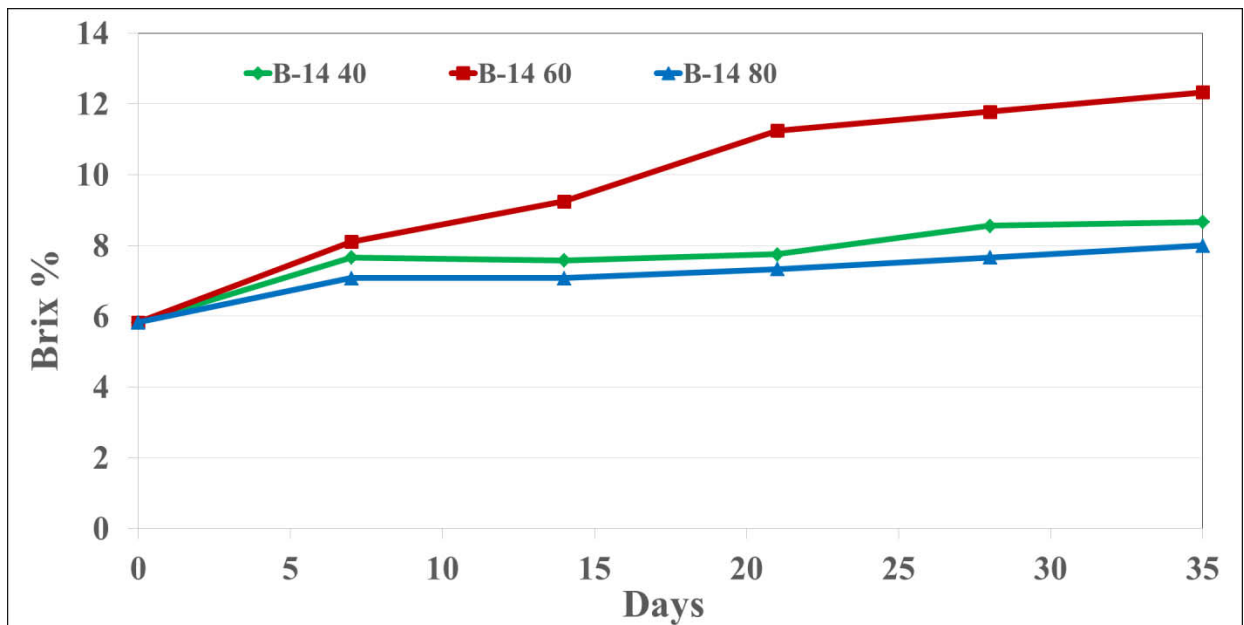


Fig. 1. Postharvest changes in ‘Beauregard-14’ sugar content over time.

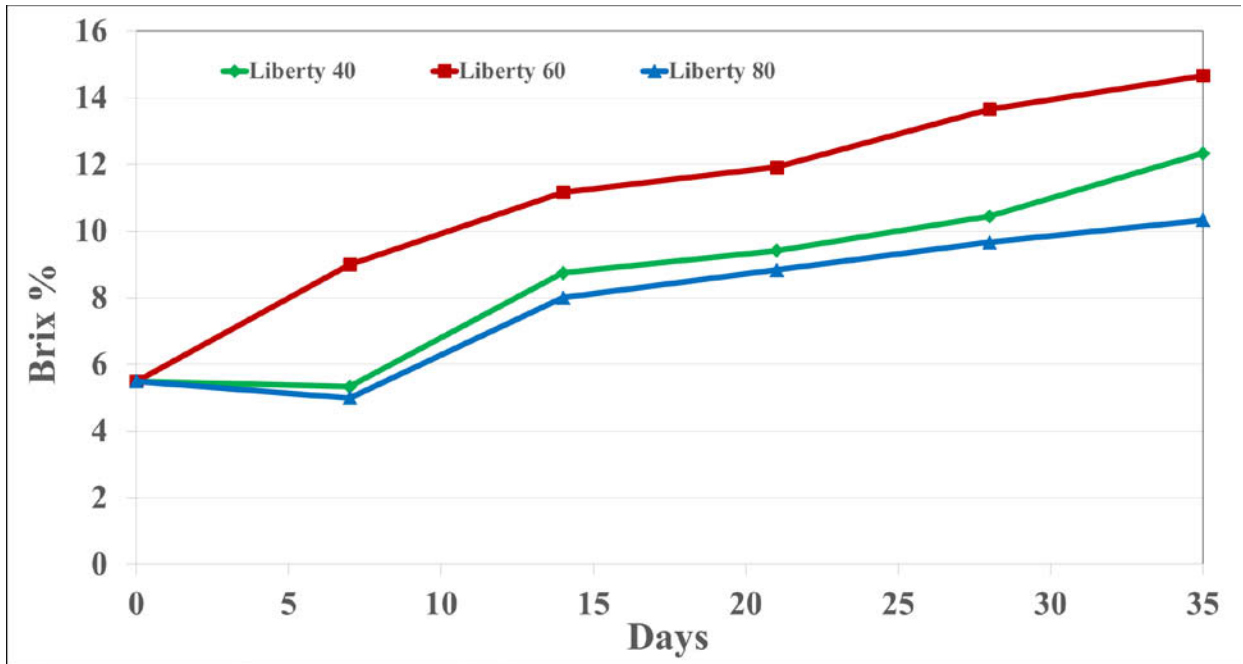


Fig. 2. Postharvest changes in 'Liberty' sugar content over time.

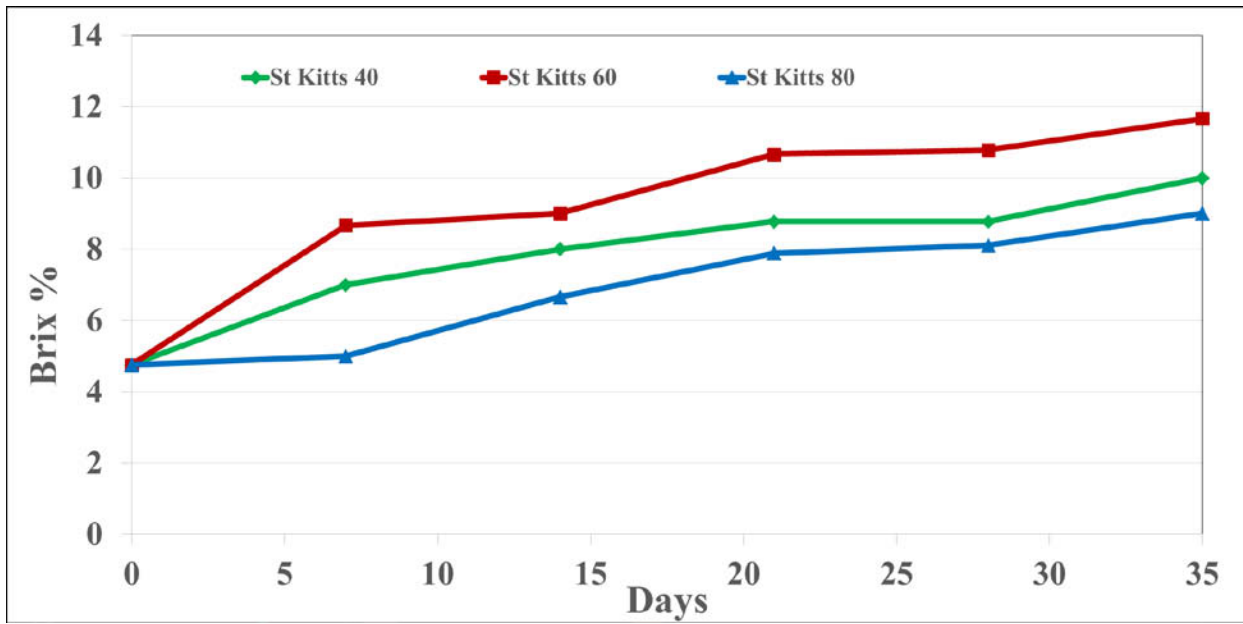


Fig. 3. Postharvest changes in 'St Kitts' sugar content over time.

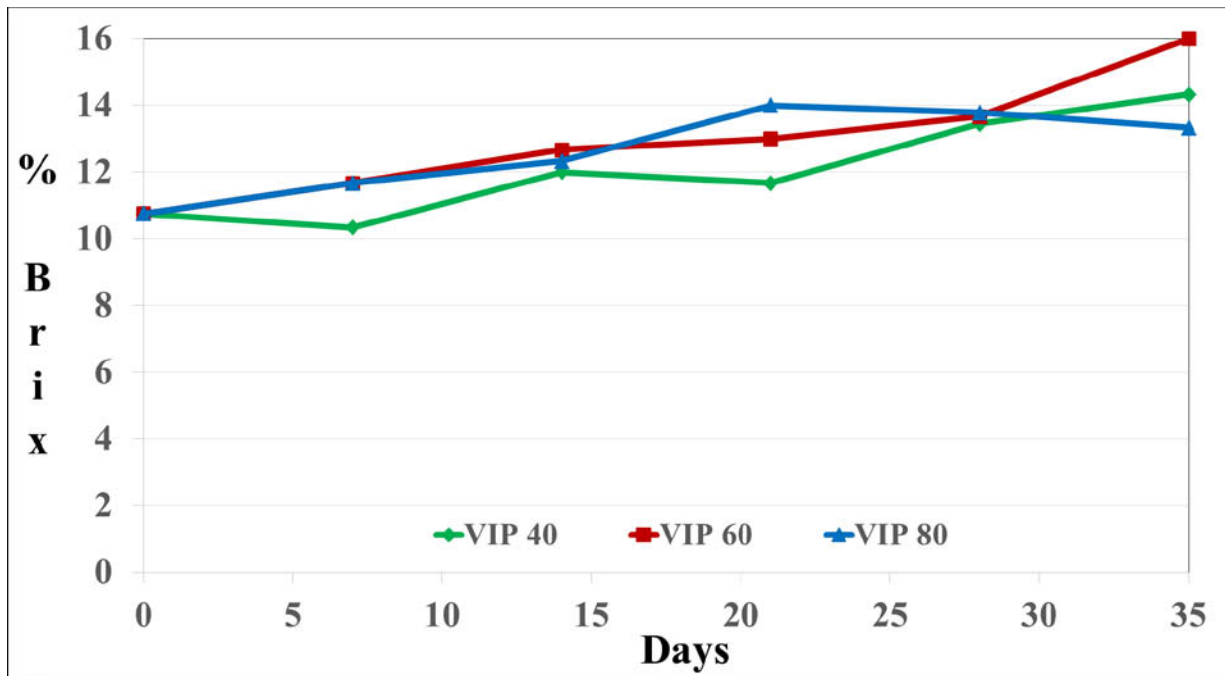


Fig. 4. Postharvest changes in 'VIP' sugar content over time.

## EFFECTS OF TEMPERATURE AND RELATIVE HUMIDITY ON *Nephaspis bicolor*, A PREDATOR OF *Aleurodicus* spp.

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**Abstract:** The spiralling whitefly *Aleurodicus dispersus* Russell was introduced to Africa and Asia during the 1990s. Among its potential biological control agents is the predatory coccinellid, *Nephaspis bicolor* Gordon. Since the coccinellid may be required to control *A. dispersus* under variable climatic conditions, four temperature (20-34°C) and two RH (78% and 90%) (55% RH at 26°C only) regimes were evaluated under laboratory conditions in Trinidad and Tobago. Temperature (but not RH) had significant effects on the development rate of all stages of *N. bicolor* and on the pupal and adult sizes. Interactions between temperature and RH were significant only for egg incubation and total duration and for size of the pupa. Mortality during development was highest at 30°C/90% RH and lowest at 23°C/78% RH. Both temperature and RH significantly affected the preoviposition period, while temperature alone affected longevity and lifetime fecundity. Adult survival at 26°C and 55% RH as well as 90% RH was significantly higher compared to all the other treatments. Based on the life table statistics, the best performance of female *N. bicolor* was at 26°C and 55% RH. Although feeding, survival, development and reproduction occurred under all the temperature and RH regimes, constant low and high temperatures were not conducive to the coccinellid since the survival of immature stages and adults was greatly reduced. Thus, the introduction of *N. bicolor* into such environments may not result in long-term establishment. It may be necessary to ‘thermally adapt’ the beetles prior to release and/or to time the field releases to coincide with favourable environmental conditions. Another solution may lie in maintaining laboratory cultures of *N. bicolor* and making periodic (inoculative/augmentative) releases.

**Key words:** *Aleurodicus cocois*, Coccinellidae, Coleoptera, Hemiptera, *Nephaspis bicolor*, relative humidity, Sternorrhyncha, temperature

### INTRODUCTION

During the last decade of the twentieth century, the spiralling whitefly *Aleurodicus dispersus* Russell (Aleyrodidae: Sternorrhyncha) was introduced to several countries of Africa and Asia (Alam *et al.*, 1997; Anon., 1993; Gungah *et al.*, 2005; Kajita *et al.*, 1991; Kiyindou, 1993; Mani and Krishnamoorthy, 1996; Wen *et al.*, 1994). The whitefly had been introduced to Hawaii and Pacific islands of the Pacific in the 1980s, where it was successfully controlled by exotic natural enemies: a parasitic wasp *Encarsia* sp. nr. *haitiensis* Dozier (Aphelinidae) and two predatory beetles, *Nephaspis bicolor* Gordon and *N. indus* Gordon (as *N. amnicola* Wingo = *N. oculata* Blatchley) (Coccinellidae) from Trinidad (Greathead and Greathead, 1992; Kumashiro *et al.*, 1983; Suta and Esguerra, 1993; Tauili’-ili and Vargo, 1993). Field studies established that *A. dispersus* did not occur in in Trinidad and Tobago and that *N. bicolor* was the predominant

species responsible for the effective control of these whiteflies in Trinidad and Tobago (Lopez and Kairo, 2003). Furthermore, *N. bicolor* was the only species encountered during field collections in Hawaii in 1996, more than ten years after the initial release of both *N. bicolor* and *N. oculata*. Therefore, the coccinellid *N. bicolor* was considered for introduction to countries invaded by *A. dispersus* and other *Aleurodicus* spp. and was evaluated in Trinidad and Tobago (Lopez, 2003; Lopez *et al.*, 1997; Lopez and Kairo, 2014).

Knowledge of climatic suitability and adaptability of candidate biocontrol agents is useful, as it allows climatic matching and provides much-needed information on rearing. Many countries have a range of environments, depending on geography/topography and the pest species may be present in several environments. Even in seemingly favourable environments, one or more of the climatic factors may deter the establishment of a particular species. In Hawaii, high *A. dispersus* population levels were present in two areas with distinctly different climatic patterns, which strongly influenced the effectiveness of *N. indus* in controlling *A. dispersus* in the two ecological zones (Kumashiro *et al.* 1983). When introduced, *N. bicolor* will be required to control *A. dispersus* and/or other species under a range of environmental conditions. Since temperature and RH are among the major environmental factors that can affect the survival, and thus establishment, of an introduced species, the study reported here was undertaken to determine temperature and humidity effects on the development, reproduction and survival of *N. bicolor*. Four temperature ranges (20-34°C) used in the study represent the tropical / subtropical conditions under which *N. bicolor* may be introduced and expected to be effective.

## **MATERIALS AND METHODS**

### Experimental conditions and prey species

Air-tight glass chambers (Patil *et al.*, 1994) were designed with dimensions of 30 cm x 23 cm x 22 cm which provided an internal volume of 15,180 cu. cm. Four glass tubes, 10 cm long each, were glued to the bottom of the chamber to form a square of side 12 cm. A plastic tray, 28 cm x 16 cm, placed on the tubes provided the platform on which petri dishes were placed inside the chamber. The cover of the chamber was made of glass and was 0.5 cm longer and wider than the chamber. A one-cm wide glass strip was glued on the inside of the cover, at a distance of 0.75 cm from the edge on all four sides, which prevented the cover from sliding off. The chamber was made airtight by applying a layer of Vaseline® along the perimeter of the cover (Figure 1).

Saturated salt solutions were used to obtain different RHs (Winston and Bates, 1960). Based on the size of the chambers, the volume of the solutions required was calculated to be 425 ml per chamber. Four chambers were set up with saturated solutions of sodium chloride (NaCl) for 75-80% RH and four with potassium chloride (KCl) for 85-90% RH. Four controlled-temperature (CT) Rooms were maintained at temperatures ranging between 20-24°C, 24-28°C, 29-33°C and ambient, respectively. Two humidity chambers (one each with KCl and NaCl) were placed in each laboratory. A layer of salt crystals was maintained at the bottom of the chambers at all times. It was not possible to set up the treatment of 55-60% humidity despite several trials. Therefore, data collected on the biology of *N. bicolor* at 26°C and 55% RH were used to compare the effects of humidity at this temperature.

A maximum-minimum thermometer was placed in each laboratory and temperatures were recorded daily. A calibrated Fisher Hair Hygrometer was used to measure the humidity inside the chamber. Observations on the duration of development were recorded daily. Throughout the experiment, *Aleurodicus cocois* (Curtis) reared on coconut plants (Lopez *et al.*, 2005) was used as the prey for feeding *N. bicolor*. The cultures were maintained outdoors under sleeve cages. Plants harbouring the required whitefly stages were brought into the CT Room at least 48 h prior to being used in order to acclimatize them.

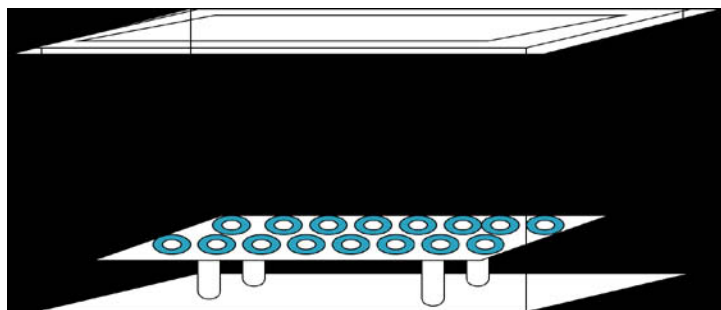


Figure 1. Line diagram of a humidity chamber (not drawn to scale).

### **Developmental biology**

Oviposition was obtained on coconut leaves harbouring larvae/pupae of *A. cocois* by releasing large number of mated *N. bicolor* females overnight to obtain uniform-age eggs. The leaves were observed under a microscope and the flocculent material carefully removed to locate the eggs, which were gently detached with a fine paintbrush. The eggs were placed individually on leaf discs with mixed whitefly stages and moved to a 4-cm diameter petri dish. The petri dishes were arranged on the 28 x 16 cm plastic tray, which was then placed on the tubes inside the humidity chamber. Under each of the nine experimental conditions, 57-78 eggs was set up and observations were recorded daily. When the eggs hatched, the newly emerged larvae were gently transferred to fresh leaf discs with a fine brush and the duration of development for each of the four stages recorded. Leaf discs were changed as required ensuring that there was always an excess of food available for the developing larvae. Measurements were made on three stages in order to assess the effect of experimental conditions on insect growth. These were 4<sup>th</sup> instar larva (width of head capsule at the widest point), pupa (width at the widest point) and newly emerged adult (length and width at the longest and widest point, respectively).

### **Reproductive biology**

Newly emerged adults were paired and released for oviposition on leaf discs harbouring mainly 3<sup>rd</sup>/4<sup>th</sup> instars and pupae. The leaf discs were changed every three days. The number of eggs laid during this interval was recorded. The insects were observed daily for mortality. If males died during the course of the experiment, they were replaced with mature males from general cultures. The experiment was terminated when all the females died.



## Data analysis

The data recorded on various developmental and reproductive biology parameters were subjected to a General Linear Model (GLM) analysis using SPSS® (Norusis, 1993). The Analyses of Variance (ANOVAs) from the GLM output were used to determine the effect of the various temperature and RH regimes as well as interactions between temperature and RH on the various parameters. Data from the third RH treatment (55%), which was available for 26°C only, was subjected to a separate ANOVA using EXCEL® to determine differences among the three RH treatments (90%, 78% and 55%) for all parameters. Since there were unequal replications, paired t-tests were used for comparing means and evaluating levels of significance for those treatments where significant F values were obtained.

Log linear models were fitted to obtain approximate  $X^2$  (chi-squared) values in order to evaluate the effects of, and interactions between, the temperature and RH treatments on the survival of the immature stages of *N. bicolor*. Data on the survival of adult female *N. bicolor* were subjected to the Kaplan Meir analysis using SPSS® (Lopez and Kairo, 2003). The correlation between longevity and fecundity was determined using SPSS®. The data on survival and egg production of females was used to compute life table parameters, according to Birch (1948): net reproductive rate  $R_0 = \sum_0^{\infty} l_x m_x$ ; mean generation time  $GT = \ln R_0 / r_m$ ; intrinsic rate of increase  $r_m = \sum e^{-r_m x} l_x m_x = 1$ ; finite rate of increase  $\lambda = e^{r_m}$  and doubling time  $DT = \ln 2 / r_m$ .

## RESULTS

The average maximum and minimum temperature, overall mean temperature and RH regimes during the course of the experiment were as follows:

Temperature regimes: minimum - maximum (average)	Humidity regimes:
1. 20 - 26° C (23.3°C)	1. NaCl: 75-81% (all temperatures)
2. 21 - 31° C (25.9)	2. KCl: 88.5-92% (all temperatures)
3. Ambient 23.3 - 31.7 (27.7)	3. CT Room 50-60% (only at 25.9° C)
4. 27 - 34°C (30.4)	

For convenience of presentation, the treatments are rounded off to the nearest whole number, e.g. temperatures are referred to as 23°C, 26°C, 30°C and ambient, and RH as 90%, 78% and 55%.

## Developmental biology

The means ( $\pm$ SE) for the duration of development and size of *N. bicolor* (Table 1) are based on the output from the General Linear Model (GLM). Under both RHs, the rate of development of *N. bicolor* generally increased as the temperature increased from 23°C to 30°C.

Table 1. Duration of development (days±SE) and size (mm±SE) of *N. bicolor* under four temperature and two humidity regimes

	23°C		26°C		Ambient		30°C	
	90%	78%	90%	78%	90%	78%	90%	78%
<b>Duration of development:</b>								
<b>Egg</b>	6.11 ± 0.061 n = 66	6.27 ± 0.062 n = 64	5.34 ± 0.061 n = 67	5.05 ± 0.064 n = 60	5.20 ± 0.058 n = 74	5.03 ± 0.064 n = 61	4.5 ± 0.061 n = 66	4.57 ± 0.057 n = 75
<b>1<sup>st</sup> instar</b>	3.07 ± 0.122 n = 54	2.95 ± 0.115 n = 61	1.84 ± 0.113 n = 63	2.06 ± 0.131 n = 47	1.78 ± 0.018 n = 69	2.02 ± 0.126 n = 51	2.13 ± 0.121 n = 55	1.96 ± 0.121 n = 55
<b>2<sup>nd</sup> instar</b>	2.94 ± 0.140 n = 48	3.07 ± 0.126 n = 59	1.93 ± 0.126 n = 59	1.93 ± 0.149 n = 42	2.25 ± 0.118 n = 67	2.00 ± 0.143 n = 46	2.02 ± 0.140 n = 48	1.96 ± 0.132 n = 54
<b>3<sup>rd</sup> instar</b>	3.77 ± 0.208 n = 44	3.44 ± 0.183 n = 57	2.54 ± 0.183 n = 57	2.62 ± 0.221 n = 39	2.60 ± 0.142 n = 65	2.65 ± 0.210 n = 43	2.67 ± 0.213 n = 42	2.65 ± 0.191 n = 52
<b>4<sup>th</sup> instar</b>	4.83 ± 0.233 n = 41	5.13 ± 0.203 n = 54	3.49 ± 1.36 n = 51	3.32 ± 0.242 n = 38	3.17 ± 0.203 n = 54	3.60 ± 0.230 n = 42	3.42 ± 0.249 n = 36	3.47 ± 0.223 n = 45
<b>Total larval</b>	20.7 ± 0.38 n = 41	20.9 ± 0.33 n = 54	15.4 ± 0.34 n = 51	15.1 ± 0.39 n = 38	14.9 ± 0.33 n = 54	15.4 ± 0.37 n = 42	14.5 ± 0.41 n = 36	14.7 ± 0.36 n = 45
<b>Pre-pupa</b>	1.90 ± 0.132 n = 40	2.06 ± 0.121 n = 48	1.91 ± 0.13 n = 43	1.43 ± 0.14 n = 35	1.32 ± 0.143 n = 34	1.39 ± 0.135 n = 38	1.24 ± 0.167 n = 25	1.26 ± 0.135 n = 38
<b>Pupa</b>	6.15 ± 0.138 n = 33	6.24 ± 0.123 n = 41	4.94 ± 0.134 n = 35	4.45 ± 0.138 n = 33	4.26 ± 0.152 n = 27	4.38 ± 0.136 n = 34	3.74 ± 0.182 n = 19	3.93 ± 0.144 n = 30
<b>Total overall</b>	28.3 ± 0.48 n = 33	28.7 ± 0.43 n = 41	22.4 ± 0.46 n = 35	20.9 ± 0.048 n = 33	20.6 ± 0.53 n = 27	21.1 ± 0.47 n = 34	18.7 ± 0.63 n = 19	20.0 ± 0.50 n = 30
<b>Size</b>								
<b>4<sup>th</sup> instar<sup>a</sup></b>	0.421 ± .002 n = 39	0.425 ± .002 n = 51	0.42 ± .002 n = 49	0.424 ± .002 n = 36	0.422 ± .002 n = 64	0.424 ± .002 n = 40	0.420 ± .002 n = 40	0.419 ± .002 n = 49
<b>Pupa<sup>b</sup> (width)</b>	1.14 ± 0.013 n = 36	1.10 ± 0.011 n = 47	1.10 ± 0.012 n = 40	1.12 ± 0.013 n = 35	1.12 ± 0.013 n = 33	1.10 ± 0.012 n = 38	1.07 ± 0.015 n = 24	1.09 ± 0.012 n = 38
<b>Adult<sup>c</sup> (length)</b>	1.48 ± 0.018 n = 27	1.49 ± 0.015 n = 41	1.44 ± 0.017 n = 30	1.47 ± 0.017 n = 32	1.46 ± 0.020 n = 23	1.46 ± 0.017 n = 33	1.41 ± 0.025 n = 15	1.46 ± 0.018 n = 27
<b>Adult<sup>b</sup> (width)</b>	1.06 ± 0.013 n = 27	1.04 ± 0.010 n = 41	1.02 ± 0.012 n = 30	1.04 ± 0.012 n = 32	1.04 ± 0.014 n = 23	1.02 ± 0.012 n = 33	1.00 ± 0.017 n = 15	1.01 ± 0.013 n = 27

n = as in Table 1.; a = width of the head capsule of 4<sup>th</sup> instar larva (at the widest point); b = width of pupa / adult (at the widest point); c = length of adult (at the longest point).

The duration of development of all stages was significantly ( $p < 0.01$ ) affected by temperature but not by RH (Table 2) and was longer for all stages at 23°C. The interactions between temperature and RH were significant only for the egg stage and total development. Significant temperature effects were recorded for pupal and adult width, while RH had no effect on the size of the insect. The interaction between temperature and RH was significant only for the width of the pupa.

Table 2. ANOVAs from General Linear Model (GLM) to investigate the effects of temperature and relative humidity (RH) on the duration of development and size of *Nephaspis bicolor*

	Temperature	RH	Temperature * RH
<b>Duration of development:</b>			
Egg	187 (254 <sup>***</sup> ) <sup>1</sup>	0.44 (1.78)	4.3 (5.8 <sup>***</sup> )
1 <sup>st</sup> instar	95 (39 <sup>***</sup> )	0.21 (0.26)	3.9 (1.6)
2 <sup>nd</sup> instar	78 (28 <sup>***</sup> )	0.22 (0.24)	2.1 (0.7)
3 <sup>rd</sup> instar	71 (13 <sup>***</sup> )	0.31 (0.16)	2.6 (0.5)
4 <sup>th</sup> instar	170 (24 <sup>***</sup> )	2.02 (0.91)	4.8 (0.7)
Total larval development	2254 (129 <sup>***</sup> )	1.44 (0.25)	6.6 (0.4)
Prepupa	24 (12 <sup>**</sup> )	0.22 (0.32)	4.9 (2.3)
Pupa	199 (106 <sup>***</sup> )	0.02 (0.04)	4.8 (2.6)
Total development	3223 (143 <sup>***</sup> )	1.88 (0.25)	59.4 (2.6 <sup>*</sup> )
<b>Size</b>			
4 <sup>th</sup> instar <sup>a</sup>	0.0007 (1.05)	0.0004 (1.78)	0.0003 (0.48)
Pupa <sup>b</sup>	0.065 (3.90 <sup>**</sup> )	0.002 (0.32)	0.049 (2.93 <sup>*</sup> )
Adult length <sup>c</sup>	0.065 (2.40)	0.031 (3.64)	0.017 (0.63)
Adult width <sup>c</sup>	0.039 (2.10 <sup>*</sup> )	0.0003 (0.07)	0.017 (1.28)

1 = Sum of squares (F values); \*, \*\*, \*\*\* = significant at  $p < 0.05$ ,  $p < 0.01$  and  $p < 0.001$ , respectively  
Degrees of freedom (df) were as follows: Temperature = 3; Humidity = 1; T x H = 3; a, b and c = as in Table 1.

At 26°C, no significant differences were found in the rate of development of the 4<sup>th</sup> instar and prepupal stages under the three humidity regimes (Table 3), while paired t-tests revealed significant differences between the other stages (Table 4). Significant differences in the size of 4<sup>th</sup> instars ( $p < 0.001$ ), pupal width ( $p < 0.001$ ) and adult width ( $p < 0.05$ ) (Table 5) were attributable mainly to the differences between the sizes at 55% and the higher RH (Table 6).

Table 3. ANOVA for the duration of development of *N. bicolor* under three RH regimes at 26°C

Stage	Duration of development (days±SE)			F (df)
	90% RH	78% RH	55% RH	
Egg	5.3 ± 0.06 (n=67)	5.05 ± 0.05 (n=60)	5.4 ± 0.09 (n=55)	8.82 <sup>***</sup> (179)
1 <sup>st</sup> instar	1.8 ± 0.07 (n=63)	2.1 ± 0.14 (n=47)	2.2 ± 0.07 (n=54)	3.13 <sup>*</sup> (161)
2 <sup>nd</sup> instar	1.9 ± 0.12 (n=59)	1.9 ± 0.12 (n=47)	2.4 ± 0.18 (n=54)	3.44 <sup>*</sup> (152)
3 <sup>rd</sup> instar	2.5 ± 0.13 (n=57)	2.6 ± 0.16 (n=39)	3.1 ± 0.19 (n=51)	3.10 <sup>*</sup> (145)
4 <sup>th</sup> instar	3.5 ± 0.19 (n=51)	3.3 ± 0.22 (n=38)	3.8 ± 0.21 (n=51)	1.52 (137)
Total (larval)	10 ± 0.24 (n=51)	10 ± 0.32 (n=38)	11.4 ± 0.32 (n=51)	8.03 <sup>***</sup> (137)
Prepupa	1.9 ± 0.18 (n=43)	1.4 ± 0.11 (n=35)	1.6 ± 0.11 (n=48)	2.83 (123)
Pupa	4.9 ± 0.17 (n=35)	4.5 ± 0.12 (n=33)	4.2 ± 0.08 (n=47)	10.35 <sup>***</sup> (112)
Total (overall)	22.4 ± 0.39 (n=35)	20.9 ± 0.42 (n=33)	22.4 ± 0.39 (n=47)	4.07 <sup>*</sup> (112)

\*, \*\*\* = as in Table 2. n = as in Table 1; df = degrees of freedom

Table 4. Results from t-tests for the duration of development (in days) of *N. bicolor* under three RH regimes at 26°C

RH 1	RH2	Stages significantly different between RH1 & RH2
90%	78%	Egg <sup>**</sup> , 1 <sup>st</sup> instar <sup>*</sup> , Pupa <sup>**</sup> , Overall total <sup>*</sup>
	55%	1 <sup>st</sup> instar <sup>*</sup> , 2 <sup>nd</sup> instar <sup>*</sup> , 3 <sup>rd</sup> instar <sup>*</sup> , Total larval duration <sup>**</sup> , Pupa <sup>**</sup>
78%	55%	Egg <sup>**</sup> , 2 <sup>nd</sup> instar <sup>*</sup> , 3 <sup>rd</sup> instar <sup>*</sup> , Total larval <sup>**</sup> , Overall total duration <sup>**</sup>

\*, \*\* = as in Table 2.

Table 5. ANOVA for the size of 4<sup>th</sup> instar larva, pupa and adult length & width (all in mm ± SE) of *Nephaspis bicolor* under three RH regimes at 26°C

Stage	Size (in mm ± SE) under			F value (df)
	90% RH	78% RH	55% RH	
4 <sup>th</sup> instar <sup>a</sup>	0.42 ± 0.001 (n=49)	0.42 ± 0.002 (n=36)	0.40 ± 0.003 (n=52)	39.51 <sup>***</sup> (134)
Pupa <sup>b</sup>	1.10 ± 0.009 (n=40)	1.12 ± 0.006 (n=35)	1.04 ± 0.007 (n=47)	17.68 <sup>***</sup> (119)
Adult length <sup>c</sup>	1.44 ± 0.019 (n=30)	1.46 ± 0.021 (n=33)	1.48 ± 0.013 (n=47)	1.24 (107)
Adult width <sup>c</sup>	1.02 ± 0.011 (n=30)	1.04 ± 0.013 (n=32)	0.99 ± 0.010 (n=47)	4.33 <sup>*</sup> (106)

\*, \*\*\* = as in Table 1; a, b, c = as in Table 1; df = as in Table 3.

Table 6. Results from t-tests for size (mm) of *N. bicolor* reared under three RH regimes at 26°C

RH 1	RH2	Sizes significantly different between RH1 & RH2
90%	78%	None
	55%	4 <sup>th</sup> instar <sup>**</sup> , pupal width <sup>**</sup> , adult width <sup>*</sup>
78%	55%	4 <sup>th</sup> instar <sup>**</sup> , pupal width <sup>**</sup> , adult width <sup>**</sup>

\*, \*\* = as in Table 2.

Overall cumulative mortality (%) was the highest at 90% RH, with 71.2% and 63.7% deaths occurring at 30°C and ambient, respectively (Table 7) and lowest mortality (40.6%) at 23°C and 78% RH. The approximate- $\chi^2$  values for the survival of immature stages revealed Temperature (T) x Survival (S) and Humidity (H) x S interactions to be significant for 1st instar, prepupa and pupa. In addition, T x S interactions were significant for the 4<sup>th</sup> instar. High variations in some

Table 7. Cumulative mortality (%) and approximate  $\chi^2$  values for the survival of immature stages *Nephaspis bicolor* under two humidity and four temperature regimes.

Stage	23°C		26°C		Ambient		30°C		$\chi^2$	$\chi^2$	$\chi^2$
	90%	78%	90%	78%	90%	78%	90%	78%	T <sup>1</sup> × S <sup>2</sup>	H <sup>3</sup> × S	H × T
1 <sup>st</sup> instar	18.2	4.7	6.0	31.7	6.8	16.4	16.7	26.7	13.93 <sup>**</sup>	7.67 <sup>**</sup>	6.14 <sup>*</sup>
2 <sup>nd</sup> instar	27.3	7.8	11.9	40.0	9.5	24.6	27.3	28.0	6.30	1.31	19.96 <sup>**</sup>
3 <sup>rd</sup> instar	33.3	10.9	14.9	45.0	12.2	29.5	36.4	30.7	7.32	0.52	23.29 <sup>***</sup>
4 <sup>th</sup> instar	37.9	15.6	23.9	46.7	27.0	31.2	45.5	40.0	9.32 <sup>*</sup>	0.29	11.08 <sup>*</sup>
Prepupa	39.4	31.3	35.8	51.7	54.1	37.7	62.1	49.3	17.29 <sup>***</sup>	4.21 <sup>*</sup>	4.16
Pupa	50.0	40.6	47.8	55.0	63.7	44.3	71.2	60.0	16.14 <sup>**</sup>	6.86 <sup>**</sup>	1.89
Rank (mortality)	5	8	6	4	2	7	1	3	-	-	-

T = Temperature; 2. S = Survival; 3. H = Humidity; Degrees of freedom (df) for both T × S and H × T = 3; df for H × S = 1; \*, \*\*, \*\*\* = approximate  $\chi^2$  values significant at p<0.05, 0.01 and 0.001, respectively

of the treatments may have resulted in significant, unexpected approximate- $\chi^2$  values for T x H interactions for instars 1-4. Under the three RH regimes at 26°C, approximate- $\chi^2$  values for survival were highly significant for all stages (Table 8).

Table 8. Cumulative mortality and approximate  $\chi^2$  values for the survival of immature stages of *Nephaspis bicolor* under three humidity regimes at 26°C

Stage	90%	78%	55%	$\chi^2$
1 <sup>st</sup> instar	6.0	31.7	1.81	14.336***
2 <sup>nd</sup> instar	11.9	40.0	3.64	18.485***
3 <sup>rd</sup> instar	14.9	45.0	7.27	17.474***
4 <sup>th</sup> instar	23.9	46.7	9.09	14.005***
Prepupa	35.8	51.7	14.55	14.029***
Pupa	47.8	55.0	16.37	18.451***

\*\*\* = approximate  $\chi^2$  values significant at  $p < 0.001$ ; All approximate  $\chi^2$  had 2 degrees of freedom.

### Reproductive biology

Means ( $\pm$ SE) for pre-oviposition period, longevity and lifetime fecundity are presented in Table 9. The number of females that died without ovipositing ranged from 0 (78% and 90% RH at 26°C and 78% RH at 30°C) to 7 (78% RH at ambient). Based on the ANOVAs, both temperature and RH had significant effects on the pre-oviposition period, while temperature alone affected longevity and lifetime fecundity (Table 10). Temperature x RH interactions were significant only for the pre-oviposition period.

The ANOVA for the three reproductive parameters at 26°C revealed that both longevity and lifetime fecundity were affected by RH (Table 11). Female *N. bicolor* maintained at 55% RH lived significantly longer than those maintained at 78% RH. They also oviposited more eggs than those at the higher RH treatments did (Table 12).

Results from the Kaplan Meier analysis for the survival (days  $\pm$  SE) of female *N. bicolor* under the nine treatment regimes are presented in Figure 2. Breslow statistics revealed that survival at 26°C and 55% RH was significantly higher compared to all the other treatments except 26°C and 90% RH (Table 13). Survival rate under the latter treatment was, in turn, significantly higher than that under the higher temperature regimes (30°C and ambient) at both RHs. Under other regimes, survival was variable and did not appear to follow any particular pattern.

Life-table statistics for each parameter were ranked in descending order for purposes of evaluation (Table 14). The best performance of *N. bicolor* was at 26°C and 55% RH, which recorded the highest values for net reproductive rate ( $R_0$ ), intrinsic rate of increase ( $r_m$ ) and innate capacity for increase ( $\lambda$ ), and the lowest for doubling time (DT). The reverse was true for the combination of 30°C and 90% RH. Reduction in the humidity to 78% at 30°C resulted in improved values for most parameters. The combinations 26°C at 78% and at 90% RH were superior to all the remaining treatments, ranking 2 or 3 for most parameters (Table 14).

Although  $R_0$  was almost half at 90% RH under ambient (4.26) compared to 23°C (8.06), the two combinations were almost on par with regard to  $r_m$ , DT and  $\lambda$ . With few exceptions, the rankings for generation time (G) followed the same pattern as the other parameter.

Table 9. Reproductive biology parameters of female *N. bicolor* under four temperature and two humidity regimes (based on GLM)

Parameter	23°C		26°C		Ambient		30°C	
	90%	78%	90%	78%	90%	78%	90%	78%
Pre-oviposition period (days±SE)	13.3±0.9 n=10 <sup>1</sup>	18.0±0.7 n=15	10.4±0.9 n=12	11.3±0.8 n=12	8.9±1.0 n=8	9.8±0.7 n=17	11.0±1.3 n=5	10.7±0.9 n=9
Longevity (days ± SE)	42.1±6.5 n=12 <sup>2</sup>	43.6±4.9 n=21	59.1±6.5 n=12	43.8±6.5 n=12	25.3±6.5 n=12	32.7±4.6 n=24	24.8±9.1 n=6	24.8±6.5 n=9
Lifetime fecundity (no. of eggs / female ± SE)	34.8±9.3 n=10 <sup>1</sup>	28.0±7.0 n=15	55.0±9.3 n=12	45.7±9.3 n=12	23.0±9.3 n=8	31.8±6.6 n=17	10.0±13.1 n=5	13.8±9.3 n=9

1 = number of insects for which pre-oviposition period and lifetime fecundity were recorded; 2 = number of insects for which longevity was recorded

Table 10. ANOVA of General Linear Model (GLM) to investigate temperature and RH effects on reproductive biology in *N. bicolor*

Parameter	Temperature	RH	Temperature * RH	Error (df)
Preoviposition period	521 <sup>***</sup> (22.1) <sup>1</sup>	46.0* (5.8)	24.6 (3.1) <sup>*</sup>	622 (79)
Longevity	3459 <sup>***</sup> (6.9)	62.2 (0.1)	615 (1.2)	51557 (103)
Lifetime fecundity	5050 <sup>**</sup> (4.883)	22.807 (0.022)	493.12 (0.477)	106525 (103)

1 and \*, \*\*, \*\*\* as in Table 2; df = as in Table 2.

Table 11. ANOVA for three reproductive biology parameters of female *N. bicolor* under three RH regimes at 26°C

Parameter	90% RH	78% RH	55% RH	F value (df)
Pre-oviposition period (days)	10.4±0.85 (n=12)	11.3±0.81 (n=12)	10.2±0.65 (n=10)	0.65 (31)
Longevity (days)	59.1±6.46 (n=12)	43.8±6.46 (n=12)	75.0±11.80 (n=10)	3.2* (31)
Fecundity (eggs/ female)	55.0±9.28 (n=12)	45.7±9.28 (n=12)	93.0±12.60 (n=10)	4.51* (31)

\* = significant at p<0.05; df = as in Table 3

Table 12. Results from paired t-tests for three reproductive biology parameters of *N. bicolor* females under three RH regimes at 26°C

RH 1	RH2	Parameters with significant differences between RH1 & RH2
90%	78%	None
	55%	Fecundity <sup>*</sup>
78%	55%	Longevity <sup>*</sup> , Fecundity <sup>*</sup>

\* = significant at p<0.05.

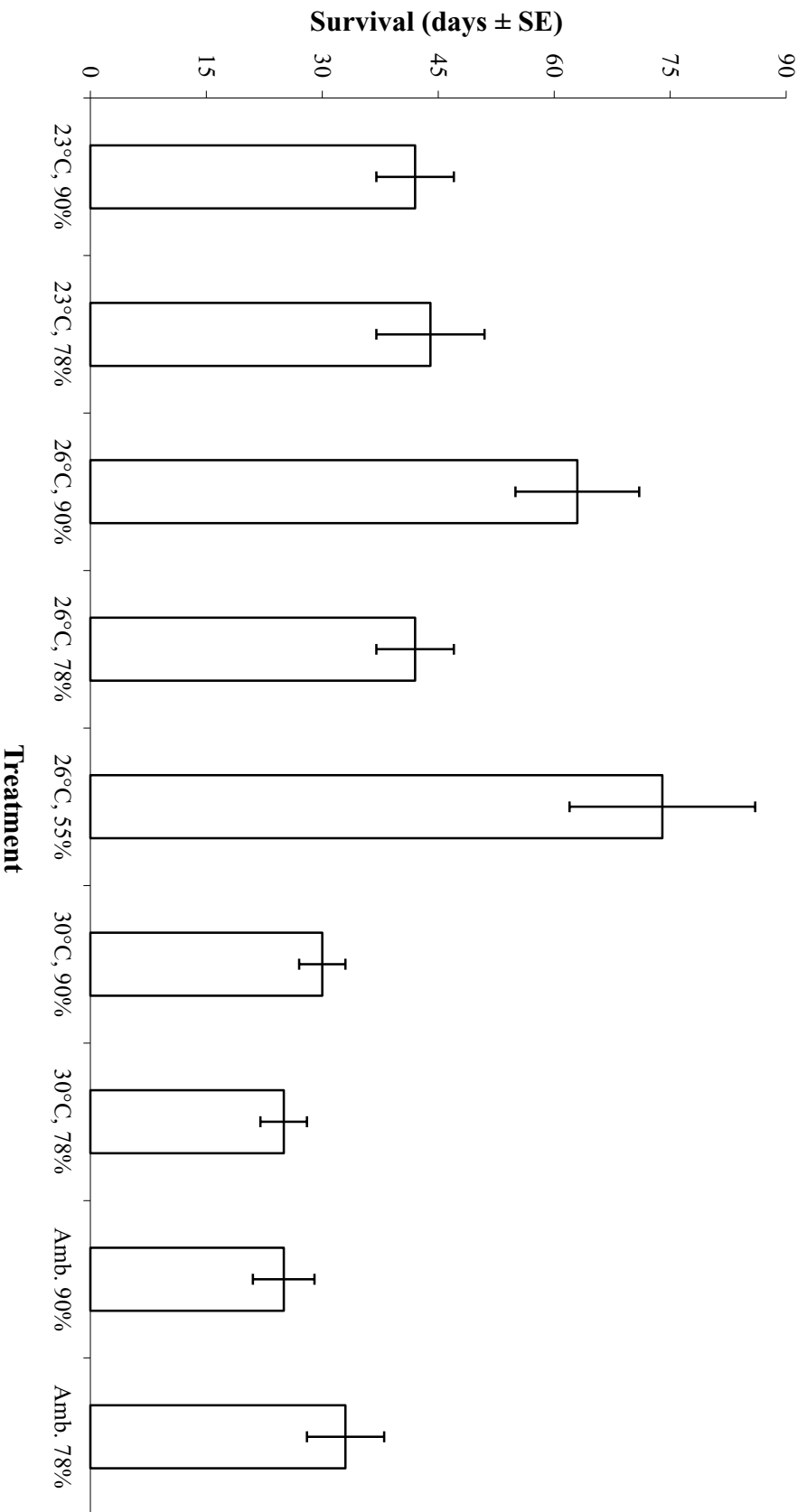


Figure 2. Survival (days ± SE) of *Nephaspis bicolor* females under nine temperature/RH regimes

Table 13. Breslow statistics for comparing the survival of female *Nephaspis bicolor* under nine treatment regimes

	23°C, 90%	23°C, 78%	26°C, 90%	26°C, 78%	26°C, 55%	30°C, 90%	30°C, 78%	Amb., 90%	Amb., 78%
23°C, 90%	-								
23°C, 78%	0.44								
26°C, 90%	4.80*	2.96							
26°C, 78%	0.00	0.66	2.80						
26°C, 55%	8.20***	4.33*	0.49	7.37***					
30°C, 90%	2.68	0.00	8.36***	1.49	16.74***				
30°C, 78%	6.35*	1.21	11.31***	4.75*	18.19***	0.68			
Amb., 90%	6.38*	1.00	11.89***	5.01*	17.20***	0.40	0.01		
Amb., 78%	2.11	0.91	7.28***	2.40	9.42***	0.03	0.46	0.43	-

\*, \*\* and \*\*\* = differences between the treatments significant at  $p < 0.05$ ,  $p < 0.01$  and  $p < 0.001$ , respectively

Table 14. Life table statistics for *Nephaspis bicolor* under four temperature and three humidity regimes

Parameter	23°C			26°C			Ambient			30°C	
	90%	78%	90%	78%	55%	90%	78%	90%	78%	90%	78%
Net repro. Rate ( $R_0$ ) (Rank <sup>1</sup> )	8.06 (6)	8.92 (4)	14.29 (2)	11.59 (3)	38.42 (1)	4.26 (7)	8.57 (5)	1.44 (9)	2.66 (8)		
Intrinsic rate of increase ( $r_m$ ) (Rank)	0.0358 (5)	0.0314 (7)	0.0487 (3)	0.0493 (2)	0.0689 (1)	0.0353 (6)	0.0435 (4)	0.0084 (9)	0.023 (8)		
Generation time (G) (Rank)	61.61 (4)	75.92 (1)	64.85 (3)	54.26 (6)	67.82 (2)	42.04 (9)	54.43 (5)	43.40 (7)	42.54 (8)		
Doubling time (DT) (Rank)	19.36 (5)	22.08 (7)	14.23 (3)	14.06 (2)	10.06 (1)	19.64 (6)	15.93 (4)	81.87 (9)	29.88 (8)		
Innate capacity for increase ( $\lambda$ ) (Rank)	1.036 (5)	1.032 (7)	1.050 (3)	1.051 (2)	1.071 (1)	1.036 (5)	1.045 (4)	1.009 (9)	1.024 (8)		

1. Ranked in descending order based on performance for each parameter



## DISCUSSION AND CONCLUSIONS

Under natural conditions in Trinidad, the average maximum and minimum temperature and RH range between 30.4-32.0°C and 20.3-22.4°C (mean 25.4-26.9°C), and 55-65% and 81-92% (mean 70-78%), respectively (based on meteorological data obtained from the University of the West Indies, St. Augustine, Trinidad). The presence of *N. bicolor* in the field throughout the year indicated that the coccinellid withstood existing temperature and RH ranges. Fluctuating field populations of *N. bicolor* appeared to be more a reflection of shifting prey populations than of any significant influence of climatic or weather factors (Lopez, 2003). Field studies in Hawaii revealed that the combination of low temperature and high RH were apparently not conducive to *N. indus*, even in areas with *A. dispersus* high populations (Kumashiro *et al.*, 1983).

Results from the present study generally support these observations. Under both RH regimes, the duration of *N. bicolor* development was longest at 23°C and became shorter as the temperature increased to 30°C. Temperature also impacted on the size of the pupae and the adults, while temperature x RH interactions affected egg incubation, total duration of development and size of pupa. RH effects, on the other hand, were not significant both on duration of development and size of the adults. Both temperature and RH impacted survival in the 1<sup>st</sup> instar and the prepupal stages, while only the 4<sup>th</sup> instar was affected by temperature. At 26°C, all three RH treatments (90%, 78%, 55%) impacted development and reproduction, and had profound effect on the survival of all stages of *N. bicolor*. Overall, the regime 26°C and 55% RH best supported all stages of *N. bicolor*, indicating that these were optimum conditions for the survival of the coccinellid.

Somewhat similar effects have been reported on other tropical coccinellids. Temperatures of 25°C and 27±1°C, and RH of 75-85% and 65±5% were optimum for *Hyperaspis raynevali* Mulsant in Congo and *Chilocorus bijugus* Mulsant in India, respectively (Kiyindou *et al.*, 1987; Rawat *et al.*, 1992). *Scymnus frontalis* Fabricius developed in 80 days at 15°C and 17 days at 30°C, with higher survival at 19°C and 26°C (Naranjo *et al.*, 1990). Temperatures of 25-30°C were optimum for the development of *Cryptolaemus montrouzieri* and there was a significant relationship ( $R^2 = 0.82$ ) between temperature and duration of development (Jalali *et al.*, 1999).

Temperature and RH effects on reproduction in *N. bicolor* were somewhat mixed and variable. Pre-oviposition period was the only parameter that was affected by temperature and RH as well as their interaction: it became shorter as temperatures increased from 23°C to Ambient (28°C), however, a further increase lengthened it significantly. Longevity and lifetime fecundity, on the other hand, increased as the temperature increased from 23°C to 26°C, but a further increase caused a decline in both parameters. Somewhat similar results have been reported for other coccinellids. Pre-oviposition period of *S. frontalis* was 20.5 and 7.7 days at 15°C and 30°C, respectively (Naranjo *et al.*, 1990). The fecundity in *C. sexmaculata* increased from 348 eggs to 2611 eggs as temperatures rose from 26°C to 30°C, however, increase to 34°C resulted in a reduction to 356 eggs (Alikhan and Yousuf, 1986). The pre-oviposition period and the longevity of *Coccinella septempunctata* L. decreased as temperatures increased from 20°C to 35°C (Xia *et al.*, 1999). Lifetime fecundity, however, increased from 20°C to 25°C, at which it was the highest, and then declined rapidly as temperatures were increased to 30°C and 35°C.

In the present study, *N. bicolor* fed, survived, developed and reproduced at all the temperature and RH regimes tested. However, constant low or high temperatures were not conducive to the development and reproduction of the coccinellid since the survival of both immature stages and adults was greatly reduced. Further evidence to support this observation was obtained by reviewing the geographic and climatic conditions of the areas where *N. bicolor* has been successfully introduced. The majority of the introductions were made in the Caribbean and the Pacific, with warm, tropical climates (temperature ranges of 21-30°C and RH 50-90%, which are very similar to Trinidad). The related species, *N. indus* (as *N. amnicola*), did not establish in Bermuda and Fiji (Kamath, 1979). Thus, even within the genus, there appears to be some variability in the response to similar environments, since *N. bicolor* became established in Fiji and also reportedly displaced *N. indus* in Hawaii (Cock, 1985). Field-collected *Nephaspis* spp. from Hawaii in 1997 consisted entirely of *N. bicolor* (Lopez, 2003). In Trinidad, *N. bicolor* often comprised 90-100% of *Nephaspis* spp. collected in the field (Lopez and Kairo, 2003). It may thus be inferred that *N. bicolor* is more competitive and adaptable than *N. indus*.

## RECOMMENDATIONS

Based on previous history of successful introduction as well as results from field studies, it is concluded that *N. bicolor* is a tropical species that can, upon introduction, become easily established in areas with similar environmental conditions as Trinidad.

Results from the present experiments also suggest that survival and long-term establishment may not occur in areas with temperature and RH ranges that are significantly different. It should be noted, however, that in many countries, there are climatic differences with seasons and altitude. It is crucial therefore that the time (season) and location of releases should coincide with the conditions that are optimum for *N. bicolor* survival in order to achieve establishment in the new environment.

Releasing climatically-matched species or biotypes of predatory coccinellids, including those adapted to local temperature conditions, is considered critical in biological control (Obrycki and Kring, 1998). Thus, if the introduction of *N. bicolor* becomes necessary in an area with seasonal lower temperatures for example, then it is suggested that further testing should be carried out simulating the conditions under which the introduction is proposed. It may also be possible to 'thermally adapt' *N. bicolor* by rearing through several generations at the required temperature prior to field release.

The example of *Cryptolaemus montrouzieri* Mulsant should also be borne in mind. It is well known that this coccinellid (like *N. bicolor*) is adapted to tropical temperatures (Peterkin *et al.*, 1998), is unable to complete development at 10-17°C and requires at least 21°C to feed and oviposit (Babu and Azam, 1987; Coddling, 1977). Thus, although *C. montrouzieri* has been successfully introduced in temperate countries for the control of mealy bugs, predator populations usually die out during winter. Commercial insectaries in these countries maintain and produce the coccinellid in the laboratory for the control of various pest species under glass house conditions, and also to initiate or augment field populations. A similar solution may be applied in the case of *N. bicolor*, i.e. maintaining laboratory cultures of *N. bicolor* and making periodic (inoculative/augmentative) releases as necessary.

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**THE EFFECT OF PREY SPECIES ON SELECTED FITNESS ATTRIBUTES OF *Nephaspis bicolor* (COLEOPTERA: COCCINELLIDAE), A PREDATOR OF ALEYRODIDAE**

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**Abstract:** Laboratory studies were carried out to assess the effects of feeding on different prey species either individually or in a sequential combination, on the development, survival and reproduction of *Nephaspis bicolor* Gordon (Coleoptera: Coccinellidae). Three species of Aleyrodidae were used as prey, two from the subfamily Aleurodicinae (*Aleurodicus cocois* Curtis and *Aleurodicus pulvinatus* Maskell on coconut and seagrape, respectively), and one from the subfamily Aleyrodinae (*Aleurothrixus floccosus* Maskell on guava). Based on development rate and the size of adults, *A. floccosus* was the most suitable prey for larvae. Prey species affected lifetime fecundity with beetles ovipositing significantly more eggs when fed *A. floccosus*. Rearing *N. bicolor* on *A. floccosus* and *A. cocois* produced the fittest adults in terms of population growth statistics. Prey substitution in larval stages did not affect survival or the duration of development. However, switching newly-emerged adults to a prey different from that fed on as larvae resulted in an increased preoviposition periods. Based on these data, it is concluded that the *N. bicolor* is adapted to utilize prey from both whitefly subfamilies and can readily switch between prey types in accordance with changes in their availability. Thus, any biological control programme that plans to introduce the coccinellid as a predator of Aleyrodidae needs to take this into consideration in the risk analysis / decision-making process.

**Key words:** *Nephaspis bicolor*, *Aleurodicus cocois*, *Aleurodicus pulvinatus*, *Aleurothrixus floccosus*, biology, prey species, prey switching

## INTRODUCTION

During the last 2-3 decades of the twentieth century, several species belonging to *Aleurodicus* (Homoptera: Aleyrodidae) were expanding their distribution range, either via accidental introduction e.g. *A. dispersus* Russell (Anonymous, 1993), or via expansion of geographic area e.g. *A. dugesii* Cockerell and *A. pulvinatus* Maskell (Martin and Watson, 1998; Zolnerowich and Rose, 1996). *Aleurodicus* spp. are generally difficult to control because they are polyphagous on woody (tree) species, have a relatively short life cycle and, in the absence of natural enemies, become rapidly entrenched in new environments that are favourable (Kajita *et al.*, 1991). Hence classical biological control i.e. introduction of specific natural enemies from the pests' native range, is often the only long-term sustainable solution for their management.

Predators belonging to the genus *Nephaspis* (Coleoptera: Coccinellidae) are among the known natural enemies of Aleyrodidae, particularly *Aleurodicus* spp. (Cock, 1985; Lopez and Kairo, 2003). Two species, *N. bicolor* Gordon and *N. indus* Gordon, were successfully used during the 1980s for the biological control of the exotic *A. dispersus* in Hawaii and some Pacific countries

(Kumashiro *et al.*, 1983; Suta and Esguerra, 1993; Tauili'-ili and Vargo, 1993). Since *Nephaspis* spp. were considered specific to Aleyrodidae (Gordon, 1985), they were potential candidates for introduction to control exotic Aleyrodidae, particularly *A. dispersus* which was rapidly spreading in Africa (M'Boob and van Oers, 1994) and Asia (Alam *et al.*, 1997; Mani and Krishnamoorthy, 1996; Wen *et al.*, 1994). Australia was also on alert for its invasion (Lambkin, 1999).

Increased concerns regarding nontarget effects of introduced natural enemies have resulted in the requirement of a rigorous host range testing of arthropod natural enemies being considered in a classical biological control programme, so that their potential host/prey range in new environments and associated risks to nontarget species can be predicted (FAO, 2005). There is little information on the prey range of *Nephaspis* spp. and their potential for attacking nontarget species, except for a preliminary study in Hawaii (Yoshida and Mau, 1985). Since *Nephaspis* is native to Trinidad, studies on prey range, focusing on *N. bicolor*, were conducted at the Caribbean Regional Centre of CAB International. Field and laboratory investigations on the prey range of *N. bicolor* revealed that the coccinellid was indeed specific to Aleyrodidae, with a marked preference for wax-producing species (Lopez and Kairo, 2003). However, the suitability of various Aleyrodidae as prey of *N. bicolor* was not known. The study reported below was therefore undertaken to determine the impact of three Aleyrodidae on the biology of *N. bicolor*. The effect of prey switching on the biology of the coccinellid was also investigated.

## **MATERIALS AND METHODS**

Two sets of studies were carried out in a controlled-temperature (CT) room, on the development and reproduction of *N. bicolor* using three whitefly species reared on their respective host plants: two Aleurodicinae - *Aleurodicus cocois* Curtis on coconut and *A. pulvinatus* on seagrape - and *Aleurothrixus floccosus* Maskell (Aleyrodinae) on guava. The first study compared suitability of the three aleyrodids as prey species of *N. bicolor* while the second study examined adaptability of the coccinellid when reared on one prey species and then transferred to the other two species. Cultures of *A. cocois* were maintained outdoors under sleeve cages while *A. pulvinatus* and *A. floccosus* were cultured in CT rooms under mesh cages. Temperatures of  $26\pm 2^\circ$  C and RH  $60\pm 10\%$  were maintained in the CT rooms. Artificial lighting was provided in the form of 4-6 fluorescent bulbs and 2-4 incandescent bulbs suspended 20-30 cm above the cages. The lighting regime used was 12 h light and 12 h dark. Coconut plants with *A. cocois* were brought into the CT rooms for acclimatization at least 48 h prior to being used.

### **Prey suitability studies**

For prey suitability studies, *N. bicolor* females reared for at least 3 generations on the respective whitefly species were used. In each case, 30-40 mated females reared on a whitefly host were released on the respective host plant to obtain eggs. On each host / host plant, the adults were allowed to oviposit for 12 h in order to obtain uniform-age eggs. The eggs were gently detached from the leaf with a fine paintbrush and placed individually on new leaf discs harbouring the same prey species. A total of 57 eggs were thus set up on coconut with *A. cocois*, 43 on seagrape with *A. pulvinatus* and 28 on guava with *A. floccosus* as prey. The leaf discs with the eggs were placed on moist filter paper in a 4-cm diameter petri dish and observed daily for egg-hatch. Development of *N. bicolor* larvae was followed through to adult stage. Observations were

recorded daily on survival and moulting. Leaf discs were changed as required, ensuring an adequate supply of food at all times. Once pupae were formed, they were gently detached from the leaf and placed on a dry filter paper in the petri dish. The date of adult emergence and sex of the emerging adults were recorded. The following measurements were made: Egg and adult - length and width along the longest and widest part, respectively; Larval stages - width of the head capsule along the widest part; Pupa - width along the widest part.

To study reproductive biology, 20 newly-emerged adults (14 pairs for *A. pulvinatus*) obtained above were paired. Each pair was released in a 4-cm diameter petri dish with the respective whitefly species. Mortality was recorded daily and dead males were replaced with mature adults from laboratory cultures. Leaf discs were changed at three day intervals and the number of eggs oviposited were counted. The experiment was terminated when all the females were dead.

### **Adaptability studies**

To study larval adaptability, about 50 uniform-age eggs oviposited on *A. cocois* by *N. bicolor* females (reared on this prey species for at least 3 generations) were used. The emerging larvae were fed on *A. cocois* until day 9 after oviposition. On day 10, thirty-two 1<sup>st</sup> instar larvae were used in setting up the experiment. Leaf discs with the three whitefly prey species on their respective host plant were each placed in 3-cm diameter petridishes. Larvae were transferred (one per petridish) as follows: 10 larvae on *A. cocois* and 11 each on *A. pulvinatus* and *A. floccosus*. All other details, including observations on size, were the same as described above for the experiment on prey suitability.

To study the adaptability of adults, pupae of *N. bicolor* were collected from a cohort that had been reared on *A. cocois* under CT Room conditions for at least 3 generations. Forty newly-emerged adults were paired and ten pairs each were transferred to leaf discs harbouring *A. pulvinatus* or *A. floccosus*, @ one pair per petridish and the oviposition was studied until all the females died. All other details were the same as described above for the prey suitability studies.

### **Data analysis**

For both studies, standard errors and analysis of variance (ANOVA) were computed for all developmental and reproductive biology parameters. Paired t-tests were performed only where the F-ratio from the ANOVA showed significant differences. Data on female survival and egg production were used to compute life table parameters according to Birch (1948), as follows:

net reproductive rate =  $\sum_0^{\infty} l_x m_x$ ; mean generation time  $GT = \ln R_0 / r_m$ ; intrinsic rate of increase

$r_m = \sum e^{-r_m x} l_x m_x = 1$ ; finite rate of increase  $\lambda = e^{r_m}$ , and doubling time  $DT = \ln 2 / r_m$ .

## RESULTS

### Prey suitability studies

The means for the developmental period of different stages of *N. bicolor* on the three whitefly prey are summarized in Table 1 together with the results of the ANOVA. Egg incubation and duration of 1<sup>st</sup> and 2<sup>nd</sup> instars and prepupae were on par on the three species. Duration of development of 3<sup>rd</sup> and 4<sup>th</sup> instars was significantly shorter on *A. floccosus*. This was reflected in the total larval period and total duration of development, which were shorter by 3 and 2 days, respectively, on this prey (Table 1). Conversely, the pupal stage on *A. floccosus* lasted significantly longer (0.7 days). Males generally developed faster than females, except on *A. floccosus* where the duration of development for males and females was the same (20.3 days).

Table 1. Analysis of variance (ANOVA) for the duration of development (days  $\pm$  SE) of various life stages of *N. bicolor* on three aleyrodid prey species

Life stage	A. cocois	N	A. pulvinatus	N	A. floccosus	N	F (F critical)	P
Egg	5.42 $\pm$ 0.09	55	5.32 $\pm$ 0.12	37	5.50 $\pm$ 0.10	28	0.61 (3.07)	NS
1 <sup>st</sup> instar	2.15 $\pm$ 0.07	54	2.42 $\pm$ 0.16	36	2.11 $\pm$ 0.08	27	1.25 (3.08)	NS
2 <sup>nd</sup> instar	2.39 $\pm$ 0.18	54	2.19 $\pm$ 0.15	36	1.88 $\pm$ 0.11	27	1.93 (3.08)	NS
3 <sup>rd</sup> instar	3.06 $\pm$ 0.19**	52	3.00 $\pm$ 0.26	34	1.72 $\pm$ 0.12	25	10.11 (3.08)	9.45 E-05
4 <sup>th</sup> instar	3.82 $\pm$ 0.21**	51	3.70 $\pm$ 0.34**	30	2.48 $\pm$ 0.13	25	7.41 (3.08)	9.91 E-04
Total larval stage	11.39 $\pm$ 0.32**	51	11.10 $\pm$ 0.47**	30	8.24 $\pm$ 0.19	25	19.3 (3.08)	7.79 E-08
Prepupa	1.65 $\pm$ 0.11	48	1.55 $\pm$ 0.14	29	1.64 $\pm$ 0.14	25	0.16 (3.09)	NS
Pupa	4.19 $\pm$ 0.08**	47	4.27 $\pm$ 0.11**	29	4.96 $\pm$ 0.10	24	17.53 (3.00)	3.09 E-07
Total duration	22.45 $\pm$ 0.39**	47	22.28 $\pm$ 0.60**	29	20.33 $\pm$ 0.20	24	5.52 (3.09)	NS
Male	21.20 $\pm$ 0.54	20	21.85 $\pm$ 1.05	13	20.38 $\pm$ 0.31	14	1.12 (3.21)	NS
Female	23.37 $\pm$ 0.48**	27	22.88 $\pm$ 0.70**	16	20.30 $\pm$ 0.21	10	6.35 (3.18)	0.00378

\*, \*\* Denotes values that are significantly different from corresponding values for *A. floccosus*. There were no significant differences between values for *A. cocois* and *A. pulvinatus*; NS = not significant

Differences in growth parameters became evident from the 2<sup>nd</sup> instar when *N. bicolor* larvae reared on *A. cocois* and *A. pulvinatus* had significantly ( $p < 0.01$ ) wider head capsules compared to those on *A. floccosus* (Table 2). As development continued, the trends changed, and in the end, head capsules adults reared on *A. floccosus* were found to be the widest and those on *A. pulvinatus* the least wide (Table 2). Adult females were larger than males on all three prey species.



Table 2. Means and ANOVA for measurements (in mm) of various life stages of *N. bicolor* reared on three aleyrodid prey species

Life stage	<i>A. cocois</i>	N	<i>A. pulvinatus</i>	N	<i>A. floccosus</i>	N	F (F critical)	P-value
Egg – length	0.402±0.002	57	0.400±0.002	4	0.404±0.002	2	0.363	NS
Egg – width	0.202±0.001		0.203±0.002	3	0.205±0.002	8	(3.069)	NS
1 <sup>st</sup> instar <sup>a</sup>	0.143±0.002	55	0.147±0.002	3	0.141±0.003	2	0.949	NS
2 <sup>nd</sup> instar	0.225±0.003	55	0.227±0.003 <sup>**</sup>	3	0.214±0.002	2	1.871	0.011
3 <sup>rd</sup> instar	0.292±0.004	54	0.319±0.007 <sup>(**)</sup>	3	0.305±0.003	2	(3.073)	0.000
4 <sup>th</sup> instar	0.398±0.003	52	0.405±0.004 <sup>**</sup>	3	0.425±0.004	2	7.900	6
Pupa – width	1.040±0.007	47	1.029±0.011 <sup>**</sup>	3	1.132±0.010	2	(3.076)	2.71
Adult length	1.478±0.013	47	1.420±0.010 <sup>**</sup>	3	1.516±0.004	2	14.47	E-06
Adult width	0.994±0.010		0.964±0.010 <sup>(*)</sup>	0	1.056±0.010	4	31.92	2.00
							(3.089)	E-11
							11.87	2.40
							(3.089)	E-05
							17.09	4.30
							(3.089)	E-07

a. values correspond to the width of the head capsule for instars 1 to 4.

\*\* denotes values that are significantly different (p<0.01) from corresponding values for *A. floccosus*

(\*), (\*\*) denote values that are significantly different (p<0.05, p<0.01) between *A. cocois* and *A. pulvinatus*

Newly-emerged adult *N. bicolor* mated 5-10 days after emergence. Thereafter, mating occurred repeatedly throughout life. The mean preoviposition period ranged from 10.0-10.4 days on the three aleyrodids. Average longevity of 74, 51 and 66 days and a life-time fecundity of 92, 51 and 85 eggs were recorded on *A. cocois*, *A. pulvinatus* and *A. floccosus*, respectively. Significant differences (p<0.05) occurred only between the oviposition on *A. pulvinatus* and the other two species (Table 3). Average number of eggs oviposited per day by *N. bicolor* females on *A. cocois* and *A. pulvinatus* was significantly (p<0.05) lower than those oviposited on *A. floccosus*.

Table 3. Analysis of variance (ANOVA) for four reproductive biology parameters<sup>a</sup> of *N. bicolor* on three aleyrodid prey species

Parameter	<i>A. cocois</i> <sup>b</sup>	<i>A. pulvinatus</i> <sup>c</sup>	<i>A. floccosus</i> <sup>d</sup>	F <sup>e,f</sup>	P-value
Preoviposition period (range)	10.2±0.65 (7-13)	10.4±0.47 (7-13)	10.0±0.52 (8-13)	0.79	NS
Longevity (range)	74.5±11.65 (39-164)	50.6±7.82 (23-115)	66.0±7.57 (24-113)	1.91	NS
Fecundity (range)	93.2±11.83 (47-164)	51.0±8.68* (16-124)	84.7±13.01 (29-179)	4.37	0.02
Mean no. of eggs /day	1.12±0.07	1.12±0.06	1.43±0.08*	4.19	0.017

a. Reproductive biology parameters = preoviposition period (in days), longevity (in days) and fecundity (mean no. of eggs per female), and mean no. of eggs / day

b. *A. cocois* (N = 10); c. *A. pulvinatus* (N = 14); d. *A. floccosus* (N = 10)

e. F critical = 3.305 for preoviposition period, longevity and fecundity

f. F critical = 3.071 for mean no. of eggs per day

\* denotes values significantly different ( $p < 0.05$ ) from corresponding values for the other two aleyrodid species

Like many coccinellids, *N. bicolor* females were synovigenic and produced eggs in batches of 3-4 throughout life. The eggs were inconspicuous and usually laid flat. Most were oviposited in the flocculent material produced by the whiteflies. Although eggs were mostly found singly, two or three eggs laid closely together were also recorded on a few occasions. Life table parameters of *N. bicolor* on the three aleyrodids are summarized in Table 4 and survival and age-specific fecundity is depicted in Figure 1. Values of several parameters ( $r_m$ , DT and  $\lambda$ ) were very similar for *N. bicolor* reared on *A. cocois* and *A. floccosus*, but on *A. pulvinatus* were much lower for  $r_m$  and  $\lambda$  and correspondingly higher for DT.

### ***Adaptability studies***

Larvae of *N. bicolor* reared on *A. cocois* and transferred to *A. pulvinatus* and *A. floccosus* readily adapted to the new prey species. They began feeding within a short time and continued to develop normally. Small differences in the duration of development of various stages were not significant. Similarly, small non-significant differences were noted in the size of the head capsule of the 4<sup>th</sup> instar, width of pupa and length and width of adults reared on the three prey species. There was no mortality in larvae reared on *A. cocois* and *A. pulvinatus*. One pupa failed to develop on *A. floccosus*. Sex ratio (male : female) of *N. bicolor* adults was female-biased on *A. cocois* (1.0 : 1.5) and *A. pulvinatus* (1.0 : 1.75) and male-biased on *A. floccosus* (1.5 : 1.0)

Table 4. Life table statistics of *Nephaspis bicolor* on three aleyrodid prey species

Parameter	<i>A. cocois</i>	<i>A. pulvinatus</i>	<i>A. floccosus</i>
Net reproductive rate ( $R_0$ ) (females per female per generation)	38.42	17.17	37.80
Intrinsic rate of increase ( $r_m$ ) (female progeny/female/day)	0.0689	0.0530	0.0692
Generation time (G) (days)	67.80	63.38	64.15
Doubling time (DT) (days)	10.06	13.08	10.02
Innate capacity for increase ( $\lambda$ ) (females per female/day)	1.071	1.054	1.072

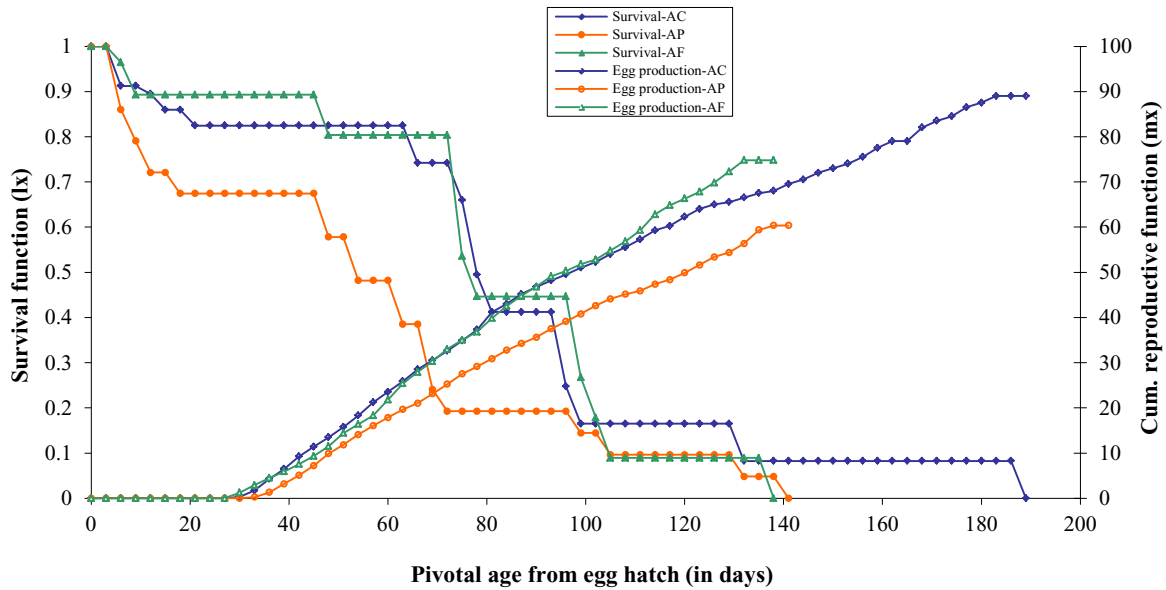


Figure 1. Comparison of survival and age-specific fecundity of female *N. bicolor* reared on *Aleurodicus cocois* (AC), *A. pulvinatus* (AP) and *Aleurothrixus floccosus* (AF).

*Nephaspis bicolor* reared on *A. cocois* to pupal stage and transferred as newly-emerged adults to *A. pulvinatus* and *A. floccosus* had significantly longer preoviposition period, compared to those transferred to *A. cocois* (Table 5). Adult longevity was on par on the three prey species, however, significantly more eggs were oviposited on *A. floccosus* and *A. cocois*, compared to *A. pulvinatus*.

Among the reproductive biology parameters, only the preoviposition period was significantly affected when the prey species were switched, while longevity and fecundity were on par (Table 6). Although prey switching increased longevity and fecundity of *N. bicolor* on *A. pulvinatus*, there was a reduction of about 2.6% in the average daily egg production in the *N. bicolor* females switched to *A. pulvinatus*. On *A. floccosus*, increased longevity and fecundity translated into a 4.3% increase in daily egg production in the switched females. Life table parameters of *N. bicolor* transferred to the three Aleyrodidae are presented in Table 7. Transfer from *A. cocois* to *A. pulvinatus* resulted in a reduction in the overall performance of the predator when compared to *A. cocois*. On *A. floccosus*, although values of  $R_0$  were higher than those on *A. cocois*, a reduction in  $r_m$  led to an increase in GT and DT and a corresponding decrease in  $\lambda$ .

Table 5. Analysis of variance (ANOVA) for four parameters<sup>a</sup> of the reproductive biology of *N. bicolor* reared on *A. cocois* and switched as newly-emerged adults to *A. cocois*, *A. pulvinatus* and *A. floccosus*

Parameter	<i>A. cocois</i> <sup>b</sup>	<i>A. pulvinatus</i> <sup>c</sup>	<i>A. floccosus</i> <sup>d</sup>	F <sup>e,f</sup>	P-value
Preoviposition period (range)	10.2±0.65 (7-13)	16.0±1.11** (12-24)	14.8±0.94** (10-20)	11.1 3	0.0003
Longevity (range)	74.5±11.66 (39-164)	71.2±0.13.09 (24-152)	80.9±0.23 (53-119)	0.30	0.743
Fecundity (range)	93±12.6 (47-164)	61±0.14.5 (11-154)	104±12.0 (58-171)	2.86	0.075
Mean no. of eggs/day	1.12±0.07**	1.09±0.05**	1.45±0.07	8.37	0.0004

a. Reproductive biology parameters: as in Table 3

b, c, d N=10 for *A. cocois*, *A. pulvinatus* and *A. floccosus* each

e. F critical = 3.354 for preoviposition period, longevity and fecundity

f. F critical = 3.064 for mean no. of eggs per day

\*\* denotes that values are significantly different ( $p < 0.01$ ) from corresponding values for *A. cocois* (for preoviposition period) and for *A. floccosus* (for mean no. of eggs per day)

Table 6. Analysis of variance (ANOVA) for four parameters<sup>a</sup> of the reproductive biology of *N. bicolor*, comparing adults reared on the same aleyroidid prey species and those switched from another aleyroidid

Parameter	Same prey <sup>b</sup>	Prey switched <sup>c</sup>	F value <sup>d,e</sup>	P-value
<i>A. pulvinatus</i>				
Preoviposition period (range)	(N=10) 10.5±0.47 (7-13)	(N=14) 16.0±1.11 (12-24)	25.97	4.2E-05
Longevity (range)	50.6±7.82 (23-115)	71.2±8.40 (24-152)	1.607	0.220
Fecundity (range)	51.0±8.7 (16-124)	61.8±14.49 (14-154)	0.434	0.517
Mean no. of eggs / day	1.12±0.059	1.09±0.046 (-2.6%)	0.105	0.747
<i>A. floccosus</i>				
Preoviposition period (range)	(N=10) 10.0±0.52 (8-13)	(N=10) 14.8±0.94 (10-20)	20.01	0.0003
Longevity (range)	66.0±7.6 (24-113)	80.9±8.05 (53-119)	1.817	0.194
Fecundity (range)	84.70±13.01 (29-179)	104.10±12.02 (58-171)	1.198	0.288
Mean no. of eggs per day	1.39±0.08	1.45±0.07 (+4.3%)	0.329	0.568

a. Reproductive biology parameters: same as in Table 3

b. Newly emerged adults transferred to same prey species i.e. from *A. pulvinatus* to *A. pulvinatus*, and *A. floccosus* to *A. floccosus*, respectively

c. Larvae reared on *A. cocois* and switched as newly-emerged adults to *A. pulvinatus* or *A. floccosus*

d. F. critical = 4.301 (*A. pulvinatus*) and 4.414 (*A. floccosus*) for preoviposition period, longevity and fecundity

e. F critical = 3.96 (*A. pulvinatus*) and 3.98 (*A. floccosus*) for mean no. of eggs per day

Table 7. Life table statistics of *N. bicolor* upon transfer from *A. cocois* to the same and two other aleyrodid prey species.

Parameter	<i>A. cocois</i> to <i>A. cocois</i>	<i>A. cocois</i> to <i>A. pulvinatus</i>	<i>A. cocois</i> to <i>A. floccosus</i>
Net reproductive rate ( $R_0$ ) (females/female/ generation)	38.43	25.48	42.92
Intrinsic rate of increase ( $r_m$ ) (female progeny/ female/day)	0.0689	0.0515	0.0555
Generation time (G) (days)	67.82	79.10	79.10
Doubling time (DT) (days)	10.06	13.46	12.49
Innate capacity for increase ( $\lambda$ ) (females/female/day)	1.071	1.053	1.057

A comparison of the survival and reproductive functions of *N. bicolor* on three aleyrodids (transferred from *A. cocois* as newly-emerged adults) is provided in Figure 2. The effect of prey switching on the survival and reproduction on *A. pulvinatus* and *A. floccosus* are depicted in Figures 3 and 4, respectively.

Longevity was the key factor in the observed fecundity on all three prey species, since the longer the adults lived, the more eggs they laid. Oviposition rate was quite similar on same and switched prey species for both *A. pulvinatus* and *A. floccosus*.

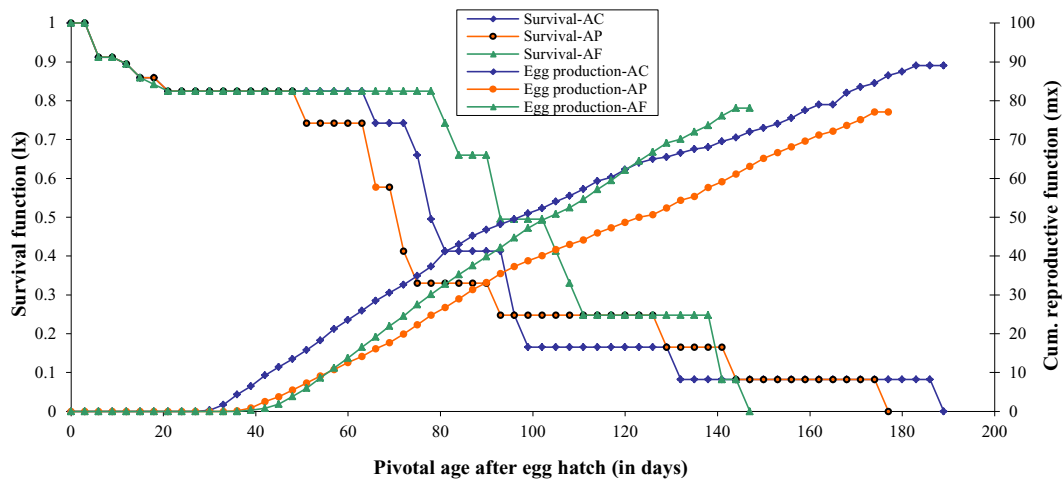


Figure 2. Comparison of age specific survival and cumulative reproduction (females/females) of *N. bicolor* reared on *A. cocois* and transferred *A. cocois* (AC), *A. pulvinatus* (AP) and *Aleurothrixus floccosus* (AF).

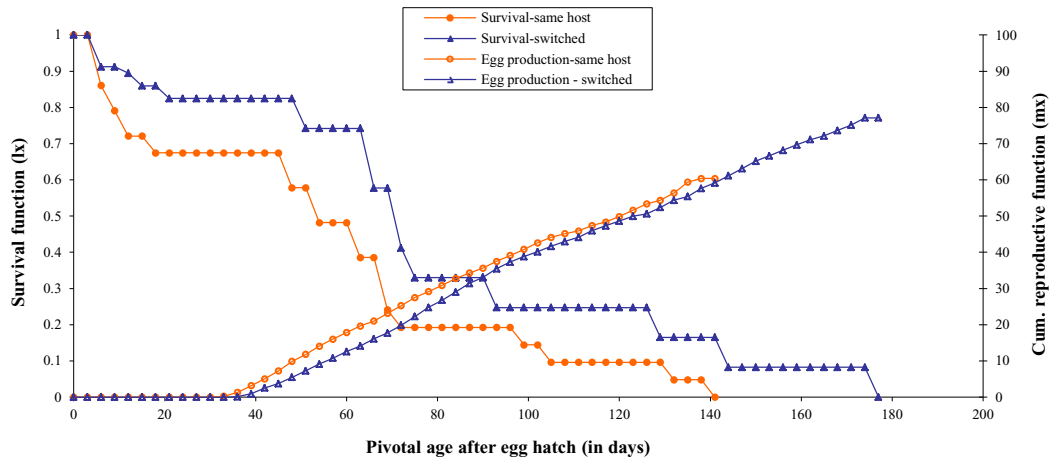
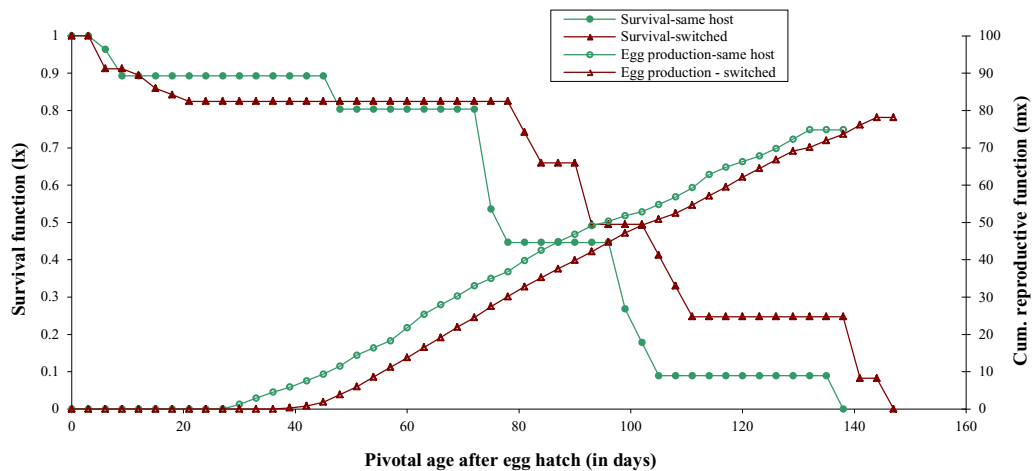


Figure 3, Comparison of age specific survival and cumulative reproduction (females/females) of



*Nephaspis bicolor* reared on *A. pulvinatus* and switched from *A. cocois*

Figure 4. Comparison of age specific survival and cumulative reproduction (females/females) of *N bicolor* reared on *A. floccosus* and switched from *A. cocois*

## DISCUSSION

Results from the present study suggest that the whitefly prey species do have an impact on several biological parameters of *N. bicolor*, in particular duration of development, sex ratio, size, longevity and life-time fecundity. Among the three aleyrodids studied, *A. floccosus* was the most suitable prey in terms of developmental period of *N. bicolor* while *A. pulvinatus* and *A. cocois* were on par. This was, however, counteracted to some extent by the sex ratios, which were female-biased on *A. cocois* (1.0:1.35) and *A. pulvinatus* (1.0 : 1.23) but were in favour of males on *A. floccosus* (1.5:1.0). However, the number of insects used in the experiment was too small to draw any firm conclusions on the effect of prey species on the sex ratio.

All stages of *N. bicolor*, except the egg and pupa, fed on all stages of the whiteflies. Younger instars preferred eggs and early stages of the prey while older instars preferred later stages and

pupae. The developmental biology of *N. bicolor* on *A. cocois* was comparable to three other *Nephaspis* spp.: *N. cocois* Gordon, *N. indus* Gordon and *N. oculata* Blatchley reared on *A. cocois*, *A. dispersus* and *B. tabaci* B, respectively (Carvalho, 1976; Liu *et al.*, 1997; Yoshida and Mau, 1985). Preferred prey stages for *N. oculata* were eggs of *B. tabaci* B (Liu *et al.*, 1997) and for *N. indus* nymphs of *A. dispersus* although all stages were fed upon (Yoshida and Mau, 1985).

Reproductive parameters of *N. bicolor*, *N. indus* and *N. oculata* were also comparable. Females were synovigenic and oviposition occurred throughout life. Longevity of the adults was thus a key factor, since the longer they lived, the more eggs they oviposited. An average of 67-75% of eggs was oviposited by *N. bicolor* during the first 50 days after the commencement of oviposition, compared to *N. indus* females which laid 'most of their eggs' within 49 days of an ovipositional period of  $131 \pm 35$  days (Yoshida and Mau, 1985). Rate of oviposition in both *N. oculata* and *N. indus*, averaging 3 eggs per day, was however much higher than the average of 1.12 - 1.45 recorded for *N. bicolor* (Liu *et al.*, 1997; Yoshida and Mau, 1985). Based on the fecundity life table analysis, the overall performance of *N. bicolor* on *A. cocois* and *A. floccosus* was on almost on par and was superior compared to that on *A. pulvinatus*. The  $r_m$  values of 0.0689, 0.053 and 0.0692 on the three species, though lower than that of *N. oculata* (0.078), was well within the expected range of 0.05-0.08 for species feeding on aleyrodids and scales.

Based on the present study, *N. bicolor* larvae and adults are clearly adaptable to new aleyrodid prey species. Switching of larvae reared on *A. cocois* to *A. pulvinatus* or *A. floccosus* did not impact on feeding, survival and duration of development of the larvae or size of the emerging adults. Such was not the case with *Chilocorus nigrata* (Fabricius) where prey switching to (normally) suitable prey species resulted in significantly retarded larval development rate and produced smaller adults (Hattingh and Samways, 1992). According to Ipert (1978), the true effects of prey preferences in predacious coccinellids can only be determined from the extent to which progeny are produced. Prey switching had little or no effect on the longevity and fecundity of the adults of *N. bicolor*. The only parameter affected was the preoviposition period, which was significantly longer in the switched adults. Prey switching of ovipositing adults to normally suitable prey resulted in short-term suppression in oviposition and feeding rates in adult *Chilocorus nigritus* (Hattingh and Samways, 1992). The changes in the life table parameters of *N. bicolor* after prey switching reflected slight, insignificant enhancements or reductions in the overall performance of the predator.

## CONCLUSIONS

The present study confirms *N. bicolor* as an oligophagous predator that is able to adapt with little difficulty to new prey species, both in subfamily Aleurodicinae and Aleyrodinae. Indeed, during field surveys in Trinidad and Tobago, *N. bicolor* and *Nephaspis* spp. were consistently found on several wax-producing aleyrodids and it is suggested the presence of waxes may be an important factor that determines the suitability of a prey species for oviposition (Lopez and Kairo, 2003). If chemical cues from waxes are used for oviposition, then this narrows down the range of potential prey species that may be attacked by *N. bicolor*. But it also means that if and when introduced, *N. bicolor* can adapt to attacking and feeding on a fairly wide range of wax-producing Aleyrodidae. In Hawaii, *N. indus* was found attacking *A. floccosus* and *O. mammaeferus*, both Aleyrodinae, following its introduction (Yoshida and Mau, 1985). There are other instances

where predatory coccinellids introduced for the control of one prey species were found attacking other species. Usually these consisted of members of the same family (e.g. *Hyperaspis notata* (Mulsant) and *Rodolia cardinalis* Mulsant) Ragab, 1995; Staubli *et al.*, 1997), but occasionally other families were also attacked (e.g. *Cryptolaemus montrouzieri* Mulsant) (Mani and Krishnamoorthy, 1999). Sands (1997) contends that the development of an exotic natural enemy on native species may be acceptable, provided the benefits achieved from the control of the pest species are considered worth the risk of reduced numbers of indigenous flora or fauna. It is recommended that the above factors should be considered in any evaluation of *N. bicolor* and decision-making for its introduction.

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Education/Extension

**ANALYSIS AND THEMATIC, INSTITUTIONAL AND GEOGRAPHICAL MAPPING OF CFCS PUBLICATIONS IN THE 21ST CENTURY**

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**Abstract:** The Caribbean Food Crops Society (CFCS) is celebrating its 50th annual meeting. This oral presentation responds to thoughts that have hosted the General Assembly of members in recent years and the work of the Strategic Planning Committee which CFCS has created since 2008. Authors propose to return to the work that has been presented in the CFCS meetings that occurred in recent years to provide some assistance to the prospective analysis needed to better plan the future of our Society of the Caribbean. It involves organizing the information contained in the last twelve "proceedings" edited (2000-2012) and analyze this information in terms of thematic, geographical, institutional developments... A bibliographic database "CFCS data" was constructed using methodological guides available at INRA with a bibliographic software named End-Note X7™. It was fueled by the records of papers presented at the CFCS, available in different bibliographic databases (CAB ProdINRA...) and manually completed for all non-indexed records elsewhere. The corpus data thus formed was then subjected to a quality treatment, then coded to meet the objectives. Through several bibliometric analysis of this corpus, indicators have been developed. They allow to characterize the preferred themes and their evolution, the contributions of different countries, including those of the French Antilles, the influence of the host country on the institutional distribution and geographical origin of the contributions, the dynamics of the networks backed to the CFCS (activation, maturation, decreasing, recovery...). This work has contributed to more synthetic and therefore more accessible content of the "proceedings" published by the CFCS. This increasing accessibility and visibility should facilitate the opening of our fiftieth association to new members in order to evolve along with the issues being addressed by the technical assessors, trainers, policy makers, farmers and scientists of all the agricultural Caribbean.

**Keywords:** Bibliometric treatment, Caribbean, Cooperation, Balance production, Prospective

La Caribbean Food Crops Society (CFCS) célèbre cette année sa 50<sup>e</sup> réunion annuelle. La présente communication fait suite aux réflexions qui ont animé l'Assemblée Générale des membres ces dernières années et aux travaux du Comité d'Orientation Stratégique dont la CFCS s'est dotée depuis 2008. Les auteurs proposent de revenir sur les travaux qui ont été présentés lors des réunions de la CFCS intervenues au cours des dernières années afin d'apporter des éléments d'aide à l'analyse prospective pour mieux envisager le futur de cette Société savante de la Caraïbe. Il s'agit d'organiser l'information contenue dans les douze derniers "proceedings" édités (2000-2012) et d'analyser cette information en termes d'évolutions thématique, géographique, institutionnelle... Une base de données bibliographique "Données CFCS" a été

construite à l'aide des guides méthodologiques disponibles à l'INRA avec le logiciel bibliographique End-Note X7™. Elle a été alimentée par les notices des communications présentées à la CFCS, disponibles dans différentes bases de données bibliographiques (CAB, ProdInra...) et complétée manuellement pour toutes les notices non indexées par ailleurs. Le corpus de données ainsi constitué a ensuite fait l'objet d'un traitement-qualité, puis d'un codage pour répondre aux objectifs fixés. Grâce à plusieurs analyses bibliométriques réalisées sur ce corpus, des indicateurs ont été élaborés. Ils permettent de caractériser les thématiques privilégiées et leur évolution, les contributions des différents pays et notamment celles des Antilles françaises, l'influence du pays organisateur sur la distribution institutionnelle et géographique d'origine des contributions, la dynamique des réseaux adossés à la CFCS (activation, maturation, décroissance, relance...). Ce travail a contribué à rendre plus synthétique et donc plus accessible le contenu des "proceedings" publiés par la CFCS. Cette accessibilité et cette visibilité accrues devraient faciliter l'ouverture de notre association cinquantenaire à de nouveaux membres de manière à la faire évoluer en même temps que les problématiques abordées actuellement par les conseillers techniques, les formateurs, les décideurs politiques, les producteurs et les scientifiques de toute la Caraïbe agricole.

**Traitement bibliométrique, Caraïbe, Coopération, Bilan de production, Prospective**

**IDENTIFYING TRAINING NEEDS OF EXTENSION OFFICERS IN THE CARIBBEAN COMMUNITY (CARICOM)**

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**Abstract:** The Caribbean Agricultural Extension Project (CAEP) provided regional trainings annually for extension officers in the Caribbean until it ended in 1992. The lack of coordinated, regular, regional trainings has created a void that should be addressed. The purpose of this research was to determine training needs for specific competencies based on gaps between extension officers' perceptions of importance and knowledge and gaps between knowledge and application. A questionnaire with eight competency areas: Professionalism and Professional Development, Extension Organization and Administration, Program Planning and Development, Extension Teaching Tools and Methods, Evaluation of Extension Programs, Information and Communications Technologies, Subject Matter Expertise, and External Linkages, was modeled after an instrument used by Awang(1992) with input from experts in the field from Florida and the Caribbean. Extension officers from Antigua and Barbuda, Anguilla, Barbados, Belize, Cayman Islands, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Trinidad, and Tobago completed the self-administered questionnaire. The Borich (1980) needs assessment model was used to measure respondents' perception on the eight competency areas identified. The participants rated their perception of importance, knowledge, and application of 102 competency items on a five-point scale. The data was analyzed using descriptive statistics and ranking procedure (Edwards and Briers, 1999). The results showed that extension officers within CARICOM are very knowledgeable in all competency areas and needed training on only five competency items. Training is needed on the ability to apply their knowledge on 55 competency items. Competency areas where priority should be given to training extension officers on application of their knowledge are: Evaluation of Extension Programs, Subject Matter Expertise, External Linkages, Program Planning and Development Extension Teaching Tools and Methods, and Information and Communications Technologies.

**Keywords:** extension officers, competencies

**DIAGNOSIS FOR THE IMPLEMENTATION OF A STRATEGIC PLAN FOR SUSTAINABILITY OF SMALL FAMILY FARMS, ESSENTIAL ELEMENTS OF AGRICULTURE AND RURALITY IN GUADELOUPE**

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**Abstract:** In Guadeloupe, more than 80% of farms fall into the category of small family farms. Despite the implemented public policies, the census data analysis shows that they are the first to disappear and therefore probably the most vulnerable. In this year of the family farming (FAO), the authors of this paper want to take a fresh overlook at the Caribbean small family farms particularly in Guadeloupe, to better consider their preservation, dealing with the uncertainties that may threaten their viability. The agricultural census data were studied over a long time (farm size, family labour, etc...), recent survey data about Guadeloupe farmers were recovered, experts were consulted for their perspective on the evolution of agriculture of Guadeloupe and their analysis of the determinants of the vulnerability of small family farms. Like the existing dynamics in most of the Caribbean countries, the weight of agriculture is gradually reduced in the production of wealth in Guadeloupe territory. In particular, numbers of farms and farms' workers are in sharp decline. In this context, multi-activity which is widespread corresponds to adaptation strategies to the partial and random nature of agricultural income. These are smaller farms which disappear mostly causing an increase in the average farm size without necessarily any linked concentration by land purchasing. Thus, most of the agricultural land which is no longer valued leaves the bosom of agriculture. Most farms fell in structured export sectors on one side, while often achieved operating through internal marketing activities with food crops and livestock on the other side, and thus developing multispecies farming systems. This reality put question as Research must consider the adequacy of technical innovations proposed, while the state agricultural services and Chamber of Agriculture must consider instruments to better support these farmers who are the core of the territory's agriculture.

**Keywords:** Family farming, Small farms, Guadeloupe, agricultural abandonment, support

Diagnostic pour l'élaboration d'un plan stratégique de pérennisation des petites exploitations familiales, mailles élémentaires essentielles de l'agriculture et de la ruralité en Guadeloupe. En Guadeloupe, plus de 80% des unités de production agricole rentrent dans la catégorie des petites exploitations familiales. En dépit des politiques publiques mises en œuvre, l'analyse des données censitaires révèle qu'elles sont les premières à disparaître et donc vraisemblablement les plus vulnérables. En cette année de l'agriculture familiale (FAO), les auteurs de la présente contribution veulent jeter un regard neuf sur les petites exploitations agricoles familiales caribéennes particulièrement en Guadeloupe, pour mieux envisager leur préservation face aux incertitudes qui menacent leur viabilité. Les données des recensements agricoles ont été étudiées sur le temps long (taille des exploitations, part de l'activité familiale, etc...), des données d'enquête récentes réalisées auprès d'exploitants de Guadeloupe ont été valorisées, des experts ont été consultés pour leur recul sur les évolutions de l'agriculture guadeloupéenne et leur analyse des déterminants de la vulnérabilité des petites exploitations agricoles familiales. A

l'instar de la dynamique existant dans la plupart des pays de la Caraïbe, le poids de l'agriculture s'est progressivement réduit dans la production de richesse du territoire guadeloupéen. En particulier, le nombre d'exploitations et d'actifs agricoles sont en nette régression. Dans ce contexte, la pluriactivité correspondant à des stratégies d'adaptation au caractère partiel et aléatoire des revenus agricoles, est omniprésente. Ce sont les plus petites exploitations qui disparaissent majoritairement provoquant un accroissement de la taille moyenne des exploitations sans qu'il n'y ait nécessairement de concentration par rachat. L'essentiel du foncier agricole qui ainsi n'est plus valorisé quitte le giron de l'agriculture. Ces exploitations s'inscrivent pour la plupart dans une des filières structurées pour l'exportation, tout en fonctionnant souvent grâce à une activité de commercialisation de productions destinées au marché local et en développant donc des systèmes de production multiespèces. Cette réalité interpelle tant la Recherche qui doit réfléchir à l'adéquation des innovations techniques proposées, que les services de l'Etat et de la Chambre d'Agriculture qui se doivent d'envisager des instruments pour mieux accompagner ces producteurs qui constituent l'essentiel du tissu agricole du territoire.

**Mots clés:** Agriculture familiale, Petites exploitations, Guadeloupe, déprise agricole, accompagnement

**ENHANCING CARIBBEAN FAMILY FARMERS THROUGH A COURSE IN LEADERSHIP DEVELOPMENT**

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**Abstract:** The challenges of farmers in the Caribbean have been well documented. However, it appears that less has been shared about the opportunities these same farmers have. Organizations exist which provide targeted instruction to this group relative to the five most common areas of agricultural risk: production, marketing, financial, human resource and legal. Whereas this type of information is needed and provides small farmers with some of the tools they need to successfully operate their farms; this instruction is not inclusive of all they need to know. It appears that very limited information is available on providing farmers in the Caribbean with the tools to become better agricultural leaders and how to make better farm related decisions. Small scale, limited resource farmers in the southern regions of the United States, have had the benefit of participating in this type of training, thus becoming better leaders and decision makers as a result of the Southern University Agricultural Research and Extension Center's Small Farmer Agricultural Leadership Institute, which began in 2005. Small-scale farmers who have successfully completed this class have gone on to become decision makers in the agriculture arena. They serve on local, state, regional and national governing / advisory boards, as policy makers and small farm representatives on USDA boards, a few even appointed by the US Secretary of Agriculture. In a recently published profile of small-scale farming in the Caribbean, it was observed that many small farmers of this region seem to have some of the same challenges as small, limited resource farmers in the southern portion of the United States. If this is the case, then it might be worthwhile to offer these farmers the same type of training which has benefitted southern US farmers in leadership development.

**Keywords:** small farmers, leadership development, farmer training, agricultural risk management

**Proceedings of the Caribbean Food Crops Society. 50:127. 2014**

**SOUTHERN SARE RESEARCH & EDUCATION: FUNDING AND OUTREACH OPPORTUNITIES FOR RESEARCHERS**

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**Abstract:** Southern Sustainable Agriculture Research & Education (SARE) is a USDA-funded program that, for 25 years, has been providing grant funding and outreach opportunities for researchers across the Southern region to conduct sustainable agriculture research practices and techniques. U.S. Virgin Islands and Puerto Rico fall within our region, and while we have funded sustainable agriculture projects out of both protectorates, we continue to strive to support researchers and educators as they explore practices that improve stewardship, profitability, and the social and economic health of farm communities. This oral presentation is intended to introduce researchers and educators to the SARE program, our grants programs, and how to apply. In addition, the presentation will cover some of the grant projects that have been funded in the past, and the research opportunities available to grantees related to the conference theme, “Enhancing Family Farms through Sustainable Energy, Research and Technology.” The oral presentation will include a Power Point presentation and supporting Southern SARE publications and outreach materials.

**Keywords:** Grants, Outreach, Education, Sustainable Agriculture



**Proceedings of the Caribbean Food Crops Society. 50:128. 2014**

**ADVANCING SUSTAINABLE AG INNOVATIONS: SOUTHERN SARE FUNDING OPPORTUNITIES FOR PRODUCERS**

James Hill, Southern SARE/Fort Valley State University, P.O. Box 4061, Cooperative Extension Program, Fort Valley, GA 31030 Email: hillj@fvsu.edu

**Abstract:** For 25 years, the Southern Sustainable Agriculture Research & Education (SSARE) program has been supporting farmers as they explore sustainable agriculture practices that improve environmental stewardship, farm profitability, and the social and economic health of farm and rural communities. The primary tools of the SARE program are grants, which are offered annually in an effort to help develop new approaches and new ideas. In addition, SARE emphasizes outreach and the dissemination of project results so that the grant program will have the widest possible benefit. In Puerto Rico, SSARE has offered funding opportunities for seven Producer Grant projects. In the Virgin Islands, we have yet to fund a Producer Grant sustainable agriculture project. The purpose of this oral presentation is to introduce farmers to the SARE program and the funding opportunities that are available for those interested in sustainable agriculture research, education and outreach, as well as encourage farmer/researcher/educator/community collaboration on sustainable agriculture efforts supported by the Southern SARE program. The oral presentation will include a Power Point presentation, along with supporting relevant SSARE publications and outreach materials.

**Keywords:** Grants, Farmers, Sustainable Agriculture, Education, Outreach, Collaboration

Environmental and Energy Concerns

**EXTRA VIRGIN COCONUT OIL [EVCO]: II. PHYSIO-CHEMICAL ANALYSIS AS A BIO-FUEL**

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**Abstract:** Biofuel is a renewable fuel constituting an alternative to fossil based diesel fuel. Coconut [ *Cocos nucifera* ] oil is widely used as a liquid biofuel that is clean, relatively cheap, easy to extract, non-toxic and aromatic. In addition to jatropha [*Jatropha carcas*] , moringa [*Moringa oliefera*] and castor bean [*Ricinus communis*] oils, the University of Trinidad and Tobago [UTT] in the Renewable / Bio-energy program is evaluating coconut oil, and other waste vegetable oils [WVO] as potential biofuel or bio-diesel blends. This study evaluated four sources/production process of coconut oil available in the local market and one extra-virgin coconut oil [EVCO] produced in UTT. The samples were prepared at the Waterloo Research Campus, and the analysis conducted at the Petrotrin Laboratory, Pointe-A-Pierre using the following methods DAF, D 4052, and D 486. The results indicated that there were no significant differences between the different types of coconut oil for Specific Gravity (0.919), Gravity (22.4 , AP1 @ 60°F), Ash (0.001% wt) and Cloud Point (20°F). However there were significant differences (P>0.05) between oil types for Flash Point (245 to 490°F) and Pour Point (6 to 18°F). There were significant (P>0.01) variations in total Sulphur content (0.02 to 0.009 % wt). All the samples have similar gross Calorific values (19130 BTU/lbs) and Net Calorific values (17973 BTU/lbs). These values were well within the ranges for bio-diesel ASTM standards.

**Keywords:** virgin coconut oil, bio-fuel, bio-diesel, calorific value, flash point.

**A SIMPLE WEB-BASED METHOD FOR SCHEDULING IRRIGATION IN  
PUERTO RICO AND THE U.S. VIRGIN ISLANDS**

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**Abstract:** Over application of irrigation water can lead to the waste of water, energy, chemicals and money, and also may lead to the contamination of ground and surface waters. Over application of water can further lead to leaching of fertilizers past the root zone and water logging, resulting in lower crop yields. Under-application of irrigation water can lead to water stress with reduced crop yields and a loss of revenue to the grower. There are various approaches for scheduling irrigation. One approach is to supplement rainfall with enough irrigation so that the cumulative rainfall and irrigation, over a specific period of time matches the estimated crop evapotranspiration. Crop evapotranspiration (ET<sub>c</sub>) can be estimated by the product of a crop coefficient (K<sub>c</sub>) and the reference evapotranspiration (ET<sub>o</sub>). In this study we present an approach based on applying irrigation to the crop to meet the crop water requirements derived from a remote sensing technique. Reference evapotranspiration is obtained from an operational water and energy balance algorithm (GOES-PREWEB) which produces a suite of hydro-climate variables on a daily basis for Puerto Rico and the U.S. Virgin Islands. The algorithm produces daily estimates of the Penman-Monteith, Priestly-Taylor and Hargreaves-Samani reference evapotranspiration. The crop coefficient curve is constructed per the methodology recommended by the United Nations Food and Agriculture Organization (FAO). Daily rainfall can be obtained from radar (NEXRAD) if rain gauge data is not available for the farm. A detailed example is provided for a farm growing tomato in Juana Diaz, Puerto Rico. The approach is relatively simple and the near-real time data is available to any farmer in with Internet access.

**Keywords:** Satellite remote sensing, evapotranspiration, irrigation, Puerto Rico, USVI, irrigation scheduling

**BUILDING SUSTAINABLE BIOMASS-BASED ENERGY SYSTEM FOR CARIBBEAN ISLANDS**

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**Abstract:** Interest in renewable energy from agricultural biomass has increased in recent years. Among renewable energy sources, biomass is considered indeed as an attractive option for sustainable energy production. This is particularly true in the case of small tropical island states, where energy demand is increasing and the energy mix currently heavily relies on fossil imported resources. Diversifying and orientating the energy mix toward locally grown energy crops could therefore be a promising sustainable option. However, the introduction of such bioenergy systems under existing conditions and current agricultural models is still rather uncertain and requires achieving several sustainable goals. In order to build new sustainable energy systems, modelling the biomass supply is a critical step prior to investment. In this paper we propose an original modelling framework in order to tackle this issue in an integrated approach. Our framework consists in the linkage of three types of models: 1) a biophysical crop model to simulate agronomic options (including choice of genotypes, crop and soil management), 2) a farm scale model aimed at simulating farmer's decisions to adopt growing biomass and 3) a spatially explicit model whose aim is to simulate at the regional scale the biomass supply and sustainability indicators. The framework is applied to the building of scenarios of fibercane-based energy systems at territorial scale in Guadeloupe, a small tropical island in the Caribbean. Through an optimisation module, it is possible to identify agro-economic scenarios of biomass systems satisfying multiple objectives and constraints in a sustainable way. We finally discuss about the genericity of our approach and on factors affecting the success of biomass systems implementation in small tropical island states.

**Keywords:** energy crops, sustainability, farm model, landscape scale

## EVALUATING RENEWABLE ENERGY OPTIONS FOR THE AGRICULTURE SECTOR IN SURINAME

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**Abstract:** The threat of climate change is one of the driving forces behind the development of renewable energy. Governments around the world, including Suriname, have committed themselves to reduce CO<sub>2</sub> emissions. The energy sector has proven to be the main source of CO<sub>2</sub> emissions. Therefore, countries have taken measures such as generation of electricity from bio energy to reach this reduction. The rapid introduction of renewable energy options is a success story in various parts of the world. It offers new economic perspectives for sectors such as agriculture. It can be integrated into farm activities and contributes to new employment opportunities. In lieu of this, a study was conducted in Suriname to consider renewable options in the agriculture sector and determine which policy measures are needed to minimize negative impacts. The approach used in this study included: (1) an assessment of the current renewable energy activities in Suriname; (2) a literature study based on the environmental impacts of renewable energy used in the agriculture sector and; (3) interviews with 50 key stakeholders on their opinions on renewable energy options, policies, and practical measures to ensure that renewable energy is produced in a sustainable manner. Results of the study include: (1) promotion of bio gas development as an effective way to solve environmental problems caused by bio waste; (2) limited information exists on the potential environmental impacts on bio-energy crops including maize, sugarcane, and jatropha in Suriname; (3) Further research and development is required on the management practices that can deliver both reductions in greenhouse gas savings and improve sustainability.

**Keywords:** Bioenergy, renewable energy, biofuel crops, agricultural waste

**CLIMATE CHANGE ADAPTATION IN SMALLHOLDER RICE FARMS IN GUYANA:  
THE SUCCESS STORY OF THE “SIX POINTS PRACTICE”**

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**Abstract:** Guyana’s Agriculture Sector contributes about 20 % to the Gross Domestic Product and is the source of livelihood for nearly 38 % of the population. This sector continues to grow and has been the key to poverty alleviation and overall economic development of the country and has been successful in keeping pace with the rising food demand of the country and the region as a whole. Rice (*Oryza sativa* L.) is the most important crop in Guyana. The production of this staple food has seen increased trend over the past 25 years recording the highest production of rice, 500,000 tons, in 2013. Today more than ever, increased food production depends on judicious use of resources. In addition, issues such as climate change, climate variability, and the long-term impact on food security and environmental sustainability, have become important. Many weather, soil, genetic and management factors affect the way the rice crop will respond to irrigation, fertilizer and other management practices. Determining appropriate crop management strategies under these uncertainties has major economic and environmental implications. The six point practices developed by the Guyana Rice Development Board have proven to be successful in all the rice growing regions of Guyana. In this study we examine the use of the six point practice to adapt to climate change in selected rice growing regions. The study found that the six point practicing farmers have recorded more than 25 % increase in yields compared to the conventional practices and thus farmers were able to record higher profits from their cultivation. The Extension Department of the Guyana Rice Development Board will continue to transfer this technology to rice farming communities so as to continue and enhance the development of the rice industry and the economy of Guyana

**Keywords:** Climate Change, Adaptation, Guyana, Six Points Practice

**AGROFORESTRY IN THE CARIBBEAN, TRADITIONAL SYSTEMS,  
BOTH SUSTAINABLE AND BIODIVERSE**

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**Abstract:** This presentation discusses various agroforestry practices as they are practiced in the islands in the Caribbean Sea. Agroforestry is association of crops and trees. It has been practiced since the dawn of agriculture, some 11,000 years ago since crops and trees were growing in proximity to each other. It is the oldest form of agriculture but on the most productive soils and on large properties has been supplanted by mechanized high input monocultures. Agroforestry is low input and tends to be practiced by small farmers on marginal soils. Since agroforestry is such an ancient practice, we would like to show the historical continuity of these practices from the Pre-Columbian times to the present. The authors live and work on the island of St Croix, US Virgin Islands, so there is going to be a certain emphasis on agroforestry as it is practiced on St Croix. We discuss forest gardens, home gardens of trees, shade grown crops, shifting agriculture and fallows, alley cropping and living hedges, and finally, silvopastoral systems.

***Drosophila suzukii*: A POTENTIAL THREAT TO SOFT FRUITS IN THE CARIBBEAN AND SOUTH AMERICA**

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**Abstract:** The spotted wing drosophila (SWD) (*Drosophila suzukii* Matsumura) is an invasive global pest that poses a serious threat to soft fruits in the Caribbean and South America. This pest was first recorded in southern Brazil from fruit samples collected from five localities during 2012 and 2013 field seasons. The spotted wing drosophila readily attacks most soft thin-skinned fruits. As the name suggests, SWD males have a distinct single black spot on the outer edge of each wing. Unlike other drosophila species that infest dead and decaying fruits, SWD females have a serrated ovipositor that is used to puncture ripe and ripening fruits. Adult flies are tan colored with red eyes, about 2-3 mm (1/8 inch) long. Eggs are deposited just below the surface of soft-skinned fruits leaving oviposition marks and respiratory tubes. The larval stages develop inside the fruit rendering it unmarketable. Effective management of SWD relies on a combination of strategies that include effective monitoring, use of reduced-risk pesticides (rotating among the various classes) and cultural control (removal of secondary host and ripe fruits). We evaluated a series of reduced-risk and conventional insecticides for control of SWD and recorded significant differences among treatments. Synthetic pyrethroids, Mustang (zeta-cypermethrin) and Hero™ (zeta-cypermethrin + bifentrin), as well as an anthranilic diamide, Exirel (Cyazapyr) were effective in reducing SWD population and a new chemistry, Apta (Tolfenpyrad) performed as well as the pyrethroids. Finally, a spinosad product, Entrust labelled for organic use was also effective in killing SWD flies.

**Keywords:** cooperativas, alimentación, modelo de gestión económica, actualización del modelo económico cubano.



**CAEPNET: INTEGRATING EXTENSION SYSTEMS IN THE CARIBBEAN**

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**Abstract:** The Caribbean Agricultural Extension Providers Network (CAEPNet) was officially launched by the Honourable Minister of Agriculture, Guyana Mr. Leslie Ramsammy. This event occurred on Wednesday 9<sup>th</sup> October during the 13<sup>th</sup> Caribbean Week of Agriculture, Guyana. Following the launch, Minister Ramsammy obtained the endorsement of CAEPNet at the Council for Economic Development (COTED). The Dean, Faculty of Food and Agriculture (FFA), Dr. Isaac Bekele represented the University of the West Indies (UWI) and indicated the institution's commitment to this new endeavour. The launch accompanied several relevant discussions in two panel discussions and regarding the current state of extension delivery in the Caribbean. These pertained to the potential changes in the region's extension systems. There was an attentive audience of 35 participants from Antigua and Barbuda, Barbados, Guyana, Jamaica, Saint Kitts Nevis, Tonga in the Pacific and Trinidad and Tobago. One farmer from Guyana attended the event. It was concluded that CAEPNet will continue to develop and would potentially contribute to improved Extension Advisory Services for the Caribbean region.

**Poster Presentations**

**FIELD FOOD SAFETY EDUCATION FOR STUDENTS WORKING IN SCHOOL GARDENS**

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**Abstract:** School gardens are often used as teaching tools to engage students in meaningful learning activities. To provide students the opportunity of eating healthy produce, many schools are considering the use of student-grown food in their cafeterias. To minimize the risk of illness, students and adults working in school gardens should know about pathogens that can contaminate produce in the field. This program was designed to teach students about microorganisms that cause foodborne illnesses, how to identify conditions in the field that may increase the risk of contamination, and how to develop and follow procedures that will reduce those risks. During the first session, middle school students learned basic course vocabulary that would be used. Each of the three 90 minute sessions consisted of activities that taught concepts through hands-on learning activities. Some activities included visiting the growing site where existing risk factors were assessed, growing yeast colonies and observing them under microscopes, and developing in-field procedures that students could follow to reduce risk. The average knowledge gain of the 34 participants was 74%, as indicated by pre and post-tests. However, 100% of the students indicated they would use this knowledge later in life. Due to the feedback and course success, a second presentation was made to teachers representing six different schools on how to incorporate these activities into their own school garden programs. Educating students about foodborne pathogens and risk management will improve the safety of school garden produce and provide students with important life skills.

**EXAMINING FARM TO SCHOOL NETWORKS IN INDIANA**

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**Abstract:** The national farm to school network movement is a rapidly growing model introducing school children to local foods and local farmers. Indiana formed an interest group in 2012 composed of producers, local chefs, school district food directors, distributors, state employees from department of health, education and agriculture and Extension specialists. This group called the Indiana Farm to School Network (IFSN) generated a list of items to accomplish to move farm to school efforts forward using specialty crops. Using 77 self-identified school district directors from the U.S. Farm to School Census, we have created a case study to address the following: (1) identify challenges and opportunities to increase procurement of local foods, (2) identify farmers in a 30 mile radius of interested school districts to link producers to schools, (3) create promotional outreach educating Indiana school children on farm to school activities and (4) creation of knowledge needed to jump start farm to school activities. Preliminary data shows demographic and psychographic profiles of school districts play a role in selecting produce and pre-packaged or processed (ready to eat) items are preferred and fit easily into capabilities of food service workers. Community gardens and field trips are the preferred farm to school activities.

**Keywords:** specialty crops, farm to school, local food systems

## EVALUATION OF FOUR TOMATO VARIETIES FOR COMMERCIAL ORGANIC PRODUCTION IN THE U.S. VIRGIN ISLANDS

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**Abstract:** Organic farming provides an opportunity to positively impact the environment, human health, and future yields. Tomato (*Solanum lycopersicum* L.) is a high value vegetable grown for the fresh market in the United States Virgin Islands. Four cultivars: “Mountain Fresh”, “Red Defender”, “Security 28”, and “Defiant” were evaluated for yield potential in an on-farm trial with farmer’s participation at Sejah Farm, St. Croix. The experimental design was a complete randomized block with three replications. The trial was conducted from November, 2012 through March, 2013. Crops were grown using National Organic Program standards and approved practices. Seeds were planted in seedling trays containing organic (farmer produced) compost, reared in the greenhouse, then transplanted into the field 21 days after germination. Plots consisted of three rows spaced 1.2 m apart and in-row plant spacing at 0.6m for a total of 13,883 plants per hectare. Organic fertilizer (Nature’s Nectar 5-4-5) was applied on a weekly basis using standard commercial fertilization rates through drip tape fertigation. The field was monitored for diseases and insect pests periodically by staff and our extension entomologist. Weeds were controlled manually and mechanically. Data on average fruit and yield per plant and overall yield was collected from eight harvests during the growing season. No significant differences were observed between the four cultivars tested for marketable, unmarketable, or total yield (marketable plus unmarketable yield). “Mountain Fresh” produced numerically higher total fruit yield with 37.1t/ha. “Defiant” produced numerically higher marketable (US #1) fruit yield with 25.0t/ha and also had numerically lower unmarketable fruit with 10.5t/ha. Based on these observations, all four cultivars tested can be recommended for commercial organic production in the USVI.

## INTRODUCTION

Organic farming increased rapidly in recent years but growth has been much slower in most of the U.S. Caribbean region. The slow adoption and growth of organic farming is mainly due to the fact that it requires more specified production and management practices than a conventional production system. It requires different types of markets due to high price premiums and consumers who are willing to pay that price. Studies suggest that other obstacles to more widespread adoption of organic farming systems include the high managerial costs and risks of shifting to a new way of farming, limited awareness of organic farming systems, lack of marketing and technical infrastructure, and inability to capture marketing economies (OTA 2012). A study by the Economic Research Service pointed out that fees charged by state and private certifiers may also be a barrier in adopting certified organic farming system for some producers, particularly small and limited resource farmers (USDA-ERS, 2005).

In the USVI, consumers in the region are looking for locally produced, organically grown food; they are also looking for local growers to take measures to reduce impacts on the environment, for example, by practicing no- or low-till soil management. Farmers are inherently interested in methods that can reduce the deleterious effects to soil quality, soil erosion, soil compaction, excess fuel consumption, and contribution to greenhouse gases that can be caused by extensive tilling.

Organic vegetable production is challenging due to disease and insect pests in the hot, humid summers. Tomatoes are a high-value commodity in the United States Virgin Islands (USVI) and throughout the Caribbean. High yields of high quality tomato fruits can bring in good profits for growers. Many cultivars are available which are purported to have improved characteristics such as increased disease and pest resistance, high quality fruit, moisture tolerance, heat tolerance, and higher yields. However, cultivar testing is limited in our region. The objective of current was to evaluate four tomato varieties in the organic management system in local conditions, for the following characteristics: total yield, marketable yield, plant height, individual fruit size, length, and diameter.

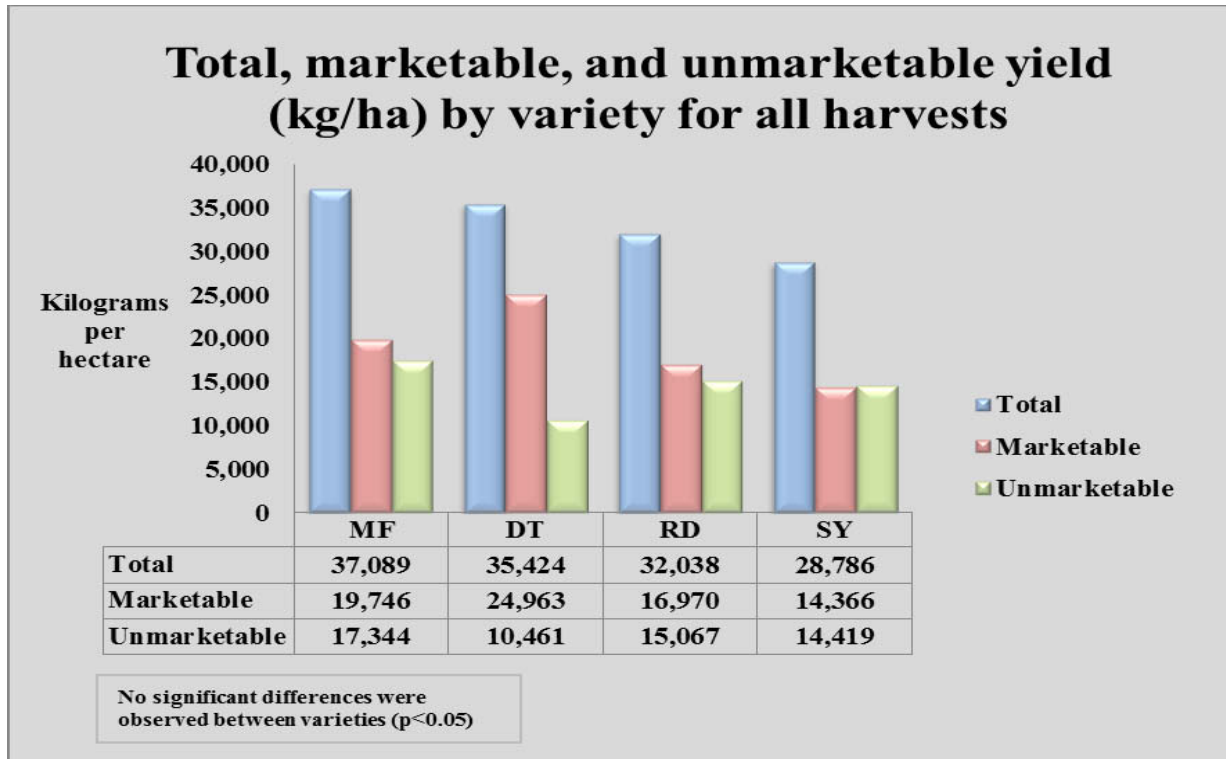
## **MATERIALS AND METHODS**

Organic seeds of four tomato varieties “Mountain Fresh”, “Red Defender”, “Security 28”, and “Defiant” were procured from Harris Seeds Co., NY and planted in trays in November, 2012 at the University of the Virgin Islands on St. Croix, reared in the greenhouse, and transplanted into the field 21 days after germination at Sejah Farm, St. Croix. Crop was grown under organic management practices approved National Organic Program (NOP) and products listed by Organic Materials Review Institute (OMRI). Transplants were raised in the greenhouse and transplanted in the field 3 weeks after germination. Field was disk harrowed and roto-tilled prior to transplanting. Plots consisted of three rows spaced 4’ apart, with 12 plants per row spaced and 2’ between the plants within a row. Plants were tied and supported with T-posts (6’). Supplemental water and nutrients were provided through gravity-fed drip irrigation. Dipel (*Bacillus thuringiensis*) was used to control *Manduca quinquemaculata* and Spinosad was used to control *Tetranychus urticae*, when pest populations exceeded action thresholds. Data collected from plants #2-11 from center row on maturity, plant height, fruits weight, marketable fruits (US#1), and yield. Fields were scouted and monitored for insect pests and diseases by Extension entomologist periodically. Weeds were controlled manually or mechanically. N, P and K fertilizers obtained from Planet Natural Inc., Bozeman, MT and applied weekly basis. Data on plant height, fruit weight and marketable yield collected from eight harvests during the growing seasons. Harvesting occurred twice weekly. Data were analyzed using GLM procedures of SAS.

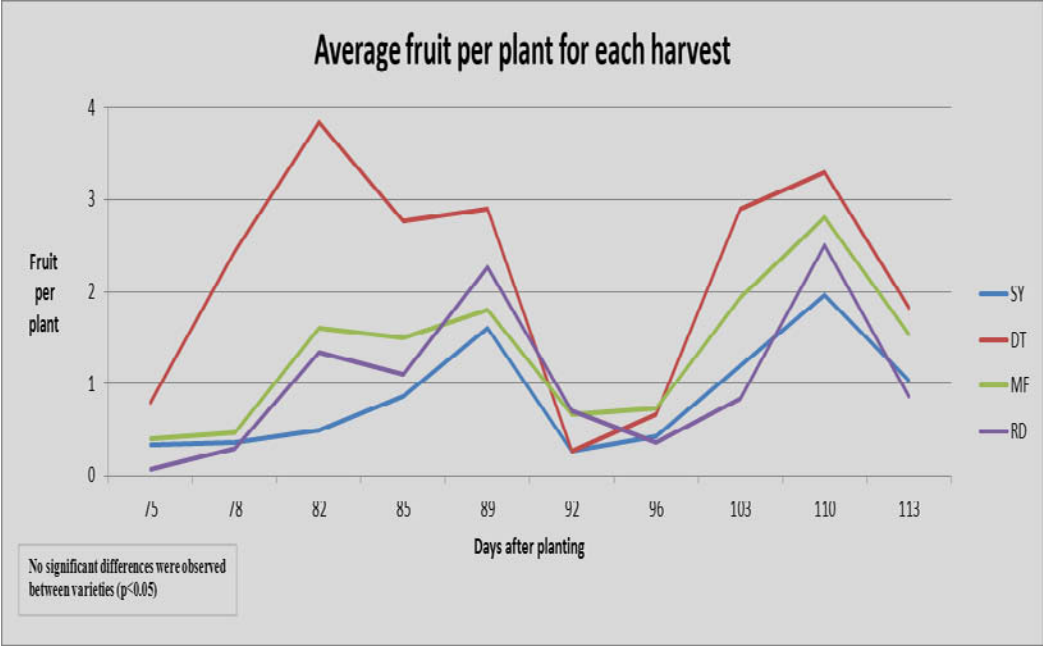
## **RESULTS AND DISCUSSION**

No significant differences were observed between the four cultivars tested for marketable, unmarketable, and total yield. “Mountain Fresh” produced numerically higher total fruit yield with 37.1t/ha (Fig.1, 2). “Defiant” produced numerically higher marketable (US #1) fruit yield with 25.0t/ha and also had numerically lower unmarketable fruit with 10.5t/ha (Fig. 3, 4). “Mountain fresh” produced biggest fruit (5.03oz) of the four varieties evaluated. Varieties showed good tolerance to pest and diseases in the growing season.

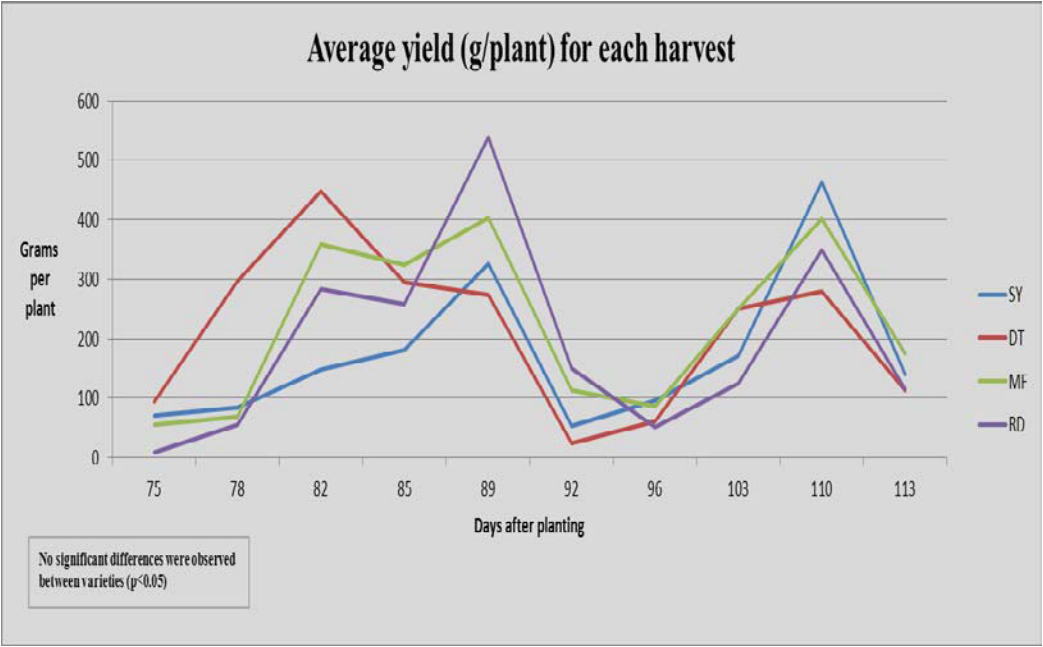
Results of tomato variety trial have been ongoing research interest at the Agricultural Experiment Station (Collinwood et al, 1982; Nandwani 2013; Ramcharan 1981). Palada and co-worker (Palada et al., 1999) found suitable six tomato varieties “Bonita”, “Empire”, “Keepsake” “Merced”, “Mountain Pride” and “Sunmaster” for organic production in the USVI. Tomatoes are one of the most popular fresh market vegetables grown commercially in the USVI. With the rising consumer demand for organic products, organic tomatoes should be an excellent prospect for local fresh market sales. The results will assist growers in choosing varieties that will improve their yields and profits in organic tomato production without using chemical fertilizers and pesticides.



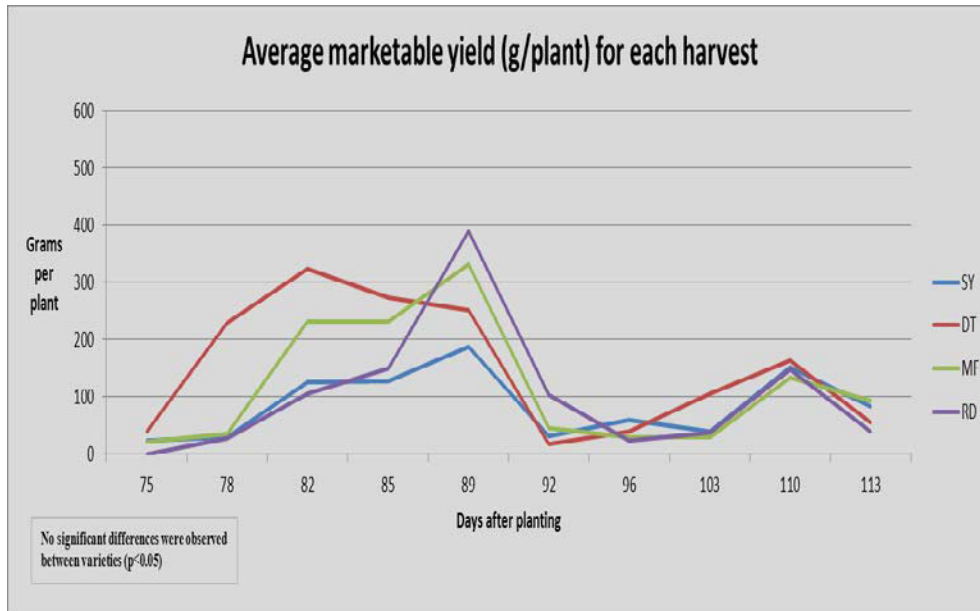
**Figure 1.** Yield characteristics for each cultivar selected.



**Figure 2.** Fruit yield per plant for each cultivar.



**Figure 3.** Total yield per plant by harvest for each cultivar.



**Figure 4.** Marketable yield per plant by harvest for each cultivar.

## ACKNOWLEDGEMENTS

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**SUSTAINABLE AGRICULTURE IN THE CARIBBEAN: EXAMPLES FROM USDA SOUTHERN SARE PROGRAM**

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**Abstract:** In 1988, responding to a growing call for greater investment in sustainable agriculture, Congress provided the first funding for USDA's Sustainable Agriculture Research and Education (SARE) program: a science-based, regionally directed, problem-solving competitive grants program. Since then, SARE grantees have led the way to advance sustainable agriculture systems that simultaneously value and improve productivity, profit, stewardship and quality of life for farmers, ranchers and society as a whole. Here in the Southern region, the SARE program supports 13 states and two territories: Puerto Rico and U.S. Virgin Islands. Since 1988, Puerto Rico has received \$703,239 to support 17 projects covering a wide variety of sustainable agriculture topics. U.S. Virgin Islands has received \$917,380 to support 7 sustainable agriculture grant projects. This poster presentation highlights some of the most recent grant-funded projects from both territories and how the research results and outreach/education outcomes of the projects have helped further sustainable agriculture practices and techniques in the Caribbean.

**Keywords:** Sustainable agriculture, grants, outreach, education

**AQUAPONICS RESEARCH AND EXTENSION AT KENTUCKY STATE UNIVERSITY**

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**Abstract:** There are a number of challenges that have consistently hindered development of local and regional food systems, with a major one being seasonality of production. However, an indoor production system has been in development which can produce both fresh fish and vegetables year round and be located directly within urban areas. This places production in close/direct proximity to the consumers. In the continental United State, the average agricultural product travels over 1,500 miles from the farm to the consumer. Not only does this travel compromise the nutritional integrity of the produce, it also creates a very large carbon footprint during transportation. One way to decrease the average "food miles" is to produce the food in closer proximity to the end consumer. With the increasing urbanization of the U.S., and in fact the world, that means producing food in or near the cities. Aquaponics is the integration of aquaculture and hydroponics. Fish are raised at high densities in tanks. The water containing their waste products is circulated out through hydroponic beds where the fish wastes act as fertilizer for the plant crops. Their removal by the uptake of the plants cleans the water, which is then cycled back to the fish in a constantly recycled system. Aquaponics is a model of sustainable food production as; 1) the waste products from one biological system serve as nutrients for a second system, 2) it yields multiple healthy crops, 3) it is extremely water efficient and 4) being located in the urban setting puts production in close proximity to the end consumers. Supplemental lighting research for aquaponic systems is being conducted including Fluorescent, metal halide, and light emitting diode (LEDs) light sources and will be discussed.

**Keywords:** Aquaponics, Aquaculture, horticultural crops

**GERMPLASM RESEARCH AT THE KENTUCKY STATE UNIVERSITY PAWPAP REPOSITORY**

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**Abstract:** The North American pawpaw, *Asimina triloba* (L.) Dunal, is a native tree-fruit that is in the early stages of commercial production. Pawpaw fruit have fresh market appeal for farmers markets, community supported agriculture, and organic markets. This fruit also has processing potential for frozen pulp production. Annonaceae relatives of the pawpaw, such as cherimoya, sweetsop (sugar apple), soursop, and atemoya also have low yields, due to low rates of natural pollination. Kentucky State University (KSU) serves as the National Clonal Germplasm Repository for Pawpaw. Two goals of the Repository research efforts are germplasm acquisition and evaluation. The repository contains over 2000 accessions from 16 different states; additionally, both open pollinated seedlings from superior genotypes and crosses of superior selections have been incorporated into the repository collection. The repository contains over 45 cultivars that are currently available from nurseries. As part of KSU pawpaw breeding and selection efforts, the KSU Horticulture Program released its first pawpaw variety 'KSU-Atwood™' in 2010. However, new high yielding cultivars with excellent fruit fresh market or processing quality would assist in the development of a pawpaw industry worldwide. A number of advanced selections, such as Hi1-4 and Haz-1.4, have been identified in the Repository collection with unique fruit types and promising new characteristics as new potential cultivars. Pawpaw varieties with fruit weights over 120 g per fruit are considered to have a large enough fruit size for commercial sale and processing. The selection Hi1-4 has a pleasing orange flesh, and large fruit size (361 g). The selection Haz-1.4 has a pleasing orange flesh that would be excellent for processing and large fruit size (201 g). Additional pawpaw germplasm is being examined as potential new cultivar releases.

**Keywords:** Annonaceae, tree fruit, horticultural crops, germplasm, pawpaw

**THE CENTER FOR SUSTAINABILITY OF FARMS AND FAMILIES AT KENTUCKY STATE UNIVERSITY**

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**Abstract:** Kentucky is a state of small, limited-resource farms. In 2007, more than 75% of the Commonwealth's 85,260 farms were less than 180 acres, and 80% have an annual income under \$25,000. Kentucky's small farmers, many of whom are or have been growing tobacco, are interested in growing high-value fruit, vegetable, and nut crops for farmers' markets, on-farm markets, CSAs, locavore cooperatives, and restaurants for improved long-term economic stability. The Kentucky State University Center for Sustainability of Farms and Families (KSU-CSFF) Small Scale Farm Grant Program has been developed to support expansion of certain types of agriculture in Kentucky, especially among certain underserved groups. The Center is supporting new economic opportunities for limited resource farmers through demonstration projects and mini grants funded through support from the Kentucky Agricultural Development Board and Tobacco settlement funds. Grant funding decisions are based upon the impact the grant is expected to have on the production and sales of Kentucky-grown or -raised farm products. As part of a 2012 grant entitled "Enhancing agricultural opportunities for small scale farmers" from the Kentucky Agricultural Development Fund, small farm families throughout the Commonwealth are receiving mini-grant support through CAFSSS for expanding their economic opportunities. To date we have received over 100 requests. The greatest demand is in the Value-Added category for farmers, with many requests also in the Aquaculture and Organic categories. Small farm families throughout the Commonwealth are receiving mini-grant support through CAFSSS for expanding their economic opportunities. To date we have received over 100 requests for \$1,000,000 in funding support. Of those, the grant committee has approved over 50 proposals, awarding over \$250,000. The greatest demand is in the Value-Added category for farmers, with many requests also in the Aquaculture and Organic categories.

**Keywords:** Aquaculture, Organic Agriculture, horticultural crops

**NEW APPROACHES IN THE PRODUCTION OF CITRUS IN PUERTO RICO**

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**Abstract:** Citrus production in Puerto Rico has been threatened since the detection of citrus greening (HLB) caused by *Candidatus Liberibacter asiaticus*. In addition, there are other diseases prevalent in the citrus production area, such as Citrus Tristeza Virus (CTV). A citrus germplasm collection was established in insect proof structures in the University of Puerto Rico, Agricultural Experiment Stations at Isabela and Rio Piedras, where 33 accessions of certified material remain free of diseases. This germplasm is the source of material for vegetative propagation for the local citrus industry in Puerto Rico. This collection is being evaluated and validated in separate experiments at Isabela, Corozal and Adjuntas Substations. In Isabela and Corozal, 'Tahiti' lime achieved good performance during four years of evaluations when using an intensive nutritional program, even in the presence of HLB. The program included the use of slow release fertilizer formulation 15-3-19-3 applied to the soil twice a year (1.8 kg/tree/application). A supplemental foliar application of micronutrients, SRN (30-0-0), Phosphite 0-29-26, Recover Rx 3-18-18 and a biological fungicide was performed once a month. In Isabela, 'Nova' mandarin in the fourth year showed no symptoms of HLB and flowered well prior to the first commercial harvest. Preliminary results of sweet orange 'Pera' and 'Marr's Early' on different rootstocks, planted in Adjuntas, showed earliness, good yields and fruit quality. Because of their earliness, these varieties may be an alternative for the local citrus industry during the months of August through November when citrus fruits are scarce in the local market. The Department of Agriculture of Puerto Rico will promote citrus nursery plant production in protected structures to keep the citrus psyllid and the HLB out of citrus nurseries. In order to succeed in citrus production, it is vital to begin with healthy material.

**Keywords:** germplasm, diseases, nutrition

**YIELD AND QUALITY ASSESSMENT OF FOUR *Urochloa* sp. CULTIVARS ON AN OXISOL IN PUERTO RICO**

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**Abstract:** The objective of this study was to assess dry matter yield (DMY) and nutritive value [crude protein (CP) and neutral and acid detergent fiber (NDF and AD) concentrations] of four *Urochloa brizantha* (Hochst. ex A. Rich.) cvs. Toledo, Piata, Mulato II and Caiman seeded on an Oxisol (pH 5.5, and 2.2% organic matter). In June 2013, seeds of the four *Urochloa* cvs. were seeded with a billion seeder calibrated at 10 kg/ha on a well-prepared seed bed. The experimental design was a complete block with three replicate. Plants were allowed 6-mo growth (no fertilizer) and baled in mid-December 2013 and March, 2014. At 6-weeks regrowth, dry matter yield was estimated using a double sampling technique (20 plant disk heights and four destructive measurements of plant height and weight in a 0.25 m<sup>2</sup>). Subsamples were taken and analyzed for CP and fiber concentrations. Data were analyzed using SAS (2009) and mean when significant separated using Tukey. There were differences in DMY ( $P < 0.05$ ) among cultivars (highest for Toledo at 3.3 Mg/ha), 25% increase in DM over the other three cultivars. Crude protein, however, was higher for Mulato II and Caiman (10.2%), two percentage units higher than those of Toledo and Piata, but fiber concentrations were similar among grasses (62%). Mulato II and Caiman, offer potential for use in total mixed rations for dairy cows because of higher CP, but Toledo maybe better suited for grazing.

**Keywords:** Dry matter yield, nutritive value, *Urochloa*, Total mixed rations

**IMPACTO DE SISTEMAS INTEGRADOS DE LEGUMINOSAS PLATANOS (*Musa* sp.)  
SOBRE MALEZAS Y APORTACION DE N**

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**Resumen:** Un sistema integrado de leguminosas (SIL; living-mulch) en cultivos agronómicos minimiza las malezas y aportan N. Sin embargo, en Puerto Rico no existe información sobre el uso de SIL. Estudios en dos localidades evaluaron el efecto de tres SIL [Canavalia; Canavalia ensiformis (L.) DC., *Crotalaria juncea* L. cv. Tropic sunn y Gandul; *Cajanus cajan* (L.) Millsp.] -plátano cv. Maricongo con siembra convencional (SC) sobre control de malezas y aportación de N. Estos trabajos se llevaron a cabo en las Estaciones Experimentales Agrícolas de Corozal (un ultisol de la serie Aibonito, pH 4.5) e Isabela (un oxisol de la serie Coto, pH 5.0). Los cormos se establecieron en junio 2013 a una distancia de 1.5-m entre ellos y 3-m entre hileras. Entre las filas del plátano se sembraron cuatro hileras (60-cm) de los SIL mecánicamente (Tropic sunn y *Crotalaria*) y manual la canavalia. Se estimaron biomasa de malezas y de leguminosas, y muestras representativas se tomaron, secaron y molieron para análisis de N por el método Kjeldahl. En la zona montañosa de Corozal, biomasa de maleza no se midió, pero si se encontró diferencias ( $P < 0.05$ ) entre los SIL con 4.0, 3.5 y 2.9 Mg/ha para canavalia, Tropic sunn y gandul, respectivamente. En el noroeste de Puerto Rico, Isabela, las malezas (3.4 Mg/ha) fue mayor que las del SIL (0 Mg/ha). Biomasa, también, fue distinta entre leguminosas (13.8; 8.5 y 5.5 Mg/ha, para Tropic sunn, gandul y canavalia, respectivamente). Aportación de N en los SIL en Corozal (100, 69, y 59 Kg/ha, para canavalia, gandul y Tropic sunn, respectivamente) fue menor que en Isabela (174, 237 y 276 Kg/ha, para canavalia, gandul y Tropic sunn, respectivamente) debido a menor rendimiento de los SIL en la zona montañosa. La utilización de SIL en ambas localidades redujo la presencia de malezas y aportó una cantidad aceptable de N al sistema.

**EFFECTOS ALELOPATICOA DE CROTALARIA (*Crotalaria juncea* CV. TROPIC SUNN), GANDUL (*Cajanus cajan*) Y CANAVALIA (*Canavalia ensiformis*) SOBRE LA GERMINACION DE CULTIVOS TRPOPICALES**

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**Resumen:** Se evaluó el efecto de cobertura muerta y extractos acuosos (3.3% m/v) de crotalaria (*Crotalaria juncea*) cv. Tropic sunn, canavalia (*Canavalia ensiformis*) y gandul (*Cajanus cajan*) sobre la germinación de maíz dulce (*Zea mays*) var. Suresweet, sorgo granífero (*Sorghum bicolor*), habichuela (*Phaseolus vulgaris*) var. Verano, soya (*Glycine max*), gandul, caupí (*Vigna unguiculata*) y lechuga (*Lactuca sativa*). Se realizó análisis de contrastes para evaluar la media de los tratamientos y su efecto en la germinación. En el experimento de laboratorio el diseño fue un DCA con seis replicas, cada plato petri con diez semillas, incubadas durante 7-d a 29.5 0C y 10 ml de cada extracto acuoso obtenido de leguminosas con 6-sem de crecimiento. Comparaciones entre el tratamiento control (agua destilada) vs cada una de las leguminosas exhibió que el tratamiento de la canavalia presenta diferencias ( $P<0.05$ ) con gandul y sorgo a los 7-d. Adicionalmente, caupí y sorgo presentan una tendencia ( $P=0.0613$  y  $P=0.0758$ , respectivamente) en menor germinación a los 7-d y 4-d respectivamente. En el invernadero se desarrolló un DBCA, en macetas de 20 cm de profundidad con 10 g de las leguminosas de 3-m trituradas y dispuestas sobre la superficie del suelo con diez semillas. Contrastes entre el tratamiento control (sin cobertura muerta de leguminosa) vs. cada una de las leguminosas se encontró diferencias ( $P<0.05$ ) en el tratamiento de sorgo con gandul y lechuga con Tropic sunn germinadas a los 7-d. Así mismo, el gandul presenta tendencia a inhibir la germinación de habichuela ( $P=0.0571$ ) y sorgo ( $P=0.0622$ ) a los 4-d y 7-d respectivamente. En conclusión, ninguna de las leguminosas evaluadas afectan la germinación del maíz dulce y soya, pero si en los otros cultivos.

**Palabras claves:** Cobertura muerta, extractos acuosos, contrastes, y Tropic sunn



**BIOLOGICAL CONTROL OF VARROA MITE, THE INVASIVE AND DESTRUCTIVE ECTO-PARASITE OF HONEY BEE POPULATIONS**

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**Abstract:** The honey bee *Apis mellifera* is critical for honey production and crop pollination. The ecto-parasitic mite *Varroa destructor* is currently the most serious threat to beekeeping and infested honey bee colonies can perish within a few weeks. Populations of *Varroa* mite have developed resistance to miticides used for control. Therefore, we examined the use of fungal pathogens as an alternative control strategy. Several fungal isolates were screened for pathogenicity and virulence against *Varroa* mites. Colonies infested with mites were treated with fungal spores in different formulations to assess their field efficacy. Mite infestation levels were estimated using sticky boards and ether rolls. The numbers of mites within sealed brood cells and colony strength were determined in the assessment of the survival of the honey bee colonies. Data indicated that *Hirsutella thompsonii* and *Metarhizium anisopliae* were highly pathogenic to the *Varroa* mite and harmless to the honey bee. Several field trials indicated that strips or paddy-blend formulations of 10 g of conidia per hive were successful in significantly reducing numbers of mites per adult bee, reducing number of mites in sealed brood cells, improving hive survival, reducing numbers of residual mites, and improving colony strength in terms of adult bee populations and brood development. Thus, microbial control of *Varroa* mite with fungal pathogens is feasible and could be a useful component of an integrated pest management program for the honey bee industry.

**EFFICACY OF FUNGICIDES APPLIED AT THE COTYLEDON STAGE FOR MANAGEMENT OF DOWNY MILDEW ON KALE GROWN FOR SPRING MIX PRODUCTION**

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**Abstract:** Due to its versatility and nutritional benefits, kale has risen in popularity among U.S. consumers. One popular form is baby leaf kale for use in spring-mix salads. A short-season crop (usually 24-30 days), baby kale is planted at very high densities in rows spaced at only 5 cm and the canopy fills in rapidly. This reduces air flow through the crop and the resultant lengthy periods of leaf wetness are very conducive to downy mildew, incited by *Hyaloperonospora parasitica*. A field trial was conducted to evaluate various fungicides applied at the cotyledon stage for their efficacy in controlling this disease. The experiment consisted of a randomized complete block design with three replications of 12 treatments. Fluopicolide, mandipropamid, dimethomorph, cyazofamid, and potassium phosphite were each trialed at a single rate, while mefenoxam and oxathiapiprolin were each tested at three different rates. All treatments with the exception of the control also received a single application of potassium phosphite one week after the initial application. Disease was assessed by visually estimating the percentage of canopy displaying symptoms at two randomly selected areas of each experimental unit 22 and 26 days after the initial treatment. Although disease pressure in the area was extreme, all fungicide treatments provided significant downy mildew control, with mefenoxam, oxathiapiprolin, and mandipropamid providing the best results (no disease vs 37% severity in the untreated check on Day 22). However, by Day 26, all treatments displayed some disease, and rate effects were significant among the three rates of mefenoxam and oxathiapiprolin. Results demonstrate that preventative applications of efficacious fungicides can successfully manage downy mildew under even extreme conditions, but that one or more subsequent fungicide applications are necessary for full season control.

**Keywords:** disease management, chemical control

## PHYSICAL CHARACTERISTICS OF PUMPKIN, TOMATO AND SWEET PEPPER HARVESTED IN TRINIDAD, WEST INDIES: LINKAGES TO CONSUMPTION USES

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**Abstract:** At point of harvest, the physical dimensions, degree of defect and quality usually determines the end-use of harvested crops. The aim of this study was to determine physical and quality characteristics of pumpkin, tomato and sweet peppers varieties harvested in Trinidad and link to end-uses. Seven pumpkin and sweet pepper varieties and 15 varieties of tomato were sampled from a pool of National Agricultural Marketing and Development Corporation (NAMDEVCO) registered farmers in Trinidad. Quality measurements undertaken were weight, length, width, firmness, bioyield point, instrumental and manual chart colour, °Brix and pH. Physical defects, bruises and disease were visually observed. Statistical analyses were carried out using Minitab 16 to determine significant ( $p < 0.05$ ) differences by varieties. The largest pumpkin variety was the *Jamaican Squash* (mean weight 9.9kg), a suitable variety for wholesale. There were no significant quality losses in pH, soluble solids as °Brix and colour by variety. The firmer pumpkins were *Bodles Globe*, *Future NP999*, *Crapaud back* and an unknown *Jamaican Variety* ( $p < 0.05$ ) which also showed higher bioyield points (1809.3g - 2634.1g.). The largest tomato variety was *Big Dean* ( $p < 0.05$ , mean weight 203.5g) and the smallest was *Cello* (mean weight 5.97g) from protected agriculture. The most popular open field varieties, were *Delhi 501* (56.56g) and *Hybrid 61* (55.63g) which were mostly either sautéed at homes or purchased by small micro enterprises for processing into value added products. The *Chareleston* tomato variety had the firmest flesh 248.9g ( $p < 0.05$ ) which makes it ideal for slicing. *Summerstar* and *Rhapsody* had the lowest acidity (pH,  $p < 0.05$ ) of 4.0, while the *Cello* was the sweetest (°Brix 6.5,  $p < 0.05$ ) and had an intense red attractive colour. The sweet peppers, *Early Sensation* grown under protected agriculture, had the highest (133.9g) weight ( $p < 0.05$ ) as compared to the Aristotle of open field (110.9g). None were diseased. Green house varieties, *Bullnose* had the firmest flesh of 284.1g, and *California* had the highest bioyield point of 987.2g. *Bullnose*, *Aristotle* and *Geneva* were least acidic (pH: 5.6). The soluble solids as Brix did not vary significantly by sweet pepper varieties. All crop varieties varied significantly in weight, width, length, firmness and bioyield point, and pH while the total soluble solids remained unaffected for sweet peppers.

**Keywords:** consumption, quality, value added products, open-field, protected agriculture

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### **INITIATING IPM FOR MANGO WEEVIL, *Sternochetus mangiferae* (FABRICIUS) (COLEOPTERA: CURCULIONIDAE), IN THE U.S. VIRGIN ISLANDS**

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**Abstract:** The mango weevil is now established in the U.S. Virgin Islands. In 2012, I started sampling for a mango grower in St. Croix who had been struggling with mango weevil infestations for more than 10 years, but had not implemented any controls. Throughout the 2012 harvest season, we gathered 348/505 fruits (68.9%) with weevil infestation in the seed, and 13/305 fruits (4.3%) with weevil infestation in the pulp. In 2013, we initiated an IPM program with trunk sprays (malathion + oil), canopy sprays (carbaryl), and sanitation (rapid removal and destruction of dropped fruits). We gathered 110/606 fruits (18.2%) with weevil infestation in the seed, and 3/606 fruits (0.5%) with weevil infestation in the pulp. However, the majority of infested fruits (105/410, 25.6%) was collected during June and September, and was likely a result of late initiation and early elimination of controls. We found only 5/196 fruits (2.6%) with weevil infestation in the seed, and no infestations in pulp, during sampling of fruits harvested in July and August. In 2014, we plan to continue with trunk sprays and sanitation, but replace canopy sprays with a soil application of a systemic neonicotinoid. We hope our efforts will eventually yield effective conventional and organic integrated pest management (IPM) programs that will work for large and small mango orchards and residential plots.

### **INTRODUCTION**

Mango cultivation in the U.S. Virgin Islands is a relatively organic process- pesticide inputs are rare. However, an increasing number of fruits infested with the recently established mango weevil is prompting many growers to consider controls for this pest. This paper shows my results from the first two years of integrated pest management (IPM) for mango weevil.

### **MATERIALS AND METHODS**

A mango orchard of 60 large trees (most over 20 years old), with a 10+ year history of mango weevil infestation, was sampled for the 2012 and 2013 harvest seasons. A minimum of 10 ready-to-harvest fruits were picked from each sampled tree randomly throughout each season, sliced in half, and inspected for weevil infestation in both the pulp and seed pit. Sanitation (prompt removal of fallen fruits) occurred both years. Pesticides (malathion for trunk sprays and carbaryl for canopy sprays) were utilized in 2013, following assessment of infestation data from 2012. The same sampling and control program was utilized for 2014, except canopy sprays of carbaryl was replaced with a single soil drench of thiamethoxam shortly after flowering.

### **RESULTS AND DISCUSSION**

See Table 1 for results. Our infestation levels dropped dramatically after implementing IPM. We were slow to implement sprays in 2013, likely resulting in higher infestations in the early and

late part of that season (25.6% in seed and 0.5% in pulp) than in the mid-season (2.6% in seed and 0.0% in pulp). Despite our successes, this program was reliant on large amounts of neurotoxic pesticides which are no longer registered for mango in the United States. For the 2014 season, we continued using malathion for early season trunk sprays, but replaced carbaryl with thiamethoxam (a soil drench application of a systemic neonicotinoid at the post-flowering/early fruiting stage). We believe our revised IPM program will further reduce mango weevil infestations while also minimizing the impact of insecticides on farm workers, pollinators, and other beneficial insects.

Table 1. Mango weevil damage in pulp and seed pit from 2012, 2013, and 2014 (projection).

Season	2012		2013		2014	
	Seed	Pulp	Seed	Pulp	Seed	Pulp
Infested fruits	348	13	110	3	25	2
Total sample	505	305	606	606	500	500
Infestation (%)	68.9	4.3	18.2	0.5	5.0	0.4

## CONCLUSION

At present, mango weevil is well-established in the Caribbean, but not in Puerto Rico or south Florida, where the majority of mangoes are grown in the United States. Establishment is likely in time (mango weevil is the most intercepted pest by customs officials in Puerto Rico). An effective IPM program will benefit growers and the surrounding environment in our territory, Puerto Rico, south Florida, and elsewhere where mango weevil is a problem.

## ACKNOWLEDGEMENTS

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## **CUCUMBER CULTIVAR STUDY IN THE U.S. VIRGIN ISLANDS**

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**Abstract:** Cucumbers are a valuable commodity throughout most of the Caribbean, including the U.S. Virgin Islands. Downy mildew, a foliar disease caused by the oomycete *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow, is one of the most destructive pathogens of cucurbits. Cucumber growers in U.S. Virgin Islands observed disease in their crops. Nine cultivars of cucumber (slicing type) “Dasher II”, “Fanfare”, “Indio”, “Intimidator”, “Speedway”, “Stonewall”, “Thunder”, “SVR 3462”, and “SVR 4719” evaluated for disease resistance and yields in the summer of 2013 at the University of the Virgin Islands Agricultural Experiment Station. All marketable fruits were weighed to determine total yields for each cultivar. Three fruits of each cultivar were randomly selected at each harvest and measured to determine individual weight, length, and diameter. Once downy mildew infestation was significant, 50 leaves of each cultivar were randomly picked and analysed using a disease severity assessment key. “Indio” had the highest marketable yield (166.3 kg), followed by “Stonewall” (159.8 kg) and “SVR 4179” (148.7 kg). “Indio” had the significantly lowest rating of downy mildew (2.69), followed by “Speedway” (3.29) and “SVR 4179” (3.31). Matching fruit qualities to downy mildew resistance, study shows the “Indio”, “Intimidator”, and “SVR 4719” cultivars were found more suitable for U.S. Virgin Islands conditions.

## **INTRODUCTION**

Cucumber (*Cucumis sativus*) is a valuable commodity throughout most of the Caribbean, including the U.S. Virgin Islands. Cucurbit downy mildew, caused by the pathogen *Pseudoperonospora cubensis*, is a disease of worldwide importance (Call et.al, 2012). Recently, growers in U.S. Virgin Islands observed downy mildew in cucumber fields and concerned about the methods of control for this disease. Historically, downy mildew was the most important disease on cucumber in the southeastern United States (Gusmini et.al, 2008). U.S. Virgin Islands warm and humid climate is favorable for the disease. There are many cultivars available with claims of improved fruit qualities, higher yield, and increased disease resistance (Wehner and Shetty, 1997). However, testing of cultivars is limited in the region. The objective of current study was to evaluate the cucumber cultivars in the local soil and climatic conditions and evaluate for the resistance to downy mildew and yields.

## **MATERIALS AND METHODS**

Seeds of cucumber cultivars were obtained from Stokes Seeds, NY. Field plots were established at the University of the Virgin Islands Agricultural Experiment Station, using randomized complete block design with three replicates, in the summer 2013 season. Nine cultivars of cucumber were evaluated in this study: “Dasher II”, “Fanfare”, “Indio”, “Intimidator”, “Speedway”, “Stonewall”, “Thunder”, “SVR 3462”, and “SVR 4719”. Standard management

practices were applied for the cucumber crop throughout the season. Plots consisted of three rows spaced 4' apart, with 12 plants per row spaced 2' between the plants within a row in drip system. Fungicides were intentionally omitted during the study. Marketable fruits were harvested and measured for overall yield, as well as average fruit weight, length, and diameter for each individual fruit. Harvesting took place three times weekly. Once downy mildew infestation was significant, 50 randomly selected leaves were picked from each plot and analyzed using a disease severity assessment key (DSAK), with ratings from 1 to 8 for 0% to 100% infected leaf tissue, respectively.

Fruit quality data was averaged with standard error values. Downy mildew ratings were analyzed with analysis of variance and multiple regression using statistical procedures from SAS software. Leaves were randomly picked, photographed and sent to disease diagnostic laboratory in NC State University (Todd Wehner) to process with a disease severity assessment key and statistical analysis (Thompson and Jenkins, 1985).

## **RESULTS AND DISCUSSION**

Results of disease rating and marketable yield are presented in Table 1. The “Indio”, “Stonewall”, and “Intimidator” cultivars were the most preferable for overall marketable yields, respectively, and the “Indio”, “Speedway”, and “SVR 4179” cultivars were the most preferable for downy mildew resistance, respectively. Results for individual fruit weight, length, and diameter were variable and desirable for all cultivars. Visual analysis suggested the “Indio”, “Intimidator”, and “SVR 4179” cultivars to be most favorable, respectively, with all characteristics weighed evenly.

The results are valuable for growers in the region. Drier and more windy summer than usual occurred during the study. Results may vary with increased humidity in a more typical summer, the wetter seasons, or in other regions with greater humidity. If undertaking a similar study in the near future, overhead irrigation and inoculation of seedlings for a better test of downy mildew resistance is recommended.

Matching fruit qualities to downy mildew resistance, our study shows the “Indio”, “Intimidator”, and “SVR 4179” observed superior cultivars for U.S. Virgin Islands conditions. Ironically, the “Indio” cultivar was removed from the market many years ago. Hopefully, results from this and other similar studies will convince the breeders to bring this cultivar back. Regardless, our growers have proven results from our region to aid them in selecting the best slicing cucumber cultivars for profits and improved IPM for downy mildew.

## **ACKNOWLEDGEMENTS**

Todd C. Wehner, North Carolina State University, for disease severity assessment key ratings and statistical analysis; Liam Marin, Antioch College, for statistical analysis of yield and fruit quality data; funding for this research is supported from Hatch project funds.

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**Table 1.** Characteristics for each of nine selected cultivars: Dasher II, Fanfare, Indio, Intimidator, Speedway, Stonewall, Thunder, SVR 3462, and SVR 4179. Characteristic values are for overall marketable yield (kg), individual fruit weight (mean, kg), individual fruit length (mean cm), individual fruit diameter (mean, cm), and resistance rating for downy mildew. Superscript values indicate significant differences for rating of downy mildew resistance.

Cultivar	Marketable yield (kg)	Mean fruit weight (kg)	Mean fruit length (cm)	Mean fruit diameter (cm)	Downy mildew resistance rating
Dasher II	131.8	0.41 ± 0.10	21.39 ± 2.89	5.46 ± 0.50	4.50 <sup>b</sup>
Fanfare	108.9	0.43 ± 0.08	23.23 ± 2.22	5.35 ± 0.33	5.04 <sup>a</sup>
Indio	166.3	0.46 ± 0.08	22.56 ± 2.14	5.53 ± 0.42	2.69 <sup>e</sup>
Intimidator	151.5	0.44 ± 0.08	23.00 ± 2.30	5.49 ± 0.35	3.63 <sup>cd</sup>
Speedway	135.0	0.44 ± 0.10	21.45 ± 2.30	5.57 ± 0.47	3.29 <sup>d</sup>
Stonewall	159.8	0.50 ± 0.10	24.01 ± 2.15	5.41 ± 0.63	3.93 <sup>c</sup>
Thunder	144.0	0.47 ± 0.10	23.47 ± 2.41	5.51 ± 0.46	4.89 <sup>ab</sup>
SVR 3462	136.0	0.50 ± 0.10	23.93 ± 1.01	5.63 ± 0.43	3.71 <sup>cd</sup>
SVR 4179	148.7	0.47 ± 0.10	21.86 ± 2.88	5.63 ± 0.55	3.31 <sup>d</sup>





Fig.1. Nine cultivars of cucumber were planted using randomized complete block design with three replicates. UVI-AES horticultural experiment field on St. Croix, Kingshill Campus

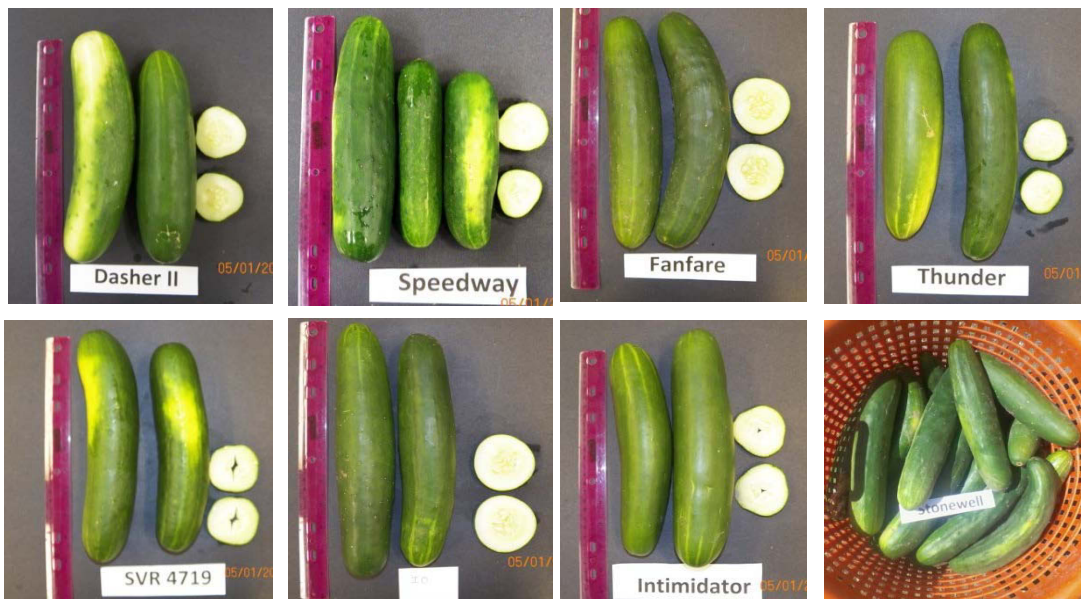


Fig.2. Fruits of cucumber cultivars screened



Fig.3. Leaves were randomly picked, photographed, and then sent to NC State Plant Disease Diagnostic laboratory (Todd Wehner) to process with a disease severity assessment key and statistical analysis

**ARE THERE ENERGY SECURITY LESSONS FOR THE CARIBBEAN FROM FLORIDA'S ENERGY POLICY?**

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**Abstract:** The Caribbean region is often referred to as a Third Border to the USA and Florida is sometimes considered part of the Greater Caribbean Region. Despite significant differences between Florida's economy and those of the Caribbean countries, there are noticeable similarities. They are all net food importers and rely extensively on imports of fuel to satisfy their energy demand. With respect to fulfilling its energy demand Florida relies primarily on natural gas supplies and crude oil imports from other states, since it produces only a small amount of crude oil and natural gas. With the goal of a stable, diverse and reliable energy supply, the state developed its first energy plan in 2006, which evolved into a balanced energy policy currently being aggressively implemented. Energy is pivotal to all aspects of livelihood and, in that regard, the underlying tenets of Florida's energy policy may provide useful guidelines for the Caribbean countries with respect to their improved energy security. The majority of the Caribbean countries, like Florida, also rely on fuel imports, ranging from 100% to 86%, to meet their respective energy demands. Yet, many of the Caribbean countries seemingly have the potential to generate some energy from their indigenous resources, thus enhancing their energy security. The purpose of this study was to evaluate the measures taken by Florida to enhance its energy independence with a view to ascertaining to what extent these may be applicable to the Caribbean countries, considering their indigenous resources.

**Keywords:** Energy security, energy policy, alternative energy sources

**EVALUATION OF SIX EDIBLE-POD PEA VARIETIES AS A POTENTIAL HIGH VALUE CROP FOR THE U.S. VIRGIN ISLANDS**

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**Abstract:** Snow pea (*Pisum sativum* L. var. *saccharatum*) and Snap pea (*Pisum sativum* L. var. *macrocarpon*) are high value vegetables typically grown in temperate regions. Three cultivars of Snow pea; ‘Oregon Giant’(OG), ‘Mammoth Melting’(MM), ‘Little Sweetie’(LS), and three cultivars of Snap pea; ‘Cascadia’(CA), ‘Sugar Sprint’(SS), and ‘Super Sugar Snap’(3S) were grown at the University of the Virgin Islands, Agriculture Experiment Station, St. Croix, US Virgin Islands. The experimental design was a complete randomized block consisting of six cultivar treatments with four replications. Prior to planting, trellises were constructed by stretching 1.5 meter tall plastic mesh fencing between metal posts at 3 meter intervals. Peas were hand planted on Feb 4, 2014 in double rows with individual peas spaced at 7.6 cm and rows spaced at 1 meter for a total of 262,466 plants/ha. Peas were micro-irrigated daily based upon soil moisture and fertigated weekly at a rate equivalent to 67 kg/ha nitrogen using a commercial 20-20-20 fertilizer. There was no difference in germination rate observed between cultivars (89-93%). Data on total, marketable and non-marketable pod yield were collected bi-weekly for a total of 10 harvests. Plant height and Brix% measurements were collected during the growing season. The snow pea cultivar LS produced the highest total fruit yield for the season across all cultivars at 14,306 kg/ha ( $p < 0.0002$ ). Of the three sugar snap cultivars tested, 3S yielded 9,042 kg/ha which was greater than CA, MM and SS ( $p < 0.05$ ), but similar to OG. Non-marketable fruit for LS was 1,691 kg/ha which was similar to OG, MM, and 3S, but greater than CA and SS ( $p < 0.01$ ). However, non-marketable fruit for LS represented 12 percent of the total harvest which was similar to all other cultivars, except MM (27% non-marketable fruit). Fruit Brix% was similar for SS, 3S, CA, and OG at 11.0, 11.0, 10.8, and 10.2, respectively, while all three sugar snap cultivars had higher Brix% than MM and LS at 9.8 and 9.5, respectively ( $p < 0.05$ ). The snow pea cultivar LS was higher yielding, but had the lowest Brix% content. The sugar snap cultivar 3S had acceptable fruit yield and had equally as high Brix% as the other sugar snap cultivars. Results of this experiment indicate that both sugar snap and snow pea varieties have potential as a specialty high value crop when grown in the cooler months on St. Croix, USVI.

**BREEDING ELEPHANT GRASS AND GIANT KING GRASS FOR IMPROVED BIOMASS YIELD AND BIOSAFETY**

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**Abstract:** Elephant grass (*Pennisetum purpureum*) also known as Napier grass is one of the best adapted warm season perennial grasses for production of large amounts of high quality forage biomass. The biofuels industry has identified elephant grass as one of the most productive feedstocks for lignocellulosic biofuel production in the southern US. However, the currently available cultivars and naturalized populations can produce large amounts of wind dispersed seeds, which contribute to their potential for invasiveness. Elephant grass can be propagated through stem cuttings for new plantings. Hence, seed production is not required for establishment and its suppression will significantly reduce its potential for invasiveness. In order to enhance the biosafety of elephant grass, interspecific hybridizations were made between elephant grass ( $2n=4x=28$ ) and pearl millet ( $2n=2x=14$ ). This interspecific hybrid is also called Giant King Grass and represents genotypes that display male and/or female sterility due to their triploid ( $2n=3x=21$ ) nature. We produced more than 3000 triploid, interspecific hybrids between elephant grass and pearl millet. Phenotypic variability present in these hybrids allowed selecting lines which produced similar or higher biomass amounts than the seed producing elephant grass cultivar Merkeron. Flowering in elephant grass is induced by shortening day length. Genotypic differences were observed in different elephant grass accessions regarding the beginning and duration of their flowering period. This offers the opportunity for the enhancement of biosafety by genetic hybridization and selection of late-flowering accessions with high biomass yield. Therefore, five genetically distant accessions were crossed to produce around 1600 F1 hybrids. Selected hybrids were vegetatively propagated in replicated row plots for evaluation during two years and four harvest cycles with a commonly used elephant grass cultivar Merkeron as a control. Phenotypic data were recorded to correlate different traits with biomass yield. Late-flowering F1 hybrids were identified with significantly higher biomass yield than Merkeron.

**Keywords:** Giant King Grass, Elephant Grass, Biofuel, Feedstock, Forage

## EVALUATION OF DROUGHT TOLERANCE IN FIVE NATIVE CARIBBEAN TREE SPECIES WITH LANDSCAPE POTENTIAL

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**Abstract:** Seedlings of five tree species native to the US Virgin Islands and Puerto Rico with potential for landscape plantings were grown in a greenhouse and subjected to 3 different watering intensities. We wanted to determine how fast nursery stock would reach an appropriate size for outplanting and how plant biomass would be allocated. Tree heights were measured weekly for 28 weeks after which trees were harvested to determine root, stem, and leaf weights. All species survived under the different watering regimes but had different responses in both height growth and biomass allocation. Only one species, *Andira inermis*, if subjected to abundant watering reached outplanting height by the end of 28 weeks. *Plumeria alba* growth did not respond positively to increasing water and field capacity was wasteful of water. In terms of biomass allocation *A. inermis* was plastic in the allocation of biomass by dedicating more biomass to roots while under water stress and dedicating more biomass to stem wood when watered at field capacity. Other species, in particular, *Bucida buceru* did not change biomass allocation in response to watering levels. The results indicate that Virgin Island nursery managers can save water during growing of these species by controlling watering levels and still obtain marketable local trees. This research was supported from USGS-WRRI and USDA-McIntireStennis grants.

**Keywords:** drought tolerance, landscape plantings, native tree species, tropical dry forest, *Andira inermis*, *Bucida buceru*, *Jacquinia arborea*, *Pimenta racemosa*, *Plumeria alba*

### MATERIALS AND METHODS

Five native tree species, *Andira inermis*, *Bucera bucida*, *Jacquinia arborea*, *Pimenta racemosa*, and *Plumeria alba* were grown in 11.4 L pots filled with a substrate of 50% Promix, 25% top soil and 25% sand (Figure 1.). There were 18 trees per species and each tree was assigned a treatment: 1L, 2L or 3.8 L of water per week (Figure 2). The pots and plants receiving 3.8L of water kept soil at field capacity or close to it. Field capacity is the ability of a soil to hold water. We calculated field capacity by subtracting the dry weight of a pot before watering and then the wet weight of the pot, after excess water has drained out. Tree heights were recorded weekly for 28 weeks. At the end of the experiment, 9 plants of all the species, except *P. alba* were harvested, dried, separated into its components and weighed (Figure 3). The data was statistically analyzed using JMP. Graphs were generated in Excel. The statistics of interest were: mean, ANOVA and Comparison of Mean. The P value is equal or less than 0.05.

### RESULTS AND DISCUSSION

All species survived under the different watering regimes but had different responses in both biomass allocation and height. *A. inermis* is plastic in the allocation of biomass. It dedicated

more biomass to roots while under water stress and more biomass to stem wood when watered at field capacity (Figure 4). Other species, in particular, *Bucida buceras* did not change biomass allocation in response to watering levels (Figures 5) *J. arborea* and *P. racemosa* allocated more biomass to leaves (Figures 6, 7). In terms of height growth see Table 1. *A. inermis* continued height growth with 3.8L and 2L of water applied weekly but 3.8L was better. *B. buceras* grew the fastest, but growth stopped once the plant needed all the water to maintain its leaf area. *J. arborea* grew at the same rate if it received 3.8L or 2L. *P. racemosa* and *P. alba* growth did not respond positively to increasing water and field capacity was wasteful of water. However, *P. racemosa* needed more water than *P. alba* in order to keep its foliage from wilting.

Ideally, nursery managers want to produce trees ready for landscape planting in the least amount of time possible with the least amount of water. We discovered that *A. inermis* and *B. buceras* grew best when watered to 100 percent field capacity weekly, *J. arborea* and *P. racemosa* grew best when watered to 66 percent field capacity weekly and *P. alba* had similar growth rates regardless of irrigation regime. These relative differences are also reflected in total biomass. Growth and biomass allocation among treatments suggests that differences among species can be attributed to their relative drought tolerance and natural habitats. It would be worthwhile to continue evaluation of native tree species for landscaping uses by conducting this study with other tree species as well as with the same species grown in larger pots.

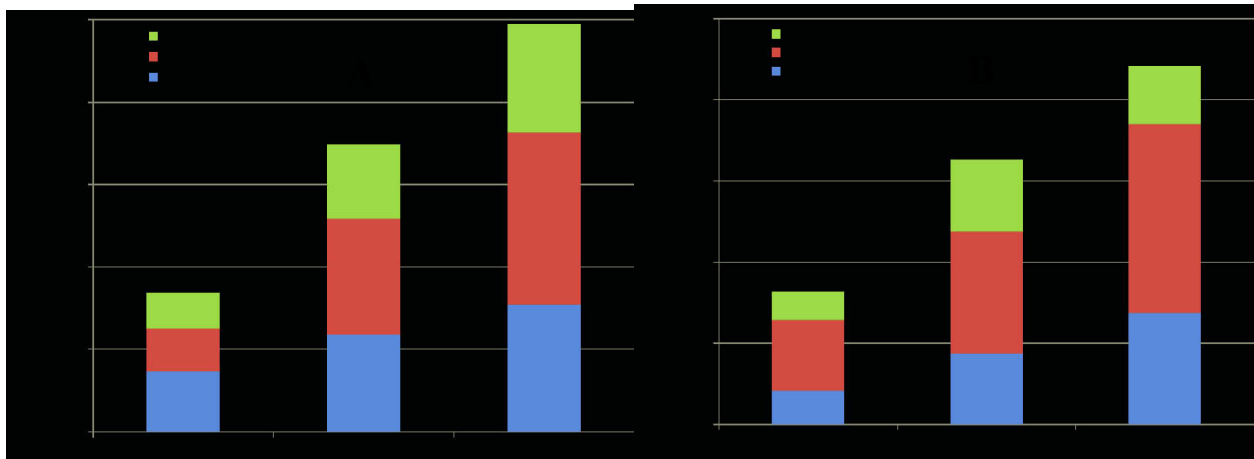


Fig. 1. Biomass production and allocation for *Andira inermis* (A) and *Bucida buceras* (B) by watering treatment.

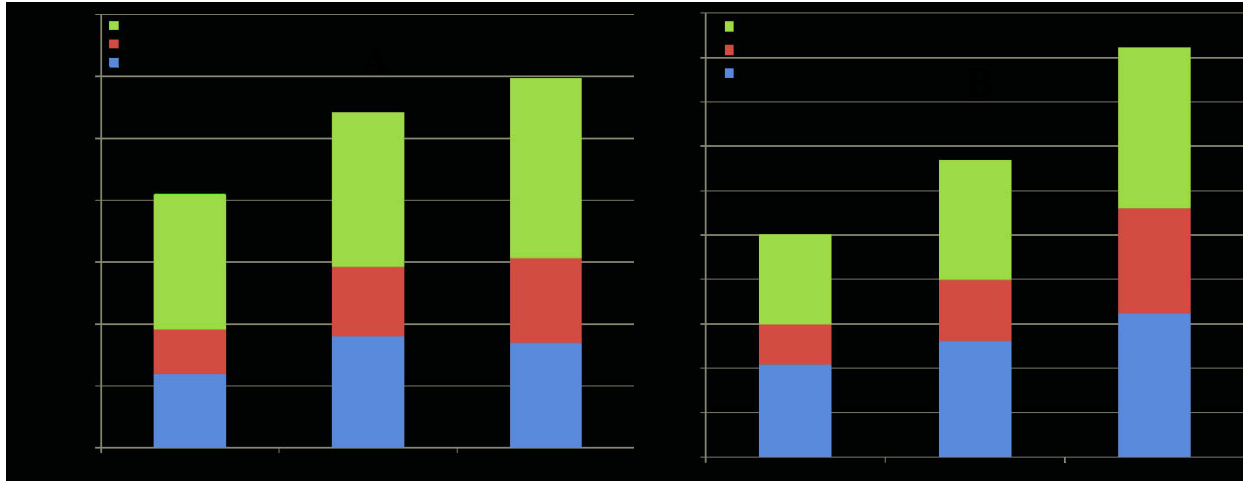


Fig. 2. Biomass production and allocation for *Jacquinia arborea* (A) and *Pimenta racemosa* (B) by watering treatment.

Table 1. Tree growth in height of five species and treatment of three watering regimes. Numbers followed by different letters within a species are significantly different  $P=0.05$

[The content of Table 1 is obscured by a large black redaction box.]



**ORGANIC HIGH SUCROSE SUGARCANE SYRUP**

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**Abstract:** The use of organic products has become a modern trend due to increased health and environmental impacts. This project used locally grown organic sugar cane (O.S.C.) to create a high sucrose cane sugar product which can be used to replace imported maple syrup and other syrups used in baking and confectionary. The O.S.C. is crushed and pressed to produce O.S.C. juice that is treated using various non-chemical methods such as variations in filtration, storage temperature, storage time, and evaporation time. Variations in the method produced seven syrup samples with differences in viscosity, flavor, odor and colour. These parameters were used to evaluate the syrup of choice via a taste test conducted on fifteen participants. Sample number three (3) was selected as the overall favorite where the % of participants that selected for each parameter respectively was: viscosity (26.7%), flavor (46.7%), odor (46.7%) and colour (73.3 %). Sample number three (3) will therefore be used as the base syrup with further improvements to be made with respect to viscosity, flavor and smell while keeping this colour for the base syrup. Flavors of tropical fruits will be used to extend the flavor of this new pancake syrup and compote.

**Keywords:** organic product, sugarcane, high sucrose syrup, maple syrup

***Moringa oliefera* LEAF EXTRACT AS PLANT GROWTH REGULATOR ON PAK CHOI SEEDLINGS**

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**Abstract:** *Moringa oliefera* leaf extract (MLE) is a bio-stimulant that would help decrease fertilizer inputs, by increasing nutrient availability in the soil for plant use, and in return minimize environmental degradation. This study assesses the application of *Moringa oleifera* leaf extract to stimulate plant growth in white pakchoi seedlings. Foliar applications of MLE, using both water and hydrogen peroxide as extractants, at varying concentrations of 20%, 40%, and 60% and a commercial bio-stimulant, Sugar Mover, at varying concentrations of 5ml, 10ml, and 15ml, were conducted at 5 day intervals from the 1<sup>st</sup> day of transplanting (DAT) for a period of 8 weeks. Both physical and chemical data was collected and analyzed. The results indicated that for both extractants, the MLE at concentration 20% and the commercial bio-stimulant (Sugar Mover) at concentration 15ml had the highest growth and yield characteristics.

**Keywords:** *Moringa oliefera*, bio-stimulant, bio-stimulant, bio-stimulant

**ESTIMATION OF STEROL CONTENT IN EXTRA VIRGIN COCONUT OILS (EVCO) USING UV-VIS SPECTROPHOTOMETRY**

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**Abstract:** Phytosterols are components of vegetable oils that have been shown to lower the serum cholesterol levels in humans and reduce the risk of heart disease. This group of steroid-alcohols is similar in structure and functions to cholesterol, but have different side-chain configuration and are common in soybean, sunflower, corn, rapeseed and coconut oil. Virgin coconut oil produced by mechanical or natural means without the use of heat, or chemical or physical refining are reported to be excellent sources of this phytosterols. In this study, the phytosterols contents of extra-virgin coconut oil [EVCO] and moringa and palm oil were evaluated using UV-Vis spectrophotometer at a wavelength of 640nm. A calibration curve was obtained using sterol standard and all oils samples were analyzed. The results indicated EVCO had between 0.28- 0.39 mg/dL of sterols. Moringa and palm oil showed to have  $1.82 \pm 0.03$  mg/dL and  $0.60 \pm 0.03$  mg/dL of sterol conten, respectively. Further, with increased storage time, the phytostereol content the aged EVCO did not deteriorate and ranged between 0.30 – 0.50 mg/dL of sterol.

**Keywords:** Phytosterols, extra-virgin coconut oil, extra-virgin coconut oil

**USE OF BIOSOLIDS AS A SOIL AMENDMENT AND ORGANIC FERTILIZER II:  
RADISH PRODUCTION**

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**Abstract:** Biosolids are detrimental waste resulting in environmental and health hazards, but when treated can be a sustainable growing medium in urban agriculture. There is a demand for organic fertilizers and sustainable growing media for production of both ornamental and food crops. This series of study assess the recycling of biosolid in a crop rotation scheme as a soil amendment to improve soil properties as well as an organic fertilizer. Radish was used as the root test crop in the second crop succession preceded by lettuce and pak choi. Five (5) biosolid - soil mixtures [50, 36, 25, 12 and 0%] were used to cultivate the crop under normal agronomic practices. Growth and development measurements were recorded over the 6-month cropping period. A soil chemical analysis for Zn, Mn, Fe, Mg, Pb, Cd, Cu, Cr elements was also conducted. The results suggested that soil amended with biosolids promoted greater plant and tuber growth than that of pure soil. Treatment 4 (12%) appears to be the mixture displaying the best results suggesting that only a small addition of biosolids to soil is required to improve tuber growth (circumference, tuber fresh and dry weights) in radish. The heavy metal contents of plant and soil material were found to be significantly lower than levels indicated by international regulations. Biosolids possess the potential to be innovated into commercial potting medium for urban agriculture and can substitute synthetic fertilizers and soil enhancers.

**Keywords:** Biosolids, crop rotation, chemical analysis, Soil Amendment

**EVALUATION OF CHINESE MILK VETCH (*Astragalus sinicus*) AS A BIO-FERTILIZER IN THE TROPICS**

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**Abstract:** *Astragalus sinicus* or Chinese milk vetch (CMV) is a temperate green manure legume native to China, Japan and Korea which can fix nitrogen with rhizobia and the vegetative parts used as animal fodder. It has the potential to reduce the negative effects of inorganic fertilizer particularly with respect to ground water contamination and the use of fossil fuel in the production process. This study evaluated the plant as a source of bio-fertilizer in a maize – pak choi rotation under greenhouse conditions. The maize crop was grown in soil subject to 3 treatments: manure, fertilizer, or no treatment. After the maize harvest, the CMV was established in each pot at a seeding rate of 2 plants / pot and grown until flowering and a crop growth analysis conducted. The rotation crop of patchoi was cultivated with no nutrient application and harvested at maturity. The experiment was laid out in a randomized block design. The three crops were analyzed for RGR, NAR, LAI and SLA. The results indicate that CMV can be grown under tropical conditions and the yield of rhizobia and nitrogen can supplement inorganic fertilizer.

**Keywords:** Chinese milk vetch, bio-fertilizer, rhizobia, maize – pak choi rotation

**Proceedings of the Caribbean Food Crops Society. 50:173. 2014**

**RESPONSES OF ‘HADEN’ AND ‘DAVIS HADEN’ MANGOS IN THE NURSERY TO A BIOSTIMULANT EXTRACT OF THE ALGA *Ascophyllum nodosum***

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**Abstract:** Research was conducted in Mayagüez, Puerto Rico, to determine the effects of a biostimulant extract of the marine alga *Ascophyllum nodosum* (ANE) on ‘Haden’ and ‘Davis Haden’ mangos in the nursery. Starting 30 days after cleft grafting the ‘Haden’ and ‘Davis Haden’ onto ‘Colombo Kidney’ rootstock, the ANE extract was applied in aqueous solution as a soil drench, supplying 150 ml of solution/tree every two weeks, at the rates of 0, 1, 2, 3, 4 and 5 ml of ANE/L. ‘Haden’ and ‘Davis Haden’ mango plants responded statistically the same to ANE rates, with increasing ANE rates resulting in increased root biomass, scion shoot length and biomass, leaf area, and leaf chlorophyll content. Thus, increasing ANE rates led to overall enhanced plant size and reduced the time in the nursery for the mango plants to be ready for transplanting to an orchard.

**Keywords:** brown alga, kelp, fruit crop.

**YIELD OF LETTUCE GROWN IN A PROTECTIVE STRUCTURE AS AFFECTED BY FOLIAR APPLICATIONS OF A BIOSTIMULANT**

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**Abstract:** Experiments were conducted in the greenhouse in Mayagüez, Puerto Rico, to assess the effects of foliar sprays of a biostimulant on the yield of ‘Black Seeded Simpson’ lettuce grown in containers. A commercially-available formulation of an extract of the marine alga *Ascophyllum nodosum* (ANE) was dissolved in water (0, 1, 2, 3, 4 and 5 ml ANE/L) and sprayed to run-off on the lettuce foliage at 10-day intervals starting when plants had four true leaves. Increasing ANE rates from 0 to 5 ml/L resulted in greater SPAD-chlorophyll concentration in the leaves, whereas increasing ANE rates from 0 to 4 ml/L resulted in augmented root biomass, leaf length, and lettuce leaf weight. These results indicate ANE may be used to enhance size and yield of lettuce grown in containers in the greenhouse.

**Keywords:** brown alga, kelp, vegetable crop, leafy crop

**PURPLE NUTSEDGE (*Cyperus rotundus*) INTERFERENCE WITH PURPLE BASIL IS AFFECTED BY NITROGEN FERTILIZATION**

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**Abstract:** A study was conducted in a clay soil in Mayagüez, Puerto Rico, to determine the effect of nitrogen (N) rates on the interference of purple nutsedge with purple basil. N rates (50, 75, 100, 125, and 150 kg/ha) were applied to the soil the same day the purple nutsedge tubers (averaging 0.2 g each) and purple basil plants (15 cm-tall) were transplanted in containers. Purple basil was grown weed-free (one basil plant/container) or with purple nutsedge at a density of 40 plants/m<sup>2</sup>. Purple nutsedge plants were allowed to grow unchecked alongside the purple basil until the crop was harvested 60 days after transplanting. When grown weed-free, purple basil fresh biomass above-ground was greater at the N rates of 50-125 kg/ha. In the weedy containers, purple nutsedge above-ground biomass increased as N rates were higher, and purple basil fresh biomass was lower than in the weed-free crop receiving the same N rates. Purple basil above-ground fresh biomass yield loss when growing with purple nutsedge was as high as 57% at the N rate of 150 kg N/ha. Purple basil growers should endeavor in suppressing purple nutsedge and properly supplying N to help reduce potential yield loss due to nutsedge interference.



**CURRENT STATUS OF MANAGEMENT OF MELON THRIPS, *Thrips palmi* KARNY (THYSANOPTERA: THIRIPIDAE) IN TOMATOES IN SOUTH FLORIDA**

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**Abstract:** The melon thrips, *Thrips palmi* Karny, is an invasive insect pest that arrived in Miami-Dade County, Florida, USA in 1990. Since its arrival, it has established as a key pest of all vegetable crops in the southern part of Florida. Growers use insecticides of various classes to control this pest but with minimum success due to its development of resistance against various classes of chemical insecticides. Three studies were conducted in commercial fields and Tropical Research and Education Center research fields to evaluate efficacy of chemical insecticides belonging to the classes: neonicotinoid, diamide, spinosyn, organophosphate, pyridinecarboxamide, pyrethroid and carbamate for controlling melon thrips. In the first study, bifenthrin (Brigade<sup>®</sup>) provided 71% reduction of melon thrips followed by chlorpyrifos (Lorsban<sup>®</sup>) in combination with esfenvalerate (Asana<sup>®</sup>). In the second study spinetoram (Radiant<sup>®</sup>) in combination with tolfenpyrad (Torac<sup>®</sup>) significantly reduced melon thrips than all other treatments. In the third study, spinetoram provided significant reduction of melon thrips followed by a premixed product (abamectin + cyantraniliprole). This information will be useful to tomato and other vegetable growers to control melon thrips and other thrips on their crops.

**Keywords:** thrips, new insecticides, vegetable crops, management

## **INTRODUCTION**

Melon thrip, *Thrips palmi* Karny, is a key pest of vegetable crops since its arrival in 1990. It is a polyphagous insect feeding on about 50 different plant species (Wang and Chu 1986). It feeds on almost all vegetable crops belonging to the families- solanacea, cucurbitacea and leguminoseae (Nakahara 1984, Talekar 1991). Until the present study, it has not been found as a pest of tomato in the United States (Seal 2015, unpublished data). However, it has been reported as a pest of tomato in the Caribbean (Capinera 2000).

It is a native to Sumatra and Java (Indonesia) where it was first reported by Karny (1925) as a pest of tobacco. Subsequently, it became established in most Asian countries (Bangladesh, Brunei Darussalam, China, Hong Kong, India, Japan, Malaysia, Myanmar, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan and Thailand. In Africa, it was reported from Mauritius, Nigeria, and Sudan. In North America, it was reported from Hawaii and Florida. In Central America and Caribbean, it was reported from Antigua, Barbuda, Barbados, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Martinique, Puerto Rico, St. Lucia, St. Kitts and Nevis, Trinidad and Tobago. In South America, it was reported from Brazil, Guyana, and Venezuela. In Oceania, it was reported from Australia, Guam, New Caledonia, Samoa, Wallis and Futuna. In Europe, it was reported from the Netherlands. Later it extended its distribution to Sudan and Taiwan. It has been considered as a significant pest in southern Japan (Sakimura et al. 1986). In 1990, melon thrips arrived in Homestead, FL.

Melon thrips is a foliage feeder and damage is mostly caused by both adult and larval feeding. Although it feeds on all vegetable crops, its populations become rapidly abundant on eggplant, cucumber, bean and squash. At the initiation of infestation, melon thrips adults and larvae congregate on the underside of a host leaf along the main veins and veinlets. As infestation progresses and population abundance increases, adults and larvae move to rest on the under surface of a leaf and then to the upper surface of the infested leaf. Melon thrips also attack flowers and fruits of the host crops. In a severe case, they infest leaf petioles and stems of feeding crops. In southern Florida, melon thrips has been reported as a devastating pest of bean, squash, cucumber, eggplant, pepper, potato and okra (Seal and Baranowski 1992). It was observed occasionally on tomato but did not reproduce there (Seal, field observation).

In a recent study in 2015, melon thrips adults were collected in >80% tomato flowers (Seal 2015, Unpublished data). However, very few larvae were collected from these samples. We did not observe any life stages of melon thrips in tomato leaf samples. Further sampling using tomato leaves and flowers will be continued. Melon thrips has been reported to transmit tospoviruses (Nagata et al. 2002). Further research studies need to be conducted to confirm *T. palmi*'s ability to transmit tospoviruses.

*Thrips palmi* is a tropical insect and could not survive winter conditions in southern Honshu (Tsumuki et al. 1987). At 25°C, duration from egg – egg lasts for 17.5 days. *T. palmi* mates immediately after emergence, but pre-oviposition period lasts for 1-5 days. Nonmated females oviposit within 1-3 days of emergence (Wang et al. 1986). Eggs are deposited individually in the host tissue underneath the epidermal layer positioning at 45° angle with the micropylar end somewhat exposed. Embryonic development lasts 3-5 days in a field condition. It has two larval instars, each lasts for 4 to 6 days. Larval stage is followed by a short prepupal period which drops from the plant hosts to the soil surface for pupation. Pupal period lasts for 2-4 days. The total development period from first instar to adult emergence lasts for 10 to 12 days.

Management of melon thrips were principally based on chemical insecticides, although importance of naturally occurring predators and pathogens should not be ignored (Seal and Baranowski 1992, Seal et al. 1993, Seal 1997, Seal and Sabines 2012). We evaluated several dozens of insecticides belonging to the classes- neonicotinoid, diamide, tetramic acid (Movento<sup>®</sup>, Group 23), pyridinecarboxamide (Beleaf<sup>®</sup>, Group 9c), pyrazole (Tolfenpyrad), carbamate, organophosphate, chinomethionate, inorganic, triazine IGR, botanical, benzoylphenyl urea, pyrethroid, wax, phenylpyrazole and fermentation product. Percentages reduction of melon thrips varied from 20 -95% depending on various classes. Fermentation products (spinetoram, spinosad and abamectin) were more effective (55-95%) followed by carbamates (methomyl, oxamyl) and organophosphates (malathion).

Among natural biocontrol agents, minute pirate bug, *Orius insidiosus* (Say) is the most effective with the ability to feed on 15 to 21 melon thrips larvae from first to 10<sup>th</sup> day of its life cycle (Seal 1997). Minute pirate bug disappears from the commercial fields due to the use of various chemicals for controlling pest insects.

Currently abundance of melon thrips is increasing in all vegetable crops (Seal 2015, unpublished data) even after routine application of commonly used insecticides. Further studies should be

conducted to use insecticides in rotation or combination by applying them as a foliar spray or soil drench or both methods when needed in order to achieve better control of melon thrips. In the present program we conducted three studies to evaluate various insecticides of different mode of actions by applying them alone, in combination or in rotation. Information generated from this study will help growers to effectively manage melon thrips and other related thrips.

## **MATERIAL AND METHODS**

Three studies were conducted to evaluate effectiveness of insecticides for controlling melon thrips on tomato varying in locations and insecticide treatments. The first study was conducted at Tropical Research and Education Center (TREC), University of Florida-IFAS, Homestead FL. The soil type of the experimental field was Rockdale. For planting tomato, raised beds of 6 in. high, 36 in. wide were prepared which were covered with black on white 1 ml polyethylene mulch (Grower's Solution LLC., 1211 A Boyd Farris Rd., Cookeville, TN 38506). Beds were provided with two parallel lines of drip tape (T-systems, DripWorks, Inc., 190 Sanhedrin Circle, Willits, CA 95490) having 5 inch emitter spacing to supply 1500 gallons of water/acre/day. The T-tapes were placed 12 in. apart on both sides of the center of each bed to irrigate and fertigate the host plants. At the time of preparation of beds, granular fertilizer 8:16:16 (N: P: K) at the rate of 1200 lbs./acre was broadcast on the upper surface of a bed and incorporated mechanically with 4 in. deep soil. 'BHN 585' tomato seedlings were planted 18 in. apart within rows and 36 in. apart in between rows. Plants were drip irrigated and fertigated with 4-0-8 liquid fertilizer by applying 0.5 lb. N/day/acre starting at 4 weeks after planting and progressively with an increment of 0.25 lb. every two weeks until 4.0 lb. N/acre/day when plants were bearing fruit.

Each treatment plot consisted of two beds each 30 ft. long and was arranged in a Randomized Complete Block (RCB) design with four replications. A 5 ft. wide nonplanted area separated the blocks from each other. Insecticide treatments evaluated in this study included: i) combination of abamectin and chlorantraniliprole (8.0 oz/acre, A21390a, Syngenta Crop Protection); ii) combination of abamectin and chlorantraniliprole (8.0 oz/acre, A21390b, Syngenta Crop Protection); iii) combination of abamectin and chlorantraniliprole (8.0 oz/acre, A21390c, Syngenta Crop Protection); iv) spinetoram (8.0 oz/acre, Radiant<sup>®</sup>, Dow AgroSciences); v) combination of thiamethoxam + chlorantraniliprole (13.0 oz/acre, Durivo<sup>®</sup>, Syngenta Crop Protection); vi) cyantraniliprole foliar formulation (13.5 oz/acre, Exirel<sup>®</sup>, Dupont Crop Protection). All insecticide treatments, except Durivo, were applied on foliage.

The second study was conducted in a commercial field following all management practices as described in the first study. Twelve treatments used in this study included:

i. cyantraniliprole (21.4 oz, Exirel<sup>®</sup>); ii. spinetoram (8.0 oz/acre, Radiant<sup>®</sup>); iii. bifenthrin + imidacloprid (5.0 oz/acre, Brigadier<sup>®</sup>, FMC Corporation); iv. dinotefuran (5.0 oz/acre, Venom<sup>®</sup>, Valent USA) in combination with spinetoram (8.0 oz/A); v. acetamiprid (6.0 oz/acre, Assail<sup>®</sup>, United Phosphorus, Inc.) in combination with chlorpyrifos (16.0 oz/acre, Lorsban<sup>®</sup>, Dow AgroSciences); vi. flonicamid (4.0 oz/acre, Beleaf<sup>®</sup>, FMC); vii. spirotetramat (5.0 oz/acre, Movento<sup>®</sup>, Bayer Crop Science) in combination with spinetoram (8.0 oz); viii. clothianidin (6.0 oz/acre, Belay<sup>®</sup>, Valent USA) in combination with malathion (32.0 oz/acre, Malathion<sup>®</sup>, Loveland Products Inc.); ix. chlorpyrifos; x) abamectin (16.0 oz/acre, Agrimek<sup>®</sup>, Syngenta Crop

Protection); xi) bifenthrin (2.5 oz/acre, Brigade<sup>®</sup>, FMC) and xii) a nontreated control. All treatments were applied on foliage.

The third study was also conducted in commercial field following management practices as discussed in the previous two studies. Seven treatments included in this study were: i. tolfenpyrad (21.4 oz/acre, Torac<sup>®</sup>, Nichino America); ii. spinetoram (8.0 oz/acre Radiant<sup>®</sup>, Dow AgroSciences); iii. spinetoram (8.0 oz/acre) in rotation with tolfenpyrad (21.4 oz/acre); iv. clothianidin (6.0 oz/acre); v. oxamyl (32.0 oz/acre, Vydate<sup>®</sup>, Dupont Crop Protection) in combination with spinosad (8.0 oz/acre, Spintor<sup>®</sup>, Dow AgroSciences); vi. zeta-cypermethrin + bifenthrin (6.0 oz/acre, Hero<sup>®</sup>, FMC Corp.) in combination with abemectin (16.0 oz/acre, Agrimek<sup>®</sup>, Syngenta Crop Protection) and vii. a nontreated control. All insecticides were applied on foliage.

Foliar application of all insecticides was performed by using a backpack sprayer delivering 70 GPA at 30 psi. on four dates at weekly intervals. Induce<sup>®</sup>, a nonionic surfactant, was added to each treatment solution at 0.25% v/v. Soil application of insecticides was performed by drenching 120 GPA using a backpack sprayer without nozzle.

Evaluation of treatments was made 48 h after each spray by randomly collecting 10 flowers from each treatment plot. All flowers from a treatment plot were placed in a zip-lock bag and were marked with date, treatment and block number. While collecting in the field, the samples were temporarily placed in an icebox (28 x 16 x 16 in.) to avoid desiccation. At the end of collection, all samples were transported to the laboratory. Leaf sample in each zip-lock bag was soaked in 50 ml of 70% ethanol for 15-25 minutes to separate thrips from the flower samples. Flowers were then carefully taken out leaving thrips in the alcohol. All thrips left in the alcohol were separated by sieving alcohol using a 500 mesh (26 micrometer) nematode extraction sieve (W.S. Tyler<sup>®</sup> Industrial Group, 8570 Tyler Boulevard, Mentor, Ohio 44060). Finally, thrips specimens in the sieve were transferred to a Petri dish with 5-10 ml ethanol (70%) to count numbers of adults and larvae using a binocular microscope at 10-20 X.

### **Statistical analysis.**

Data were transformed using square-root ( $x + .25$ ) before analysis of variance. The transformed data were analyzed with one-way analysis of variance (SAS, 1989). Means were then separated by Duncan's (1955) multiple range test when significant ( $P < 0.05$ ) values were found in the analysis of variance (ANOVA).

## **RESULTS AND DISCUSSION**

In the first study, melon thrips adults in all prespray samples did not differ statistically from the nontreated control (Figure 1). Mean numbers of melon thrips adults in the post spray samples, average across the four sampling dates, were significantly fewer than the prespray sample. Each insecticide treatment significantly reduced melon thrips as compared to the nontreated control. Radiant<sup>®</sup> provided the highest reduction of melon thrips adults on tomato. Effectiveness of Spintor<sup>®</sup>, a very closely related chemical of Radiant<sup>®</sup>, in controlling melon thrips adults and larvae was reported in a previous study by Seal et al. (2013).

In the second study, insecticide treatments significantly reduced melon thrips adults on tomato when compared with the prespray samples (Fig. 2). Mean numbers of thrips in each treatment sample differed significantly from the nontreated control. The highest percentage reduction of melon thrips was achieved by applying Beleaf<sup>®</sup> followed by Venom<sup>®</sup> plus Radiant<sup>®</sup> (Fig.3). When mean numbers of melon thrips adults for all treatments were compared together Radiant<sup>®</sup> in combination with Venom<sup>®</sup> provided better control of melon thrips than Radiant<sup>®</sup> applied alone or Radiant<sup>®</sup> applied in combination with Movento<sup>®</sup>. Belay<sup>®</sup> in combination with Malathion<sup>®</sup> did not differ significantly from Radiant<sup>®</sup> applied alone in the mean numbers of melon thrips adults.

In the third study, melon thrips were collected from all treatment plots (Fig. 4). Vydate<sup>®</sup> in combination with Entrust<sup>®</sup>, and Hero<sup>®</sup> in combination with Agrimek<sup>®</sup> did not reduce melon thrips when compared with their respective prespray samples. However, the mean numbers in these two treatments significantly differed from the nontreated control. In the nontreated control, the postspray date thrips number was greater than the prespray date number. In this study, Radiant<sup>®</sup> in rotation with Torac<sup>®</sup> provided best control of melon thrips followed by Belay<sup>®</sup> alone.

## ACKNOWLEDGEMENT

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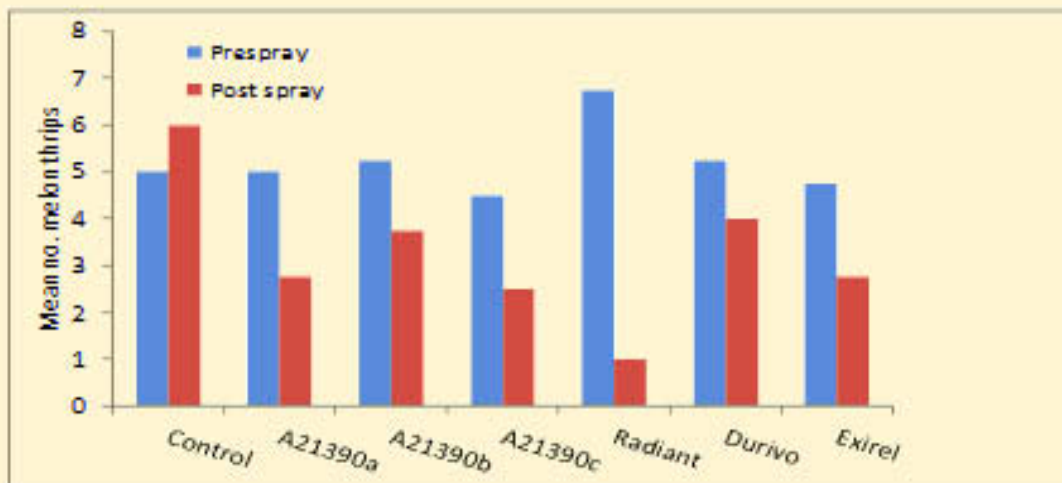


Figure 1. Melon thrips control on tomato using various insecticide treatments at TREC, UF-IFAS, 2014-2015

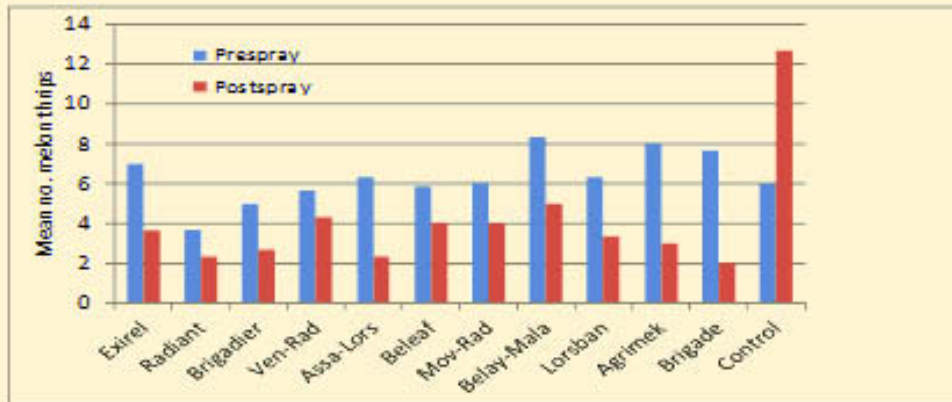


Figure 2. Melon thrips control using various insecticide treatments in a commercial tomato field, 2014-2015

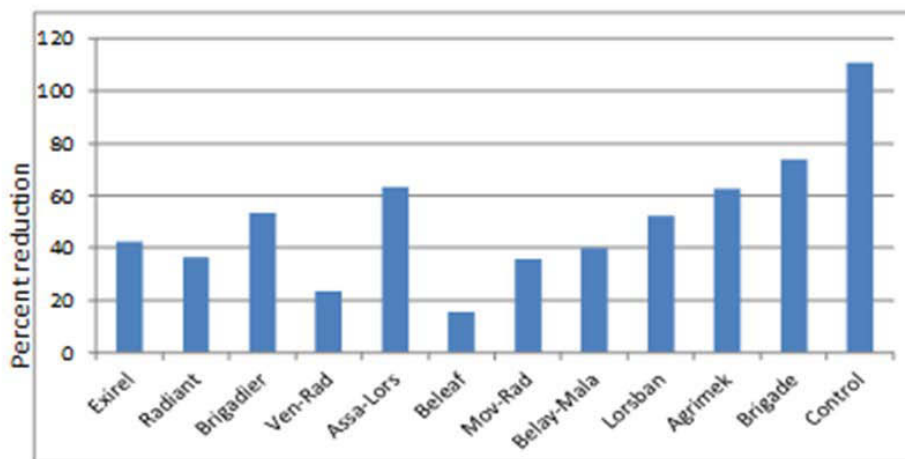


Figure 3. Melon thrips control using various insecticide treatments at a commercial tomato field, 2014-2015

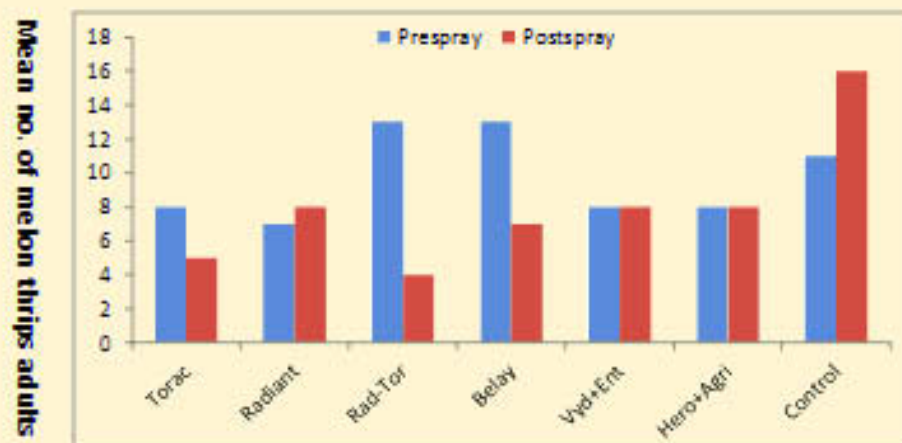


Figure 4. Melon thrips control using various insecticide treatments at a commercial tomato field, 2014-2015



**ASSESSING THE NEEDS OF SMALL LIVESTOCK PRODUCERS**

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**Abstract:** Small Farms in Marion County and Florida represent over 90 percent of agricultural operations. Providing up-to-date, research based educational opportunities for small farmers in pasture management is a priority in this county due to economic and environmental reasons. **Methods:** A three part pasture management school series was designed covering topics such as basic plant physiology, forage varieties for Central Florida, weed control and grazing strategies. Four classes and a field trip were conducted as part of this course. A total of 28 people attended the Small Farms Pasture Management School. Their animal species of interest were small ruminants (12%), poultry (8%), bovine (35%), equine (35%) and swine (12%). Forty five percent of the audience farmed 1 to 10 acres, 20 percent farmed 11 to 20 acres and 21 to 50 acres while 15 percent had 50 acres or more. **Results:** Survey response rate was eighty-nine percent (n=25). One hundred percent (n=22) would consider implementing pasture management practice changes discussed during the meetings. Examples of practice change include: grazing management (n=8), winter forage production (n=6) and weed management (n=8). **Conclusion:** The survey results indicated a significant need for more educational programs targeting small farmers and ranchers in the State of Florida. Further educational needs identified were: manure management (n=7), farm and pasture mathematics such as calculating fertilization rates (n=6), animal nutrition (n=3) and weed control (n=3). The survey also indicated that the Small Farms Pasture Management School had an average value of \$917.85 to the attendees.

**Keywords:** small farms, Florida, pasture management

**SELECTION OF AN AQUACULTURE PRODUCTION SYSTEM FOR FARMERS IN THE US VIRGIN ISLANDS**

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**Abstract:** Two aquaculture production systems have been developed by the University of the Virgin Islands Aquaculture Program - the UVI Aquaponic System and a biofloc system. The systems were designed to address the constraints and opportunities of local farmers and promote their integration with other traditional farming activities. The systems intensify production to minimize land requirements, conserve fresh water which is scarce and reclaim fish wastes as nutrients for either hydroponic or agronomic vegetable production. The program is well known for the development of design criteria and operation guidelines for these systems and has trained over 600 individuals from around the globe. The UVI Aquaponic System in particular has been adopted by many entrepreneurs in temperate zones facing the same limitations of available land and water and the desire to reclaim nutrients instead of discharging them into the environment. Adoption of these aquaculture systems by USVI farmers has been limited. Most attempts to implement the technology have been on the home/hobby scale. Only one investor developed a commercial-scale farm which ceased operation after a hurricane in 1995. To better inform local farmers about the production and costs of the UVI designed systems a decision tree was developed. A decision tree helps farmers select a production system given their individual constraints: access to capital and availability of land and water. An assumption is made for equal production of tilapia and the costs associated with that production is evaluated for each system. Evaluation of FCR, survival, production ( $\text{kg}/\text{m}^3$  and  $\text{kg}/\text{ha}$ ), energy inputs ( $\text{kg}/\text{kWh}$ ) and labor guide the decision process. The addition of vegetable crops in hydroponic beds or adjacent fields adds additional costs and revenues to both systems. Given this decision making process, a farmer can make an informed decision and select the best production system for his enterprise.

**EFFECT OF FOLIAR SPRAY APPLICATION OF CALCIUM AND PHOSPHORUS ON FRUIT PRODUCTION OF ZUCCHINI (*Cucurbita pepo*)**

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**Abstract:** The UVI Aquaponics System is a food production technology which integrates tank fish culture components with hydroponic vegetable cultivation. The integration conserves land and water and recovers waste nutrients from fish into a valuable vegetable crop. The primary waste from fish metabolism is ammonia-nitrogen which is converted by biological nitrification processes into nitrate-nitrogen which is used by plants to grow stems and leaves. Previous research at UVI-AES has focused on the production of lettuce and other leafy vegetables. Research has been limited on production of fruiting plants which need phosphorus and calcium to promote fruit set and produce quality fruit. The purpose of this study was to quantify zucchini production when foliar sprayed with different levels of calcium and phosphorus. To determine the effect of calcium on the zucchini production we look at both the marketable and nonmarketable production. In the calcium group, five set of plants were treated including a control group that was not treated. The application rates of 0.0 (control), 1.25, 2.50, 3.74 and 5.0 mg/l were applied weekly to the plant leaf surfaces. The plant that was sprayed with a 3.75 mg/l concentration of calcium was most effective and had a great production of zucchinis, 33.9/m<sup>2</sup> for the production period. The control group however produced a high amount of unmarketable zucchinis (28.5/m<sup>2</sup>). The marketable yield mass of 7.5 kg/m<sup>2</sup> with the 3.75 concentration was most effective. The same method was used to determine the effect of different levels of phosphorus on the zucchini plants. Five sets of plants were used for this experiment including a control group. The application rates of 0.0 (control), 0.5, 1.0, 1.5 and 2.0 mg/l were applied weekly. The plant that received the 1.00 mg/l concentration of phosphorus was most effective and had a great production of marketable zucchinis. It also yielded the highest mass (7.4 kg/m<sup>2</sup>). The plant that received 0.50 mg/l concentration of phosphorus was yielded the greatest number of unmarketable zucchinis. Foliar application of both calcium and phosphorus was effective in elevation production number and mass for zucchini grown in an aquaponic system. Future research will evaluate combined nutrients to further enhance production.

## **INFLUENCE OF EXTENDED REFRIGERATION ON PEA SEED VIABILITY**

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**Abstract:** Peas are a commercially grown vegetable that is nutritious in providing the human body with various minerals, vitamins and anti-oxidants. The purpose of this study was to evaluate the influence of refrigerated storage on snap peas (*Pisum sativum*) and snow peas (*Pisum macrocarpon*) seed viability after four years. A germination viability test was conducted using six varieties which were replicated in petri-dishes with each treatment containing 50 seeds. Results indicated that the four year of refrigeration significantly reduced the seed viability of the snap pea varieties ‘Super Sugar Snap’ (23%), ‘Sugar Sprint’ (35%), and ‘Cascadia’ (24%). There was no change in the germination rate for the snow pea varieties “Little Sweetie” and ‘Oregon Giant. The “Mammoth Melting Sugar” snow pea variety had an increased rate of germination by 15% indicating a possible after-ripening. Refrigerating seed for four years can be used to maintain seed viability for the selected snow peas varieties but not for the selected snap peas. This research was supported by USDA-Hatch and USDA-NIFA-Insular Tropical Grant funds.

## **INTRODUCTION**

Germination is the process by which a dormant seed begins to sprout and grow into a seedling. Epigeal (*Epigeous*) germination implies that the cotyledons are pushed above ground by the hypocotyl. The hypocotyl grows, while the epicotyl stays the same length. However in hypogeal (*hypogeous*) germination, the hypocotyl remains short, the cotyledons forces the radicle and epicotyl axis to extend out of the seed coat. The epicotyl and the seed with the enclosed cotyledons remains underground. The purpose of this study was to evaluate the influence of refrigerated storage on snap peas (*Pisum sativum*) and snow peas (*Pisum macrocarpon*) seed viability in vitro and in situ after four years.

## **MATERIALS AND METHODS**

Seed viability was evaluated through germination conducted on six varieties of Pea seeds obtained from Twilley, Stokes, and Whillhite seed companies in 2010 and stored in a refrigerator for four years. Two types of peas was used :snap pea varieties “Super Sugar Snap”, “Sugar Sprint”, and “Cascadia”. Snow pea varieties consisted of “Little Sweetie” and “Oregon Giant”, and “Mammoth Melting Sugar”. In vitro germination involved selecting 50 seeds and placing them in a petri plate that contained a piece of wetted paper towel. Each variety was replicated twice. Water was applied as needed and the seeds observed daily for five days. Germination was counted and recorded when the radicle emerged from the seed. After the in vitro lab test, seeds were planted in the field with four replications in a randomized block design. Seeds were inoculated with rhizobium bacteria to encourage nitrogen fixation prior to planting. Seeds were planted at 7.5 cm spacing on both sides of the irrigation line. Germination was counted eight

days after planting when the epicotyl emerged.  $X^2$  analysis was used to compare in vitro and in situ germination with the published rate from 2010.

## RESULTS AND DISCUSSION

In Vitro germination tests indicated that the four year refrigeration significantly reduced the seed viability of the snap pea varieties “Super Sugar Snap”, “Sugar Sprint” and “Cascadia” (Figure 1). There were no significant changes in the germination rate for “Oregon Giant” and “Little Sweetie”. “Mammoth Melting Sugar” a snow pea variety had a significant increased germination rate of 15% indicating a possible after-ripening. In Situ germination, resulted in a significant decrease in germination for “Super Sugar Snap” and “Cascadia” (Figure 2). A significant increase was again evident in the “Mammoth Melting Sugar” seed’s viability.

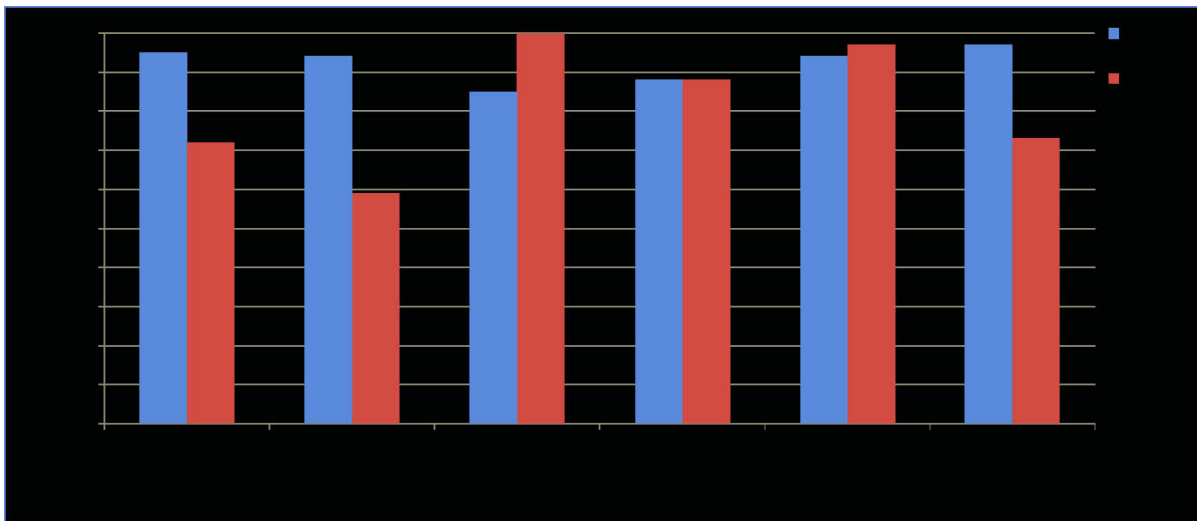


Fig. 1.  $X^2$  analysis of in vitro pea germination compared to original expected germination four year old seed from 2010.

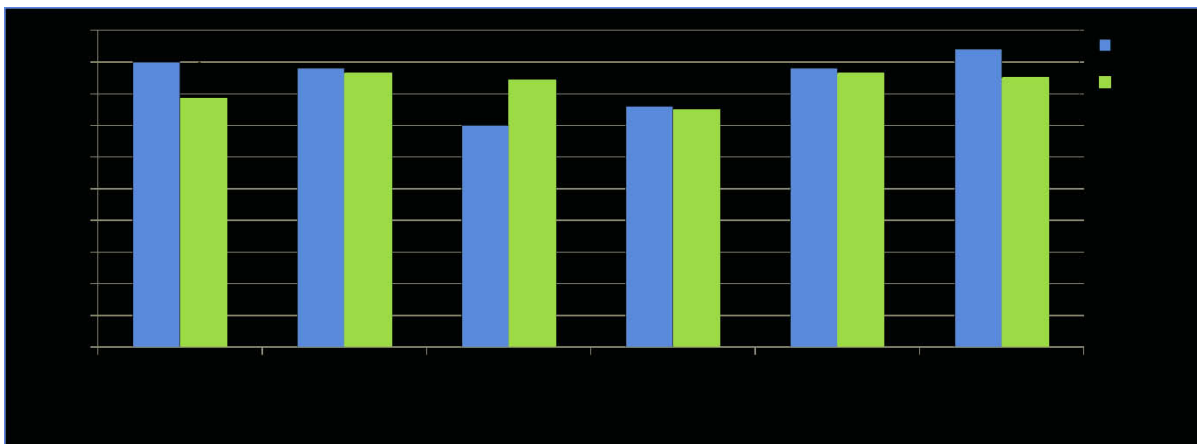


Fig. 2.  $X^2$  analysis of in situ pea germination compared to original expected germination four year old seed from 2010.

## **CONCLUSION**

Refrigerating seed for four years can be used to maintain seed viability for the selected snow peas varieties but not for the selected snap peas. In vitro germination is not always identical to in situ germination which has less environmental control.

## NITROUS OXIDE PRODUCTION IN TROPICAL SOILS UNDER DIFFERENT MOISTURE REGIMES AND N-APPLICATION RATES

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**Abstract:** Nitrous oxide (N<sub>2</sub>O) is a potent trace gas responsible for approximately 6% of the current greenhouse gas (GHG) effect with 60 to 80% of total global emissions originating from the agricultural sector. Within this sector, the majority of N<sub>2</sub>O emissions come from soils arising mainly from N fertilizer additions. In the Caribbean, no studies have been conducted to quantify the N<sub>2</sub>O flux from our soils, although this information is crucial in gaining a better understanding of how to manage N fertilizers, such as urea, to minimize N<sub>2</sub>O fluxes. In our region, urea represents approximately 80% of N-fertilizer used. In this laboratory study, the effects of urea-N rate and soil moisture on N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> flux were investigated on three soils from Trinidad. The 18 treatment combinations were arranged in a completely randomized design with four replicates (72 experimental units). The equivalent of 220 g oven dried soil were placed in 1L mason jars and incubated at 50% Water Filled Pore Space (WFPS) for 7 days. Then, urea-N solutions of 0, 75 and 150 kg N/ha were applied and the soil moisture was further adjusted to 60% and 90% WFPS. Jars were then sealed and headspace air was sampled using a syringe via a rubber septum on the lid at regular intervals: three times on day 1 and then once per day for the next two weeks. Gas samples were injected into evacuated exetainers and analyzed for N<sub>2</sub>O, CO<sub>2</sub> and CH<sub>4</sub> concentrations using a gas chromatograph equipped with a Flame Ionization Detector (FID) and an Electron Capture Detector (ECD). Increases in N-fertilizer application rate did not have a significant effect on N<sub>2</sub>O production however it must be noted that N<sub>2</sub>O emissions were greater as N-applicate rate increased. Soil moisture was significant to N<sub>2</sub>O production with highest emissions under 90% WFPS compared to 60% WFPS. Soil type also had a significant effect with the greatest emission from the Nariva peaty clay soil type. The N<sub>2</sub>O flux data presented in this paper is the first report for Trinidad soils. This study has implications for improving urea-N fertilizer use efficiency, which could enhance soil productivity while minimizing environmental pollution.

**Keywords:** Nitrous oxide, Nitrogen fertilizer, Fertilizer use efficiency, Water Filled Pore Space (WFPS)

## INTRODUCTION

Sustainable ecosystems are necessary for people and the environment today and for future generations. Anthropogenic activities, particularly the intensive use of non-renewable natural resources has resulted in the degradation of environmental quality, adversely affecting these ecosystems (Picone et al. 2014). Global warming has been reported to be a direct consequence of such activities caused by the increase in the atmospheric concentration of greenhouse gases such as nitrous oxide (N<sub>2</sub>O) (Picone et al. 2014). N<sub>2</sub>O significantly contributes to global warming and mitigating N<sub>2</sub>O is essential in combating global climate change (Chen et al. 2014).

According to the Intergovernmental Panel on Climate Change (IPCC) 2013, N<sub>2</sub>O has a global warming potential that is 298 times higher than that of carbon dioxide (CO<sub>2</sub>) even though it only accounts for 8% of the global anthropogenic greenhouse gas emissions (Picone et al. 2014). Once it is released into the atmosphere, the stratospheric reaction with atomic O<sub>2</sub> to produce nitric oxide (NO) induces the depletion of the stratospheric ozone layer (Wrage et al. 2001, Kool et al. 2010, Crutzen 1981). Over the past few decades and presently, the concentration of N<sub>2</sub>O continues to increase at an annual rate of 0.25% which suggests there is definitely a cause for concern regarding N<sub>2</sub>O emissions.

Most of the direct N<sub>2</sub>O emissions arise from agricultural soils and this has contributed to the increasing atmospheric N<sub>2</sub>O concentration in recent times (Chen et al. 2014, Kool et al. 2010, Pihlatie et al. 2004, Wrage et al. 2004, Wang et al. 2013). The IPCC second assessment report estimated that the total N<sub>2</sub>O emission from farmland is 350 x 10<sup>4</sup> tN y<sup>-1</sup> and this quantity accounts for 61.4% of anthropogenic emissions and 23.8% of global N<sub>2</sub>O emissions. Other authors even suggest that 80% of total anthropogenic N<sub>2</sub>O emissions arise from agricultural activities (Yan et al. 2014).

It has therefore become imperative to understand and identify the processes producing N<sub>2</sub>O and the key factors affecting the production rates in agricultural soils (Pihlatie et al. 2004). It is well established that the microbial processes of nitrification and denitrification represent the main sources of N<sub>2</sub>O emissions (Firestone and Davidson, 1989). While nitrification is a two-step process which involves the oxidation of ammonium (NH<sub>4</sub><sup>+</sup>) to nitrite (NO<sub>2</sub><sup>-</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>) (Garrido et al., 2002) which provides the raw material for potential N<sub>2</sub>O formation, denitrification is the biological reduction of NO<sub>3</sub><sup>-</sup> to nitrogen (N<sub>2</sub>) gas by facultative heterotrophic bacteria which is the process directly responsible for the emissions (WPC, 2010). However, in a process called “nitrifier denitrification”, ammonium oxidizers containing NO<sub>2</sub><sup>-</sup> reductase may use NO<sub>2</sub><sup>-</sup> as an alternative electron acceptor in O<sub>2</sub>-limiting conditions, to produce NO and N<sub>2</sub>O emissions (Muller, 1999; Myrold, 1998)

The emissions of N<sub>2</sub>O are greatly influenced by soil moisture content, soil temperature, mineral N (NH<sub>4</sub> and NO<sub>3</sub>), organic carbon contents, placement of fertilizer and soil texture (Davidson, 1991, 1993; Smith et al., 1998, Dobbie et al., 1999, Skibia and Ball, 2002). According to Taggart et al. (2002), the interaction of soil texture, fertilization and soil moisture has a significant influence on N<sub>2</sub>O emissions. Increasing moisture content in soils according to Simojoki and Jaakola (2000) acts as a catalyst to N<sub>2</sub>O emissions up to 90% water-filled pore space (WFPS). The emissions of N<sub>2</sub>O is known to be predominant in anaerobic conditions following a period of aerobic conditions and has been observed to be emitted in large bursts about 20-24 hours after rainfall (Wagner-Riddle et al., 1996).

An analysis of literature reveals that techniques for measuring N<sub>2</sub>O generally fall into two main categories- chamber (enclosure) and micrometeorology techniques (IFA, 2001). Ryden et al. (1978) in his study concluded that the chamber technique offer the most useful approach for this measurement primarily because gases emitted by the soil into a chamber are not continually diluted with external air allowing smaller fluxes to be measured. Additionally, a properly vented chamber effectively avoids the potential for an influx of gases by mass flow from outside the



chamber by maintaining equal pressures inside and outside the enclosure (Hutchinson and Mosier 1981).

It is essential to investigate and understand how these factors as well as their interactions would affect the production of N<sub>2</sub>O in tropical soils since no published research exist to describe N<sub>2</sub>O production in Trinidad and by extension the Caribbean region. The main objective of this study was to investigate the influence of soil moisture, soil texture and N-application rate on N<sub>2</sub>O production in Trinidad soils.

## MATERIALS AND METHODS

### Soil material and preparation

The soil types used for this trial were the A horizon of River Estate Series from the University of the West Indies field station, Mt. Hope Trinidad, Nariva Series and Arena Series from East Trinidad. River estate series is a freely drained loam soil developed from alluvium where the parent material is essentially micaceous phyllite alluvium. Nariva series has impeded drainage and a mineral topsoil of very dark gray or black humic peaty clay. Arena series is a freely drained soil where the parent material is quaternary sand.

These soils were taken from the top 0-20 cm at the respective locations and this corresponds with the depth to which they would be cultivated during land preparation. The soils were air dried, homogenized, and sieved to separate the fine-earth fraction (<2 mm) to remove visible roots and other impurities in preparation for soil testing as well as for use in the trial. Selected physical and chemical properties for each soil texture from composited samples were analyzed as listed in Table 1.

Table 1: Some physical and chemical soil properties from soil analyses before pre-incubation of air dried soils

Soil Properties	River Estate Series	Arena Series	Nariva Peaty Clay
Sand (%)	23	94	14
Silt (%)	66	6	37
Clay (%)	11	0	49
pH	5.64	4.34	4.47
Soil Organic Nitrogen (SON) (%)	0.149	0.059	0.635
Soil Organic Carbon (SOC) (%)	1.155	0.615	5.367
Ammonia (NH <sub>4</sub> ) <sup>+</sup> (mg kg <sup>-1</sup> )	3.411	2.637	5.828
Nitrate (NO <sub>3</sub> <sup>-</sup> ) (mg kg <sup>-1</sup> )	4.190	2.698	10.538
Bulk Density (g cm <sup>-3</sup> )	1.089	1.4695	0.9328

\* Methods of analysis were obtained from Soil Sampling and Methods of Analysis: Part 1 and 2 (Carter and Gregorich, 2008).

### Experimental design and Treatments

In a completely randomized design, the effect of soil texture (3 soil types), soil moisture (60% and 90% WFPS) and N- application rate (0, 75 and 150kgN/ha) were investigated. WFPS is the volume of water in the soil relative to the total volume of pores (Guo et al. 2010) and was calculated as:

$$\text{WFPS} = (\text{soil gravimetric water content} \times \text{bulk density}) / [1 - (\text{bulk density} / \text{particle density})]$$

\*Particle density assumed to be 2.65g/cm<sup>3</sup>

### **Experimental set-up**

220g of each type air dried soil was moistened homogenously with distilled water to 50% WFPS and then placed in 1-L mason jars. The jars were randomly placed in an incubator and left for a 7-day aerobic incubation (jars were uncovered) at 25°C to stimulate microbial activity.

Following the 7-day aerobic pre-incubation, N-Fertilizer (urea solution) was applied uniformly to the soil surface followed by distilled water to make up the 60% and 90% WFPS. The water was added after fertilizer application to ensure even distribution of the fertilizer. After treatment application, the jars were left open to provide atmospheric air exchange between successive N<sub>2</sub>O flux measurements. This **oxic phase** lasted approximately 7 days which is the expected time for enhanced N<sub>2</sub>O emissions to return to ambient levels.

On day 7, the WFPS treatments in each jar was adjusted to initial levels, jars were sealed with air tight lids and subsequently flushed with N<sub>2</sub> for 6 minutes. The purpose of this is to replace headspace air with nitrogen until the oxygen concentration in the headspace air is less than 5% and create intensely anaerobic conditions and signal the start of the anoxic phase. An oxygen consumption pretest was conducted before the experimental set up and the results for all soil types revealed that after 6 minutes, the oxygen concentration was below 3.7%. After flushing with nitrogen, headspace air samples were taken from each of the jars and analyzed for oxygen concentration. Results revealed that the oxygen concentration in all jars were below 3.3% and N<sub>2</sub>O flux measurements were immediately started and also lasted 7 days. The temperature inside the incubators was monitored daily to ensure that it was more or less constant (25°C).

### **Gas (N<sub>2</sub>O), Soil and WFPS measurements**

N<sub>2</sub>O emissions were intensively monitored for 14 days following the application of treatments. During the first 7 days of sampling, jars were sealed only at the time of sampling (Oxic Phase) as compared to the second week where the jars remained sealed throughout the entire trial (Anoxic Phase). Immediately after applying treatments, jars were sealed and headspace air was sampled using a 20ml polypropylene syringe via a rubber septum on the lid at regular intervals: three times on day 1 and then once per day for the next two weeks. Gas samples were taken at 0 and 60 minutes during each sampling event. Gas samples were injected into evacuated 12ml exetainers (Labco, Buckinghamshire, UK) and analyzed within 2 weeks of sampling for N<sub>2</sub>O, CO<sub>2</sub> and CH<sub>4</sub> concentrations using a gas chromatograph equipped with a Flame Ionization Detector (FID) and an Electron Capture Detector (ECD).

The increase in N<sub>2</sub>O concentrations between 0 and 60 minutes was used to determine the N<sub>2</sub>O emission rates following the linear model of N<sub>2</sub>O accumulation over time. Cumulative N<sub>2</sub>O

emission for each jar was estimated by linear interpolation between data points assuming that measured fluxes represented average daily fluxes. Fertilizer Induced Emission was calculated as the percentage of cumulative N<sub>2</sub>O-N emissions from the applied N during a given period (Yan et al. 2014). N<sub>2</sub>O fluxes were calculated from the change in concentration, C, inside the jars as follows and expressed as mg N<sub>2</sub>O-N m<sup>2</sup> h<sup>-1</sup>:

$$C_m = \frac{C_v \times M \times P}{R \times T}$$

C<sub>v</sub> = Volume concentration (ppm)

GMW = Gram Molecular weight (g)

P= Pressure (mmHg)

n= Number of Moles (Unitless)

R= Gas Constant (m<sup>3</sup> mmHg K<sup>-1</sup> mol<sup>-1</sup>)

T= Temperature (K)

Gravimetric soil moisture contents were measured daily by weighing the mason jars and adjusting the WFPS to the initial levels to closely monitor the temporal variability of N<sub>2</sub>O and WFPS. At the end of the incubation period, the soil-treatment mixture was homogenized and sub-sampled for determination of mineral N (NH<sub>4</sub> and NO<sub>3</sub><sup>-</sup>), pH, DOC concentration (labile C) and moisture content determination. Air temperature of the laboratory was measured using a thermometer. Wind speed, solar radiation and humidity were measured using a portable micrometeorological station.

### Statistical Analyses

Repeated measures ANOVA was used to examine the main effects of Water Filled Pore Space (WFPS), soil type and fertilizer application rates on N<sub>2</sub>O flux. Statistical analyses were conducted using GenStat Discovery Edition 4.

## RESULTS AND DISCUSSION

### Effect of WFPS on N<sub>2</sub>O flux

WFPS had a significant effect on N<sub>2</sub>O flux, cumulative N<sub>2</sub>O emission and fertilizer induced emission as shown in Table 2. In the control jars, only the Nariva soil consistently resulted in positive emissions with higher N<sub>2</sub>O flux values under 90%WFPS compared to 60%WFPS. All other treatment combinations produced negative or below ambient emissions (Figure 1). N<sub>2</sub>O production here may be due to nitrification/denitrification of the resident inorganic nitrogen present in the soil prior to the start of the experiment. Ammonia and nitrate levels before the start of the experiment were in the order; *Nariva* > *River Estate* > *Arena sand*. At 60%WFPS in these control jars, Nariva showed a peak flux of 1.2 mg N/m<sup>2</sup>/h on day 8 of the trial and 4.1 mg N/m<sup>2</sup>/h on day 10 for 90%WFPS.

In all treatment combinations where 75kgN/ha was applied, N<sub>2</sub>O flux rates were relatively low; either negative or below ambient levels (Figure 1). This indicates that for instance, where soil WFPS was 90% and soil nitrogen levels was high, N<sub>2</sub>O flux were still low. This may be due to

the influence of other factors independent to inorganic nitrogen controlling  $\text{N}_2\text{O}$ -N losses by denitrification (Yoshinari, Hynes, and Knowles 1977) e.g. temperature and /or carbon availability. There are studies (Burton and Beauchamp 1985) that suggest that even in soils with high nitrate levels, C availability is the most limiting factor controlling denitrification. A carbon content range greater than 60 - 80 mg C  $\text{kg}^{-1}$  was even suggested to be required for denitrification (Burton and Beauchamp 1985), In this experiment, dissolved organic carbon (DOC) was measured at the end of the trial and results of the concentration are pending. This would better be able to indicate to some extent the effect of C on denitrification. On the other hand, when 150kg N/ha was applied, only the Nariva soil type produced emissions that were above ambient levels. For this soil, peak  $\text{N}_2\text{O}$  flux occurred in 48hrs (7.4 mg  $\text{N}/\text{m}^2/\text{h}$ ) for the 90%WFPS and 72 hours for the 60%WFPS (1.9 mg  $\text{N}/\text{m}^2/\text{h}$ ). In these treatments, peak emissions generally occurred later for the wetter treatments.

Jars fertilized with 150kg N/ha produced greater  $\text{N}_2\text{O}$  fluxes at 90% WFPS as compared to those fertilized with 75kg N/ha. More specifically, fluxes were greatest for the Nariva peaty soil (-1.5-7.4 mg  $\text{N}/\text{m}^2/\text{h}$ ) and least for the Arena sand (-0.5-0.1 mg  $\text{N}/\text{m}^2/\text{h}$ ). Fluxes increased in the order *Nariva*>*River Estate*>*Arena sand*. In all other treatment combinations, negative or below ambient  $\text{N}_2\text{O}$  fluxes were obtained (Figure 1). These results support the suggestion that  $\text{N}_2\text{O}$  emissions is greater in wetter soils which is in agreement with other studies (Dobbie, McTaggart, and Smith 1999, Skiba and Ball 2002, Khalil and Baggs 2005) suggesting that the emissions were predominantly due to denitrification.

During the oxic cycle for the Nariva soil 90% WFPS treatment, there was a gradual increase in  $\text{N}_2\text{O}$  flux until day 2 (peak flux) followed by a steady decline in emissions where it remained low until the end of this cycle (Figure 1). This gradual increase may have been driven by  $\text{NO}_3$ -N availability and all other soil properties that were measured (available C and soil water content-particularly in the 90%WFPS). The decline in emission towards the end of the oxic phase could be due to low carbon availability since soil  $\text{NO}_3$  and  $\text{NH}_4$  levels at the end of the experiment was very high. However, this can only be concluded when DOC analysis is obtained. For the first 2 days of the anoxic cycle however, negative  $\text{N}_2\text{O}$  fluxes were obtained followed by an increase in emissions but throughout this period, all flux rates were below ambient levels (Figure 1). Again, this may be as a result of low carbon availability. Since this trend was specifically observed in the Nariva soil with 90%WFPS, denitrification is probably more influenced by the diffusion of the  $\text{NO}_3$ , even at high concentrations to the active denitrification sites instead of its availability (Yoshinari, Hynes, and Knowles 1977). This is because, increases in WFPS generally results in more denitrification with maximum emissions occurring at WFPS values >60% (Davidson, Rogers, and Whitman 1991).

Table 2: Repeated measures ANOVA on the effect of WFPS, Soil type and N- application rate on N<sub>2</sub>O flux, Cumulative N<sub>2</sub>O emissions and Fertilizer derived emission factors.

Source	df	F	P
<b>N<sub>2</sub>O Flux</b>			
WFPS	1	25.63	<.001
N- application rate	2	0.44	0.649
Soil type	2	32.33	<.001
WFPS*Soil type	2	24.63	<.001
WFPS*N application rate			
<b>Cumulative N<sub>2</sub>O Emissions</b>			
WFPS	1	30.32	<.001
N- application rate	2	1.41	0.255
Soil type	2	37.75	<.001
WFPS*Soil type	2	27.87	<.001
WFPS*N application rate	2	2.02	0.143
<b>Fertilizer induced emission</b>			
WFPS	1	8.82	0.006
N- application rate	1	1.88	0.179
Soil type	2	11.54	<.001
WFPS*Soil type	2	8.86	<.001
WFPS*N application rate	1	3.36	0.076

df, degrees of freedom; *F*, F statistic; *P*, probability level.

*P* < 0.05 determines significance

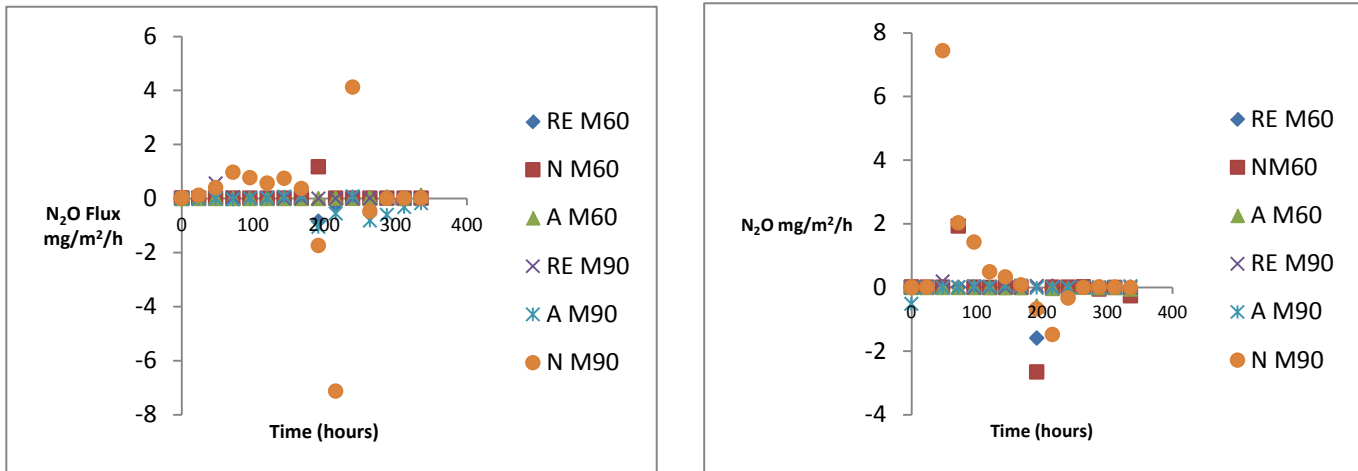


Figure 1: N<sub>2</sub>O Flux under 0, 60 and 90%WFPS with no fertilizer addition, 75kg N/ha (left) and 150 kg N/ha (right).

#### Effect of N-Application Rate on N<sub>2</sub>O flux

Increased availability of NO<sub>3</sub> should increase denitrification (Barnard, Leadley, and Hungate 2005) however N- application rate was not significant to the production of N<sub>2</sub>O in this trial (Table 2). N<sub>2</sub>O flux however increased non-linearly with increasing N application rate only in

the 90% WFPS but was highly variable to N addition in 60% WFPS treatment ranging from slightly positive to highly negative values (Figure 2). (Tiedje 1988) explains the lack of response to denitrification to fertilization because labile C may be limiting in fertile mineral soils. Negative responses to N addition may occur due to competition between heterotrophic bacteria for labile C where denitrifiers may lose (Barnard, Leadley, and Hungate 2005).

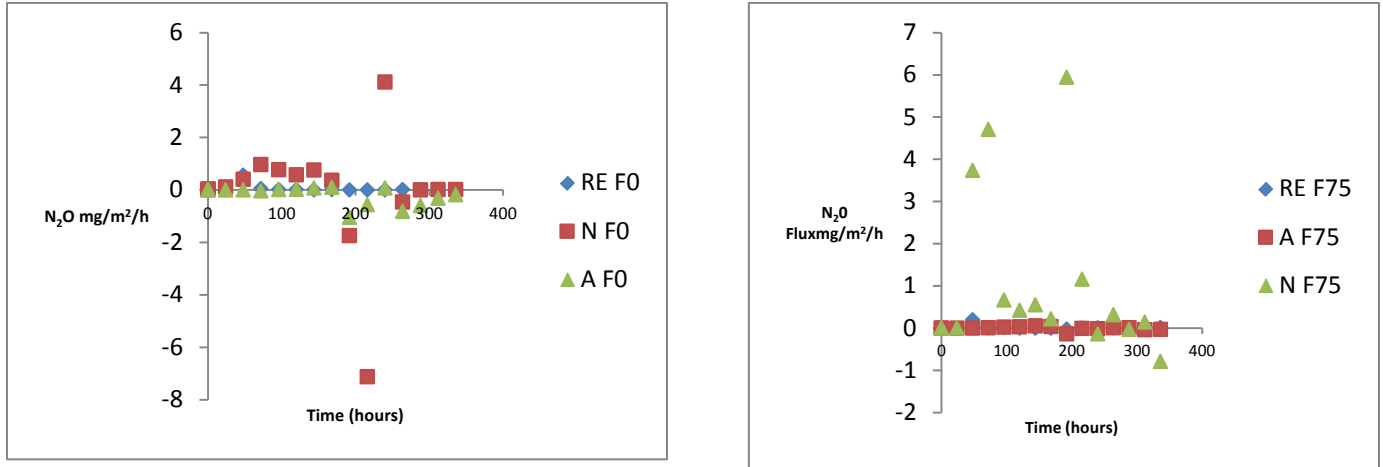
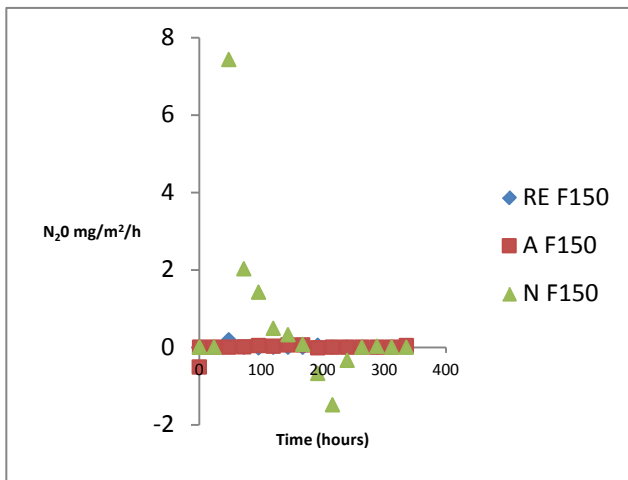


Figure 2: Effect of N-Application rate under 90%WFPS



Cumulative N<sub>2</sub>O Losses and Soil type effect on N<sub>2</sub>O Flux WFPS, soil type and their interaction had significant effects on cumulative N<sub>2</sub>O losses; N –application rate did not (Table 2). This suggests that factors that determine soil aeration such as soil moisture and soil texture strongly regulates N<sub>2</sub>O production (Pihlatie et al. 2004). Evidence of this is seen where cumulative N<sub>2</sub>O losses was greatest in all the Nariva soil treatments at 90% WFPS followed by those under 60% WFPS (except when 75kg N/ha was applied). Arena sand had the lowest N<sub>2</sub>O losses. Soil characterization of the Nariva soil (Table 1) revealed greater concentrations of NO<sub>3</sub> and NH<sub>4</sub> in addition to soil organic carbon compared to the other soil types, all necessary for N<sub>2</sub>O production.

This soil also possessed the greatest clay content indicating poor aeration, again a condition favorable for denitrification (Barnard, Leadley, and Hungate 2005) . Additionally, (Chen et al. 2014) also suggests higher N<sub>2</sub>O production in heavier textured soils possibly because they

exhibit stronger anaerobic conditions over longer periods than the lighter textured soils. This can also explain N<sub>2</sub>O production in the unfertilized treatments due to N mineralization. Soil moisture (%WFPS) is also seen to be a strong regulator since the cumulative emissions for all soil types were generally greater in the 90% WFPS treatments.

WFPS, soil type and their interaction had significant effects on cumulative N<sub>2</sub>O losses; N – application rate did not (Table 2). The emissions were low for all treatments with the highest being 3.2% in the Nariva treatment fertilized with 75kg N/ha at 90%WFPS followed by the other Nariva treatments that received 150kgN/ha; (0.4% under 90% WFPS and 0.3% under 60%WFPS).

## **CONCLUSION**

This study evaluated the effect of increasing moisture content and N-fertilization on N<sub>2</sub>O emissions in three tropical soils. Increases in N-fertilizer application rate did not have significant effects on N<sub>2</sub>O however soil moisture did with highest emissions under 90% WFPS compared to 60%WFPS. Soil type also had a significant effect with the greatest emission from the Nariva soil possibly due to greater clay content, concentrations of NO<sub>3</sub> and NH<sub>4</sub> in addition to soil organic carbon compared to the other soil types, all necessary for N<sub>2</sub>O production.

Peak emissions occurred at later dates in the trial for the wetter soils (90%WFPS) but only in the unfertilized jars. The jars that received the greatest concentration of N-fertilization had peak emissions occurring at later dates for the drier (60%WFPS) treatments. Soil moisture and soil type both had significant effects on cumulative N<sub>2</sub>O losses and fertilizer derived emission. Cumulative N<sub>2</sub>O losses was greatest in all the Nariva soil treatments at 90% WFPS followed by those under 60% WFPS (except when 75kg N/ha was applied). Arena sand had the lowest N<sub>2</sub>O losses. Fertilizer derived emissions were low for all treatments with the highest being 3.2% in the Nariva treatment fertilized with 75kg N/ha at 90%WFPS followed by the other Nariva treatments that received 150kgN/ha (0.4% under 90% WFPS and 0.3% under 60%WFPS). Generally, this experiment concluded that N<sub>2</sub>O emissions may be more closely related to soil properties and soil moisture than to the N application rate.

This experiment investigated some key regulating factors of N<sub>2</sub>O production under controlled laboratory conditions. Further research is still needed to adequately understand how these factors would control N<sub>2</sub>O production under field conditions for different crops and management practices. These studies would assist in adequately selecting agricultural practices that would ultimately reduce N<sub>2</sub>O emissions in Trinidad.

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**COLLECTING AND COMPARING BREADFRUIT SELECTIONS IN PUERTO RICO**

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**Abstract:** Breadfruit (*Artocarpus altilis*) is a fruit crop of increasing importance in Puerto Rico. Breadfruit is widely distributed in the island, mostly as a backyard and semi-wild tree, but interest in commercial production in organized orchards is on the rise. So far little has been done to select and compare breadfruit germplasm in the Puerto Rico. A Puerto Rico Mayaguez Campus (UPRM) Agriculture Research Station project was started to (a) collect planting material from selected trees in different parts of Puerto Rico and establish tree collections to characterize them and to study their performance in agricultural settings, and (b) to conduct selection comparison experiments to evaluate their growth, pest and disease susceptibility, flowering, fruit attributes and yield. As of 2014, two collections have been established with more than 40 entries (from different mother trees) in the UPRM research stations at the municipalities of Lajas (drier, southwest) and Isabela (wetter, northwest) to serve as germplasm banks in controlled settings. In addition, experimental orchards with randomized complete block design were established in Lajas and in Isabela to study and compare selections of breadfruit.

American Phytopathological Society Caribbean Division  
Student Oral Competition

**EVALUATION OF THE TEPARY BEAN (*Phaseolus acutifolius*) CIAT GERMPLASM COLLECTION FOR RESPONSE TO BEAN COMMON MOSAIC NECROSIS VIRUS (*BCMNV*)**

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**Abstract:** Aphid-transmitted Bean Common Mosaic Necrosis Virus (*BCMNV*) and Bean Common Mosaic Virus (*BCMV*) are potyvirus that cause production losses in bean. Pathotype groups correspond with resistance genes that can be organized in two groups. One group has resistance conferred through recessive isolate-specific genes with five alleles, *bc-1*, *bc-12*, *bc-2*, *bc-22*, and *bc-3* at three loci that need *bc-u* for expression. The second group has resistance conferred through the dominant *I* gene. Developing resistance to viruses will be critical for expanding tepary bean production in areas where they have a high incidence. This study evaluated the response of 207 genotypes from the CIAT (Centro Internacional de Agricultura Tropical) tepary collection to *BCMNV* using a glass house. The inoculum of the NL3 strain was prepared using *BCMNV* infected leaves in cold 0.05 M phosphate buffer, pH 7 (aprox. 1:10 w/v). One week after emergence the primary leaves were inoculated. Cultivar ‘Verano’ (which has the *I* gene) was used as a control. Veinal necrosis and local pinpoint necrotic lesions were identified as a response to *BCMNV*. Genotypes G00041, G00042, G00044 and G40177E1 showed consistent symptoms in three inoculations, with veinal necrosis on the inoculated leaves suggesting the presence of the *bc-12* gene. Genotype G40177E showed restricted local pinpoint necrotic lesions, which in *P. vulgaris* indicates the presence of *I* protected by the *bc-22* gene, however the SW13 SCAR marker did not function in tepary. G40001, G00078, G40177A2, G40269 showed an inconsistent inoculated response.

**Keywords:** bean common mosaic virus, *Phaseolus acutifolius*, tepary bean

**IDENTIFICATION AND MOLECULAR CHARACTERIZATION OF PIGEON PEA WITCHES'-BROOM PHYTOPLASMA IN PLANTS AND ITS POTENTIAL VECTORS IN PUERTO RICO**

Jorge Caicedo Chávez, Agro-Environmental Sciences, College of Agricultural Sciences, University of Puerto Rico, Mayagüez Campus, Mayagüez, Puerto Rico

**Abstract:** Few studies have determined the presence of phytoplasma from important crops in Puerto Rico. Typical phytoplasma symptoms were observed in different plant species such as pigeon pea (*Cajanus cajan*), periwinkle (*Catharanthus roseus*), tabebuia (*Tabebuia pallida*), Spanish lime (*Melicoccus bijugatus*), jungle geranium (*Ixora coccinea*), mango (*Mangifera indica*), cacti (*Opuntia* spp.), citrus trees (*Citrus* spp.), and coffee (*Coffea arabica*). Sixty two plant samples from these species were tested using end point PCR with universal and specific primers (i.e., nested PCR) that amplify the 16S rDNA and ribosomal protein genes (rpIV-rpsC) genes. Fifty one percent of the samples tested corresponding to periwinkle, pigeon pea, citrus, coffee and tabebuia were positive for phytoplasmas with amplicons of 0.8 and 1.2kb, respectively, depending upon the primers used in PCRs. In both cases the DNA sequences and restriction patterns (RLFP) obtained from these samples showed 99% of identity with pigeon pea witches'-broom phytoplasma (PPWB) belonging to group 16SrIX. Due to the lack of studies of potential insect vectors, common auchenorrhyncha species were sweep-collected from pigeon pea and citrus and tested for phytoplasma. Of nine insect genera collected, *Empoasca kraemeri*, *Melornemis antillarum* and *Colpoptera maculifrons* were positive for PPWB phytoplasma using conventional PCR and DNA sequence analysis. These findings indicate that these insects feed upon the aforementioned plant species, and may act as potential phytoplasma vectors in the field. Finally, specific primers were designed for qPCR assay to amplify a 102-bp region of the 16S rDNA gene from samples with low level infections of phytoplasma. By the SYBR® Green method, the melting temperature (T<sub>m</sub>) recorded in positive samples was 82.3oC. These primers amplified and identified DNA of phytoplasma belonging to the groups and subgroups 16SrV-A, 16SrIII-H, 16SrII-D, 16SrV-C, 16SrII-C, 16SrVI-A, 16SrXII-A and 16SrIX-C.

**GENETIC DIVERSITY OF *Ralstonia solanacearum* STRAINS CAUSING BACTERIAL WILT OF POTATO IN COSTA RICA**

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**Abstract:** Potato bacterial wilt caused by *Ralstonia solanacearum* (Smith 1896) Yabuuchi et al. (1995), also known as potato brown rot, remains a major threat for potato (*Solanum tuberosum*) production worldwide. Different strains incite the disease at cooler temperatures as well as in tropical and warm-temperature zones. In Costa Rica, while the disease has been reported previously, the diversity of local *R. solanacearum* strains has not been characterized, information which would be key for the successful development of breeding and integrated management programs. Twenty-three bacterial strains were isolated from tubers of wilting potato plants from the two major potato-growing regions of Costa Rica, northern Cartago and Zarcero. Genetic diversity of the Costa Rican isolates was assessed based on species-specific PCR, biovar (bv) determination, phylotype classification and endoglucanase gene (*egl*) sequence (sequevar). PCR using species-specific primers identified all the isolates as *R. solanacearum*. All strains belonged to bv2, phylotype II and sequevar 1, traditionally known as race 3 biovar 2 (R3bv2). The identity of the isolates as *R. solanacearum* R3bv2 was confirmed by PCR with 630/631 specific primers. To the best of our knowledge, this is the first time that the phylotype and sequevar scheme has been applied to address the diversity of *R. solanacearum* in potato in Costa Rica.

**MONITORING OF ENDANGERED PLANT SPECIES AT THE KARST REGION OF PUERTO RICO TO DETECT PLANT PATHOGENIC THREATS**

Cecilia Monclova-Santana, University of Puerto Rico Mayagüez Campus

**Abstract:** Forests at the northern and southern karst of Puerto Rico enclose more than 20 endangered plant species. A diversity of biotic factors such as pest and diseases are usually overlooked as potential precursors of final extinction events of these plants. Thus, this research pursues the evaluation of 23 endangered plant species in 8 forest of the karst region to detect plant pathogenic threats. Plant populations were evaluated in term of health, viability, reproduction, quantity of individuals and, associated plant pathogens. At each location, symptomatic tissue from leaves, fruit, flower or stem was collected for further analysis. Fungi and bacteria were isolated in respective selective media and identified using morphological and molecular criteria. The most frequently isolated fungi were: *Colletotrichum* spp., *Pestalotia* spp., *Curvularia* spp., *Phomopsis* spp. and *Botryodiplodia* spp. All of these fungi were isolated from several of the 23 endangered plant species at both karst regions. Pathogenicity test conducted in *Stahlia monosperma* (“cobana negra”) confirmed that *Colletotrichum* spp. and *Pestalotia* spp. are able to infect the plant with and without lesion causing necrotic spots on leaves. In *Ottozulshia rhodoxylon* (“palo de rosa”), *Eugenia woodburyana* and *Banara vanderbiltii* (“palo de ramón”) only *Pestalotia* spp. were able to directly penetrate plant tissue. *Colletotrichum* spp. and *Botryodiplodia* spp. were less virulent causing necrotic lesions in these two plant species. Two out of the seven bacteria strains isolated were gram negative. One strain was identified as *Pseudomonas* spp. that colonized *Calyptronoma rivalis* (“palma manaca”) inflorescence. To our knowledge this is the first report of these plant pathogens affecting endangered plant species in Puerto Rico. These data will be useful to develop protocols to accomplish the conservation of these plant species.

**IDENTIFICATION AND CHARACTERIZATION OF *Colletotrichum* spp. AFFECTING YAM *Dioscorea* spp. CROP IN PUERTO RICO**

Stephanie Fuentes Aponte, University of Puerto Rico

**Abstract:** Yam anthracnose, caused by *Colletotrichum gloeosporioides*, is widely distributed in most yam-producing areas worldwide, causing losses of up to 90 % in the most palatable species, *Dioscorea alata* and *D. rotundata*. To increase yam production in Puerto Rico, the objectives of this research were to determine disease severity throughout the island and identify and characterize *Colletotrichum* species associated to yam. Fungal isolates obtained were characterized based on morphology, pathogenicity and with two sets of molecular markers (ITS and  $\beta$ -tubulin). Two hundred twenty four isolates of fungi were collected from the germoplasm collection located at the Agricultural Experiment Station in Corozal, Puerto Rico and from yam production fields throughout the island. Of these, 43 isolates were characterized as *Colletotrichum* spp. showing different growth rates and phenotypes on selective media. Using the ITS region, one isolate of *D. alata* (cultivar PI 15587) was identified as *Colletotrichum gloeosporioides*. Nine other genera of fungi were also identified. The majority of *Colletotrichum* isolates were identified from *D. alata*, specifically from cultivars PI 15587, Kabusach, and Gunung. Koch's postulates confirmed the pathogenicity of *Colletotrichum* spp. on *D. alata* and *D. rotundata*. The most severely affected by anthracnose was the Barranquitas municipality with a 70 % of disease severity on *D. rotundata* followed by the municipality of Moca with 50% disease severity on *D. alata*. These results are of significant importance to establish reliable control measures to increase yam production in the region.

**FUNGAL PATHOGEN COMPLEXES ASSOCIATED WITH DISEASES OF RAMBUTAN, LONGAN AND MANGO IN PUERTO RICO**

Luz Serrato-Diaz, Department of Biology, University of Puerto Rico-Rio Piedras

**Abstract:** Different fungi have been associated with diseased inflorescences, leaves, and fruits of mango, rambutan and longan. During a fungal disease survey conducted between 2008 and 2013 at six orchards of rambutan and longan, and one orchard of mango in Puerto Rico, symptoms such as fruit rot, inflorescence blight, rachis canker, flower and vascular necrosis, flower abortion and leaf blotch were observed and sampled. Diseased tissues were disinfested and plated onto APDA medium. A total of 1143 fungal isolates were isolated and identified morphologically and by DNA sequencing of the ITS1-5.8S-ITS2 region of the rDNA, partial region of the 28S large ribosomal subunit, and fragments of  $\beta$ -tubulin gene, histone H3, calmodulin, actin, chitin synthase, glyceraldehyde-3-phosphate dehydrogenase and trans elongation factor 1-alpha (EF1- $\alpha$ ). A total of 262 (22.7%) isolates belonged to the Botryosphaeriaceae, 172 (15%) as *Diaporthe* spp., 128 (11.2%) as *Pestalotiopsis* spp., 112 (9.8%) as *Lasmenia* sp., 93 (8.1%) as *Fusarium* spp., and with lesser frequency, *Gliocephalotrichum bulbilium*, *G. simplex*, and *Calonectria hongkongensis*. Pathogenicity tests confirmed that fruit rot of rambutan was caused by a complex of pathogens such as *Lasmenia* sp., *Lasiodiplodia* sp., *Colletotrichum* sp., *C. hongkongensis*, *G. bulbilium*, *G. simplex*, *Pestalotiopsis* sp. and *Diaporthe* sp. Four fungal species in the Botryosphaeriaceae (*Lasiodiplodia theobromae*, *Neofusicoccum* sp., *N. parvum*, and *N. mangiferae*) caused inflorescence blight in mango. *Lasiodiplodia theobromae* also caused inflorescence blight and fruit rot of longan. *Lasiodiplodia* sp. caused leaf blotch and inflorescence blight of rambutan. *Albonectria* sp. caused inflorescence wilt, vascular and flower necrosis in rambutan, longan and mango. *Diaporthe pseudomangiferae* caused inflorescence rot, rachis canker and flower abortion of mango. Fungi, such as *Guignardia mangiferae*, *Cladosporium cladosporioides*, *Nigrospora oryzae*, *Alternaria alternata* and *Xylaria* spp., were endophytes on these fruit crops. Knowing the pathogens involved in each disease complex will allow for better plant disease management practices.

**REACTION OF *Musa* HYBRIDS AND CULTIVARS TO COLOMBIAN ISOLATES OF *Mycosphaerella fijiensis***

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**Abstract:** Black leaf streak (BLS), caused by *Mycosphaerella fijiensis*, is the most important foliar disease of *Musa spp.* Six *Musa* hybrids and 10 cultivars were screened for their resistance to six *M. fijiensis* isolates, under greenhouse conditions. Inoculations were made on 6 months old plants and carried through a virulence assay using weighed fragmented mycelia brushed onto delineated areas on the abaxial surfaces of the first and second fully unfolded banana leaves. Grand Naine and FHIA-23 were used as susceptible and partially resistant controls, respectively. The disease progress over time was assessed at each inoculation site using a qualitative scale, thus obtaining the variables: infection degree (ID), incubation period (IP) and time of evolution of symptoms (TES). Disease severity was also rated at the end of experiment (day 84 after inoculation). Correspondence analyses were performed to characterize the interaction cultivar-isolate in terms of evaluated variables, and the resistance groups were categorized by cluster analysis. BLS symptoms were produced in all *Musa* accessions and were observed from the 21 day after inoculation. There was significant differences ( $P < 0.001$ ) between isolates for disease severity, that is virulence levels were determined using the mycelium-based assay. Considering only the most virulent isolates, the hybrids FHIA-23, FHIA-17, FHIA-18 and the cv. Saba were the most resistant accessions (i.e. higher IP and TES, and lower DS and ID), whereas the Grand Naine and Kelong Mekintu were the most susceptible cultivars. The other hybrids (FHIA-03, FHIA-01 and FHIA-25) and cultivars (Fougamou, Maritu, Pelipita, Prata, Pysang Ceylan, Red Yade and Yangambi km5) showed low to moderate levels of partial resistance. Thus, *Musa* resistance to Colombian isolates of *M. fijiensis* were confirmed and could be a valuable tool in integrated pest management against *M. fijiensis* by reducing the pathogen pressure on plantain and banana fields.



**SCELROTIA GERMINATION AND ASCOSPORE FORMATION OF *Claviceps gigantea***

Celeste Moreno-Manzano, Colegio Postgraduados, Mexico

**Abstract:** The disease known as “horse’s tooth” in *Zea mays* is caused by *Claviceps gigantea*, which seems to be an endemic fungus of the Toluca Valley, México. The first report of this disease was done by Fuentes y De la Isla in 1961, but it was not until 1964 when Fuentes and his team described the causal agent for the first time. In recent times farmers in the Toluca Valley have reported yield losses of 90 %. The typical disease symptoms is the rupturing of the apical part of the husk of the corn, this rupturing is caused by fungal structures known as the sclerotia which also replaces the grains of corn. Little however is known about the biology of the fungus. This paper is about the germinating time of the sclerotia and the development of the sexual bodies in an attempt to understand the life cycle of the fungus and provide insight into the disease and its possible control or management. Sclerotia were naturally and artificially germinated on different substrates such as oats seeds, commercial charcoal, charcoal residues and soil. The results show highly significant differences ( $p \leq 0.0001$ ) in sclerotial germination when incubated six months at 4 °C and two months at 22-24 °C in charcoal residue. Under this treatment the germination percentage was 55 % and produced five stromatic heads meanwhile the others did not induced germination. Stromatic heads were seen 15 d after primordial appearance. In natural field conditions, primordia of stromatic heads emerged from the sclerotia after six month incubation period at 4 °C and 64 d on soil surface with an average temperature of 14.07 °C. Mature stromatic heads and ascospore release were observed 23 d after primordial appearance. The release of ascospores was recording on video for the first time.

## FUNGI AND OOMYCETE PATHOGENS ASSOCIATED WITH PEPPER WILT IN MICHOACÁN, MEXICO

Nelson Laville, Posgrado en Protección Vegetal, Universidad Autónoma Chapingo, Mexico

**Abstract:** Pepper wilt significantly reduces yield in peppers (*Capsicum annuum*) inducing farmers to change crops or abandon farm lands that are infested with the associated pathogens. Although in general *Phytophthora capsici* has been associated to the disease in producing regions from central Mexico, more plant pathogens have been associated, but their interactive effects on the disease severity are unknown. The objective of this research was to evaluate the co-existence of these pathogens and the development of disease symptoms in pepper. In order to determine the fungi/oomycete associated to pepper wilt, a survey from July to November of 2013 was conducted in Yurecuaro, Vista Hermosa and Tanhuato municipalities in Michoacán Mexico. Isolations were done on V8 and PDA media. From 200 samples processed, 32 % corresponded to *Fusarium oxysporum* and *Fusarium solani*, 29% to *Phytophthora capsici* 24% to *Rhizoctonia solani*, 4% to *Pythium* and 11% to pathogens not previously identified associated with pepper wilt. Identification at the molecular level through total DNA extraction from fungi using the method of 2% CTAB was performed. Amplifications of the internal transcribed spacer (ITS) region of the rDNA were performed, using primers ITS5 and NL4 amplifying approximately 1100bp. The amplified fragments were verified by horizontal electrophoresis and sequenced using Sanger methodology. The pathogens *F. oxysporum*, *F. solani*, *P. capsici*, *R. solani*, *Pythium* sp. and *Plectosphaerella cucumerina* were identified after the sequences were compared with those deposited in the GenBank database. This is the first time that *Plectosphaerella cucumerina* has been associated with pepper wilt in Michoacán, Mexico. This novelty will inform future management strategies for pepper wilt in this region.

**PATHOGENIC, MORPHOLOGICAL AND MOLECULAR CHARACTERIZATION OF *Phytophthora* spp., CAUSAL AGENT OF CACAO BLACK POD DISEASE IN PUERTO RICO**

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**Abstract:** Cacao (*Theobroma cacao* L.) production is concentrated in West Africa, and Central and South America. In recent years its production has increased significantly exceeding an annual growth of 2.2% according to FAO in 2010. The final report of the “Global Industry Analysts, Inc.” stated that cacao production will reach 4.8 million tons by 2015. Worldwide this crop is affected by diseases that drastically reduce its production. Among them, cacao black pod caused by *Phytophthora palmivora*, with losses that exceed \$400 million annually. The aim of this study was to characterize three (*Phytophthora* spp.) isolates on the basis of morphology, DNA analysis and pathogenicity. Isolates were obtained from symptomatic cacao pods of clones HY 27418, UF 122 and SIAL 56, collected at Tropical Agriculture Research Station (TARS) germplasm collection located in Mayaguez, Puerto Rico. Oomycetes isolates were cultivated on acidic PDA, PARPH and V8 agar. Isolates were identified by light microscopy using taxonomic keys. Criteria such as sporangia shape, size and prominence of papillae, as well as chlamydospore production were examined. PCR amplification of cytochrome c oxidase gen (COXI) was used for molecular characterization of isolates. Pathogenicity tests were conducted on healthy cacao fruits, inoculated with one ml of sporangia (1x10<sup>4</sup> sporangia/ml). (*P. palmivora*) was identified using morphological characters. To confirm our findings COXI gen was amplified and sequenced from an isolate obtained from clone SIAL56. DNA sequence has 99% homology with (*P. palmivora* GenBank accession number: AB688308. Four days after inoculation, isolate obtained from SIAL 56 recorded the highest disease severity per fruit (50.93%) compared to the other two isolates obtained from clones UF 122 (30.82%) and HY 27418 (29.76%).

## Poster Presentations

### 3-DIMENSIONAL MODELING OF PROTEIN STRUCTURES DISTINGUISHES CLOSELY RELATED PHYTOPLASMAS

Robert Davis, USDA-Agricultural Research Service.

**Abstract:** Phytoplasmas (formerly mycoplasma-like organisms, MLOs) are cell wall-less bacteria that inhabit phloem tissue of plants and are transmitted from plant-to-plant by phloem-feeding insects. Numerous diseases affecting hundreds of plant species in many botanical families are attributed to infections by phytoplasmas. Phytoplasmas are classified in 16S rRNA gene (16S rDNA) RFLP groups and subgroups that to date embrace over 35 '*Candidatus Phytoplasma*' species. However, closely related strain and species lineages can be difficult to distinguish based on conserved gene sequences such as 16S rDNA. In this work, we studied the deduced amino acid sequences of selected proteins encoded by the genomes of phytoplasma strains and compared the 3-dimensional structures the proteins modeled in silico. Closely related strain lineages, as well as distantly related strains, were clearly distinguished by differences in protein structural models. The results indicated that some amino acid positions in a protein may reflect lineage differences more clearly than do others, and that 3-dimensional modeling can provide useful means for distinguishing closely related strains that may differ in biological properties.

**PLANT PATHOLOGY AND MICROBIOLOGY TRAINING AT UNIVERSITÉ DE LA NOUVELLE GRAND'ANSE, HAITI**

Guy Knudsen, University of Idaho

**Abstract:** Haitian smallholder farmers have relatively little access to information on plant disease diagnosis and management. A primary goal of the curriculum at Université de la Nouvelle Grand'Anse (UNOGA) in Jérémie is broad-based training of students in agronomic sciences, for the long-term benefit of Haitian agriculture. In November, 2013, we taught classes and a workshop in the subjects of microbiology for health and agriculture, and plant pathology, to a total of approximately 50 upper-level students at UNOGA. Sponsored by the APS Office of International Programs, the hands-on plant pathology workshop consisted of eight half-day sessions on disease identification and management, and presentations also were made to farmers in the nearby community of Roseau. Course materials were placed on the internet (small files for low bandwidth) since although printed materials are not readily available in Haiti there is relatively widespread internet access, including via cell phone. Two e-books (“Phytopathologie” and “Microbiologie en Santé et l’Agriculture”) were published online and are available free of charge. Study materials and course presentations were in French, and talks with community groups were presented in Haitian Kreyol with the help of a translator. During the two-week workshop, we covered a range of topics including diseases important to Haitian food crops (banana/plantain, citrus, mango, breadfruit, coffee, rice, corn, sugarcane, cassava). Field trips and laboratory exercises included diagnosis of plant maladies, and isolation of fungi, bacteria and nematodes. We brought laboratory equipment and supplies including digital compound and dissecting microscopes, agar, petri dishes, and general lab supplies for use in the workshop. UNOGA students are recruited with the expectation that they will return to their communities to help solve real-world problems, and a distance mentoring relationship is being maintained with several senior students who are conducting pathology and entomology research projects.

**BIOFUMIGATION WITH MUSTARD SEED MEAL TO CONTROL *Globodera pallida*, THE PALE CYST NEMATODE**

Louise-Marie Dandurand, University of Idaho

**Abstract:** *Globodera pallida*, the pale cyst nematode (PCN), is a quarantine pest that is present in some Idaho potato fields, and efforts are underway to eradicate it. While methyl bromide fumigation has some efficacy against PCN, it is costly and may become unavailable due to environmental concerns. We evaluated isothiocyanate-generating mustard seed meal as a biofumigant for PCN control. Nematode cysts were placed (inside nylon bags) in soil containing meal obtained from *Brassica juncea*, *B. napus*, or *Sinapis alba* at rates of either 1 or 4 tons/ac, or in unamended soil, then incubated for 2 wk. Cysts were then removed and crushed, and egg samples were placed in potato root diffusate solution for one wk, at which time juvenile nematodes were counted. Also, at the end of the incubation period, samples of cysts (10 per sample) were placed in pots with a 2:1 sand:soil mix, into which 4-wk-old tissue culture plantlets of potato ('Russett Burbank') were transplanted. After 16 wk in the greenhouse, total cysts were extracted and enumerated from each pot. PCN hatching was significantly reduced by *B. juncea* at both amendment levels and by *B. napus* at 4 tons/ac. Hatching was not reduced by *S. alba* at either rate. Biofumigation with *B. juncea* at either rate resulted in no cysts after 16 wk, compared to controls which had an average of 206 cysts. Biofumigation with *B. napus* resulted in significantly fewer cysts, compared to controls, at both the higher rate (0 cysts) and the lower rate (70 cysts). *Sinapis alba* meal did not significantly reduce cyst numbers. Cyst production results are thus in agreement with the hatching assays. Current experiments are focused on extracting active compounds from *B. juncea* to allow formulation with less plant material, and on determining the possible influence of meal on breaking nematode egg dormancy.

**EDUCATIONAL STRATEGIES TO PROMOTE PLANT PATHOLOGY AT PUBLIC SCHOOLS AND AT THE UNIVERSITY OF PUERTO RICO**

Lydia Rivera-Vargas, University of Puerto Rico

**Abstract:** Our goal as educators is to radically change student's perceptions of agricultural sciences as a backward field, towards a new paradigm of agriculture constantly led and improved by new technological advancements. Techniques based on DNA analysis, immuno- and nanotechnologies are newer ways to study food- and plant- microbe interactions. Sponsored by a USDA's NIFA/HSI grant we have implemented different educational strategies that had directly impacted public schools and university students in their understanding and use of complex cellular and molecular concepts in plant pathology. So far, through the organization of 8 science clubs ("Club de Agro-Microbios") we have impacted 108 students from public schools of the Western region of PR. We have increased the number of skilled students, faculty and technicians in the application of DNA-based, immuno and nano- technologies to solve phytopathological problems at University of Puerto Rico (UPR). This has been achieved by laboratory instrumentation acquisition by which these novel technologies are integrated in various undergraduate and graduate courses, and in students' research projects of the crop protection program at UPR. In addition, a summer workshops series focused in the applications of bio- and nano- technologies in plant pathology have introduced students, faculty and technicians to modern technologies used for rapid diagnosis and management of DNA sequence data of plant pathogens, while providing fundamental principles in plant pathology. We have increased the numbers of highly educated alumni in areas related to crops and food biosecurity. Acquired knowledge will have a major impact in the success of new Hispanic scientists through their training in new applications, and their improved capability to formulate and solve new questions related to crop biosecurity and food safety of tropical agricultural production systems. The ultimate goal is to improve the quality of life of more than 900 underrepresented Hispanic minorities in Puerto Rico.

**DEVELOPING IPM STRATEGIES FOR SMALL FARMS IN MISSISSIPPI**

Daniel Collins, Alcorn State University, Department of Agriculture, Mississippi

**Abstract:** Small farmers in Mississippi face serious challenges in managing diseases and insect pests in vegetable crops. Yield loss due to these problems can be substantial. Some plant diseases impacting small farmers in Mississippi are tomato early blight caused by *Alternaria solani*, Zucchini yellow mosaic virus (ZUMV) on multiple plants, and southern blight caused by *Sclerotium rolfsii* on a wide variety of vegetable crops. Other important insect pests that cause direct or indirect damage to vegetable plants include whiteflies, flea beetle, spotted cucumber beetle, fruit worms, thrips and Colorado potato beetle. Previous studies have shown that lack of irrigation management can influence the occurrence of diseases and pests on crops. There is a lack of coordinated integrated pest management (IPM) extension programs targeting small farms. The objective of this project is to educate small farmers on sustainable pest management strategies for vegetable production using techniques such as crop rotations, irrigation management, cover crops, trap crops, insect pest identification and monitoring program, plant disease diagnostics training, and selection of resistant varieties. Outcomes of this project include increased awareness of insect pest management, irrigation management for plant health, plant disease diagnosis and epidemics, improved knowledge of disease impact on crop production, and enhanced field IPM practices.



## IDENTIFIED FUNGI IN FIELD RICE PLANTS AND THEIR SENSITIVITY TO FUNGICIDES

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**Abstract:** Field rice plants at Campeche, Mexico, presented symptoms as spots on stems, leaves and brown grain discoloration. Grains after polished, may cause dark kernels, thus reducing their market value. This work identified the presence of fungi and determined their sensitivity to fungicides. Plant samples with symptoms were collected from wetland fields and tissues from leaves, stems and grains, were then disinfested. Tissues or seeds were placed on water agar plates or blotter to fungi growth at 25 °C. Pure cultures were performed on PDA medium. Based on the morphological characteristics, 14 different fungi genera were identified. *Fusarium*, *Curvularia*, *Bipolaris*, *Papulospora* and *Thielaviopsis* were found in stems, leaves and grains. *Nigrospora* was found in stem and leaf samples. *Nakataea* and *Phoma* were found in stems tissues. *Cladosporium*, *Rhizopus* and *Aspergillus* were present in leaves only. *Microdochium* was seen in stems and grains. *Pyricularia* and *Rhizoctonia* were found in grains only. Sensitivity to fungicides in vitro tests were performed with 13 fungicides at commercial doses for *Fusarium* and *Curvularia* fungi. Three fungicides reduced more than 95% *Fusarium* mycelia growth (Benomil, Azadiractin and Carbendazim) and two fungicides presented the same mycelia reduction for *Curvularia* (Cupric oleate and Cymoxanil + Mancozeb). Field tests showed that of the best eight (8/13) fungicides tested in vitro, kasugamicina reduced 94% grain discoloration incidence. In addition at harvesting, grains from the eight fungicides treatments, showed the presence of the fungi *Fusarium*, *Curvularia*, *Aspergillus* and *Bipolaris* at different percentages. This work documented the incidence of different fungi genera in rice field plants and showed grain discoloration reduction level with commercial fungicides.