

Pineapple News

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Pineapple Working Group News

New's about IX International Pineapple Symposium (IX IPS)

The IX IPS was held in Havana, Cuba from October 15 to 19, 2017. The meeting was organized by the Tropical Fruit Research institute (IIFT) and the Agriculture Enterprise Group from the Ministry of Agriculture, Republic of Cuba, with the backing of the International Society for Horticultural Science (ISHS). An abbreviated summary of the meeting follows, and the entire summary can be found in: Juliette Valdes-Infante Herrero and Lester Hernandez Rodriguez. 2018. IX International Pineapple Symposium. *Chronica Horticulturae* 58: (1), 37-38.

There were 143 in attendance at the IX IPS and it was confirmed from email country codes that registrants came from Australia, Brazil, China, Costa Rica, Cuba, Ecuador, France, Mexico, South Africa and Spain (Canary Islands). The four main topics covered were: Management of pineapple agro-ecosystems; Genetic resources, breeding and biotechnology; Postharvest, industrialization and commercialization; and Plant protection. The symposium included 34 scientific oral presentations and 34 poster presentations.

Abstracts presented at the symposium and news of the ActaHort proceedings

The ISHS has again agreed to make the 52 abstracts of the papers presented orally or as posters available in this issue of Pineapple News. Those abstracts can be found on page 56. below. Some abstracts are in Spanish. If you can't read Spanish, an acceptable translation can be done by pasting abstract content into translate.google.com (<https://translate.google.com/>). If an abstract exceeds the character limit, translate long abstracts a section at a time.

Technical editing of the 29 papers that were accepted for inclusion in the proceedings of IX IPS was completed in mid July 2018. Those papers are now in the hands of the convenors and we hope soon will show up as a volume of *Acta Horticulturae*. When the proceedings is published an email announcing its availability will be sent to the Pineapple News mailing list.

X International Pineapple Symposium

The 10th International Pineapple Symposium is scheduled to convene in Punta Cana (Dominican Republic), on April 13, 2020 and end on April 19, 2020. It is expected that more information will be coming soon.

Links to information on pineapple.

Digital editions of the books by:

Py, C., Lacoëuilhe, J.J., and Teisson, C. 1984. *L'Ananas Sa Culture, Ses Proudits*. Paris, Editions G.-P. Maisonneuv,

Py, C., Lacoëuilhe, J.J. & Teisson, C. 1987) *The pineapple. Cultivation and uses*, Paris, Editions G.-P. Maisonneuve. **are available at** <https://evols.library.manoa.hawaii.edu/handle/10524/55419>.

Pineapple News archives

All back copies of Pineapple News can be found at the links below.

<http://www.ishs.org/pineapple/pineapple-newsletters>

<https://scholarspace.manoa.hawaii.edu/handle/10125/41067>

A searchable table of contents of all issues of Pineapple News can be viewed at:

https://docs.google.com/spreadsheets/d/1ePrvOxZK_fAetf5dDG9KSJ-iI3TGbWEuVPqNWSIC1k/pubhtml

Pineapple cultivar listing by country. Additions and corrections welcomed.

<https://docs.google.com/spreadsheets/d/1NDR9v3FSZLP8W3m9rYhScErrxed8vEc7f8meDyLXEmg/edit?usp=sharing>

Pineapple cultivars have a specific identity and changes in morphology or physiology when cultivars are moved into new environments doesn't justify renaming them. When publishing research on pineapple, it is important to use the cultivar name. Using local names for a named cultivar render research results relatively useless to the rest of the pineapple world because the information cannot easily and quickly be connected to other research papers where the correct cultivar name has been used.

The google spreadsheet provides a searchable cultivar list that is alphabetized by country and by cultivars within each country where the various cultivars are found. The list also includes any colloquial name used in the country, other relevant comments and the first published mention found of the cultivar in each country.

In addition to documenting the presence of cultivars within a country, the list can be used to identify the pineapple cultivar in papers that often only cite the colloquial (local) name of the cultivar. Some colloquial names, Sugarloaf and Sugar loaf being examples, are used to name more than one cultivar, which makes papers on the cultivar relatively inaccessible. It is hoped that the list will help expand access of researchers to published research on the cultivars grown in various countries and encourage researchers to link their research publications to the body of literature on a given cultivar by identifying the colloquial and cultivar name in their papers.

Pineapple Botany, Production and Uses, 2nd edition.

Edited by Garth M. Sanewski, Duane P. Bartholomew and Robert E. Paull and written by an international team of experts, this book is completely updated with new content and full-colour figures throughout. The second edition of this successful book continues to provide comprehensive coverage relating to pineapple breeding, production and yield. Pineapple is an increasingly important crop and demand for fresh pineapple is steadily growing; stakeholders in the value chain are worldwide. The book is an essential resource for researchers, growers and all those involved in the pineapple industry.

This contents of this second edition:

- includes new chapters on organic production and production for other uses (fibre and ornamentals)
- Includes major updates to content on taxonomy, biotechnology, cultural systems, nutrition, varieties and genetic improvement
- Explores physiological changes associated with the year-round growing of pineapple in addition to the associated cultural practices and mineral nutrition
- Considers the impact of climate change and environmental issues on pineapple crops, and relevant mitigation strategies
- Looks at the effect of new cultivars and new technologies on cultural practices and plant nutrition

The list of chapters and their authors are provided below.

Chapter 1: History, Distribution and World Production

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Chapter 2: Morphology, Anatomy and Taxonomy

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Chapter 3: Origin and Evolution

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Chapter 4: Breeding and Varietal Improvement

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Chapter 5: Biotechnology

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Chapter 6: Crop Environment, Plant Growth and Physiology

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Chapter 7: Cultural System

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Chapter 8: Plant Nutrition

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Chapter 9: Organic Production

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Chapter 10: Production for Other Uses

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Chapter 11: Inflorescence and Fruit Development and Yield

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Chapter 12: Pests, Diseases, and Weeds

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Chapter 13: Postharvest Physiology, Handling, and Storage

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News from Brazil

Brazil – EMBRAPA

Embrapa's national research center on cassava and tropical fruits, Cruz das Almas, Bahia, Brazil, has carried out studies to identify value-adding opportunities for the growers of these crops. Among other alternatives its pineapple team has focused on the ornamental potential and on the high leaf fiber contents of genotypes present in the Active Pineapple Germplasm Bank composed by more than 700 accessions.

In North Brazil, especially in the State of Pará, the curauá pineapple (*Ananas comosus* var. *erectifolius*) has been grown for its high-quality fiber used in the car industry, especially as material for filling of armchairs and other uses, and has also been tested for the cement industry (bricks, blocks and tiles). Embrapa wanted to know if there are other genotypes with leaf fibers of quality similar or even superior to that supplied by curauá and if the cultivars grown for fruit production also have an acceptable fiber quality and production. The answers are being looked for within the project on "Use of foliar fiber as an alternative in the pineapple production chain and in the development of products for the agricultural and civil construction sectors".

As more than 80% of the annual harvested area of around 67.000 ha in Brazil is cultivated with 'Pérola' pineapple, the fiber production potential and fiber quality of this cultivar are being tested. Recently, a ratoon field of 'Pérola' pineapple, grown with irrigation until the first cycle fruit harvest was selected for evaluation and the preliminary results are described below.

Estimation of fiber yield in a 'Pérola' pineapple field

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The characterization of pineapple germplasm (*Ananas comosus* L. Merrill) has allowed the identification of genotypes with good quality fibers for crafts and industrial purposes. With the growing search for materials from renewable sources, pineapple fields, now destined for fruit production, can also have economic potential for fiber extraction. The objective of this work was to quantify fiber yield and productivity of a 'Pérola' pineapple field based upon manual fiber extraction in a Paraíba type machine widely used for sisal fiber extraction in Brazil. The study was carried out in a commercial field in the municipality of Iaçú, Bahia, with an irrigated area of one hectare planted in a spacing of 80 x 40 x 40 cm (41,666 plants/ha). The plants went through a normal cycle until fruit harvest, followed by a period of four months of ratoon suckers growth. These suckers, presenting green leaves of different sizes, suitable for the extraction of fibers, were separated from the plants and weighed. Their leaves were then removed, weighed, defibrated (wet fibers) and air dried. Data obtained were then used to estimate fiber yield and productivity. Lots with ten complete suckers (initial weight) weighed an average of 10.9 ± 1.9 kg and, after removal of their stems, their leaves weighed 7.3 ± 1.2 kg. The newly processed and still wet fibers weighed 0.91 ± 0.16 kg and after air drying, 0.30 ± 0.06 kg. Therefore, the dry fiber yield was $2.7 \pm 0.3\%$ of the initial weight. Considering the density of 41,666 plants/ha and that each ratoon sucker weighed an average of 1.1 ± 0.2 kg, there is an estimated

average productivity of 45.8 tons of leaves and 1.2 tons of dry fibers per hectare, considering the fiber yield of 2.7%. This productivity may be higher if the less vigorous and flaccid leaves originated in the first cycle of the plants could also be used, what will depend on the evolution of the fiber extraction technology.

Key-words: *Ananas comosus* L. Merrill; Fiber production; Manual defibration.

Acknowledgements: FAPESB; CNPq; PNPd; CAPES; Embrapa Mandioca e Fruticultura.

Effect of plastic mulching and fruit covers on the quality of 'BRS Imperial' and 'Pérola' organic pineapples

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Protection of fruits against sunburn and of the soil by plastic mulch are important cultural practices in pineapple cultivation in regions with high insolation and scarcity of labor force, such as the Chapada Diamantina region in central Bahia State, Brazil. In organic production systems the use of newspaper wraps for fruit protection, as widely used in Brazil, is not allowed. The objective of this study was to evaluate the physical-chemical characteristics of 'BRS Imperial' and 'Pérola' pineapples in an organic production system in response to the use of soil plastic mulching and different covers during fruit maturation. Both cultivars were grown with and without plastic mulching and with the following types of fruit protection: cover with paper, 50% shading screen, 70% shading screen, and one uncovered control, setting up a 4x2 factorial scheme as experimental design.

Fruits were harvested at the "painted" stage (up to 25% yellow skin) for 'Pérola' pineapples, and "colored" stage (more than 50% yellow skin) for 'BRS Imperial' ones, and were characterized by physical and chemical-physical determinations of pH, soluble solids - SS (°Brix), titratable acidity - TA (% of citric acid), ratio (SS/TA), vitamin C (%), fruit length (cm) and diameter (cm); pulp instrumental color measured by luminosity, color intensity and tonality. Analyzes were performed in triplicate and data submitted to analysis of variance and means comparison by the Tukey test at 5%.

There were differences between the two cultivars in response to the treatments of mulching and covers studied. 'BRS Imperial' fruit length and diameter and juice yield increased with use of mulching regardless of the type of fruit cover used. However, there was no significant effect of the treatments on pH, SS, titratable acidity and ratio of the pulp. The fruits from the uncovered treatment showed a clearer and more intense coloration of the pulp when compared to the fruits covered with paper, whereas shading screen covers did not differ from both treatments. Soil mulching also contributed to a clearer pulp tonality. Vitamin C content was lower when mulching was used together with fruit cover with paper, 50% shading screen and without cover, but not when combined with a 70% shading screen treatment, suggesting that the plastic mulch used increased radiation reflection towards the fruit, with an acceleration of vitamin C degradation, an effect only reduced when the higher degree of shading was used.

For 'Pérola', there was no significant effect for the interaction between the treatments. When the 'Pérola' pineapple was cultivated with soil plastic mulching, there was an increase in fruit dimensions, pulp pH and a reduction in SS content, and also a tendency for juice yield increase. Fruit covers, especially with use of shading screens, showed tendencies for reduction of pulp pH, increase of fruit length, soluble solids content and juice yield without significant changes on acidity, vitamin C content and pulp coloration. Fruit cover with paper reduced acidity and increased ratio in comparison to shading screen covers.

Confirming results from previous studies, 'BRS Imperial' produced smaller fruits with higher SS contents and ratio and lower juice yield than 'Pérola', which is known for its succulent fruits with lower fiber contents. Results showed that soil plastic mulching and fruit protection with shading screen, especially with a 50% shading degree, are practices that should be taken into account when setting up an organic cultivation system for pineapple under the environmental conditions of the Chapada Diamantina region, a highland zone in central Bahia State of Northeast Brazil.

News from Cuba

Effects of potassium chloride and potassium sulphate on 'MD-2' pineapple fruit yield and quality

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ABSTRACT.

A field experiment was carried out in the UEB Pineapple farm of Ceballos Agroindustrial Company (UEB; 21°47'N 78°48'W). Propagules of 'MD-2' pineapple (*Ananas comosus* var. *comosus*), approximately 300 g of fresh weight, were planted in 0.173 ha plots in March 2016. The planting density was 72,000 plants per hectare resulting in approximately 12,384 plants per plot. The treatments were standard UEB pineapple production system (CONTROL potassium chloride (KCL)) and UEB standard practice except KCl was replaced with SCPA SIVEX K-Leaf® (SCPA), which contained 20% less K as K₂SO₄. There were two replicates per treatment. Physical and bromatological analyses were performed on 10 fruits selected at random at harvest according to the criteria established by the UEB. The replacement of potassium chloride KCl with K₂SO₄ reduced the quantity of K but resulted in a significantly larger fruit weight (without crown) (1.66 for SCPA vs 1.34 for the CONTROL). The increase in fruit weight resulted from more fruitlets per fruit as well as a greater fruitlet mass (15.9 for the SCPA treatment vs 13.9 g the CONTROL). Fruit total soluble solids was slightly higher in the UEB treatment (13.4) than in the SCPA treatment (12.4) while there were no other notable differences in fruit characteristics between the two treatments. The results indicate that the use of K₂SO₄ makes it possible to reduce the amount of K applied with no significant reduction in average fruit weight or in fruit quality.

INTRODUCTION.

The pineapple (*Ananas comosus* var. *comosus*) occupies third place in world tropical fruit production, after bananas and mangos. It is cultivated to meet the food needs of the population and constitutes an important line for the production of preserves and sale of fresh fruit.

Since the last decade of the last century, the introduction of new cultivars has been encouraged, including the hybrid 'MD-2' (MD-2), which requires excellent agro-technology because of its susceptibility to stress, natural flower induction and fungal diseases. It also is recognized that MD-2 requires high levels of potassium and nitrogen, which must be supplied by frequent foliar fertilizations to achieve normal growth and development (Bartholomew, 2009).

Fertilization is among the most expensive items of agro-technical management of any crop, and it is also the cultural practice that requires more technical knowledge about the behaviour of soil and plants. An efficient fertilization program leads to economical use of the fertilizer, without reaching excesses or deficiencies, since in both cases they can limit the development of the crop (Leon and Kellon, 2012).

Foliar fertilization has become an important practice in many agricultural production systems because it allows the rapid and appropriate correction of nutritional deficiencies without over application, which supports optimum plant growth, produces high yields of fruit of the highest quality. Foliar fertilization does not substitute for soil fertilization but supplements soil nutrition and can supply certain nutrients during critical stages of cultivation or high nutritional demand, such as flowering and development of the fruits (Vieira Amorim *et al.*, 2011).

Potassium is one of the nutritional elements in greatest demand and pineapple requires high levels (600 kg/ha approximately) in the development cycle. Potassium sulphate (K₂SO₄) helps reduce soil pH, is required for normal functioning of plant stomata, and improves the use of phosphorus, iron and many other elements. Fruit of plants adequately supplied with potassium contain more pigments, which improve their

colour and appearance. The fertilization of pineapple with K_2SO_4 (completely or combined with KCl) showed better results than did KCl alone (Teixeira *et al.*, 2011).

Fertilization of pineapple with KCl decreases pulp color, increases acidity and reduces performance of the fruit compared to K_2SO_4 (Marchal *et al.* 1981). The application of excess Cl can cause burns on leaves under certain conditions. On the other hand, Cl increases the acidity of the fruit and KCl is recommended when fruits lack acidity (Py *et al.*, 1984).

The constant increase in the price of fertilizers causes producers to use them with greater efficiency to obtain adequate productivity so that economic costs are covered yet allows the plant to express its greatest productive potential.

Therefore, it is necessary to improve fertilizer supply practices during growth to increase crop nutrient absorption efficiency. The objective of the present work was to increase SCPA SIVEX potassium sulphate efficiency on MD-2 pineapple to reduce production costs.

MATERIALS AND METHODS.

The present work was carried out in the UEB Pineapple Production belonging to the Ceballos Agroindustrial Company (21°47'N 78°48'W). Fresh propagules of MD-2 pineapple weighing approximately 300 g were used. The soil is compacted red ferrallitic, which according to soil analysis data from the Soil Laboratory, Camagüey Province, has a pH of 4.5 and an organic matter level of 2.46%.

General procedures

The experiment was planted March 2016 in 0.173 ha plots with two replicates per treatment. The planting density was 72,000 plant ha⁻¹, which resulted in approximately 12,384 plants/plot. Plants were irrigated during the experiment with Central Pivot Machine (Western, marketed by TUSA SA) to maintain a soil moisture level close to 60% of field capacity. Foliar fertilizer spray applications were made by a machine having 76 nozzles and a capacity of 3,200 L. Eight foliar applications were made during the crop cycle, beginning in the fourth month after planting.

Experimental treatments

The experimental design was a randomized block with two treatments, each replicated in two plots. The experimental treatments were UEB pineapple production system standard practice (control, where K was applied as KCL (CONTROL) and UEB standard practice except the KCl was replaced by SCPA SIVEX KalifePotesse® potassium sulphate (K_2SO_4) with 20% less K (SCPA). K-Leaf® is soluble K_2SO_4 and at normal concentrations is compatible with most fertilizers except those containing calcium, which causes the precipitation of calcium sulphate ($CaSO_4$).

Natural flower induction occurred spontaneously in about 75-85% of the plants approximately eight months after planting. Plant weights in both treatments reached an average of 1.83 kg at the time of natural flower induction. When the basal part of fruits began to change color from green to yellow they were selected homogeneously in both treatments for bromatological analysis.

Quantitative, qualitative and chemical analyses were performed on ten fruits selected at the same stage of maturity at the time of harvest according to the criteria established by UEB. Chemical characteristics included total soluble solids (TSS), titratable acidity (TA), pH, and ascorbic acid (vitamin C). All chemical determinations were made with the respective methodologies of the Official Association of Analytical Chemistry (AOAC, 1998 and 1990). Fruit pH was measured using a potentiometer, TSS by hand-held refractometer and juice titratable acidity (TA, % as anhydrous citric acid) was by titration (a 2 g sample was diluted with 20 mL of distilled H₂O and was titrated with 0.1N NaOH). In fresh fruit the maturity index was calculated as the ratio TSS/TA. Ascorbic acid (vitamin C) concentration in the samples was analyzed by the AOAC method (1990).

The quantitative and qualitative physical characters evaluated were fruit length (cm), skin thickness, upper diameter (cm), lower diameter (cm), index of cylindricity (CI), depth of the eyes, mass of the fruit without crown, mass of the fruit with crown, number of spirals, number of eyes of the longer spiral and internal colour.

Statistical treatments of the results

The statistical treatment of the results was developed with the use of the utility "Statgraphics Plus". The Student's T-test and the Tukey's means test were performed ($p = 0.05$).

RESULTS AND DISCUSSION.

The fruits of the treatment to which K_2SO_4 was applied were significantly longer, had a thicker skin, had greater mass without and with crown and had a greater number of eyes when compared to the KCl treatment (Table 1). Treatment effects on fruit diameters and cylindricity index were not different.

Table 1. Physical data for MD-2 pineapple fruits . fertilized with two forms of potassium (n = 10)

Treat.	Length (cm)	Skin thickness (cm)	Upper diameter (cm)	Lower diameter (cm)	CI	Mass w/o crown (kg)	Mass w/ crown (kg)	Eyes/ spiral	No. Eyes the spiral greater
K_2SO_4	15,9 a	0,30 a	12,00 a	12,55 a	0,95 a	1,66 a	1,97 a	15,0 a	104,5 a
KCL	14,2 b	0,23 b	11,89 a	11,93 a	0,99 a	1,34 b	1,63 b	12,4 b	96,2 b
Signif.	*	*	NS	NS	NS	*	*	*	*

*Indicates significant differences ($p = 0.05$) NS = not significant.

Pineapple plants fertilized with K_2SO_4 produced significantly larger fruits, had significantly larger crowns and had a greater number of eyes per spiral. The larger fruit resulted from more fruitlets per fruit as well greater fruitlet weight (15.9 g vs 13.9g). Detrimental effects of KCl were assumed to be due to excess chlorine. In general, the use of K_2SO_4 as the potassium source in the pineapple nutritional program promoted superior results on pooled variables related to plant growth, compared with KCl (Mânica *et al.*, 1984, Teixeira *et al.*, 2011).

The form of the fruit at harvest is also an important quality feature for the three types of markets in Cuba. The results of this work show that there were no significant treatment effects on lower and upper fruit diameters. In the fresh market, the very cylindrical fruit is less appreciated and distances itself from the characteristics of the MD-2 hybrid, which makes the so-called reject fruit for the international market and is not exported. However, in the case of the industrial market, this cylindrical pineapple has a higher yield in slices, which means that this important production is not lost (Cruz, 2006).

The physical indicators of pineapple fruits are important for the commercialization moment, however, the chemical analyses denote the organoleptic quality of fruits. Fruit TSS and ascorbic acid levels were significantly greater in the KCl treatment than in the K_2SO_4 treatment while other fruit characteristics were not different (Table 2).

Table 2. Effect of potassium sources on MD-2 pineapple fruit characteristics.

Treatment	TSS (%)	Ascorbic acid (mg/100 mL juice)	Acidity (%)	Maturity index	pH
K_2SO_4	12,45 b	42,60 b	0,58 a	21,4 a	5,0 a
KCL	13,44 a	45,91 a	0,62 a	21,8 a	5,1 a
Signif.	*	*	NS	NS	NS

Each data represents the mean for n = 10. NS = not significant.

Fruit from plants fertilized with KCl had significantly higher TSS and ascorbic acid contents than fruit of plants fertilized with K_2SO_4 . Fruit TSS is indicative of the grade of maturity that the fruit has at the time of harvest, in the case of the pineapple (non-climacteric fruit) it is an important

indicator of quality, since once the fruit harvested it maintains its internal qualities. The average TSS for both treatments is below the optimal value for the harvest, when compared with results of the literature where it is proposed for the fruit of MD-2 can reach up to 18 °Brix at the time of harvest (Rodríguez *et al.*, 2016). In other studies, the use of K₂SO₄ resulted in improved fruit quality when compared to fruit produced by plants fertilized with potassium chloride (Mânica *et al.*, 1984, Teixeira *et al.*, 2011).

The maturity index is related to the optimum point of ripeness of the fruit, therefore it can indicate the appropriate moment of consumption. In pineapple MD-2, a significant decrease in the content of ascorbic acid was observed in the sulphate treatment compared to that of chloride. Pineapple is an important source of ascorbic acid comparable to citrus fruits and this content contributes to its nutritional value.

The pH of pineapple juice decreases as the state of full maturity approaches and this is another quality which can also serve as a criterion for harvesting. As a quality standard, the pineapple is required to have a pH value of 3.6. The pH of about 5.0 in both treatments is another indicator that they were at an optimum stage for harvest when it was performed.

Among the properties most perceptible by consumers are °Brix and titratable acidity, since they are the main responsible for flavour. For the fruits evaluated in this study, TSS and TA values were within the normal ranges resulting in fruit that has a sweet taste with ideal acidity and so would highly accepted by consumers.

CONCLUSIONS

- 1- Foliar application of potassium sulphate (KalifePotesse®) increased the fruit mass and, therefore, yields, but produced fruit with reduced TSS and ascorbic acid.
- 2- The replacement of potassium chloride with potassium sulphate (KalifePotesse®) in the UEB technological package is feasible since higher yields were achieved with less potassium while still producing fruit while the organoleptic quality of the fruits for exported is maintained.

ACKNOWLEDGEMENTS: The authors are grateful to MSc. Barbara Valle and Maria Teresa Gonzalez for the Bromatological analyses and to D.P. Bartholomew for editing suggestions.

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Foliar fertilization of 'MD-2' pineapple plants (*Ananas comosus* var. *comosus*) during the acclimatization phase

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Summary

Fertilization of vitroplants in the acclimatization stage is vital to achieve good adaptation to different conditions of in vitro culture. Pineapple has a 5 month period of acclimatization that can be diminished if new variants of fertilization are applied. The aim of this work was to evaluate the effect of three systems of foliar fertilization on morpho-physiological variables of micropropagated 'MD-2' pineapple (*Ananas comosus* var. *comosus*) during the acclimatization phase. Two new systems of fertilization every 15 days were compared with a control (established fertilization system). This system was based on the combination of products manufactured by the firms Meristem (FT1) and Inagrosa (FT2). Morphological and physiological variables evaluated were: plant length (cm), fresh and dry mass of the plant (g), fresh and dry mass of root (g). Fertilization with FT1 and FT2 achieved better development of pineapple plants in the five months of acclimatization compared to the control treatment. The best results are achieved in the variables length, fresh and dry mass of the plant, and fresh and dry mass of roots of plants that were fertilized with FT1.

INTRODUCTION

The need to increase pineapple production led Cuba to introduce the 'MD-2' pineapple hybrid to our province in 2009. This hybrid is characterized by high yields, a fruit with excellent organoleptic characteristics and bromatological quality that surpasses other varieties when cultural and fertilization requirements are met. A characteristic of this hybrid is that it produces few offshoots per plant, so to provide the planting material required to plant the 2,000 ha projection of the Ceballos Agroindustrial Company, it is necessary to create seed banks where the new propagules are developed.

In the Bioplant Center, a protocol was established for the production of pineapple plants by micropropagation (Daquinta and Benegas, 1997). Multiplication in temporary immersion bioreactors (Escalona et al., 1999) with a period of acclimatization that can reach 6 months (Yanes et al., 2000) causes this phase to increase production costs in the established micropropagation protocol.

Recent studies on the manipulation of environmental and substratum conditions has reduced this time to five months. However, work is continuing on reducing the time and on producing plants of higher quality that are better prepared for transfer to the field (Pino Legrat, 2014; Villalobo et al., 2012).

In the case of fertilization, the Bioplant Center established a fertilization scheme (Yanes et al., 2000) which has been used until now; however, no studies have been made of new fertilizers that have come to the market that could improve the morpho-physiological variables of pineapple seedlings. The objective of this work was to evaluate the effect of three foliar fertilization systems on morpho-physiological variables of micropropagated 'MD-2' pineapple (*Ananas comosus* var. *comosus*) plants during the acclimatization phase.

MATERIALS AND METHODS

This research was conducted in specialized laboratories and acclimatization areas of Bioplants Center at the University of Ciego de Avila, "Maximo Gomez Baez" (41° 53'N, 78° 41'W, 45 m asl) between January and May of 2016. The test material was micro-propagated 'MD-2' pineapple plantlets (*Ananas comosus* var. *comosus*) produced using the protocol of Daquinta and Benegas (1997).

Plantlets selected from plastic culture vessels were about 18.0 cm tall, 4.0 to 5.0 g fresh weight (FW), and had 5 or 6 leaves (Escalona et al., 1999). Plants were dipped in 3.0 ml L⁻¹ of Previcur Energy® (Bayer Crop Science) for 5 min and planted in 250 cm³ plastic containers filled with a 1:1 (v:v) mixture of

red ferralytic soil and sugarcane bagasse filter cake (Villalobo et al., 2012). Plants were acclimated into a greenhouse during three months under $80\% \pm 3\%$ relative humidity, $25.5 \pm 2^\circ\text{C}$ temperature and $250 \pm 25 \mu\text{mol m}^{-2}\text{s}^{-1}$ photosynthetic photon flux (PPF). Sprinkler irrigation was done for 30 min at 9:00 am daily. After these three months the plants were moved to nursery conditions, $72\% \pm 5\%$ relative humidity, $26.3 \pm 6^\circ\text{C}$ temperature and $800 \pm 60 \mu\text{mol m}^{-2}\text{s}^{-1}$ photosynthetic photon flux (PPF), for another two months. Covered with a mesh that allowed 75% of the solar irradiance during the first month in the nursery and then maximum solar irradiance throughout the day in the second month.

The fertilization treatments listed below were applied foliarly every 15 days using a backpack sprayer of 16 L capacity.

Control: (foliar application every 15 days with 16 g L^{-1} NPK (12-2-44) and 1 g L^{-1} MULTIMICRO (produced by Haifa-Micro™ and containing in %, 7.1 Fe, 3.48 Mn, 1.02 Zn, 0.76 Cu and 0.485 Mo).

Fertilization Treatment 1 (FT1): Based on fertilizers produced by Meristem® (CTA Stimulant 4, CTA Humus, Kafom Cu, Bullitem, Glucomer, Meristem 20-5-20) at doses recommended by the manufacturer for use on other crops.

Fertilization Treatment 2 (FT2): Based on fertilizers produced by INAGROSA® (Fosnutren 20, Aminol Forte 20, Humiforte 20, Nanoforte) at doses recommended by the manufacturer for use on other crops.

Table 1. Total nutrients applied plantlets/plants in the treatments below after 5 months of acclimatization.

Treatment	Quantity applied per treatment in g										
	N	P	K	Fe	Mn	Zn	B	Cu	Mo	Mg	Free aminoacids, (%)
Control	19.5	3.0	66	0.71	0.35	0.10	0	0.08	0.049	0	0
FT1	5.31	3.37	6.48	0.05	0.07	0.07	0.005	0.1	0.005	0.48	1.11
FT2	2.1	2.22	1.6	0.43	0	0	0	0	0	0.65	1.84

FT1: Fertilization Treatment 1, FT2: Fertilization Treatment 2

Each treatment consisted of 300 plants. Each month 30 plants were collected per treatment and plant length (cm) and the fresh and dry weights (g) of the tops and roots of each plant was measured. Percentage dry matter was calculated for samples collected at 120 and 150 days after treatments began by the equation:

$$\text{DM, \%} = \frac{(\text{DW})}{(\text{FW})} \times 100$$

Where DW = plant dry weight (g) FW = plant fresh weight (g).

Statistical analysis.

Data were analyzed using the statistical software package Statistica v. 8.0 (Statsoft Inc., Tulsa, OK, USA, <http://www.statsoft.com>). Before carrying out statistical tests the normality of data was checked by “Kolmogorov–Smirnov statistic” ($P > 0.05$) and variances homogeneity by “Levene’s test” ($P > 0.05$). Data was compared by “ANOVA” ($P < 0.05$) and “Tuckey multiple comparison test” ($P < 0.05$).

RESULTS AND DISCUSSION

The plant length (Figure 1) was greater in fertilization treatments 1 and 2 with significant differences from the control treatment observed after 90 days. Treatments FT1 and FT2 grew 19.6 and 19.7 cm respectively, while the control reached 16.1 cm. Note also that there was a marked and significant decrease in plants length up to 90 days. This is assumed to be associated with physiological and morphological changes that occurred as plants were adapting to natural, and possibly more stressful, environment. Pineapple plants in vitro have a morphology characterized by long, narrow and thin leaves. These characteristics are due to conditions of low light intensity

(40-80 $\mu\text{mol m}^{-2}\text{s}^{-1}$ PPF), low concentration of carbon dioxide and high concentration of sucrose in the growth medium. When the plants are subjected to higher values of light intensity (more than 250 $\mu\text{mol m}^{-2}\text{s}^{-1}$ PPF) there is a change in the metabolism from C3 to CAM and accompanied by a change in the structure and morphology of the leaves becoming wider and shorter. (Aragón et al., 2012; Rodríguez-Escriba et al., 2015).

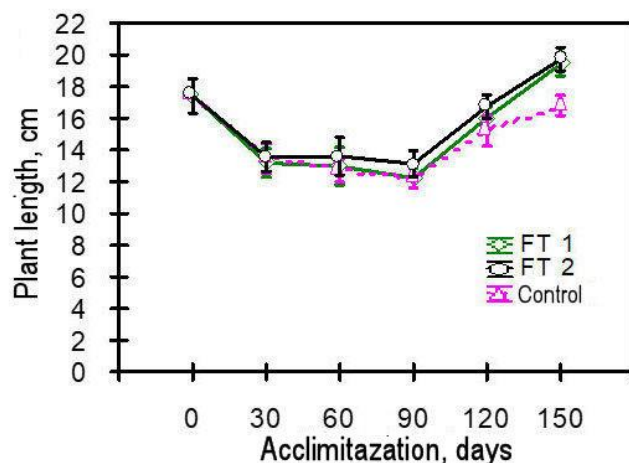


Figure 1. Effect of fertilization treatments on plant length (cm). Each point represent the mean of $n=30$. The vertical bars show the dispersion of the standard error of the mean. Bars that do not overlap indicates a significant differences for $\alpha = 0.05$. DIA: days

It is appreciable that treatments 1 and 2 despite having lower concentrations of macronutrient, cause further growth in plants.

Unlike plant length, increases in fresh and dry mass (Figure 2) follow typical exponential plant growth curves. This exponential growth is because although there is a shortening in the size of the plant in the first 90 days of acclimatization, as a result of the change in metabolism and morphology, the photosynthetic and storage tissues are increased in response to new conditions, drier and with less nutrients compared to *in vitro* conditions. At 150 days after treatment, the highest fresh mass obtained for the FT2 treatment while the highest dry mass was obtained with the FT1 treatment.

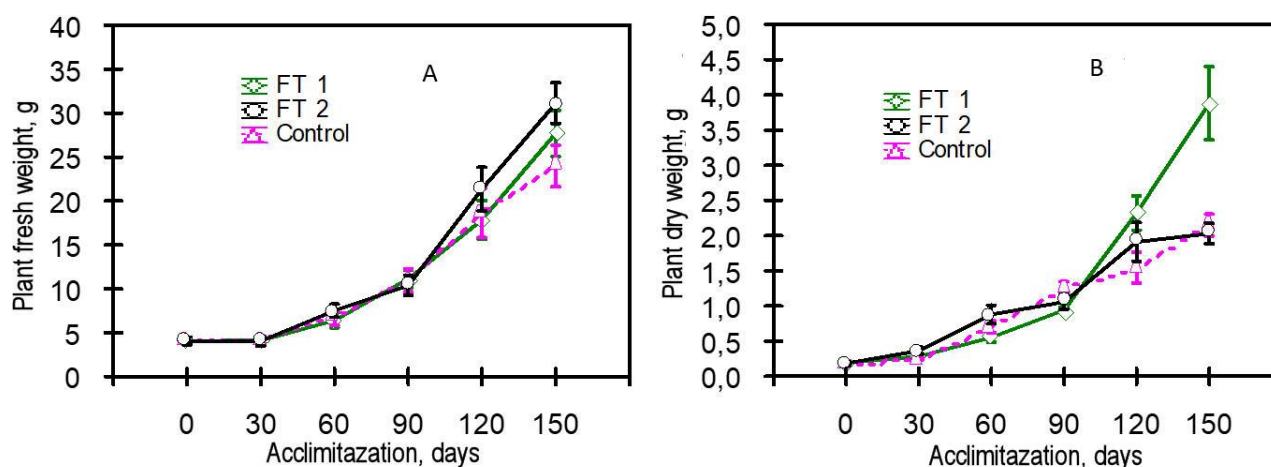


Figure 2. Effect of fertilization treatments on fresh (A) and dry (B) weights of the plants. Each point represents the mean of $n=30$. The vertical bars show the dispersion of the standard error in the mean. Bars that do not overlap means that there are significant differences for $\alpha = 0.05$. DIA: days in acclimatization.

It is very interesting how plants of the FT1 treatment after 120 and up to 150 days, reach the highest values in fresh mass but only 2 g of dry mass of the 31 g of fresh mass registered at 150 days.

Table 2 shows that FT1 maintains higher values of dry matter content in the hardening period compared to the other treatments, which indicates a greater production of photosynthetically active and reserve tissues. This facilitates the transit to the field and a possible greater survival of these plants in comparison with the other treatments

Table 2. Content of dry matter at hardening stage in relation with fertilization treatment.

Days in acclimatization	FT1	FT2	Control
120	18,2 ± 0,90	9,8 ± 0,57	9,9 ± 0,80
150	14,7 ± 0,62	7,6 ± 0,29	9,6 ± 0,48

Values in the cells represent the mean of n = 30 ± the standard error of the mean.

The relationship between the fresh mass and the dry mass is recognized, since that is an indicator of creation of tissues in the plant as a function of the photosynthetic and nutritional state. It can be increased in fresh mass but this does not necessarily indicate a growth of photosynthetic tissues but it can be an accumulation of water and more in a CAM plant with great development of water-bearing tissues such as pineapple (Bartholomew et al., 2003; Bartholomew et al., 2002)

On the other hand, the variables fresh mass and dry mass of the root (figure 3 A and B) show that after 90 days of acclimatization the FT1 treatment reaches the highest and most significant values compared to the other treatments in the variable masses Fresh, this behavior was maintained until the evaluation performed at 150 days. In the evaluation of the dry mass (figure 3 B) FT 1 showed as in the previous evaluation a better behavior.

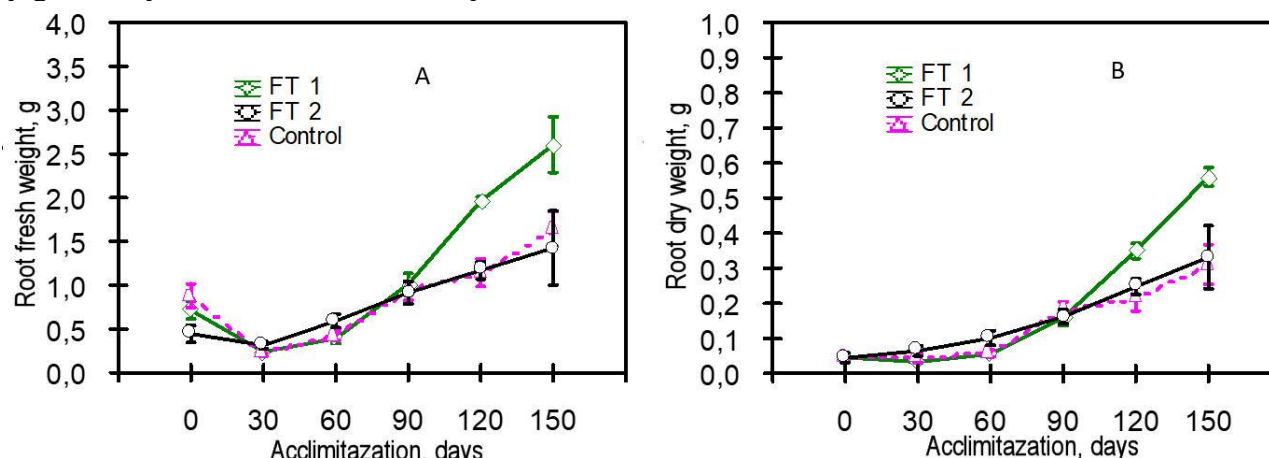


Figure 3. Effect of fertilization treatments on the variables of the fresh weight of roots (A) and dry weight of roots (B). Each point represents the media of n=30. The vertical bars show the dispersion of the standard error in the mean. Bars that do not overlap means that there are significant differences for $\alpha = 0.05$. DIA: days in acclimatization.

It can be summarized that the FT1 treatment improved the dry and fresh mass of the roots significantly, with respect to the control and the FT2 treatment. This shows that there was a balance in the growth of the aerial and radicular part of the plants under these treatments. Not being the case of the FT2 treatment where there was an increase of the fresh mass and the length of the plant (figure 1 and 2), but a poor production of dry mass (figure 2) and little development of the roots (figure 3).

CONCLUSIONS

The pineapple plants fertilized with the FT1 and FT2 treatments showed greater length and fresh weight of the plant compared to the control. The FT1 treatment also showed better performance in dry weight of the plant, fresh mass of the root and dry weight of the root. This treatment was superior to FT2 and to the control with respect to these variables.

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to D.P. Bartholomew for his editing suggestions.

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News from Hawaii (U.S.A.)

Permission to publish the following three documents reporting on research done by the Pineapple Research Institute of Hawaii (PRI) in Pineapple News No. 25 was given by Daniel Nellis, President, Pineapple Growers Association of Hawaii (PGAH) by email to Duane Bartholomew on August 15, 2018.

It is believed that the three articles would be of interest for the following reasons.

The paper by Medcalf (1949) is the first found/known reporting on research on the possibility of using climatological data in plantation operations. The effects of temperature on plant growth were observed centuries ago and the summing of temperature information and relating it to plant phenology dates to the 18th century (Wang, 1960). Modeling of pineapple is a rare activity that apparently began at the Hawaiian Pineapple Company (later named Dole Pineapple Co.) plantation on Lanai Island, Hawaii (Medcalf, 1949).

The paper by Thorne (1950) reports on very early research on the effects of water supply on the physiological responses of pineapple. Similar data may have been produced elsewhere but no publications were found on the effects of water supply on leaf elongation.

The paper in this issue on foliar fertilization suggests that the exhaustive research of Williams (1960) on pineapple seedling culture may provide useful information to who propagate pineapple seedlings or plantlets produced by micropropagation.

Medcalf, J.C., 1949. I. Some Use of Climatologic Data in Plantation Operations. PRI Seminar Summary March 4:3-22.

Thorne, M.D., 1950. A Preliminary Report on Irrigation of Pineapples. PRI Seminar Summary May 5:1-10.

Wang, Jen Yu. 1960. A Critique of the heat unit approach to plant response studies. Ecology, 41, 785-790.

Williams, D.D.F., 1969. Seedling production technique at PRI. PRI News 17:69-96.

Some use of climatologic data in plantation operations

Abstract of Monthly SEMINAR SUMMARY
March 4, 1949

James C. Medcalf II

James Medcalf of the Hawaiian Pineapple Company will discuss some of these applications developed by that Company for this purpose.

The primary objectives in our climatological investigations have been as follows: First, to evaluate the interrelationship of all essential factors of production in terms of plant and fruit response; and second, to determine how the controllable factors of production can best be manipulated to take advantage of the environmental background. Since we are using the pineapple plant as the integrator of all these factors, the crop log has been our basic yardstick for measuring plant and fruit response.

As a practical example of how some of our weather studies have been put to use on the Plantation, we might turn first to the use of temperature records as a means of estimating fruit harvest. Before we go into the actual technique of using these temperature records in estimating fruit ripening, it might be well to spend a while describing our method of reporting air temperatures.

The Air Temperature Growth Unit method for reporting air temperatures

As you probably know, it is generally customary to report air temperatures as the average of the maximum and minimum. This method is very simple and for many types of studies it is entirely adequate. However, where air temperatures are to be used in conjunction with plant growth studies, this simple method has certain obvious disadvantages. What is needed is some simple method of weighting temperatures which will take into account the differential growth rate of pineapple plants at high and low temperatures.

Temperature weighting values, based on the relative growth of pineapple crowns grown in constant temperature chambers, have been utilized for this purpose. These weighting values were developed some years ago by Dr. Nightingale and are based on greenhouse studies conducted by Carl Farden. Pineapple crowns were grown in a dark chamber under constant temperature conditions. Temperatures ranging from 45°F to 100°F were employed. The elongation of young crown leaves during a one-week exposure period to any given temperature was measured, and the resulting data used to plot the curve shown in Figure 1 (*all figures can be found at the end of the document*).

The difference in the growth-wise effectiveness of a degree of temperature from 50° to 90°F is obvious. For example, one degree of temperature in the 75° to 80°F range has approximately five times the effectiveness of one degree of temperature in the 50° to 55°F range.

Using these leaf elongation values for the various temperatures, a series of weighting factors were devised. For convenience, a weighting factor was assigned to each 5° temperature range from 50°F to 95°F. These weighting factors are listed in Figure 3. This system of reporting air temperatures is known as the Air Temperature Growth Unit Method. To obtain the Air Temperature Growth Units for any weather station for a given interval of time, the following steps are employed. (See Figure 2 for thermograph tracings of a typical summer and winter day). The Air Temperature Growth Unit information listed on Figure 3 was taken from these tracings.)

Step I. Using the 5°F temperature range listed in Column 1, Figure 3, draw a series of lines across the thermograph chart. These lines are drawn merely to assist in collecting the data described in Step II.

Step II. Determine the total number of hours that the thermograph tracing remains within each 5° temperature range. These values are listed in Figure 3 under the column titled "Total Hours."

Step III. The total hours in each 5° range is then multiplied by its appropriate weighting factor. The sum of the product is the Air Temperature Growth Units for the interval of time concerned. In Figure 3, totals of 15.01 and 8.20 Air Temperature Growth Units were accumulated in a twenty-four-hour period of a summer and winter day respectively.

As can be readily seen, the Air Temperature Growth Units for a typical summer day are almost twice those for a winter day. In other words, where neither moisture nor any other growth factor is limiting, we can expect the growth of pineapple plants to be almost twice as rapid in the summer as in the winter. A study of crop logs and Air Temperature Growth Unit records under a wide range of conditions in Hawaiian Pineapple Company fields have shown that this sort of temperature versus growth correlation does exist.

The Air Temperature Growth Unit also affords a convenient yardstick for evaluating calendar time in relation to plant growth. It is, in essence, a "physiological yardstick." We have already seen from Figure 3 that a typical summer day may have almost twice the growth potential of a typical winter day. Likewise, one year of calendar time in a cool area will have relatively much less "growth potential" than one year in a warm area, all other factors being the same, such as moisture, planting material, fumigating, etc. By the same token, for any given area, the "growth potential" for a given period of calendar time, such as a day, week or month, will vary throughout the year.

These differences in "growth potential" on an area and time-wise basis are shown in Figure 4. In this figure the long term (an eleven year period) monthly average Air Temperature Growth Units for a typical cool and warm area on Lanai are shown by a series of bar graphs. In the warm Palikaholo Area the average annual total of Air Temperature Growth Units is 4,250, as against 3,560 for the cool Waiakeakua Area. This amounts to an annual difference of 690 units. Growth-wise this would be equivalent to about two months of growing time. Or to put it another way, under conditions of adequate moisture, 12 months of growing time at Palikaholo are approximately equivalent to 14 months at Waiakeakua. The relative "growth potential" of

a typical February (coolest month) versus a typical August (warmest month), in either area, is also self-evident.

These differences on either an area or time-wise basis are of considerable magnitude and worth consideration in the long-range planning of plantation operations.

The Air Temperature Growth Unit also lends itself nicely to comparing differences in time of planting as related to "growth potentials" between areas or for various times of the year within any given area. This is illustrated by the following comparison of September 1st and December 1st versus a March 1st and June 1st planting date in the Waiakeakua and Palikaholo areas (Table 1). The Air Temperature Growth Units for this comparison are taken from Figure 4.

Table 1. Comparison of Air Temperature Growth Unit totals between various dates of planting – cool versus warm areas.

Month	Palikaholo (warm)	Waiakeakua (cool)	Difference
September	390	340	50
October	391	329	71
November	350	291	59
Total	1131	960	171 (18%)
March	313	271	
April	331	243	
May	364	305	
Total	1008	819	189 (23%)

Fruit estimation by the Air Temperature Growth Unit method

Although the weighting factors used in the Air Temperature Growth Unit Method were based on the elongation of pineapple leaves, this system of reporting temperatures has been the basis of what appears to be a promising method for estimating the time of fruit harvest. Presumably the effects of temperature on leaf elongation and fruit development are quite similar.

Numerous observations over the past years have demonstrated that temperature has a profound effect on the rate of ripening of pineapple fruit. Fruit ripening on plants in cool, cloudy areas may take as much as two months longer than fruit ripening on plants in warm, sunny areas. Records on Lanai have shown that a difference in average air temperatures of only 2°F may bring about a difference of five weeks in time of ripening.

Accumulated Air Temperature Growth Unit totals have been used to forecast the time interval from forcing and/or half-inch open heart to harvest. The assumption is made that the total Air Temperature Growth Units required for any interval of fruit development is constant.

On this basis, the date of harvest for a particular field could be tentatively made on the day the forcing agent was applied, providing certain temperature data were available. First, a thermograph station would be required in, or reasonably near, the field in question. Second, a long series of past temperature records, preferably not less than ten years, should be available so that future expected monthly Air Temperature Growth Unit totals could be projected on the basis of past values.

A typical calculation of the estimated harvest date for a plantation field forced with A.N.A. is presented in Figure 5. Past studies show that for a field of this sort, 2,600 Air Temperature Growth Units would be required from the date of forcing to three-quarter ripe fruit. The various steps in the fruit estimation calculation are as follows:

Step 1. The long-term monthly average Air Temperature Growth Units, based on eleven years of past records, is listed in the column headed "Expected." For example, for the period from June 15th to June 30th, if the weather followed an average pattern based on past records, 189 Air Temperature Growth Units would be expected.

Step 2. The "Expected" values for each month are listed together with the accumulated total. As of December 31, 1948, providing the weather followed an average pattern, a total of 2,464 Air Temperature Growth Units should be accumulated. This leaves a balance of 2600 - 2464 = 136 units as the balance required from December 31, 1948, to the estimated harvest date.

Step 3. The expected Air Temperature Growth Unit total for January is 302. This is equivalent to $302 \div 31 = 9.74$ units per day. Since we anticipate that 9.74 Air Temperature Growth Units will be accumulated per day, it will require $136 \div 9.74 = 14$ days to accumulate a total of 136 units. Therefore, it is anticipated that the Air Temperature Growth Units total of 2,600 will be reached on January 14, 1949.

Actually, the field reached a peak of harvest on January 11, 1949, with an actual accumulated Air Temperature Growth Unit total of 2,640. Thus, seven months in advance of harvest, it was possible to forecast the harvest peak with an error of only three days.

Naturally, there will be years when the weather will deviate considerably from the expected pattern. It may be warmer than expected, in which case Air Temperature Growth Units will accumulate at a faster rate to bring the fruit in early, or it may be cooler than expected, in which case the harvest date will be delayed.

In this method of fruit estimation, however, it is possible at all times to compare the actual and "expected" accumulated Air Temperature Growth Units. Corrections to the original estimated date of harvest can thus be made as we go along.

To illustrate the extreme in harvest date which might be experienced for the field under consideration, Air Temperature Growth Units for the coolest and warmest years on record (eleven-year record: 1938 to 1948) are shown in Table 2.

In forced plant crop fields with small plants, fruit exposure is at a maximum due to the long peduncle, absence of slips and vegetative carry-over plants. Under such conditions, about 2,600 Air Temperature Growth Units are generally required from forcing to harvest and 1,750 to 1,800 from 1/2 inch open heart to harvest.

In lush growth and irregular fruiting plant crop fields, or in ratoons, fruit exposure is at a minimum and as many as 2,900 Air Temperature Growth Units are required from forcing to harvest and 2,000 Air Temperature Growth Units from 1/2-inch open heart to harvest.

Some typical Air Temperature Growth Unit totals for these various conditions are shown in Figure 6. The plant crop experiments in this Figure are arranged in order of the increasing plant size and lushness of growth (decreasing fruit exposure). Air Temperature Growth Unit totals in these cases range from 1,796 to 2,040. This is equivalent to a difference in time of ripening of about two and a half weeks during the summer months when Air Temperature Growth Units are accumulated at the rate of about 14 units per day.

Table 2. Comparison of air temperature growth unit (A.T.G.U.) totals, from the closeout force with α naphthalene acetic acid to harvest for a cool (39-40) and a warm (42) year¹. Expected A.T.G.U.s are based on average monthly temperatures for the past 11 years.

Month	Actual A.T.G.U. 1939-1940		Actual A.T.G.U. 1942		Expected A.T.G.U.	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
June 15-30	159		201		189	
July	361	520	430	631	407	596
August	367	887	441	1072	408	1004
September	345	1232	420	1492	390	1394
October	350	1582	416	1908	391	1785
November	304	1886	382	2290	348	2133
December	297	2183	313 ³	2600	331	2464
January	277	2460	201		189	
February	140 ²	2600	430			

¹Warmest and coolest years experienced in eleven years of records from the same thermograph station as used in Figure 5.

²February 1-15; closeout to harvest, 8 months and 6 days.

³December 1-26; close-out harvest 6 months and 14 days.

In order to take into account the effects of fruit exposure on the Air Temperature Growth Unit totals to be used in the fruit estimation calculation, logs of fruit exposure are made. An Air Temperature Growth Unit total, based on previous experience with fields or experiments showing approximately the same degree of fruit exposure as the field in question, is then used in the final calculation.

The possibility that periods of extremely dry weather may introduce an error in the Air Temperature Growth Unit method has also been considered. Information that is presently available suggests, however, that the effects of drought are not important unless the drought is extremely severe and prolonged. In Figure 6, the values from irrigated and unirrigated crops are shown, and as can be seen, the Air Temperature Growth Unit totals for both are essentially the same. Studies are continuing along these lines to determine at what point a moisture deficit within the plant may influence the rate of fruit maturation.

Growth rates as related to climatic and agronomic factors

We have already seen that reliable estimates of the time of fruit harvest can be made from temperature records. Of equal, if not greater, importance to the plantation are estimates of future plant performance which could be made during the vegetative growth period.

Is a field going to carry-over or fruit in the normal harvest season, when can we anticipate the peak of differentiation, and what will be the plant size at differentiation? These are just some of the questions which the practical field man would like to know; and the earlier in the growth stage that they can be answered, the better.

Growth rate provides some indication of time of differentiation. To determine the growth rate we have used leaf weights almost exclusively. Initial studies made on Lanai in 1944 indicated that leaf weights are a good index of the growth trend in pineapple plants. The same bundle of ten leaves used for the regular crop log leaf analyses is weighed to obtain leaf weights. The weights are reported in grams and are the average of ten leaves. Some typical leaf weight versus time curves for a series of plantation fields planted with slips are shown in Figure 7.

It was soon apparent that, as in the case of most of the crop log measurements, the trend of the growth curve was as important as any single point along the curve. With good growing conditions it was also observed that the leaf weight curve for slip plantings generally leveled off at an average leaf weight of between 80 to 95 grams. Considerable significance is attached to this feature of the curve. Whenever this "leveling-off" in the leaf weight curve occurred by the fall or early winter of the intermediate year a high percent of "normal" budding was recorded. This situation is shown in Figure 7, leaf weight curves 1 and 2. In contrast, when through a combination of climatic and agronomic factors the leaf weight curve fell short of the 80-gram level prior to the intermediate winter, very little "normal" budding occurred, see Figure 7, curve 3.

The "leveling-off" of the leaf weight curve marks the stage in plant growth where further gains in plant weight are largely the result of an increase in the number of leaves of this maximum size. Furthermore, in any given area, there is a direct correlation between total plant weight at differentiation or red bud and the date of intersection of the leaf weight curve with the 80 gram line. This is shown by the leaf weight curves in Figure 7. The plants in curve 1 which attained the 80 gram level in July 1948 reached a total plant weight of 10.5 pounds by January 1949. The plants in curve 2 did not attain the 80 gram level until September 1948, and reached a plant weight of only 6.6 pounds by January 1949.

This "leveling-off" in the leaf weight curve between 80 and 95 grams evidently marks a critical stage in plant growth. At this stage the plant is extremely sensitive to the environmental factors generally associated with floral differentiation, such as low temperatures, day length, etc. From what little data is available for sucker plantings, it appears that the "leveling - off" of the leaf weight curve may occur at a slightly lower weight range than for slips. This would account for the somewhat earlier budding which is commonly observed in sucker plantings.

Plants which do not attain an 80 gram leaf weight by the intermediate fall or early winter period tend to carry-over completely with very little budding until the following fall. Practically no budding occurs during the warm summer months even though leaf weights of over 80 grams are attained. This is presumably due to the absence, at that time, of the environmental factors which are believed to be associated with floral differentiation.

The estimation of (1) whether a field will carry-over or fruit normally and (2) the approximate plant size at red bud is directly related to the future trend of the leaf weight curve. An estimation as to when the leaf weight curve will level off in the 80-95 gram range has been used as a means of answering these questions.

A study of many leaf weight curves of the same sort as those shown in Figures 7 and 8 tells us that the attainment of a satisfactory leaf weight by the intermediate fall depends on two factors:

1. The point on the vertical (Y) or leaf weight axis where the growth curve starts; in other words, the size or leaf weight of the planting material (slip, sucker or crown).
2. The slope of the curve or the favorability of all growth factors such as moisture, temperature, fertilizers, fumigants, etc. With all these factors at optimum the curve will rise at a steep rate. Weather studies come into the picture at this point to help tell us the effects of rainfall, temperature, and sunlight on the growth curve.

The effects of an adequate moisture supply on the leaf weight curve are shown in Figure 8. In this experiment, irrigation of a February planting of 18 ounce slips in a warm area enabled the plants to attain a leaf weight of 80 grams nine months after planting. 80 to 90 percent normal fruiting was obtained in these plots. With the same size of slips and date of planting but without irrigation, the leaf weight curve showed a much slower rate of increase. A leaf weight of only 40 grams was reached in these plots nine months after planting. Close to 90 percent carry-over was recorded.

Similar growth responses due to available moisture are also presented in Figure 7. The plants in curves 2 and 3 with essentially similar air temperature growth unit totals from planting to December 1, 1948, received considerably different amounts of rainfall. The plants in curve 2 with a total of 38 inches of rainfall made good vegetative growth and reached the 80-gram leaf weight by September 15, 1948. The majority of these plants subsequently budded. The plants in curve 3 with only 23 inches of rainfall exhibited a very poor growth curve and fell far short of the 80-gram level during the intermediate winter. Very little budding occurred, in fact, these plants were eventually treated with hormone to bring about budding.

From experiments employing a range of slip sizes under both irrigated and unirrigated conditions, it has been found that the leaf weight attained at any stage of vegetative growth is directly related to slip size at planting. Earlier intersection of the leaf growth curve with the 80-gram leaf weight line, earlier budding and larger total plant weight at red bud, all have been found to be directly related to the size of the planting material employed. These facts seem quite logical when we realize that a high leaf weight (large slip, sucker, or crown) at planting simply means that a plant has less distance to go along the growth curve to eventually reach a leaf weight of 80 to 95 grams. Plant size, which would otherwise have to be "bought" with additional growing time, is instead obtained "gratis" at the start of the "race."

This relationship suggests the possibility of evaluating differences in growth units between planting dates in terms of the weight of planting material. Information of this sort should be helpful in determining planting schedules. For example, suppose that a six-ounce slip planted on October 1st is found to be equivalent growth wise to a 16-ounce slip planted on December 1st. What is the sum of total available growth units (rainfall, temperature, and sunlight) equivalent to this ten-ounce difference in slip weight? Or the question can be posed the other way around: what size of slip should be planted in December to compensate for the growth units that can be anticipated (again we make use of past weather records) in a given area, between October 1st and December 1st?

An attempt has been made to bring together this sort of information by means of graphs that show the relationship between slip weight at planting and the number of air temperature growth units required from planting to the 80-gram leaf weight under three different moisture conditions (Figure 9). The data used in constructing these graphs were taken from actual experiments.

Graph 1 is based on information from a series of irrigated experiments employing various sizes of slips. The relationship here is presumably one of slip size versus temperature with moisture not a limiting factor. Graphs 2 and 3 are from two unirrigated experiments under different amounts of rainfall. In these graphs the interval from planting is a function of slip size, temperature, and moisture. The limiting effects of inadequate moisture are indicated by the shift of both graphs to the right of graph 1. Thus, in comparison with graph 1, any given weight of slip under the moisture conditions of graphs 2 and 3 required a greater number of air temperature growth units to reach the 80-gram leaf weight.

Figure 1 (below). Comparative elongation of pineapple leaves as affected by temperature. Note the almost complete cessation of growth at temperatures below 50°F and the drop in growth at temperatures above 90°F. The "weighting" values employed in the air temperature growth unit method of reporting temperatures are based on the relative rates of leaf elongation shown by this curve.

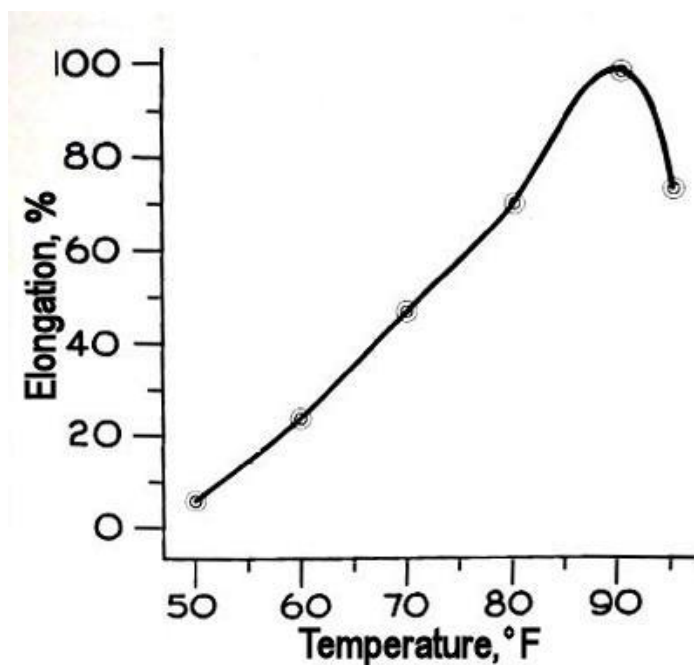


Figure 2 (below). A reproduction of a thermograph tracing for a typical winter and summer day. Note the greater number of hours during which the tracing remains above 70°F in the case of the summer day as contrasted to the winter day. The air temperature growth unit calculations for these two days are presented in Figure 3.

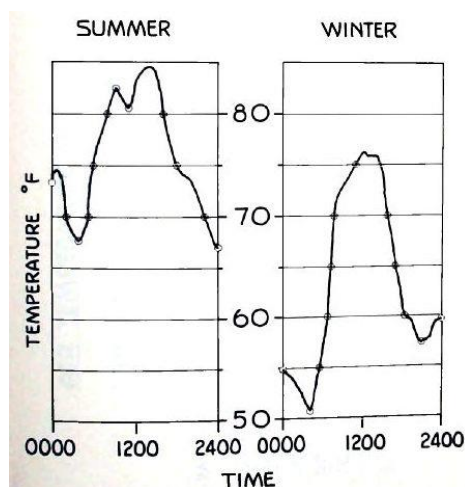


Figure 3 (table below). Calculation of the air temperature growth units for a typical summer and winter day based on the thermograph tracings shown in Figure 2. The number of hours that the thermograph tracing remains in each five degree temperature range is listed in the column titled "Total Hours." These values are in turn multiplied by the appropriate weighting factor to give the air temperature growth units for each five degree temperature range. The sum of these products, listed in the two columns on the right hand side of the table, is the total air temperature growth units for the 24-hour period. Based on their respective air temperature growth unit totals and under conditions where no other growth factors are limiting, the "growth potential" of a typical summer day is almost twice that of a winter day.

Temperature Range, °F	Total hours		Weighting factor	A.T.G.U.	
	Summer	Winter		Summer	Winter
50 - 55		5.50	0.12		0.66
55 - 60		6.75	0.20		1.35
60 - 65		2.00	0.31		0.62
65 - 70	5.25	1.75	0.43	2.26	0.75
70 - 75	6.75	4.25	0.55	3.71	2.34
75 - 80	4.00	3.75	0.66	2.64	2.48
80 - 85	8.00		0.80	6.40	
Total				15.01	8.20

Figure 4 (below). Monthly average air temperature growth units based on eleven years of past records for cool Waiakeakua and a warm Palikaholo area on Lanai, Hawaii. Note the area and time-wise differences in air temperature growth units. The difference in average annual air temperature growth unit totals for these two areas is 690 units or a difference of 18 percent. The relatively greater "growth potential" of the warm area is thus clearly demonstrated by the air temperature growth unit technique. Differences of even greater magnitude are apparent when comparing summer and winter months in either area. Equal calendar periods may thus have greatly different "growth potentials" depending on the area and time of year concerned. The air temperature growth unit, therefore, is the logical "yardstick" to employ when comparing calendar time differences in relation to pineapple plant growth.

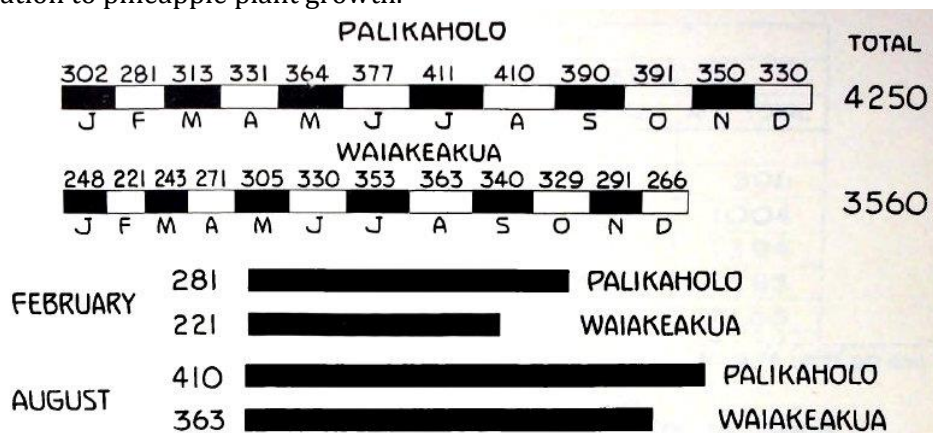


Figure 5 (tale below). Calculation of the estimated fruit harvest peak seven months in advance of harvest by means of the air temperature growth unit method. At the time of forcing with α -naphthalene acetic acid (ANA) on June 15, 1948 it was estimated that 2,600 air temperature growth units would be required to bring the fruit to the harvest peak. Monthly "expected" air temperature growth units (based on eleven years of past records) were then projected from the forcing date to estimate the future date 2,600 air temperature growth units would be accumulated. This estimated date of harvest was January 14, 1949 while the actual date occurred on January 11, 1949.

Interval	Actual A.T.G.U		Expected A.T.G.U	
	Interval	Summed total	Interval	Summed total
June 15 - 30	184		189	
July	447	631	407	596
August	424	1055	408	1004
September	405	1460	390	1394
October	393	1853	391	1785
November	354	2207	348	2133
December	326	2533	331	2464
January 1 - 11	107	2640	136	2600

Figure 6. Typical air temperature growth unit totals obtained in various experiments in both plant crop and ratoon fields for α -naphthalene acetic acid (ANA) closeout and half-inch open heart to peak harvest periods. The plant crop experiments are arranged in approximate order of decreasing fruit exposure from top to bottom. Note the greater number of required air temperature growth units under conditions of poor fruit exposure. Logs for fruit exposure made at time of hormone closeout or half-inch open heart are the basis for determining the proper air temperature growth unit total to employ for any particular set of conditions.

Experiment number	Crop	Total A.T.G.U.s	
		ANA closeout to harvest	½" open heart to harvest
8. 5. 2. 15	Plant		1796
16. 4. 2. 24	Plant		1804
8. 5. 2. 16	Plant		1947
16. 4. 2. 25	Plant		2040
16. 4. 2. 25 - irrigated	Plant		2027
2. 3. 2 18	Plant	2591	
2. 3. 220	Plant	2656	
16. 4. 2. 35	Ratoon	2879	1994
16. 4. 2. 36	Ratoon	2800	1948
2. 6. 2. 3	Ratoon		1966

Figure 7. Typical leaf weight curves for three plantation fields. The dates of planting are indicated by the circled numbers along the left hand edge of the time scale. The first logs of leaf weight were not collected until some months after planting and explain the fact that the curves do not extend back to the planting date. Field 1, a spring planting, with a long growth period attained the 80 to 95-gram leaf weight range well in advance of the intermediate fall and close to 100% normal budding was recorded. Field 3 planted in the fall in a warm but dry area was handicapped by inadequate moisture. This is reflected in the relatively flat leaf growth curve which failed to reach 80 grams by the intermediate fall. Close to 100% carry-over was observed in this field. Field 2, a late summer planting in a cool area, with close to an adequate supply of moisture, attained an 80 gram leaf weight during the intermediate fall resulting in a high percent of normal buds. Being in a warm area, Field 3 was potentially capable of achieving a satisfactory leaf growth had moisture not been a limiting factor. This is demonstrated by the leaf growth curves in Figure 8.

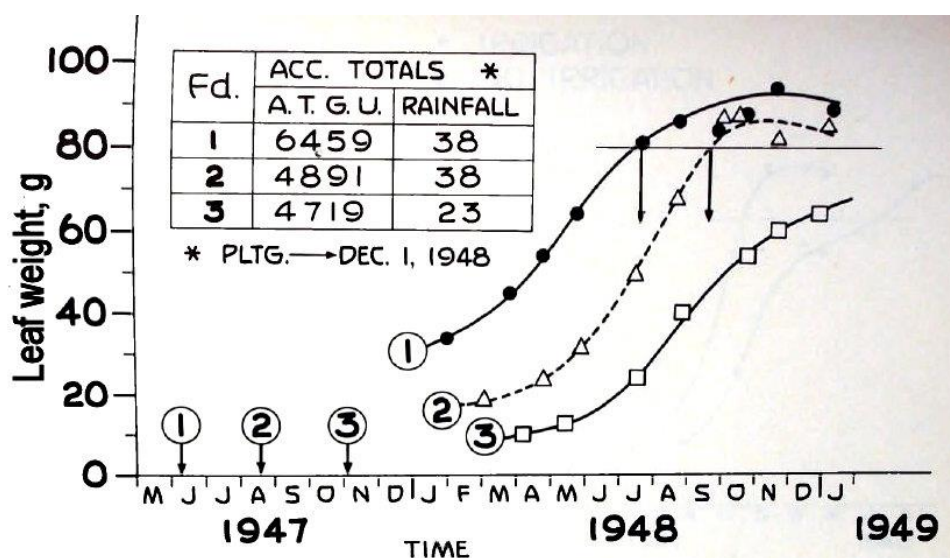


Figure 8. Effects of irrigation over time (months) on the leaf growth curve in a warm but dry area. Irrigation in a February planting of large (18 ounce) slips resulted in an extremely steep leaf growth curve during the summer and fall months with the attainment of an 80 gram leaf weight in the intermediate fall 9 months after planting. Compare this leaf growth curve with that of Field 3 in Figure 7. Approximately 90 percent budding was recorded in the irrigated plots. The unirrigated plots received only 9" of rainfall during the first 9 months following planting, most carried-over (little or no budding). This factor coupled with the short growing period available from planting to the intermediate fall was reflected in inadequate leaf growth. The majority of these plants carried-over. Note that large slips alone are not the panacea for eliminating carry-overs. Rather for most effective results, optimum slip size for planting must be determined on the basis of the total growth units expected from planting to the intermediate fall period.

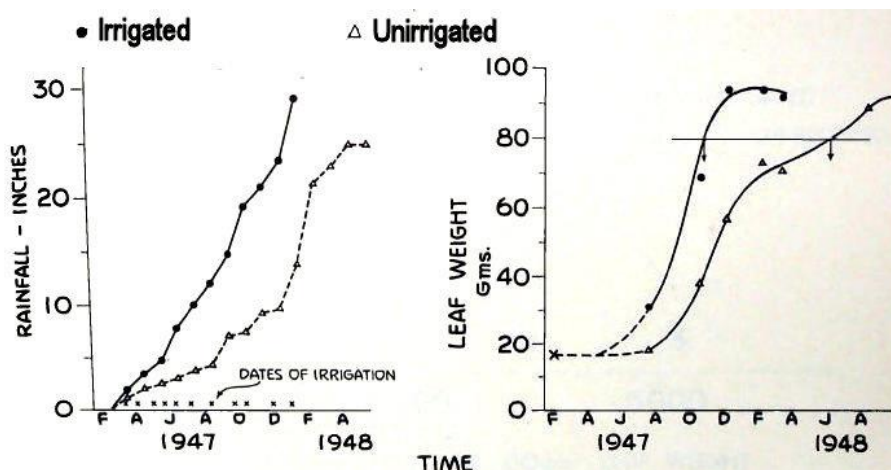
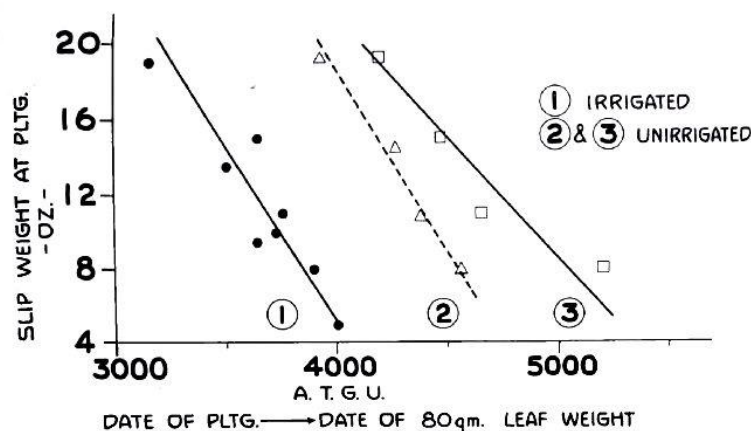


Figure 9. The curves in this figure represent an attempt to evaluate the rate of pineapple leaf growth in terms of slip weight at planting, soil moisture and air temperature growth units (A.T.G.U.). Three separate curves representing an irrigated planting and two different unirrigated plots. The x-axis scale is essentially one of time, but uses the air temperature growth unit, our "physiological unit" of time. For any particular set of moisture conditions it is apparent that there is essentially a linear relationship between slip weight and the air temperature growth units required from planting to the 80-gram leaf weight. This is merely another way of saying that large slips will reach the 80-gram leaf weight ahead of small slips regardless of moisture conditions. Note, however, that for any given size of slip the growth period from planting to the 80-gram leaf weight increases as moisture becomes limiting.



A preliminary report on irrigation of pineapples

Pineapple Research Institute of Hawaii Abstract of Monthly Seminar Summary

May 5, 1950 Department; Soils

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M.D. Thone

History of Irrigation of Pineapples

Experimental irrigation of pineapples "began in some of the very early plantings in Hawaii. An area in Waiava Valley was irrigated in 1893 by J. P. Keppeler, according to Wadsworth's report in *Planters' Record*, Volume 37, Page 148, 1933. Irrigation was "by furrows" between the rows with applications at ten-day intervals. Keppeler reported remarkable yields of fruit and planting material. Mature fruit weighing from 12 to 15 pounds was secured in from 14 to 18 months. Despite such reported yields, the venture was unsuccessful, and the practice of irrigating pineapples seems to have been dropped for a long period following this.

Experiment with Maui Pineapple Company. In 1933, W. A. Baldwin reported in *Pineapples News*, Volume 7, Page 54, the results of a field experiment with Maui Pineapple Company at Pulehu, Maui. No details are given except, he stated, that the check plots failed to fruit, while irrigated plots produced fruit with an average weight of 4.12 pounds. Previous to this, Sideris and Krause had made a study in the greenhouse of water requirement of pineapples. They used three soils at six moisture contents to determine the required soil-moisture content for pineapple growth under these conditions (perhaps Sideris, C.P. and Krauss, B.H., 1928. *Water relations of pineapple plants*. *Soil Science* 26:305-314.).

Experiment with Libby, McNeill & Libby on Maui. In 1933, Linford and Magstad conducted an experiment on a Libby field at Makawao, Maui, to determine the effects on fruit quality of irrigation two weeks before harvest. The addition of water to wet the soil to a depth of 24 inches or more resulted in a fruit weight increase of 10 percent, and an increase in sugar content with a corresponding decrease in acidity.

Experiments of Hawaiian Pineapple Company. Beginning about 1936, a number of irrigation experiments were conducted by Hawaiian Pineapple Company men on their two plantations. James C. Medcalf's summary of the Lanai experiments follows later in this report.

Early PRI Experiments. About 1942, a series of experiments was begun at PRI under the direction of Beatrice H. Krauss. The effects of irrigation for various lengths of time during the interval between red bud and harvest of fruits were studied in a greenhouse experiment. A small plot experiment at the PRI Station at Wahiawa was made to study the effects of a drought period of three months at various stages of plant growth, both before and after differentiation.

In 1944, an experiment was conducted at the Koko Head garden of the Institute to determine irrigation results under field conditions. The area received unusually heavy rains which tended to minimize the differences due to irrigation. Considerable soil variability was also encountered. However, increases in fruit size and slip numbers resulted from irrigation in these small, unreplicated plots. This study, reported in detail in *PRI Monthly Report*, 1944, Pages 257-276, demonstrated the desirability of future field experimentation in irrigation.

Recent Cooperative Experiments. In 1948, an experiment was initiated cooperatively between CPC and PRI on Molokai. This was essentially an expansion of exploratory experiments previously conducted by the company. This first cooperative irrigation experiment produced plant-

crop fruit in 1949, and the results will be given later. Three more experiments on Molokai and one on Oahu have been begun cooperatively between PRI and CPC.

A demonstration experiment was started in cooperation with Maui Pineapple Company in 1949. No fruit yields can be reported for this as yet. A more complete experiment is now in progress with this company, and more information will be given about it later.

Four cooperative experiments with Hawaiian Pineapple Company were begun on Lanai within the past year. More details of these experiments will be given subsequently.

Objectives of Irrigation Research

Maximum Returns from Water Available. The main objective of research on irrigation of pineapples might be most simply stated as the attainment of the maximum returns from the amount of water available for irrigation. This would differ somewhat from the aims of an irrigation program where water is abundantly available. At the present time, however, there is a limited supply of water that can be used for irrigation of pineapples, and it is possible that there may never be completely adequate amounts.

The criteria for determining just what are the maximum returns will vary for different plantation requirements. It is always desirable to produce the greatest amount of fruit of satisfactory quality. However, where planting material is in critical demand, it may be more desirable to attain a high production of such material, even at the expense of fruit production. Uniformity of harvest date of a given field is, of course, highly desirable, and it may be that some persons would give this top priority in an irrigation program.

Best Methods of Application. To obtain the maximum returns from a given amount of irrigation water, we must determine the most advantageous methods, rates, and times of application. The two main application methods in use in other regions are the surface and the overhead types. The surface method of application requires little equipment and is generally lowest in cost. Use of mulch paper would interfere with effective surface applications of water for pineapples. Surface application is also very wasteful of water, and this loss will usually more than offset any saving in application costs. Three variations in the overhead method of application have been used for pineapples: (a) revolving sprinklers, (b) perforated pipes, and (c) spray-boom trucks. The effect of wind on the pattern of distribution makes use of revolving sprinklers unsatisfactory for most areas. In field trials with winds of about 20-mile-per-hour velocity, the stream will shoot only about 10 feet upwind while it may go 100 feet or more downwind. It is also impossible to avoid considerable loss of water on field roads when revolving sprinklers are used. This loss may amount to more than 10 percent of the water applied. The use of perforated pipe gives a much better distribution pattern in the presence of wind. The manpower requirements for moving this pipe are high, however, and it is a correspondingly more expensive method.

Spray-boom trucks have been used quite successfully for irrigation of pineapples. For both commercial and experimental irrigations, the water has been supplied to the truck by regular tank supply trucks or by a hose reel from a pipe line or pump. It is possible to attain a more nearly uniform application in the presence of winds with the spray-boom method of application. It gives the most efficient use of water, since little is wasted on roads and no overlapping is necessary to insure uniform coverage, as is the case with sprinkler and perforated pipe but the cost may be higher as explained below. The nozzles can be aligned over the plant rows, and this will result in deeper penetration in the actual root zone from a given amount of irrigation water with less of the water going into the cultivator space. A shaping of the bed at planting time to leave the bed lower than the interspace should also help to attain the best utilization of irrigation water.

If the water is supplied to the boom through a hose, it is cheaper to put on the entire amount desired in successive passes back and forth over the area before uncoupling the hose. This sometimes becomes objectionable because it causes runoff on sloping land. Loss of water, fertilizer, and topsoil results from such runoff. If trash-mulch culture is successfully adopted in regions that could be irrigated, this objection would be minimized. If water supply is by tank trucks, the boom truck may make the interval between successive passes over any area sufficient to eliminate runoff.

Preliminary figures indicate that the spray-boom method of application is not appreciably more expensive than sprinklers or perforated pipe when the hose-reel supply is used. If tank trucks are used for supply, the costs run much higher. Experimental work is being carried on in cooperation with the various companies to determine the most satisfactory and economical method of application under the different conditions encountered. From these experiments will come data for fruit and planting-material production. Cost-of-application data cannot be secured satisfactorily in these experiments, of course. These will have to be secured in large-scale applications by the various interested companies.

Best Rates and Frequencies of Application. Studies are underway to determine the best rate and frequency of application for different conditions. These will vary with the age of plants, since there seems no point in wetting the soil below the depth to which the roots reach at the respective stages of growth. The rate and frequency of irrigation applications required for best efficiency is also affected by the properties of the soil involved. Probably the most important soil property in this connection is the moisture holding characteristic of the soil.

Moisture-Holding Characteristics of Soil. Anyone who has squeezed water from a sponge or wrung water from clothes has found that as water is removed, it becomes harder and harder to get the next bit out of the material. While there are basic differences between a soil and a sponge, they are quite similar in this respect. As more and more water is removed from the soil by plants or by any other means, increasingly greater effort is required to get out the next amount.

Soil and plant scientists have devised means of expressing the increasing difficulty of removal of water in terms which may be easily learned by anyone. We express this as the energy necessary to remove equal amounts of water as the soil is dried out. We can determine the number of atmospheres of air pressure which are needed to force the water out of the soil and through a membrane. Suppose, for example, we apply 10 atmospheres (or 10 times 14.7 lbs. per square inch) of pressure to a certain soil which has been saturated in contact with the membrane. After the water has stopped coming through the membrane, we find the soil has 25 percent moisture remaining in it. This would mean that at a moisture content of 25 percent, this soil held its moisture with an energy of 10 atmospheres. This energy is called the soil-moisture tension value. So, we would say that the 10-atmosphere tension value for this soil is 25 percent.

Moisture -Release Curves. In a similar manner, we may determine the tension values for all soil-moisture contents between saturation and wilting point. We then may draw a curve showing exactly how soil-moisture content varies with the tension. This is usually called a moisture-tension curve or a moisture -release curve. This curve shows us just how "available" the water will be to plants at different soil-moisture contents. Figure 1 gives the moisture-release curves for the soils upon which some of the cooperative irrigation experiments are located.

The moisture content of the soil layer which has been wetted by a rain or irrigation and which has been drained by gravity is called field capacity. The moisture tension at field capacity is about one-third of one atmosphere. Actually field capacity is hard to determine for soils as high in clay content as most of those on which pineapples are grown. However, we can easily determine the one-third atmosphere value or the moisture equivalent, which is also about equal to the one-third atmosphere value.

Field Measurement of Soil Moisture. Moisture-release curves give an indication of the manner in which field moisture-measuring instruments will operate for a given soil. Tensiometers, for example, will not perform satisfactorily at tensions above about two-thirds of one atmosphere. For many soils, this covers more than half the range of available moisture. For the soil from CPC, Field 86 on Oahu, as represented by curve 3 in Figure 1, this statement holds very well. Tensiometers have been found to operate satisfactorily in this experiment. For the soil in CPC Field 315 on Molokai, as represented by Figure 1, graph 1, however, only about one-third the available moisture is found at tensions less than two-thirds of one atmosphere. In the experiment in this field, the soil dried beyond the range of operation of tensiometers much more quickly after an irrigation. Tensiometers have not given entirely satisfactory results in this experiment.

The electrical conductivity methods for determination of soil moisture appear to be better adapted to use for irrigation work with pineapples than are tensiometers. The Bouyoucos and Coleman instruments are the best-known of the electrical type. These measure the resistance to the passing of an electrical current through a small element buried in the soil. The resistance of this element varies with its moisture content and hence with the moisture content of the soil. These instruments will give an indication of moisture content throughout most of the available range. The readings are subject to error if the soluble salt content changes appreciably, and it may be expected that fertilizer applications may exert an influence. However, these instruments have been used for one year now in an experiment with satisfactory results.

If plants are grown in the soil without any water being added, the soil-moisture content will obviously steadily decrease. Eventually, the plants cannot obtain sufficient moisture to maintain their vigor, and they wilt. The moisture content of the soil at the time plants will not recover from the wilt is called the permanent -wilting percentage. The permanent wilting percentage for most

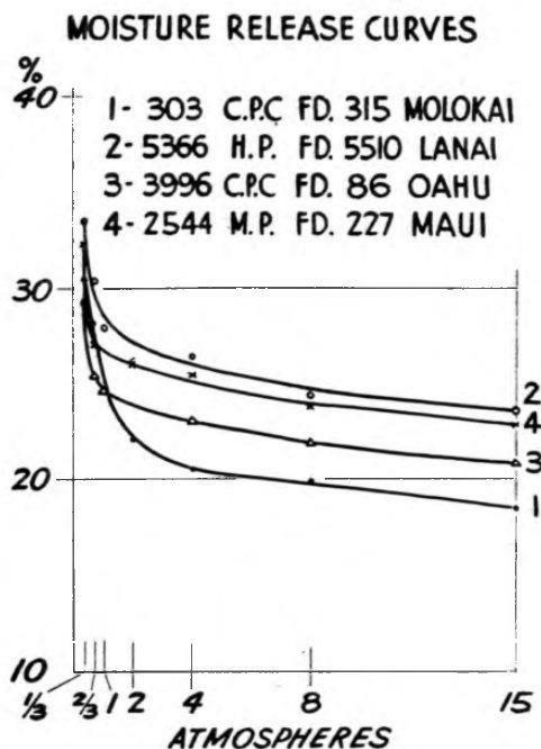


Figure 3. Moisture release curves of soils on which some cooperative irrigation experiments are located. These show the decrease in moisture content which results when pressure is increased to force the moisture out of the soil. The pressure is measured in atmospheres and corresponds to the tension or energy with which the remaining moisture is held in the soil.

plants corresponds to 15 atmospheres tension. The amount of moisture in any soil between the field capacity (or one-third atmosphere value) and wilting point (or 15-atmosphere value) is called the "available moisture." Thus, if one-third atmosphere value is 30 percent and 15-atmosphere value is 20 percent, there is a 10 percent available moisture content for that soil.

Moisture Tension as Criterion for Irrigation Need. We are using a number of soil-moisture tension values in our present experiments to determine the value at which it is most profitable to irrigate. Obviously, we cannot maintain the soil at any one tension value throughout the experiment. The alternative is to allow the soil to dry until the desired tension value is reached and then apply the irrigation. It will require a great deal of experimental work under a number of different soil and climatic conditions to provide a solution to this problem.

Plant Indexes for Irrigation Need. The use of plant indexes for determining irrigation need are also being studied. Leaf-water deficiency and leaf-moisture content are being investigated as well as leaf-growth rates. Mr. Medcalf will discuss these further in his report.

Cooperative irrigation experiment, California Packing Corporation (CPC) Field 3I5B, Molokai

W. R. Gill*

* Mr. Gill of PRI, who prepared the following summary of the results of this experiment, presented this at the seminar in the absence of R. B. Chambers, who would have represented the company in giving the report.

Most of the cooperative irrigation work has been started only recently. Hence, there are little yield data from such experiments as yet. We have plant-crop results from the first test started with California Packing Corporation on Molokai.

This experimental area was planted in November 1947 and irrigations begun in the summer of 1948, as originally designed, there were two methods, two frequencies, and two rates of application.

The revolving-sprinkler method proved unsatisfactory because of strong winds in this locality. No data will be presented from these plots because the rate of application varied so much throughout the plots as to render meaningless any statement about amounts of water applied. A regular booms-pray truck was used to apply water to the remaining plots. Either two acre-inches or one and one-half acre-inches were applied per irrigation.

During the first summer, irrigations were made whenever the soil moisture dropped to one of two contents. One set of plots was allowed to dry to wilting point (19%) and another to dry to 4 percent above wilting point (23%). For the plant-crop pre-harvest irrigations, two additional frequencies were included by splitting the original plots. These two new treatments consisted of irrigating whenever soil moisture dropped to 25% or to 27%.

Trash-plus-paper plots were included in the test, both with and without irrigation. Seventy tons of trash per acre were placed in the cultivator spaces after planting. The old ratoon had been turned under during a two-year fallow period.

The entire experiment was hormone forced, but some plants were too small to differentiate. Fruit weights and suckers per plant for this experiment are given in Table 1. The rainfall received is given in Table 2.

There was not sufficient replication of treatments in the experimental data in Table 1 to allow detailed comparison between the various irrigation treatments. This experiment does

indicate the possibilities of irrigation research and has provided much valuable information for guidance in later experiments.

Table 1. CPC field 315-B, Molokai plant crop results 1949.

Irrigation treatment		Fruit wt., lbs.	Fruiting, %	Tons/acre	Suckers/plant
1948	1949				
Mulch paper, no trash					
None	None	2.60	29	6.51	0.20
None	4"	3.25	30	8.42	0.28
8"	None	3.23	92	20.68	0.70
8"	6"	3.67	95	30.12	0.88
Trash plus mulch paper					
None	None	4.38	88	33.30	0.86
None	4"	4.41	87	33.15	0.90
8"	None	4.17	97	34.95	0.88
8"	6"	4.78	98	40.13	1.05

Table 2. Inches of rainfall at CPC field 315-B, Molokai.

Month	1947	1948	1949
Jan.	0.70	5.85	5.76
Feb.		4.58	3.27
Mar.		0.00	0.12
Apr.		1.00	0.4
May		0.06	0.00
Jun.		0.08	0.13
Jul.		0.00	0.12
Aug.		0.00	0.00
Sep.		0.36	0.00
Oct.		0.00	0.00
Nov.		0.82	0.96
Dec.		0.51	1.27

It is interesting to note that while the trash mulch without irrigation gave good yields in this experiment, this was not true for an experiment installed in an adjacent area the next year. During the exceptionally dry summer following the 1948 fall planting in the latter experiment, the plants made so little growth, even with trash mulch, that practically no fruit was produced in unirrigated plots. In 1948, there were six consecutive months having less than one-half inch rainfall, while in 1949 there were eight such

months. It would seem that the one-inch rain in April 1948 and the 0.36 -inch rain in September 1948 accounted for most of the difference in moisture status of the non-irrigated trash-mulch plots for the summer of 1948 as compared to 1949. It is of interest also that the September 1948 rainfall all

fell during one day, thus probably providing for maximum utilization under these conditions.

Questions and answers

Question: Is the figure for average suckers in the CPC experiment computed on the plants fruiting or on the total population of the plot?

Answer: It is computed on the basis of total plants in the plot.

Question: When were irrigations applied?

Answer: In 1948, irrigations were in July, September, and November. In 1949, May, June, and July. Of course, each plot was not irrigated every time. The total amounts applied are shown in Table 1. The plots receiving 8 inches had four 2-inch applications and those receiving 6 inches had four 1-1/2 inch applications.

Hawaiian Pineapple Company's (HPACO) irrigation studies on Lanai

James C. Medcalf, Hawaiian Pineapple Company*

* The Hawaiian Pineapple Company began irrigation investigations on Lanai more than ten years ago. This was followed by detailed studies, and a great deal of information has been accumulated to date. The company has given permission to Mr. Medcalf to present to the industry the results of investigations carried on at Lanai under his direction.

Introduction

The material reviewed in this portion of the Seminar was taken from irrigation experiments conducted on Lanai by the Hawaiian Pineapple Company. Much of this work was exploratory in nature and served largely to define the problems involved. As anticipated, these early experiments brought many new problems regarding irrigation which are now being studied.

Objectives of Lanai Research. These objectives may be briefly outlined as follows: (a) on-schedule fruiting with a minimum of holdovers and three complete crops in a five-year cycle; (b) large, good-quality fruit; and (c) adequate slip production i.e. numbers, size, and early maturity.

Under the severe drought conditions which often persist on Lanai, experimental data have indicated that it may be difficult to completely achieve these objectives, especially on-schedule fruiting, if irrigations are withheld until the final differentiation period.

Proper Timing. Early in these experiments, it was apparent that proper timing is most important if maximum gains are to be obtained from irrigation. It was found that the pineapple plant was most responsive to adequate moisture at two stages of growth: the predifferentiation and the preharvest

periods. Adequate moisture applied to drought-stricken plants at these times was invariably associated with striking gains in both growth and fruit yields.

Fertilizer applications were most effective at all stages of growth when irrigations were timed to insure adequate nutrient availability to the plants. The crop log proved to be an invaluable guide in coordinating these two operations.

Plant Size and Leaf Weight. The attainment of on-schedule fruiting has been found to be closely associated with plant size. Unless a reasonably large plant could be produced by the intermediate fall, plant-crop fruiting was generally delayed. Adequate plant size at differentiation is thus considered as much a desired objective as such things as 15% No. 1 color or leaf potassium.

A fairly good idea of the minimum-size plant necessary in the fall months to insure heavy on-schedule fruiting has been obtained from an historical survey of Lanai field and experimental log data. Expressed in terms of D-leaf weights, this minimum size appears to range between 65 and 85 grams, depending on other factors such as plant composition and plant maturity.

Desired or par leaf weights for various stages of vegetative growth have also been tentatively established from these historical studies. In more recent experiments, irrigation schedules have been extended to cover most of the vegetative period. Monthly leaf weights have been used as a yardstick of growth. Plotted graphically, they afford a convenient picture of growth trends.

Current growth trends can be compared with par values taken from appropriate historical curves. Some estimate of probable crop performance may then be made, depending on whether current trends are above or below the par values. This technique, along with other log values, applied to irrigation experiments, affords a means of appraising the efficiency of irrigation practices during the vegetative period.

The growth curve has also served to focus attention on the seasonal change in the growth-producing value of water. This value is never a fixed quantity. It changes according to the age of the plant and the season of the year. During the warm months from June to November, when moisture is

available, growth is rapid. Water at this time has a high growth-producing value. In the winter months, the growth curve is very flat; temperature rather than moisture is the limiting factor. Water at this time has a very low growth-producing value.

Interaction with Other Practices. Similarly, the growth curve emphasizes the interplay of many practices, other than irrigation in achieving the objectives of irrigation. Planting material and time of planting and trash mulch are outstanding examples. Late -fall planting dates, coupled with small planting material, represent initial handicaps that often may not be overcome even with adequate irrigation. The growth curves enable us to measure the degree to which such factors may limit optimum performance. Such information can be of considerable help in determining how best to distribute a short supply of irrigation water over the plantation in time of drought.

Whenever water has been limiting, crop-log and yield differences between irrigated and unirrigated plots have been extreme. In most cases, this information has been obtained from experimental areas irrigated during only a portion of the vegetative and fruiting periods. Soil moistures in only one or two portions of the available range were usually tested simultaneously. In other instances, soil moistures were allowed to fluctuate over a broad range, often in the drier end of the scale. In this earlier work, it was not possible to evaluate in terms of the soil-moisture energy scale, the moisture contents.

New Experiments. To complete the irrigation picture, it therefore seemed desirable to obtain growth, crop-log, and yield records from plants maintained both continuously and intermittently at various soil-moisture levels throughout the available range. By using comparable moisture tension values instead of comparable moisture percentages in the different experiments, the comparison of results will be on a more logical basis. Both the vegetative and fruiting periods must be considered.

New experiments have been installed during the past year to collect this information. As many as four soil-moisture tension values are being studied simultaneously with and without trash mulch. Under dry Lanai conditions, these treatments, during the vegetative period, may involve a range in total water applied of from 10 to 30 acre-inches. The plan calls for evaluating the growth and yield data against the irrigation costs to arrive at an efficiency rating for each soil-moisture tension value.

Considering these new experiments along with past data, it seems quite likely that the law of diminishing returns will come into play at the higher moisture levels. There are good indications that the most efficient soil moisture level in terms of yield per unit of water applied may be at or slightly above the midpoint in the available moisture range.

Monthly leaf-weight measurements have been helpful in defining broad overall growth responses to irrigation. This measurement, however, is not sufficiently sensitive to be used as a week-to-week guide for scheduling irrigation applications in the field. Letting the plant tell us when to irrigate may be especially useful in ratoons. There is good reason to believe that under stress there may be water movement within the plant from the mother plant to the ratoon sucker. It seems logical to believe that the effects of such water movement on growth are more apt to be detected by a plant index.

Leaf-Elongation Measurements. In our search for a suitable index, we have again turned to the pineapple leaf. Initial trial of this new technique in irrigation experiments was made on Lanai in the spring of 1949. In this technique, the rate of elongation of the young heart leaves is measured. Under favorable growing conditions, these leaves may grow as much as 4 inches per week. A small portable metal measuring device, illustrated in Figure 2, is used to take these readings. A metal pipe is driven into the ground next to a group of plants to serve as a permanent bench-mark. The measuring device is then placed on the bench-mark, and a reading is taken on one heart leaf of each plant. By means of a sliding arm as many as 7 or 8 plants can be measured from one bench-mark. One week later, the same leaves



Figure 2. Leaf elongation meter, a portable instrument for measuring leaf elongation. A metal pipe is driven into the ground as a permanent bench-mark. The meter is placed on the pipe and the height of a heart leaf of 7 or 8 plants is measured at each location.

from these plants are again measured, and the average increase in height is reported as the weekly leaf elongation. For convenience, the measurements are reported in millimeters. One millimeter is equivalent to about 1/25 of an inch. This technique is relatively accurate and rapid. In one day, a team of two men can take about 500 individual measurements.

Whereas leaf weights afford only a monthly picture of leaf growth, leaf elongations are sensitive enough to show daily trends. In fact, through the use of suitable magnifying devices even hourly trends may be observed.

Leaf Elongation and Soil Moisture.

The first question to be answered was whether this technique was responsive to changes in soil moisture. Preliminary information on this point was obtained from irrigation experiments in progress during the dry summer and fall of 1949. Typical curves are shown in Figure 3 and in a different form in Figure 4.

It was evident from an examination of these data that the rate of leaf elongation was intimately associated with the soil-moisture supply. When soil moistures during the summer were in the wet end of the available range, weekly leaf elongations often were as high as 80 mm. As soon as soil moisture diminished, leaf elongations decreased. At the recorded.

Several other interesting features were also apparent from these initial experiments. These were in connection with the response of leaf elongation to air temperatures.

Leaf Elongation and Air Temperature. As anticipated, leaf elongation proved to be very sensitive to temperature changes also. One or two days of low daytime temperatures were usually sufficient to cause a measurable drop in the weekly rate of leaf elongation. This is illustrated by the drop in

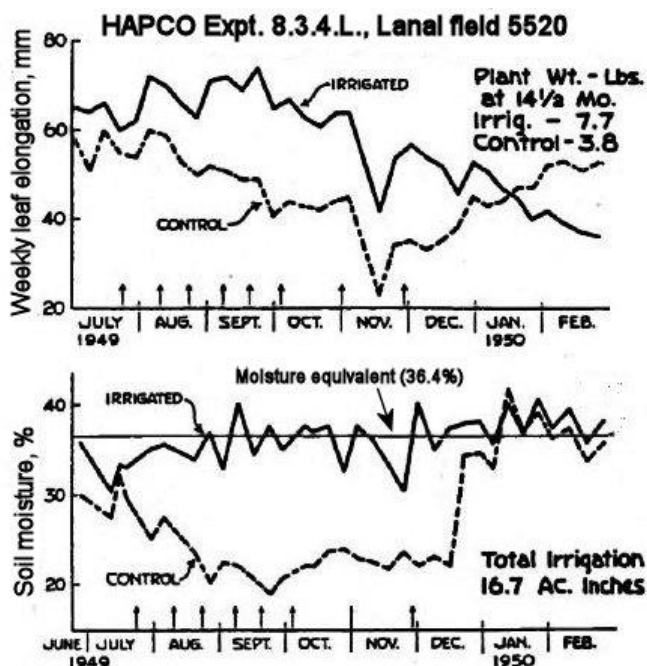


Figure 3. These graphs illustrate the typical relationship between leaf elongation and soil moisture observed in many Lanai irrigation experiments. This correlation between soil moisture and leaf elongation suggested the possibility of employing leaf elongation as part of a practical irrigation index. The steady decrease in leaf elongation in the large irrigated plants during the winter was apparently associated with the initiation of floral differentiation (50% red bud was recorded in March). Vegetative growth all but ceases at red bud. A period of cold weather in mid-November resulted in a sharp drop in leaf elongation.

Wilting percentage, values of 30 to 40 mm were

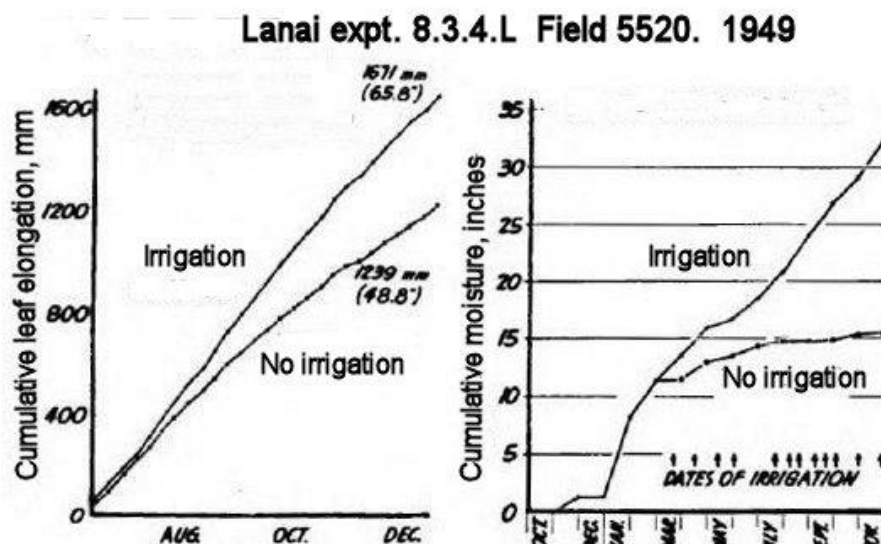


Figure 4. These graphs, based on the data of Figure 3, show both the rate and the cumulative increase in length at any given date. The irrigation graph shows rainfall plus irrigation while the no-irrigation graph shows rainfall plus irrigation.

weekly leaf elongation in the curves in Figure 3. Response to temperature for irrigated and unirrigated groups of plants was almost identical. Curves for the two move up and down in remarkable unison even though their absolute rates differed greatly. This suggests that the response of pineapple plants to temperature is relatively similar over a wide range of moisture conditions. For any given area and providing other growth factors are not limiting, temperature will determine the maximum possible growth rate.

These preliminary observations indicated that the leaf-elongation index might have real possibilities as a practical guide to irrigation when used to compare treatments in which moisture is the main variable. This idea is based on the assumption that differences in leaf elongation between adjacent

groups of plants were a measure of the degree to which water was limiting. In other words, leaf elongation was assumed to be the plant's expression of all limiting factors resulting from lack of moisture.

Many limiting factors may be involved, some directly, others indirectly. These might range from lack of water per se for normal growth processes within the plant to inadequate leaf N-P-K brought about by nutrient unavailability. Crop-log measurements, such as No. 1 color, leaf-water deficiency, and leaf analyses, would be used to determine the ways in which lack of moisture was exerting its greatest limiting effect.

Roots and Soil Moisture. The root log would also be an important part of this picture. Damage to the root system by soil pathogens could very seriously limit moisture uptake and reduce leaf elongation. Expenditures of irrigation water to correct this situation would be extremely inefficient and wasteful. In this case, soil-moisture measurements would indicate that irrigation was not necessary, even though the plant was in moisture stress.

In using leaf elongation as a practical guide to irrigation applications, we are again faced with the question of the most efficient level of growth to maintain during the vegetative stage. Should large quantities of water be applied to maintain the rate of elongation at the maximum set by prevailing temperatures or would lesser amounts be more efficient and economical? These are practical questions which must be answered before we can make best use of water.

The experiments in which various soil-moisture levels are being tested should furnish much helpful information along these lines. Some of the data, accumulated on these experiments, are shown in the figures in this report.

Irrigation at Planting

Immediate Objectives: Set plants and stimulate early root development.

Results: Most fall-planted experiments show only slight or no gain. Growth differences generally wiped out by usual fall and winter rains.

Remarks: High-rainfall probabilities during fall and winter make significant or economic responses doubtful. With prolonged drought, however, and especially in spring plantings, significant gains may be more likely.

Irrigation During Mid-Vegetative Period (4 to 9 Months)

Immediate Objectives: Maintain growth at sufficient rate to insure desired plant size at differentiation. Adjust fertilizations and irrigations so as to insure no prolonged periods of nutrient deficiencies.

Irrigation Indexes: Leaf-weight curve for overall trends, leaf elongation and soil moisture for weekly guide and leaf logs for plant status.

Results: Experiments show good gains, especially if efforts are continued through differentiation.

Irrigation During Fruiting Period

- I. Immediate Objectives: Increase fruit size, improve fruit quality, increase slip weight and benefit developing ratoon suckers.
- II. Irrigation Indexes: Leaf-water deficiency, soil moisture and root logs.
- III. Results: Fruit gains uniformly good when irrigations; (1) started not later than 3 - 4 weeks prior to harvest, (2) plants display at least 25% or more leaf-water deficiency and (3) sufficient water applied to materially improve moisture conditions within plant.
- IV. Remarks: Most experiments conducted during period 4 - 8 weeks prior to harvest. Need for additional irrigation studies in period from red bud to flat eye stage. Use of fruit growth measurements as a plant index for water needs should be studied. May perform function similar to leaf elongation.

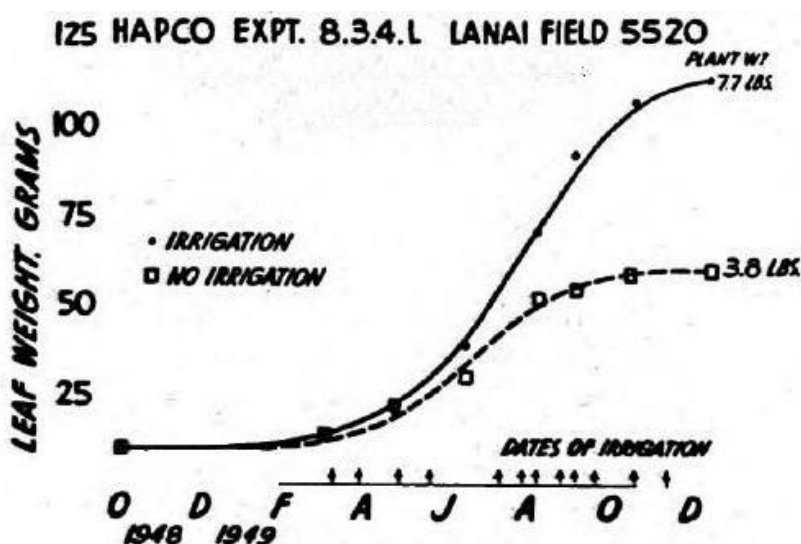


Figure 5. A typical graph of growth for irrigation experiments during a drought year. The flat portion of the graph during the fall and winter months following planting is the result of cool temperatures rather than of limiting soil moisture. Irrigations were begun in March as temperatures began to increase. Both plots show a response to the higher temperature in the summer and fall. However, moisture during this time was limiting in the no-irrigation plots. As a result, leaf growth decreased sharply as compared with that in the irrigated plots. These differences in growth were ultimately reflected in a twofold increase in plant weight at differentiation. Associated with this difference in plant size, on-schedule natural budding was much greater in the irrigated plots. Irrigations were scheduled with two objectives in mind, (1) to achieve a large plant size at differentiation by maintaining a rapid growth rate, especially during the warm months, and (2) to bring the plants into floral differentiation with as near optimum leaf levels (No. 2 color, N-P-K) as possible.

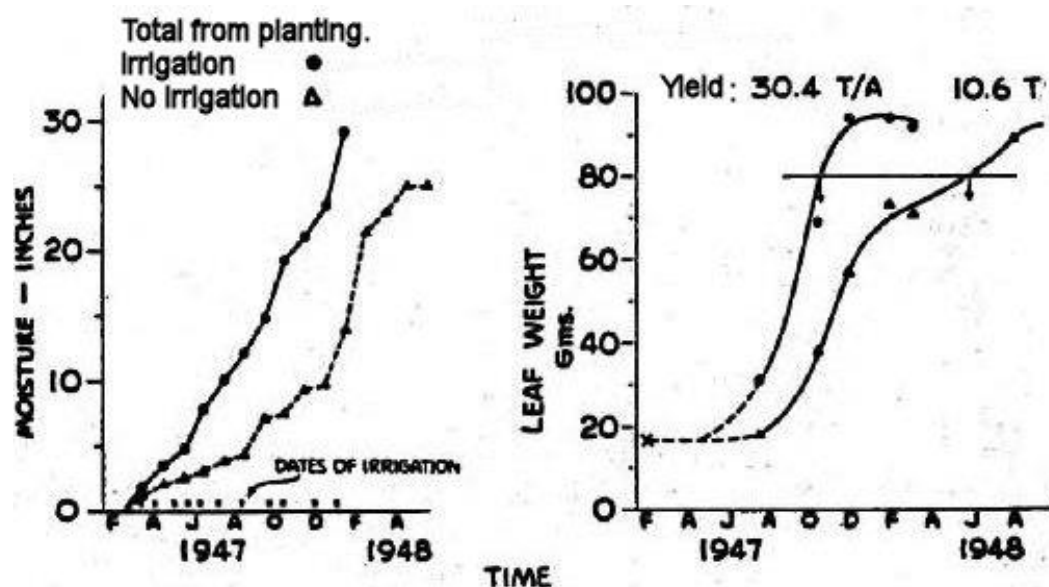


Figure 6. These data were taken from an experiment located in a warm, dry area of Lanai. The tremendous growth potential from irrigation during the warm months of the year is clearly shown by the leaf weight graph for the irrigated plots. In a four-month period between July and December the "D" leaves in these plots tripled in weight. Correlated with these growth differences, 30.4 and 10.6 tons/acre of on-schedule fruit were produced in the irrigated and unirrigated plots (see Figure 7). The importance of blending many essential factors for maximum crop production is indicated by these data. Both plots were also seriously handicapped by the late winter (February) planting date. Although both plots were planted with large slips (19 oz), irrigation was required to produce a good crop. For maximum yields with irrigation, it is necessary that all other agronomic factors are optimum.

Table 3. 8.3.4.L Monthly rainfall and Air Temperature Growth Units (A.T.G.U.) conditions and irrigation schedule for the experiment cited in Figure 5. A severe drought persisted throughout most of the vegetative period. Less than two inches of rain fell during the seven-month period between June and November.

Month, 1948-49	Rainfall, inches		A.T.G.U.		Irrigations, inches
	Monthly	Total	Monthly	Total	
Oct. 15-31	0.03	0.03	187	187	
Nov.	1.34	1.37	317	504	
Dec.	0.04	1.41	286	790	
Jan.	6.73	8.14	250	1040	
Feb.	3.16	11.30	266	1306	
Mar.	0.11	11.41	286	1592	1.0
Apr.	1.48	12.89	292	1884	1.2
May	0.58	13.47	335	2219	1.0
Jun.	0.70	14.17	350	2569	1.0
Jul.	0.40	14.57	370	2939	1.0
Aug.	0.03	14.60	380	3319	2.0, 2.0
Sep.	0.13	14.73	363	3682	1.5, 1.5
Oct.	0.50	15.23	354	4036	1.5
Nov.	0.19	15.42	307	4343	1.5, 1.5
Dec.	1.93	17.35	302	4645	

Irrigation Prior to and During Floral Differentiation

Immediate Objectives: Bring all of leaf levels to desired standards and maintain growth at maximum.

Irrigation Indexes: Leaf logs for plant status and leaf weights and elongation for growth rates.

Results: This is the period of vegetative growth when maximum responses to water can be achieved. Fruit and slip gains have been consistently large and highly significant.

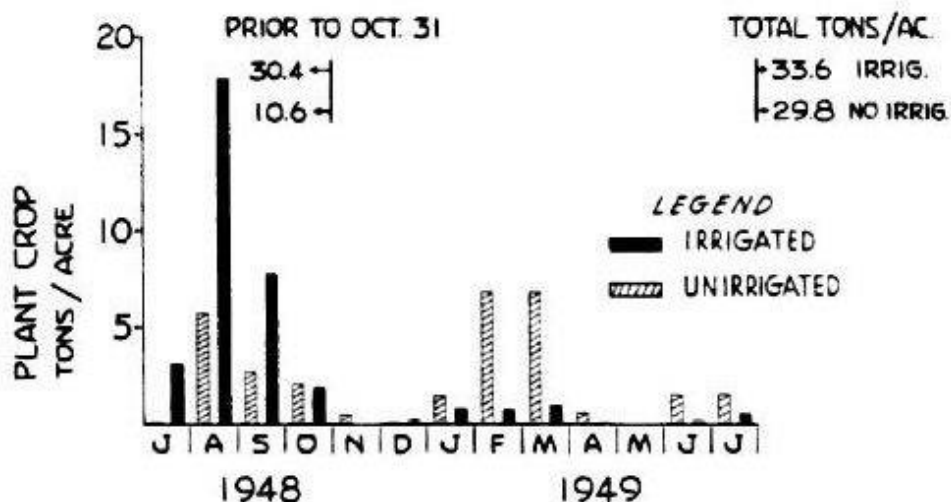


Figure 7. Distribution of fruit harvested from plants naturally induced during the winter months of 1947-48 (HAPCO experiment 8.3.4.L). No hormone forcing was done in the experiment so a higher percentage of plants in the unirrigated plots were too small for budding to occur. Fruit yield is expressed as tons per acre per month and data show that 90% of the fruit in the irrigation plots was harvested in a four-month period between July and November while only 36% was harvested in the unirrigated plots. Experience indicates that these fruiting patterns also persist into the ratoons. On an overall basis, total five-year cycle tonnage will thus be considerably increased by irrigation.

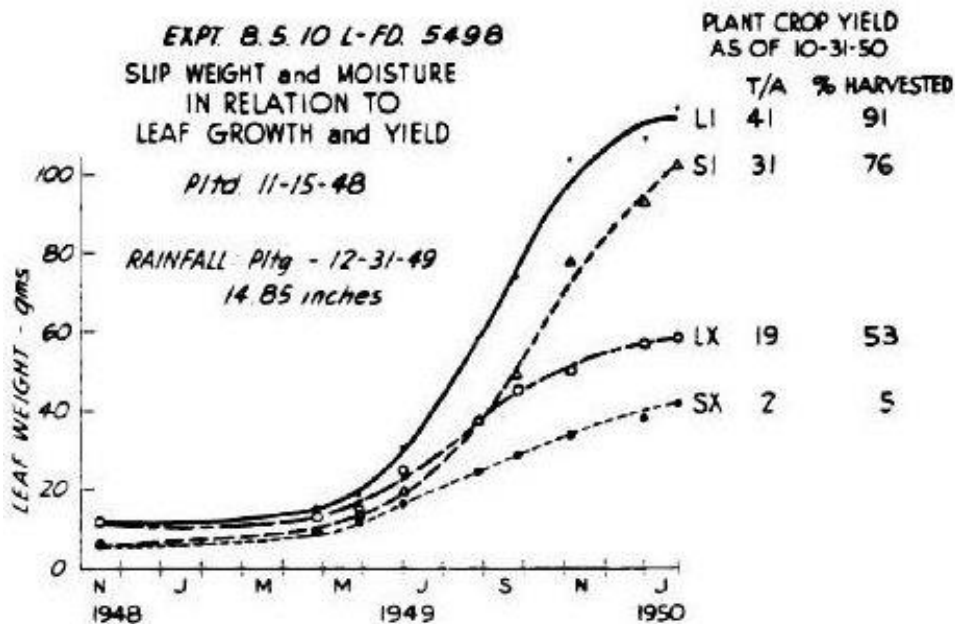


Figure 8. Treatments are as follows: LI, 15 oz slips irrigated – 15 irrigations, 1.95 acre-in.; LX, 15 oz slips – no irrigation; SI, 7.5 oz slips irrigated – 15 irrigations, 16.95 acre-in.; SX, 7.5 oz slips, no irrigation. These data demonstrate the use of graphs of leaf growth to measure the overall effects of several agronomic variables, in this study slip weight and irrigation. Note the correlation between growth and yields. The pre-differentiation leaf weights were a good clue to yields produced the following summer. Used in conjunction with other crop-log measurements, the growth curve is a

reliable measure of crop performance. Note that in both the irrigated and unirrigated plots the large slips out-yielded the small slips by a large margin.

Table 4. Leaf weight and cumulative leaf elongation in relation to various soil-moistures levels during vegetative growth. Experiment 13.1.22 aL - Lanai field 3510. Planted December, 1949.

Plot	Irrigations as of Nov. 2, 1950 ¹		Soil moisture ⁴ %	Crop log values on November, 1950		
	Number	Acre inches ³		No. 1 color, % ²	Leaf wt., g	Elongation, mm
A	16	21.25	34.2	35	101	1723
B	9	13.75	32.4	38	97	1684
C	6	9.25	30.3	46	86	1611
D	4	6.25	27.9	53	67	1464
X	None	0	25.0	79	44	1151

¹Period is from April to November.

²Percentage of leaves that are yellow green (moderately deficient in N).

³Rainfall from planting to October 31, 1950 = 18 inches.

⁴Soil moisture constants are 34.5% = moisture equivalent or 0.33 atm; 0.7 atm, 30.3; 4.0 atm., 26.4; 15 atm, 23.4.

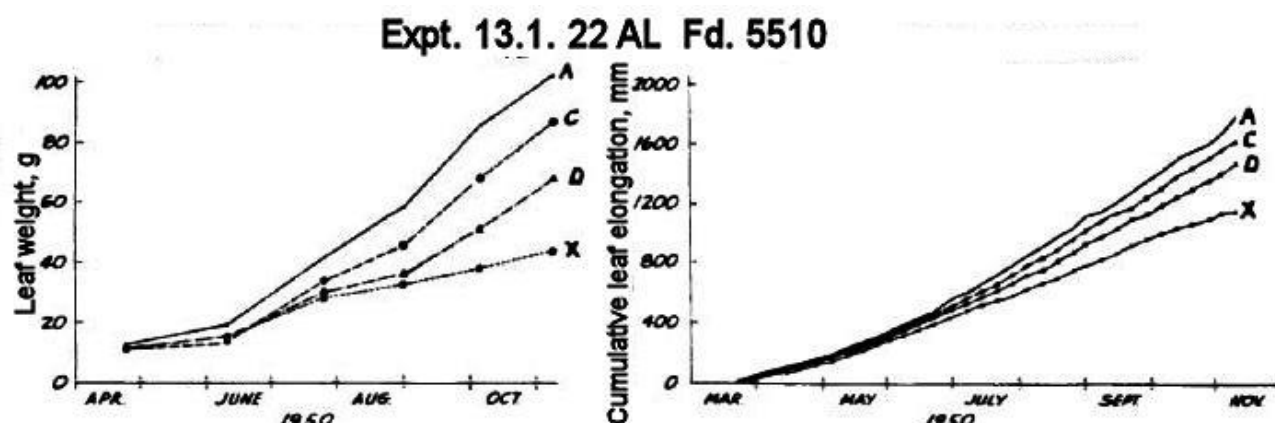


Figure 9. The graphs are based on the records tabulated in Table 4. Relative differences in growth resulting from varying amounts of irrigation are clearly defined by measurements of leaf weight and elongation. Note the greater response to water at the lower end of the moisture scale. The gain in growth of plants in plots D over plots X was achieved with only 4 irrigations. Compare that with the much smaller gain of plants in plot A over C obtained at the expense of 10 additional irrigations.

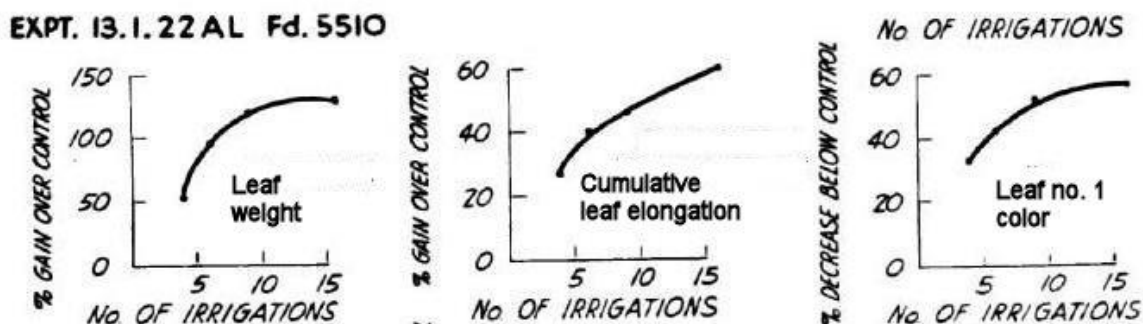


Figure 10. These graphs show the data of Table 4 and Figure 9 as a percentage gain over the control. The law of diminishing returns is clearly illustrated by this presentation of the data. Each increment of gain requires increasing amounts of water as the soil moisture content is maintained nearer field capacity (moisture equivalent or 0.33 atm).

Lanal field 5520, Expt. 8.3.4. L

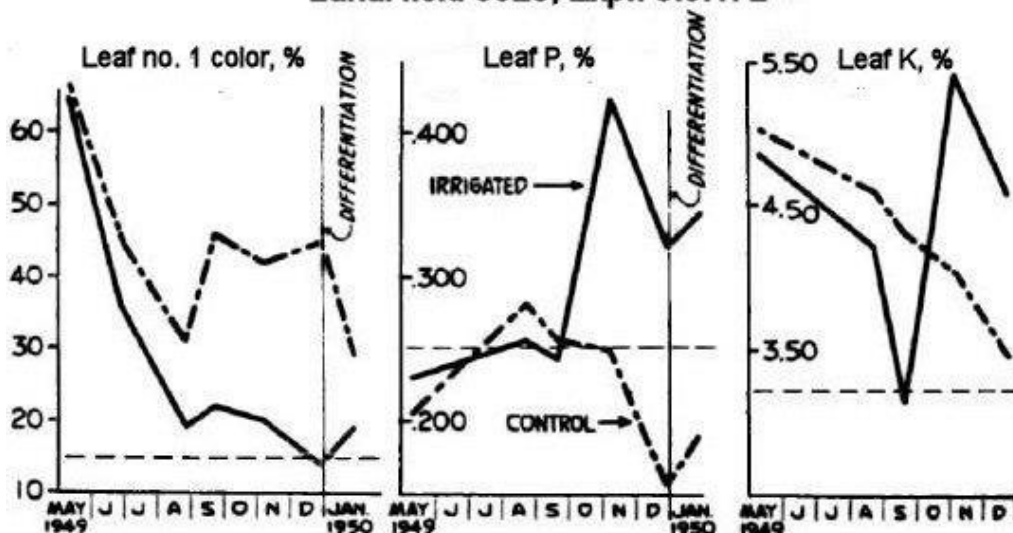


Figure 11. The leaf composition graphs for the experiment cited in Figures 3 and 4 are shown here. Desired leaf standards at floral differentiation are indicated by the horizontal dashed lines. Predifferentiation leaf levels in the irrigated plots (solid lines) were lower (no. 1 color) or higher (leaf P and K) than those in the unirrigated control (broken lines). Leaf no. 1 color in the irrigated plots reached the desired 15% while those in the control plots were >40%. With equal amounts of phosphorus fertilizer leaf P in the irrigated plots at differentiation was as much above the desired level as values for the controls were below. Although leaf K was not limiting in either treatment during differentiation, values were much higher in the irrigated plots.

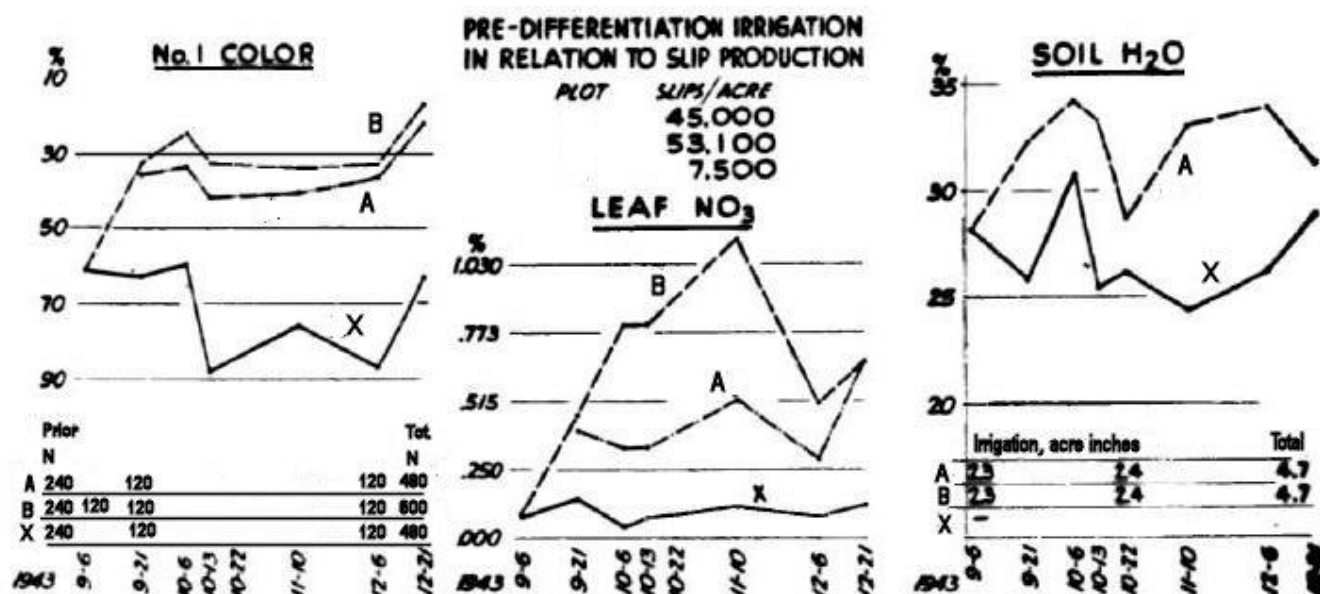


Figure 12. Proper plant status at floral differentiation is as important for fruit and slip yields. Prior to predifferentiation irrigation, plants in all plots in field 5451 were suffering badly from drought. Leaf color was high (60% No. 2) and leaf nitrate was extremely low. Irrigations of plots A and B on September 6 and October 11 promptly raised soil moisture above 30% and increased leaf nitrate and greened up the leaves (reduced the percentage of leaf no. 1 color). As a result, slip numbers were increased six to seven times over the controls (plots X). Plots B with the same irrigation as plots A, but with 120 pounds more predifferentiation nitrogen, attained a lower No. 1 color and a higher leaf-nitrate level. This was associated with a good gain in slip numbers over plots A, with an accompanying increase in fruit yields as well.

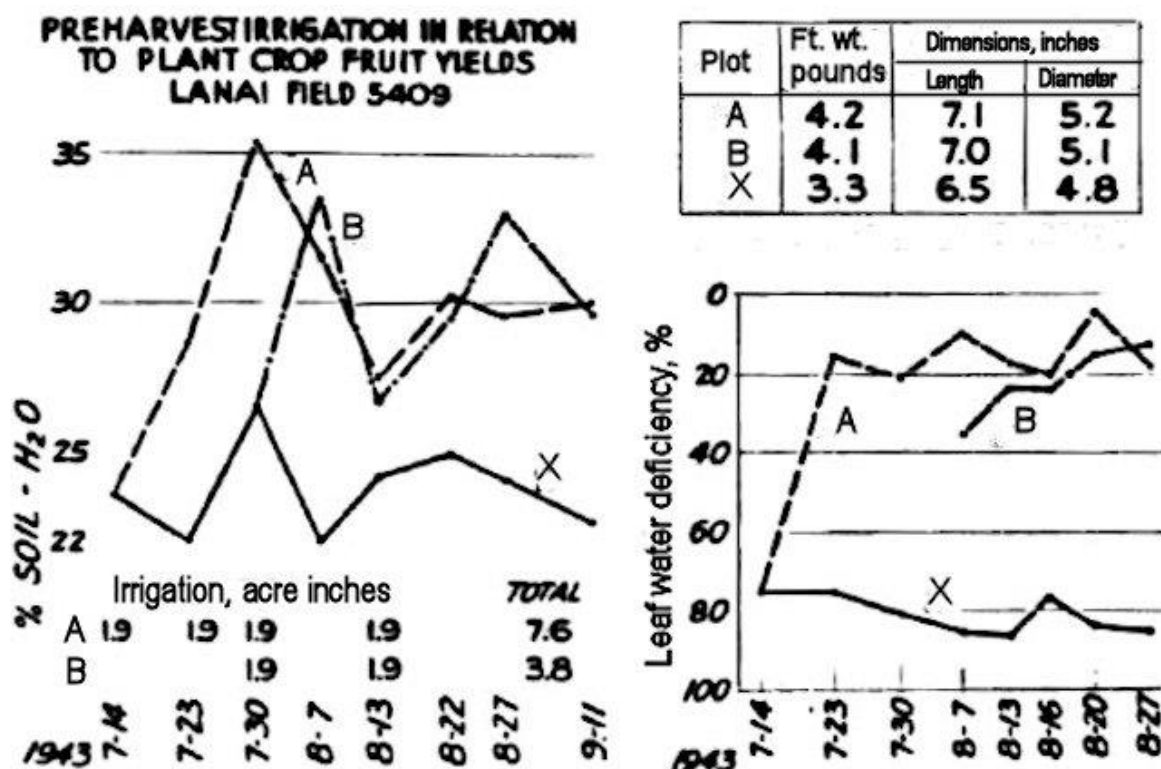


Figure 13. An example of the typical hat is possible with pre-harvest irrigation is shown in the figure. Preharvest irrigation of water-deficient plants invariably resulted in a gain in fruit size and striking tonnage gains. Drought was very severe in mid-July, six weeks prior to harvest. Reduced leaf thickness indicated leaf water deficiency was close to 80% and soil moisture was at about the wilting percentage. Irrigations of plots A and B resulted in a rapid decrease in leaf-water deficiency in both plots and fruit weight gains were almost a pound. There was only a slight fruit weight gain in the A plots from the additional irrigations they received. Leaf water deficiencies in both plots were less than 25% during the final three weeks. Experience has indicated that gains from preharvest irrigations are generally small when leaf water deficiencies are less than 25%.

Seedling production technique at PRI

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SUMMARY

A series of investigations into the effect of light, temperature, and nutrition on the storage life and germination of pineapple seeds and subsequent seedling growth is reported. The modified seedling production method being adopted at PRI is as follows:

1. Seed is stored in a closed container over desiccant at 46 °F, after extraction and initial drying in the warehouse.
2. Seed is scarified for 1-2 minutes with 50% H₂SO₄ (v/v), washed twice in tap water, rinsed in 95% ethyl alcohol to facilitate immediate drying and then sown on silica sand pre-sterilized in the germination trays by moist autoclaving.
3. The seed trays are then held in a cabinet at 90-95 °F, subjected to 100 foot-candles illumination, with the light and heating provided by fluorescent lights, the light at seed level reduced to 100 foot-candles by interposition of white wrapping paper.
4. The water level in the trays is held near the lower surface of the seeds by lifting the glass tray covers and adding water three times weekly, using sterile water until germination starts and sterile nutrient solution thereafter.
5. Seedlings are pricked out when >1 cm tall (approximately 30 days after seedling) into flats containing blended peat moss and vermiculite in equal volumes. This compost is pre-soaked by watering with tap water containing 1% Tergitol (to facilitate wetting) and is preplant fertilized with Foliar 63 solution (1/4 gal./flat; 1lb./40 gal.) the afternoon before planting.
6. Seedlings are fertilized fortnightly, beginning one month after pricking out, using Orchid-Zyme solution (3 tbsp./gal.) for the first three months, starting with 150 ml/flat and going by increments to 1000 ml/flat/application at the end of three months. Then Foliar 63 is substituted for Orchid-Zyme and the flats are drenched at each application. Seedlings should be 5 g. average fresh weight before the transition is made from Orchid-Zyme to Foliar 63.
7. Greenhouse temperature is kept above 65°F at all times, and above 85°F during the day. This is accomplished with thermostatically controlled propane heaters (CO₂ producers) and ducts, fans, and shutters set to circulate air inside the greenhouse when the heaters are on and to draw in outside air for cooling when the inside temperature is above 100°F.
8. Seedlings are grown under clear fiberglass. This permits transplanting them directly from the greenhouse to the field, making it unnecessary to preharden them in a lathhouse.
9. Seedlings are field planted after they weigh at least 2 oz. Those with butt diameter less than 1 cm at the time they are pulled from the flats for transplanting are discarded, as this diameter is necessary for rapid field establishment.

Following this system, it is possible to move three batches of seedlings through the greenhouse in one year, if necessary growing some of them on in the lathhouse or in the open until everything is favorable for field planting. Spring, instead of fall, field planting with subsequent summer forcing and winter selection are being contemplated for some of the seedlings, as the program increases seed production to the point where three seedlings can be made annually.

INTRODUCTION

Seedlings at PRI were originally raised in composts of soil blended with organic matter, and were transplanted from high to successively lower density in flats or cans prior to field planting. This method provided the seedlings with adequate nutrition and freedom from overcrowding, but plant stunting or death from pathogenic soil-borne organisms, alkali accumulation at the flat edges, or water-logging were not

uncommon. These problems and the excessive labor requirement for serial transplanting were largely overcome by switching to peatmoss-vermiculite compost in the late Fifties. However, this switch introduced nutrient deficiency problems. Recourse was made to over-the-plant drenching with nutrient solutions, using complete formulations recommended by the Physiology Department, but with varyingly successful plant response.

In 1967, outstanding improvement in seedling growth followed when Orchid-Zyme solution was substituted for the regular nutrient solution (PRI News 15:67-69). As no study had been made of pineapple seedling nutritional requirements, it was not clear whether the response to Orchid-Zyme resulted from a peculiarly appropriate N, P, K and/or minor element balance and concentration, or from the presence of some other growth stimulating substances.

Experiments were accordingly started in 1968, to study the effect of varying N:P:K levels on seedling growth, to find optimum Orchid-Zyme application rates, and to determine the basis for Orchid-Zyme effectiveness. It became clear from these experiments by spring 1968 that it might be possible to grow two batches of seedlings in the greenhouse per year instead of one. This would require extra seed storage time for the second planting, and necessitate germination of seed during the spring or early summer besides the usual winter germination.

Some stored seed was germinated during late spring 1968 to provide seedlings for follow-through nutrition tests. Germination was slow, erratic and generally poor. From observations of shading along the greenhouse germination incubator, it appeared that high temperature was retarding germination. The seed also appeared to have lost some viability during storage. Investigations were therefore initiated to determine appropriate seed storage and germination techniques for spring-summer seedlings.

Approximately half of the time taken to prepare seedlings for field planting had been devoted to hardening them in a lathhouse. To take full advantage of the increased growth from improved nutrition in the greenhouse, it was necessary to find ways to hasten the hardening process. Experiments were therefore initiated to evaluate the effects of earlier initiation of hardening, reduced shade in the lathhouse and, subsequently, the effect of higher light intensity during growth in the greenhouse. The experiments, pertinent observations, and conclusions are reported under the subject matter headings: Seed storage, seed germination, seedling nutrition, and seedling hardening.

SEED STORAGE

Introduction: Prior to 1968, seeds from current crossing were planted insufficient numbers the winter after crossing to provide seedlings to fill the greenhouse, and the rest of the seed was discarded when the next years' seed became available (MR 39:258).

Some plantings of 1967 cross seed made in early summer of 1968 indicated an apparent 50% loss in viability during ten months' storage. This seed had been kept in loose-lidded boxes in a warehouse. No reference to pineapple seed storage requirements was found in the literature.

Effect of storage temperature and humidity on seed germination: An experiment (PRI Expt. 3.16.PB6a) was initiated in July 1968 to evaluate the relative effectiveness of six easily obtained storage conditions at PRI, these being either open storage or closed (desiccator) storage over anhydrous CaCl₂ in three different locations, namely, in the warehouse, an air-conditioned laboratory, and the walk-in reefer. The temperatures in these three locations during the course of the experiment were as follows:

Walk-in reefer 45°F

Laboratory 68-79°F first three months, then 64-77°F for balance of storage

Warehouse 68-95°F first three months, then 56-85°F for balance of storage

Humidity in the reefer was 95-100% relative humidity (RH) throughout. In the laboratory, it fluctuated between 55 and 100% RH, and in the warehouse between 30 and 100% RH. Humidity over anhydrous CaCl₂ was found to be 10% in the reefer and 8% in the laboratory and warehouse (using a hygrothermograph calibrated with a sling psychrometer over the range 45- 100% RH).

Seeds of the following crosses were placed in storage under the specified conditions on July 26, 1968:

Seed Lot	Crosses
6576	56-126 x 59-443
6636	59-242 x 56-126
6640	59-443 x 57-226

Four coin envelopes containing 100 apparently good seeds to each lot were placed in each of the six storage treatments. Two packets from each lot-treatment were removed for germination on October 25, 1968 and on June 3, 1969, after three and ten months storage, respectively.

Seed was germinated in the laboratory under fluorescent lights, the first batch under two diurnally fluctuating temperature ranges; 72-91°F replicate 1, 72-110°F replicate 2, and the second batch under diurnally fluctuating temperature; 88-95°F for both replicates.

Mean cumulative germination following the six storage treatments after three and ten months' storage is presented in Figs. 1 and 2, respectively (only data from replicate 1 was used for plotting the three-month storage treatments).

Open warehouse storage was the best for seed stored only three months, although not significantly better than laboratory or reefer storage over CaCl₂. After ten-months storage, seed kept in the open in the warehouse had lost 28% of its former germination capacity, while that stored over CaCl₂ at 45°F germinated slightly better than at three months.

This latter improvement was caused by the better understanding of seed germination temperature requirements at the time the second batch of seed was germinated. Not only was the total number of seeds germinated improved by reefer storage over CaCl₂, the seed also germinated faster so that a high percentage of seedlings were ready to prick out at one time, and at an earlier date.

It is clear that seed may be stored very satisfactorily for at least one, and probably two or more years at 10% RH and 45°F.

Possibly better results would be obtained from other relative humidities than those tested. Both Figs 1 and 2 demonstrate a strong interaction between temperature and humidity in their influence on the storage longevity of pineapple seed, with indication that 8% RH is lower than optimum for ambient temperature storage. An experiment (PRI Expt. 3.16.PB9) is currently being installed to determine the relative merit of 10, 20, 30, 40, and 50% RH with reefer storage.

SEED GEMINATION

Introduction: The seed germination techniques used at PRI were developed at the turn of the Thirties. Seed scarification with H₂SO₄ was initiated in 1927, together with the use of silica sand as a substrate (N1:38). The discovery that seed germinated well at 95 °F resulted in 1931 in the construction and use of a large electrically heated, thermostatically controlled incubator in the greenhouse (N5:80). In 1932, it was found that seedlings grew better when the germinating seeds were watered with nutrient solution, rather than sterile water (N6:25) and this practice was adopted. This encouraged lush algal growth so the incubator was covered with black paper until the seed was germinated and the seedlings 1-2 cm long and etiolated. The paper was then removed and the seedlings allowed to turn green and produce a few normal leaves prior to pricking out. Seed was invariably started in late fall and germination was usually satisfactory although some years it was slow and quite variable in different seed pans containing seed from the same cross.

Attempts to germinate seed in the incubator "off season" in May 1968 were unsuccessful and when the '68 cross seed was planted in the incubator in late August, germination was extremely slow and erratic. It was then discovered that the temperature in the seed pans was rising to 115°F during the mid-afternoon, and further it was noted that germination was best in pans shaded by the greenhouse superstructure.

The higher temperature during the day clearly retarded both initiation and rate of germination. This made it obvious that the greenhouse was not a suitable place for spring through early fall seed germination, as even after heavy saran shade was draped above the incubator the temperature in the seed pans rose above 100°F during sunny afternoons.

Light and light x temperature effects on seed germination: Seed germination and seedling growth obtained in the 74-92°F laboratory growth chamber was far superior to any previously seen in the greenhouse incubator. The seed pans had been covered with two layers of cream-colored file card to screen out light and thereby stop algal growth. Some light (15 foot-candles) penetrated the cards, whereas the black mulch paper used on the greenhouse incubator had screened out all light. An experiment (3.16.PB6b, Test 2) was therefore started November 29, 1968 to determine the effect of light, diurnally fluctuating and constant temperatures on seed germination and growth.

Thirteen environments were evaluated. Darkness and constant temperature of 80, 90, and 100°F or diurnally fluctuating temperatures 75-90°F and 85-90°F; 15-20 and 500-550 foot-candle illumination with a 24-hour day-length at 90°F with or without a three-day break in illumination or a 12-hour daylength with diurnally fluctuating temperatures 75-90 °F and 85-90°F.

Three seed lots, 6611 (57-806 x 58-1239), 6625 (59-66 x 59-443), and 6632 (59-176 x 57-59) were used, 100 seeds of each to each treatment, with two of the treatments replicated twice to obtain a measure of experimental error.

Cumulative germination is presented for all treatments in Table 1, while the influence of temperature on germination in darkness, and the effect of a short interposed dark period on germination in weak and strong light, is illustrated graphically in Figs. 4 and 5, respectively. Clearly, the majority of the seeds would not germinate in darkness when the temperature was held constant. Reference to Fig. 4 shows that fluctuating temperature overcame the inhibitory effect of darkness on germination, and the initiation and rate of germination in darkness was speeded by wider diurnal fluctuation. Seeds germinated best with 75-90 °F temperature in darkness although in both weak and medium light this treatment gave the slowest germination, with the indication that germination was successively better as the temperature was raised (see Table I).

It is of interest to note (see Fig. 5) that the effect of light on germination is not limited to the first few days after seeding and, additionally, rather higher intensities are apparently involved than those needed to induce germination in such seeds as lettuce. It may also be noted that germination was about the same under 12-hour and 24-hour photoperiod.

From a practical standpoint, to obtain fast concentrated germination, the lights should be kept on each day, and as germination was best at 90 °F and it is cheapest to construct a system for continual operation, the 90°F 24-hour treatment would appear to be the best. Excellent germination was obtained (see Fig. 2) when the temperature was held within the range 88-95 °F. This range is easy to obtain and maintain by using fluorescent lights to both light and heat the germination chamber, initially setting the temperature range by making small holes in the chamber walls to adjust the amount of convective air movement in and out of the chamber. The temperature should not be allowed to reach 100°F and seedling pans should be set on an open structure to permit air circulation under the pan. Uneven temperature in the pan caused by direct contact with shelving heated by the light fixtures induces uneven germination and seedling growth.

Effect of light intensity on seedling morphology: High light intensity, such as that encountered in a whitening shaded glasshouse (3-4000 foot-candles), induces pineapple seedling growth characterized by short leaves, short internodes, and horizontal leaf posture. These seedlings are difficult to separate from each other in the seedling pan and require considerable dexterity to plant correctly in the seedling flats. The flats must also be watered very gently at first to avoid burying the seedlings. When the light intensity is reduced below 120 foot candles, upright long leaves are induced and the resultant seedlings are very easy to prick out and can be watered vigorously without injury.

Seedling growth from seedlings started under 20 and 500 foot-candle illumination was observed for six months after pricking out and in general the seedlings started under the higher light intensity were a little larger, and in no cases were they smaller than the seedlings started under 20 foot-candles. The best light intensity for practical purposes is, therefore, the maximum that can be used and still produce desirable shaped seedlings, which is around 100 foot-candles.

Effect of nutrient solution watering on seed germination and growth in light: One of the replicates of the seed germinated after ten months storage was watered in the seed pans (three times weekly) with sterile

water and the other with nutrient solution containing 450 ppm N, 300 ppm P, 450 ppm K, and 100 ppm Ca. Nutrient solution had given enhanced seedling growth when used on seed germinated in the dark (its use had been a standard practice since 1932). The mean germination of the seeds given the various combinations of storage and watering treatments is presented in Table 2.

Germination was not markedly affected after desirable storage but was depressed by nutrient solution use where the seed had been given sub-optimal storage conditions. It was also noted that algal growth was suppressed in the dishes containing vigorously growing seedlings; probably the seedlings were competing with the algae for the nutrients. Lot number 6636 seeds that germinated more than four weeks after seeding were largely inhibited in growth beyond mere radicle emergence. The radicles turned brown and no epicotyl emerged.

Avoiding nutrient solutions in the early stages appears to be especially important for genetically weak-germinating families and for seed which has lost viability through prolonged or inappropriate storage. With the improved germination technique, the seedlings are removed from the pans less than five weeks after the seed is planted and only about three weeks after germination. It is, therefore, doubtful that a response to seed-pan fertilization will occur, anyway. In fact, none of the seedlings produced in the 1968-69 germination tests, apart from those in the ten-month storage test, were fertilized in the seed pans, yet subsequent growth has been excellent. To avoid germination depression and still gain possible benefits from seed-pan fertilization, the wise procedure is to water with sterile water until germination is essentially completed, which will be for the first three weeks if seeds are correctly stored and germinated, and change to nutrient solution for the balance of the time the seedlings are in the seed pans.

Agar as a seed germination medium: Under proper light and temperature, pineapple seed may be germinated and pricked out in 4-5 weeks. Agar medium (0.75%) substituted for the silica sand in the germination pans, at a depth of one inch remains moist enough for this length of time to support seedling growth without addition of extra water. If pineapple seedlings could be started satisfactorily on agar, it would no longer be necessary to water the seed pans and the seed could be sowed in the pan by swishing it wet onto the agar surface. This would eliminate the need for drying seed after the scarification process.

An experiment was started March 20, 1969 to investigate the feasibility of using agar as a medium under semi-sterile conditions by adjusting the pH with HCl to control bacteria and adding Benlate to control fungi. The following media were compared, all except the control, containing 0.75% Bacto-Agar:

- Water agar, pH 5 (unadjusted)
- Water agar + Benlate, 100 ppm
- Nutrient agar, pH 6.2 (unadjusted), N - 450 ppm, P - 300 ppm, K - 450 ppm, Ca - 100 ppm
- Nutrient agar, pH 6.2 (unadjusted) + Benlate 100 ppm
- Nutrient agar, pH 5.0 (adjusted)
- Nutrient agar, pH 5.0 (adjusted) + Benlate 50 ppm
- Nutrient agar, pH 5.0 + (adjusted) + Benlate 100 ppm
- Nutrient agar, pH 5.0 + (adjusted) + Benlate 200 ppm
- Nutrient agar, Silica sand + sterile water (control)

Four dishes, each sowed with 100 seeds swirled on in 5% sodium hypochlorite solution were prepared for each treatment, two dishes each sowed with seed of lots 6613 and 6652. Germination was under 100 foot-candles at 90 °F.

Percent germination was excellent for all treatments but subsequent seedling growth in the dishes was strongly influenced by the different treatments. Benlate severely retarded seedling growth in both water and mineral nutrient agar. Growth was also retarded in plain water agar (pH 5). The presence of mineral nutrients enhanced growth at both pH 5 and pH 6.2 and growth at pH 6.2 exceeded that of the seedlings on silica sand.

Four weeks after seeding, 0.75% Bacto-Agar in nutrient solution, without any fungicide or pH adjustment, appeared to be very promising as a medium for starting pineapple seeds. At this point, most of the seedlings on agar were attacked and destroyed by a *Penicillium* sp. The use of nutrient agar for

starting seedlings should be further investigated as it requires considerably less labor than does silica sand culture. Possibly, other fungicides, or removal of seed pan covers after germination is completed, would eliminate the danger of fungal attack.

SEEDLING NUTRITION

Introduction: Prior to the late Fifties, adequate continuing nutrition was supplied seedlings by replanting them at intervals into fresh compost containing decaying organic matter. This procedure required very high labor input and seedling loss from root rots was quite common. Various alternatives were tested and eventually vermiculite:peat moss compost was adopted. The latter is relatively cheap, very light and easy to handle, has excellent drainage characteristics and pineapple seedlings show little tendency to rot in it. The nutrient content of this compost, the amount of nutrients contained in the amount of compost held by one steel flat (14" x 20" x 3-1/2"), and the amount of nutrients required to bring the seedlings to 4 oz. mean weight is presented in Table 3.

The magnesium, potassium, iron, calcium, and manganese are present in the vermiculite as ions adsorbed on the surface of the alumino-silicate leaves of its micaceous structure, and these minerals are at least partially available to pineapple roots because seedlings have been grown on this material to field planting size without magnesium fertilization. The peat moss is still largely undecomposed at the time the seedlings are field planted; probably less than U g of nitrogen is released per flat. Some nitrogen is also made available to the plants through the action of nitrogen fixing bacteria, which are known to be quite active in well aerated soils kept constantly moist.

It would therefore appear that Mg, K, Fe, Ca and Mn are present in adequate amounts in the compost for the seedlings' needs, if they can absorb them. Nitrogen and phosphorus must be supplemented and there might be a need for small amounts of sulfur and possibly trace amounts of boron, copper, zinc, and molybdenum.

Seedling growth in this compost was often slow and normally the seedlings were pale green. Complete nutrient solution was tried, applied at regular intervals, but plant response was erratic. Then in 1967, Orchid-Zyme solution was tried instead of the regular inorganic nutrient solution. Seedling growth and green color were spectacularly improved (PRI News 15:67-69) compared with the standard nutrient solution.

It was not clear whether the response to Orchid-Zyme was due to a particularly appropriate N, P, K and/or micro-element balance, or to the presence of some other growth stimulating substance. A series of experiments was therefore started in February 1968 to establish the most beneficial Orchid-Zyme fertilization program, the effect of different N, P, and K levels on seedling growth, and to investigate the reason for Orchid-Zyme's effectiveness.

Orchid-Zyme application rates (3.16.PB5, Test 1): Orchid-Zyme solution (3 tbsp/gal. = 938:614:389 ppm N:P:K) was applied, with a syringe fitted with a Teejet 8003 nozzle, over 14" x 24" flats containing 104 seedlings, beginning one week after pricking out, at the rates of 0, 25, 50, 75, 100, and 125 ml/flat, with both one and two-week intervals between applications. Each of the eleven treatments was replicated twice, applications starting on December 22, 1967, using different seed lots for the two replicates.

Weekly applications of more than 50 ml/flat retarded growth, compared with the unfertilized check, until two months after initiation of fertilization, while growth with fortnightly application interval was best with 75 ml/flat. Two months after the treatments were started, those seedlings receiving the highest application rates began to outgrow those receiving the lower rates. By the time these seedlings were four months old, they were able to tolerate and responded to drenching with Orchid-Zyme.

This experiment established that pineapple seedlings are initially sensitive to foliar fertilizer, and that it should be applied in amounts barely sufficient to wet the leaves to begin with, increasing the volume slowly as the plants become more tolerant, until by the time the seedlings are about three months old or average 5 g in weight, the compost is being drenched at each application.

Preplant compost fertilization and amendment (3-16.PB5, Test 3): After the extreme initial sensitivity of pineapple seedlings to foliar fertilization had been established, an experiment was undertaken to

determine the effectiveness of preplant fertilization of the compost. Compost pH amendment was also included as a variable because a study of compost pH in flats at different stages of seedling growth had revealed a gradual climb in pH from an initial 3.75 to 4.4 at two months, and 5.1 at the end of one year. It was thought that the increase in pH might be related to the rather dramatic acceleration of seedling growth which normally occurs two months after pricking out. Optimum pH for pineapple root growth is reported (Res. Kept. 86:32) to be 5.0-5.6. The following treatments were applied, replicated three times, one flat per treatment replicate:

1. Orchid-Zyme weekly, 50 ml/flat (2tbsp/gal.)
2. Foliar 63 preplant, 1000 ml/flat (13.6 g./gal.)
3. Foliar 63 preplant, 1000 ml/flat, pH adjusted to 5.0 with powdered CaCO₃
4. Foliar 63 preplant, 1000 ml/flat, CaSO₄ + CaCO₃ incorporated, pH unchanged (3.75), same Ca⁺⁺ added as for treatment 3.

Two weeks after the seedlings were planted, those in the preplant-fertilized flats were darker green and slightly larger than those receiving the Orchid-Zyme foliar feeding. Compost pH adjustment to 5.0 seemed to induce slightly better growth, although the difference was not large enough to be significant when the plants were measured. This effect was due to pH and not calcium because growth was retarded by Treatment 4. Six weeks after planting, the preplant-fertilized treatment plants were far superior to those receiving foliar fertilizer.

This experiment established that the sensitive portion of the young pineapple seedling must be the region of the leaf axils. Growth retardation had occurred when sufficient foliar spray was applied to induce leaf run-off in the earlier experiment, and this experiment indicated that the damage was not due to root sensitivity. Preplant fertilization was therefore adopted as a standard practice, beginning with the 1968 cross seed. Compost pH amendment has not been adopted because it is too time-consuming to justify the minor seedling response.

Seedling response to N, P, K level and brand-name fertilizers (3.16.PB5, Test 2): A 3³ NxPxK factorial foliar fertilization test was initiated February 16, 1968, using seedlings from seed started December 19, 1967 and pricked out February 8-12, 1968. Each of the 27 treatments was applied to three flats, one from each of three seed lots, arranged in a complete block fashion. Seven other treatments involving Orchid-Zyme, 8-12-4 equivalent to Orchid-Zyme in NPK level and source, Foliar 63, and Greenzit were applied in identical fashion but using three other seed lots. The flats were randomized within the same three replicate blocks as those in the factorial experiment. The date of application and volume applied per flat were as follows:

Date of application	2/16	3/4	3/29	4/22	5/14	5/28	6/11	6/25
Vol./flat (ml)	25*	25	25	500**	500	600***	800	1000

*Treatment 3 received 100 ml. **Half-strength. ***Higher concentrations, see Table 6

Treatment interval and volume were based on the results obtained earlier in the Orchid-Zyme experiment and on the results from exploratory side experiments. Half-strength solutions were used Apr. 22 as it had become evident that insufficient fertilizer could be applied to pace plant growth at this stage without inducing leaf burn at the higher NPK concentrations, for all except the Orchid-Zyme treatment. Observation indicated that the seedlings had passed through the highly fertilizer sensitive stage by May 28, and on this date only, the concentrations were increased several fold to establish an upper limit for fertilizer concentration without phytotoxicity.

Flats were transferred to the lath house in mid-September and pulled for weighing on November 16, immediately prior to field planting. The roots were trimmed off before weighing and the plants graded into rejects and field plantable, according to treatment.

In the factorial experiment, P and K levels had no consistent effect on plant vigor or color. Apparently, there is enough in the Vermiculite (see Table 3) for a low fertilizer K level to be adequate for optimum growth for at least four months after pricking out. The lowest P level was apparently adequate to meet the seedlings' needs, which was to be expected because the compost used has a negligible P fixing capability and the P

applied was several-fold the amount which healthy seedlings of this size would normally contain. Increasing levels of N increased plant size at all levels of P and K that were tested.

Seedling performance was similar whether fertilized with Orchid-Zyme, Foliar 63 or 8-12-4. It must be noted that these three treatments supplied similar levels of nitrogen, and that higher levels of 8-12-4 or Foliar 63 than those applied for the first two months would have caused plant damage. Plants were fertilized with Orchid-Zyme at higher rates in other experiments, with resultant higher growth rates. Those figures (Table 4) indicate that Orchid-Zyme does not contain any growth substance of a hormonal nature. In Treatment 3, 8-12-4 was applied at the same rate as for Treatment 2, except that 100 ml instead of 25 ml/flat was given on the first date (2/16). It caused very severe initial growth retardation and plant loss, whereas identical Orchid-Zyme (also of 8-12-4 analysis) levels applied in other experiments were beneficial.

Orchid-Zyme's special feature is that pineapple seedlings can tolerate it at higher rates than straight inorganic NPK.

Greenzit, which is Foliar 63 fortified with chelated iron, manganese, copper, and zinc, caused plant stunting and leaf-tip necrosis even when used at half-strength (Treatment 5). This jibes with an earlier observation made at PRI that pineapple is sensitive to the chelating agent EDTA.

By May 28, 1968, the seedlings in the factorial NPK experiment averaged 5-10 g fresh weight, and concurrent side tests indicated that plants this size were capable of tolerating drenching doses of Foliar 63 or Orchid-Zyme. At this date, the NPK levels were increased to establish an upper limit of seedling NPK concentration tolerance. The levels applied and the consequent leaf burn are presented in Table 6.

It is clear that although the seedlings had grown out of the extremely fertilizer-sensitive stage, they still were unable to tolerate N and P at concentrations commonly applied to plants in the field. Moderate burn resulted from 1800 ppm N as ammonium nitrate, although including high levels of P and K (1800:3300 or 3300:3300 ppm, respectively) with N at 1800 ppm reduced the burn to minor levels. Nitrogen at 3300 ppm produced a moderately severe plant burn, although here too there was an indication of reduced burn when high levels of K were also present. It would seem wise to avoid the use of straight N fertilizer in pineapple seedling foliar nutrition. Little damage resulted from high levels of potassium, and the burn produced by 3300 ppm of P was counteracted by including equal levels of K.

Two weeks after plant burn appeared, the seedlings started to recover. Some residual effect of the damage done is indicated; however, in the plant growth data recorded at the time the seedlings were lifted for field transplanting. These are presented in Table 7 for Treatments 1-7, and in Figs. 6 and 7 for the factorial NPK treatments.

Table 7. Effect of fertilizer type and dilution on growth and suitability for planting of pineapple seedlings.

Fertilizer	Dilution	Seedling wt. at field pltg. (lbs./3 flats)	Percent seedlings field plantable
Orchid-Zyme	Standard(25 ml)	21.4	6
8-12-4 + sequestrenes	Standard (25 ml)	18.6	51
8-12-4 + sequestrenes	Standard (100 ml)*	15.0	42
Foliar 63	Standard	24.5	74
Foliar 63+ sequestrenes	0.5 x Standard	22.7	70
Foliar 63+ sequestrenes	Standard	21.8	64
Foliar 63+ sequestrenes	2 x Standard	19.8	56

*100 instead of 25 ml fertilizer solution per flat one month after planting, otherwise identical fertilization to that given the preceding treatment.

The following points may be made from Table 7. (a) The addition of sequestered Fe, Mn, Zn, and Cu to Foliar 63 reduced seedling weight from 24.5 lbs. to 21.8 lbs. and reduced the percentage of field-plantable seedlings from 74 to 64%. This "fortified" Foliar 63 is marketed under the trade name of "Greenzit". (b) Reducing fertilizer concentration to one-half strength, and applying it in double volume, to hold the total NPK level constant, resulted in improved plant growth and percentage of plants suitable for field planting, (c)

Foliar 63-fertilized seedlings were 14.5% heavier than those fertilized with Orchid-Zyme and 74% compared with 63% for Orchid-Zyme were suitable for field planting.

Reference to Table 4 shows that Orchid-Zyme fertilized seedlings were slightly larger four months after pricking out. The Foliar 63-fertilized seedlings overhauled the Orchid-Zyme fertilized seedlings in the later stages of growth in the seedling flat. Reference to Figs. 6 and 7 reveals that optimum seedling growth in the NPK factorial experiment resulted from moderate (600 ppm) nitrogen levels. While this may have been partly a reflection of the higher damage caused to the high N level seedlings by the nutrient solution applied May 28, the NPK concentration and balance of Foliar 63 (763:310:580) is closer to the apparent optimum levels from the factorial experiment (600:300:450) than that of Orchid-Zyme (938:614:389). The presence of minor elements in the Foliar 63 is probably not a major factor because equal or superior growth was obtained from Orchid-Zyme in other tests in which higher rates were applied at early stages of seedling growth.

Basis of Orchid-Zyme's superiority as a foliar fertilizer for pineapple seedlings: Experiment 3.16.PB5, Test 2, indicated that equal growth results from Orchid-Zyme or equivalent NPK provided the latter is not applied at rates high enough to cause growth retardation. Several small experiments were conducted to try to explain why pineapple seedlings can tolerate higher levels of NPK as 'Orchid-Zyme' than as regular commercial fertilizer and to ascertain whether Orchid-Zyme' contains some other "growth promoting" substances. It was noted that Orchid-Zyme spreads over pineapple seedling leaves rather readily while commercial fertilizer solutions of the same NPK concentration do not. It was found that tolerated levels of Greenzit and Foliar 63 on six-week old seedlings could be increased three-fold by addition of spreader (X-77, 3 drops/100 ml), but that this level of tolerance was still less than that for Orchid-Zyme.

To further determine whether Orchid-Zyme' contains some growth-promoting substance besides NPK and minor elements, it was applied at regular dilution (3 tbsp./gal.) to seedlings at the following stages of development, with proper check precautions:

1. Swelling seed
2. Radicle emergence
3. Epicotyl emergence
4. Etiolated seedlings up to 15 mm tall
5. One day prior to pricking out

The subsequent growth of the treated materials was compared with the controls and there was no evidence of any difference in growth of the treated and untreated plants. Both had received the standard nutrient solution during the seed pan stage of growth.

It is therefore speculated that the organic colloids present in Orchid-Zyme have both a spreading effect on the solution and a binding effect on the fertilizer ions and that these two phenomena account for its superiority.

Seedling sensitivity to foliar fertilization: Several factors were found to influence the degree of seedling sensitivity to foliar fertilization. These included plant age, plant size, seedling parentage, temperature and seedling vigor. Sensitivity was increased by low temperature and low vigor, either due to suboptimal growing conditions or genetic weakness. It has been observed, additionally, that although seedlings are extremely sensitive when small, up to about 5 g fresh weight, if they do not receive nearly the maximum amount of fertilizer they can utilize without phytotoxicity prior to this stage then their subsequent growth will be retarded regardless of how well they are fertilized thereafter.

Seedling nutrition practice adopted at PRI: To avoid complications caused by low temperatures in the winter months, the greenhouse is now being heated with thermostatically controlled propane burners. Some growth improvement is anticipated from the CO₂ enrichment of the atmosphere which will result from the burners venting in the greenhouse. Sufficient nutrients are blended with the compost, by watering with Foliar 63 solution just prior to pricking out, to carry the seedlings without further fertilization for one month.

Provided the temperature is kept above 65 °F, the seedlings are then able to respond well to Orchid-Zyme at 150 ml/flat (3 tbsp./gal.). This solution is subsequently applied fortnightly, increasing the volume/flat until it is being drenched at three months. Seedlings of different size and age groups are kept separated so that they receive appropriate volumes of nutrient. After the seedlings average 5 g or more, fresh weight, Foliar 63 is substituted for Orchid-Zyme, and drenched on fortnightly.

SEEDLING HARDENING

Pineapple seedlings cannot be started in full, direct sunlight, or under clear glass. Such light rapidly bleaches the leaves and causes leaf-tip dieback and growth cessation. Seedlings have consequently been grown under glass shaded with white paint which allows passage of approximately 30% of the visible incident radiation when the glass is clean, dropping to as low as 10% where the paint has become red with blown dust and the inside of the glass has a coating of algal growth. Seedlings grown in a greenhouse have quite different leaf morphology from that of vegetatively propagated field-grown plants (Tech. Paper 186:351-365, 377). If taken directly from the greenhouse to the field, the leaves bleach and dessicate rapidly and the plants take several months to resume growth. Seedlings have therefore been moved into an open lath-house for "hardening" for up to a year prior to field planting.

After the improved understanding of pineapple seedling nutrient requirement was gained, it became possible to grow seedlings in five months to the size at which hardening was normally started instead of 12 months. An experiment was therefore started to determine whether the "hardening" process might be speeded by increasing light intensity (decreasing the shade). Two percentages of shade were compared with that used on the lathhouse roof: 30%, 50% versus 70% (lathhouse). Four flats of seedlings, one each of four families, were placed under each shade. The seedlings under the lightest shade (30%) "hardened" much faster than those under heavier shade. Trichome development was faster and denser, the leaves took on a more horizontal posture, water storage tissue became thicker and the leaves were stiffer. At this level of shade, there was some bleaching of some of the seedlings in one of the four families, but the improved rate of "hardening" justified adjustment of the lathhouse shade to 30%. With the improved nutritional practices and increased light in the lathhouse, it is now possible to raise seedlings ready for field planting ten months after seed is sown.

The relationship between light intensity and speed of "hardening" disclosed by the shading experiment suggested that pineapple seedlings may not be inherently different from mature plants in those aspects of anatomy that are related to ability to withstand full field exposure. An experiment was therefore installed to determine whether increased light intensity in the greenhouse would induce "harder" seedling growth.

Pairs of flats of seedlings with identical parentage and similar size and vigor were selected in December 1968 and one left in the PRI greenhouse while the other was taken to the Leilehua High School greenhouse. Seedlings which had been pricked out one day, one-, two-, and three-months previously were included. The Leilehua High School greenhouse has clear fiberglass glazing, which transmits an average of 65% of the incident light, including loss due to the superstructure. After two months, all the paired flats were placed outdoors, with full light exposure, at PRI. The seedlings carried in the PRI greenhouse bleached, ceased growth and developed severe terminal leaf burn. Those from the fiberglass house continued growth without any interruption due to bleaching or leaf burn. This experiment has been repeated with similar results with seedlings taken to the fiberglass house in June, when light intensity and heat are greatest.

The seedlings ability to grow well in the high light intensity under fiberglass (the fiberglass transmits 90% of the visible incident light) while it will scorch under similar light intensity under glass is assumed to be due to the light diffusing properties of the fiberglass. The relative transmittance of blue, red, and far-red wavebands was calculated and found to be quite similar for the clear glass at PRI and the fiberglass at Leilehua, which opposes the idea that the fiberglass preferentially screens out the near and far-red, thereby reducing leaf temperature while permitting passage of the more photosynthetically active wavebands. The PRI greenhouse is now being converted to fiberglass glazing and it is expected that this will make it possible to grow on seedlings from germination to field planting in less than six months, without intervening hardening in the lathhouse.

IX International Pineapple Suymposium Abstracts

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Brassinosteroids and humic acids effect on the production of plantlets from pineapple crowns

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Abstract: The pineapple is one of the most important crops in Brazil. Obstacles to increase pineapple productivity or the supply of planting material have been attributed to the lack of high quality and quantity plantlets for the establishment of new crop areas. The supply of healthy plantlets is the main way to ensure the success of pineapple cultivation, but production of plantlets, when performed following the appropriate technical recommendations, results in high costs. Among the methods of rapid propagation, the destruction of the shoot apical meristem (decapitation) of pineapple fruit crowns shows a great potential. Along with this technique, input applications such as humic acid and brassinosteroids can be used as a strategy to accelerate the growth of plantlets and to reduce the time of plantlet formation. Thus, the aim of this study was to evaluate the effect of various combinations of humic acid and brassinosteroids on the production of plantlets from decapitated pineapple fruit crowns. A randomized complete block design with brassinosteroid treatments of 0, 0.5, 0.75 and 1.00 mg L⁻¹ with or without humic acid arranged in a 4x2 factorial experiment was used. The first shoots were observed 30 days after planting the crowns and they were harvested when they reached at least 10 cm of height. At 360 days after planting, it was observed that brassinosteroids treatment of 0.5 mg L⁻¹ without humic acid increased by 20% the shoot number produced while humic acid alone increased shoot number by 32%.

The importance of water to handle rot and bacterial issues in Pineapples

Mr. Zak Motala, (info@puroxi.com)

Abstract: Puroxi Pure Water Global Inc has been in the water treatment and purification business since 2008, specializing in agriculture of all types. We have thousands of satisfied customers throughout Canada, USA, Middle East, and Latin America. Clear, clear, nutritional water is our passion, because access to healthy uncontaminated water is an ever-increasing challenge, for farmers/operators, to harvest healthy products with minimal loss, reduced costs, and increased profits and yield in an eco-friendly manner. We have developed a variety of safe, effective methods to treat contaminated/compromised water, while keeping the nutritional value intact. We treat specific water issues with a customized solution for each location/operation to enhance the health & well-being of our clients' livestock and crops. Our basic approach is to first determine the challenges present in the water, and their cause, in order to offer a knowledgeable effective solution using our products and methods. The first step is to perform a detailed water analysis of a water report prepared by an independent local lab. The detailed analysis examines all types of contamination, heavy metals, pesticides, fungicides, acidity (pH), total dissolved solids (TDS), and other elements found in the water sample tested. Using our proprietary products we increase the oxygen levels naturally, thus increasing nutrient intake, while making the organism more resistant to disease, infections, and fluctuations in temperature. Direct spraying application also prevents or reduces pest infestation. Addition of filters, pumps, and other equipment, along with our specific recommendations, will ensure an ongoing successful and profitable operation. Our customers have reported additional benefits of using our products and procedures, such as removal of rust, mold, and bacterial issues. Our systems do not harm the soil, while helping with less emitter and sprayer clogging and giving the user the opportunity to use a more natural method in effective treatment. Our approach enhances the nutrient uptake of any plant. Empirical data is available from various crop operations. These include: cauliflower, lettuce, grapes, potatoes, spinach, corn, peanuts, alfalfa, tomatoes, oranges, mangos, rubber trees, pineapples, bananas, nuts, melons, and tobacco. Our product line, application, and system protocols offer proven effective solutions for any challenging water issues. We recommend implementing a controlled trial for one cycle - with and without Puroxi - using precise detailed documentation to gauge accurate comparisons in an ethical, unbiased, and scientific method.

Populations and frequency of yeasts and bacteria associated to pineapple fruit during postharvest

Mr. Johanny Castro (jocach62@gmail.com) and Gerardina Umaña

Abstract: Fungi are common microorganisms causing peduncle molds in pineapple fruits, but there is a lack of information about other microorganisms colonizing pineapples. Yeasts and bacteria are among the main microorganisms recovered in different fruits, but there is not enough information about their role in pineapple fruits. The objective of this research was to determine and quantify the frequency of yeasts and bacteria associated to pineapple fruit in postharvest. Monthly samplings were performed during 12 months in 2 packing houses of Costa Rica. The colony forming units (CFUlog10) of yeasts and bacteria (Y + B) were determined in fruit peel and peduncle before (NP) and after commercial processing (P), and in both P and NP fruits stored 18 days at 7 °C + 3 days at 18 °C. Molecular characterization analyzing ITS1 and ITS2 regions and frequency of the main recovered yeast was carried out. Populations of Y + B were greater in P than in NP fruits throughout the year in both packing houses, with values between 0.5 and 4.5 CFU/ml in NP peduncles, and between 0 and 2.68 CFU/ml in P peduncles. In peels, populations were similar between P and NP fruits with values between 0.7 and 5.62 CFU/ml. At the end of storage, populations of Y + B reached a maximum of 6.75 CFU/ml in NP

peduncles and of 5.75 CFU/ml in P peels. *Wickerhamomyces anomalus* was the most frequent yeast isolated within a range of 20% to 100% and it has been reported as a potential biocontrol microorganism in different crops. More research is needed to identify the role of yeasts and bacteria in pineapple fruit, specially the potential of *W. anomalus* as a biocontrol agent that could be introduced as part of an integrated management program of pineapple peduncle molds.

Hot water treatments to control internal rot caused by *Fusarium verticillioides* in pineapple fruit (*Ananas comosus* var. MD-2)

Rosa Vilaplana Ventura, (rosavilaplana6@gmail.com), Alfredo Rosero and Silvia Valencia-Chamorro

Abstract: Postharvest fungal infections in pineapple (*Ananas comosus* var. MD-2) cause the majority of losses during export. Leading strategy for decay control is the use of synthetic fungicides, but constraints associated with the use of this kind of products have led to the search for alternative methods to reduce fungal infections. Hot water treatments have the potential to improve the postharvest life on various fruits in order to control the germination of several pathogens. In this research, the efficacy of hot water dips at several temperatures and times for the control of *Fusarium verticillioides* rot in pineapple during cold storage was assessed. Results showed that fruits treated with chemical fungicide prochloraz (3 cm³ L⁻¹) presented 59.2% of disease reduction after 21 days at 8°C and 90% HR; on the other hand, fruits immersed at 40°C for 1 minute showed 35.3% of *F. verticillioides* reduction, whereas the reduction of internal fruit rot in pineapples dipped at 50°C for 1 minute was 22.4%, all treatments were compared with non-treated fruits. Moreover, during storage (21 days at 8°C) treatment at 40°C for 1 minute significantly reduced (*pF. verticillioides* in pineapple during postharvest conservation without negative effect on its physicochemical quality. It is a residue-free method, respectful with human health and environment. However, further experiments will be carried out to overcome the lack of knowledge about alternative treatments for controlling postharvest losses in tropical fruits.

Production of pineapple fertigated with effluent of sewage treatment plant

Victor Maia (victor.maia@unimontes.br), Fernanda Oliveira, Rodinei Pegoraro, Silvânio Santos, Marcos Kondo, Marlúcia Santos, Glender Pinheiro and Rodrigo Medrado

Abstract: The availability of clean water to irrigation at arid and semiarid lands is becoming scarce for irrigation use. One of solutions to allow food production in those lands is water reuse. This study aimed to evaluate the production of pineapple fertigated with effluent from sewage treatment plant (STP). The experimental was in randomized blocks split plot design with fertigation of effluent from STP (0, 117,3; 234,1; 351,4 and 468,3 mm) as main plots and pineapple cultivars ('Perola', 'Smooth Cayenne', 'IAC Fantástico' and 'Vitoria') as sub-plots with 4 replicate. The slips were planted in furrows, in a double row system, spaced 0.60×0.30×0.20 m, resulting in a density of 111,111 plants ha⁻¹. The forcing date was previously defined on 14 months after planting. This area was irrigated by drip. Evaluations were made of fruit weight (g), fruit without crown weight (g), crown weight (g), total yield (ton ha⁻¹) and fruit yield (ton ha⁻¹). The results were submitted to analysis of variance and regression. Perola cultivar showed the highest values of fruit weight, fruit without crown weight, crown weight, total yield and fruit yield. On the other hand, Vitoria's fruit weight, fruit without crown weight, total yield and fruit yield were the lowest values. There weren't effects of fertigation with effluent from STP on the characteristics evaluated. However, the use of effluent from STP can reduce up to 15,5%; 16% and 26% of nitrogen and potassium fertilization and clean water use on pineapple without reduce its production. (Support: CNPq; CAPES; FAPEMIG; COPASA).

STS applied inside the spiral rosete does not inhibit pineapple natural flowering

Victor Maia (victor.maia@unimontes.br), Lucas Ferreira, Virgínia Araújo, Rodinei Pegoraro, Josimara Rabelo and Bárbara Salles

Abstract: Brazil is the second largest producer of pineapple, with a planted area of 62,481 hectares and production of 2.3 million t. Natural flowering of pineapple is a complex process with multifactorial control and presents several drawbacks for directly affecting the management and conduction of the crop and the harvesting and marketing of fruits. This study aimed to determine the effect of silver thiosulfate (STS) in inhibiting natural pineapple flowering. The experimental design was a randomized block in a factorial 4 x 5, for 4 cultivars and 5 STS doses, with 4 replicates being each pot an experimental plot. The cultivars studied were 'IAC Fantástico', 'Pérola', 'MD2' and 'Vitória'. STS doses were 0; 0.5; 1; 2 and 3 mmol L⁻¹ of STS, that were applied inside the spiral rosette of the pineapple plants, twice a month, with an interval of 15 days, during June and July. The characteristics evaluated were the percentage of plants with natural flowering, fruit weight with and without crown, fruit length, diameter of fruit and number of seedlings per plant. The soluble solids (SS), texture, hydrogenionic potential (pH) and titratable acidity (TA) of the pulp were also determined. Beyond that, the weights of fresh and dry matter of each compartment of the plant were determined. The results showed that application of STS inside the spiral rosette does not inhibit natural pineapple flowering, increases the diameter of the fruit and dry matter of the 'D' leaf, and reduce the pH of the pulp. (Support: FAPEMIG, CNPq, CAPES).

Chemical control of symphilids on pineapples

Mario Araya (marioa@amvac-chemicalcr.com)

Abstract: *Scutigerella immaculata* and *Hanseniella ivorens* are common soil pest in Costa Rican pineapples. They feed on plant roots causing extensive crop damage reducing water and nutrient uptake ending in yield reduction. Then, two experiments in a Randomized Complete Block Design were conducted to determine an effective Mocap® 72EC rate for its control. Increasing rates tested were: 0, 6, 8, 10, 12 and 13.6 L ha⁻¹ in 3000 L of water by hectare with five repetitions. The number of symphylids for every 5 plants, before product application, was similar among treatments in both experiments, varying from 10.4 to 22.8 in Exp I (P= 0.4978) and from 17.4 to 29.8 in Exp II (P= 0.0855). In both experiments, at 15 and 30 days after the application, a decreasing linear effect (P< 0.0001) on symphylid numbers was observed as rate increased. The average reduction was 0.55 and 0.52 individuals in Exp I and 0.47 and 0.52 in Exp II per liter of increase on the applied rate at 15 and 30 days, respectively. No differences in biological efficacy among rates were found, varying from 67.5 to 100% (P= 0.1073) in Exp I and from 83 to 100% (P= 0.5263) in Exp II. Then, the recommended rate was from 8 to 10 L ha⁻¹ of Mocap® 72EC, depending of the infestation, where the biological efficacy was higher than 88% at 15 days, and higher C 75% after 30 days of application.

Chemical control of mealybugs on pineapples

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Abstract: The mealybug *Dysmicoccus brevipes* is frequently found on Costa Rican pineapple plantations threatening the crop because of its association with the devastating disease known as pineapple mealybug wilt (PMW) caused by virus. Then, an experiment in a Randomized Complete Block Design was conducted to determine an effective Nemacur® 40EC rate for its control. Increasing rates tested were: 0, 4, 6, 8, and 10 L ha⁻¹ in 2000 L of water by hectare with five repetitions. With exception of the untreated control (P= 0.8654) mealybug mortality was significant (P< 0.0001) 15 days after product application. An increasing linear effect (P< 0.0001) on mealybug mortality was observed as rate increased. For every liter of increase in the rate, the percentage of mortality increased in average in 6.66 percentage units. The highest mortality (78%) was observed in the plants treated with 10 L ha⁻¹ surpassing (P= 0.0252) in 26.8 percentage units to the average of the rates of 4, 6 and 8 liters. Since the mortality in the untreated control was so low (2%), the efficacy on mealybug control was similar to the mortality rate. Then, the recommended rate was 10 L ha⁻¹ of Nemacur® 40EC with a biological efficacy of 78% 15 days after application.

Towards a better management of the gustatory quality of pineapple using the Simpiña crop model

Elodie Dorey (elodie.dorey@cirad.fr), Philippe Tixier and Mathieu Léchaudel

Abstract: Fruit quality has become increasingly important in fruit production, and improving the quality of products is an economic, public health, and scientific concern. The gustatory quality of fruit at harvest can be highly variable because it is affected by the environment and by management. In the case of pineapple, the harvest index is determined by the sugar/acid ratio. On Reunion Island, pineapple Victoria ('Queen') grown under a wide range of climatic conditions where elevation ranges from 50 to 900 m a.s.l and annual rainfall ranges from 500 to 5000mm. Harvesting can take place from January to December which implies a large variability in fruit size and fruit quality. A process-based model simulating the change in total soluble solids (TSS (%)) in fruit flesh was developed to describe the effect of climatic conditions on the sugar content. Then, a statistical model was developed to identify the periods during the flowering-harvest interval during which climatic variables (rainfall, global radiation and temperature) affect titratable acid content (TA) of pineapple fruit at harvest and to predict TA at harvest. These two quality models were linked to Simpiña, a crop model that accurately predicts pineapple growth. TSS values were highest for pineapples grown in dry locations without N deficiency. TSS values were lowest (< 17 °Brix) for pineapples grown under N-deficit conditions, regardless of soil water conditions. Concerning TA, temperature greatly affected TA in early growth periods, whereas total radiation had a considerable effect in late growth periods. Rainfall greatly affected TA in both early and late growth periods. Comparison of model predictions and observations from 14 pineapple fields indicated that the model accurately predicted TSS (%) (RRMSE = 0.04) and TA (RRMSE = 0.08). This modelling framework could have a practical application by helping farmers to manage fruit quality, plan harvest and marketing.

Influencia del ácido giberélico en tamaño, peso y calidad interna de las frutas de piña (*Ananas comosus*) variedad MD-2, San Carlos, Costa Rica

Alexandra Miranda-Vindas (lexandramv9@gmail.com), Danny Esquivel, Eduardo Murillo and Noel Molina

Abstract: El 75% de la producción de piña en Costa Rica está destinada para la exportación. Los tamaños del fruto influyen el tipo de comercialización. Tamaños 5 a 7 se exportan como fruta fresca y en industria, los tamaños de 8 a 10 son comercializados a menor precio y con restricción de volumen. Con el fin de aumentar el porcentaje de frutas con tamaños grandes, se realizaron varios estudios con ácido giberélico, regulador de crecimiento que causa elongación de células y podría retarda los efectos del etileno en la maduración interna de la fruta. La disminución de los efectos del etileno reduciría el riesgo de alta translucidez, aumentaría la firmeza de la fruta a cosecha y retardaría la senescencia del fruto en postcosecha. Se evaluó, en varios ensayos y condiciones, la influencia cualitativa y cuantitativamente del ácido giberélico en dosis de entre de 80 y 120 ppm, en el tamaño y la calidad de frutas de piña variedad MD-2, las aplicaciones se llevaron a cabo a los 100 días después de la inducción floral, usando sprayboom y un volumen total de 2400 litros de agua/ha. Como resultado hubo aumento en el peso promedio de 120 g/fruta en primera cosecha, 200 g/fruta en segunda cosecha y 300 g/frutas en tercera cosecha. La maduración se atrasó 7 días con respecto a los testigos. Se observó menor

desarrollo de color externo durante el periodo de evaluación en cámara de simulación (30 días), mayor uniformidad en la translucidez y firmeza a través de la fruta.

Influence of giberelic acid on size, weight and internal quality on pineapples fruits (*Ananas comusus*) variety MD-2, San Carlos, Costa Rica

Alexandra Miranda-Vindas (alexandramy9@gmail.com), Danny Esquivel, Eduardo Murillo and Noel Molina

Abstract: The 75% of the pineapple production in Costa Rica is destined to be exported. The size of the pineapple fruit has an influence on the type of commercialization. Sizes 5 to 7 are exported as fresh fruit and are used in the juice and canning industry and fruit sizes 8 to 10 are commercialized at a lower price and restriction of volume. With the objective of increasing the percentage of fruits with a higher sales value, studies have been made with giberelic acid, which is a hormone in plants that causes cellular elongation and at the same time slows down the effects of ethylene on plants. The decrease on the effects of ethylene will reduce the risk of high translucency, also will increase the firmness of the fruit in harvest and slowing down the process of senescence in postharvest. Do to qualitative and quantitative evaluations show the influence of giberelic acid at dosis between 80 – 120 ppm, on size and quality of the MD-2 pineapples fruits, specifically through the moment of mayor growth and elongation of the fruit, applying on the 100 day after floral induction using a sprayboom with a volume of 2400 liters of water/ha. As a final result there was an increase of 120 g/fruit to the average weight on first harvest, for the second harvest there was an increase of 200 g/fruit and 300 g/fruit for the third harvest. Also the ripening of the fruit was delayed for 7 days compared to the control plants as well as less development on external color through the period of evaluation in a reefer container simulator (30 days), as well as giving the fruit more uniformity in translucency and firmness throughout the fruit.

Pineapple cultivation under agro-ecological management with biotechnologies approaches

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Abstract: Over the last three decades, sophisticated systems of production have been developed for pineapple, mostly based on intensive use of chemical inputs. A common practice is systematic applications mixing insecticide and fertilizer to prevent any buildup of pathogen populations. A more reasonable use of pesticides is done when applications are scheduled from parasite monitoring. These intensive monocultural ways of producing pineapple have lost ecosystemic services that are provided by more ecological agrosystems, as regulatory functions which allow natural balance between beneficial and pathogenic organisms. A strong societal demand arises to limit environmental pollution and health risks. Authorities produce new regulations reducing the availability of pesticides. Where pesticides are prohibited, farmers are facing a strong impact of pest and disease enhanced by climate changes. The challenge for the pineapple industries is to design new cropping systems respectful of the agroecology concept, which promotes an agriculture that protects man in a preserved environment. The most recent biotechnologies may help agronomists in elaborating new environmentally friendly practices, particularly for pest management. A non-exhaustive list includes : tissue culture plants for fast multiplication of disease-free planting material, non-pathogenic fungi inoculation to reduce competitively the development of pathogenic fungi, mycorrhizal fungi to increase nutriment availability from the soil, bacteria for direct action on pathogens, nitrogen-fixing bacteria to reduce nitrogen applications or to accelerate tissue culture plants acclimatization, bacteria and mycorrhizal fungi to stimulate systemic resistances against a wide panel of pathogens... This presentation shows the possible integration of some of these biotechnologies and the impact on the design of pineapple cropping systems.

Dinámica de la producción de piña en México y Costa Rica

Angelica Torres Avila (angelica_t_a@hotmail.com) and Jorge Aguilar Avila+

Abstract: Antes de la Segunda Guerra Mundial, el producto dominante de la piña era en forma procesada. A partir de la década de los 80s el mercado en fresco empezó a crecer progresivamente, generándose una reconfiguración en su oferta mundial, donde Costa Rica tomó una posición que le permitió convertirse en el principal productor. Así, el estado actual del cultivo de piña es resultado de varios cambios en los que se ha visto inmersa la cadena de valor, reflejados en el aumento o disminución de la superficie y en las mejoras en el rendimiento por hectárea. El objetivo de la investigación fue analizar la dinámica de la producción de piña en México y Costa Rica, con la finalidad de comprender el estado actual de la actividad y mostrar las transiciones que han ocurrido en ambos países. Se utilizó el modelo econométrico propuesto por Venezian & Gamble (1969) para cuantificar el incremento de la producción de piña en tres periodos comprendidos entre los años 1971-2013. De acuerdo con este modelo, los efectos que explican el crecimiento de la producción son la superficie, el rendimiento y la interacción de ambas variables. Los resultados muestran que el incremento histórico en la producción de piña en México y en Costa Rica se define primeramente por un crecimiento vía superficie. Para México, la producción de piña ha pasado por varias transiciones que han determinado la estructura de su crecimiento; así, el periodo que define su situación actual es 1993-2003, donde el crecimiento de la superficie fue resultado del rol que grandes y medianos agricultores desempeñaron. Por su parte, en Costa Rica la transnacional Del Monte ha jugado un rol determinante en el crecimiento de la superficie y la aplicación de paquetes tecnológicos que han propiciado una intensificación de la producción de piña y han estimulado la inserción de otros agricultores a esta actividad.

Pineapple rooting and growth in response to 3-indoleacetic acid and monoammonium phosphate

Victor Maia (victor.maia@unimontes.br), Marlúcia Santos, Fernanda Oliveira, Bruno Silva, Matheus Aguiar, Glender Pinheiro, Rodrigo Medrado, Rodinei Pegoraro, Silvânio Santos and Ignacio Aspiazú

Abstract: Conventional pineapple propagules do not show roots before planting and can spending between 15 up to 60 days until rooting. Therefore, vegetative cycle becomes longer and as consequence total cycle too. Practices that promote pineapple rooting can reduce vegetative cycle and the interval between planting to harvest. The objective of this work was to study the influence of 3-indoleacetic acid (IAA) and monoammonium phosphate (MAP) on pineapple rooting and growth. The experiment was conducted under greenhouse conditions. The 5 x 5 factorial arrangement was used, corresponding to 5 concentrations of IAA (0; 250; 500; 1.000 and 2000 mg L⁻¹) and 5 concentrations of MAP (0; 4.834,3; 9.668,8; 14.503,2 and 24.172 mg L⁻¹), totaling 25 treatments. The experimental design was completely randomized (DIC), with five replicate, each plant being one replicate. Before planting on 5 liter pots, conventional propagules were immersed during 5 minutos in IAA and MAP solution. Then, the plants were harvest 9 months after planting and total and root fresh and dry matter, root volume and root/plant ratio were evaluated. Significant models were adjusted for all variables. The immersion of conventional pineapple propagules in solution containing 2.000 mg L⁻¹ of IAA and 5.300 to 7.300 mg L⁻¹ of MAP promoted highest rooting of conventional pineapple propagules. The same concentration of IAA and 6.500 to 8.200 mg L⁻¹ of MAP promote greater vegetative growth reducing vegetative cycle (Support: CNPq; CAPES; FAPEMIG).

Postharvest quality of pineapple fertigated with effluent of sewage treatment plant

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Abstract: Reuse of treated wastewater on agriculture to save water for another noble uses is becoming more common even in developing countries. This study aimed to evaluate postharvest quality of pineapple fertigated with effluent from sewage treatment plant (STP). The experiment was in randomized blocks split plot design with fertigation of effluent from STP (0, 117,3; 234,1; 351,4 and 468,3 mm) as main plots and pineapple cultivars ('Perola', 'Vitoria', 'Smooth Cayenne' and 'IAC Fantastico') as sub-plots with 4 replicate. The slips were planted in furrows, in a double row system, spaced 0.60×0.30×0.20 m, resulting in a density of 111,111 plants ha⁻¹. The forcing date was previously defined on 14 months after planting. This area was irrigated by drip. After harvest pulp firmness (N), soluble solids (Brix), pH, titratable acidity (mg of citric acid /100 g juice), and ratio (soluble solids /titratable acidity) evaluations were made. The results were submitted to analysis of variance and regression. Perola cultivar showed the lowest values of pulp firmness and soluble solids and the highest value of pH. In terms of pulp titratable acidity and ratio, 'Smooth Cayenne' showed the higher and the lower values, respectively, in comparison the other cultivars studied. There were effects of fertigation with effluent from STP only on pulp pH of 'Vitoria', pulp titratable acidity of 'Smooth Cayenne' and pulp titratable acidity and ratio of 'IAC Fantastico'. (Support: CNPq; CAPES; FAPEMIG; COPASA).

Diagnosis on the interest of small growers on establishing pineapple crops in for diversifying agriculture in Pedro Afonso, to, Brazil

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Abstract: The pineapple plant is considered a tropical fruit species of expressive economical and nutritional importance in Brazil, very much demanded in the in natura fruit market, and grown in almost all states in the country. Tocantins (TO, Brazil) produced 56,850 tons of pineapple in 2015. Nonetheless, not many pineapple crops are established in the municipality of Pedro Afonso (TO, Brazil), despite the prevalence of suitable edaphoclimatic conditions for the plant growth and development. The objective of this research was to find out about the interest of small growers in establishing pineapple crops as an alternative for diversifying agriculture in Pedro Afonso, as well as to identify the hindrances to the development of the pineapple production chain in the municipality. The research was based on an exploratory-descriptive survey applying questionnaires with both open and closed-ended questions. After the survey, the data were compiled and analyzed using a qualitative-quantitative approach. The comments made by the growers for justifying their answers were registered. Most of the growers were acquainted with the regional aptitude for growing pineapple plants, and also with the potential of the local market for its fruit, demonstrating interest in the crop. The lack of technical advice was mentioned as one of the hindrances for the establishment of the crop. The poor road network infrastructure for merchandise distribution flow (either for the acquisition of agricultural inputs, or for produce distribution) was another obstacle to the establishment of pineapple crops in the region pointed out by the small growers. However, it must be emphasized that those problems are commonly faced, on a daily basis, in the development of all other agricultural activities they endeavor in that region. Still, the growers considered that their lack of experience in selling the production and the individual commercialization of fruits as the main bottlenecks for developing the pineapple production chain in Pedro Afonso.

Short-term gas exchange responses of pineapple to diuron

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Abstract: Diuron is a herbicide widely used in pineapple cultivation. However, its application is recommended only during the implementation of the crop. The objective of this work was to evaluate the gas exchanges of four cultivars of pineapple submitted to the application of the herbicide diuron in the reproductive phase. The experiment was carried out with pineapple cultivars IAC Fantástico, Vitória, MD2 and Pérola using the active ingredient diuron at a dose of 7.5 mL L⁻¹. Measurements of CO₂ assimilation rate, stomatal conductance, transpiration, vapor pressure deficit and water use efficiency were done weekly, every one hour, on two plants per cultivar, over a 24 hour period. These determinations were carried out two days before application of the herbicide and at 8, 15, 22, 29 and 36 days after application of the herbicide. Measurement of photochemical efficiency was performed weekly on the same dates and all these determinations were made in the 'D' leaf. Measurements of gas exchange were performed with an infrared gas analyzer (IRGA) and o chlorophyll fluorescence with a fluorometer. The application of diuron reduced the assimilation of CO₂ in the varieties of pineapple IAC Fantástico, Vitória, MD2 and Pérola, in the reproductive phase, in all phases of CAM metabolism. Diuron promoted transient reduction of stomatal conductance and transient increase in water use efficiency. The photochemical efficiency of the studied pineapple cultivars was negatively affected by the herbicide diuron, with recovery of the initial values by the cultivar IAC Fantástico. (Support: CNPq; CAPES; FAPEMIG).

Control of pineapple natural flowering by ethylene action inhibitor

Victor Maia (maia@unimontes.br), Josimara Rabelo, Fernanda Oliveira, Rodinei Pegoraro, Ignacio Aspiázú, Evander Ferreira, Mirna Sousa, Glender Pinheiro and Bárbara Salles

Abstract: The natural flowering of pineapple is an undesirable process and its occurrence can be reduced or eliminated with the use of inhibitors of ethylene action. The objective of this work was to evaluate the effect of silver thiosulfate (STS) on inhibition or delay of pineapple natural flowering. Slips propagules of 'Vitória' pineapple were used. A randomized complete block design with three replicates and five STS concentrations (0, 0.5, 1, 2 and 3 mmol L⁻¹) was used. 50 mL of STS solution was applied over the entire plant with a 15 day interval, from May to July. Were evaluated the following characteristics: monthly percentage of plants with natural flowering, cumulative percentage of plants with natural flowering, stem diameter, soluble solids, pH and titrable acidity of fruit harvested from natural flowering. Data were submitted to analysis of variance (p

A new sample collection model for preservation of germplasm and the microbiome associated with the genus Ananas

Fernanda Souza (fernanda.souza@embrapa.br), Francisco Ferreira, Everton Hilo Souza, Saulo Alves Oliveira and Carlos Raimundo Santos Souza

Abstract: The rhizosphere microbiome plays an important role for plants and no studies exist about the microbial community of the genus Ananas in its zones of natural occurrence. This type of study enables identification of potential groups of microorganisms that can be useful, both to promote growth and protect against pathogens. No less important is the use of this knowledge for germplasm preservation to compose a new model of conservation. The first step is to change the method of collecting. In each plant population a sample of plants is collected considering a spatial distribution. The samples are then identified and maintained with the same AGB number, but with independent codes for each sample. The entire plant is extracted from the site, including the soil under the influence of the roots for physical and chemical analyses. To conservation of the functional microbiome, the same AGP number is maintained, but each target of collection is separated into different fractions: rhizospheric soil; rhizoplane soil (soil adhered to the roots, removed by washing); roots; stem; leaves; and fruits. The different fractions are used in steps for isolation of total bacteria and fungi, as well as isolation in selective media for the functional groups: actinobacteria, *Bacillus* spp., flowering *Pseudomonas* and *Trichoderma* spp. Since a substantial portion of the microbiome cannot be cultured, diversity of the samples should be determined by denaturing gradient gel electrophoresis (DGGE) and metagenomic analysis. Leaves are collected for indexation and detection of different strains of the pineapple mealybug wilt-associated virus (PMWaV). Finally, to the passport data, the information about microbiome and viral species of the PMWaV complex is added.

First report of Pineapple Mealybug Wilt-associated Virus in bromeliad species

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Abstract: Mealybug wilt of pineapple (MWP) is a devastating disease of pineapple worldwide. The disease is characterized by severe leaf tip dieback, wilting of the leaves and can lead the plant to die. The MWP is associated with three Ampelovirus species, Pineapple mealybug wilt associated virus-1 (PMWaV-1), PMWaV-2, and PMWaV-3. Actually, PMWaV was only reported infecting species of genus *Ananas*. The Embrapa's pineapple germplasm collection harbors more than 700 accessions, including several species from Bromeliaceae, which are kept near the pineapple plants, thus exposed to contamination by PMWaV. Therefore, these plants are important sources of information about the susceptibility of bromeliads to PMWaV, and its role in the spread of the virus. In order to address this hypothesis, plants from seven bromeliad species (*Bromelia balansae*, *B. laciniosa*, *B. goeldiana*, *B. caratas*, *Billbergia* sp.,

Tillandsia sp. and Dickia sp.) were analyzed for the presence of PMWaV. Results from RT-PCR with specific primers detected the virus in all species and high incidence, 89% of the plants tested (18). PMWaV-2 and PMWaV-3 were the most prevalent (both with 69%) and PMWaV-1 was detected only in B. caratas and in mixed infection with PMWaV-2 and PMWaV-3. The occurrence of plants with mixed infection was common. The presence of PMWAVs in different species of bromeliads is a new fact and should open a space for discussion its role as a source of virus dissemination.

In vitro nodal segment cultivation: an alternative method to propagate wild accessions of pineapple

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Abstract: Wild pineapples are used in the breeding programs as source of interesting traits and resistance against important diseases. The use of nodal segments from in vitro etiolated plants is an interesting alternative to micropropagation of no cultivated pineapple plants. The aim of this work was to evaluate the micropropagation of ten accessions (BGA-25, 203, 205, 206, 207, 232, 233, 465, 472 and 772) of wild varieties of *Ananas comosus* var. *anassoides* using nodal segments from in vitro etiolated plants. To obtain the plants, fourteen shoots of each accession were introduced in MS medium, supplemented with 3 % of sucrose, 5,37 μ M NAA, solidified with 7.0 g L⁻¹ of agar and pH adjusted to 5.8 under dark condition at 27 ± 1 °C. The nodal segments obtained were used for multiplication and were inoculated in MS medium, supplemented with 3 % of sucrose, 0.54 μ M NAA, 0.89 μ M BA, solidified with 7.0 g L⁻¹ of agar and pH adjusted to 5.8. To evaluate the response of accessions to plant etiolation and nodal segments formation the following traits were measured after 60 and 90 days of incubation: length of the main stem (cm); number of stems; number of nodal segments/stems and clusters formation. The multiplication rates were evaluated in five subcultures at intervals of 45 days, considering the number of shoots per plant. The response of accessions to etiolation was variable and the best multiplication rates were obtained with the accession BGA-203. The use of nodal segments from in vitro etiolated plants showed to be effective for most evaluated accessions.

Frequencies and population densities of plant-parasitic nematodes in pineapple (*Ananas comosus*) plantations in Costa Rica

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Abstract An analysis of the plant-parasitic nematodes found in the pineapple (*Ananas comosus*) plantations in the counties of Pococí, Puntarenas, San Carlos, Sarapiquí and Upala of Costa Rica from 2008 to 2016 was carried out. Nematode were extracted from roots by the maceration or maceration-centrifugation method. Data were subjected to frequency analysis in PC-SAS and the absolute frequency was calculated for each individual genus. Three plant parasitic nematodes were detected, and based on their frequencies and population densities the importance of nematode genera in decreasing order was: *Helicotylenchus* spp. > *Pratylenchus* spp. > *Meloidogyne* spp. *Helicotylenchus* spp. was the most abundant nematode accounting for 7.6 to 76.2% of the overall root population, followed by *Pratylenchus* spp. with 11.5 to 92.4% of the population throughout the different analyzed years. From a total of 5352 root samples, 67% contained *Helicotylenchus* spp., 38% *Pratylenchus* spp., 1% *Meloidogyne* spp., and when all nematodes present were pooled (total nematodes) 74% of samples had nematodes. Large numbers of samples with nematode population above the economic threshold suggested of one nematode by root system or two nematodes in 100 ml of soil were observed in all the years, months and the five sampled counties. The statistical differences ($P < 0.0001$) detected for nematode frequencies among years, months and counties more likely are associated to the high number of samples included in each year, month and county, since variations in frequencies for each nematode genus were small.

New innovations in Queen pineapple production in South Africa

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Abstract: Pineapple cultivation in South Africa has been growing to an industry where 95% of the local fresh market is supplied by the Queen pineapple growers. Increasing production cost and a relatively low consumer consumption (less than 1.6 kg fruit/capita/year) have forced the farmers to farm smarter and maximize production inputs. Close collaboration with pineapple researchers, have led to improved as well as new practices. The collaboration involved the diagnostic service project of the Hluhluwe research station, the bi-annual block competition amongst farmers, as well as the pineapple growers study group. The diagnostic services offered by the Hluhluwe research station is an initiative to improve Queen pineapple production by identifying problem areas. Results of the service are used to understand the population dynamics of the pests subjected to the cultivation practices applied by each grower. Nematodes, and in particular lesion nematode (*Pratylenchus brachyurus*), and mealybug (*Dismyccoccus brevipes*) are considered major pests in Queen pineapple production. The effect of the factors influencing pest control strategies are evaluated for each farmer and control strategies are optimized. The most important aim of the bi-annual block competition is to stimulate innovation by exploring new concepts on a specific aspect of cultivation. These innovative ideas are then refined in a research project or certain research aspects will be tested in a project and can then be optimized in a block competition. By multiplying specific trial concepts on the farms of the study group members, results can be compared and the influence of factors such as soil type, crop history and topography can be established in a relatively short period.

Designing climate-smart pineapple cropping system in Guadeloupe (FWI)

Jean-Marc Blazy (jean-marc.blazy@inra.fr), Loïc Guinde and Schimrith Selbonne

Abstract: Pineapple is grown since a long time in Caribbean islands as it was introduced in the region by pre-Columbian civilizations. Today, one of the major issues that pineapple cropping systems have to face is climate change. It is indeed expected an increase of the vulnerability of pineapple cropping systems due to more frequent droughts, floods, soil salinization and hurricanes. While adaptation to climate change is needed, pineapple cropping systems could also contribute to the mitigation of GES emissions and the secure of food self-sufficiency of small tropical islands. Satisfying this triple objective is the aim of what was called climate-smart agriculture by FAO (Lipper et al., 2014). In this paper we present a method to design prototypes of climate-smart pineapple cropping systems and its application in Guadeloupe. The method is based on 1) agro-economic diagnosis of current cropping systems, 2) identification of innovations at all scales (field, farm, supply chain, markets and policy) with stakeholders, 3) design of new consistent sets of practices mobilizing innovations (the prototypes to be tested), 4) participatory assessment of prototypes with field trials and 5) assessment with a bio-economic model of the potential impacts of the prototypes at the territorial scale (Chopin et al., 2015). The application of the three first steps of the method in Guadeloupe yielded a prototype involving the following agro-ecological principles: mixing pineapple with other plant species, using a variety of pineapple pest-tolerant cultivars, permanent soil covering to manage weeds, introduction of pest-repelling plants and minimum disturbance of soil.

Limitations for pineapple production and commercialization: the international researches contribution to solve limitations and its future projections

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Abstract: Pineapples are grown in more than 80 countries of tropical and subtropical regions. The global volume reached 25.44 million tons in 2014 (FAO), ranking pineapple among the most important fruits. About 81% of that amount was produced in Asia and Latin America, where are located the leading countries of Costa Rica, Brazil, Philippines, Thailand and Indonesia. In spite of their similar large production volumes, there are significant differences among these countries in technological levels of crop and post-harvest management and in the fruit markets targeted. Even within large countries like Brazil there are great variations in these aspects due to contrasts in regional environmental conditions and social factors representing strong challenges to be addressed by growers and traders. Costa Rica and Indonesia, among the big producers, as well as Australia among smaller producers, are examples of pineapple industries with high technological input and outcome mostly focused on international markets. On the other side, there are many countries, such as Brazil, where pineapples are mostly produced by small growers using low input and directed to national markets. And there are other countries in an intermediate position, such as Mexico and South Africa, with important volumes placed both into national and international markets. This work will give information on main challenges for pineapple production and commercialization in Australia, Brazil, Mexico, South Africa and some African countries with French background and make an analysis on research contributions to mitigate some of these problems.

Modeling for prediction and simulation of pineapple growth and production

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Abstract: Calibration of growth models using reliable databases and field studies allows the creation of software that can be used to recommend cultural practices, predict harvest, estimate productivity, teach, as well as simulate plant responses to environment changes and different cultural practices. After 12 years of field research and data collection of the growth of pineapple coupled with climatic variables, growth models were developed for two cultivars ('Pérola' and 'Vitória'). These models were adjusted from plants harvested during vegetative and reproductive phases, with fresh and dry matter determinations made of each compartment (roots, stem, leaves, fruit, propagules). We determined that pineapple growth can be estimated from simple measures of stem diameter or leaf fresh and dry matter coupled with heat unit accumulations. The predicted growth from these models can also be adjusted and modified for different planting densities and nitrogen fertilization. Growth models were validated with field trials. It was also possible to estimate growth and yield from absolute or relative growth rate values and heat unit accumulations. In addition, it was possible to make corrections to the growth models in order to make them more reliable. We also estimated the amount of carbon fixed in each compartment as well as in the entire pineapple plant. (Support: CNPq; CAPES; FAPEMIG).

Effects of some rotation crops on the population of *Rotylenchulus formis* And *Hansenella* sp, two soil borne parasites on pineapple crop

Paul-Alex Marie-Alphonsine (paul-alex.marie_alphonsine@cirad.fr) and Alain Soler

Abstract: In European territories, the pest management in pineapple crop was efficiently done until the last decade using intensively pesticides. But today most of the pesticides are forbidden, and an alternative may be the use of rotation crops that limit the development of the populations of these parasites. We tested different possible rotation crops for their potential in decreasing the inoculum of *Rotylenchulus reniformis* and *Hansenella* sp, parasites affecting the growth and the production of pineapple crop in Martinique. Several tests, carried out in controlled conditions (climatic chamber and greenhouse), showed that *Crotalaria juncea* and

spectabilis were the most efficient plants among those tested in reducing both parasites inoculum. Field experiments confirmed the efficiency of *Crotalaria* against nematodes and symphylids.

The selection and characterization of pineapple cold-resistant somaclonal variant lines

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Abstract: Pineapple is cold-sensitive and usually suffered low-temperature injury during winter period, especially in subtropical cultivation areas. The breeding of the cold resistant varieties is of great concern for the development of the pineapple industry. The suckers, whose maternal plants have survived after an extreme cold wave, were adopted for further tissue culture, including callus subculture and somatic embryogenesis. After tests for different temperature sets and time length, 0°C+72 hour was identified as the critical lethal condition for the pineapple cell cultures. Continuous three wheel cultures were performed through somatic embryogenesis, which promote the proliferation of the candidate cultures and extend the potential somatic variations. Three lines of pineapple cold-resistant lines were obtained from the cultures that have survived after the artificially cold treatments. The results of a series of cold-related experiments, including semi lethal temperature determination, the activities SOD and CAT, the contents of MDA, and the leaf stomatal density, indicated that the cold-resistant lines were more tolerant to low temperature than the control. The molecular level differences between cold-resistant lines and control were characterized with ISSR markers. Some important cold-responsive transcription factors were found to be expressed significantly higher in cold-resistant lines, which may be associated with the cold-resistant traits. The subsequent field experiment was undergoing, and the field performances of these lines need further observation and analysis. The characterization of the cold-resistant somaclonal variant lines would greatly promote the development of the pineapple cold resistant breeding.

Limitations for pineapple production and commercialization and international research towards solutions

Domingo Haroldo Reinhardt (domingo.reinhardt@embrapa.br), Daniel Uriza, Garth Sanewski, Elmarie Rabie and Alain Soler

Abstract: Pineapples are grown in more than 80 countries of tropical and subtropical regions. The global volume reached 25.44 million tons in 2014 (FAO), ranking pineapple among the most important fruits. About 81% of that amount was produced in Asia and Latin America, where are located the leading countries of Costa Rica, Brazil, Philippines, Thailand and Indonesia. In spite of their similar large production volumes, there are significant differences among these countries in technological levels of crop and post-harvest management and in the fruit markets targeted. Even within large countries like Brazil there are great variations in these aspects due to contrasts in regional environmental conditions and social factors representing strong challenges to be addressed by growers and traders. Costa Rica and Indonesia, among the big producers, as well as Australia among smaller producers, are examples of pineapple industries with high technological input, and outcome mostly focused on international markets. On the other side, there are many countries, such as Brazil, where pineapples are mostly produced by small growers using low input and directed to national markets. And there are other countries in an intermediate position, such as Mexico and South Africa, with important volumes placed both into national and international markets. This work will give information on main challenges for pineapple production and commercialization in Australia, Brazil, Mexico, South Africa and some African countries with French background and make an analysis on research contributions to mitigate some of these problems.

Main pests affecting pineapple plantations and its impact on crop development

Domingo Haroldo Reinhardt, (domingo.reinhardt@embrapa.br)

Abstract: Pineapple is part of the Bromeliaceae botanical family. It is native to South America and was disseminated throughout Central America and the Caribbean probably by fruit trading for consumption among the native people. Portuguese and Spanish people took the pineapple to several countries during the 16th Century. Nowadays pineapple is grown commercially in about 80 countries in the tropics and in some warm subtropical regions. In many of these countries some pests, diseases and weeds have been reported as main constraints for pineapple production. Significant yield losses have been caused by bacterial fruit collapse, bacterial heart rot, Phytophthora heart and root rots, fruitlet core rot, fusariosis, nematodes, mealybug wilt, mites, fruit borer, pink disease, black rot, internal browning and several weeds. Special characteristics of the pineapple crop, such as all year round fruit production and fields with plants in several developmental stages of both the plant and the ratoon crops facilitate the incidence and permanence of those pests and diseases. This paper will focus on interactions of pests, diseases and weeds with the pineapple crop as important knowledge towards the definition of an effective integrated pest, disease and weed management program for a sustainable production.

Exploration of microbial communities associated to Fruitlet Core Rot in 'Queen' pineapple from Reunion Island

Jean-Christophe Meile (jean-christophe.meile@cirad.fr), Julie De Stefano, Lola Filippi, Bastien Barral and Marc Chillet

Abstract: In Reunion Island, 'Queen' pineapple is the first fruit production. But this production is facing losses due to several diseases, including Fruitlet Core Rot (FCR), a postharvest disease which develops in pineapple upon maturity.

FCR disease has a significant impact on both local and export markets because there are no visible external symptoms. It is mainly due to the development of phytopathogenic fungi, *Talaromyces stollii* and *Fusarium ananatum* in the fruitlets that cause black spot in the fruit flesh. The occurrence of FCR disease can be linked to different parameters, such as climatic conditions, agricultural practices and fruit composition. However, the causes of fungal development in the fruitlets remain poorly understood.

Since the fruitlets are not sterile, they could be colonized by a variety of microbial (bacterial and fungal) communities. The role of microbial communities associated to fruitlets in FCR disease development has not been investigated yet; this is why we decided to explore microbial communities associated to pineapple fruitlets. For this purpose, molecular biology (PCR-DGGE) and conventional microbiology techniques were used in order to study and identify the different microbial communities present in healthy and diseased fruitlets. The study was performed on about 120 fruits samples originating from 30 different production sites harbouring various climatic conditions (altitude, humidity, rainfall) and agricultural practices.

We aimed at linking production factors to variations in microbial communities and identifying microbial markers associated with FCR disease. The data obtained from bacterial and fungal communities will be presented and discussed.

Fruitlet core rot disease of pineapple - Importance of phenolic compounds in the host pathogen interaction

Marc Chillet (marc.chillet@hotmail.fr), Bastien Barral, Lola Filipi, Jerome Minier and Sabine Galindo Schorr

Abstract: Fruitlet core rot (FCR) is the most important postharvest disease of pineapple produced in Indian Ocean islands, which develops during fruit ripening. In French island Reunion, this disease mainly occurs during the winter season. The two fungi responsible *Talaromyces stollii* and *Fusarium ananatum* cause black spot in the flesh of the fruit. These internal damages make the FCR difficult to diagnose for the producers and consumers because there is no external symptoms. The contamination occurs at the field and symptoms appear during ripening. There is no postharvest treatment against this disease.

Firstly, we conducted a survey to determine which pathogen is the more present in the island. Secondly, we conducted a diagnostic survey about agricultural practices over 27 plots distributed throughout the island. During the winter season, almost all pineapples had the FCR symptoms. A relation was founded between the occurrence of FCR and Nitrogen and Potassium inputs.

A metabolomics approach, of healthy and inoculated fruitlets allows us to determine which putative metabolites are involved in the FCR. The phenolic compounds seemed to be determining markers of black spot. Based on those results, we conducted experiments on evolution of black spot disease with a focus on phenolic compounds. Coumaroylquinic and chlorogenic acids increased drastically in the infected fruitlets after inoculation. These compounds are known to play a major role in the plant disease resistance.

Caracterización molecular de germoplasma de piña de las Islas Canarias

María José Grajal-Martín (migrajal@icia.es) Juan Cabrera Cabrera and Federico S. Laich

Abstract: Pineapple is a tropical crop of commercial interest for the agriculture of the Canary Islands. The development of this crop in the islands begins in the twentieth century at the beginning of the eighties. In the early years different plant materials were tested. Of all of them, the selected material is included within the Spanish Red group, being mainly grown on the island of El Hierro. In the last decade, other cultivars have been introduced among those MD2 is the most important and is currently cultivated on El Hierro, as well as on Tenerife, Gran Canaria and Fuerteventura islands. In this work, 25 cultivars from the germplasm collection of the Canary Islands Institute of Agricultural Research (ICIA) are characterized by random amplifications of polymorphic DNA (RAPD) and specific microsatellites (SSR) analyzed using an automatic sequencer. The results of this characterization show the diversity present in pineapple germplasm conserved in the ICIA, which allows the differentiation of the majority of the cultivars. These results will complement the information obtained in the morphological characterization that is being carried out using the specific descriptors for this species according to the UPOV criteria.

Impact of main pests on the pineapple plantation and crop development

Aristoteles Pires de Matos (aristoteles.matos@embrapa.br)

Abstract: Pineapple is part of the Bromeliaceae botanical family. It is native to South America and was disseminated throughout Central America and the Caribbean probably by fruit trading for consumption among the native people. Portuguese and Spanish people took the pineapple to several countries during the 16th Century. Nowadays pineapple is grown commercially in about 80 countries in the tropics and in some warm subtropical regions. In many of these countries some pests, diseases and weeds have been reported as main constraints for pineapple production. Significant yield losses have been caused by bacterial fruit collapse, bacterial heart rot, *Phytophthora* heart and root rots, fruitlet core rot, fusariosis, nematodes, mealybug wilt, mites, fruit borer, pink disease, black rot, internal browning and several weeds. Special characteristics of the pineapple crop, such as all year round fruit production and fields with plants in several developmental stages of both the plant and the ratoon crops facilitate the incidence and permanence of those pests and diseases. This paper will focus on interactions of pests, diseases and weeds with the pineapple crop as important knowledge towards the definition of an effective integrated pest, disease and weed management program for a sustainable production

Mineral nutritional contents and visual symptoms on leaves of pineapple 'BRS Vitória' grown under nutrients deficiency

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Abstract: Pineapple cultivation has a great economic importance that are cultivated in several countries and in all Brazilian regions, occupying the sixth position of the fruits produced in Brazil, mainly cultivated in the North, Northeast and Southeast. According to 2016 statistics, the state of Rio de Janeiro occupied the sixth national position with production of 92.7 million pineapple fruits with an area of 3,614 ha. The productivity of the pineapple is considered low and its main factor is the fusarium, a fungal disease caused by the etiological agent *Fusarium subglutinans*. The development of fusarium-resistant cultivars, such as 'BRS Vitória' pineapple, is an important issue that helps to achieve high productivity. However, each cultivar has its characteristics regarding the absorption and the transportation of nutrients, that make it differentiate drastically from the observations already reported for the cultivars traditionally planted, which requires more detailed studies of the mineral nutrient supply. In this context, the objective of this study was to evaluate the effect of macronutrient and boron deficiency on growth, leaf nutrient content and characterization of visual symptoms in 'BRS Vitória' pineapple. The experiment was conducted in October 2016, in a greenhouse at the Universidade Estadual do Norte Fluminense Darcy Ribeiro. The experiment was arranged in the randomized complete block design with six replicates. Eight treatments were applied: Complete (C), Nitrogen deficient (-N), Phosphorous deficient (-P), Potassium deficient (-K), Calcium deficient (-Ca), Magnesium deficient (-Mg), Sulfur deficient (-S) and Boron deficient (-B). Shoot types plantlets were used, produced by Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (INCAPER), planted in pots with 14 kg of washed sand. At 270 days after planation in pots in greenhouse, the leaf contents found in leaf "D" of the plants grown in the complete treatment were: N: 15.28 g.kg⁻¹; P: 1.83g.kg⁻¹; K: 33.8g.kg⁻¹; Ca: 3.75g.kg⁻¹; Mg: 2.87g.kg⁻¹; S: 1.32g.kg⁻¹ and B: 15.74 mg.kg⁻¹. Generalized yellowing and leaf "D" reduction were observed, as well as nitrogen and phosphorus contents of plants cultivated under N deficiency. Plants cultivated on the -Ca treatment presented a reduction of 33.5% in the potassium content and a reduction of 15.74% in the width of the "D" leaf. There was a reduction of 37.86% in the potassium contents of the plants under -K treatment.

Eficacia de Aviglicina en la Reducción de la Floración Naturalmente Diferenciada en Ananas comosus var. comosus en Costa

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Abstract: La floración naturalmente diferenciada (NDF) en *A. comosus* es regulada por temperatura baja y días cortos, estimulando mayor biosíntesis de etileno. Se evaluó la eficacia de Aviglicina (AVG) como agente inhibidor de la biosíntesis de etileno durante el periodo de mayor susceptibilidad de las plantas de piña MD-2 en la Región Huetar Norte de Costa Rica, considerando tres dosis de la formulación PinCor® 20 SL en alto volumen (2.000 L/ha) y bajo volumen (25 L/ha) en plantas de 213 a 225 días y 1,7 kg a 1,87 kg de peso, mediante aplicaciones con intervalo de siete días entre las semanas 48 del 2015 y ocho del 2016. PinCor® 20 SL (AVG) (0,25 L/ha, 0,50 L/ha y 1,0 L/ha) en 25 L/ha (2.000 ppm, 4.000 ppm y 8.000 ppm) y en 2.000 L/ha (25 ppm, 50 ppm y 100 ppm) reduce la NDF del 43,7% al 6,9%, sin afectar la sensibilidad al etileno exógeno aplicado foliar, y la magnitud de la incidencia de NDF puede estar influenciada por el microambiente. El volumen aplicado no afecta la eficacia, mientras que conforme se incrementa la dosis la incidencia es significativamente menor y en 8.000 ppm suprime la NDF al 100%, aunque en altas concentraciones genera síntomas de leve reacción clorótica temporal en las plantas. El 100% de NDF se expresó entre las semanas dos y ocho del 2016; coincidente con la exposición de la plantación por más de 50 minutos diarios a temperatura inferior a 20 °C asociada a un diferencial inferior a 4 °C, incidencia tendiente a incrementar conforme aumenta la exposición foliar.

Transcriptome analysis of symptomatic and asymptomatic PMWaV infected plants

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Abstract: Brazil is the second largest producer of pineapple (*Ananas comosus* var *comosus*) with an annual production of 25 million tons. However, mealybug wilt of pineapple (MWP) can lead to losses of up to 80% of production. MWP is caused by the Pineapple mealybug wilt-associated virus (PMWaV) complex associated with the mealybugs *Dysmicoccus brevipes*. The disease is characterized by the dryness of the roots, wilting of the plant and consequent difficulty in fruiting. The molecular mechanisms involved in plant-pathogen interaction in the symptomatology of MWP are still unclear. In this work, the comparative transcriptome of asymptomatic and symptomatic pineapple plants was evaluated using Illumina RNA sequencing technology. From a total of 79 million reads per sample, 16,097 genes were identified using STAR aligner. Differential gene expression analysis was carried out using DESeq2 with an FDR cutoff of ≤ 0.05 . From the set of differentially expressed genes (DEGs) 268 were up-regulated and 121 were down-regulated in asymptomatic plants. The enriched gene ontology terms were identified using AgriGO analysis (Plant Slim GO and biological process gene ontology). Response to stimulus, response to stress and response to abiotic stimulus were the three most significantly enriched GO terms with 44%, 31% and 22% of the DEGs respectively. In addition, the analysis indicated the overexpression of genes involved in plant defense, which justifies the occurrence of infected and asymptomatic plants that may assist in the identification of genes involved in pineapple tolerance to PMWaV. Thus, this work provides complementary information for the understanding of pineapple-PMWaV interaction. Support provided by CNPq and FAPES.

Evaluation of a bait for integrated pest management (IPM) of ants in tropical fruit crops in Espírito Santo, Brazil

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Abstract: Use of baits containing insecticides to control of ants associated with sap-feeding pests in fruit crops may be effective in reducing ant and associated pest populations. Therefore, experiments were conducted from November 2016 through May 2017 to evaluate a granular bait containing abamectin (0.01% AI) for control of ants in pineapple, coffee, and cocoa crops in Espírito Santo, Brazil. Each crop site had a randomized complete block design with three replications consisting of 10 X 10 m plots separated by 15 m. Each block contained one treated plot with bait; and one untreated plot without bait. At the start of the test, bait (35 g) was placed in a bait station located at the base of one plant located at each corner of treated experimental plots with additional bait (35 g) added at ~4 week intervals. Ant (Formicidae) activity in plots was monitored at ~4 week intervals, as follows: two open 50 ml plastic centrifuge tubes with untreated bait (5 ml) were placed in each plot and after ~1.5 hour the tubes, with ants attracted to the bait inside, were closed, and the number of ants present in the tubes determined. The mean number of ants collected was significantly lower in abamectin treated plots compared to untreated plots in pineapple and coffee crops. Thus, 0.01% abamectin granular bait application at approximately monthly intervals and 10 m between baits may be effective in reducing ant activity in tropical crops such as pineapple and coffee. Support provided by CNPq and FAPES.

Conservation, propagation and new paths for pineapple genetic resources

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Abstract: The Embrapa Cassava and Fruits research unit (Embrapa Mandioca e Fruticultura) maintains a pineapple active germplasm bank (AGB Pineapple) with approximately 700 accessions of the genus *Ananas*. In recent years, several of these accessions, of all botanical varieties, have been lost as a result of infection by the Pineapple Mealybug Wilt-associated Virus complex (PMWaV). Because of this threat, the establishment of security duplicates is a priority for the managers of AGB Pineapple, to minimize losses in the field as well as to increase the efficiency of preservation. Two strategies to preserve this germplasm have been used in recent years: in vitro conservation and cryopreservation. The presentation will cover the limitations of the two techniques and in particular the advances achieved and proposals being analyzed for better conservation of this important germplasm. It will also cover the efficiency of propagation techniques, the precautions that need to be considered and their convergence with preservation and genetic improvement of pineapple species. Finally, the creation of a global collaborative structure for genetic resources of the genus *Ananas* will be discussed, for the purpose of assuring their conservation by different strategies, based on cooperation, to facilitate use of the methods by researchers in various countries.

Conservation, propagation and new paths for pineapple genetic resources

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El sistema agroindustrial de la piña en Costa Rica

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Abstract: El sistema agroindustrial piña (*Ananas comosus* var. *comosus*) en Costa Rica es una actividad productiva, dinámica, de enorme importancia socioeconómica. Piña fresca MD-2 se ha consolidado como fruta de gran aceptación y las exportaciones han mantenido un crecimiento sostenido hacia mercados internacionales altamente competitivos con precios estables. Representa gran beneficio para la economía, con alto valor agregado, generando empleos directos e indirectos a personas de todo nivel. El sistema corresponde a pequeños y grandes productores y su desempeño se impulsa desde una perspectiva socio-ambiental, considerando como pilares la calidad, la sostenibilidad y el apoyo laboral y comunal, con más de 40.000 hectáreas, densidades desde 60.000 a 100.000 pl/ha y producción promedio de 100 t/ha. El Estado capacita en Buenas Prácticas Agrícolas, Manejo Integrado de Plagas y de Plaguicidas en pro del cumplimiento de la Normativa Nacional e internacional respecto a límites máximos de residuos (LMR), traducido a reducción del uso de agroquímicos, del impacto ambiental y de costos de producción, y mantenimiento y apertura de nuevos mercados. La generación de tecnología es producto del esfuerzo de universidades estatales, entidades privadas y casas

comerciales, junto con el sector productor y la Cámara Nacional de Productores y Exportadores de piña, con investigaciones orientadas al mejor aprovechamiento de los recursos naturales, humanos y tecnológicos; con retos para el manejo adecuado de desechos orgánicos, de las plagas dañinas a terceros y de los efectos bióticos y abióticos relacionados con floración natural y daños en fruta, además, problemas erosión y acidez. La producción ocupa terrenos de cultivos tradicionales o áreas de pastoreo, de diversos tipos de suelo, ubicados bajo diferentes regímenes de precipitación, periodos secos y temperatura; y la construcción de ingenieriles canales de drenaje con la utilización o no de riego. El laboreo convencional del terreno requiere la utilización de equipo agrícola especializado, también se implementa mínima labranza. Se conforman bloques de diferente número de camas, redes de canales de drenaje, y caminos principales e internos para el acceso de maquinaria. La semilla es seleccionada por sanidad y clasificada por tipo, tamaño-peso, desinfectada y distribuida sobre las camas para su siembra. Se aplican herbicidas y se extraen malezas principalmente en operaciones de piña orgánica o donde se usa cobertura de polietileno. La nutrición basada en resultados de análisis de suelo y foliares, el abonamiento granular no es generalizado; fertilizaciones foliares con diversas fuentes, mezclas, intervalos y frecuencias, inician al mes de sembrado con equipos aspersores. El control de plagas está basado en el Manejo Integrado de Plagas (MIP). El forzamiento se realiza en plantas de ocho meses con 2,5 kg - 3,0 kg, aplicando fuentes de etileno y etileno inyectado; frutas con 21 semanas de desarrollo son pre maduras en busca de uniformidad de color externo y cosecha simultánea la siguiente semana; la fruta es trasladada a centros de acopio de plantas empacadoras de fruta fresca o de proceso industrial para jugo y concentrado. Se pueden obtener hasta tres ciclos de producción sin detrimento de la calidad.

Eficacia de aviglicina en la reducción de la floración naturalmente diferenciada en *Ananas comosus* var. *comosus* en Costa Rica

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Abstract: In Costa Rica, pineapple (*Ananas comosus* var. *comosus*) is the second most important product with a performance of 7% of total exports. The forcing process allows a constant and programmed production of fruit throughout the year, which is the key of the sustainability of farms. The Naturally Differentiated Flowering of pineapple (NDF) is the major limiting factor in the orderly production, resulting in unscheduled fruitfulness and it is considered one of the biggest problems; especially, from December to March. NDF increases production costs and reduces the benefits for the producer. This phenomenon is regulated by various environmental factors, principally low temperatures and short days, which stimulate the increase of ethylene biosynthesis. AVG is an agent that inhibits ethylene biosynthesis, several authors' state that AVG reduces and delays the NDF in pineapple. The PinCor® formulation is considered as an alternative to reduce the incidence of NDF in pineapple plantations; as a result, it arises the need to prove it through field studies. The aim of this study was to evaluate the effectiveness of Aviglycine (PinCor®) in reducing the NDF in MD-2 pineapple during the year's biggest susceptibility period. The research was conducted in Agrícola Agromonte S.A., located in Boca de Arenal, San Carlos, Alajuela, Costa Rica. In two lots of plantation, there were used three doses of PinCor® (0.25 L/ha, 0.50 L/ha and 1.0 L/ha) applied at high volume (2,000 L/ha) were evaluated at low volume solution (25 L/ha) plus an absolute control. In the process, plants of 213- 225 days old were treated, with average plant weight of 1.7 kg to 1.87 kg. Consecutive weekly applications were made, starting in week 48 of 2015 and concluding in week 08 of 2016. The results show that PinCor® (AVG) in doses of 0.25 L/ha, 0.50 L/ha and 1.0 L/ha, applied in solution volume of 25 L/ha (2,000 ppm, 4,000 ppm and 8,000 ppm a.i) and solution volume of 2,000 L/ha (25 ppm, 50 ppm and 100 ppm) reduced the natural flowering from 43.7% to 6.9% in contrast to untreated plants; during the week 48 of 2015 to week 08 of 2016. The lot factor was shown to be statistically significant (p@. Instead each dose level application PinCor® showed highly significant differences (p @ in concentrations of 2,000 ppm to 8,000 ppm, applied in solution 25 L/ha, can generate temporary chlorotic symptoms in response to high concentration of a.i. The incidence of 100% of NDF was expressed during the second week of 2016 to week number eight 2016, with the highest incidence during week three (24.4%), week five (23.5%) and week six (27.1%) 2016. The NDF events are related to daily plantation exposure for over than 50 minutes to conditions of temperatures below 20 °C associated with a differential temperature below 4 °C, and on a higher daily exposure under the same terms, the NDF tends to increase. Based on the percentages of fruits obtained by natural flowering and artificial induction (forcing) no evidence was found that AVG affect the plant sensitivity to exogenous ethylene applied as foliar by ethylene gas. The observed variation in the incidence of NDF in plants treated with Aviglycine (PinCor®) and untreated plants, demonstrates that AVG reduces NDF pineapple, and can suppress the phenomenon with foliar application of 8,000 ppm, applied to low volume of solution. Under the environmental and cultural conditions of cultivation, NDF events occurred with greater magnitude in January and February. NDF expression coincides with conditions of low temperatures below 20 °C. AVG not affect the sensitivity of pineapple plants to exogenous ethylene.

Twenty years (1997-2017) of research on pineapple germplasm cryopreservation in Cuba

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Abstract: Pineapple is a clonally propagated crop and is maintained in ex situ collections mainly in field conditions and in in vitro medium-term storage with major drawbacks. Another problem is related with the exclusion of pineapple from the List of crops of the international and multilateral system of exchange. Cryopreservation, i.e. storage at ultra-low temperature of liquid nitrogen (-196°C), is the only current method ensuring long-term storage of germplasm from vegetatively propagated species. At this temperature, all cellular divisions and metabolic processes are stopped; therefore, plant material can thus be maintained without alteration or modification. Moreover, cultures are stored in a small volume, protected from contamination, requiring very limited maintenance. In Cuba, the pineapple cryo-research started in 1997 to set up and refine a cryopreservation protocol for apices of in

vitro plants throughout national including international projects of collaboration. During 1997-2000 "Preliminary experiments for cryopreservation of apices from in vitro plants" (IPGRI Letters 97/026 and 97/072, Italy) were started. During 2013-2015 "Cryopreservation technology applicable to the germplasm collection using droplet vitrification of apices for long term conservation and safety duplication" (Marketplace, EMBRAPA, Brazil) were carry out. During 2016-2017, research related with cryopreservation of apices using the V cryo-plate technique (Matsumae, NIAS, Tsukuba, Ibaraki, Japan) were continued. As results, the established vitrification and droplet-vitrification approaches were successfully applied and extended to nine pineapple accessions belonging to the in vitro collection of Bioplasmas Centre. In the conclusion, we discuss the possibilities of utilization of pineapple cryo-research as model for the long-term storage of other vegetatively propagated tropical plant species.

Evaluation of three fertilization systems in 'MD-2' pineapple plants

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Abstract: The pineapple (*Ananas comosus* var. *comosus*) occupies third place in world tropical fruit production, after the bananas and mangoes. It is cultivated to meet the food needs of the population and constitutes an important line for the production of preserves and sale of fresh fruit. The yield of this cultivar depends on two fundamental factors, the density of planting and the adequate fertilization levels of both NPK and micronutrients in general. The objective of the study was to determine the effects of three fertilization systems on the morphological and physiological aspects of 'MD-2' pineapple plants during field cultivation, for which a randomized experimental block design was used in which each treatment was replicated in two plots of 0.25 ha each with a number of plants per replicate of approximately 17 895. The morpho-physiological indicators evaluated were: fresh mass of plant (kg), length of plant (cm), number of leaves, fresh mass of leaf "D" (g), dry mass of leaf "D" (g), fresh weight relative to leaf area "D" (g cm⁻²), length of leaf "D" (cm), width of leaf "D" (cm). The results show that CODA fertilization system manifests superiority in the morpho-physiological variables: fresh mass, number of leaves, fresh and dry mass of leaf "D", length of leaf "D" evaluated in the growth stage of the 'MD-2' pineapple plants, reaching the floral induction time at least one month before the UEB and COMBINED systems. However, the COMBINED treatment reaches the highest values in yields (99.19 t ha⁻¹), perhaps due to the use of the Bulitem fertilizer in the final development of the fruit.

Evaluación de la actividad antimicrobiana de bacterias endógenas contra *Phytophthora parasitica* var. *nicotianae*. (Antimicrobial activity of endogenous bacteria against *Phytophthora parasitica* var. *nicotianae*)

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Abstract: One of the diseases with the greatest impact on the MD2 hybrid pineapple is the decay of the heart of pineapple or bud rot caused by *Phytophthora parasitica* var. *nicotianae*. Fungicides are the main solution to disease control, but their use is controversial because of the undesirable environmental effects they cause. In this sense has emerged the use of microorganisms as possible replacements of chemicals for the control of a wide range of diseases in plants. The control of this pathogen continues to be a problem of interest to the growers of the crop and the need to continue to deepen its control motivates studies to evaluate other ecological alternatives, such as the use of beneficial microorganisms for prevention and control to reduce the effects of *Phytophthora parasitica* var. *nicotianae* on pineapple cultivation. The objective of the research was to determine and compare the in vitro antagonistic capacity of native strains of endophytic bacteria isolated from pineapple and banana crops in different regions of Martinique against two isolates of *Phytophthora parasitica* var. *nicotianae*. Eleven bacteria from the CIRAD collection were selected. To evaluate the antagonism, the dual culture technique (Bashan et al., 1996) was performed in Petri dishes. The area of growth inhibition of the pathogen was measured and compared to the radial growth of the fungus on the control plates. With the measurements obtained the percentage of radial growth inhibition (PICR) Suárez et al. (2008). All bacterial strains evaluated had an inhibitory effect on *P. parasitica* strain CUBA. The strains *Herbaspirillum huttiense*, *Bacillus toyonensis*, *Micronospora maritima*, and *Aureimonas altamirensis*, exerted inhibitory action for strain PHY9. The percentage of inhibition of bacteria reached values above 50% in all cases, which makes them good candidates for future trials evaluating their effect on plants.

Bromatological characterization of fruits of 'MD-2' pineapple plants from micropropagation

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Abstract: Pineapple (*Ananas comosus* var. *comosus*) is a species of great commercial demand, among the most promising varieties is the 'MD-2', which has grabbed consumer attraction in recent years. For this reason, micropropagation techniques are used to achieve plants with better agronomic characteristics and produce seeds of excellent quality. In Cuba, although some attempts have been made to introduce vitroplants under the conditions of production of State Entities and Agricultural Companies, this objective has not been satisfactorily achieved for various reasons. The present work was framed in determining the bromatological indicators of the fruits of pineapple plants 'MD-2' coming from micropropagation. These indicators were physical (quantitative and qualitative) and chemical according to the 1982 Cuban Standards (total soluble solids (°Brix), titratable total acidity (%), ascorbic acid (mg /100 g juice) and fruit pH). It was possible to demonstrate by bromatological analyzes carried out on the fruits, that they comply with the described characteristics for the pineapple 'MD-2' and that the agro technical attentions made to the crop influenced the results achieved.

Superoxide dismutase activity and jasmonic acid during in vitro-ex vitro transition of pineapple (Ananas comosus var. comosus) 'MD-2' micropropagated plantlets

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Abstract: Recent agriculture is characterized by intensive and cleaning productions, which need seeds with high quality in large quantities bonded by in vitro culture labs. Nevertheless in vitro-ex vitro transition and during acclimatization occur losses due to the death of plantlets unable to survive this abiotic stress. Reactive Oxygen Species production during jasmonic acid-induced changes previous transition was demonstrated. The role of superoxide dismutase in regulation of oxidative metabolism signaling in response to environmental stress is analyzed. Pineapple plantlets treated with jasmonic acid showed higher protein biosynthesis, which can be associated with a better regulated metabolic predisposition to face this phase, when superoxide dismutase activity showed adequate control against this stress related to superior water-use efficiency and survival.

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Scale up of in vitro plant production of pineapple MD2 free of Pineapple mealybug wilt-associated virus-1, -2 and -3 for introduction to productive scale in Cuba

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Abstract: In Cuba, the national production of pineapples (Ananas comosus var. comosus) was based exclusively on cv. Spanish Red for many years. In 2009 the cv. "Gold Extra Sweet" MD2 was introduced. The adaptation of pineapple cv. MD2 to the edaphic-climatic conditions of Ciego de Avila was successful, despite being sensitive to different factors such as drought, poor drainage of soils, Phytophthora sp. infection and pineapple Wilt virus disease. However, the projections for development of this crop are to reach 2 000 hectares in 2018 at Ciego de Avila, while other provinces refer attention for establishing this genotype. However, the availability of plant material for planting limits the scope of this objective. To this interest have been answered some commercial laboratories (biofactories) that also demand technology and starting material plant. In the present work the in vitro propagation of certified pineapple cv. MD2-free virus (Pineapple mealybug wilt-associated virus) PMWaV-1, PMWaV-2 and PMWaV-3 was achieved. This propagation of pineapple cv. MD2 reached more than 100 000 units, produced with different product formats and delivered to producers in different regions of the country. This result is an alternative to create high quality seed banks and meet the demand of producers in biofactories and productive areas.

Establishment of a list of minimum descriptors for the germplasm of pineapple in Cuba

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Abstract: The minimum descriptors allow the rapid characterization of the germplasm and facilitate the researcher's work. The objective of the research is to establish a List of Minimum Descriptors that will facilitate the morphological characterization of the pineapple collection ex situ in Cuba. For this, 47 accessions were used, which were characterized with 30 morpho-agronomic descriptors established by the IBPGR. The data were processed by Multivariate Analysis, where Multiple Correspondence Factor Analysis was used for qualitative characteristics and Principal Components Analysis for quantitative characteristics. A list with 14 minimum descriptors was proposed. The fruit shape, fruit shape, fruit colour when ripe, flesh colour, crown characters, eye shape, fruit height, fruit diameter, number of differently oriented spirals, fruit mass without crown and mass ratio of the crown were selected as minimum descriptors. Most descriptors are related to fruit traits, which are important for the genetic improvement and commercialization of pineapple. This list allows the reduction of 50% of the number of descriptors that are used in the characterization of pineapple germplasm.

Effect of temperature on pre-conditioning pineapple in vitro donors plants for cryopreservation protocol of apices

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Abstract: The present work was carried out with the objective of evaluating the effect of temperature on the pre-conditioning of pineapple in vitro donor plants for a cryopreservation protocol of apices. During the pre-conditioning plant in vitro donors were established in two temperature conditions at $25 \pm 2^\circ\text{C}$ during all day and at $35 \pm 2^\circ\text{C}$ during the day (hours 6:00 h -18: 00 h) and during the night (hours 18:00 h- 6:00h). In the results it was verified that plants pre-conditioned to $35 \pm 2^\circ\text{C}$ during the day and those set at $25 \pm 2^\circ\text{C}$ throughout the day, they had C3 metabolism. In the regeneration, the cryopreserved apices of in vitro plants, pre-conditioned donors at $35 \pm 2^\circ\text{C}$ during the day, they had the highest cell viability and survival. The shoots of these apices obtained the best results in the morphological variables with higher chlorophyll content and performed gas exchange in the evening hours, without presenting activity in the day schedules characteristic of CAM plants. The regenerated shoots of cryopreserved apices of in vitro donor plants pre-conditioned at $25 \pm 2^\circ\text{C}$ they performed gas exchange during the daytime hours characteristic of C3 plants. The CAM buds had a better response to cryopreservation with increases in protein contents in the SOD and POX Activity. These results allow to verify that the cryopreservation of pineapple apices preserves the cellular structure and the metabolism of the donor plants.

The viral complex associated with mealybug wilt of pineapple disease in Cuba

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Abstract. Mealybug wilt of pineapple (MWP) disease has been associated with the infection by a complex of ampeloviruses [pineapple mealybug wilt-associated virus 1 (PMWaV-1), PMWaV-2, PMWaV-3, PMWaV-4 and PMWaV-5]] (Closteroviridae) and badnaviruses [pineapple bacilliform CO virus (PBCOV) and pineapple bacilliform ER virus (PBERV) (Caulimoviridae)]. In Cuba, PMWaV-1, PMWaV-2, PMWaV-3 and PBCOV are widespread in commercial pineapple fields, but the association of these viruses with the etiology of the disease remains unknown. During 2009 to 2012, a survey to detect PMWaV-1, PMWaV-2 and PMWaV-3 by RT-PCR, and PBCOV by non-radioactive Dot Blot hybridization was carried out on samples collected from asymptomatic or MWP symptomatic pineapple plants from 24 commercial fields in 10 provinces and Isla de la Juventud. PMWaV-1, PMWaV-2, PMWaV-3, and PBCOV occurred in simple or mixed infections, whereas PMWaV-2 was the viral species most frequently detected in symptomatic plants. The positive or negative diagnostic results of the RT-PCR to detect PMWaV-2 was more reliably associated with the MWP symptomatic or asymptomatic status of the sampled plants, respectively, than those from PMWaV-1, PMWaV-3 or PBCOV detection techniques. This work discloses the correlation between the infection by PMWaV-2 and the presence of MWP symptoms in Cuba, supporting previous studies indicating the major role of this virus triggering MWP disease.

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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, 2018. 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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