Pineapple News

Newsletter of the Pineapple Working Group, International Society for Horticultural Science
Issue No. 20, July, 2013

Table of Contents

Pineapple Working Group News

From the Editor

Dear Colleagues:

I begin this newsletter by recollecting some post-retirement work that has been challenging, interesting and, ultimately, rewarding for me as well as for pineapple growers who must deal with natural induction of reproductive development (NI) of pineapple. For about the past 10 years I have led cooperative trials in Hawaii that explored the potential of the ethylene biosynthesis inhibitor aminoethoxyvinylglycine to control NI of pineapple, also known as naturally differentiated flowering (NDF). My reward consisted of the pleasurable opportunity of working with committed people on a project that seemed to become more important for pineapple growers as time passed. The research was funded by Valent Biosciences Corporation, which covered my out-of-pocket expenses and paid for my travel to the 5th and 7th International Pineapple Symposia, and by Dole Food Company's Hawaii division, which provided the fields where the Hawaii trials were conducted. As a result of trials in Hawaii and elsewhere, Valent's PinCor™ (http://www2.hawaii.gov//hdoa/labels/8187.38_2014.pdf), a liquid formulation containing 20% aminoethoxyvinylglycine hydrochloride (AVG), is now registered for the control NI of pineapple in the United States and in a number of other countries.

As the results of trials in Hawaii and other locations where pineapple cultivars sensitive to NI were grown accumulated, it became obvious that NI was one of the most serious problems confronting growers of fresh pineapple who sought to provide fruits to the fresh market at reasonable cost on a year-around basis. The main cultivars sensitive to NI include 'MD-2', the main cultivar grown by plantations that export fresh fruits, clones of 'Queen', 'Perola', which is the main cultivar in Brazil, and one or two 'Queen' x 'Smooth Cayenne' hybrids that are grown in Taiwan. However, NI is a problem for all pineapple cultivars at the extremes of the environmental range where pineapples are grown.

The cost of controlling NI with AVG is significant, perhaps as high as $2,400/ ha for fields where NI must be controlled to prevent a fruit glut in June and July and a fruit shortage in the late summer-early fall period. To date and outside of Taiwan, where winters are dry and good results are obtained with fortnightly treatments, best results are obtained by weekly sprays of at least 100 mg L^{-1} of AVG in 2,400 L ha^{-1} water. To prevent fruit deformity caused by AVG, sprays must begin before any NI has occurred. If plant growth appears to be suppressed for any reason, recent studies in Central America show that control improves in such fields as the concentration of AVG is increased.

While the greatest benefit of NI control accrues on farms where ratoon crops are grown, the following list of benefits have been demonstrated in multiple on-farm trials.

1. Control of NI makes it possible to synchronize fruiting on schedule, which reduces or eliminates fruit gluts in early to mid summer and helps to assure uniform supplies the late summer and fall.
2. Harvest rounds are significantly reduced, which reduces in-field traffic, soil compaction and leaf canopy damage, which reduces weed control problems when a ratoon crop is to be grown.
3. Initiation of ratoon suckers, which occurs when the mother plant is forced or induced, is much more uniform. As a result, variation in fruit size in the ratoon is reduced and ratoon yields should increase.

I hope readers will find something interesting, enjoyable, or educational among the following.

News from Australia

8th International Pineapple Symposium

The 8th International Pineapple Symposium will be held from 18 to 21 August in Brisbane, Australia in 2014 as part of the International Horticultural Congress (IHC 2014). IHC 2014 will include many symposia covering a range of tropical and subtropical horticultural industries.

Information on the IHC2014, including accommodation and venue information, can be found at the website, http://www.ihc2014.org/icmsa/index.html. The **8th International Pineapple Symposium** is No. 32 under the **Tropical Fruits and Vegetables** sub-theme.

The pineapple symposium program will run from Monday 18 August to Thursday 21 August (registration on 17 August) and will include presentations, posters and a technical tour to view pineapple farms and research in South-East Queensland. The program, which will include invited speakers, will cover the latest developments in pineapple research and development from around the world. The format will be similar to those of previous pineapple symposia but will offer concurrent IHC sessions in a range of other symposia for those with broader horticultural interests.

Key dates for all symposia including the pineapple symposium can be found on the IHC2014 home page.

Key dates for presenters are;

Open Abstracts	1 April 2013
Close Abstracts	1 Nov 2013
Notification to Authors	14 Jan 2014
Presenter Registration closes	17 Feb 2014

Key dates for attendees are;

Attendee Registration opens	30 Sept, 2013
Early Bird Closes	17 Feb, 2014

For further queries regarding the 8th International Pineapple Symposium contact G. Sanewski (garth.sanewski@daff.qld.gov.au).

On behalf of the 8th International Pineapple Symposium, ISHS, IHC 2014 and sponsors, the organising committee invites you to attend the 8th International Pineapple Symposium and IHC2014 in Brisbane in August, 2014.

Organising Committee 8th International Pineapple Symposium

FarmFLOW
growth through good practice

Living mulch: Disease and erosion research

Cropping soils are at their most vulnerable from the bed-forming and planting stage until canopy closure of the inter-row space. One of the main issues associated with pineapple production is the loss of soil and sediment off-site in runoff water. Linked to this is the loss of nutrients, herbicides and pesticides to the surrounding waterways.

Previous research clearly shows that soil losses are higher in the first 10 to 12 months when the inter-row surface is exposed to rainfall. Growers have indicated that top soil erosion should reduce once canopy closure protects the inter-row space from raindrop impact.

Questions that need answers

- Does living mulch have the ability to reduce topsoil erosion? If so, by how much?
- How cost effective is using living mulch compared with standard practice?
- Does canopy closure effectively reduce the erosion process?

Trial setup

- Feed oats seed was planted in the inter-row at a rate of 50-60 kg/ha as the living mulch crop for both trials and sprayed out using Verdict 520, Viking, Fusilade and a wetting agent (Uptake) using a boom spray.
- The standard practice plot retained bare ground between rows.

Soil loss from fields with living mulch was up to 78% less than from fields under standard management practice.

How did the living mulch perform?

- The first sampling period at Toorbul showed 90% more soil loss in the standard practice compared to the living mulch practice.
- Erosion was still much higher in the standard practice even after the crop canopy had closed over the inter-row space.
- The first sampling period at Elimbah (on a lower slope) had similar results to Toorbul where sediment loss was 39% higher in the plot where the inter-row space was left bare.
- Inter-row living mulch significantly reduced erosion and plant bed heights were maintained.
- Oats suppress weed growth, reducing the amount of herbicide required.

Other Living Mulch fact sheets: #1 What is living mulch?
#3 Establishment

Healthy Country partners:

SEQ Catchments · Healthy Waterways · Queensland Government · SEQTIDA

Living mulch factsheet #2

Table 1 – Soil loss at Toorbul and Elimbah sites

Farm	Sample period	Soil loss (t/ha)		Difference	Total rainfall
	(from planting)	Standard practice	Living mulch	%	(mL)
Toorbul	17 mths	68.7	14.7	78.5	1005
Elimbah	3 mths	1.2	0.7	38.7	69

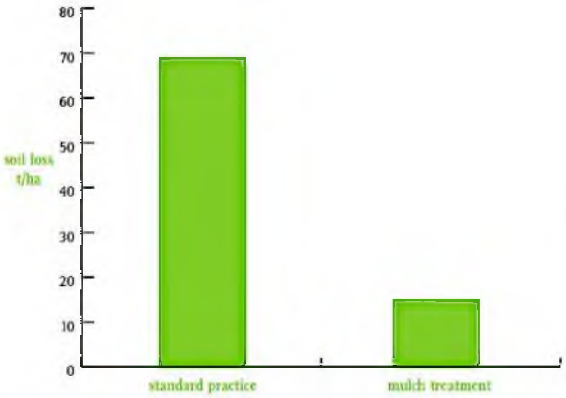

Figure 1 – Living mulch trial results

The major user of living mulch in the Pumicestone catchment noted "it was clear early in the piece that there were big differences" in soil lost between the trial blocks, and that there was "no noticeable difference in yield" between living mulch and standard blocks for this summers' pick.

Living mulch – Is it worth it?

Comparison of weed control costs for standard practice and for living mulch after bed formation and planting.

Table 2 – Comparing costs of inter-row management

Standard practice	$/ha	Living mulch	$/ha
Hyvar 5 kg/ha	275	Oats 50 kg/ha	60
Diuron 7 L/ha	53	*To spray off Oats at 8 weeks*	
Diuron + 3.5 L/ha	27	Diuron 3.5 L/ha	27
		Viking 5 L/ha	65
		Fusilade 0.6 L/ha	120
		Wetting agent 0.5 L/ha	15
Total	$355	Total	$287

Cost benefits of using living mulch

- No obvious effect on crop yield or quality.
- Using living mulch is cost-neutral because the cost of pre-plant herbicides (e.g. Bromacil, Diuron) is offset by the cost of establishing the living mulch.
- Use of living mulch reduces the overall amount of Diuron applied by two-thirds. Diuron is currently under review and there may be restrictions put on application rates.
- To eliminate an extra tractor pass, the seed can be sown when rolling in pineapple tops after planting. Tractor speed is best at 5 km/hr to sow seed. Seating pineapple tops takes 4.5 hours/ha.

For more information

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Acknowledgements

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The Healthy Country Project is a three-year partnership project between SEQ Catchments, DPI&F, scientists from Healthy Waterways and Indigenous representation through the SEQ Traditional Owners Alliance. The other project partners are coordinating river restoration works and water quality monitoring in three 'focal' case study areas in the Lockyer, Bremer and Logan-Albert catchments.

FF08-003

Queensland Government
Department of Primary Industries and Fisheries

For further information contact:
DPI&F Business Information Centre
13 25 23 (weekdays 8 am to 6 pm)
Email: callweb@dpi.qld.gov.au
www.healthywaterways.org

FarmFLOW
growth through good practice

Pre-plant nitrate efficiency for pineapples

Fertiliser application rate recommendations in pineapples are based on research undertaken 17 years ago. Currently, pre-plant application rates of between 1000–1500 kg/ha of standard N, P, K fertiliser blends are common and generally based on soil test results. Research shows that high rates of conversion (ammonium to nitrate) promotes leaching, making standard granular fertilisers extremely inefficient at maintaining adequate nitrate nitrogen levels in the soil.

The aim of this trial was to assess plant response and leaching effects of various rates and types of pre-plant fertilisers.

What did we do?

The trial site was at Elimbah on a sandy loam with a pH 4.8. Initial soil test results reported 5 kg/ha of *nitrate* nitrogen prior to pre-plant fertiliser application. A NATA accredited laboratory analysis from the same plot reported 7 kg/ha *nitrate* nitrogen and 26 kg/ha *ammonium* nitrogen with 500 kg/ha of *total* nitrogen (TN) reported. Industry suggests the optimum level of nitrogen in the soil at planting is 120 kg/ha of *nitrate* (NO_3). (Note: the level of *nitrate* nitrogen is a measure of the amount of nitrogen directly available to the plant from the total nitrogen present.)

We applied different rates of pre-plant nitrogen to the soil then measured:

- nitrate levels in the soil for the first 10 weeks after pre-plant fertilisers were applied
- root and leaf growth at three and nine months after planting (following the procedure outlined in Chapter 14 of the *Pineapple Best Practice Manual*).

Nitrogen rates applied during bed preparation on 4 Feb 2009 were:

- 115 kgN/ha (full traditional N rate derived from the soil test result)
- 60 kgN/ha of controlled release fertiliser (half recommended rate)
- 0 kgN/ha (zero N).

Pineapple tops were planted two weeks after the fertiliser application (18 Feb) and nitrate availability was measured by sampling and analysing the soil solution at 15 cm and 30 cm depths in each of the three treatments.

A side-dressing was applied to all treatments during week 10 at which time sampling ceased.

What did we find?

Nitrogen levels

No fertiliser: The results for zero N inputs in this trial were encouraging, indicating that pineapples are able to establish and grow with no pre-plant nitrogen applied, instead utilising the soil nutrient reserves and crop residues after fallow. Energy reserves contained in the planting material would also assist in the early establishment phase. This observation is emphasised through the soil nitrate levels (0–30 cm) where we see during the first seven weeks all levels were similar (Figure 1).

50% Slow release fertiliser: The half rate application of controlled release fertiliser (CRF) provided a greater consistency of availability when compared to the full application rate across both 15 cm and 30 cm depths, highlighting the inefficiencies of traditional fertiliser types (Figures 1–3).

The most interesting result is the nitrate availability for the zero nitrogen treatment. How can there be nitrate levels similar to the full and half treatments if nothing was applied? The answer lies in the results obtained from the pre-plant soil test which recorded 500 kg/ha of total nitrogen (TN). Whilst the soil *nitrate* levels were very low (7 kg/ha) when measured prior to planting there must have been a steady conversion of mineral and organic forms of nitrogen (TN) to the plant available nitrate form which was adequate for the needs of the growing plants during the sampling period.

Root and leaf growth

Root and leaf growth were measured at three and nine months after planting. There were no large differences, either visual or measured between treatments at these sampling times. Interestingly, root length after three months in all treatments was only 10–15 cm (Figures 4–5). Photographic evidence at three months growth reinforces this (Figure 6).

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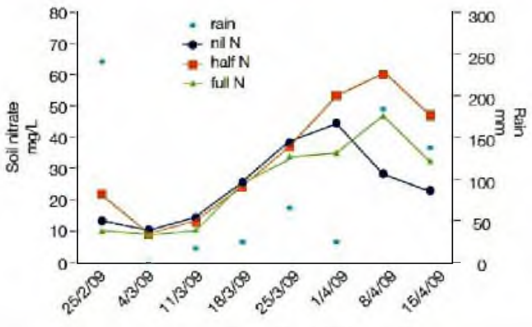

Figure 1. Mean soil nitrate 0–30 cm. The left Y axis indicates mean soil nitrate availability. The right Y axis is the total weekly rainfall. Each mean calculated from six soil solution samples collected each week.

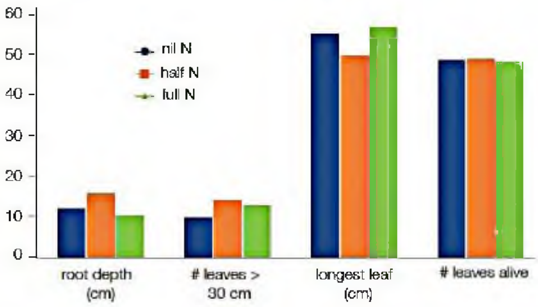

Figure 4. Root and leaf growth characteristics for each treatment at 3 months.

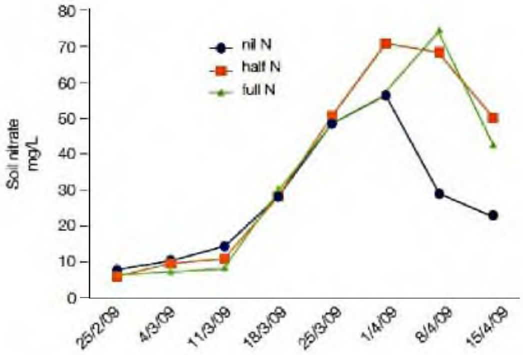

Figure 2. Mean soil nitrate available at 15 cm. Each mean calculated from three soil solution samples collected weekly during 2009. (Note: mg/L = ppm =kg/ha)

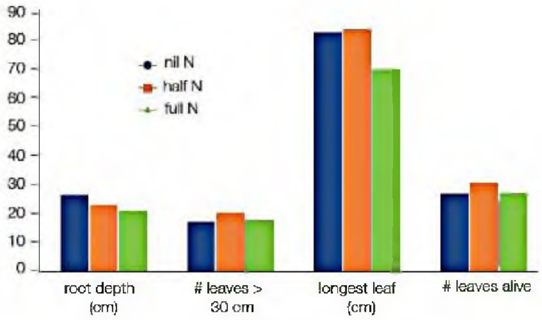

Figure 5. Root and leaf growth characteristics for each treatment after 9 months of plant growth. Side dressing was applied after 10 weeks.

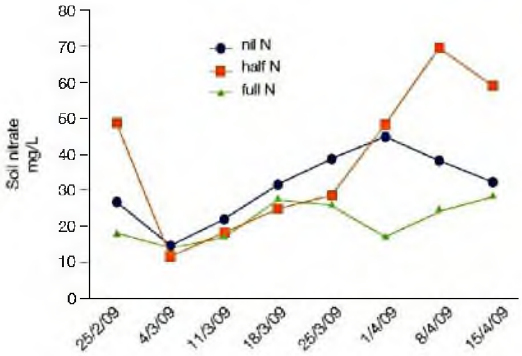

Figure 3. Mean soil nitrate available at 30 cm. Each mean calculated from three soil solution samples collected weekly during 2009.

Field testing soil nitrogen levels using Mottes tubes.

What have we learned?

- There may be potential savings of up to $1200 per hectare on pre-plant fertiliser.
- During the first nine months after planting, root and plant growth have not been affected by reducing the pre-plant N rates to zero or half.
- The benefits of applying pre-plant N at industry recommended rates of 120 kg/ha should be questioned by the industry.
- There is great potential to improve fertiliser efficiency by either reducing or removing nitrogen as a pre-plant requirement and better utilising crop residues and existing soil nutrient reserves.
- As the roots only reached a maximum depth of 15 cm after three months it is likely that traditional inorganic sources of nitrogen could be leached beyond the root zone, and therefore ineffective and potentially causing soil acidification and downstream water quality issues.
- Growers should question the methods and reporting used by soil testing laboratories to make pre-plant nitrogen recommendations.
- The total nitrogen (TN) pool in the soil needs to be measured before recommendations are given.
- Research needs to refocus on nitrogen fertilising practices for pineapples.

Future directions

Growers are encouraged to undertake their own trials using reduced rates of pre-plant nitrogen and/or controlled release fertilisers to see how nitrogen applications can be reduced without affecting plant growth.

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For more information

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Figure 6. Plants randomly sampled for root and leaf measures at three months.

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News from the Azores

An Overview of Pineapple Culture in the Azores

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Keywords: *Ananas comosus* var Smooth Cayenne; Azores; glass greenhouses; Flowering induction

BRIEF HISTORY OF PINEAPPLE IN THE AZORES

The Azores islands are an Autonomic Region of Portugal formed by nine islands located in the north Atlantic (36º 55' W; 39º 45' N) and considered the European Western border. The Islands have approximately 250.000 inhabitants with a total area of 2,333 km^2 and the economy depends, nowadays, essentially on dairy industry and tourism. It is believed that pineapple was introduced in the Azores as an ornamental plant during the 18th century when the Islands were a stopping point for ships crossing the Atlantic, trading goods from South America to Europe. At the time, pineapple was mainly grown as an ornamental. Orange, the main crop produced in the islands during the 19th century, was devastated by *Phytophthora* sp. and the need for a substitute crop to fill the fruit export gap led to the rise of pineapple cultivation (Tavares and Silva, 1997). As practiced in Europe during the 19th century, pineapple in the Azores was cultivated inside glass greenhouses (Figure 1) with organic soil extracted from local mountain landscapes. The exportation of pineapple began in 1864 and expanded for several decades in São Miguel Island. At the beginning of the 20th century the industry had approximately 4,300 greenhouses, representing more than 100 acres (Tavares and Baptista, 2004). The fruits with the trade name of "St. Michaels

Figure 1. A typical pineapple production house on S. Miguel Island, Azores. The structure is very similar to the original counterparts from the late 19th century.

pineapple" were exported to England, Germany and Russia and re-exported to Austria, Italy and Scandinavia. A small percentage was also shipped to New York (Krauss, 1940). Until the Second World War the region maintained the monopoly of the European fresh-fruit pineapple market (Bartholomew et al., 2003) competing with fruits from Nigeria (Gibberd, 1944), India and South Africa (Levie, 1933). During the 1930s, an average of 1.9 million fruits were exported per year to Europe and pineapple was a major economic resource of S. Miguel Island, occupying a considerable amount of the Islands labor for direct and indirect jobs such as carpenters for greenhouse maintenance, transporters and soil carriers (Tavares and Baptista, 2004). The proximity of the European market was the main factor contributing to the expansion of the industry since it took only 5 days to reach Europe whilst African pineapple took almost 2 weeks, but the small scale of "St. Michael pineapple" led to supply disruptions Levie (1933) in the Netherlands. After the Second World War the Azorean pineapple industry entered a period of crisis due to overproduction that raised market supply and significantly reduced incomes; excessive demand of organic material from uncultivated highlands soils; the fast development of a highly organized and technological dairy industry that transformed several hundred acres of uncultivated soils into pasture for animal feeding (Krauss, 1940; Tavares and Silva, 1997) and the expansion of the forest area, mainly *Cryptomeria japonica*. Also, in recent decades the appearance of low cost pineapples from large farms and plantations in Africa, Thailand, Philippines, Brazil and Costa Rica in the European market reduced, over the years, the demand for Azorean pineapples. Price competition from the global market has resulted in low incomes for farmers. Nowadays, Azorean pineapples are mainly shipped to the Portuguese market (Voth, 2000) and the product has low competitiveness compared to its counterparts from different origins. The lack of legislation to protect the culture and its heritage, escalating land prices due to real estate market speculation for housing construction on land occupied with greenhouses, and increases in labor and other production costs have reduced, over time, the competitiveness of the industry.

PINEAPPLE CULTURE IN THE AZORES

Krauss (1940) described pineapple culture in the Azores as: "*…a highly developed art*." The pineapple cultivation system used in the islands requires soil rich in organic matter, and atmospheric temperatures between 18 ºC and 32 ºC (Bartholomew et al., 2003), which are not typical of the Azores climate. For instance, climatic data for S. Miguel Island (25º 40' W; 37º 45' N), perhaps the most extreme latitude for commercial pineapple production, during the 20th century shows that the average minimum and maximum temperatures were 14 ºC and 21 ºC, respectively (Miranda et al., 2006). The climate is moderated by the Azores Current, which ranges from about 16.5 to 18.5 ºC, but is still below the optimal for pineapple cultivation, therefore the need of greenhouses (Figure 2; Miranda et al., 2006). The major production areas (Figure 2C) show the industry is concentrated mainly in the south cost of the Island between longitude

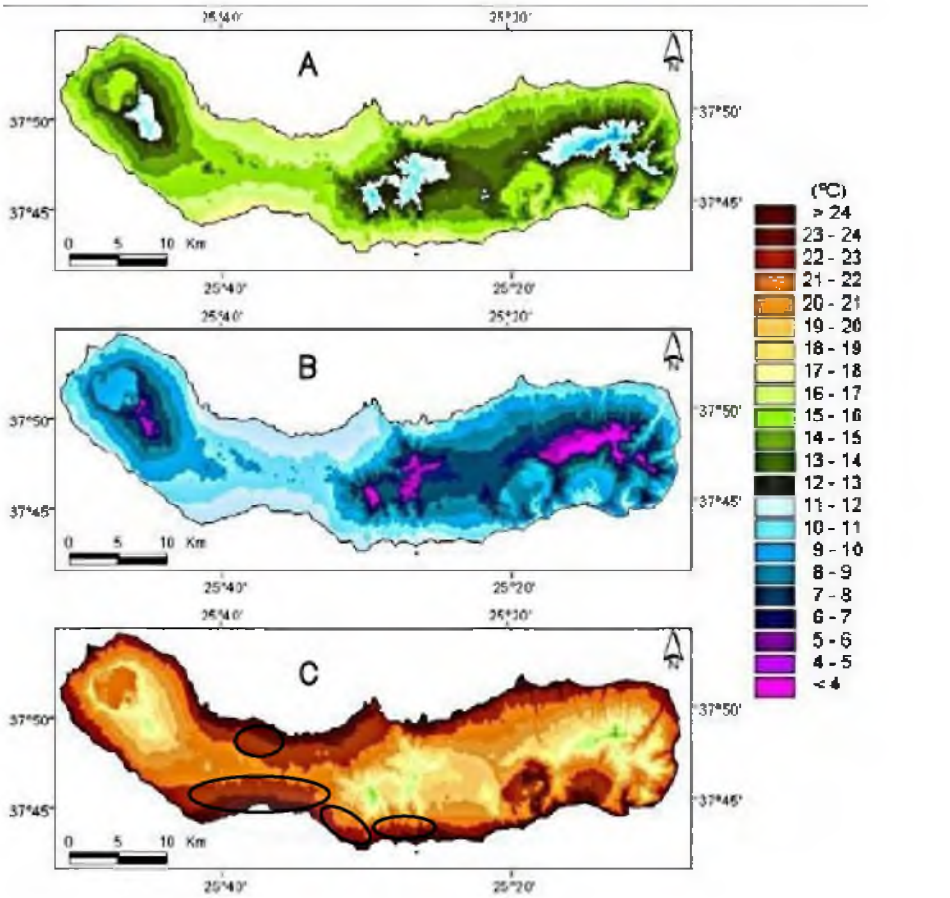

Figure 2. Temperature distribution in S. Miguel Island from 1961 to 1990: (A) Annual average; (B) Annual average min.; (C) Annual average max. Main areas of pineapple production outlined in black. Reproduced with copyright authorization of P. Miranda, Faculty of Sciences, Lisbon University) from Miranda et al. (2006).

25°40' and 25°30' where the land is flatter, wind-protected and sun exposure is more intense and favorable to the culture.

One of the major characteristics of pineapple culture in the Azores is the soil preparation, locally known as "beds". The initial method, used for more than a century, started by the unmechanized removal of up to 40 cm of soil, approximately 17 m^3/house from the previous culture. Then a bottom layer of (about 10 cm) ground branches of *Pittosporum undulatum* Vent was added followed by old soil (about 5 cm). The upper layer was filled with soil-organic material (about 15 cm), locally known as "*leiva*", which was covered by old or new mineral soil, followed by replanting. *Leiva*, is the superficial soil layer (about 10 to 15cm) of the mountain landscape in São Miguel and is composed of mineral and organic soil horizons, very rich in total carbon and humus, a pH <4.5, with a vegetative community composed by woody plants (e.g. *Calluna vulgaris* (L.) Hull; *Erica azorica* Hochst; *Rubus* app; *Myrsine africana* L.; *Vaccinium cylindraceum* Sm.; *Viburnum tinus* L.) and herbaceous (e.g. *Sphagnum compactum* Mitten.; *Rhacomotrium lanuginosum*; *Sellaginela kraussiana Pteridium aquiline*; and grasses from the genus *Holcus*; *Poa*; *Agrostis* and *Danthonia*) (Pinto Ricardo et al., 1977). After extraction from the highlands, *leiva* was carried to greenhouse farms and placed in piles, called "*palâmes*", to mature before application. Such materials were formerly removed from the slopes of uncultivated soils in highlands. However, *leiva* became scarce due to high demand of the industry, leading to the desertification of highlands. Access also was limited by the occupation of highlands with pastures for animal feeding.

Leiva use on pineapple culture was prohibited by the Azorean Government due to environmental protection of the species and landscape regeneration issues (Tavares and Silva, 1997). *Leiva* substitution resulted in several setbacks to the industry; however, during the 80s and 90s, testing of several materials and different formulations lead to its gradual replacement (Tavares and Baptista, 2004). Nowadays "beds" mainly consist of wood powder from local industries and *P. undulatum* chips mixed with land from prior cultures. Ongoing studies are evaluating new soil formulations using compost from local vegetable organic wastes as the major source of organic matter in the soil to enhance fruit quality and reduce costs. Vermicompost is also being studied. Plant physiological responses to different compost formulations coupled with different variables (photoperiod, thermoperiod, water supply, light intensity, soil temperature) are being studied in controlled environments and also in industrial scale greenhouses. Preliminary results show that compost is well balanced in total carbon, humus, total exchange capacity, nutrients and pH=7.5. This material, which has a very slow rate decomposition and release of nitrogen and phosphorous and high available water capacity, stimulates pineapple growth and results in increased fruit size and weight.

The production cycle of Azorean pineapple is mainly divided into four stages. First, plant material is propagated from stem cuttings in a "nursery" greenhouse. When the plantlets reach the appropriate size, usually after about 4 to 6 months, they are transferred to a propagation greenhouse for vegetative growth. After 12-15 months, plants are transplanted to the final production greenhouse where they are grown for 6-7 months and have an average weight of 1.5 kg. They are then forced to flower with smoke (Figure 3) and, depending on the season, fruit is harvested 6 to 9 months after flowering induction. Total cycle length varies from 22 to 29 months.

Figure 3 Smoke production inside a greenhouse in the Azores to force pineapples to flower.

As discussed previously, atmospheric temperature in S. Miguel is less than optimal for pineapple cultivation. Greenhouse temperatures are quite variable during the year. During the summer months direct sunlight can result in greenhouse air temperatures above 50 °C, causing heat injury/sunburn to the plants. To avoid such temperatures, roofs are whitewashed with slaked lime (calcium hydroxide) from April to October to reflect sunlight. On the other hand during the winter, temperatures may hardly exceed 25 ºC which delays plant development. Climate records inside and outside greenhouses have been gathered since early 2012 and used to integrate plant physiological responses at each season to help producers manage their plantations using a scientific approach rather than relying mainly on their own expertise and empirical knowledge. Winter conditions in the Azorean pineapple cycle result in a low rate of plants propagated from the stems. Producers are aware of the problem and avoid propagating plants during the winter. *In vitro* propagation methods are being tested to create alternatives to the traditional propagation system.

FLOWERING INDUCTION WITH SMOKE

The use of greenhouses to cultivate pineapples in the Azores led to the accidental discovery in 1874 that smoke from burning organic materials induces flowering, allowing harvest synchronization. Three different stories are known but it is believed that while trying to enhance temperature inside the greenhouse to promote plant growth, smoke from burning organic material leaked inside the greenhouse causing premature flowering (Krauss, 1940). Knowledge of the technique became widespread and was used in Puerto Rico where flowering was forced by covering plants with muslin cloth and building smudge fires under the muslin (Rodriguez, 1932). This accidental discovery in the Azores led to the discovery of ethylene and acetylene as important agents in flowering control of pineapple. The activity of all other chemicals that subsequently were shown to force flowering in pineapple such as 2-chloroetilfosfonic acid (ethephon), calcium carbide, α-naphthalene acetic acid and other auxins, and 2,4-hydroxietilhidrazine and β-hydroxietilhidrazine, either promote ethylene biosynthesis or its release as a degradation product (Bartholomew et al., 2003; Cunha, 2005). However, the molecular mechanisms by which ethylene mediates the transition from vegetative to reproductive development still needs to be discovered and integrated with the knowledge accumulated for decades on flowering induction chemicals (Van de Poel et al., 2009).

In the Azores, flowering induction is still performed with smoke produced by burning dry material like leaves of *Cryptomeria japonica*, leaves of banana plant, bean straw, dried herbs or wood chips inside metal cans. The metal cans (8-10) are spread along the greenhouse gangway and left to burn for at least one hour at the end of the afternoon with the smoke retained in the house during the night (Figure 3). The number of applications depends on the season and may vary between 9 consecutive night applications in summer to 21 or more in the winter. In the morning the greenhouses are opened, and the metal cans are removed to be refilled for further applications. Prior to and during the fumigation period it is normal to stop water supply to the plants. Watering is resumed once the fumigation is terminated (Tavares and Baptista, 2004). Empirical knowledge of the producers detected that smoke efficiency in forcing pineapples in the Azores is higher when moon light is reduced so it is a cultural practice to start smoke application at the time of the new moon. A possible explanation is the interference of moonlight with the photoperiodic measurement of time by plants (Bünning and Moser, 1969).

Temperature controls the speed at which the inflorescence develops (Fleisch and Bartholomew, 1987; Lechaudel et al., (2010) and the seasonal variation in the time from differentiation to harvest in the Azores (Figure 4) is a manifestation of this. In the Azores, the time from flower induction to the appearance of the inflorescence is approximately 30-35 days from May to July. In August and April, it takes approximately 40 days and increases to 50 days in February, March and September, 60 days in October and January and 90 days in

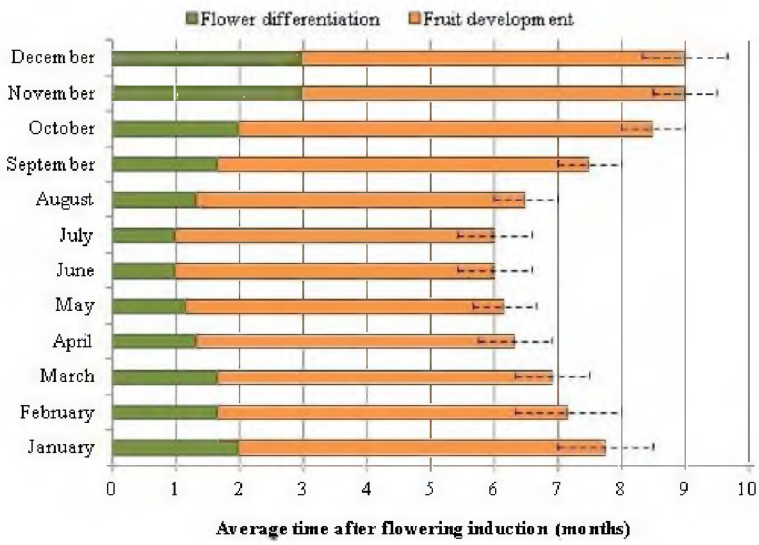

Figure 4. Seasonal variation in time from induction of flowering with smoke to inflorescence emergence and to fruit harvest, with standard deviation, in S. Miguel Island, Azores. Data compiled from Tavares and Baptista (2004) and Profrutos C.R.L professionals (pers. commun., 2012).

November and December. This variation is due to temperature variations inside greenhouses, which are controlled by atmospheric temperature and, mostly, by sunlight intensity during the year. Averages only provide general guidance because, for example, in December, inflorescence development can be reduced to 70 or 80 days if the average temperature of the following months is higher than the expected. Also, if the nocturnal temperature is high during smoke application, inflorescences would develop faster. Environmental conditions can also increase or decrease the sensitivity of pineapple to external flowering induction applications (Conway, 1977; Min and Bartholomew, 1997).

The time between flower induction and fruit harvest varies with the month in which smoke is applied (Figure 4). In different regions of the tropics and subtropics, the interval from flower induction to fruit harvest for ‘Smooth Cayenne’ varies from 135 days in Ghana (D. Bartholomew, pers. commun) to more than 280 days in South Africa (Dalldorf, 1985). In the Azores, the cycle varies between 6 months when smoke is applied in June up to 9 months when applied in November and December and the longer flowering and fruit forming periods cause important delays in harvest time. Normally, the Christmas season represents nearly 40% of the total yearly production (Profrutos, 2012, pers. commun.). Producers choose their final plantation cycles based on a higher local demand for fruit at Christmas but also because fumigation from May to July results in shorter production cycles with higher harvest yields.

AZOREAN PINEAPPLE CHARACTERISTICS

Normally, Azorean pineapple is harvested at a shell color approximately 30-40% yellow when harvested for long distance export. The fruits have an average size of 0.9 to 1.5 kg and a small crown (1/3 to 1/4 of the fruit height), which results from the apical meristem removal 3 months after flowering induction. Apical meristem removal also allows the Azorean pineapple to have a distinct presentation compared to the other pineapples imported into Europe. The main post-harvest treatments are peduncle sterilization and the transportation with spongy materials to avoid contact and bruises. The unique set of practices gives an acceptably proportioned fruit (Orsi and Pagani, 1972), with unique organoleptic characteristics such a sugar/acid balance and a high aromaticity. The aromatic profile of Azorean pineapple is well recognized (Tavares and Baptista, 2004) and is one of the major values of the pineapple culture in the Azores. Also, the concentration and diversity of amino acids, hydrophilic vitamins and bromelain was shown to be higher in the Azorean pineapple in comparison with fruits from other origins and under different production techniques (Tavares and Baptista, 2004). These unique characteristics led, since 1996, the Azorean pineapple to be recognized as Protected Designation of Origin (PDO) product by the European Union rule CE nº1107/96 of June 12 and a set of conditions were defined to certify the pineapples cultured according to the Azorean traditional techniques. For instance, the certification is only assigned to “Smooth Cayenne” pineapples cultured inside greenhouses, with “organic beds” and in which smoke is used for flowering induction. Also, quantitative specifications of the physicochemical properties of fruits were regulated (Table 1) by the Technical Committee on Certification and Control for Azorean pineapple as a PDO product (normative order nº 259/93 of December 30).

Table 1. Specifications of the Azorean pineapple pulp as a Protected Designation Product by the European Union rule CE nº1107/96 of June 12, certified by the Technical Committee on Certification and Control (normative order nº 259/93 of December 30th).

Pulp characterization			
Water content	85±1.5%	Volatile acidity	0.013±0.005%
Soluble residues	13.2±0.8%	Total ash	0.33±0.03%
Insoluble residues	0.8±0.2%	Cellulose	0.67±0.03%
Total residues	14.0±1.0%	Protein	0.45±0.05%
Total sugars	10.0±1.0%	Vitamin C (mg/100 g)	17.00±2.00
Reducing Sugars	4.5±1.0%	Vitamin B1 (mg/100 g)	0.08
Sucrose	5.5±1.0%	Vitamin B2 (mg/100 g)	0.04
pH	3.5±0.5	Calories (100 g)	~52

In the Azores fruit size and quality varies with harvest season. This feature is typical of pineapple production in high latitudes with seasonal temperature variations and is well documented for different geographical locations (Wassman, 1990; Bartholomew et al., 2003; Joomwong and Sornsrivichai, 2005). In the Azores, fruit harvested from November to March is characterized by total sugars between 4.4 and 13.2 g/100 g sample. Fruits harvested from May to October have higher Brix (total sugars between 11.7-16.6g /100 g sample). The total sugar variation observed throughout the year is attributed to the sucrose content since reducing sugars only vary from 5 to 8 g/ 100 g sample. Regarding at least sugar content, Table 1 does not account for seasonal variations and the characterization seems to be outdated.

The organic production of the Azorean pineapple (Figure 5) is a major value attribute to the marketing of the fruit for export, and more than 40% of the producers are certified as organic producers. High costs of production make it difficult to compete with large scale producers for traditional markets. To remain competitive, it is necessary to reduce the time-consuming and costly greenhouse manual labor requirement, perhaps by introducing new materials and equipment, adopting more modern types of greenhouses or by moderate changes to the structure of the glass greenhouses currently in use. A project involving industry and scientific institutions has been established to study the 'Smooth Cayenne' clone maintained in the Azores for 150 years as well as the subjects mentioned above. *In vitro* propagation methods are being established to reduce propagation time and provide growers with adequate amounts of uniform plants. The lack of historical climate records inside and outside the greenhouse is being rectified by measurements done since early 2012. The project also covers the study of watering regimes and management of drought periods, as stress induction affects both flowering and fruit development stages. It is crucial to standardize and maximize the Azorean pineapple production and increase its quality, enhancing its organoleptic properties by improving organic cultivation techniques.

Figure 5 – Azorean pineapple marketing label.

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The Molecular Mechanisms of Flowering. Is Pineapple Flowering Totally Understood?

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Keywords: Ananas comosus; flowering pathways

MOLECULAR MECHANISMS OF FLOWERING: AN OVERVIEW

Flowering is a unique, integrated and very complex process under multifactorial controls. The ecophysiological to biophysical aspects of flowering have been studied extensively over several decades (Glover, 2007). Flowering occurs as a result of reprogramming the identity of the shoot apical meristem cells (Blázquez et al., 2006). Rather than initiating stems, leaves and axillary buds, a reproductive (or floral) meristem gives rise to an inflorescence, i.e. flowers and their subtending bracts (Öpik and Rolfe, 2005). The reprogrammed identity of the floral meristem is due to signals from flowering pathways that converge to a restricted group of genes named “floral pathway integrators”. Physiological studies revealed that the expression of such genes occur in response to both endogenous factors (autonomous and gibberellin pathways) and environmental cues (photoperiod and vernalization) (Amasino and Michaels, 2010; Wigge, 2011). In addition, less well characterized factors such the carbohydrate metabolism (Moghaddan and Van den Ende, 2013), temperature (Blázquez et al., 2003), light quality (Valverde et al., 2004), stress (Wada and Takeno, 2010) and hormonal changes (Davis, 2009) may also play a role in the flowering “decision.”

Four major floral pathways have been characterized in the intensively studied *Arabidopsis thaliana* (reviewed in Kim et al., 2009) (Figure 1), which has been used as a model system because of its short generation time, ease of manipulation and a small genome for a complex, multicellular, eukaryote organism. The autonomous pathway for floral inhibition and induction is central to the entire process of floral transition. Flowering is repressed in Arabidopsis through the expression of the FLOWERING LOCUS C (FC) gene and FC-relatives in the shoot apical meristem (Simpson, 2004). FC represses the expression of the floral pathway integrator genes FLOWERING LOCUS D (FD), FLOWERING LOCUS T (FT), and SUPPRESSOR OF CONSTANS 1 (SOC1) (Kim et al., 2009). The vernalization pathway is found in those plant species where flowering is promoted by prolonged exposure to cold temperatures. This pathway acts by silencing the repressor FC in the shoot apical meristem (reviewed in Amasino and Michael, 2010; Kim et al., 2009), which leads to the activation of the floral pathway integrators FD, FT and SOC1.

In the photoperiod pathway, inductive photoperiods promote the circadian expression of a CONSTANS (CO) protein acting between the circadian clock and the control of flowering time (Suárez-López et al., 2001). CO protein directly activates the expression of the FT gene, which is normally in the leaves. During the last decade several FT gene homologs were identified in different plant species and the protein produced by this gene family (FT protein) was shown to be a floral-promoting signal that can be transported from the leaves to the apical meristem (Xu et al., 2012). In the meristem, FT and FD proteins interact and initiate flowering by activating SOC1, which integrates the photoperiod, temperature, hormone (gibberellin pathway), and autonomous (age-related) signals into a unitary signal at the shoot apical meristem (Lee and Lee, 2010). SOC1 regulates LEAFY (LFY), which controls the expression of a wide variety of genes required for organ development (Amasino and Michaels, 2010; Blázquez et al., 2006; Kim et al., 2009; Siriwardana and Lamb, 2012).

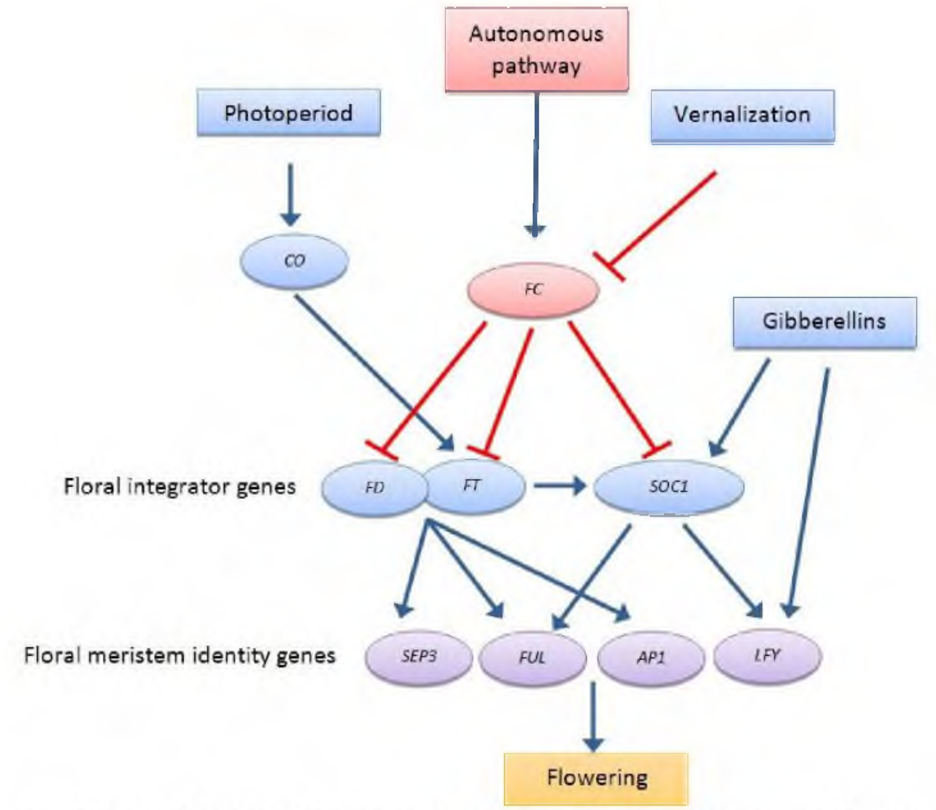

Figure 1. Outline of flowering in *Arabidopsis*. Components and genes that promote flowering are in blue, those that repress flowering are in red (adapted from Kim et al., 2009). Abbreviations are AP1, APETALA 1; CO, CONSTANS; FC, FLOWERING LOCUS C; FT, FLOWERING LOCUS T; FD, FLOWERING LOCUS D; FUL, FRUITFULL; LFY, LEAFY; SEP 3, SEPPALLATA 3; SOC1, SUPRESSOR OF OVEREXPRESSION OF CONSTANS 1.

Plant growth regulators and other substances interact with various genes to promote or inhibit flowering. In species where gibberellins (GAs) promote flowering, they do so by directly activating SOC1 and such floral meristem-identity genes as LFY (reviewed in Mutasa-Göttgens and Hedden, 2009; Wigge, 2011). Nitric oxide (NO) promotes the vegetative phase by suppressing genes related to the photoperiod pathway and enhancing FC expression through the autonomous pathway (Figure 1; He et al., 2004; Seligman et al., 2008). Ethylene biosynthesis in response to environmental stress delayed flowering in *Arabidopsis* by repressing GA synthesis (Achard et al., 2007). However, in the Bromeliaceae family, ethylene biosynthesis, as well as treatment with ethylene, induces flowering (Rodriguez, 1932; Kerns, 1936; De Proft et al., 1984), but no studies of the mechanism of action were found. The silencing of ACC synthase, an enzyme responsible for ethylene biosynthesis, delays floral initiation in Ananas comosus (Trusov and Botella, 2006). Other hormones such as abscisic acid, jasmonic acid, salicylic acid and the cell division regulators auxins, cytokinins and brassinosteroids were also shown to be players in the floral transition (Davis, 2009).

Over the past 15 years, tremendous advances in the knowledge of flowering pathways revealed that several critical events need to occur under certain environmental and endogenous conditions before plant reproduction takes place. Whereas the picture in *Arabidopsis thaliana* is close to complete, much less is known about the genetics of flowering in other plant families. For instance, there are some striking differences between the circuitry and components of vernalization in *Arabidopsis* and cereals while the photoperiod pathway is much more conserved within plant families (Higgins et al., 2010; Kim et al. 2009). Also, comparative genomics of flowering time pathways between monocots (e.g. *Oryza* sp., *Brachypodium* sp.) and dicots (e.g. *Arabidopsis* sp.) suggest that it will be possible to integrate knowledge of gene function into a widely accepted model (Higgins et al., 2010). Nevertheless, studies on the manipulation of flowering related genes to improve crops are appearing worldwide. For instance, photoperiod-insensitive cultivars are being produced to improve cereal production (Tsuji et al., 2011) whilst others attempt to reduce natural flowering induced by environmental cues to schedule and synchronize fruiting by silencing a specific ACC synthase gene (Trusov and Botella, 2006). Recently, Flachowsky and Hanke (2011) produced an early flowering transgenic apple tree, for breeding purposes, using a FUL-like gene from silver birch to reduce the long vegetative phase. Improved knowledge of flowering pathways can have an important effect on agronomical practices in the future, by introducing crops with synchronized flowering mechanisms adapted to different environments in order to achieve maximum efficiency in crop planning and labor costs and to maintain a scheduled crop to be marketed according to the consumer's demands.

PINEAPPLE FLOWERING

A remarkable hallmark of Bromeliaceae species is the induction of flowering with ethylene, an accidental discovery linked to the late 19th century discovery that pineapples cultured inside greenhouses in the Azores were forced to flower using smoke (Rainha et al., 2013). Ethylene was later identified as the active substance in smoke (Rodriguez, 1932). This feature is exploited worldwide by commercial pineapple growers to synchronize flower and fruit development resulting in, at most a few harvest passes. Several growth regulators initiate pineapple flowering with 2-chloroethylphosphonic acid, (ethephon), ethylene, acetylene (and calcium carbide) being the most used (Cunha, 2005). Each substance directly releases ethylene to the plant (Bartholomew et al., 2003; Py et al., 1987), triggers the biosynthesis of ethylene in plant tissues, as is the case for auxins (Burg and Burg, 1965) or mimics the effect of ethylene such as acetylene (Py et al., 1987).

Plant sensitivity to forced induction of flowering varies with cultivar, plant size, age and environmental conditions (Bartholomew et al., 2003; Conway, 1977). When plants are less sensitive to natural induction, a second treatment improves the outcome. (Py et al., 1987). The most effective induction is achieved using ethylene or acetylene applications at night. It is assumed that night treatments are more successful because pineapple stomata are open at night for CO_2 uptake as required by the Crassulacean Acid Metabolism (CAM) (Bartholomew et al., 2003; Py et al., 1987). Flowering inducers are continuously under study in order to achieve the maximum efficiency for each variety (Lebeau et al., 2009; Maruthasalam et al., 2010; Van de Poel et al., 2009).

Sometimes, delaying flowering is much more profitable for producers than inducing early flowering (Cunha, 2005; Kist et al., 2011). Flowering inhibition in pineapple can be accomplished using the ethylene biosynthesis inhibitor aviglycine (Bartholomew et al., 2011; Kuan et al., 2005; Wang et al., 2007), 2-(3-chlorophenoxy)-propionic acid (Cunha, 2005), paclobutrazole and uniconazole (Min and Bartholomew, 1996), the latter by reducing ethylene production through the inhibition of ACO, however Antunes et al., (2008) showed that paclobutrazole slightly lowered fruit yield. More recently, Kist et al., (2011) stated that urea enhances the flowering inhibition effect of the contact herbicide Diquat in pineapple with a slight reduction of fruit yield.

Natural flowering is one of the long lasting agronomic problems in pineapple (*Ananas comosus*) cultivation causing considerable losses and a disrupted market supply due to the heterogeneous fruit development and multiple harvest passes (Min and Bartholomew, 1996; Wang et al., 2007). Pineapple natural flowering mostly occurs under short day conditions (Friend and Lydon, 1979; Gowing, 1961) which in subtropical environments coincide with lower night temperatures. Py et al., (1987) stated that the photoperiod is the most important factor determining floral differentiation, closely followed by the thermoperiod. Anyway, the effect of low temperatures in pineapple flowering in not yet clear. Sanewski et al., (1998) suggested that drops in temperature may act as a stress factor, which stimulates a burst of ethylene biosynthesis on warm up, but failed to determine the conditions required to achieve natural flowering under a cyclical cooling and warming thermoperiod. More recently, it was determined ethylene production is increased in response to short-term cold stress (Maruthasalam et al., 2010).. This inductive condition could be used to reduce the concentration of acetylene used to force 'Tainon 17'. Mild water stress is also believed to be inductive while severe water stress is inhibitory. It is assumed that these inductive conditions either trigger ethylene biosynthesis in the shoot apex or increase plant sensitivity to naturally produced ethylene with the consequence being a switch from vegetative into flowering stage in pineapple (Bartholomew et al., 2003).

The ethylene biosynthetic pathway is well established (Yang and Hoffman, 1984) and the expression patterns of the main ethylene biosynthetic genes have been well characterized over the last decades in different plant species (Argueso et al., 2007; Lin et al., 2009). Two key enzymes are important for ethylene biosynthesis, namely, ACC synthase (ACS), which converts S-adenosyl-L-methionine into 1-aminociclopropane-1-carboxílic acid (ACC) and ACC oxidase (ACO), which degrades ACC to ethylene (Yang and Hoffman, 1984). In pineapple, three ACS genes have been cloned and two of them have been characterized (Cazzonelli et al., 1998; Botella et al., 2000). AcACS1 was shown to be expressed in fruits and in wounded leaves (Cazzonelli et al., 1998). The AcACS2 gene is induced in the meristem by conditions that promote flowering and silencing by genetic engineering techniques delayed flowering (Trusov and Botella, 2006). There are multiple unique and apparently unrelated plant responses to ethylene and induction of flowering of Bromeliads in response to endogenous or exogenous ethylene is one them. The following section is an attempt to link what is known about the genetics of flowering and the genetics of ethylene response to attain a better understanding of ethylene and flowering of pineapple.

For many years ethylene was thought to interact with a receptor molecule, resulting in an active complex that elicits a series of reactions, including modifications in the expression of genes, leading to a wide diversity of physiological effects (Cunha, 2005). As pineapple flowering is unequivocally an ethylene promoted event, its signaling pathway is expected to have a major role in targeting the expression of flowering genes at the nuclear level. How this signaling pathway operates in pineapple,, resulting in the promotion of flowering, is not known, however in *A. thaliana* ethylene signals the repression of GA biosynthesis delaying flowering (Achard et al., 2007). . Moreover, Bartholomew (D. Bartholomew, personal communication) showed in 2004 that 1-methylcyclopropene (1-MCP), a compound that binds to ethylene receptors blocking its effect, prevented flowering initiation of pineapple treated with ethylene the day of and two days after but not 11 days after 1-MCP treatment and similar results were obtained recently with acetylene (Wu et al., 2012), showing that both ethylene and acetylene may use the same receptors system. This important result also suggests that ethylene signals the transcription of important genes in pineapple flowering initiation, at the nuclear level. In *A. thaliana*, several gene families are reported to encode proteins involved in the recognition of ethylene at the cell membrane such as ETHYLENE RESPONSE (ETR), ETHYLENE RESPONSE SENSOR (ERS) and ETHYLENE INSENSITIVE (EIN) (Zhao and Guo, 2011). Essentially, the ethylene receptors activate the repressor CONSTITUTIVE TRIPLE RESPONSE 1 (CTR1), which signals the downstream activity of EIN2, a central component of the ethylene signaling pathway, at the endoplasmic reticulum, to suppress the ethylene response in the absence of ethylene. Downstream of EIN2, two plant-specific transcription factors, EIN3 and EIL1 (EIN3-like 1), are both necessary for the activation of ethylene-regulated gene expression at the nuclear level (Yoo et al., 2009; Zhao and Guo, 2011). The ethylene response depends on EIN3 stability. In the absence of ethylene, EIN3 is targeted for degradation via the proteasome pathway. EIN3 operates upstream of the GA-DELLA pathway as shown by Achard et al., (2007) in *Arabidopsis* in which ethylene production delayed flowering. Recently, Moreira et al., (2013) identified and characterized the expression of two putative DELLA genes in pineapple, induced with Ethrel, suggesting a role in flowering time control.

The ethylene signaling pathway is not characterized for pineapple and at this point it is not possible to answer how this hormone represses flowering in *A. thaliana* and activates gene expression of flowering initiation in pineapple. New insights on hormone balance in pineapple flowering showed that exogenous application of ethephon (= ethylene) induces flowering, promotes the biosynthesis of abcisic acid and 2-isopentyl adenine (cooperative factors) and inhibits the production of GA3, zeatin and indole-3-acetic acid during inflorescence initiation (Liu et al., 2011) . Furthermore, the homologous gene flowering pathway integrators LFY and FT were identified in *A. comosus* variety “Comte de Paris” (Figure 1; Lv et al., 2011; Lv et al., 2012a) suggesting that flowering pathways are conserved in the pineapple genome. Curiously, unlike other FT homologs, expression of FT in *A. comosus* was not found in the leaves but in fruit stem, flesh and sepals revealing that FT plays an important role not only in flower development but also in fruit development (Lv et al., 2012a). Furthermore, the characterization

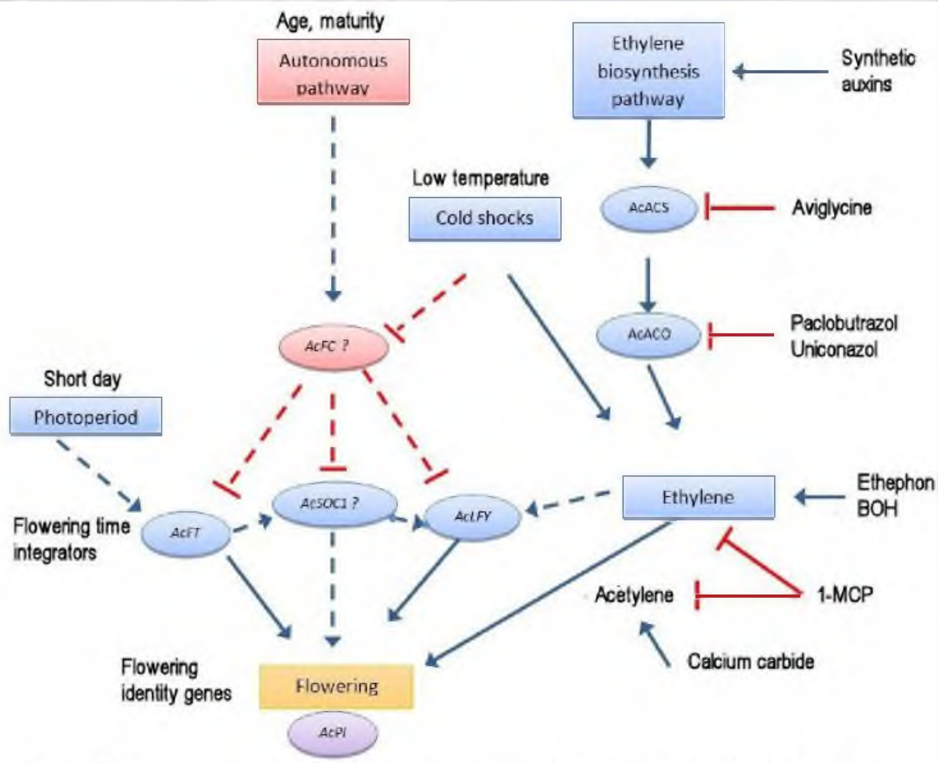

Figure 2. Proposed pathways for pineapple flowering. Components and genetic interactions that promote flowering are shown in blue; those that repress are shown in red. The dashed lines represent proposed connections for pineapple flowering. Abbreviations (Ac prefix indicates an *A. comosus* homolog gene) are: 1-MCP, 1-methylcyclopropene; AcACS, ACC synthase; ACO, AcACC oxidase; AcFC, FLOWERING LOCUS C; AcFT, FLOWERING LOCUS T; AcLFY, LEAFY; AcSOC1, SUPRESSION OF OVEREXPRESSION OF CONSTANS 1; BOH, 2-hydroxyethylhydrazine. Genes with a "?" have not been described for pineapple.

of a PI homolog gene in *A. comosus* (Lv et al., 2012b) suggests that flower differentiation follows the same model (ABC) as *Arabidopsis* (Haugh and Somerville, 1988).

A comprehensive view of the possible flowering pathways for pineapple is proposed in Figure 2. Based on field evidence, we propose that three major pathways are involved in pineapple flowering: photoperiod, ethylene and an autonomous pathway which would inhibit flowering until endogenous or environmental signals are activated. The identification and characterization of FC-like and SOC1-like genes in pineapple should confirm the existence of the autonomous pathway. The effects of photoperiod and cool temperatures on pineapple flowering have been known for quite long time (Gowing, 1961; Friend and Lydon, 1979; van Oveerbeek and Cruzado, 1948; Sanewski et al., 1998). However, the effect of low temperatures in pineapple flowering can not be considered a vernalization pathway since the evidence points to a short-term effect which increases ethylene production and not a prolonged exposure as required for vernalized plants.

We propose that the recently described AcFT gene (e.g. http://ip.com/patfam/en/45378443) is related to the photoperiod pathway, although this connection was not shown by Lv et al., (2012a). Since natural flowering of pineapple normally occurs when short day conditions are coupled to or confounded with low temperatures, the two mechanisms may cooperatively affect the flowering decision as described for *Arabidopsis*, with independent gene targets (Figure 2, Kim et al., 2009). Low temperatures would inhibit an FC-like gene, removing the inhibitory effect of the autonomous pathway whilst the photoperiod pathway induces flowering gene activation in the shoot apical meristem through flowering pathway integrators (e.g. SOC1-like).

The most common method of triggering flowering of pineapple is to use ethylene or substances that activate ethylene biosynthesis while flowering is inhibited by aviglycine. Figure 2 shows a proposal integration of several chemical substances into a unitary pathway. Acetylene is shown near ethylene since it mimics the effect of the latter. Ethylene and acetylene can either activate directly or induce a signal through the ethylene signaling pathway that lead to the expression of flowering genes. Water stress is also believed to induce flowering in pineapples, especially in regions were photoperiodism and temperature variations are small (Py et al., 1987; Cunha, 2005). However, Min and Bartholomew (2005) showed that relatively severe water stress did not promote early flowering and the ethylene biosynthetic pathway produced less ethylene under drought stress compared to flooding stress. Both treatments were shown to reduce average fruit weight. Also, cold shocks may have a role inducing ethylene production (Soler et al., 2006).

Controlling flowering time in pineapple is one of the most important factors affecting production costs and fruit quality. The characterization of flowering pathways in pineapple could provide insights that could lead to important tools to control natural flowering of the plant. Transgenic pineapple cultivars with increased resistance to natural flowering are already under development (Botella et al., 2000; Wang et al., 2009). The research could progress more rapidly and with greater precision if the molecular mechanisms involved in pineapple flower differentiation were better understood. It appears that the unique role of ethylene receptors and ethylene signaling pathways in pineapple flowering have been overlooked or forgotten. Nevertheless, important tools such as the pineapple bioinformatics resource (Moyle et al., 2005), the recent publications of the pineapple genetic map (Carlier et al., 2012; Sousa et al., 2013) and next generation sequencing technology which allows massive parallel sequence of genetic material could be the starting point for a new era in pineapple flowering research.

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News from Costa Rica

Some Thoughts and Recommendations On Nutritional Monitoring In 'MD-2' With One Case Analysis

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When analyzing a foliar result in a crop, it is desirable to have a comparative parameter to infer nutritional balance or imbalance. Much literature exists inherent to optimum nutritional content for each element (critical levels) for pineapple. However, this information is often mistakenly used to make changes in a fertilization package. Although the fertilization package is one of the main tools used to modify the nutrition of the crop, several factors are equally important for the proper diagnosis, monitoring and understanding crop nutrition.

Case Analysis: Foliar Applications of Fe in Pineapple Crop

Auchter (1951; cited by Bartholomew *et al*,.2012) indicated that a severe chlorosis was the first factor that limited expansion of the area planted to pineapple in Hawaii in the early 1900s. The chlorosis occurred on large areas of so-called black soils that were high in manganese. The problem was not encountered in soils at higher elevations where rainfall was higher and soils were more highly leached and had lower pH values. The disorder was described and associated with manganese levels in soil and it was discovered that high manganese rendered soil iron unavailable to pineapple plants. Sprays of iron sulphate cured the problem and also were successful in curing a chlorosis of pineapple plants growing in calcareous soils in Puerto Rico (Bartholomew et al., 2012). The iron problems were quite serious; however, it also seems that the problems were limited to soils with low pH and high manganese and soils with high pH where iron was limiting and absorption of microelements was decreased.

In Costa Rica, sprays of iron sulfate are common to pineapple nutrition programs in all areas of the country. This widespread use could be evidence of direct transference of Hawaii-developed technology to Costa Rica, since the large-scale production of pineapple in the country came with the technology developed in Hawaii.

In the following results the levels of all macro and microelements in 'D' leaves were analyzed but the tables include only those elements relevant to the discussion of iron availability in soils or where significant differences in tissue levels in the various soils were found. However, the main objective is to demonstrate the importance of knowing the effect of plant available (soluble) Fe on levels in the 'D' or index leaf .

The Fe content in the basal part of the D leaf (Table 1) is lowest in the Entisol, intermediate in the Ultisol and highest in the Inceptisol. The total iron contents in soils (Table 2) increases in the order Entisol, Inceptisol, and Ultisol.

Table 1. Nutrient content of three sections of the'D' leaves of pineapples grown in soils of three different orders with the same fertilization package. Means within a soil order followed by the same letters indicate no significant differences $p < 0.05$, N = 12. Data of J. Vásquez, 2010.

Soil	Leaf section	N, %	P, %	Ca, %	K, %	B	Fe	Mn	Fe/Mn
Entisol	Apical	2.85 b	0.11 a	0.15 a	1.79 a	34 c	58 a	54 a	1.13 a
	Basal	1.97 a	0.15 b	0.19 b	2.62 c	14 a	55 a	62 a	1.00 a
	Middle	2.30 a	0.11 a	0.14 a	2.20 b	25 b	100 a	44 a	2.71 a
Ultisol	Apical	2.20 b	0.10 a	0.18 a	2.29 a	31 b	145 b	317 a	0.46 b
	Basal	1.65 a	0.12 b	0.18 a	2.86 b	12 a	77 a	341 a	0.23 a
	Middle	1.77 a	0.09 a	0.18 a	2.49 a	19 a	89 a	294 a	0.30 a
Inceptisol	Apical	2.62 b	0.13 a	0.18 ab	3.69 a	38 b	110 a	240 a	0.46 a
	Basal	2.33 a	0.19 b	0.24 b	4.41 b	13 a	151 a	244 a	0.61 a
	Middle	2.34 a	0.12 a	0.13 a	3.43 a	25 b	79 a	162 a	0.54 a

However, soluble and bioavailable forms of iron are highest in the Entisol. This is important since in the pineapple industry, the inclusion of iron into the fertilization packet is nearly universal, when in reality there are cases where iron applications are not necessary or even counterproductive. For example, although the Fe level in the Entisoil is low, as is the foliar level of iron relative to that in leaves of plants grown in soil of the other orders, the ratio Fe / Mn, which should be only about 0.2 so there is no Mn-induced Fe deficiency, is more than five times the desirable ratio (Figure 1). Based on the contents of Mn in the soils (Figure 2), it is more reasonable to consider adding Mn to the fertilizer packet. Despite this, at least in Costa Rica, Mn is not commonly considered in pineapple fertilization programs.

Table 2. Fractionation of iron in mg kg^{-1} in three soil orders in Costa Rica; N = 12. Data of J. Vásquez, 2010.

Form	Entisol	Inceptisol	Ultisol
Soluble	0.74 ± 0.16	0.09 ±0.08	0.21 ±0.18
Exchange	0.28 ±0.18	1.57 ±0.19	0.83 ±0.25
Associated with organic matter	2,023 ±25	5,331 ±1,570	814.5 ±276.0
Associated with amorphous oxides	601.3 ±373.2	3,646 ±1,492	3,756 ±788.25
Associated crystalline oxides	14,937 ±1,868	29,351 ±2,575	18,830 ±2,568
Remaining	8,834 ±3,321	13,817 ±4,672.31	31,593 ±6,181
Total	26,396 ±2,677	52,146 ±4,031.88	54,995 ±4,886
Bioavailable	450.4 ±131.3	67.0 ±22.6	39.9 ±12.0

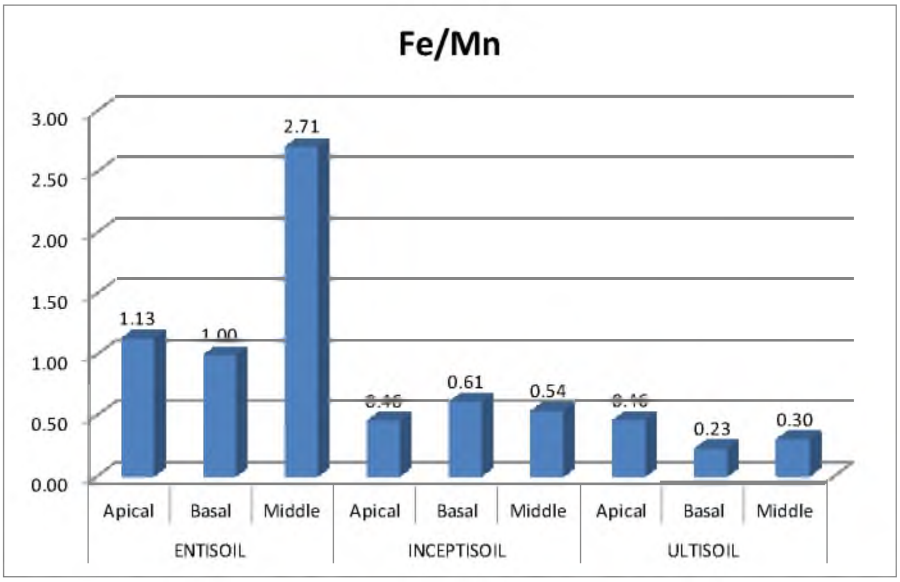

Figure 1. Foliar Fe/Mn content in three sections of ‘D’ leaves of pineapple plants grown in three soil orders using the same package of fertilization. Data N = 12 by order of soil. Data of J. Vásquez, 2010.

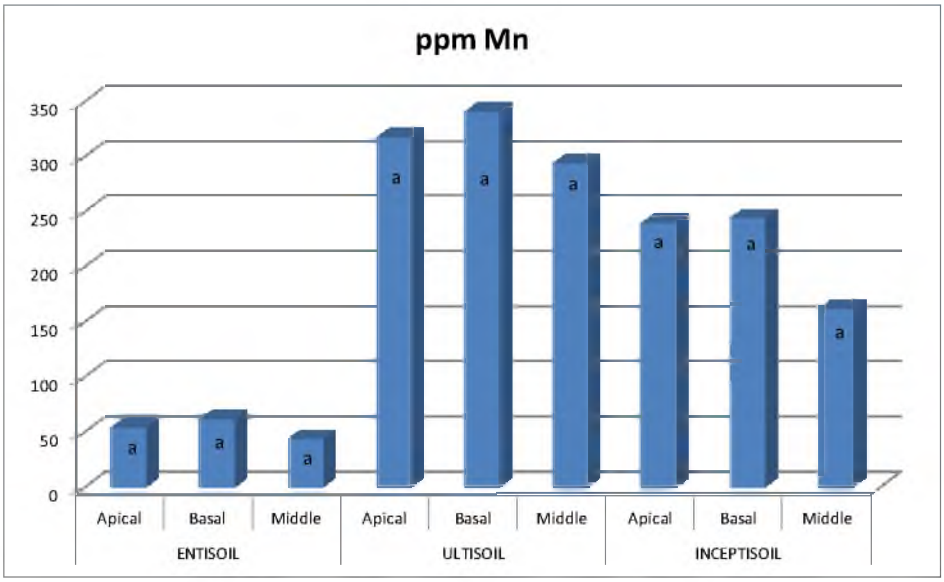

Figure 2. Foliar manganese content in three sections of 'D' leaves from pineapple plants grown in three soil orders using the same package of fertilization. Data N = 12 by order of soil. Data of J. Vásquez, 2010.

Fertilizer Recommendations For the Pineapple Crop

The following is based on production records and management programs of some farms in different soil types, as well as some research. A healthy root system is required to get this behavior in response to Fertilization/Nutrition. In drought conditions without irrigation, as well as excessive moisture and poor drainage, the behavior can be different. The color-coded table below (Table 3) was developed by the author to illustrate the type and method of applying the various plant nutrients to achieve the best response and return to grower. It is shared here with the goal of generating more information to the extent that other researchers, decide validate on their own and share their results.

Table 3. Ways for supplying fertilizer salts and / or nutrients to pineapple crops.

Elements		**Soil**	**Foliar sprays**
N			Nitrate + Ammonium
P			MAP
K		KCL	KCL
Mg		Dolomite	Sulphates
Ca		Calcium carbonate	Nitrate
S			
Fe			Sulphates
Zn			Sulphates
B			Boric acid
Mn			Sulphates
Color key	Heavy loss	Regular achievement	Great achievement

The aim of the following section is to review those factors that may help to better systematize the information that is often used as a nutritional diagnostic tool in pineapple. It is essential to collect valid information to make decisions on crop fertilization and the following list can help assess the quality of the information available on the farm and the changes that can be made in the current operation to refine the quality of information received from the laboratories of soil and plant analysis.

1. Set the 'D' leaf as the leaf of nutritional monitoring and ensure that staff are able to identify the D leaf in pineapple plants.

2. Collect samples based on the minimum handling unit. Avoid mixing sections or blocks, as there may be interference by type of seed, seed sizes, and differences in fertilization that has been applied to these areas.
3. Use the concept of Sanford 1962 (Pineapple Crop Log), to determine the management unit to be sampled that represent larger areas, with this comes saving on laboratory analysis and more precise results.
4. Use the formation of groups that is ordinarily making in the farm, as a basis for selecting sample units.
5. Only sample crop units that were planted with the same type and size of seed.
6. Define a standard methodology for field sampling (number of leaves to be sampled, how to obtain them in each section or minimum management unit).
7. It is very important to remember that the part of the D leaf to be analyzed is the middle one-third of the basal white tissue. In heavy soils and wet conditions, this part tends to get dirty, so you need to ensure it is thoroughly clean before sending to laboratory, the presence of soil here significantly affects the analysis results. DO NOT assume that the laboratory does this job, although they have protocols to do so.
8. DO NOT send the entire leaf to the laboratory. Remember that common sense is the least common of the senses. Some people prefer to analyze nitrogen in the middle third, that's fine, but it creates an additional process, and increases the margin for human error. It is possible to obtain a good calibration for all elements using the basal third.
9. Define an on-farm protocol for sample processing (cut each sample of leaf group yourself; do not leave this work to the lab). Make sure to use the third basal, and that it is sectioned correctly according to the overall size of the group that makes up the sample.
10. Make professional use of the information, this needs to take the following decisions.
11. Define ages of crop development on which you will be making nutritional diagnostics. For example three ages (3-4 months, 5-6 months, 7-8 months).
12. Define each age according to the number of foliar fertilization applications. For example, take sample 1 with 4 cycles applied, sample 2 with 8 cycles applied and sample 3 with 12 cycles applied.
13. If the farm is very large (over 500 hectares), try to monitor by batch, or at least areas that are differentiated from the other lots based on manageability or fertility, without compromising the performance of logistics and teams as this may represent a saving in materials.
14. Knowing the soil mineralogy of the farm, to correctly interpret nutritional outcomes, take a soil sample of the areas that can be given a different management and request at the laboratory the fractionation of each nutrient element as follows: (soluble , change, associated with the organic material, associated with amorphous oxides, associated with crystalline oxides, residual and, very important, bioavailability).
15. Based on the above, it is possible to reason better the behavior of conventional soil analysis and nutritionally content in the D leaf tissue, to contrast it with the package of fertilizer and make decisions.
16. At least once leave a couple of growing beds as absolute controls (no fertilizationr) during the period from planting to forcing, to have a base and additional criteria showing what nutrition the unfertilized soil provides.
17. Remember the laboratory is not infallible and is only responsible for ensuring the quality of analysis of the sample entered, which makes it imperative to ensure the quality of the process of sampling and sample handling performed on the farm.
18. Remember that the extractants used in soil analysis can remove some of the elements that are in forms not available to plants (especially micronutrients), indicating quantities available when they really are not.
19. Question in the guild about the top laboratories of soil and plants testing ("precision and accuracy" and response time), choose one and try to only use that lab, to get consistency in the information.
20. Know of extraction and reading methodologies of nutrients employed by your laboratory, if you need to change laboratories, it is important to continue using the same determination and quantification methodologies for nutrients.
21. Structuring a database statistically analyzable with variables of productivity and fruit quality are essential.
22. It is important for each farm to build and define its own critical levels.
23. Be guided by the table 3, to improve nutrient levels once you have identified opportunities to improve nutrition.

All the above points will help strengthen the technical criteria to make adjustments and improvements to the fertilization technology package, which means you will be using agricultural science to benefit the environment "to apply just enough" and pocket "to leave off buying what is not needed. "

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Technical and Social Considerations Of a Rapid Increase in Pineapple Production in Costa Rica

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INTRODUCTION

Pineapple production for export has become one of the top economic activities of Costa Rica. Although pineapple has been grown in this country since more than four decades ago, it wasn't until the 1990's that the number of growers and land dedicated exclusively to the production of this crop increased rapidly (Barquero 2011). It is estimated that in the last twenty years, there has been a 10-fold increase in pineapple planted area reaching approximately 45,000 hectares (ha) in 2010. This rapid expansion reflected the high profitability of pineapple exports and also the changes in land use. From the economic perspective, pineapple is usually one of the top two most important crops in Costa Rica, commonly disputing the first place with banana. It is for this reason that pineapple has gained major relevance in Costa Rica affecting agricultural and environmental policies and regulations (Camacho Sandoval 2009).

Pineapple large-scale production is relatively recent, and unlike crops with more tradition within Costa Rica's economy, such as coffee, banana or sugarcane, there are no formal public institutions that conduct research and train growers. Therefore, it is uncertain if new pineapple growers know how to efficiently grow the crop maintaining low production costs, and minimizing negative environmental impacts. This last point is critical in Costa Rica because of its strong efforts in favor of the protection of natural resources over the last forty years.

Most of the pineapple production technologies used in large plantations have been developed by international corporations such as Del Monte and Dole. However, the "know-how" of those technologies is not available to all growers. This situation has forced many growers that start producing pineapple to rely on trial and error approaches for figuring out the best way to produce this crop, which has generated a wide range of production practices. Nevertheless, because there are no standard production protocols or public statistics about production techniques for comparison, it is hard for growers to assess if their practices are adequate or minor modifications or complete changes are warranted.

Not only growers starting in pineapple production had to face challenges, communities where pineapple became an important crop had to face rapid changes in their lifestyles. On one side, pineapple farms increased employment due to its high labor demand for activities such as planting, harvesting, and packing. Also, medium and large size farms improved public infrastructure such as roads and bridges for transporting the fruit from farms to the packing plant. On the other hand, there have been problems such as bromacil (preemergence herbicide mainly used in pineapple farms) leaching and reaching water reservoirs polluting drinking water in several communities, deforestation and wetland drainage to use those areas for growing pineapple, and excessive erosion (Cantero 2009; Chacon 2012; Loaiza 2010). These types of conflictive situations have underscored the importance of proper communication and agreements between pineapple farms and the communities where they operate to ensure mutual benefits in the long run.

For these reasons, a survey was conducted to make an inventory of general production practices in pineapple production in the North and Caribbean lowlands of Costa Rica. The main goal was to provide a general overview of the production practices used by pineapple growers, so strengths and areas that need improvement could be identified. This information then could be used as a reference so any pineapple producer can compare his/her production practices to those implemented by other growers. Additionally, we conducted other surveys in communities where pineapple production is an important component of the local economy, but where neighbors and environmental groups have requested pineapple farms to make sure that they do not negatively impact the environment. This was done to generate information that growers can use to modify their production practices and improve their relationship with the communities where they operate.

Many results of the aforementioned surveys have been published (Leon and Kellon, 2012, etc.), so in this manuscript we highlight the most important findings of those studies. Furthermore, we will provide details of some of the aspects that have not been published and are pertinent to understand some of the challenges that pineapple growers face in Costa Rica.

METHODOLOGY

The survey of growers was conducted in 2011 in the Northern and Caribbean lowlands of Costa Rica and covered 24,637 ha of farmland with an effective area planted with pineapple of 13,698 ha, which represented about two-thirds of pineapple production area in the region of the study and about a third of Costa Rica's pineapple production area. Growers were contacted by telephone or email, and those willing to participate in the survey were interviewed personally at their farms using quantitative and open discussion questions. The person providing the information was either the farm owner or the production manager. After individual interviews, the preliminary results were analyzed with focus groups of pineapple growers, which provided insight for result interpretation. The answers were tabulated, and frequency and regression analyses were conducted (Leon and Kellon 2012). In the case of the surveys, with community members, a formal random sampling scheme was developed making sure that it would comply with the population structure of the region. This was done in collaboration with the National Census and Statistics Institute (INEC). Community members were interviewed about their concerns and preferences about pineapple production in their communities using no synthetic pesticides but no capacity to improve public infrastructure vs. large farms with synthetic pesticide use and capacity to improve public infrastructure. In this regard, several possible scenarios that were a combination of alternatives to the current production practices were presented to the respondents. Additionally, respondents had to reassess their answers using a deliberative methodology. In this way, the analysis allowed identifying preferences that properly represented the priorities of the respondents after dealing with the tradeoffs associated with the changes they were expecting pineapple growers and policymakers to make. Please see Richardson et al. (2013) for specific details about the sampling structure, and the survey methodologies used.

RESULTS

Yields

The growers' survey showed that the average yield was 7130 25-lb boxes/ha with a threshold around 8000 boxes/ha for the mother plant crop. However, some farms surpassed 9000 boxes/ha (Leon and Kellon 2012). An important finding was that the ratoon crop yields were dramatically lower with an average of 4783 boxes/ha. The average yield was 65% of the mother plant crop. This reduction was considered unavoidable but still profitable by many growers. However, several high yielding farms reported consistently reaching 85 to 90% of plant crop yields. This suggested that a high ratoon yield is possible and highlights the need for more growers to learn how to manage their plantations to obtain higher ratoon yields. When asked about how they minimized yield loss in the ratoon crop, growers were reluctant to provide details; however, several of them mentioned that specific fertilization programs and cultural practices associated with pruning after harvest are important components for fields that will be ratooned.

Planting density and Fertilization

Among the different variables studied, planting density was the main determinant of yield. The average planting density was 62,594 plants/ha with a range of 35,000 to 72,400 plants/ha. It is important to mention that farms using the highest planting densities reported obtaining fruits of the desired size for export (1.75 to 1.90 kg). However, growers using high densities warned that if the crop is not managed properly, especially from the nutrition perspective, the percentage of small fruit could increase significantly.

The nutrition of the crop was also an important driver of management. Very few growers reported conducting soil or leaf analyses, so they operate under the assumption that the soil contribution to the nutrition of the plant is negligible, so all the nutrients must be provided to the crop by pre- and post-planting fertilization.. Fertilization was overall comprised of a basic granular fertilization (less than 20% of crop requirements) at planting and then frequent foliar applications of soluble fertilizer formulations until harvest. The variation in fertilizer use was large (Leon and Kellon 2012), but the average rates for the mother plant and ratoon crops, respectively, were 632 and 520 kg/ha for nitrogen (N), 129 and 93 kg/ha for phosphorous (P), and 400 and 340 kg/ha for potassium (Fig.1). The highest yielding farms did not have the highest fertilization rates. In fact, those farms reported fertilization rates closer to the average or even lower. Additionally, those farms also reported using some of the highest planting densities. Focus groups mentioned that N and P levels were high and that they could be reduced 20% and 66%, respectively without sacrificing high yields. Therefore, it seems that many of the interviewed growers have potential to make their fertilization programs more efficient. The adoption of fertilization programs based on soil and leaf analyses is warranted to achieve this goal.

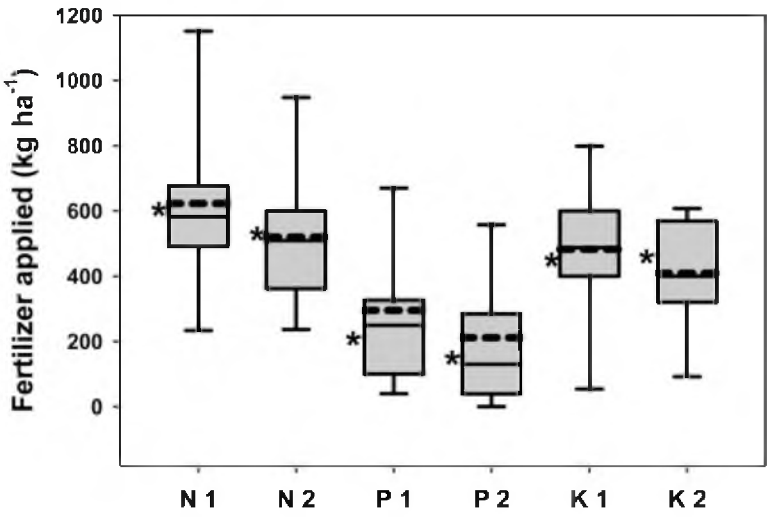

Fig. 1. Amount of nitrogen (N), phosphorous (P) and potassium (K) supplied to 'MD-2' pineapple in mother plant (1) and ratoon (2) crops based on reports by growers on 44 pineapple farms in Costa Rica in 2011. The error bars show the range of responses; the middle, lower and upper lines in the box show the median, and the 25 and 75 percentiles respectively; the dashed line shows the mean; and the stars indicate the fertilization levels used by the highest yielding farms. Source: Leon and Kellon (2012).

Technical Information Sharing

The fact that there was so much variation in fertilization rates and in planting densities indicated that growers were not sharing their experiences. When asked for their opinion about the level of technical information sharing among growers, more than half said that the exchange of technical information among growers was limited or very limited. Only 31% considered that it was fluid or very fluid, but further evaluation showed that the growers that were exchanging technical information were doing it mainly with business partners.

Harvest Efficiency

Small (<50 ha and no packing plant) and medium (50-250 ha and packing plant) size farms reported leaving 10-20% of the fruit in the field due to low quality while fruit rejection at packing was 0-12%. Most of these fruit left in the field had aesthetic problems (e.g. color, shape, deformed crown). The small and medium farms conduct a very meticulous fruit selection in the field to avoid unnecessary transportation costs of low quality fruit that they will not be able to export. Large farms (>250 ha and packing plant) reported harvesting 95-100% of the fruit, but at the packing plant, 20% of these fruit are rejected. Large farms harvest all the fruit because they also have access to processing alternatives such as canning, juice or dehydration. Ultimately, all farms reject about 20% of their fruit that doesn't meet export standards, which mainly represents the average amount of fruit that has aesthetic or size limitations but has no flavor problems. Developing processing options for small and medium size farms would reduce the consistent loss of 20% of their production.

Environmental Impact

Many growers considered soil erosion as the main environmental problem associated with pineapple production, and they acknowledged that they have no effective solution for it, especially in an area with very high rainfall (>2500 mm per year). Most farms (73% respondents) reported using deep-tillage (40-80 cm) and 14% of the farms till even deeper. Their main objective is to ensure proper drainage to avoid soil-borne diseases such as *Phytophtora* spp. and *Fusarium* spp. The average number of tillage passes was 8 with disking the most common practice (4 passes), followed by deep chisel plowing (2 passes) and finally a bed shaper pass. Although most growers reported using soil conservation practices such as contour planting and soil traps, the need for reduced-tillage production practices that maintain plant residues on the ground was evident. Most farms reported maintaining land exclusively for natural resources conservation (20% of the farm area) including forest, wetlands, and areas prone to erosion. However, growers agreed there was need for developing effective technologies that allow soil conservation practices within the pineapple planted area.

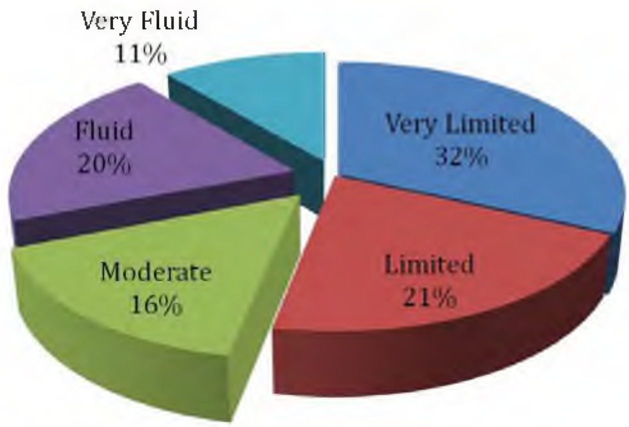

Fig 2. Opinion of interviewed growers about the level of exchange of technical information among pineapple growers.

Community Concerns

The survey of community perceptions about pineapple production showed that unlike portrayal by some media, community members in the study area do not oppose pineapple farms. Instead, most community members would like to see changes in production practices that would help protect environmental and human health without negatively affecting the ability of the farms to operate locally. Importantly, the study shows that respondents maintain a realistic perspective about which changes can be made and also have a good degree of knowledge about agricultural production as well as awareness of potential environmental problems. More importantly, the results showed that respondents were willing and able to compromise in order to make sure that the changes they considered critical are addressed.

One of the most frequent concerns that community members had was about the presumed excessive use of pesticides on pineapple farms. However, although they were presented with the alternative scenario of having small organic farms in their community to replace conventional farms that use synthetic pesticides, most respondents rejected this option, not because they did not appreciate the benefits of organic production on small farms, but precisely because they took into account the tradeoffs inherent to implementing this kind of production scenario (i.e., less employment opportunities and ancillary benefits for community members as farm size decreases). Interestingly, when the preferred scenario was identified, it was evident that respondents were willing to accept a moderate number of synthetic pesticide applications/year in exchange for an increase in soil conservation and/or monitoring/technical assistance to ensure the use of best management practices.

Community respondents were also very concerned about soil conservation. Most were willing to accept other production practices they might have concerns about in order to ensure that adequate soil conservation practices would be required on pineapple farms. Furthermore, during tradeoff analysis, respondents specifically addressed their concerns about pesticide use and soil conservation. Respondents, especially those that had knowledge about pineapple production either because they worked on pineapple farms or they have relatives that did, ranked soil conservation higher than reduced pesticide use. The main justification they provided was that soil erosion is not reversible and jeopardizes land productivity for future generations, while pesticide issues are usually transient, and there are more alternatives to ensure proper pesticide use.

While the majority of respondents stated that they would prefer small or medium-sized farms in or next to their communities as they consider smaller farm sizes to have a lower environmental/human health impacts, after the tradeoff analysis, many respondents considered that it would be better in the long run to have properly-managed (in terms of soil conservation and pesticide application) medium-large farms in the area because of the benefits they bring in relation to employment and other amenities (funding for schools, roads, community activities, etc.) for their families and the local communities.

Based on the results, it seems that farms that are mindful of community concerns, make clear efforts to preserve the soil and reduce pesticide use, and are large enough that they can provide stable jobs and collaborate with public infrastructure would have good support from the community. However, in the absence of technologies that allow for pineapple production with significantly reduced soil erosion, growers might have to deal with negative situations with nearby communities and local authorities.

Future Perspectives

Finally, in 2011 when this survey was conducted, 96% of the interviewed growers considered pineapple production for export an activity of at least moderate risk, half thought it was very risky and 12% thought it was extremely risky (Fig. 3). The higher risk relative to that of 1990s and early 2000s was due to increased production costs, dollar devaluation, lower prices in the international markets, and uncertain environmental regulations. Despite these problems two thirds of the growers viewed their future in pineapple production as acceptable or even positive, while a third were planning on diversifying their cropping systems, and a minority considered stopping growing pineapple.

Currently, the area planted with pineapple has stabilized. Based on personal communications with growers and pineapple specialists in Costa Rica, it seems that growers have gained experience, which has favored more consistent production practices. However, there is still a need for information sharing among growers. It is our opinion that this is one of the most important impediments for the improvement of pineapple production technologies not only in Costa Rica but worldwide, and the absence of a formal mechanism for growers to share technical information will make it more difficult to solve future pineapple production and market challenges in a timely fashion.

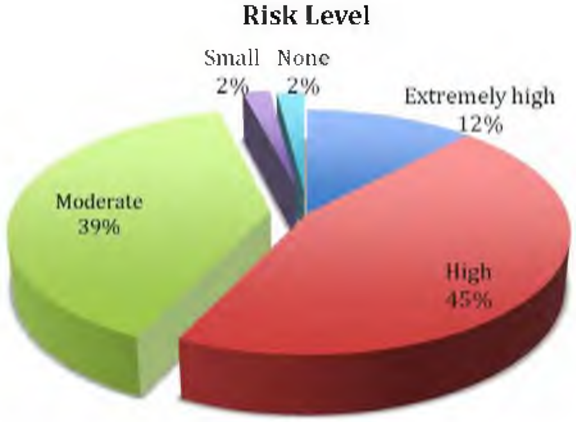

Fig. 3. Opinion of interviewed growers about the level of risk in pineapple production for export relative to that perceived in about 2000.

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RyzUp® 40SG Delays Fruit Maturity and Increases Fruit Weight In Pineapple cv. MD-2 Under Costa Rican Growing Conditions

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INTRODUCTION

Gibberellic Acid 3, sold under the brand name RyzUp® 40SG (RyzUp) is a plant growth regulator used in agriculture in a variety of crops for improving seed germination and increasing fruit weight. Among other uses it will increase size and bunch stretching in grapes, cause induction of grass growth under low temperature conditions, delay maturity and reduce peel physiological disorders in citrus, maintain peel tissue green in lemons, extend postharvest green life in plantain and bananas. Yamane & Ito (1970) and more recently Li et al. (2011) found that GA_3 increased fruit weight 'Smooth Cayenne' and the 'Queen' clone Compte de Paris. This report summarizes the effect of postforce RyzUp sprays on maturity, fruit weight and quality of 'MD-2' fruits under the growing conditions of Costa Rica.

MATERIALS & METHODS

Results presented below are representative of 6 studies conducted in Costa Rica during 2011 and 2012 in two growing regions: North and Atlantic. All the studies were carried out in commercial fields; specifically in Alpiña for study 1 and 2, Fruver and Tres Amigos for studies 3 and 4, respectively and Ojo de Agua for studies 5 and 6. Table 1 provides more information on the total number of treatments in each trial, growing region, experimental blocks, sampled fruits per block to carry out productivity analysis, forcing week, ethephon spray for degreening, harvest date and the best tested RyzUp treatment in each trial. Fruit was degreened using TSS and translucency criteria as commercially carried out by each farm. For simplification during result presentation, only two treatments per trial are shown unless otherwise stated; the untreated control (UTC) and the best RyzUp treatment (Table 1) in each trial.

Fruit Maturity Evaluations

Starting approximately 3 weeks prior to harvest and prior to an ethephon degreening spray, 4 to 12 fruits of the same size (s) per block were surveyed at least at 7 d intervals. Since pineapple fruit maturity varies with fruit size, data were collected for fruit weight, total soluble solids and translucency only on the same number of larger fruits (5's to 8's). A subjective translucency scale was used varying from 0 to 6 in trials 1 to 4, and 1 to 3 for trials 4 and 6. In all cases, 0 represented an immature fruit with white flesh while 4 or 6 corresponded to overripe fruit with near 100 % of the flesh having high translucency. External color was also evaluated using a subjective color chart varying from 0 to 6; with 0 being fruit completely green and 6 completely yellow. Regardless of treatment condition, fruit from all trials were degreened when fruit was in color stage 0.

Fruit and Crown Weight, Crown Length and Fruit Circumference

Fruits from each experimental block (Table 1) were weighed on an electronic balance and crown and fruit measured using a standard tailor measuring tape.

Titratable Acidity and Total Soluble Solids (TSS)

Longitudinal sections were taken from 5-6 fruits per experiment for analysis. For titratable acidity, one compound sample per experimental unit was sent to Agroanálisis de Costa Rica (Grecia, Alajuela). For TSS, each fruit was juiced and TSS evaluated using a refractometer.
A Randomized Complete Block Design was used in all trials. ANOVA, mean confidence interval plot analysis and mean separation using Tukey (p value ≤ 0.05) were calculated using Minitab® 16.

Table 1. Experimental area characteristics for each trial.

Trial		1-N[1]	2-N	3-N	4-N	5-A	6-A
Treatments		6	5	6	6	2	2
Crop		PC[2]	PC	PC	PC	RC	PC
Fruits/block		64	80	65	60	90	80
Forcing Week		38/10	46/10	47/11	28/11	23/12	23/12
Degreen date	UTC		4/25/11	4/21/12	12/2/11	10/31/12	11/2/12
	RyzUp	03/05/11	5/2/11	4/28/12	12/10/11	11/8/12	11/9/12
Harvest date	UTC	03/07/11	4/29/11	4/27,29; 5/1,3/12	12/5-6/11	11/6/12	11/5/12
	RyzUp		5/5-6/11	5/1,3,5/12	12/13/11	11/14/12	11/12/12
Best treatment	RyzUp, g/ha	300[3]	400	600	600	800	800
	Time, WAF[4]	14 & 17	14 & 16	14	14	14	14
	Spray, L/ha	2,400	2,400	2,650	2,300	1,880	1,880

[1]N= northern (San Carlos) regiốn; A=Atlantic regiốn.
[2]PC, plant crop; RC, ratoon crop.
[3]Active ingredient.
[4]WAF = Weeks after force.

RESULTS AND DISCUSSION

Ryzup® Delays Fruit Maturity; TSS and Translucency Development Prior Degreening

Maturity delay as measured by TSS and translucency was found in all trials (Figure 1). Therefore, with the exception of trial 1, RyzUp treated fruit were harvested 7 - 10 d later than untreated fruits. Maturity was delayed by about 3-5 d in trials 4 and 6, suggesting some fine tuning is still required to understand how fruit maturity, and especially translucency development, can be consistently delayed for at least 7 - 10 d. This arbitrary time period was chosen as the minimum threshold in these trials. Further research carried out by our group shows that the maturity delay provided by RyzUp is highly dependant on dose rate, fruit developmental stage at the time of RyzUp spray and spray volume (data not shown). In recent studies, double sprays of 400 g a.i./ha in 2,350 L/ha at 14 and 16 WAF consistently delayed pineapple maturity for at least 7 d under the growing conditions of the Atlantic and Northern Costa Rica. Figure 2 shows characteristic pulp condition in UTC and RyzUp treated fruit at the time the UTC fruit was at appropriate maturity to be sprayed with ethephon for degreening.

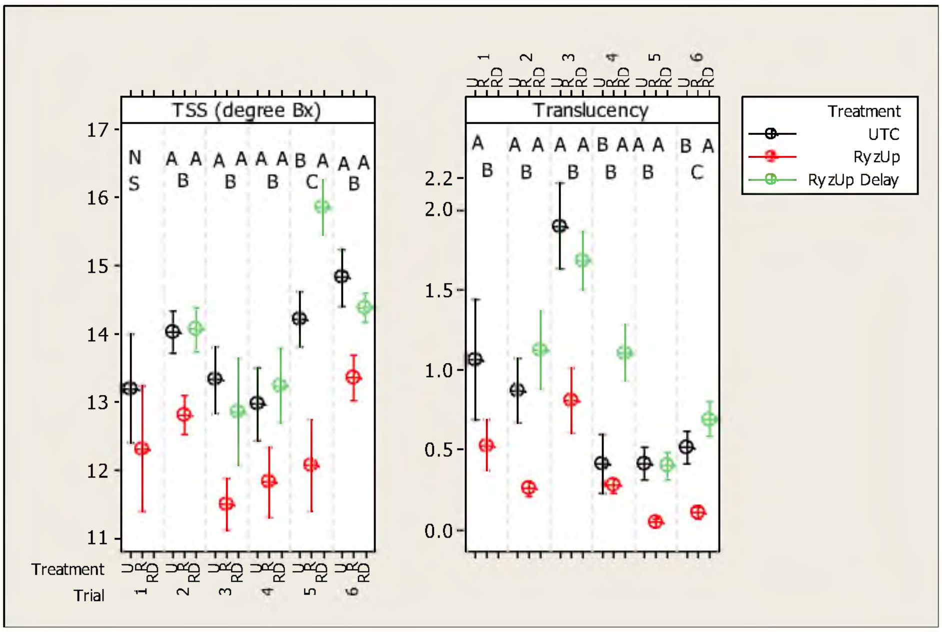

Figure 1. Fruit total soluble solids (TSS) and translucency for the untreated control (U) and RyzUp® (R) treatments, which were evaluated on the same day and prior to ethephon degreening. The delay in maturation due to RyzUp® (RD) was evaluated 7 - 10 d after degreening of U fruit but prior to degreening of R fruit. Vertical lines represent the 95% confidence interval of the mean and different letters (A, B) associated with means within a trial indicate significant differences using Tukey (p value ≤ 0.05).

Maturity Delay In Ryzup® – Treated Fruit Originates Fruit Weight Gains

Fruit weight with or without crown generally was increased by treatment with RyzUp in all six trials (Figure 3). RyzUp treated fruit was sprayed with ethephon between 7-8 d later than UTC with the exception of trial 1. In Trial 1, both treatments were sprayed with ethephon and harvested at the same time. The weights of UTC and RyzUp treated fruits did not differ in trial 1 because they were harvested the same day, and RyzUp treated fruit was significantly less mature than UTC fruits (Figure 6 and 10). The harvest delay due to RyzUp treatment in trial 2 to 6 (Table 1) resulted in significantly increased total fruit and crownless weight (Figure 3); the latter varying from 86 to 339 g/ fruit or approximately 4 to 16 ton / ha. The crownless fruit weight gain in trial 6 was not significant, but ANOVA p value was low (=0.063) which suggest statistically differences might have been detected if the trial would have had higher experimental power; more blocks and/or more fruit sampled per block.

Figure 2. UTC and RyzUp® – treated fruit prior to degreening of the UTC with ethephon. Picture was taken on October 29, 2012, 143 days after forcing.

Maturity Delay In RyzUp® –Treated Fruit Increased Fruit Circumference

Fruit circumference (Figure 4) was significantly increased in all RyzUp treated fruit with the exception of trial 6, which also had a low P value (0.086). RyzUp decreased fruit length in trial 1 and increased it in trial 5. Trial 5 was the only trial in a ratoon crop area. Trial 5 had the highest weight gains among all trials which may suggest that RyzUp effect on Ratoon Crop involves both lateral and longitudinal fruit growth. Fruit length was not significantly affected by RyzUp in trial 2, 3, 4 and 6. Some packing facilities in Costa Rica have started using weight sorters that will facilitate demonstrating box yield gains.

The majority of exporters still pack the fruit using visual sizing from trained packing personnel. These studies also suggest that RyzUp changes fruit size due to its effect on fruit circumference and sometimes fruit length. Careful training and calibration of packing personnel will be required to detect the productivity gains RyzUp provides in commercial pineapple fields.

Ryzup® Increases Crown Length and Relative Crown Length/Fruit Length

RyzUp significantly increased crown length when used at the dose rates and fruit developmental stages tested in these trials (Figure 5). Depending on the growing region, season of the year and market expectations, this effect might be beneficial, especially under situations of reduced crown growth, or be counterproductive. Under the local growing conditions in Costa Rica, RyzUp-treated fruit will often require “gouging”, an agricultural practice carried out three to four weeks prior harvest to remove the shoot apical meristem and therefore, stop crown growth.

Preliminary Evidence Suggest Ryzup® Reduces, But Does Not Eliminate High Translucency Risk

Although more data needs to be generated under diverse seasons of the year and growing conditions, preliminary results (5 of 6 trials) indicate RyzUp treatment slows translucency development relative to the UTC (Figure 6). For trial 5 and 6, translucency developed more uniformly and with less high translucency symptoms at higher TSS at harvest in RyzUp treated fruit than in the UTC, (Figures 8, 9). This suggests that RyzUp treated fruit can be maintained longer in the field with lower risk of being lost due to high translucency. Under situations of extreme fruit translucency, our group has found later fruit is firmer at harvest which translates into better postharvest life (data not shown).

TSS, Titratable Acidity (TA), TSS/TA and Fruit External Color Results Are Likely To Be A Direct Effect Of The Fruit Physiological Stage At Harvest

The effect of RyzUp on TSS and external color at harvest varies with all the possible scenarios encountered; RyzUp treated fruit having less, equal and more TSS (Figure 6) or external color (Figure 10) than the UTC. The variables TA and TSS/TA (Figure 7), however, were similar in four trials while TA was higher and TSS/TA was lower in two trials. We suggest based on the multiple scenarios found on these six trials that physiological stage of the fruit at the time of harvest was perhaps the most important factor affecting the results described on internal quality and external shell color.

CONCLUSION & RECOMMENDATIONS

RyzUp delayed maturity in pineapple fruit when sprayed at 14 and 16 weeks after force under the Atlantic & Northern growing conditions in Costa Rica. The maturity delay was up to 7-10 d, but it was dependent on dose rate, spray volume, fruit developmental stage and amount of total sprays. RyzUp at 400 g a.i. sprayed twice at 14 and 16 weeks after force using 2,400 L/ha is recommended to maintain consistent results. The extra growing days resulting from the maturity delay resulted in an increase in crownless fruit weight ranging from 86 to 339 g. This is approximately 4 to 16 ton / ha mostly manifested as an increase in fruit circumference rather than longitudinal growth. Ratoon Crop fruit, where the highest effect on fruit weight was obtained, experienced longitudinal fruit enlargement in addition to lateral growth. RyzUp treated fruit also had longer crowns, which might or might not be a desirable effect depending on growing region and market expectations. Fruit TA and TSS tended to differ among the trials, likely due to physiological differences in fruit at the time of harvest rather than a consistent trend shown by any particular treatment. Nevertheless, the internal condition of RyzUp treated fruit was more uniform, with lower risk of developing high translucency than was the case for untreated controls.

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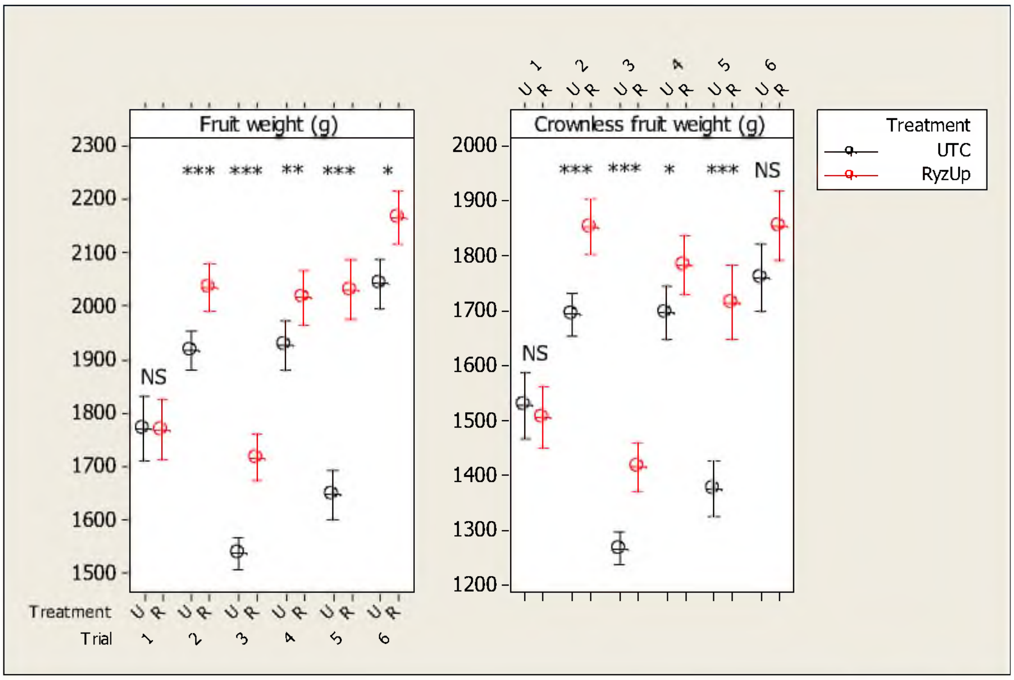

Figure 3. Fruit with crown & crownless fruit weight in each trial. NS= not significant, * ANOVA p Value ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001. Vertical lines represent the 95% confidence interval of the mean.

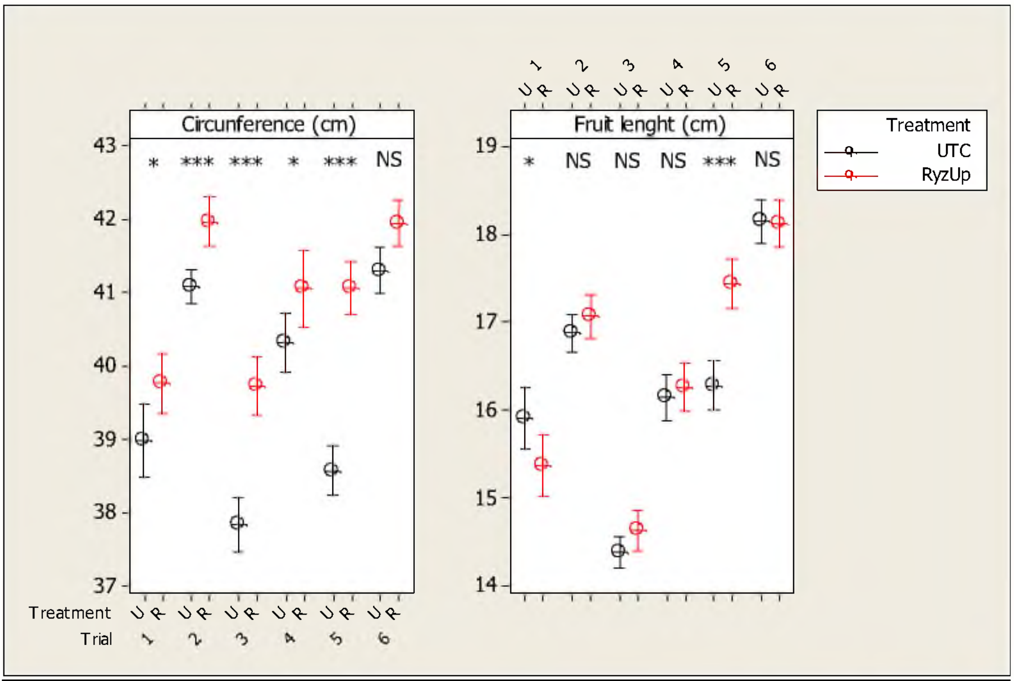

Figure 4. Fruit circumference and length in each trial. NS= not significant, * ANOVA p Value ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001. Vertical lines represent the 95% confidence interval of the mean.

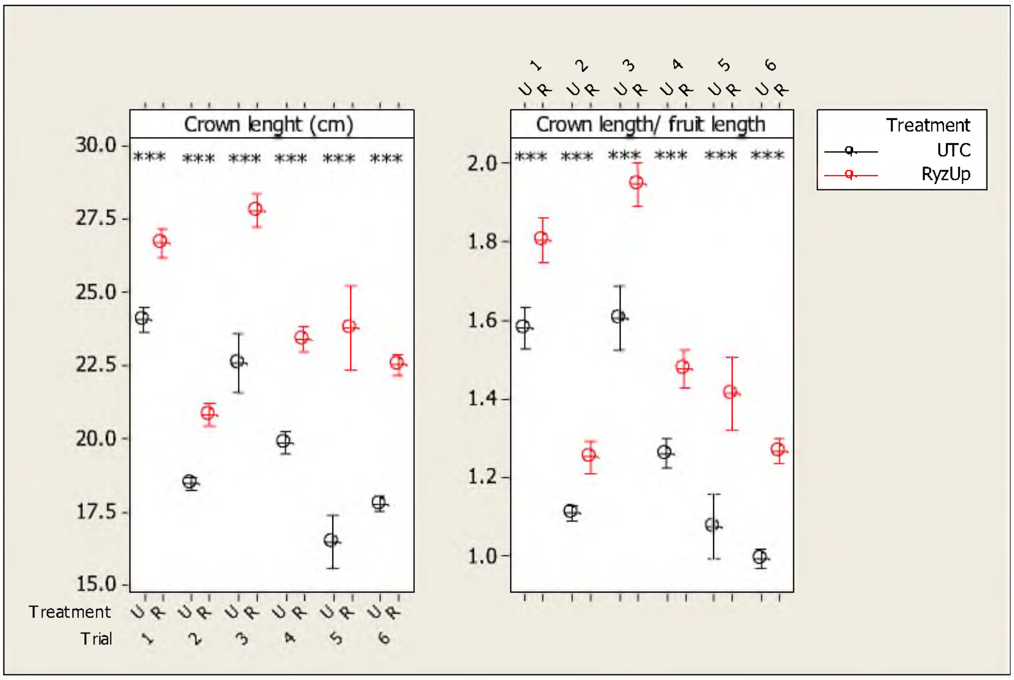

Figure 5. Crown length and relationship crown length/fruit length in each trial. NS= not significant, * ANOVA p Value ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001. Vertical lines represent the 95% confidence interval of the mean.

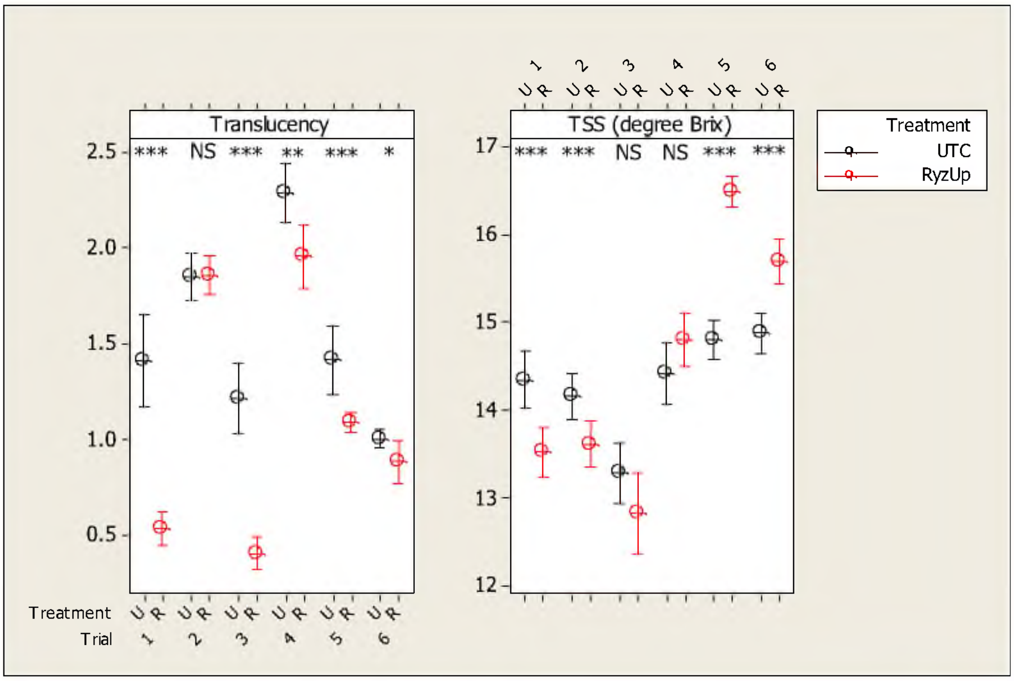

Figure 6. Translucency means and total soluble solids (TSS) in each trial. NS= not significant, * ANOVA p Value ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001. Vertical lines represent the 95% confidence interval of the mean.

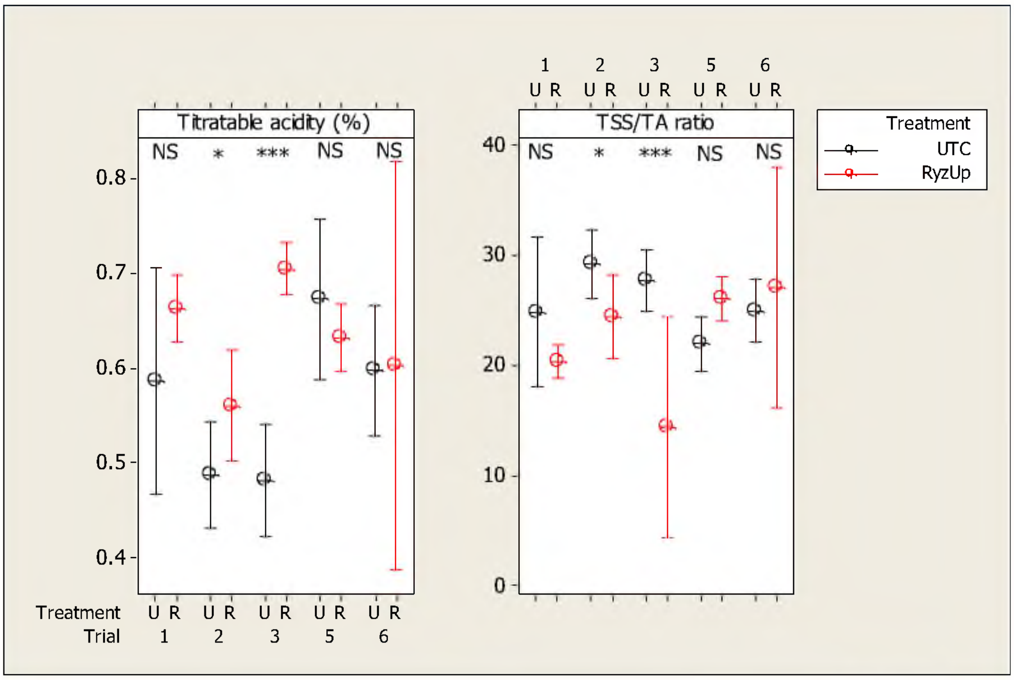

Figure 7. Titratable acidity (TA) and TSS/TA ratio in each trial. NS= not significant, * ANOVA p Value ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001. Vertical lines represent the 95% confidence interval of the mean.

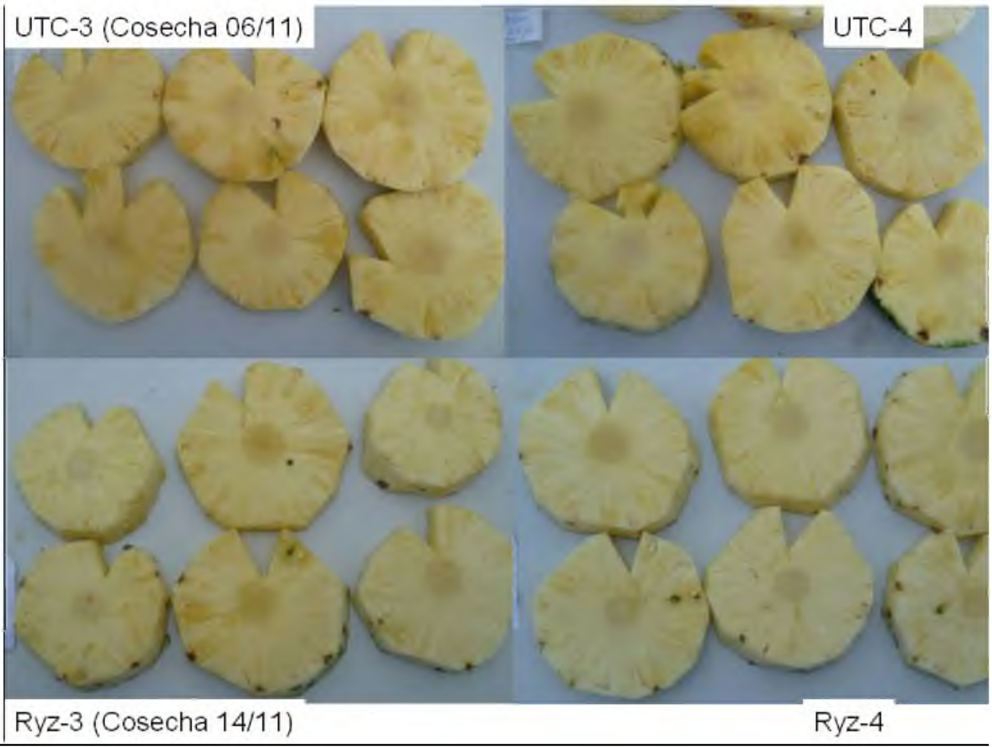

Figure 8. Internal pulp condition at harvest in UTC and RyzUp treated fruit in trial 6 (Ratoon Crop). Parenthesis indicates harvest date on each treatment.

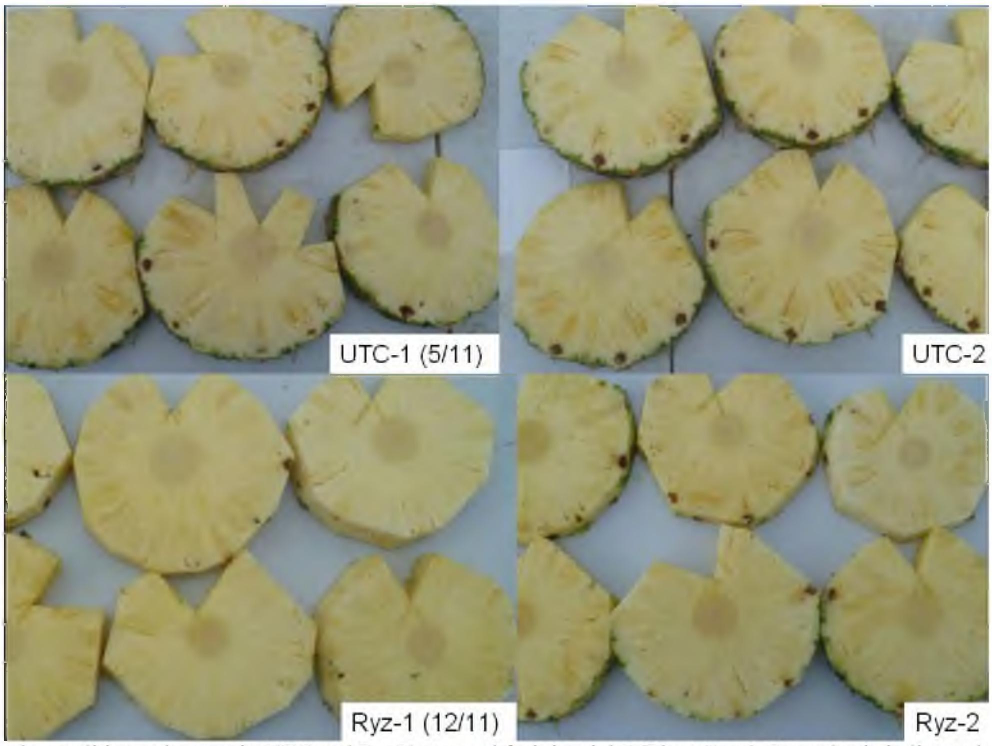

Figure 9. Internal pulp condition at harvest in UTC and RyzUp treated fruit in trial 6 (Plant Crop). Parenthesis indicates harvest date on each treatment.

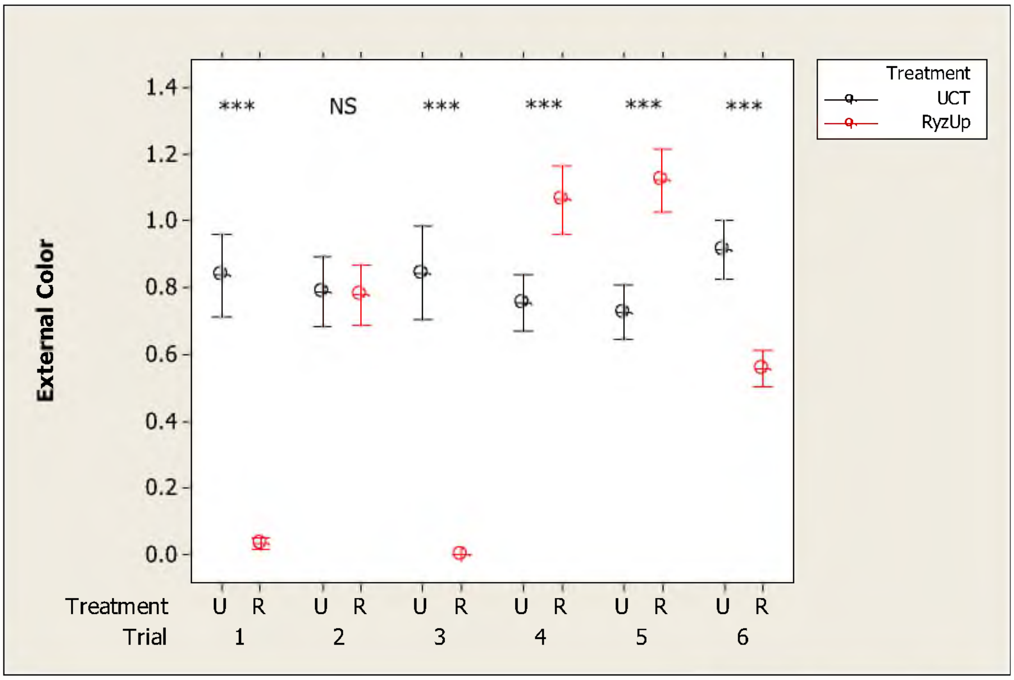

Figure 10. External color at harvest in each trial. NS= not significant, * ANOVA p Value ≤ 0.05, ** ≤ 0.01, *** ≤ 0.001. Vertical lines represent the 95% confidence interval of the mean.

Bacthon® Accelerates Postharvest Decomposition of Pineapple Residue and Decreases Populations of *Stomoxys calcitrans* in Costa Rica

Dennis Alpízar M., Mario Fallas G., Federico Aguilar B ATV Robert Arrieta C. Roger Fallas G.

Resumen

El incremento del área piñera en Costa Rica, ha llevado a un aumento también de las poblaciones de S.*calcitrans*, la cual se reproduce en los residuos postcosecha de este cultivo, generando problemas en la actividad ganadera, ya que la misma en su estado adulto se alimenta de la sangre, provocando pérdida de peso y en casos muy extremos, hasta la muerte de los vacunos. Aunque se han realizado intentos de control del problema, ya sea con el empleo de productos químicos, kairomonas, uso de pantallas con pegamento y otras alternativas, las mismas no han resuelto de una manera exitosa el problema. Dentro de los intentos realizados, el uso de microoganismos y concretamente bacterias, se probó el producto Bacthon® y los resultados en cuanto a la disminución de las poblaciones tanto de adultos, pupas y larvas son presentadas a continuación; mostrando datos muy positivos en cuanto a las disminuciones de las poblaciones de esta mosca. El Bacthon ® es utlilizado entre 2 y 3 L/ha, antes o posterior a la trituración de los residuos postcosecha de la piña.

Abstract

The increase in area planted to pineapples in Costa Rica has led to increased populations of the stable fly *S.calcitrans*, which reproduce in the post-harvest residues of pineapple, creating problems for livestock because the adults feed on the blood, resulting in weight loss and, in extreme cases, to death of cattle. Although there have been attempts to control the problem, either with the use of chemicals, kairomones, sticky traps and other alternatives, they have not successfully resolved the problem. Among the attempts, the use of microorganisms, and particularly bacteria to speed decomposition of pineapple resideu with Bacthon® has reduced populations of both adults, pupae and larvae. From 2 to 3 L ha^{-1} of Bacthon® is used before or after the crushing of pineapple residue.

INTRODUCTION

The stable fly, *Stomoxys calcitrans*, has increasingly become a serious problema nationally in the pineapple growing areas. The fly produces injury to cattle on farms near the plantations, since the adults require the blood of mammals for subsistence.

Tests with a kairomone attached to white plastic screens (Alpizar et al., unpublished) increased the attraction of *S. calcitrans* toward the screens. In these same tests, a biodegradable polymer applied to inhibit breathing of larvae of this fly greatly reduces the population of *S. calcitrans* under conditions of low precipitation but the same results were not obtained in the presence of high precipitation. On the other hand, tests with plastic bands of colors, (Cilek, 2003) showed that blue captured a higher number of adults of this fly, but the results did not differ statistically from white and orange.

At present, an alternative for the control of this pest is management of the crop residue, either by collecting them for the production of fertilizers or treating them with organic products to accelerate decomposition and not allow completion of the fly development cycle greatly reducing populations.
If one considers this waste biomass postharvest major fungal genera are constituted by (*Penicillium*, *Cladosporium*, *Aspergillus* and *Cephalosporium*). Bacterial groups belonging to the Gram-positive, of the genera *Bacillus*, *Micrococus*, some coryneform as the *Arthrobacter* and *Nocardia*. Other anaerobic strata as *Clostridium* and from gram-negative as a colonizing *Pseudomonas* number of microenvironments. (Grant et al).

Objective: To test the effectiveness of various microorganisms on the decomposition of pineapple residues after harvest.

MATERIALS AND METHODS

The test was conducted on the farm owned by Ticoverde Agroindustrial, SA, located in the very humid Atlantic Region of Costa Rica where two areas of 2500 m^2 were treated. In one area, the residue was treated with the equivalent of 1.0 L ha^{-1} of Bacthon SC before shredding followed by 2.0 L ha^{-1} after shredding. Plants in the control plot were shredded and incorporated without Bacthon SC.

After treatment with Bacthon on August 31, 2006, counts of adults were made using 20 horizontal traps impregnated with Zapicol® on September 18, 22 ,24, 27 and October 03. Both treatments were enclosed by plastic screens to ensure that the adults only came from the treated area. Also larvae counts were made on August 31, and on September 06 and 13.

RESULTS AND DISCUSSION

The mean number of *S.calcitrans* pupae in pineapple residues were significantly reduced as a result of treatment of the residues with Bacthon® (Figure 1). These data show the ability of this product in regard to the acceleration of the decomposition of the waste of the pineapple and the development of the pupal stage of *S. calcitrans*.

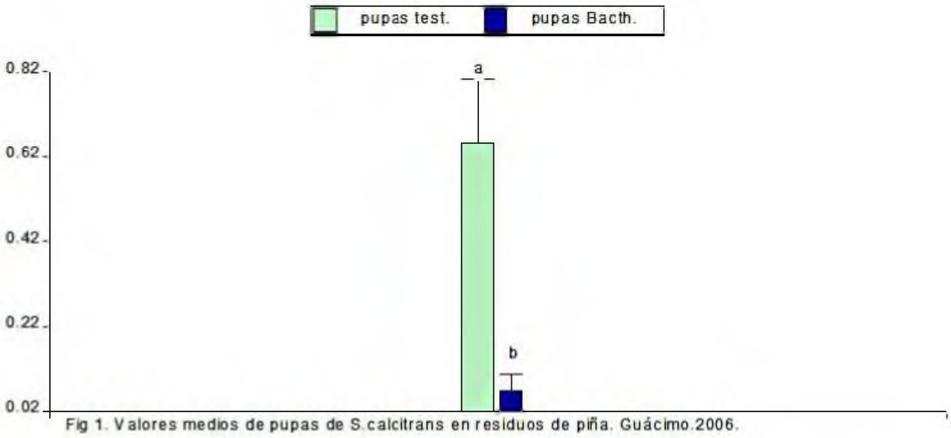

Fig 1. Valores medios de pupas de S.calcitrans en residuos de piña. Guácimo.2006.
Letras diferentes en barras indican significancia estadística según prueba t 0.01

Bacthon® treatment of the pineapple residue significantly reduced numbers of larvae relative to that of the control (Figure 2) and similar results were found for numbers of adults (Figure 3). In time studies, the number of pupae (Figure 4) and larvae (Figure 5) were much less where the residue was treated with Bacthon® than was the case for the untreated plots. Also, the greatest number of adults was captured in the untreated control plot (Figure 6).

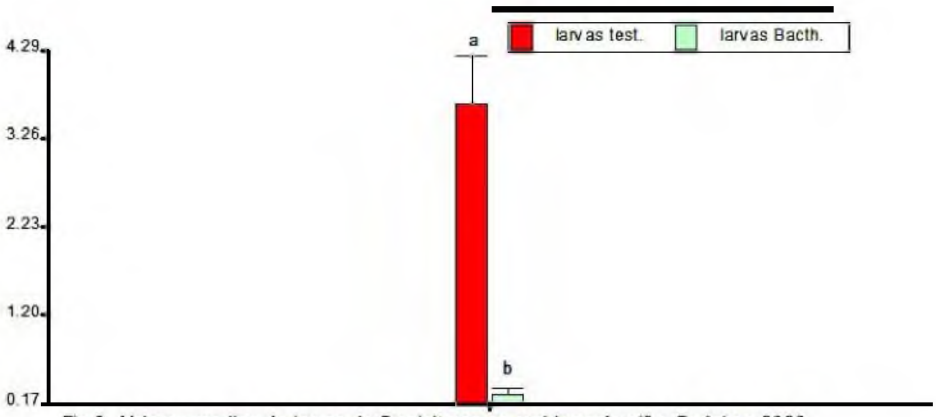

Fig.2 Valores medios de larvas de S.calcitrans en residuos de piña. Guácimo.2006.
Letras diferentes en barrras indican significancia estadística, según prueba t 0.01.

CONCLUSIONS

1-The control of *S. calcitrans* is associated almost in its entirety with the management of organic waste.
2-Implementation of several measures of control is the key to the solution of the problem.
3- Applying 2L h^{-1} of Bacthon® once or twice before and after shredding the residue accelerates its decomposition and proved to be efficient in the management of stable flies.

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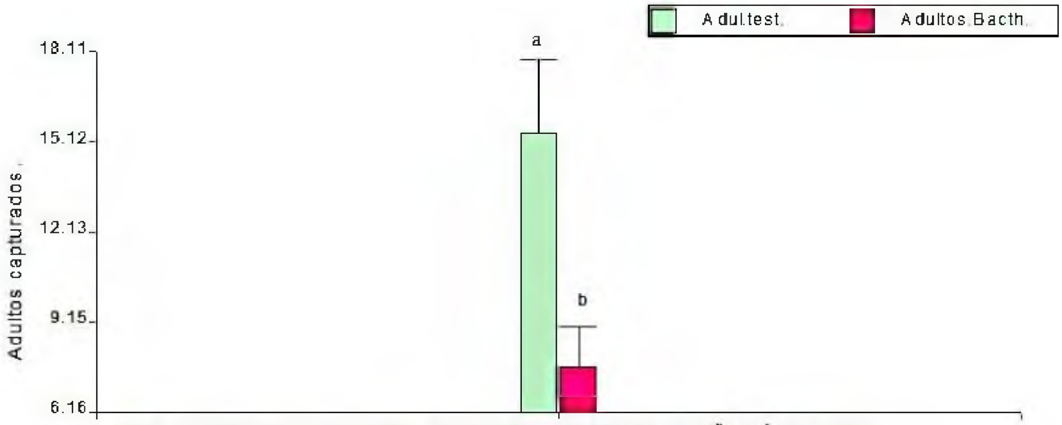

Fig 3 . Valores medios de adultos de S calcitrans en residuos de piña. Gúacimo.2006
Letras diferentes en barras indican diferencias estadístcas según prueba T.005

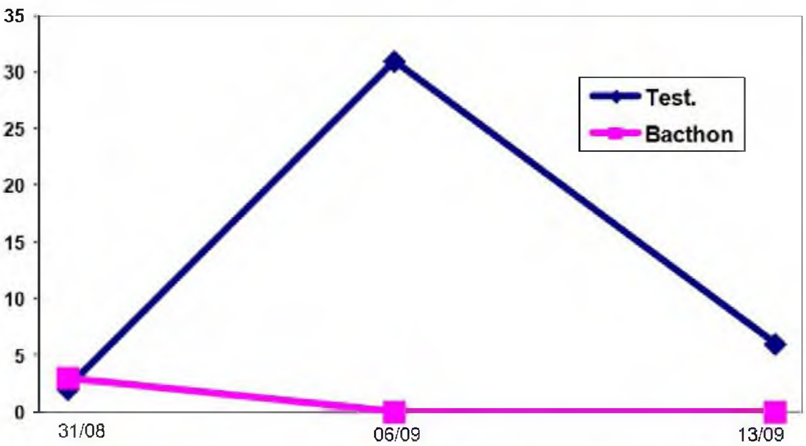

Fig.4 Efecto de los tratamientos sobre el n° de pupas de S.calcitrans.Guácimo

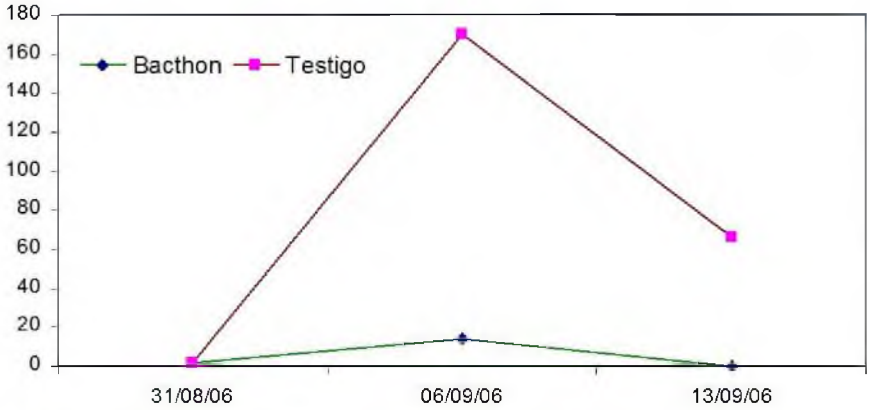

Fig.5. Efecto de los tratamientos sobre el n° de larvas de S.calcitrans en residuos de piña.Guácimo .2006.

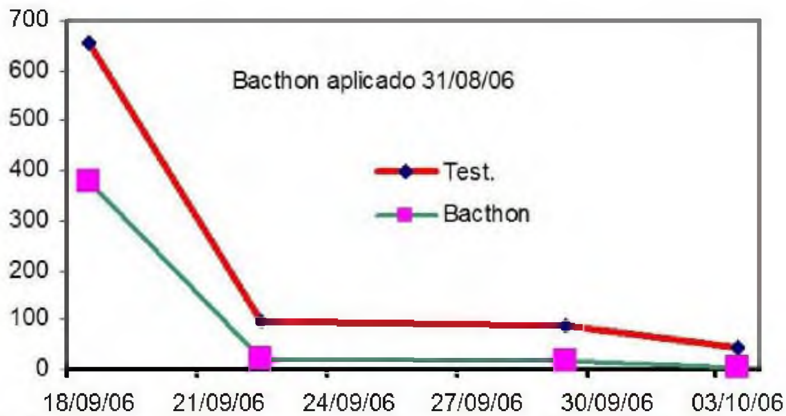

Fig.6 Adultos de S.calcitrans capturados con trampas horizontales en residuos de piña. Guácimo. 2006.

Abstracts, VII Congreso Nacional de Suelos

November 6 to 8, 2012. San Jose, Costa Rica

The language of the Congress was Spanish and most of the abstracts below are in that language. Readers interested in the content who have no knowledge of Spanish can use various electronic translation options. A translation capability is built into MS Word 2007 and, presumably, later versions of the software. The abstracts also can be pasted into translation services that are available on the internet. I have found the variety of translations, three are provided, at http://www.spanishdict.com/translation to be particularly good. Google provides translation of many languages at http://translate.google.com/.

Manejo adecuado de los rastrojos en piña

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Congreso Nacional de Suelos • Suelos y Piña 65 Q

La expansión pinera no solamente ha sido vinculada con el desarrollo del pais, sino ha sido asociada a un fuerte impacto en el medio ambiente producto de diferentes actividades ejecutadas durante el proceso de producción y cosecha de la fruta, las cuales tienen implicación sobre las áreas de cultivo y las comunidades aledañas. El problema más importante que afrontan en la actualidad los productores de piña es el manejo de sus desechos posterior a su segunda cosecha, donde el material vegetal es extraído del suelo y dejado en el campo. Ha surgido la necesidad buscar nuevas alternativas para el manejo de desechos del cultivo de piña, debido al impacto ambiental que producen las prácticas utilizadas en la actualidad. Se ha conocido que la trituración de los residuos de piña, acompañada de la aplicación de microorganismos descomponedores y su posterior incorporación al suelo ha permitido incrementar su tasa de mineralización con el evitar la generación de problemas ambientales (proliferación de moscas). También se debe considerar que la incorporación adecuada de este material al suelo constituiría una fuente de nutrimentos importante que estaría disponible para el próximo ciclo de siembra, lo cual incurriría en un ahorro en fertilizantes. Además, la adición de los residuos orgánicos al suelo no solamente mejora sus propiedades físicas, sino que también favorece al desarrollo de poblaciones de micro, meso y macroorganismos, que interactúan con el sistema radical del cultivo. Actualmente se realizan trabajos en diferentes fincas dedicadas al cultivo de la piña, con el propósito de incorporar los residuos al suelo, evitando así la proliferación de moscas y favoreciendo la disponibilidad de elementos nutritivos producto de la descomposición de los residuos. Los siguientes son los temas de investigación que realiza la Universidad de Costa Rica: Efecto del uso de diferentes grupos de microorganismos descomponedores sobre la tasa de mineralización de residuos orgánicos de piña; estudios de la disponibilidad de nutrientes en el suelo producto de la mineralización de los desechos orgánicos de piña por la acción de los microorganismos y los biofertilizantes; uso de microorganismos benéficos para el combate de plagas y enfermedades en piña, y uso de parasitoides para el combate de la mosca de establo en plantaciones de piña.

Efecto de tres fuentes de P de diferente solubilidad, sobre el crecimiento y rendimiento de la piña
Francisco Arguedas INTA-MAG
El cultivo comercial de piña (Ananas comosus (L)) en Costa Rica, es una actividad que inició en los años 60 en Buenos Aires de Puntarenas y a partir del año 2000, tomó gran auge en las zonas Norte y Atlántica de nuestro país. Según el XIII Informe del Estado de la Nación del 2007, la actividad piñera continúa con un itmo acelerado de expansión, principalmente en todos los cantones de la región Norte; creciendo un 208% entre los años 2000 al 2006. Se destaca Pital como el distrito de esa región, donde más se ha extendido la siembra de piña, según se desprende del censo. La fertilización de la piña es una de las práctica más importantes en las operaciones del cultivo, puesto que la misma tiene requerimientos nutricionales muy específicos y que la carencia ó exceso de alguno(s) de los elemento(s), puede afectar la apariencia, vitalidad y calidad de la planta y de la fruta (INPOFOS, 1997). El aumento observado en el área sembrada de piña, disparó la demanda de fertilizantes para suelo y follaje de las plantas, principalmente en la región Norte, lo cual es confirmado por los dueños de almacenes de ínsumos agrícolas. De acuerdo con las curvas de absorción de nutrientes, los elementos que más extrae la piña son el K y el N, por lo que se utilizan mucho en los programas de fertilización, usualmente a través de la fertilización foliar. La aplicación del elemento Fósforo, principalmente como fertilizante granular al suelo, es muy común sobre todo durante las tres primeras semanas después de la siembra, con fórmulas de abono altas en éste elemento. El Fósforo, que suple del 0,1% al 0,4% del extracto seco de la planta, juega un papel importante en la transferencia de energía (ATP, NAD y NADP), es esencial para la fotosíntesis y otros procesos químico-fisiológicos como la glucólisis, respiración y síntesis de ácidos grasos (XXXXX.2000). El P es indispensable para la diferenciación de las células y el desarrollo de los tejidos, que forman los puntos de crecimiento de la planta (FAO-IFA.2002, otros). El Fósforo es un macronutrimento de gran importancia en la nutrición de las plantas, fomenta el desarrollo de raíces, aumenta el número de retoños, apresura la maduración de los frutos, promueve la formación de semillas en los frutos y reduce el acame. La aplicación del fertilizante fosforado al suelo, representa un alto porcentaje del costo de la fertilización en piña, además, no hay información específica sobre el aprovechamiento de las diferentes fuentes de P, para los suelos Ultisoles presentes en las áreas pineras de la Zona Norte. Principalmente en lo que respecta a factores como eficacia, dosificación y manera de aplicación; para un mayor aprovechamiento por parte del cultivo. El objetivo del trabajo fue evaluar el efecto de tres fuentes de Fósforo con diferentes solubilidades, sobre las variables de crecimiento y rendimiento para el cultivo de piña, variedad MD-2.

Managing nitrogen nutrition of pineapple - a review of science and practice
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Crop logging practices for pineapple developed by scientists at the Pineapple Research Institute of Hawaii demonstrated that a visual leaf color index was the most effective method of assessing plant nitrogen status. Yellow-green leaves, equivalent to leaf No. 1 color, may have subjected plants to mild nitrogen stress during vegetative growth but In unirrigated fields did not significantly restrict vegetative growth. Many studies showed that if the leaf canopy was reduced to 15% No. 1 color at forced induction of flowering, there was no fruit yield benefit to fertilization after forcing. Culture systems for fresh fruit produced by the 'MD-2' cultivar are more intensive than those used for 'Smooth Cayenne' grown to produce fruit for processing. Given the high sensitivity of 'MD-2' to natural induction of flowering (NI), it is possible that a higher leaf nitrogen status would be required to suppress NI during periods of the year when it is most likely to occur. The question, which likely cannot be answered at this time, is how to best manage nitrogen on pineapple crops to make the most efficient use of nitrogen while preventing NI. Evidence from Hawaii suggests that nitrogen not utilized by the pineapple crop can move well below the root zone and have the potential to contaminate ground water resources. The intent of the presentation is

the raise awareness of the possible risk of over fertilizing with nitrogen and to encourage careful investigation of the relationship between nitrogen application and NI.

Ecophysiology of pineapple

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Pineapple leaf photosynthetic rates are determined primarily by average temperature and the highest rates occur at temperatures between about 20 and 25 °C. Irradiance likely influences leaf photosynthetic rates, but few data are available because effects can't be easily measured on leaves that assimilate carbon via the crassulacean acid metablolism pathway. Across the range of environments where clonally propagated cultivare of pineapple are grown, limited data and casual observations suggest that leaf photosynthetic rates determine such parameters as type and availability of planting material, plant population density, rate of vegetative growth, sensitivity to forced and natural induction of reproductive development, rate of fruit development, initiation of shoots used to produce planting material or a ratoon crop, fruit weight to plant weight ratio, fruit quality and the ability to produce a profitable ratoon crop. Collecting confirming data Is a major challenge that likely will require a joint public-private effort. The principle value of such data would be an increased understanding of basic processes and the education of young scientists.

Técnicas agroambientales para el MANEJO DEL CULTIVO DE PIÑA

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En la explotación de los terrenos para la producción agropecuaria, históricamente se han establecido procesos de degradación de las tierras en niveles y dimensiones preocupantes. En este sentido, la determinación de las cualidades de las tierras y las posibilidades de modificar sus limitantes, con miras a obtener mayores rendimientos agrícolas, al mismo tiempo tratando de minimizar el deterioro ambiental principalmente en lo referido a los recursos suelo y aguas, es una tarea que por mucho tiempo a preocupado y en los últimos años con mucho mayor fuerza tanto a las instituciones gubernamentales, agencias internacionales de cooperación y financiamiento, así como al sector productivo agrícola y ambiental de nuestro país. La convergencia de los intereses de producción agrícola con la preservación ambiental del entorno se basa en algunos principios técnicos generales que gobiernan la selección de tecnologías de cambio en los sistemas de producción, las cuales también deben orientar la generación de tecnologías agropecuarias como: Aumento de la productividad, Aumento de la cobertura vegetal de los suelos Aumento de la infiltración del agua en el perfil del suelo Control del agua de escorrentía, Manejo adecuado de la fertilidad, Reducción de la contaminación. El interés del productor agrícola de conservar por conservar en este caso el recurso suelo, es bajo, primero porque algunas de las prácticas conservacionistas le significan una gran erogación principalmente de mano de obra, en segundo porque el retorno económico de las mismas es a largo plazo, tercero, porque no existe una aplicabilidad debida de la normativa para castigar en muchos casos las prácticas inadecuadas existentes. Sin embargo, en el caso de la piña, la importancia es mayor, sobre todo porque en términos comerciales es un producto estrella, creciente y que se ha posícionado como un sector fuerte en términos económicos por sus ventas en el exterior, lo cual genera altos ingresos a la economía nacional y mucho más importante aún, un impacto social altísimo, sobre todo por la cantidad de empleos que genera principalmente en zonas rurales con altas tasas de pobreza y poca calificación del recurso humano, de ahi la importancia de lograr armonizar la producción de piña en términos ambientales y sociales.

Estimación de la erosión en una plantación de piña en la zona norte de Costa Rica

Mauricio Fernández Calvo, Amoldo Gadea- Rivas, Jimmy Boniche y Parménides Furcal Berigüete
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Con el propósito de generar información para el establecimiento de una estrategia de manejo del problema erosivo en los sistemas de producción de piña y como parte de un Programa de Manejo y Conservación de Suelos Chiquita, se desarrolló una serie de experimentos que permitieran estimar la pérdida de suelo en una plantación de piña, asi como evaluar el efecto de la topografía, la edad del cultivo, la precipitación y algunas prácticas de manejo de suelos sobre ese proceso y sobre el impacto económico estimado a través de la pérdida de nutrimentos. Se estableció sendos ensayos en dos fincas de la zona norte de Costa Rica, en Buenos Aires de Venecia y Sahlno de Pital. Analizando el efecto de la topografía del terreno, al aumentar la pendiente aumentó la tasa de erosión. En cuanto al efecto de la lluvia, la intensidad de los eventos lluviosos es determinante, y no sólo la cantidad de lluvia. Se observó una disminución de la tasa de erosión a través del tiempo conforme la plantación va creciendo, siendo la fase entre encamado y siembra la más crítica en cuanto a pérdida de suelo. Los resultados permiten concluir que la implementación de medidas que favorezcan la infiltración y mitiguen la escorrentia, pueden ayudar a reducir el efecto de los agentes erosivos, principalmente en los caminos y drenajes de la plantación, durante la fase preparación, establecimiento y los primeros seis meses de desarrollo del cultivo.

Estimación de la erosión de suelos en plantaciones de piña MD-2 bajo diferentes prácticas de manejo, en la Región Pacífico Sur de Costa Rica

Antonio López[1].Gerardo Matarritá[2] y Eugenia Hidalgo?

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En la Región del Pacifico Sur, la erosión natural está regulada principalmente por la pendiente, el viento y la precipitación. En la producción del cultivo de la piña, las etapas de preparación de suelo, encamado y los primeros 4 meses después de la siembra son las que presentan las mayores tasas de erosión. La cobertura vegetal durante la etapa de barbecho es capaz de reducir la tasa de erosión de los suelos en hasta un 64%, mientras que el impacto de pasar de una categoría de pendiente de ligeramente ondulado (3 a 8%) a moderadamente ondulado (8 a 15%) fue de un 21%. En plantaciones establecidas, tasas de erosión promedio de 45.9 Ton/ha/año fueron obtenidas para plantaciones de 0 a 5 meses de edad y de 7.1 Ton/ha/año para plantaciones de más de 5 meses de edad. La efectividad de la medida de control de erosión comercial quedó comprobada al permitir una reducción de pérdida de suelo del 40%. Para plantaciones de 0 a 5 meses de edad y en áreas moderadamente onduladas (8 a 12%) se debe evaluar intensificar el número de barreras por canal para llegar a reducir las tasas de erosión al límite de tolerancia máximo de 12 Ton/ ha/año reconocido por el Servicio de Conservación de Suelos del USDA para suelos profundos. El uso de *Richardia scabra como cobertura vegetal en áreas de barbecho, presenta un alto potencial para proteger los suelos de la erosión.*

Efecto de la nutrición Post Forzamiento sobre los rendimientos, calidad y empaque de la Piña Dorada
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Toda la bibliografía sobre nutrición en piña reporta aplicaciones hasta el forzamiento. Frutas de origen natural han mostrado desarrollos adecuados a pesar de su origen desde plantas de bajo peso, Los efectos negativos de la Floración Natural, especialmente en plantaciones de bajo peso, podría compensarse mediante la comprobación de una nutrición post forzamiento, Este trabajo fue realizado en la zona de Katira, Guatuso, Costa Rica. Se usó un diseño de Bloques Completos al azar, Cuatro repeticiones por tratamiento siendo tres tratamientos y un testigo comercial, con una parcela experimental de 500 plantas y una parcela útil de 56 plantas, con aplicaciones realizadas de forma comercial, con los equipos de uso normales a los 15, 30,45, 60, 90,105 y 120 días después del forzamiento. El ensayo mostró que las plantas de piña continúan su absorción de nutrientes después del forzamiento, los tratamientos arrojaron diferencias significativas que justifican claramente la necesidad de fertilizar después del forzamiento; los mejores rendimientos fueron obtenidos con el tratamiento 2, sin embargo, el tratamiento 3, aunque no presento una diferencia estadística importante, mostro un ingreso neto adicional de casi $3000 /ha. Los calibres 4 y 11 no han sido sujeto del análisis económico debido a que no son apetecidos por los mercados mas importantes y su producción debe ser menos frecuente, es recomendable, en función de las distribuciones de tamaños (calibres) prevalecientes en los mercados, continuar con investigaciones sobre densidades y pesos de forzamiento a fin de concentrar los rendimientos sobre los calibres de fruta mejor pagadas. Las condiciones de calidad de la fruta fueron iguales en todos los tratamientos. Se debe repetir este ensayo en la época lluviosa para evaluar el efecto de los fertilizantes sobre el desarrollo de la corona especialmente. Aunque no fue medido, observaciones posteriores a la etapa de primera cosecha mostraron una correlación directa entre los tratamientos y la producción de semilla en la etapa de semilleros. Se recomienda evaluar este mismo ensayo en segundas cosechas de fruta.

Evaluación de cuatro enmiendas en la corrección de la acidez del suelo en el cultivo de la piña, en la zona de Valle Hermoso, Santo Domingo de Los Tsáchilas, EcuadorFrancisco Mite Vivar[1] y Lorena Medina[2] 1lnstituto Nacional de Investigaciones Agropecuarias, INIAP, francisco.mite@iniap.gob.ec 2 Universidad Técnica Equinoccial de Santo Domingo de Los Tsáchilas. Congreso Nacional de Suelos • Suelos y Piña 69 Q
Para probar el efecto de varias enmiendas en el cultivo de piña se diseñó un experimento cuyos objetivos fueron: determinar la mejor enmienda y la dosis de aplicación, para controlar la acidez del suelos volcánicos cultivados con piña, evaluar el efecto de las enmiendas en el crecimiento radical y el rendimiento de la piña, e identificar los cambios químicos del suelo al utilizar diversas enmiendas. La investigación se desarrolló en dos fases: una fase de laboratorio e invernadero y la otra de campo. La primera se condujo en la Estación Experimental Tropical "Pichilingue" del INIAP, ubicada el Quevedo, Los Ríos, Ecuador. Esta consistió en una prueba de incubación para evaluar el efecto de la incorporación de calcita (CaC03), magnesita (MgC03), dolomita (CaC03 MgC03), y yeso (CaS04). Al terminar el periodo de incubación se procedió a secar los suelos y analizarlos químicamente. En este mismo suelo se sembró arroz, para tener un referente como planta indicadora. La segunda fase se la realizó en un experimento de campo en la Hacienda "San Francisco", ubicada en la zona de Valle Hermoso, Santo Domingo de los Tsáchilas. Las condiciones climáticas del lugar fueron: temperatura media 24,4°C, precipitación anual 3530mm, humedad relativa 88,1%, evaporación anual 975,9 mm, heliofanía 779,0 horas luz/año. El suelo del sitio fue un Andisol clásico. En esta fase se utilizaron los mismos tratamientos del experimento de incubación, Como material de siembra se usó el híbrido MD2. La calcita, magnesita y dolomita tuvieron un efecto marcado en el pH de suelo. Estos cambios se dieron en el siguiente orden: magnesita > calcita > dolomita. Para alcanzar un valor de pH 5,5, suficiente para precipitar el Al de carga variable, se necesitaron 2,9 4,4 y 5,9 t ha-1 de magnesita, calcita y dolomita, respectivamente. El sulfato de calcio no originó cambios. Uno de los principales cambios químicos que se observó fue el incremento de carga negativa en la superficie de los coloides, medido por A pH = pHkcl _ pHH20. Se observó que la CIC determinada con acetato de amonio

sobrestimó la carga en la superficie de los coloides y por esta razón se pierde la sensibilidad para evaluar la generación de carga de los carbonatas, a diferencia del análisis con cloruro de bario, que permite obtener valores más reales. Se encontró un efecto positivo en el crecimiento radical con todas las enmiendas, en las dosis 1,5 y 3,0 t ha- 1, relacionado directamente con la precipitación del Al. Aplicando 1,5 t ha-1 se logró conseguir los rendimientos más altos (magnesita 122 t ha-1). También, se observó que el rendimiento se redujo cuando se sobreencaló, debido a la presencia de *Phytopthora sp* en el cultivo, incidencia que cada vez fue mayor a medida que se incrementaron las dosis. Para la absorción total de nutrientes de las plantas de piña y de los frutos se pudo apreciar la acumulación en el siguiente orden: dolomita > magnesita > yeso > calcita. Sin embargo, al analizar la proporción de nutrientes absorbidos por el fruto en relación a la parte vegetativa de la planta el orden fue el siguiente: magnesita > calcita > dolomita y yeso.

Evaluación de dosis y fuentes de encalado en un suelo cultivado con piña en Pital, San Carlos

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La acidez de los suelos afecta algunas de sus características químicas y biológicas que reducen el crecimiento de la plantas, tales como la disminución en la disponibilidad de nutrimentos como Ca, Mg, K y P, y la proliferación de elementos como el Al y Mn que en cantidades altas pueden ser tóxicos para las plantas. El encalado constituye la práctica más apropiada y económica para corregir los problemas de acidez (Espinosa y Molina, 1999). La respuesta favorable de los cultivos al encalado se da principalmente como resultado de la neutralización de la acidez causada por AI+3, H+, y/o Mn+2, y del suministro de Ca, Mg o ambos (Kamprath 1984). La mayoría de los suelos cultivados con piña en Costa Rica son de naturaleza ácida, siendo principalmente Ultisoles, Inceptisoles dístricos y Andisoles. Se ha logrado comprobar que el cultivo continuo de piña en el suelo incrementa la acidez en el tiempo, debido a las altas dosis de fertilizantes nitrogenados amoniacales que se aplican, y a la alta extracción de nutrientes que se produce por parte de la cosecha de fruta. El objetivo de este estudio fue evaluar el efecto de diferentes dosis y tipos de enmiendas en el control de la acidez de un suelo cultivado con piña, ubicado en finca Tres Amigos en Pital de San Carlos. Los resultados de análisis de suelos mostraron que hubo un efecto significativo de la aplicación de enmiendas en las diferentes variables de fertilidad, en ambos muestreos realizados a los 3 y 6 meses después de aplicar los tratamientos. Sin embargo, a los 6 meses se presentó un incremento en el contenido de acidez intercambiable y % de saturación de acidez en las dosis de 2 y 4 ton.ha-1 de carbonato de calcio, demostrando el fuerte poder buffer del suelo que trata de regenerar la acidez en el transcurso del tiempo, sólo las dosis más altas de carbonato de calcio mantuvieron la saturación de acidez por debajo del 5% en ambos muestreos. Los contenidos de Mg aumentaron con la aplicación de las mezclas y dolomita como era predecible. Las mezclas superaron a la dolomita en el suministro de Ca y Mg en ambos muestreos de suelos, a pesar de que la dosis de éstas fue casi tres veces inferior a la dolomita. La mayoría de los tratamientos de enmiendas aumentaron la concentración de Ca foliar. Todas las dosis de carbonato de calcio incrementaron el nivel foliar de este elemento en forma significativa con respecto al testigo y el efecto se mantuvo a los 3 y 6 meses después de aplicado. Con la dosis de 6 ton.ha-1 se presentaron concentraciones de Ca superiores a 0,3% en ambos muestreos. El incremento del contenido de Ca foliar fue muy leve con la dolomita y las mezclas, quizás debido a la dosis menor utilizadas. Hubo un ligero aumento en el nivel de Mg foliar con estas enmiendas a los 3 meses, pero el efecto prácticamente desapareció a los 6 meses.

Control de la floración natural en el cultivo de piña mediante la aplicación de *caolinita calcinada (Surround WP)* **en Costa Rica**

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La floración natural genera importantes pérdidas en el cultivo de piña en Costa Rica. Se evaluó el efecto de las aplicaciones de caolinita (Surround WP, Nova Source, USA) para la reducción de la floración natural y el peso a forzamiento (inducción de floración) en el cultivo de piña. Se realizaron dos ensayos en fincas productoras de piña ubicadas en Pital de San Carlos, Alajuela y en Slquirres, Limón. Se utilizó un diseño apareado “con y sin” en un modelo de "investigación en finca" utilizando prueba de Y con los siguientes tratamientos: T1) Caolinita calcinada (Surround WP) en una dosis de 50 kg/ha en aplicaciones mensuales y T2) Testigo sin caolinita. Las aplicaciones de caolinita (Surround WP) se iniciaron la semana 37 del 2010 a los 3 meses después de siembra hasta la semana 9 y 10 del 2011 para las localidades de Pital y Siquirres, respectivamente. Se evaluó el porcentaje de floración natural, peso a forzamiento y contenido de nutrientes en ambas localidades. Además, en la finca de Siquirres se midió la producción y el rechazo de fruta. Se usaron 10 repeticiones por tratamiento y 50 unidades experimentales por repetición. En la finca de Pital las aplicaciones de caolinita redujeron la floración natural en un 96.36% e incrementaron el peso de plantas a forzamiento un 15%. En la finca de Siquirres se redujo un 45% la floración natural y se incrementó un 15.8% el peso de plantas a forzamiento. La aplicación de caolinita (Surround WP) produjo una mejor distribución de los tamaños de fruta e incrementó el rendimiento en la finca de Siquirres. Estos resultados podrían ser explicados debido a que es probado que el Surround WF permite reducir el efecto en las diferencias de temperatura del día y la noche, aumenté la captación y transmisión de luz, radiador fotosintéticamente activa (RFA) y la fotosíntesis er múltiples cultivos.

Nuevas tecnologías en nutrición y control de enfermedades
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En la actualidad existe una necesidad creciente de búsqueda de nuevas tecnologías, que permitan una mayor eficiencia en el uso de productos para nutrición y control de enfermedades de las plantas, estos deben cumplir con varias características; ser amigables con el ambiente, ser lo menos sensible a cambios climáticos, compatibles con otros productos y sistemas de manejo, y factibles de usar económicamente. Existe una correlación entre nutrición y sensibilidad a las enfermedades, se dice que si una planta está bien nutrida es más tolerante a las enfermedades, también se sabe que hay nutrientes que tienen efecto fungicida o bactericida; esto hace esta relación aún más interesante. Hoy día también se sabe que la formulación de productos esta muy relacionada con la eficacia biológica que estos presentan. En nutrición; entre más natural sea una sustancia y menor tamaño presente, más fácil es su absorción y translocación. Muchas compañías pretenden mejorar eficiencia disminuyendo tamaño de partículas; tecnologías de micronización o nanotecnología. Paralelamente, se busca el uso de productos más naturales, que sean mejor asimilados por la planta, y que no contaminen el ambiente, ni acidifiquen el suelo, preferiblemente orgánicos; carbohidratos, amino ácidos y PR proteínas. Hoy en día hay varias compañías que han logrado introducir estas tecnologías en líneas de productos, que permiten con gran eficiencia corregir acidez del suelo (Cal 56 y Activist Mag-flo), enfermedades: usando como base un micronutriente ligado a una sustancia totalmente natural, que forman un complejo químico molecular totalmente natural y sistémico, incluso con posibilidad de ser totalmente orgánico (Myelfos), o mezclas de ambas tecnologías adicionando un inductor de resistencia natural (Alexin).

RyzLIp® en piña: el retraso de madurez incrementa tamaño de fruta y mejora el valor total de la producción
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El ácido giberélico 3 (GA3) o RyzUp® 40 SG es bien conocido por su capacidad para influir en una variedad de respuestas de las frutas incluyendo la extensión del raquis, raleo e incremento de tamaño en las uvas de mesa, la reducción de los trastornos fisiológicos asociados con el envejecimiento de la corteza y mantenimiento del color verde de cáscara en varias especies de cítricos y la reducción de la maduración prematura de bananos. Este estudio evaluó el uso de RyzUp® postforzamiento en cuatro campos comerciales de piña en Costa Rica. Los estudios fueron llevados a cabo en áreas plantadas con MD-2 y forzadas bajo estándares comerciales en la semana 38 y 46 del 2010 y 28 y 47 del 2011. Aplicaciones a diversos estados de desarrollo de fruta y utilizando diferentes dosis fueron probadas. Un total de 600 a 800 g de i.a. / ha dividido en una o dos aplicaciones a 14 y 16 semanas después de forzamiento (SDF) mostraron retrazar significativamente la madurez del fruto en todos los sitios de prueba por 7-10 días (d), según lo determinado por la acumulación de sólidos solubles totales (SST) y el desarrollo de translucidez. Consecuentemente, laaspersión de etefón para inducir desverdizado del fruto y la cosecha se retrasó lo que permitió crecimiento adicional del fruto y un aumento total de peso de la fruta sin corona de 86 a 159 g dependiendo del área experimental. SST a la cosecha fue 0,8, 0,6 y 0,4 °Bx menor en fruta tratada con RyzUp® en áreas experimentales uno a tres, respectivamente en comparación con la del testigo sin tratar (UTC), mientras que en el cuarto sitio fue de 0,4°Brix superior. Translucidez a la cosecha fue inferior en áreas experimentales uno, tres y cuatro mientras que en el área 2 fue la misma que en el UTC. Menor translucencia en la fruta tratada con RyzUp® en estas tres áreas experimentales sugiere que la fruta podría haberse mantenido en el campo durante un periodo más largo de tiempo para permitir el crecimiento del fruto y la acumulación de SST. La circunferencia de la fruta tratada con RyzUp® aumentó en 0,8 a 1,9 cm, el peso de la corona en 16-33 cm y la longitud de la corona en 2,3 a 5,2 cm, dependiendo del sitio de evaluación, pero no influyó significativamente en la longitud del fruto. Análisis de la acidez titulable (AT) al momento de la cosecha sugiere que el tratamiento de RyzUp® incrementó la AT de la fruta en uno de las cuatro áreas experimentales. Un análisis de retomo a la inversión muestra que el RyzUp® aumentó productividad en el campo en 5,0 a 9,3 ton / ha y también movió la curva de distribución de fruta hacia tamaños más grandes que también tienen un mejor valor en el mercado de exportación. El valor total adicional obtenido en peso de la fruta con el uso de RyzUp® osciló entre US$2100 a US$3900/ha.

News from Cuba

Introduction of Pineapple Vitroplantas to Field Conditions In Collaboration with Farmers. Preliminary Results

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Abstract

The pineapple (*Ananas comosus* (L.) Merr.) is of great commercial value and 'MD-2', the most important fresh fruit cultivar, has dominated the fresh fruit market in recent years. For this reason micropropagation techniques have been used to produce plants with better agronomic traits and seeds of excellent quality. In Cuba, although there have been some attempts to introduce micropropagated plants under the conditions of production of State entities and agricultural enterprises, for various reasons these attempts have not been very successful. For this reason, work began to introduce 'MD-2' vitroplants in collaboration with selected farmers and their families with a view to establishing agro-technical procedures to make alternative sources of planting material available, necessary for the resuscitation of the productive cultivation of the pineapple and to develop the technological foundation needed to ensure the continuous generation of the planting material necessary to maintain the varietal strategies according to biodiversity and market requirements. The results achieved to date demonstrate that in collaboration with farmers, very high percentages of survival (95 %) of micropropagated plants was achieved during the first few months of evaluation. The management protocol that was established, increased all the variables assessed in micropropagated plants (No. of leaves, No. roots, Length of longest root, length and width of 'D' leaf, fresh mass and plant height) in field conditions.

Key words. Peasants, micropropagation, pineapple, vitroplants

INTRODUCTION

The pineapple has been an important crop in tropical America for centuries and has been an economically important export crop in many countries for more than 100 years. In more recent times, the cultivar MD-2, also known as Gold "Extra Sweet", which has high °Brix, good aroma and color and low acidity in the winter has become the preferred fresh fruit cultivar in global markets. 'MD-2', which was bred by the Pineapple Research Institute of Hawaii (now closed), is a complex hybrid that was developed by Del Monte Corp. and has been marketed as Del Monte Gold Extr Sweet since 1996. This vigorous hybrid plant grows rapidly, resulting a relatively short production cycle; in addition the it produces a large fruit, high yields and the fruit is very sweet and juicy, has a high vitamin C content and exceptional storage life. Its main defects are that it is more susceptible to mechanical damage and *Phytohpthora* than is 'Smooth Cayenne' (Bartholomew, 2009; Loelliet et al. , 2011).

This new variety was introduced to Cuba from Costa Rica by the Center for Bioplantas in 2005 and approximately 1 million plantlets were sold to Ghana (Africa) between 2005 and 2008. This hybrid is well adaptated to the climatic conditions of Cuba, so the national extension of plantings has increased from 2010 by the fruit company of Ciego de Avila. However, it has not been possible to implement a methodology that enables the establishment of these plantlets in the field under the environmental conditions of Ciego de Avila, an objective that will be evaluated in this work with the collaboration of leading peasants in the introduction of scientific-technical results and that will be part of the formation of graduate work of the same.

The project has focused in the first instance on the location of farmers who can be leaders in the agricultural production and in the implementation of the results of the science and technology. More than 20 peasants have been considered for inclusion in the development of the project, but difficulties with soils, areas fully occupied with crops for a long period of time, scarcity of irrigation system, not having the machinery and implements necessary etc, have reduced the number to five who have the willingness, the minimum resources and desired edapho-climatic conditions for the cultivation of pineapple. In this paper will show the results achieved on the farm of a peasant woman who has Bachelor's degree in agricultural sciences and the results will form part of her thesis for a master's degree in Tropical fruit.

MATERIALS AND METHODS

Researchers from the Centre of Bioplantas, have developed a novel Micropropagation protocol based on the use of a liquid medium and temporary immersion technology together with the implementation of a semi-automated system (Figure 1), which makes it possible to reduce the time required to generate sufficient amounts of vitroplants (plantlets) aimed at the creation of basic seeds that provide pineapple plantations with quality seed (Escalona et al., 1999).

Figure 1. General Process for the micropropagation of 'MD-2' pineapple.

S ix-month old 'MD-2'plantlets that had already cycled through the phases of acclimation, nursery and hardening in the sun, were selected to be planted under field conditions in the finca ¨Rabelo¨. The morphological characteristics and appearance of the plantlets are shown in table 1 and figure 2.

Table 1. Morphological variables of the plantlets at 6 months age and when transferred from nursery to field conditions. Data are means for 40 plants.

Leaf no.	Root		'D' leaf		Plant height	Fresh wt.
	No.	Length, cm	Length, cm	Width, cm	(cm)	(g)
15.05	18.85	17.89	21.65	2.11	23.91	27.78

The selection of the peasant and project leader Ing. Rosa Becquer Rabelo had already taken into account his pre-degree training in agricultural, his practical knowledge obtained during applied farm studies, and the fact that he is now studying to achieve the academic degree of Master in Tropical Fruit Crops.

As a first activity of the project and before the seedlings were transferred from the nursery area of the Center of Bioplantas to Finca Rabelo, we met with Ing. Rosa Becquer Rabelo and his family at the time of diagnosis and selection of the area, and discussed with him the issues:

- Processes of micropropagation, acclimatisation and nursery for vitroplants of pineapple.
- Edafo-climatic conditions and technical considerations in the cultivation of the pineapple.

In coordination with the Directorate of the ANAP, it was agreed that the results of the handling technology developed for 'MD-2' plantlets achieved as part of this work will be part of the master's thesis of Ing. Rosa Becquer Rabelo who will defend in the year 2014.

Prior to planting an analysis of the soil chemical properties was carried out and the results, pH of 5.94, P_20_5 content of 7.50 mg kg^{-1} and K_2O content of 60.36 mg kg^{-1}, were typical of the red ferriferous soils of the area and are suitable for the production of pineapple. The results show that the soils where 'MD-2' pineapple plantlets will be grown meets the chemical characteristics required for this crop. The pH between 5.5 to 6.5 , good availability of potassium (K_2O) and a relatively low content of phosphorus (P_2O_5), the optimum range is 10 to 50, however this item is corrected with the back-end application of 5 g per plant.

Figure 2. A typical acclimated plantlet at the time of transfer from nursery to field conditions.

The field was fertilized with 25.0 kg of composted cattle manure and 12.5 kg of crystalline N-P-K fertilizer (Haifa Chemicals Ltd. , Haifa Bay 26120, Israel) was applied in the bottom of trenches 100 m long (Figure 3). Subsequent to these applications the field was lightly irrigated before planting.

In May of 2012 the plantlets were transferred to the farm where the process of hardening (conditions of natural environment) continued for another 15 days. At the end of May and in early June 5,000 plantlets of 'MD-2' were planted. The planting distance used was of 0.40 cm between rows and 0.30 cm between plants, resulting in the equivalent of 55,000 plants/ha.

Figure 3. Application of livestock manure and NPK fertilizer (a) and development of the root system of the plantlets at the time of planting (b).

On the second day of after planting a foliar application of a fungicide (Mancozeb 2 kg/ha) was made to protect the plantlets from fungal diseases (*Phytohpthora* sp.) that there was already high ambient humidity and in the soil by consecutive rainy.

The statistical treatment of results was developed with the use of the utility "Statgraphics plus". Parametric analysis was carried out (simple classification ANOVA, Tukey test, $P < 0.05$), after checking for the normal distribution (Kolmogorov-Smirnov , P) and the homogeneity of variances (Levene, $P< 0.05$).

RESULTS AND DISCUSSION

Percentage of plantlet mortality, based on a 40 plant sample, at 30 days after planting was 4.8 % or 242 dead seedlings due to various causes (*Phytophthora*, soil in the heart of the plant and damage at the time of planting), which was considered satisfactory given the level of stresses the plantlets were exposed to. At 60 and 90 days after planting, percentage survival remained high at 93.2 and 90.2 % respectively. These results indicate that with good attention given to acclimation of plantlets, survival rates will be high when such plantlets are subject to new and stressful environmental conditions.

From the moment seedlings were exposed to the drastic conditions of natural environment (greater light intensity and temperature) plantlet leaves became whitish in appearance similar to leaf symptoms described by Py et al. (1984) for this species, although in this case no plants died. Phytoplasma was also observed in the leaves of plantlets due to the denaturing of chlorophylls, a symptom of photoinhibition. However, there was a speedy recovery of these symptoms during the evaluation period, indicating the early adaptation and rapid recovery to the environmental changes as is characteristic for CAM plants.

Some shortcomings in the time of sowing led to the death of the plantlets (Figure 4). Even though there was some mortality, the surviving population is good and vegetative crop development is also good. There have been two applications of an N-P-K fertilizer since planting and the Mancozeb, Aliete and Ridomile have been applied to prevent the occurrence of fungal diseases. Plants will be irrigated for 30 minutes every two or three days during dry periods, and a foliar fertilizer will be applied weekly at half the recommended dose beginning at 45 days of planting.

Figure 4. MD-2 pineapple seedlings affected by various causes after planting.

It is widely recognized that in soils with pH above 6.5, plants do not absorb iron and there is a higher incidence of *Phytophthora* spp. rots, which are more prevalent and cause greater damage to the crop when soil moisture and temperature are high. Therefore, it is important to apply fungicides during such conditions and to regularly supply nutrients by foliar fertilization.

The levels of survival are regarded as satisfactory when taking into account the high susceptibility of ‘MD-2’ to *Phythophthora*, which has been controlled with fungicides. These results were successful considering that this is a very stressful stage for tender plantlets that were suddenly exposed to environmental changes. Then to achieve high percentages of survival in the seedlings it is necessary to evaluate the behavior of growth variables to know if the agrotechnical practices that is used is the proper order to correct them and to achieve dynamic growth rates. At 45 days after planting (Figure 5), the plantlets retain their green color, no leaves are damaged by burns and the production of new autotrophic foliage allows for greater growth of the plantlets over time (Table 3).


Figure 5. Development of 'MD-2' pineapple plantlets 45 days after planting.

Table 3. Development of morphological variables evaluated during the permanence of the seedlings of pineapple in field conditions.

Plant age (days)	Leaves (no.)	Roots (no.)	Root length (cm)	'D' leaf length (cm)	'D' leaf width (cm)	Fresh mass (g)	Plant height (cm)
60	16.2 d	23.4 d	18.0 d	24.7 d	2.8 c	35.2 d	26.1 c
90	20.4 cd	28.7 c	22.8 d	29.4 d	3.5 bc	62.3 d	31.2 c
120	26.5 c	33.2 c	31.5 c	37.3 c	3.9 b	163.6 c	43.2 b
150	32.8 b	38.2 b	43.1 b	49.8 b	4.1 ab	225.3 b	49.1 ab
180	40.2 a	43.7 a	59.4 a	62.2 a	4.5 a	376.8 a	59.6 a
SD	3.1	2.5	3.2	2.7	0.6	15.2	4.8

Means within columns having different letters indicate statistical significance (simple ANOVA and Tukey test ($p < 0.05$)). The data are means for 20 plants.

Between 60 and 90 days after planting, there was no significant increase in most of the variables measured and only the number of roots increased significantly (Table 3). After 90 days, there is a steady and significant increase in all characteristics, indicating that after about a 90 day period of adaptation to the new environmental conditions, growth in fresh mass was exponential as is typical for well-managed pineapple crops (Py et al., 1984). It is well known that introducing plantlets to the field environment causes stress to the plants, which is expressed in terms of accumulation of ABA, proline, and reactive oxygen species (Van Huylenbroeck et al. , 1995; Hronkova et al. , 2003; González-Olmedo et al. , 2005), so it is necessary to reduce the negative effects of stressful conditions so that the plants maintain a constant growth and this is accomplished with suitable management agrotecnico crop.

The results achieved in this work have served as the basis on which other peasant farmers living near the farm where the experiments were performed are now motivated to enter this new and promising venture that will increase farm productivity. Already at this time, several farmers have been trained and became familiar with this crop from plantlets in the estate itself ¨Rabelo¨ under the direct advice of Ing. Rosa Bécquer, and her family (Figure 6).

CONCLUSIONS

1- The collaboration with the peasants has enabled us to achieve a high percentages of survival (95 %) in vitroplant pineapple MD-2 evaluated.

2- The morphological characteristics of the micropropagated delivered, next to the handling agrotecnico established side by side with the peasants allowed a good adaptation to the conditions of field which is why the increase in the assessed variables during the experiment.
3- The experience accumulated by the family Becquer during the development of the experiment has allowed the advice from other farmers for inclusion in the introduction of pineapple vitroplant MD-2 in future work.

Figure 6. Peasant Rosa Becquer and directors of the project visiting the pineapple vitroplants 8 months after planting.

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News from Ghana

Comparative Assessment Of Embedded Greenhouse Gas Emissions[1] Of Fresh Pineapple Exported to Europe from Ghana

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INTRODUCTION

This work was done within an international programme aimed at developing more sustainable commercial fruit value chains for export fruit from developing countries; this programme is managed by Solidaridad (www.solidaridadnetwork.org). The objective of these studies was to analyze the global warming potential (carbon footprint) from pineapple exported from Ghana to Europe and to understand how performance can be improved. A central part of this work was the inaugural application of a standard called PAS2050 on fresh pineapple. There were three sub-objectives for this study:

1. **Objective One:** Assessment of the carbon-footprint (global warming potential) of fresh pineapple, from farm production in Ghana to an importers warehouse in the Netherlands, using the international standard PAS2050.
2. **Objective Two:** Consider options for emissions reduction.
3. **Objective Three:** Compare emissions for alternative pineapple products that can be exported from Ghana and consumed in Europe.

I. ASSESSMENT OF THE CARBON FOOTPRINT OF FRESH PINEAPPLE EXPORTED BY SEA

The carbon footprint of a product is the life cycle greenhouse gas (GHG) emissions. In this study life cycle emissions of GHG are expressed in units of carbon dioxide equivalent (CO2e)[2]. The assessment was carried out using PAS2050; which is a specification for the assessment of the life cycle greenhouse gas emissions applicable to any good or service (See: www.bsi-global.com/en/Standards-and-Publications). PAS2050 was created in 2009 to be an internationally available standard by British Standards International. This assessment was made using the UK Carbon Trust's spreadsheet tool called Footprint Expert™ and related databases. The assessment used **primary data** from a value chain for 'MD-2' pineapple produced and traded by two businesses: a producer of pineapples in Ghana and an importer in the Netherlands. The assessment is termed a business-to-business assessment. This included production of fruit in Ghana, export by sea, up to the point where the fruit is ready for dispatch from the importer's warehouse in The Netherlands.

The second stage examined product life beyond the importers warehouse using **secondary data.** This study 'followed' the fruit to a hypothetical consumer in a town in southern Finland, with a logistic chain via a receiving supermarket supplied by the importer. This desk study followed PAS 2050 rules as far as possible. Data used in this assessment were for the period October 2009 to October 2010. Data were publicly available, or data was collated from industry partners, or were experts' estimates, e.g. from employees of industry partners, consultants etc. The assessment was divided into a series of stages. The stages were:

- **Farm** – all processes from planting to harvest;
- **Pack house** – all processes from harvest to the point where fruit are ready to leave the farm;
- **Export to the importers warehouse** – all transport and processes from the farm to the point where the fruit are ready to leave the importers warehouse;
- **Distribution to the Retail Distribution Centre** – all transport and storage as far as the regional distribution centre (RDC) of the local supermarket in Finland;

[1] ACKNOWLEDGEMENTS: This work was planned and commissioned by Solidaridad West Africa (formerly West Africa Fair Fruit), an organization promoting the development of sustainable agricultural value chains. We acknowledge the funding of **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH**, and of the international office of **Solidaridad** in the Netherlands. The work was implemented by the British consultant organization ADAS under the leadership of Jeremy Wiltshire. We thank Dr. Chris Foster of EuGeos Ltd for advice on emissions factors for some raw materials. The project was managed and supervised on behalf of Solidaridad by Rob Moss. **Disclaimer:** The findings, conclusions and opinions of this report are wholly those of ADAS and Solidaridad West Africa and not those of any of the funding organizations.

[2] Gases such as methane, nitrous oxide or leaked refrigerants have much higher global warming potential (GWP) than CO2. Methane has a GWP 21 times higher than CO2, so the GWP of 1 kg of methane is 21 kg CO2e.

- **Retail** – all transport, storage and disposal of waste from the RDC up to the point of purchase; and
- **Consumption & end of life fate** – all emissions arising from the storage and disposal of the tops and skin in the consumer's home in Finland.

Once the PAS2050 assessment was complete it was submitted for independent verification by the Carbon Trust, the certification body authorized to certify PAS2050 assessments. The verification concluded that the assessment was good, with only a small clarifications needed should we have required a certificate to be issued.

Results

Total life cycle emissions (primary production to end use and waste disposal) were calculated per 1 kg whole fruit (as purchased by the consumer) and per 100 g portion of edible fruit (see Figure 1).

- Carbon footprint = **0.954** kg CO_2e per **1.0** kg of whole fruit purchased by consumer.
- Carbon footprint = **191** grams per **100** gram edible portion.

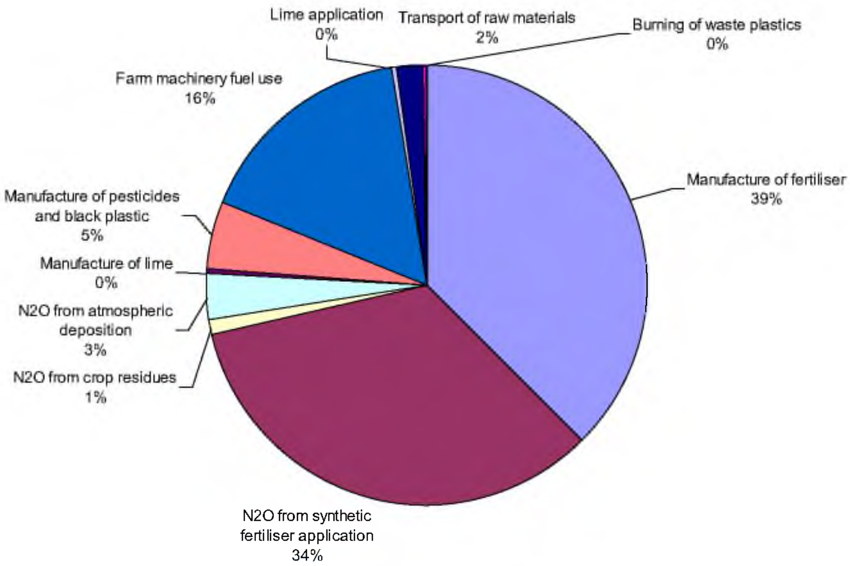

Figure 1. Farm production (excluding packing) = 0.26 kg CO2e per kg of export fruit entering the pack-house (27.3% of whole lifecycle emissions); or 52 grams CO2e per 100 g of edible fruit flesh; based on a yield of 70 tonnes per hectare.

The analysis of farm production (Figure 1) shows that manufacture and use of fertilizers (including fertilizer-derived N_2O emissions from soils) contributes 73% of total farm emissions. Almost all fertilizer related emissions are due to nitrogen fertilizer. The other 'hotspot' is fuel use (16%). These two hotspots account for 89% of farm emissions and should therefore be the main target for any mitigation efforts. Under the rules of PAS2050 by-products, such as non-export quality pineapples sold locally, are accounted for in terms of their relative financial value. So if 90% of the value of the harvest is for export then 90% of farm emissions is allocated to exported fruit. This analysis does not include any carbon losses from the soil or ecosystem or potential carbon sequestration, as the rules of PAS2050 mean that these have not needed to be included. However, there are two possible sources of CO_2e losses due to land use change:

- Changes in soil carbon content from soil after it comes into cultivation from either erosion decay of organic matter or accumulation of organic matter. Decay will accelerate with intensive cultivation, but with good soil management and rapid crop growth soil carbon should at some point become stable or increase.
- Changes in carbon due to land-use conversion from its pre-pineapple farm use. PAS2050 rules only require post 1990 conversion to be included. The land in this study became a pineapple farm in 2005, when the land was already farmland. Had it been forest at that time, then the estimate of carbon lost during the conversion to agricultural use would have been attributed to the export fruit in the PAS2050 calculations.

Table 1. Estimates of emissions for all stages across the whole supply chain to consumption and disposal of all waste.

Stage	Emissions for 1 kg whole pineapple kg CO_2e / kg	Life cycle emissions: % of total	Emissions per 100g ready to eat fruit g CO_2e / 100 g
Farm and packing			
Farm production	0.26	27.30%	52
Manufacture of packaging	0.098	10.30%	19.7
Disposal of waste in pack house	0	0.00%	0
Transport of packaging to farm	0.007	0.70%	1.4
Energy use in pack house	0.041	4.30%	8.3
Total farm emissions (including packing)	**0.407**	**42.60%**	**81.4**
Export to Europe			
Transport of pineapples from farm to warehouse	0.22	23.00%	43.9
Energy use (in port & warehouse)	0.014	1.50%	2.9
Refrigerant leakage from containers	0.032	3.40%	6.5
Total up to importers warehouse	**0.673**	**70.50%**	**134.7**
Transport to RDC (Finland)			
Transport (importer's warehouse to Finland)	0.183	19.20%	36.6
Energy use at RDC	0.005	0.50%	1
Disposal of waste at RDC	0	0.00%	0
Total, up to Retail Distribution Centre	**0.861**	**90.20%**	**172.2**
Retail, home use & disposal			
Transport to retail	0.08	8.40%	16
Energy use at retail	0.01	1.10%	2.1
Disposal of waste at retail	0.002	0.20%	0.4
Disposal of waste at in home	0.001	0.10%	0.2
Total for whole life cycle	**0.954**	**100%**	**190.8**

There was no other published data on pineapple carbon footprints available when this work was in progress. However, the study team did see a confidential draft of a similar study in another country that had broadly similar results. The expectation of the team working on this study is that most fresh 'MD-2' supply chains will have similar profiles with similar 'hotspots'. To put these pineapple emissions calculations in a broader context, GHG emissions associated with some other foods are shown in Table 2.

This data suggests that pineapple emissions are relatively high, but largely due to off-farm emissions, especially refrigerated transport and storage. However, pineapple is not among the highest emitters and is probably no better or worse than many refrigerated tropical fresh products entering Europe by sea. All air-freighted fresh foods are expected to be more polluting.

II. EMISSIONS IMPROVEMENT PLANNING

The aim of this part of the study was to focus on defining 'hotspots' where emissions are concentrated and to consider options for action to reduce emissions. The consultants' estimations were that GHG emissions savings of over 20% may be possible across the chain. Some hotspots are beyond the scope of businesses directly involved with the pineapple trade. The most obvious and most important is related to the impact of refrigerated shipping on overall emissions. That will only change if shipping operators invest in more energy-efficient ships and, for example, switch fuels from heavy oil to lower carbon alternatives like gas.

One option would be to change the nature of the product by shipping fruit that has the crown removed. This would be the basis for substantial increases in packing density and in emissions reduction. Crownless fruit are considered a different product to conventional pineapples and so this aspect is discussed in the final section of this report.

Table 2. Emissions from pineapple and some other foodstuffs consumed in Europe.

	Calories	Carbohydrate (%)	Fats (%)	Protein (%)	g CO_2e / 100 g portion	g CO_2e / Calorie
Retailed products						
Pineapple (consumed in Finland)	50	94	2	4	191	3.8
Bread retailed in the UK	266	78	11	11	163	0.6
Milk (semi skimmed, as retailed in UK)	50	39	35	26	140	2.8
Apple juice at farm shop in the UK	46	---------- No data ---------			160	3.5
Products before retail stage						
Pineapple at importers warehouse, NL	50	94	2	4	135	2.7
Apple at farm gate, UK	52	95	3	2	6.6	0.1
Chicken meat (raw) at slaughterhouse in UK	319	0	81	19	370	1.2
Beef (trimmed lean, raw) at slaughterhouse in UK	142	0	36	64	3000	21.1

Source: data compiled by ADAS from published data.

Table 3. Hotspots as a percentage of life cycle emissions.

Greenhouse gas emission hotspots	Percentage of life cycle emissions
1. Manufacture of fertilizer (mainly due to nitrogen fertilizer)	10.3%
2. Emissions of N_2O from soil (due to Nitrogen fertilizer)	9.2%
3. Farm fuel and energy use	4.5%
4. Cardboard carton manufacture	8.4%
5. Processing energy in the pack-house, mainly for cooling (off-grid/using generator)	4.3%
6. Refrigerated shipping by boat	24.8%
7. Energy use in ports (including cold storage)	1.5%
8. Road transport in refrigerated trucks to the Retail Distribution Centre	19.2
9. Road transport in refrigerated trucks from the RDC to the point of final sale	8.4%
10. Disposal of the cardboard carton	0.2%
11. Disposal of waste peel, tops and core in the consumers home	0.1%
Total	**90.8%**

The four key areas for improvement that were identified are presented below.

Nitrogen Fertilizers – Up to 10% Saving in Lifecycle Emissions Possible

Roughly 20% of whole life-cycle emissions are due to Nitrogen fertilizer and the stakeholders and consultants participating in this study believe that with time and investment in research 50% reductions from emissions related to fertilizer per tonne of product are feasible.

N_2O is a potent greenhouse gas which may be released during N-fertilizer manufacture as well as on the farm. Efficient modern factories have lower emissions when they use certain manufacturing technologies such as steam reforming natural gas ammonia facilities (which can have an energy efficiency close to the technological limit and **CO_2e** emissions as low as 1.8 tons **CO_2e** /ton NH3). Some nitric acid plants use N_2O abatement technology which also significantly reduces N_2O emissions[3]. It would therefore be possible to cut emissions significantly simply by selecting fertilizer suppliers based on the life cycle emissions of their manufacture.

[3] http://www.fertilizerseurope.com/site/fileadmin/issuu/annual_reports/Fertilisers_AR_V12_1_.pdf

Different types of fertilizer have different emission levels in manufacture and uptake by plants as well as different agronomic efficiencies. So, for example calcium ammonium phosphate is more expensive than urea but less of the N content is wasted, so that it is possible that emissions can be reduced by switching fertilizer without increasing the cost of N fertilization.

A recent survey in Costa Rica showed that nitrogen fertilizer use on 'MD-2' pineapple did correlate with yield, though the efficiency of uptake was not uniform between farms[4]. This suggests that with better agronomic monitoring and better practices fertilizer-use-efficiency can be improved. Higher efficiency reduces cost of production per tonne of fruit so there is self-interest for farms to pay careful attention of N efficiency[5]. Average yields of 'MD-2' from Costa Rica were estimated to be 85 tonnes ha^{-1} from the plant crop. This PAS2050 is for yields of 70 tonnes; better agronomy to increase yields combined with efficient plant nutrient management is expected to reduce emissions per tonne. There are many old and new plant-nutrition and fertilizer technologies that might reduce costs while also reducing emissions. For example:

- Foliar and soil analysis combined with good agronomic monitoring and management of performance using benchmarks and critical levels and ratios to manage plant nutrition. This is an established approach that is used on many crops, but there are still large numbers of commercial farms that could improve fertilizer efficiency, yield and farm profits through better agronomy.
- Urea is currently a major source of N in the pineapple industry in West Africa but urea can suffer high post-application losses in hot and humid conditions. Urease inhibitors or controlled-release /encapsulated urea may have potential to reduce losses, at least for soil applied urea.
- Biological nitrogen fixation may be able to contribute some nitrogen and improve soil quality through contributing organic matter. Planting in rotation with *Mucuna pruriens* as a cover crop is from time to time practiced by some commercial pineapple farms in Ghana. Some farms have tried *Mucuna* but decided not to grow it because it is difficult to clear and suppress. Research has indicated that when growing conditions are optimal a *Mucuna* crop provides an equivalent of up to 120 kg N kg ha^{-1} of N fertilizer in 12 weeks of growth[6]. In crops like sugarcane commercial products containing diazatrophic bacteria have been shown to increase both yield and fertilizer use efficiency, these products have not yet been thoroughly tested on pineapple but may have potential to increase yield with no extra fertilizer.

This study was for data from a plant crop only. In Costa Rica many farms follow the plant crop with a ratoon crop. Growing a ratoon may also be a way that overall yield per tonne of nitrogen fertilizer will increase and so reduce emissions. This and most other aspects of improved agronomic management have potential to reduce emissions and improve financial performance. These opportunities can only be assessed with detailed agronomic research.

There is a case for coordinated agronomic trails on plant nutrition management in export pineapple in order to boost fertilizer-use-efficiency for the industry as a whole, not just in West Africa. For this some international public funding would be necessary as no individual farms or businesses have the resources or expertise to do this type of work alone.

Fuel and Energy Use on Farms – Up to 2.0% of Life Cycle Emissions Reductions Possible.

This case study is for a farm that at the time of the study was not yet connected to the Ghana power grid. Farms connected to the grid benefit from power for cooling that is mainly derived from hydro-power, and so has a lower GHG emissions factor.

Fuel consumption on farms can be reduced in many ways: e.g. training drivers, ensuring optimal tire pressure, good maintenance of tractors and implements, imposing speed restriction. Tractor manufacturers are

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[4] Characterization of 'MD-2' Pineapple Planting Density and Fertilization Using a Grower Survey. Ramon G. Leon and Delanie Kellon. Hortechnology. October 2012 22:644-650.

[5] Range of emission factors for N fertilizers (not including N_2O emissions from soil). AN = ammonium nitrate; FE = Footprint Expert:
AN manufacture best available technology = 2.7 kg CO_2e per kg N; AN manufacture FE standard emission factor = 8.2 kg CO_2e per kg N; AN application (FE standard) = 4.8 kg CO_2e per kg N; AN application IPCC 2006 methodology (N_2O) = 6.2 kg CO_2e per kg N; Urea manufacture European average (2006) = 1.58 kg CO_2e per kg N; Urea manufacture best available technology = 1.13 kg CO_2e per kg N; Urea manufacture FE standard emission factor = 3.09 kg CO_2e per kg N. From Brentrup, F. and Paliere, C. (2008). GHG emissions and energy efficiency in European nitrogen fertilizer production and use. In: Proceedings of the International Fertilizer Society Conference, 11th December 2008. Cambridge, UK.

[6] Sanginga N et al; Plant and soil 1996, vol. 179, n°1, pp. 119-129

now starting to rate their machines according to fuel efficiency and a new generation of more efficient and lower emission engines are being developed which will be available in future and will reduce emissions.

Pineapple has potential as an energy crop[7]. An approach to reducing emissions may be in the use of biogas generated on the farm as a power source. Two European companies, Steyr of Austria and Valtra of Sweden, have developed dual fuel diesel/biogas tractors to the stage of advanced prototype or pilot manufacturing. Pineapple farms have two potential sources of fuel for biogas generation that could fuel a biogas tractor:

- Damaged, rotten or otherwise unsalable fruit, this is unlikely to be more than 5% of the total crop.
- Crop residues, in particular the stumps of old plants which have high starch content.

There are numerous published papers that report on the use of fruit waste as a potent raw material for biogas generation. For example, Cahyari and Putra[8] calculate that a relatively small scale system can generate 124 kWh of electricity per tonne of waste fruit. PT Great Giant Pineapple Co. has adopted biogas on a large scale and claims to produce 30,000 m^3 day^{-1} of methane biogas to supplement and replace fuel oil and coal used in its boiler (www.pollutionsolutions-online.com).

According to Py et al[9], stems of 'Smooth Cayenne' contain 11% starch on a fresh weight basis and not all starch is converted to fruit sugar by the time the fruit is to be harvested. We have seen no data on the starch content of 'MD-2' stems at the time of harvest. However, it is possible that biogas potential is significant and that this could partially replace diesel fuel, generate power for cooling or be sold into the power grid. We have not calculated the investment and running costs that this would entail, but we assume these would be substantial. More analysis is needed to evaluate if biogas is a realistic alternative to conventional fuel and power generation on pineapple farms.

Packaging - up to 4% Emissions Reductions Possible

Multi-use folding plastic crates are now becoming common in supermarket distribution systems. Introducing these for international pineapple shipping has the potential to reduce life-cycle emissions by 4% (*pers. comm.* managers at Container Centralen). No information was seen on testing reusable crates within the pineapple export sector; however there are anecdotal reports from staff of importers who have seen test shipments of pineapple in supermarket distribution centers.

Transport Within Europe - Up to 5% Emissions Reductions Possible

Reductions in emissions could be made through selecting transport companies that have low carbon systems in place, such as speed restrictions on their vehicles. A new generation of trucks that have more efficient engines to meet tightening emissions standards are being developed so reductions are possible as new generations of truck come into service. Emissions on all trucks are reduced through ensuring regular maintenance of vehicle and of container refrigeration units.

III. COMPARISONS OF DIFFERENT PINEAPPLE EXPORT PRODUCTS

The objective of this part of the study was to compare emissions from conventional fresh pineapple exported by sea with other alternative forms of pineapple for export. This used secondary data, but as far as possible followed the methodology of PAS2050 to compare emissions from whole sea-freighted pineapples with alternative forms of pineapple for export. It was assumed that emissions from production of pineapples on the farm remained the same regardless of the method of processing or transport. It was assumed that processing would have occurred in an adjacent factory, close to the farm such that no significant additional local transport emissions were incurred.

Different forms of fruit for export are compared, in each case using 100 grams of edible fruit flesh as the basic unit. For example, for dried pineapple the calculation starts with 100 grams of fruit-flesh which is then dried, packed and exported; for juice the amount of juice extracted from 100 grams of fruit-flesh is used as the

[7] Marzola, D.L. & Bartholemew, D.P. (1979), Photosynthetic parthway and biomass energy production. Science, 205, 555-559
[8] Khamdan Cahyari and Ryan Anugrah Putra. Design of Biogas Plant from Fruit Market Waste in Indonesia. Renews 2010. Proceeding of the Renewable Energy Conference, Berlin, Germany, 12 -13 October 2010.
[9] The pineapple: cultivation and uses. Py.C., Lacoeuilhe J.J., Teisson C. Pubs: Maisonneuve et Larose. 1987.

unit. To ensure the methodology remained simple, all farm production emissions are considered the same for all types of pineapple product. In reality producing for processing would change farm management and the emissions profile. For example a drying business may use 'Smooth Cayenne' which can be grown with less fertilizer, tops can be used for planting (eliminating the need for sucker production) and a drying factory may have fruit waste with which to generate biogas for powering the dryer with the digester sludge sent back to the farm to recycle plant nutrients. Real pineapple processing facilities often produce a range of co-products (e.g. a factory for canned pineapple would most likely also produce pineapple juice). This reduces wastage and can thus lower the carbon footprint of each of the co-products. This aspect has been deliberately overlooked in this study, because of the shortage of data, but also to make the analysis uncomplicated. The comparisons are therefore approximations of the likely carbon footprints of different types of product. However we believe that they are a reasonable basis for comparison, showing the main differences between one product type and another.

The comparison was based on hypothetical product life-cycles (for example there is no export of tinned pineapple from Ghana). Assumptions were made as to the most likely production process for each individual product, information from individual pineapple processors, and information from technical data sheets for equipment likely to be used. Data derived in this way will always carry a degree of uncertainty, as utilization rates and resource consumption will vary from factory to factory.

Results

Both forms of air-frieght product (Fruit chunks by air and Whole fruit by air; Figure 2) have a carbon footprint far above the other six forms of pineapple for export. For air-frieghted produce there seems to be little opportunity to reduce emissions substantially. For all other types of export there are believed to be opporuntities to substantially reduce emmissions.

Decrowned Fruit in High Density Packing Configuration For the Fresh Fruit Trade

Data for estimated emissions for decrowned pineapple sent by sea is included in Figure 2 and 3. Fruit is shipped in this way from Ghana to Europe in conventional cardboard cartons for cutting in Europe for fruit salad. The crown is roughly hacked off and this allows carton weight to increase from 12 kg to 14 kg. An additional class would be fruit neatly decrowned in the packing shed and shipped for sale in supermarkets to consumers; this is a class which does not yet exist and so was not included in this comparison.

The reason fruit is not sold in this way is because it is believed that consumers would not buy 'disfigured' fruit. However, a marketing company commissioned by Solidaridad discussed this with a marketing study consumer focus group in The Netherlands and their feedback was that they would buy decrowned fruit if it was well marketed and if they were aware that it was either cheaper or 'better' in some way (i.e. from an environmental performance perspective). This suggests that with marketing effort decrowned fruit could be sold in place of fruit with crowns with sufficient marketing effort.

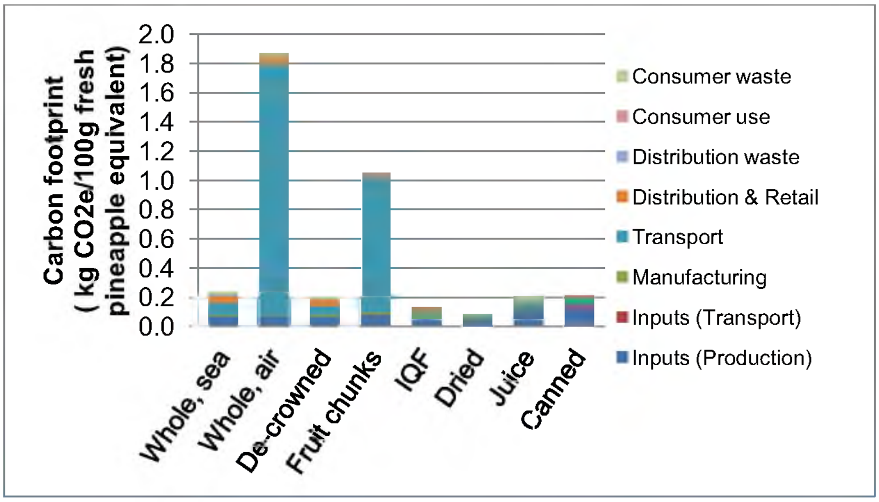

Figure 2. Comparison of the carbon footprint of different pineapple products including the two forms of air freight (whole fruit by air, and fruit-chunks by air).

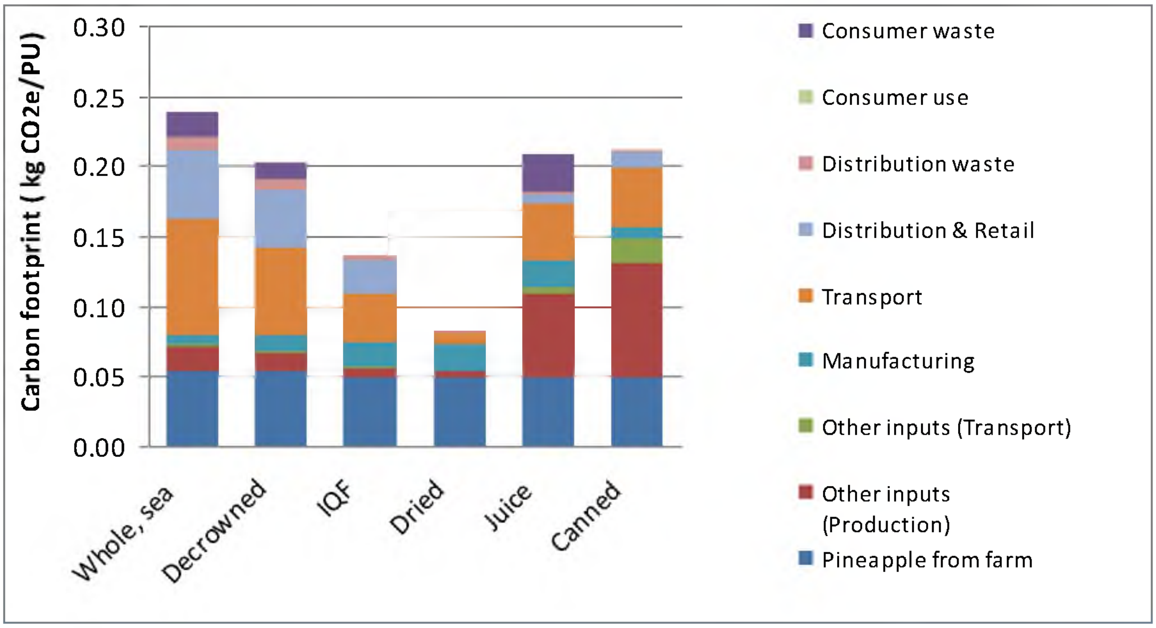

Figure 3. Comparison of the carbon footprint of different processing methods for pineapple, (excluding those using air freight).

The maximum load in 40 ft. refrigerated container is about 30 tonnes. Conventional loading fills a container with 18 tonnes of fruit, of which 10%-17% is the weight of the crown. The inedible crown takes a lot of space and needs to be protected from crushing to preserve the cosmetic appearance of the fruit (so fruit must be packed in single layers). Crown removal) would mean that substantially more fruit could be packed. If this is done leaving a small stump (at least one cm) there is no browning of the fruit flesh. For a test shipment pineapples were packed in bins and crates of various dimensions with the objective to pack the fruit as tightly as possible and to see by how much loading could be increased; in some cases decrowned fruit was packed four layers deep. Fruit arriving in Europe underwent a detailed quality inspection and no unusual quality problems were reported. Packing density gains depended on many factors, but the main conclusions were that packing-density gains of up to 60% additional fruit might be possible with a combination of decrowning and packing in larger crates or bins. This approach assumes the availability of a class of bin or large crate designed for disassembly and return shipment; however, no appropriate bins that fit this design concept have been found. An additional issue is that shipping fruit in this way would need fruit to be repacked into supermarket crates at distribution centers, incurring additional cost that would partly offset other savings. However there is no doubt that developing a system specifically for decrowned fruit would have a major impact on changing the emissions profile and cost profile of long distance fresh pineapple. The main constraint for the consultants and the organizations and businesses involved in this study is that we have not found any supermarket willing to participate this initiative and to be a champion for a more sustainable pineapple supply chain.

CONCLUSIONS OF THE STUDY

1) The carbon footprint of fresh pineapple has been done by consultants with expertise in the methodology and the results were verified by the Carbon Trust confirming that the methodology was consistent with PAS2050. The study concluded that emissions per 100g of edible fruit was 135 grams CO_2e at the distributors' warehouse and 191 grams CO_2e once consumed by a hypothetical consumer in Finland.
2) The main source of embedded emissions in farm production is nitrogen fertilizer manufacture and use. There is evidence that on many farms this could be reduced through better agronomy leading to higher yields with lower fertilizer use per tonne. Focused agricultural research is needed to promote better agronomy for plant nutrition management. Bearing in mind the structure of the sector this is unlikely without funding by international institutions.

3) There are various other emissions hotspots along the supply chain; several of these significant emissions reductions appear possible.
4) The only form of renewable energy generated by pineapple farms and factories across the world is biogas from fruit waste at canneries and other processors. It is possible that exporters of fresh pineapples could generate biogas from crop residues; there is currently no data to confirm what biogas energy yield is theoretically possible or what costs would be incurred.
5) All forms pineapple products shipped by air freight have a very high carbon footprint. All forms of processed pineapple that can be exported by sea (IQF, juice, dried etc.) have a lower footprint than fresh fruit by sea. If imports to Europe are affected in future by tightening emissions standards (e.g. carbon taxes) then low emissions products will have a competitive advantage.
6) Marketing decrowned pineapples that are shipped in novel packing systems aimed at maximizing packing density in refrigerated containers has a very good potential for cost savings and substantial reductions of life-cycle emmissions. However, this is a new product and Euopean supermarkets queried about this have shown no interest in promotion and marketing of decrowned fresh pineapple. Lack of interest by retailers is the biggest barrier to developing decrowned pineapple as a new form of export pineapple.

Services

The listings below are provided as a convenience to readers and should in no way be construed as an endorsement of those providing commercial or professional services. Those offering specialized services to pineapple growers or researchers are invited to contact the editor for possible inclusion in the listings below.

Commercial Services

- **Centro de Bioplantas**. Dr. Justo L. Gonzalez Olmedo, Director of Foreign Affairs Office, Centro De Bioplantas. Universidad De Ciego De Avila, Carretera a Moron Km 9. Cp69450. Cuba. Centro De Bioplantas offers certificates of authenticity for pineapple material propagated in their tissue culture facility. Web site: http://www.Bioplantas.cu.
- **Maintain CF 125** continues to be available for use in pineapple plant propagation anywhere in the world. Supplies can be obtaine from N. Bhushan Mandava, Repar Corporation, 8070 Georgia Ave., Suite 209, Silver Spring, MD 20910. Tel: (301) 562 – 7330; Fax: (202) 223 – 0141; On the web at www.reparcorp.com; E-Mail: mandava@compuserve.com.
- **Thai Orchids Lab**, Dr. Paiboolya Gavinlertvatana. Horticulture/ agriculture/ forestry tissue culture laboratory with exports to Australia, U.S.A., Africa, and Asia. CO2 & MD2 pineapple available (open to acquiring additional varieties) or confidential exclusive contract propagation. Phone: +1.617.910.0563 Website: http://www.tolusa.com/.
- **Vitropic**, Zone d'Activités Economiques des Avants, 34270 Saint Mathieu de Tréviers France; Tel: + 33 (0)4 67 55 34 58; Fax: + 33 (0)4 67 55 23 05. E-mail : vitropic@vitropic.fr. Web site: www.vitropic.fr. Vitropic proposes the best individuals from the CIRAD FHLOR selected clones including: Cayenne Group, Queen Group, Perolera Group, MD2, Ornamentals pineapples. The range is continuously extending, do not hesitate to ask for more information.

Professional Services

- **Dr. Surya P Bhattarai**. CQUniversity Australia, Rockhampton, QLD 4702, Australia; Tel: +61 7 4923 2140 (w), +61 438191391 (m) ; E-mail: s.bhattarai@cqu.edu.au. Experience: More than 25 years of experience in agronomy/physiology in a large range of horticultural crops including pineapple. Recent focus on crop water management and irrigation of pineapple in Australia. Will work on collaborative research projects (global, regional or local) on pineapple in the area of crop agronomy, postharvest and value chain.
- **Szu-Ju Chen**. 2-6 Dehe Rd., Dehe Village, Changjhih Township, Pingtung County 90846, Taiwan. E-mail: suju@mail.kdais.gov.tw. Assistant Researcher, Kaohsing District Agricultural Research and Extension Station. Area of specialization: Improvement of cultural practices and postharvest management of pineapple and other tropical fruits.
- **Dr. Mark Paul Culik**. INCAPER, Rua Alfonso Sarlo 160, CEP 29052-010, Vitoria, ES, Brazil; Tel: 27-3636-9817; E-mail: markculik3@yahoo.com. Experience: PhD in Plant and Soil Sciences with more than 25 years of agricultural pest management experience in crops ranging from apples to papaya and pineapple, identification of pests and beneficial arthropods ranging from mites to fruit flies, and current work on scale insects, including pineapple mealybugs. Areas of specialization: Entomology, Insect and Pest Identification, Integrated Pest Management.

- **Dr. Herve Fleisch.** Interested in consulting on most agronomic and managerial aspects of production operations. See on-line profile at http://www.linkedin.com/pub/herve-fleisch/28/536/21a and web page at www.cuenca-caribe-consultores.com.
- **Eng. Agr. Rafael Garita C.** E-mail: rafagarita8@yahoo.com. Twenty years of experience with 'MD-2' pineapple at Del Monte Fresh Produce (Pindeco) in Costa Rica under the guidance of Mr. George Yamane who led development of 'MD-2' at Del Monte. Worked on pineapple projects in the Philippines (Cagayan de Oro) and was involved in preliminary studies in Indonesia: Sulawesi Islands Molukas (Halmahera). Also consultant in Costa Rica, Panama, Puerto Rico, the Dominican Republic, Colombia, Ecuador, El Salvador, Guatemala and others.
- **Ching-San Kuan**. No.2, Minquan Rd., Chiayi 60044, Taiwan. E-mail: Kuan@dns.caes.gov.tw. Associate Researcher, Taiwan Agricultural Research Institute, Chiayi Agricultural Experiment Station. Area of specialization: Pineapple breeding and cultural practice improvement.
- **Juan Luis Morales Ch.** E-mail: jlmoralesch@gmail.com Tel.506-83988772. I was responsible for research, technical services and quality control of 'MD-2' pineapple in Pinedeco-Del Monte, for over 20 years and have experience in many parts of the world. I can advise pinneaple growers on agronomy practices, crop protection and quality control.
- **Mr. Graham J. Petty** 13 Somerset Place, Lambert Road, Port Alfred, 6170, Republic of South Africa. Phone: +27 (0) 46 624 4868; E-mail: pettys@telkomsa.net. Experience: M.Sc. (Agric) Pretoria : Pr. Sci. Nat. . Researcher and advisor to the South African Canning Pineapple Industry on matters of Pest Management in pineapple culture, for 34 years. Economic entomology and management of biological control agents have received particular attention
- **Ing. Jhonny Vásquez Jiménez**, MSc. San Carlos, Costa Rica. E-mail: jvasquez@proagrocr.com, (506) 89103878, (506) 24756795. Advice on the agricultural management of pineapple crop. Analysis and improvement of pineapple crop systems for producer companies (environment and productive potential, nutrition, control pathology, crop management). For Agrochemical Companies, designing and conducting researches for new production technologies in the area of nutrition, plant pathology, weeds and other disorders.
- ***Mr. José R. Vásquez**, MBA with emphasis in Agribusiness (E-mail: jrva46@excite.com, jrva46@gmail.com). Phone: 504 2668 1191; 504 94899901. Experience: Environmental and Sustainable Agriculture. Pineapple and melon production, from seed propagation, planting, field maintenance, forcing, harvesting, post-harvest management and commercialization.
- **Dr. José Aires Ventura**. Incaper, Rua Afonso Sarlo 160 (bento Ferreira), 29052-010, Vitoria-ES, Brazil. E-mail: ventura@incaper.es.gov.br; Tel.: 55-27-36369817. www.incaper.es.gov.br. Area of Specialization: Plant Pathology (research in pineapple diseases management; *Fusarium* diagnosis, diseases resistance).
- **Ren-Huang Wang**. 2-6 Dehe Rd., Dehe Village, Changjhih Township, Pingtung County 90846, Taiwan. E-mail: rhwang@mail.kdais.gov.tw. Assistant Researcher, Kaohsing District Agricultural Research and Extension Station. Area of specialization: Improvement of cultural practices and postharvest management of papaya, pineapple and other tropical fruits.

Book Reviews and Web Sites

Book Reviews

No reviews were provided for this issue.

Web Sites of Possible Interest

- http://www.fruitnet.com/americafruit/article/158143/del-monte-gets-gm-pineapple-green-light
- http://www.buildingconservation.com/articles/pineapples/pineapples.htm
- http://www.thepacker.com/fruit-vegetable-enewsletter/Week_In_Review/Del-Monte-testing-genetically-modified-pineapple-204909111.html
- http://www.youtube.com/watch?v=5VnXiP3RNSk
  http://www.youtube.com/watch?NR=1&feature=endscreen&v=RJ50XkG2gJQ
- http://www.itfnet.org/v1/news/e-newsletter/

New References on Pineapple

The list below includes papers related to various aspects of pineapple culture, physiology, processing, preservation or byproducts that were published or located for the period since the last issue up to about March 31, 2013. Some papers may seem relatively unrelated to pineapple but the list follows the principle of inclusion to provide the widest possible content. Often, abstracts of the papers listed below can be found on-line. I suggest searching using the paper title. Of course all abstracts of papers published in Acta Horticulturae are available from info@ishs.org. For a larger view, adjust the magnification in Adobe Reader.

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Readers of Pineapple News are invited to contribute articles to this newsletter. The scope of contributions includes:

- Timely news about research on issues related to culture, processing, storage, and marketing of pineapple.
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- Country or status reports on the local pineapple industry.
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