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Pineapple NEWS

Newsletter of the Workgroup Pineapple, International Society for Horticultural Science

Issue N°. 28, August 2022

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Workgroup Pineapple News

Recent events, especially the restrictions imposed by the Covid-19 pandemic, since the beginning of 2020, have reduced the actions and interactions that characterize the ISHS Pineapple Working Group.

The main event organized by the group, the International Symposium, planned to take place in the Dominican Republic in April 2020, has been postponed three times. Finally, we hope that everything goes well and that the important event will be held from May 1 to May 5, 2023, at Uvero Alto, Altagracia Province, Dominican Republic, within the theme "Protection and Management of biodiversity: A 21st century agriculture concern". We encourage everyone to make a special effort to participate in the Symposium. It will be a great opportunity for a joyful reunion and fruitful discussion not only of the most current issues in world pineapple farming, but also for an analysis of the functioning of our group and possible actions for its improvement.

Another setback was the interruption of the edition and publication of Pineapple News in 2021. This magazine has been an important vehicle for information on the pineapple community and a highlight in the ISHS sections. Supported by the work and tireless dedication of Professor Duane Bartholomew, Pineapple News appeared in 1994. It reached its 27th annual edition in 2020. Unfortunately, health problems made it impossible for Prof. Duane Bartholomew to follow this path, something very understandable. In fact, the interest of volunteers to take on this important task was lacking at that time. A poll carried out by email in 2022 showed that there was a lot of interest in continuing the magazine. There was no doubt about the existence of valuable subjects and information in the research groups and among the agents working in the pineapple production chain in different countries and continents.

Based on this expectation, we took responsibility for carrying out the edition of Pineapple News 2022, which we are now sending to everyone on the ISHS Pineapple Community Membership List. We hope that the magazine contains information of interest to everyone and that this flame remains lit to ensure the regular continuity of the magazine each year.

X International Pineapple Symposium (IPS)

See at http://www.cedaf.org.do/eventos/xpineapple2020/en/ishs.html

Information on the X IPS that will be carried out in the Dominican Republic in 2023, from May 1 to May 5. Email for contacts is xpineapple2020@gmail.com

If you want to look at the X IPS program, mostly based upon the papers submitted in 2020, open the following link: http://www.cedaf.org.do/eventos/xpineapple2020/en/programa.html

The organizers will keep fidelity to the papers submitted and accepted for presentation at the X IPS since its initial date in April 2020. However, some new submissions may be done and, if accepted, inserted into the program for the event in 2023.

ISHS Workgroup Pineapple and Pineapple News archives

See whats new about pineapple at the ISHS https://www.ishs.org/pineapple and find all back copies of Pineapple News at the links below.

https://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 in a google spreadsheet at: https://docs.google.com/spreadsheets/d/1ePrvbOxZK_fAetf5dDG9KSJ-iI3TGbWEuVPqNWSIC1k/pubhtml

News from Australia

The Australian Pineapple Industry in 2022

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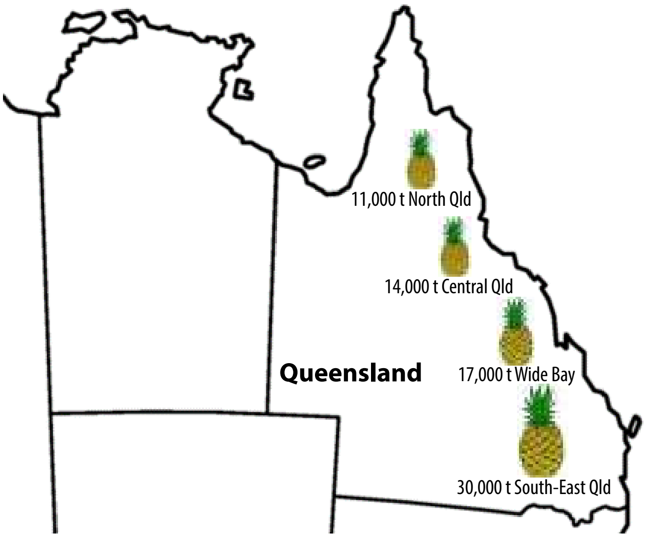
The Australian pineapple industry is relatively small by world standards. It is orientated towards the domestic market with almost no fruit exported and is one of the few pineapple industries in the world without access to low-cost labor. To compensate for the high costs of labor the industry has embraced technology and mechanization.



Australian pineapple production regions and tons in 2019.

Australian pineapple production has remained steady over the last decade but with an ongoing reduction in reliance on processing and more emphasis on the fresh fruit market. The industry is based in the state of Queensland.

Production for processing is principally based in South-East Queensland (SEQ) close to the Golden Circle processing factory at Nundah in Brisbane, although some fruit from as far as Central Queensland (CQ) is processed. In more recent years the processor has introduced a payment system based more heavily on quality. The processor stops intake for about six weeks during July and August each year to enable maintenance of processing lines but also because fruit picked at this time is low in sugars and high in acidity and requires the addition of sugar. There is a lower consumer demand for artificially sweetened product. The cannery also closes for December and January.

The high labor costs and a predominantly subtropical production environment make it difficult to compete with imported processed product from countries with relatively low labor costs and a more tropical climate. The processing market provides a valuable second market for growers in the southern production regions.

Early History

The first pineapples are thought to have been introduced to Australia from India in 1838 by a German missionary, although some records indicate pineapples were grown near Sydney as early as 1824. The first commercial plantings were established in Nundah in the early 1840's. The first commercial plantings were probably 'Rough Leaf' pineapples ('Queen' variety) with 'Smooth Cayenne' coming later from Kew gardens in England. This importation from England probably occurred around 1858.

Pineapples were initially grown close to Brisbane as the fruit had to be transported to market by horse-drawn conveyances. Production of pineapples increased gradually as new areas opened up in the Sunshine Coast hinterland and rail lines were established. The World War I returned soldier settlements featured in this expansion. Production was however still limited to demand by the fresh market. It was not until supply exceeded demand that consideration was given to establishing a processing facility.

Production increased dramatically from the 1920's onwards when the State Government established the State Cannery in Brisbane, principally built to process the crops of the soldier settlements in the Beerburrum region just north of Brisbane. Records from 1929 show fresh production at 8,881 tons exceeded cannery production at 5,258 tons.

Recent history

Golden Circle Ltd dominated the Australian pineapple industry from 1947, when its cannery at Nundah in Brisbane commenced operations, until 2008 when the grower-owned company was sold to Heinz (Heinz was subsequently purchased by Kraft in 2015). As a grower-owned cooperative Golden Circle Ltd provided a high level of support to the pineapple industry including one-to-one agronomic support to growers through three or four full-time agronomists, research, responsibility for registration of pesticides and often as a spokesperson for the industry. Staff at the Department of Agriculture and Fisheries (DAF) also conducted research, development and extension often in association with Golden Circle Ltd. After its sale in 2008, the grower base supplying the cannery was rationalised and all its research as well as industry and agronomic support ceased.

The number of individual pineapple growers has shrunk significantly from about 1,000 in the 1970s to about 70 in 2022 and there has been a universal trend to larger scale production units.

Production

From the early days, pineapple farms in Australia have traditionally been small family-operated businesses. The average farm size at that time was six to twelve hectares. The industry has changed in profile since those early days with the loss of many small farms being partly compensated for by the increase in size of the larger farms. The industry reached a maximum production of 154,000 tons (from 6,660 ha) in 1988.

In the last 20 years the Australian pineapple industry has moved from one focused predominantly on the processing market to one aimed at fresh fruit consumption. In the early 1990s the Golden Circle cannery in Brisbane processed 120 to 130,000 tons per annum whilst only about 20,000 tons were sent to the fresh fruit markets. By 2019 this had reversed with the annual intake by Golden Circle down to 23,000 tons per annum and the fresh fruit market up to about 49,000 tons, giving a total production in 2019 of 72,000 tons from an estimated 2,200 ha.

Production regions

Because pineapple is susceptible to frost and sunburn, plantings are grown along the coastal strip, never more than about 40 km inland. Whilst pineapples are grown from just north of Brisbane to Mareeba in tropical North Queensland, most production is in a sub-tropical environment.

Production is split between four regions, South-East Queensland (Wamuran to Gympie), Wide Bay (Maryborough, Hervey Bay, Childers and Bundaberg), Central Queensland (Yeppoon) and North Queensland (Mackay, Rollingstone and Mareeba). These four regions produce 42%, 23%, 20% and 15% of the national crop respectively.

The crop cycles are quicker in the northern regions due to the warmer temperatures and although pineapples can be harvested year-round in each zone there are more suitable times associated with each. For South-East Queensland these are February to May (autumn) and August to October (spring), for Wide Bay January to May (late summer and autumn) and September to October (spring), for Central Queensland January to May (late summer and autumn) and August to November (spring) and for North Queensland October to December (early to mid-summer).

Varieties

In the 1990s both market destinations, fresh and processed, were supplied almost entirely with the Smooth Cayenne variety apart from a small volume of 'Rough Leaf' (also known as 'Queen') that was grown for the fresh fruit market. 'Smooth Cayenne' is well suited to processing because it is high yielding, juicy and has sufficiently high acid levels. However, in winter the acid levels are too high and sugar levels too low to make it suitable for fresh fruit consumption and less profitable for processing due to the need to add sugar. Today the processing market is still based on 'Smooth Cayenne' and in summer some is still sold on the fresh market, but two thirds of the fresh fruit market is now supplied with other varieties, and these have a higher sugar to acid ratio, more yellow flesh and greater storability.

Currently, the two principle fresh market varieties grown in Australia are the imported Hawaiian varieties '73-50' (*syn*, 'CO-2') and 'MD-2' which are collectively referred to as the 'Gold' or 'Hybrid' varieties. Neither '73-50' or 'MD-2' are marketed under their varietal names, both are sold under a plethora of brands, usually associated with a pack-house or marketing group but often both will have the same label and be retailed in mixed displays. '73-50' has been the most successful to date being more suited to the subtropical conditions that characterize most of the Queensland industry. 'MD-2', which dominates world fresh fruit consumption, is better suited to the tropical climate of North Queensland but some is grown in the Central Queensland district too. Usually both are sold under generic names associated with the specific marketing group. 'Smooth Cayenne' is still a suitable fresh fruit variety in summer and is sold with crowns still attached.

Currently the industry is very dependent on '73-50' and 'MD-2' but they are both highly susceptible to root rot and natural flowering.

DAF has released three varieties, which are in various stages of commercialization under a controlled-marketing system. These include Aus-Jubilee™, Aus-Festival™ and Aus-Carnival™. Both 'Aus-Jubilee' and 'Aus-Carnival' offer greater resistance to root disease and natural flowering.

Pests, diseases and disorders

Pineapple has many pests, diseases and disorders. Most of the serious pests and diseases attack the weak root system of pineapple.

- **Pests**

  Nematodes, symphylids and mites are the main pests, but cane grubs, African black beetle, scale and mealybug are also significant pests. Minor pests include birds, rats, mice and feral pigs.

- **Diseases**

  Phytophthora root rot (caused by *Phytophthora cinnamomi*) is the biggest production issue of the industry in all areas. Other significant diseases are Phytophthora heart rot, base rot, water blister, mealybug wilt and yellow spot. Minor diseases include fruitlet core rot, green fruit rot, inter-fruitlet corking, white leaf spot, yeasty rot, marbling and pink disease.

- **Disorders**

  There are several disorders, the most serious of which are natural flowering, translucency, physiological browning ('blackheart'), sunburn and abnormal crowns. Minor disorders include russeting and tapered fruit.

Farm management practices

The industry is relatively labor intensive and is heavily dependent on pesticides and a high level of mechanical cultivation. Significant issues remain with soil erosion and off-farm deposition of fertilizers and pesticides, and these issues are recognized by the industry, which is working on ways to improve this situation. Access to suitable and sufficient labor can be an issue.

The most expensive part of growing pineapples is the harvesting operation, and this is followed by planting. For many years, there has been a desire to reduce the dependency on manual labor for harvesting. This culminated in recent years in the redesign of harvesting booms to incorporate a de-topping saw or blade (which removes the crown mechanically). The de-topper harvester boom has led to a reduction of fatigue amongst the picking staff, potentially increased the speed of harvesting and has opened up the picking task to a wider range of staff. Recent efforts to advance to true mechanical harvesting are utilizing several approaches including GPS and satellite/drone technology to identify fruit and map their stage of maturity by fruit development algorithms.

Extension, research and development

DAF leads an extension project to deliver a range of extension services including regular grower study group workshops in each of the four regions, information resources, a grower website, quarterly newsletter, regular updates of industry production statistics and field trials designed primarily as sites to demonstrate best practice but also to screen new pesticides and to showcase other new farming practices.

The DAF breeding project is aiming to incorporate resistance to both root disease and natural flowering in new fresh fruit varieties to help 'future proof' the industry. This program is utilizing the latest in marker sequencing and genomic selection tools to achieve this.

The Australian industry is proactively working to reduce the loss of soil, pesticides and fertilizers from the farm to the local environment, watercourses and the Great Barrier Reef. A group called the Pineapple Environmental Team (PET) was formed in 2019 consisting of representatives of Australian Pineapples, DAF, Growcom and the Department of Environment and Science. Several trials have been established to test and demonstrate a range of measures to growers that will reduce the off-farm deposition of soil, pesticides and fertilizers. This has been developed in response to the new regulations associated with protecting the Great Barrier Reef.

Industry organization and funding for research, development and extension

The Australian pineapple industry is small by world standards involving just 70 growers and producing about 72,000 tons per annum. Growcom acts as the peak industry body. The industry has a representative group called Australian Pineapples made up of a grower representative from each of the four production regions plus others closely associated with the industry such as agronomists and representatives from DAF, Golden Circle Ltd and Growcom. This group is not incorporated but acts on behalf of the growers and works closely with its peak industry body Growcom. Growcom serves and represents a number of Queensland's fruit, vegetable and nut growers and their core purpose is to advocate on behalf of industry members.

The industry became members of Horticulture Innovation Australia Ltd (Hort Innovation) and in 2008 the research and development (R&D) levy, marketing levy and the ability to raise an Emergency Plant Pest Response Deed (EPPRD) levy were struck. As members of Hort Innovation, the industry has a Strategic Investment Advisory Panel, which is made up of four growers, an industry agronomist, and an independent scientist.

Fruit russeting on variety PRI_73-50 on Coastal Sands – Queensland, Australia

G. M. Sanewski, Department of Agriculture and Fisheries, Maroochy Research Facility, Nambour. Australia

The principle fresh market pineapple variety in Australia is PRI 73-50 (syn. CO-2), a sibling to 'MD-2'. Within Australia, it is grown from the sub-tropics to the tropics. Nutrient programs are largely based on 'Smooth Cayenne' and are usually managed to provide a soil pH of 4.5 to aid with control of *Phytophthora cinnamomi*. A form of russeting and a potentially associated growing point and crown disorder have been increasingly observed on some farms on highly leached coastal sands. The term 'chocolate' has been adopted in line with grower description but has not been described as such anywhere in the literature.

The obvious symptom of 'chocolate' appears to be a superficial suberisation or 'corking' of the fruit epidermis of usually the upper half of the fruit, although it might also occur infrequently on the lower portion. The most severe incidence covers the entire fruit (Figure 1). The condition appears to be apparent at early fruit development as a lack of trichomes covering (white bloom) (Figure 2). Trichomes are waxy structures that are highly reflective and, in pineapple, hydrophobic. It is believed they act as a protective layer. Figure 3 shows affected fruit without trichomes and normal fruit with trichomes. Other symptoms exhibited in the same field as 'chocolate' fruit include death or abnormalities of the crown growing point (Figure 4), plants with stiff, upright leaves or a dead growing point (Figure 5), stunted plants, and plants with a bent peduncle (Figure 6).

Photos: Garth Sanewski

Figure 1. Fruit affected with the russeting disorder called 'chocolate'. Figure 1C is a very severe form.

Photos: Garth Sanewski

Figure 2. A healthy syncarp (A) and one with reduced trichome covering (B), believed to be associated with the russeting disorder, 'chocolate'.

Photos: Garth Sanewski

Figure 3. Healthy (A) and affected fruit (B).

Photos: Garth Sanewski

Figure 4. Affected crowns in a field exhibiting symptoms of 'chocolate'.

Photos: Garth Sanewski

Figure 5. Growing point death (A) and stiff upright leaves with terminal necrosis and margin scalloping (B) in a field that has exhibited 'chocolate' in a previous crop.

Photos: Garth Sanewski

Figure 6. Bent peduncle in a field exhibiting symptoms of 'chocolate'.

An examination for Pineapple Fruit Mite (*Stenotarsonemous ananas*) was conducted by collecting 100 young leaves from a young field showing early symptoms similar to those in Figs 2 and 5. The leaf bases were rinsed in ethanol, the sample solution centrifuged and small aliquots from the bottom of the tube examined under a binocular microscope for mites. No mites were observed.

Soil analyses was conducted for two affected farms (Table 1). Leaf analyses were conducted for the same two affected farms and a third farm on a different soil type not showing any symptoms (Table 2).

Results

- The symptoms are not restricted to certain sides of the fruit suggesting it is not from sun exposure alone.
- The majority of plants with affected fruit appear otherwise normal relative to those with unaffected fruit close-by suggesting it occurs at a specific time in plant development.
- Affected fruit are distributed across the field apparently randomly. Affected fruit are not restricted to field margins. There is no spray pattern evident.
- There is a high incidence of the disorder in several fields fruiting in the winter to spring period.
- The symptoms, their distribution and frequency are suggestive of a physiological or nutritional disorder.
- No mites were observed in affected fields.
- Spray combinations used in the period post induction were tested for phytotoxicity with no observed deleterious effect.
- Table 1 shows soil calcium and manganese to be low on both affected farms. Farm 2 soil was also deficient in magnesium, zinc and boron.
- Table 2 shows affected farms 1 and 2 to both exhibit deficient leaf levels of calcium, magnesium and manganese. Farm 2 was also deficient in copper. The clean farm was adequate in all elements except copper. Potassium was high on all farms when using the MD-2 standards for Costa Rica.

Table 1. Soil analysis for two affected farms.

Element	Farm 1 Affected	Farm 2 Affected	Optimum	
			Cayenne Australia	All crops (Loamy sand)
pH (1:5 water)	4.2	4.6	4.5 - 5.6	5.0 - 5.5
Ca (ppm)	**61**	**55**	100	375
Mg (ppm)	89	**11**	50+	75
Na (ppm)	<50	18	-	25
S (ppm)	242	86	-	100 - 1,000
Zn (ppm)	5.1	**1.2**	3+	3
Fe (ppm)	9,322	86	-	15
Cu (ppm)	3.5	2.0	2+	1.2
Mn (ppm)	**10**	**0.6**	-	15
B (ppm)	2.4	**0.3**	-	1

Table 2. Leaf analysis for two affected and one clean farm.

Element	Farm 1 - affected soil pH 4.2	Farm 2 - affected soil pH 4.6	Farm 3 - clean soil pH 5.8	Optimum standards	
				Cayenne Australia	MD-2 Costa Rica
N (%)	2.09	1.37	2.38	-	1.5 - 1.8
P (%)	0.20	0.21	0.29	0.14 - 0.35	0.20
K (%)	6.27	3.71	5.83	4.3 - 6.4	2.7 - 3.0
Ca (%)	**0.03**	**0.07**	0.28	0.22 - 0.40	0.25 - 0.30
Mg (%)	**0.11**	**0.11**	0.34	0.41 - 0.57	0.25 - 0.30
Na (%)	<0.01	0.05	<0.05	0.004 - 0.015	-
S (%)	0.20	0.21	0.21	-	0.13 - 0.15
Zn (ppm)	17	15	23	15 - 70	30 - 35
Fe (ppm)	339	98	36	80 - 150	100 - 200
Cu (ppm)	12	**7**	8	10 - 50	10 - 15
Mn (ppm)	**9.8**	**21.6**	246	150 - 400	75 - 100
B (ppm)	7	13	14	-	35 - 40

Discussion

Soil analyses **(Table 1)** generally agree with leaf analyses **(Table 2)** and both confirm affected fields are low in several cations and likely very deficient in some. The growing point disorder could be associated with low soil cation levels exacerbated by reduced root activity or increased damage to root tips by disease over the winter period and cation imbalances. Cations potentially implicated include calcium, magnesium, manganese, zinc and copper. Calcium is considered the most likely candidate as the majority of symptoms are consistent with a deficiency. Some of the symptoms are also similar that of copper deficiency (lack of leaf trichomes) or zinc deficiency (bent peduncle). However, at present there is no demonstrated direct link between the growing point disorder or russeting and the nutrient status of plants.

Other factors which might interfere with cation availability in the plant at critical times include high potassium, high phosphates and high phosphite from potassium phosphonate.

Recommendations for affected farms include:

- increasing pH to 5.5,
- improving soil CEC,
- reducing potassium application,
- avoiding excessive use of phosphonates,
- improving soil levels of calcium, magnesium, copper and zinc.
- maintaining a balanced nutrient spray program.

Pineapple producers pursue water quality improvement and sustainability practice change

Stuart Irvine-Brown, Senior Research Agronomist, Queensland Department of Agriculture and Fisheries, Australia

In short:

- Pineapple producers in Australia are supporting Queensland Department of Agriculture and Fisheries (DAF) research and industry development into the use of denitrification bioreactors to remove agricultural nitrogen from shallow groundwater exiting their farms, entering adjacent natural waterways and affecting the environment.
- The water quality improvement research was trialled in the Pumicestone Catchment, a major horticultural production area adjacent to the important Ramsar listed wetlands of Moreton Bay.
- By strategically placing woodchip denitrification bioreactors to intercept shallow ground water or run-off water containing high nitrogen there is a removal process whereby nitrate is naturally converted to nitrogen (N_2) gas by microorganisms and water quality is improved.
- Establishing effective bioreactor treatment systems complements grower sustainability practice change on reduced pre-plant fertiliser applications to address off-farm environmental impacts.

Pineapple producers in South East Queensland, Australia, have been collaborating with the Queensland Department of Agriculture and Fisheries (DAF) by supporting agronomic research investigations into water quality improvement. The Pumicestone Catchment is the main area for pineapple production in Australia and its river systems connect to the Ramsar listed wetlands of Pumicestone Passage and Moreton Bay. These freshwater and marine environments are of significant ecological value and are protected under internationally recognised environmental legislation. Water quality decline in this important freshwater and marine ecosystem is apparent due to the legacy of intensive horticultural production systems of which pineapples are a major commodity. Water quality impacts span sediment and agrochemicals, but are also related to excessive nitrogen (N) transfer via leaching from agriculture due to the favourable free draining soils.

To understand the major origin of N transfer from agriculture into the environment within the catchment a consistent period of water quality testing was established. Data from testing identified that key sub-catchment land areas dominated by horticulture, and in particular pineapple production were responsible. Leaching losses of N from pineapple production are most profound during the early crop planting and establishment phase. Mineralisation of soil organic matter and pre-plant fertiliser provide a surplus of N which is not entirely utilised by the pineapple crop due to low demand and its developing root system. This surplus of N is therefore at high risk of leaching from the expanding root zone after rainfall and highlights the need for agronomic nutrient budgeting and edge of field mitigation options to prevent agricultural N from affecting aquatic environments.

In conjunction with a series of pineapple producers DAF trialled in-field ‘bioreactor beds’ and edge-of-field ‘bioreactor walls’ treatment systems proven successful in other international research studies. Addressing the issue of declining water quality by reducing potential for agricultural N to impact surrounding aquatic environments. The aim was to assess the potential of denitrification bioreactors to remove N from drainage and shallow ground water under the prevailing hot-wet and cool-dry Queensland weather systems.

Bioreactor treatment systems are essentially a collection of organic material, but primarily woodchips. This material is strategically placed to intercept and interact with shallow ground water or surface run-off waters containing N originating from agricultural inputs. The N now in the form of nitrate (NO_3^-) in this water is removed via the process of denitrification. Bioreactors work by creating a home and food source (woodchips) for naturally occurring bacteria, which due to the anaerobic underwater situation use the nitrate in the water to respire or breathe. This process converts the nitrate-N in water into (N_2) nitrogen gas, which makes up approximately 79% of the atmosphere.

Where there is a consistent amount of N in shallow ground water or in run-off, bioreactors have been extremely successful in removing N from water exiting agricultural production zones before entry into the off-farm environment. However, there are a series of soil water factors, which influence bioreactor placement to ensure that maximum N removal rates can be achieved. Aspects such as position in the landscape, soil type, ground water depth, flow volume and direction, and catchment drainage area should be accounted for to make bioreactors a successful and a cost-effective N removal method.

The first bioreactor wall in Queensland was installed on a pineapple farm in Glasshouse Mountains during June 2017. After five years of monitoring, it is still removing 100% of the N going into it from shallow ground water. This demonstrates bioreactors as effective N removal systems in the hot-wet and cool-dry subtropical conditions of Queensland. Because of this treatment system success, another perimeter bioreactor has recently been installed at another pineapple farm. Being a trench 0.4m wide, dug to a critical soil depth, but many meters long, it will interact with more of the shallow ground water table in key locations on the farm adjacent to natural waterways. Soil sampling and water testing to identify key locations where bioreactor N removal would be most effective, informed bioreactor placement.

DAF is continuing research and development work with Australian Pineapples on agronomic solutions to provide improvements in water quality, which the industry has committed to and is striving towards achieving. Practice change around productive and profitable pineapple cropping, acknowledging new and developing environmental sustainability criteria, will be vital as consumers increasingly look for ecologically aware options. DAF's current agronomic pineapple research program, informing this topic, therefore is conducting further investigations for outcomes related to sediment movement and agrochemical transfer into the environment.

If you are interested in reading more about denitrification bioreactor systems and treatment system technologies, which can improve water quality outcomes, visit this link to download publications. https://www.publications.qld.gov.au/dataset/treatment-system-technologies-to-improve-water-quality

Photo by S.I-Brown

Photo caption by S.I-Brown: Woodchips are filled into a newly excavated trench to construct a denitrification bioreactor removing nitrate-nitrogen in shallow ground water before it enters the surrounding environment at the perimeter of a pineapple farm in the Glasshouse Mountains,Australia.

News from Brazil

Current situation and performance of Brazilian pineapple production in the last ten years - 2011 to 2020

José da Silva Souza and Marcelo do Amaral Santana.

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Introduction

Statistics from the FAO (Food Agriculture Organization of the United Nations) reveals that, in 2020, world fruit production is present in almost 200 countries in the world, with a total production of 948.5 million tons and that Brazil is the third producer in the world, behind China and India. In the same year, Brazilian fruit production of 42.2 million tons represents a percentage of 4.5% in relation to the world. Pineapple's share of Brazilian fruit production was 5.8%, corresponding to a volume of 2.46 million tons, ranking fourth, behind oranges, bananas and coconuts. In the same year, Brazil ranked third (8.8%) in world pineapple production of 27.8 million tons, behind the Philippines (9.7%) and Costa Rica (9.4%) (FAO, 2020a). Brazil contributed with US$ 453 million to the global pineapple production value of US$ 9 billion, which is a share of 5.0% (FAO, 2020b). In this article, the current situation and the performance of the Brazilian pineapple crop were analyzed for the last ten years, under two dimensions of territorial division - macro-regions and producing states.

Brazilian pineapple production

The current geographic distribution of Brazil is composed of macro-regions (05), states (26), Federal District (1), meso-regions (137), micro-regions (558) and municipalities (5,563). Among the Brazilian municipalities (5,563), pineapple production occurred in 1,021 municipalities in 2020, which corresponds to 18.4% of the total. About 80% of the total occurred in about 50 municipalities, revealing a high concentration of Brazilian production. Considering the country's macro-regions, the distribution by states is as follows: North (7), Northeast (9), Southeast (4), South (3) and Midwest (3 states and the Federal District) (Table 1 and Figure 1) (IBGE, 2020).

The Brazilian pineapple production of 1.637 billion fruits[1], which corresponds to a volume of 2.46 million tons, is spread over almost all states of the federation (except Piauí) and in the Federal District, as can be seen in Table 1, where states are ranked in decreasing order of production within macro-regions.

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[1] Brazilian pineapple production is still expressed in number of fruits. In the transformation of fruit production to tons, an average weight of 1.50 kg/fruit has been used.

Table 1 - Brazilian pineapple production by macro-regions, states and the Federal District, in 2020.

Regions	States	Initials	Area harvested (ha)	Production (thousand fruits)	Yield (fruits/ha)
North	Pará	PA	13,680	357,021	26,098
	Tocantins	TO	4,727	98,523	20,843
	Amazonas	AM	2,608	66,511	25,503
	Rondônia	RO	937	23,299	24,866
	Amapá	AM	1,186	9,368	7,899
	Acre	AC	524	6,182	11,798
	Roraima	RR	415	5,391	12,990
Northeast	Paraíba	PB	9,055	272,285	30,070
	Alagoas	AL	3,541	69,646	19,668
	Rio Grande do Norte	RN	2,545	66,936	26,301
	Bahia	BA	2,499	41,806	16,729
	Pernambuco	PE	1,372	30,703	22,378
	Maranhão	MA	1,081	24,290	22,470
	Sergipe	SE	926	22,220	23,996
	Ceará	CE	38	712	18,737
	Piauí	PI	-	-	-
Southeast	Minas Gerais	MG	5,757	173,853	30,199
	Rio de Janeiro	RJ	4,559	143,454	31,466
	São Paulo	SP	2,683	77,071	28,726
	Espírito Santo	ES	2,236	42,130	18,842
South	Paraná	PR	531	17,506	32,968
	Rio Grande do Sul	RS	288	4,866	16,896
	Santa Catarina	SC	14	369	26,357
Midwest	Goiás	GO	1,927	42,695	22,156
	Mato Grosso	MT	1,391	34,588	24,866
	Mato Grosso do Sul	MS	261	5,503	21,084
	Distrito Federal	DF	6	198	33,000
Brazil			**64,787**	**1,637,126**	**25,269**

Source: IBGE (2020).

The location of the macro-regions, states and the Federal District can be seen in **Figure 1**. It is observed that pineapples are produced in Brazil from the states of the Amazon Region (near the equator) to the states of the coolest region of the country, at around 30° South latitude (IBGE, 2020).

Regarding the Brazilian macro-regions, the most important were North, Northeast and Southeast, which together made up 93.5% of the total volume of pineapple produced in 2020 (**Figure 2**).

Figure 1. Brazilian macro-regions, states and Federal District. Source: IBGE (2020).

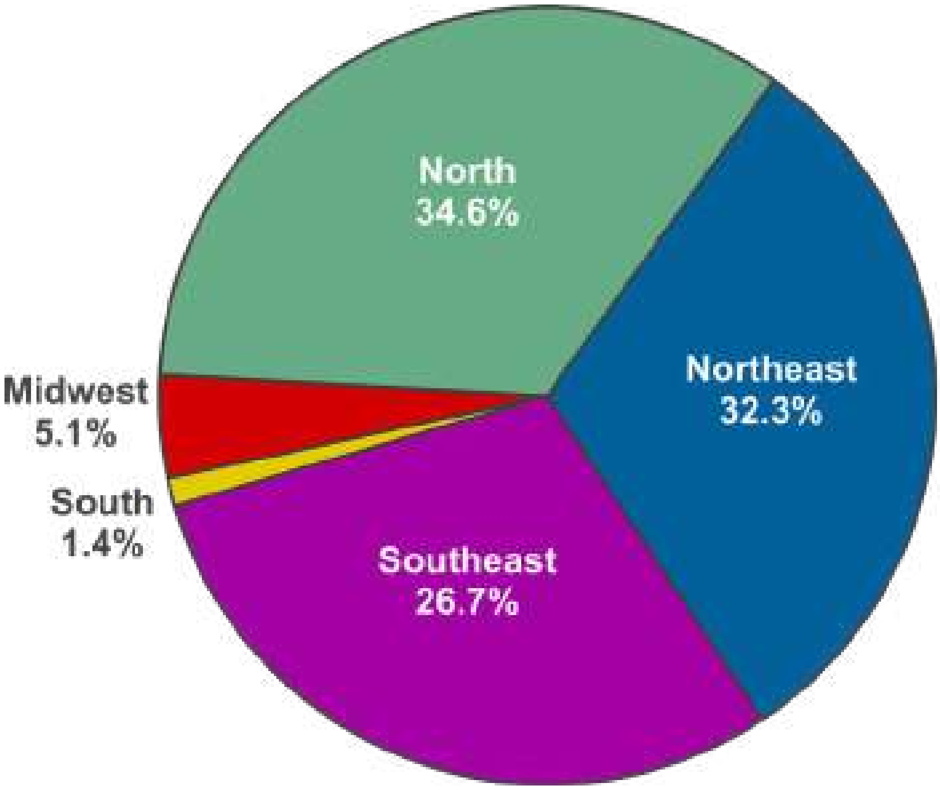

Figure 2. Shares of Brazilian macro-regions in Brazilian pineapple production in 2020. Source: IBGE (2020).

Although pineapple is produced in 25 states and the Federal District, nine states are worth mentioning, as they are responsible for 81% of national production. There are three states representing the North region – the Amazon region with a hot and humid climate (Pará, Tocantins and Amazonas); three states in the Northeast – region with a hot and mostly dry climate (Paraíba, Alagoas and Rio Grande do Norte) and three states in the Southeast region – region with a milder climate (Minas Gerais, Rio de Janeiro and São Paulo) (**Figure 3**).

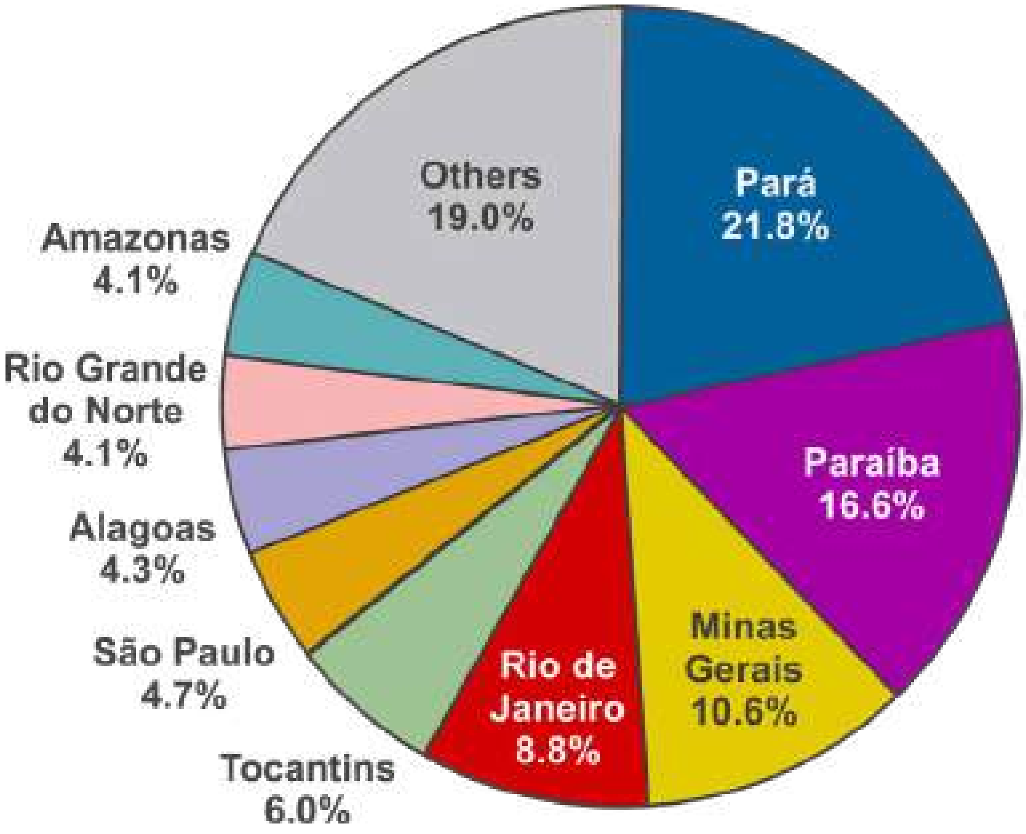

Figure 3. Shares of the main states in Brazilian pineapple production in 2020. Source: IBGE (2020).

Method used

In this study, the geometric growth rate (GGR) of pineapple production was compared, considering only the distributions of the five macro-regions, the 25 states and the Federal District. The method used to evaluate the performance over the last ten years, 2011 to 2020, was the geometric growth rate (average percentage per year), calculated by regression, after the logarithmic transformation of the data. Considering a period (ex-post) of available information, it is possible to evaluate the performance of the variables considered and their relationships. In this case, the performance of the harvested area, production and average yield of the pineapple crop were considered. The growth in production can be explained by the growth in harvested area and yield. For any crop, the ideal is for production to grow by increasing yields, which is normally a result of the incorporation of more effective technological innovations into the production system. The growth in production through increased yields also promotes the land-saving effect, as production can be maintained with the use of a smaller cultivated area. Once the calculations are carried out, the sum of the geometric growth rates of the harvested area and the yield is very close to the geometric growth rate of production.

Results and conclusions

For Brazil, the crop presented a negative GGR for production, but a very small one (-0.09% p.a.), indicating a certain stagnation of the crop in the period studied, even with a small increase in the harvested area (0.53% p.a.), which was neutralized by the reduction in yield of -0.61% per year (**Table 2**). Although Brazil is the third largest pineapple producer in the world, its production is basically directed towards the domestic fresh fruit market, with small shares by foreign markets of fresh and processed fruits. According to the IBGE, using data of 2017-2018, per capita consumption of fruits in Brazil is still small (26.414 kg/cap./year), when compared to first world countries, with values over 120 kg/cap./year. The distribution of fruit consumption in Brazil is as follows: 22.648 kg/cap./year of fruits in a tropical climate and 3.767 kg/cap./year of fruits in a temperate climate. In this context, the Brazilian per capita consumption of pineapple is also rather small, at only 1.4 kg/cap./year. With regard to yield, there is a challenge for getting an increase for this crop, as the current average yield level is very low when compared to some other countries, such as Costa Rica, a large producer and the largest world exporter of fresh fruit. There are several main constraints that explain the relatively low yield of the crop in Brazil, such as significant losses caused by diseases, especially fusariosis, the low input crop management practiced by most of the growers, which can be classified as micro or small growers, the high costs of fertilizers and pesticides in comparison to the relatively low fruit prices, among others. The offer and adoption of new varieties with fusariosis resistance, an increasing level of mechanization and the growing investment to be done by larger pineapple growers may contribute to future average yield improvements.

Considering the Brazilian macro-regions (**Table 2**), two of them presented positive values for the GGR of production: the North and the South. Regarding the North region, the growth in production (3.28% p.a.) was due to the increase in the harvested area (4.84% p.a.), as the yield showed a negative rate. The result of the South macro-region should be viewed with caution, as this region contributes the least to national production, with only 1.4% of the quantity produced. The two other important macro-regions of Brazil (Northeast and Southeast) showed a trend of reduction in production, equal to -1.42% per year. In the Northeast, this negative rate can be explained by negative rates that occurred in the harvested area (-0.74% p.a.) and in yield (-0.69% p.y.). In the Southeast macro-region, the reduction rate of harvested area (-1.88% p.a.) was partially offset by the small yield growth of 0.47% per year, resulting in a production reduction rate of -1.42% per year.

Table 2. Geometric growth rate of Brazilian pineapple production by macro-regions, from 2011 to 2020.

Macro-regions / Brazil	Geometric growth rate (% per year)		
	Area harvested (ha)	Production (thousand fruits)	Yield (fruits/ha)
North	4.84	3.28	-1.49
Northeast	-0.74	-1.42	-0.69
Southeast	-1.88	-1.42	0.47
South	0.40	4.61	4.19
Midwest	-3.52	-3.28	0.25
Brazil	**0.53**	**-0.09**	**-0.61**

Source: Calculated by the authors from IBGE data (2011 to 2020).

Table 3 presents the performances for the Brazilian states, considering their ranking in order of importance in pineapple production. The first nine states are the most important in the Brazilian pineapple production, being responsible for 81% of the total volume produced in the country. Along the last ten years, two states presented high GGR of production: Alagoas (30.83% p.a.) and Tocantins (14.40% p.a.). In both, these rates were due to the growth of the harvested area, since the yield growth rates in both states were negative. Pará (the largest producer) had a GGR of 1.65% p.a., due to the increase in harvested area (5.12% p.a.), but this excellent result was neutralized by the high negative rate of -3.30% per year in yield. With regard to the state of Paraíba, in second place, the increase in production (0.81% p.a.), although small, was due to increases in the harvested area (0.40% p.a.) and yield (0.41% p.a.). As for the third largest producer state, Minas Gerais, the reduction in production (-3.71% p.a.) was due to the reduction in harvested area (-3.95% p.a.), as the growth in yield was very small, of 0.25% per year. Rio de Janeiro, in fourth place, presented growth in production (1.46% p.a.), due to increases in the harvested area (0.58% p.a.) and in yield (0.87% p.y).

Table 3. Geometric growth rate of Brazilian pineapple production by states and the Federal District, from 2011 to 2020.

States / Brazil	Geometric growth rate (% per year)		
	Area harvested (ha)	Production (thousand fruits)	Yield(fruits/ha)
Pará	5.12	1.65	-3.30
Paraíba	0.40	0.81	0.41
Minas Gerais	-3.95	-3.71	0.25
Rio de Janeiro	0.58	1.46	0.87
Tocantins	14.89	14.40	-0.43
São Paulo	-3.45	-0.90	2.64
Alagoas	31.68	30.83	-0.65
Rio Grande do Norte	-6.45	-7.81	-1.45
Amazonas	-4.16	0.21	4.55
Goiás	-3.80	-4.00	-0.21
Espírito Santo	0.99	-0.88	-1.85
Bahia	-10.92	-16.01	-5.71
Mato Grosso	-3.74	-2.86	0.91
Pernambuco	7.46	8.51	0.97
Maranhão	0.05	1.59	1.54
Rondônia	8.21	12.00	3.50
Sergipe	3.08	3.38	0.29
Paraná	3.21	6.17	2.87
Amapá	1.22	8.02	6.72
Acre	0.60	-1.57	-2.16
Mato Grosso do Sul	-0.57	-0.64	-0.07
Roraima	12.74	16.98	3.76
Rio Grande do Sul	-3.62	0.13	3.89
Ceará	-28.20	-36.16	-11.08
Santa Catarina	8.22	15.65	6.87
Federal District	4.45	8.00	3.39
Brazil	**0.53**	**-0.09**	**-0.61**

Source: Calculated by the authors from IBGE data (2011 to 2020).

Among the nine main producing states, regarding the yield increase, which may reflect an improvement in the technological level, the states of Amazonas (4.55% p.a.) and São Paulo (2.64% p.a.) are noteworthy. Other states, in addition to the nine most important ones, showed interesting growth rates, however, they contribute very little to Brazilian production.

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Brazilian pineapple production segmented by cultivars

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Abstract

Brazil is one of the main pineapple producers in the world, in addition to being the center of origin of the species *Ananas comosus*. Despite the wide variability of varieties, commercial pineapple plantations in Brazil are based on a few cultivars. Among 5,563 municipalities in Brazil, 1,021 have some pineapple production. In the present study, it was determined that 52 Brazilian municipalities are responsible for 80% of the national production. It was estimated that in these main municipalities, 85.5% of the production is of the Pérola cultivar (in the North, Northeast and Southeast regions), 9.5% of the production is of the Smooth Cayenne cultivar (in the Southeast region) and 5.0% of the production is of the Turiaçu cultivar (under the Amazon climate). Modern pineapple cultivars, originated from breeding programs, have not yet obtained expressive productions. This is a warning for the development of future cultivars, which must consider, in addition to resistance to fusariosis, fruit quality and adaptation to the wide environmental variation of pineapple producing regions in the country, a more effective planting material production and special attention to a strategic market insertion.

Introduction

Brazil is the third largest pineapple producer in the world, being inserted in a group of countries with production volumes superior to two million tons a year, including also Costa Rica, the Philippines and Indonesia (FAO, 2019).

The country is known as a center of diversity for the pineapple plant (*Ananas comosus* var. *comosus*), considering the probable origin of the species in northern South America (Leal & Antoni, 1981). Much of the genetic diversity of *Ananas comosus* and related species is conserved in the Active Germplasm Bank of Embrapa Cassava & Fruits, in Cruz das Almas, state of Bahia. Currently, this repository maintains more than 700 accessions conserved in field conditions, 317 of them belonging to *Ananas comosus* var. *comosus* (the edible pineapple) varieties (da Silva et al., 2021).

However, despite the large production and diversity of pineapple varieties in Brazil, superior to the situation in other producing countries, there is a commercial predominance of just a few cultivars, such as 'Pérola', 'Smooth Cayenne' and 'Turiaçu', three pre-Columbian cultivars. The modern cultivars, such as BRS Imperial, BRS Vitória, BRS Ajubá and IAC Fantástico, all resistant to fusariosis (*Fusarium guttiforme*), are relatively new and have not been cultivated in a large scale.

'Pérola' is the main cultivar in the Brazilian fresh market, but also grown in Western Africa (Ghana, Benin and Cameroon), where is named Sugarloaf/Pain de Sucre. This cultivar is well adapted to a wide range of soils and climate, with moderate resistance to *Phytophthora*, tolerance to drought, mealybug wilt and nematodes, but high susceptibility to fusariosis. The plant is medium-sized and vigorous, with erect, spiny leaves. It has few plant or ground suckers, but numerous slips (5–15) surround the fruit, on the top of a long peduncle (27–35 cm). The fruit usually is of conical shape, with a green peel at maturity and a white and translucent flesh, softer, sweeter and without the usual fibrous center, compared to the other varieties.

'Smooth Cayenne', also called 'Havaiano' or 'Havaí' in Brazil, is the second most planted pineapple cultivar in the country. Due to its greater tolerance to natural flowering, it is cultivated mainly in colder regions, at higher latitude and subtropical climate, such as in the state of São Paulo, in some municipalities of Minas Gerais (Southeast region) and in the state of Paraná (South region).

'Turiaçu' is a cultivar grown in the states of Amazonas and Rondônia (North region) and in the municipality of Turiaçu, in the state of Maranhão (Northeast region, but with an Amazonian climate). The plant has an erect habit, with spiny, dark green leaves with reddish spines, long peduncle, 11 slips/plant in average, few or no suckers. The fruit is cylindrical to conical, weighs 1.6 kg, has a small to medium crown and a full yellow skin at maturity, small prominent eyes, yellow flesh, medium to high sugar content (14-18%) and very low acidity (TA 0.38%).

The objective of this article is to evaluate the Brazilian production of pineapple with a focus on the distribution of the most planted cultivars.

Pineapple production in Brazil

The Brazilian Institute of Geography and Statistics (IBGE) is responsible for surveying the harvested area, production and productivity of agricultural crops in the country. In 2020, pineapple was grown in 25 of the 26 states of Brazil and in the Federal District of Brazil. In an area of 64,787 hectares, 1,617,684 thousand fruits (1.6 billion) were harvested. Based on the conversion factor of 1.5 kg/fruit, FAO estimated Brazilian pineapple production at 2,426,526 tons. Among the Brazilian pineapple producing states, Pará (in the North region), Paraíba (in the Northeast region), Minas Gerais and Rio de Janeiro (in the Southeast Region) stand out, as they together produced more than 50% of Brazilian pineapple in 2019 **(Table 1).**

Table 1. Brazilian pineapple data in 2020 (IBGE, 2021).

States	Harvest area (ha)	Production (x 1,000 fruits)	Yield (fruits/ha)
Pará	13,680	357,021	26,098
Paraíba	9,055	272,285	30,070
Minas Gerais	5,757	173,853	30,199
Rio de Janeiro	4,559	143,454	31,466
Tocantins	4,727	98,523	20,843
São Paulo	2,683	77,071	28,726
Alagoas	3,541	69,646	19,668
Rio Grande do Norte	2,545	66,936	26,301
Amazonas	2,608	66,511	25,503
Goiás	1,927	42,695	22,156
Espírito Santo	2,236	42,130	18,842
Bahia	2,499	41,806	16,729
Mato Grosso	1,391	34,588	24,866
Pernambuco	1,372	30,703	22,378
Maranhão	1,081	24,290	22,470
Rondônia	937	23,299	24,866
Sergipe	926	22,220	23,996
Paraná	531	17,506	32,968
Amapá	1,186	9,368	7,899
Acre	524	6,182	11,798
Mato Grosso do Sul	261	5,503	21,084
Roraima	415	5,391	12,990
Rio Grande do Sul	288	4,866	16,896

Table 1. Brazilian pineapple data in 2020 (IBGE, 2021).

States	Harvest area (ha)	Production (x 1,000 fruits)	Yield (fruits/ha)
Ceará	38	712	18,737
Santa Catarina	14	369	26,357
Distrito Federal	6	198	33,000
Piauí	-	-	-
Brazil	**64,787**	**1,637,126**	**25,269**

Among the 5,563 municipalities in Brazil, 1,021 had some pineapple production in 2020, according to IBGE. Using a cut-off point of 80% of Brazilian pineapple production (100% = 1,637,126 thousand fruits, 80% = 1,309,700 thousand fruits), it is observed that this production of 1.3 billion fruits was concentrated in 52 Brazilian municipalities **(Table 2)**.

Table 2. Brazilian municipalities with the main pineapple production, and cultivar percentage in 2019.

Municipality/State	Harvest Area (ha)	Production (x 1,000 fruits)	Production based on cultivar		
			Pérola	Smooth Cayenne	Turiaçu
Floresta do Araguaia (PA)	10,000	270,000	270,000	0	0
São Francisco de Itabapoana (RJ)	4,000	128,000	126,720	1,280	0
Itapororoca (PB)	2,100	63,000	63,000	0	0
Pedras de Fogo (PB)	2,000	60,000	60,000	0	0
Frutal (MG)	2,000	60,000	54,000	6,000	0
Araçagi (PB)	1,650	49,500	49,500	0	0
Miracema do Tocantins (TO)	2,500	48,332	48,332	0	0
Itacoatiara (AM)	1,600	48,000	0	0	48,000
Guaraçaí (SP)	1,600	48,000	0	48,000	0
Conceição do Araguaia (PA)	1,200	36,000	36,000	0	0
Touros (RN)	1,200	32,000	32,000	0	0
Canápolis (MG)	700	27,200	1,360	25,840	0
Itaberaba (BA)	1,100	25,080	25,080	0	0
Ielmo Marinho (RN)	1,000	25,022	25,022	0	0
Marataízes (ES)	1,414	24,108	24,108	0	0
Santa Rita (PB)	750	22,500	22,500	0	0
Monte Alegre de Minas (MG)	700	21,700	19,530	2,170	0
Jaraguá (GO)	920	19,780	19,780	0	0
São Francisco de Sales (MG)	500	17,500	525	16,975	0
Riachão do Dantas (SE)	600	14,400	14,400	0	0
Fronteira (MG)	480	13,920	11,693	2,227	0

Table 2. Brazilian municipalities with the main pineapple production, and cultivar percentage in 2019.

Municipality/State	Harvest Area (ha)	Production (x 1,000 fruits)	Production based on cultivar		
			Pérola	**Smooth Cayenne**	**Turiaçu**
Pombos (PE)	520	13,780	13,780	0	0
Presidente Kennedy (ES)	600	13,200	13,200	0	0
São Domingos do Maranhão (MA)	580	12,635	12,610	0	25
Lagoa de Dentro (PB)	420	12,600	12,600	0	0
Mirandópolis (SP)	350	10,850	0	10,850	0
São João da Barra (RJ)	320	10,507	10,507	0	0
Tangará da Serra (MT)	300	10,500	10,500	0	0
Salvaterra (PA)	550	9,892	9,892	0	0
Maragogi (AL)	520	9,880	9,880	0	0
Cujubim (RO)	300	9,000	0	0	9,000
Cuité de Mamanguape (PB)	300	9,000	9,000	0	0
Itapagipe (MG)	300	9,000	6,300	2,700	0
Limoeiro de Anadia (AL)	350	8,600	8,600	0	0
Curral de Cima (PB)	250	8,000	8,000	0	0
São Luiz do Norte (GO)	340	7,820	7,820	0	0
Miranorte (TO)	270	7,560	7,560	0	0
Careiro da Várzea (AM)	375	7,500	0	0	7,500
Centralina (MG)	250	7,500	0	7,500	0
Rio Maria (PA)	300	7,400	7,400	0	0
Guarabira (PB)	220	6,600	6,600	0	0
Joaquim Gomes (AL)	360	6,500	6,500	0	0
Flexeiras (AL)	300	6,400	6,400	0	0
Pium (TO)	250	6,250	6,250	0	0
Sapé (PB)	200	6,000	6,000	0	0
Sertãozinho (PB)	200	6,000	6,000	0	0
São Miguel do Gostoso (RN)	200	5,850	5,850	0	0
Arapiraca (AL)	300	5,750	5,750	0	0
Hidrolina (GO)	250	5,750	5,750	0	0
Murici (AL)	315	5,670	5,670	0	0
Turiaçu (MA)	200	5,555	0	0	5,555
Araguacema (TO)	200	5,400	5,400	0	0
Percentage of production			**85.5%**	**9.5%**	**5.0%**
Total in the 52 municipalities/ cultivar			**1,111,969**	**123,542**	**64,525**
Total in the 52 municipalities			**1,300,036**		
Total in Brazil			**1,637,126**		

The IBGE's data on harvested area, production and yield do not discriminate which is the predominant cultivar in the pineapple producing municipalities. In most of these producing municipalities only one pineapple cultivar is cultivated, as in Floresta do Araguaia, PA (exclusive cultivation of 'Pérola'), Itacoatiara, AM (exclusive cultivation of 'Turiaçu') or Guaraçaí, SP (exclusive cultivation of 'Smooth Cayenne'). However, in some of the 52 municipalities mentioned, two of the three main cultivars may be planted. In these cases, consultations were made by e-mail or telephone with technicians and agronomists of state rural extension companies in those municipalities, in order to estimate the percentage of production for each of the pineapple cultivars.

These estimates allowed the calculation of pineapple production for each cultivar, considering the 52 cities that concentrate 80% of pineapple production in Brazil **(Table 2).**

Discussion

In spite of the great diversity in pineapple varieties in Brazil, one of centers of diversity and domestication of *Ananas comosus* (Coppens d'Eeckenbrugge; Duval & Leal, 2018) and the availability of at least four new modern pineapple cultivars (Sanewski; Coppens d'Eeckenbrugge & Junghans, 2018), the Brazilian pineapple production is remarkably segmented among three pre-Columbian cultivars: Pérola, Smooth Cayenne and Turiaçu.

'Pérola' is grown in all main Brazilian pineapple production regions, mainly in North, Northeast and Southeast, with 85.5% of Brazilian pineapple production in 2019. 'Smooth Cayenne' make up 9.5% of Brazilian production, the second most cultivated, mainly in São Paulo state and in some municipalities of Minas Gerais state, both in Southeast region. Finally, 'Turiaçu' represents 5.0% of Brazilian pineapple production and is grown in Amazonas, Rondônia and Maranhão states, under Amazonian climate.

The modern Brazilian pineapple cultivars did not reach great expression on Brazilian production. 'BRS Imperial', 'BRS Vitória', 'BRS Ajubá' and 'IAC Fantástico', although resistant to fusariosis, are relatively new cultivars and have shown some constrains that make difficult their adoption by growers.

The fruits of 'BRS Imperial' are mostly focused on the highly valued baby pineapple market. Its production is mainly concentrated on a few Coastal microrregions of the state of Bahia, due to the good distribution of rainfall throughout the year. However, none of the 52 municipalities responsible for 80% of Brazilian pineapple production is located in this region. This cultivar is more demanding in water supply than 'Pérola', requiring the use of irrigation in the periods of water deficit, that are common in the main pineapple producing regions of Brazil.

The fruits of 'BRS Vitória' present higher acidity than 'Pérola' fruits, being less accepted by Brazilian consumers. Its production is small and concentrated in some municipalities of the state of Espírito Santo (Southeast region). When harvested at more advanced yellow maturation stage, the fruit has attributes similar to those of 'Pérola' fruits, but its commercialization is limited as a result of logistics problems in Brazil, where the pineapples are transported at long distances, without packaging, on trucks without refrigeration.

BRS Ajubá showed to more adapted to cooler subtropical climates of the states of Rio Grande do Sul and Santa Catarina (southern region of Brazil). However, in these states pineapple production is low. None of the cited 52 municipalities is located in those States.

'IAC Fantástico', the newest among Brazilian pineapple cultivars, unfortunately presented the problem of somaclonal variation in its commercial multiplication by micropropagation, which affected its acceptance among pineapple growers, notably in the state of São Paulo.

Finally, cultivar Gold or MD-2, which was introduced in Brazil in the first years of this century and reached a considerable production in the state of Ceará (Northeast region) from 2003 to 2009, proved to be much more susceptible to fusariosis than the traditional cultivars. Cultivation has been discontinued due to the increase in production costs and yield losses caused by that disease.

Currently there are three active breeding programs in Brazil, the main one is carried out by Embrapa Mandioca e Fruticultura (Embrapa Cassava & Fruits). In addition, there are smaller ones in the Universidade do Estado de Mato Grosso/UNEMAT and the Instituto Agronômico de Pernambuco/IPA. All programs aim to develop cultivars resistant to fusariosis with a focus on fruit quality. Taking into account the rather limited adoption of modern pineapple cultivars available in Brazil, it is important to adjust the strategies for the selection, propagation and offer of new future cultivars. In addition to careful studies for their good adaptation to the different environmental conditions in the main Brazilian pineapple production poles, more attention must be given to the offer of good planting material and to an adequate strategy for their market insertion.

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Advances in the conservation of pineapple genetic resources at Embrapa Cassava and Fruits

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Abstract

The Active Pineapple Germplasm Bank (Pineapple AGB) of Embrapa Cassava & Fruits (Embrapa/CNPMF) has more than 700 accessions under field conditions. As backups, there are copies kept in a greenhouse, with one or two plants per accession, cultivated in plastic pots with commercial substrate. An *in vitro* gene bank was established in 2003, and during the past few years, several studies have been carried out to improve the *in vitro* conservation protocol. Currently, about 60% of the AGB's accessions are preserved by this protocol. Another conservation strategy used is cryopreservation of shoot tips and pollen grains, with well-defined methods. One of the most significant advances in the pineapple germplasm conservation has been the implementation of a quality control system, which enabled to define standard operation procedures (SOP) towards a more efficient and safer germplasm conservation.

Conservation, the collection and the quality system

The Active Pineapple Germplasm Bank located at Embrapa Cassava & Fruits received in 1975 the first 39 accessions from the Agronomy Institute of Campinas in São Paulo State (IAC). In 1979, Embrapa Genetic Resources and Biotechnology and Embrapa Cassava & Fruits took out several collecting expeditions in priorized regions of Brazil. Thereafter, many germplasm exchange activities occurred with different Brazilian and foreign institutions. As result, this bank became the largest collection of pineapple germplasm in the world, with a present total of 764 accessions, conserved under field and greenhouse conditions and with one *in vitro* backup (Souza et al., 2012, 2021) **(Figure 1)**.

For many years, the main users of this bank have been breeders focused on the development of varieties for fresh fruit production. However, in the last 10 years, this scenario has changed, and in addition to the contributions to breeding programs, new uses of the germplasm have been explored. Ornamental attributes, plant fibers and bioactive molecules for pharmaceutical purposes have been sought and identified, showing important value aggregation opportunities for the gene pool conserved (Souza et al., 2012, 2014, Sena Neto et al., 2013, 2017, Souza et al., 2017, Campos et al., 2019, Souza et al., 2019, Rodrigues et al., 2000, Paixão et al., 2021, Pereira et al., 2022, Cassago et al., 2022).

For at least 20 years, the accessions were kept just under field conditions. Losses occurred due to several factors, such as lack of adaptation to local environmental conditions and high susceptibility to the *Pineapple mealybug wilt-associated virus* (PMWaV). The incidence of the latter complex has increased over the last few years. In many cases, the infection has been initially asymptomatic, but under any stress conditions, the symptoms turn clear. As there is no knowledge about genetic sources of resistance to this virus, new studies must be done, especially on the ecology of the virus and on possible sources of resistance. One of the most important results of *in vitro* conservation of healthy plants is the possibility of replacing accessions that are lost in the field (Silva et al., 2016).

In 2003, an *in vitro* backup program was started, with 10 copies per accession, and duplicates of the AGB field accessions under greenhouse conditions, with 1 to 2 potted plants/accession (Silva et al., 2016). In addition, accessions of the AGB have been indexed for the presence of the PMWaV complex. Infected plants have been cleaned by cultivation of shoot tips *in vitro* (Silva et al., 2016; Silva et al., 2021).

From 2016 to 2019, a few collecting expeditions added 122 accessions to the AGB. A new approach was used based upon the sampling of the microbiome associated with those pineapple plants under natural conditions (Souza et al., 2019).

Photos: Everton Hilo de Souza

Figure 1. Active Pineapple Germplasm Bank (Pineapple AGB) in the field (A); Greenhouse (B); In vitro Genebank (C).

The pineapple AGB's professional staff fulfills Embrapa's quality requirements for the management of genetic resources. These requirements are focused on many aspects such as: resources, responsibilities, dissemination and awareness, facilities, laboratory activities, equipment, instruments and machines, services and inputs, methods, documentation, human resources, sampling, solid waste management in laboratories and experimental areas, quality policy, information technology resources, standards and reference materials, result reports and compliance assessment. The main benefit of implementing those quality requirements is to ensure traceability and reliability of RD&I results coming from germplasm banks.

The backup of the Pineapple AGB in the greenhouse

In the greenhouse, the Pineapple AGB plants are kept under a 50% shading screen in an area of 108 m^2 **(Figure 1b)**. Plants are grown in plastic pots with commercial substrate (one to two plants per pot/accession), arranged on cement benches (2.1 m x 2.4 m), and at 1.2 m above the floor covered with black raffia to prevent weeds. Micro sprinklers are irrigating the plants that receive monthly foliar fertilizations. Pests are monitored and controlled when necessary. Weeds in the pots are removed once a month. When necessary, according to fructification and age, plants are renewed and the substrate is changed together with addition of fertilizers.

In vitro Genebank

The *in vitro* conservation of pineapple germplasm consists of maintaining the plants under slow growth conditions in the Laboratory of Tissue Culture (Figure 1c), preserving their genetic stability and viability during periodic subcultures. Six to ten plants/accession are kept in a conservation room of 10.5 m^2 at a temperature of 20 ± 1 °C, photoperiod of 12 h and photon flux density of 20 $\mu mol\ m^{-2}\ s^{-1}$. The accessions are placed in test tubes (15 x 2.5 cm) with a culture medium composed of half the salt concentration and vitamins of the normal MS formulation, supplemented with 3% (m/v) sucrose and 2.4 g L^{-1} of Phytagel® as a solidifier (Silva et al., 2016).

Silva et al. (2016) studied the genetic stability and regeneration capacity of plants conserved *in vitro* for 10 years. The results confirmed that the protocol used allowed renewed growth of all the pineapple accessions studied over this long period. Plants of all accessions classified as *A. comosus* var. *comosus* and *A. comosus* var. *ananassoides* remained genetically stable. However, two accessions of *A. comosus* var. *bracteatus* presented genetic instability, requiring subsequent studies for a more precise assessment of their behavior.

Results showed that an interval of up to 24 months between subcultures should be used for pineapple plants kept under *in vitro* conservation in active germplasm banks. Moreover, ISSR markers showed to be effective to detect somaclonal variants of pineapple plants conserved *in vitro*. Confirmation of the efficiency of the protocol applied for *in vitro* conservation was also obtained after evaluation of the performance of plants transferred from long-term *in vitro* conservation to the field, in comparison with that of plants kept in the field genebank (Silva et al., 2021).

The Pineapple AGB currently is set up by 764 accessions in the field, a complete copy in a greenhouse and about 300 accessions conserved *in vitro*. This collection shows the great genetic variability of the genus **(Figure 2)**, being a good source for genetic breeding and prospection of new uses of the culture.

The collection is composed by 476 accessions of *Ananas comosus* var. *comosus*, 140 *A. comosus* var. *ananassoides,* 39 *A. comosus* var. *bracteatus*, 12 *A. comosus* var. *erectifolius*, 16 *A. comosus* var. *parguazensis,* 23 *A. macrodontes*, 15 *Ananas sp.* and 43 of other bromeliads. The *in vitro* genebank contains 177 *Ananas comosus* var. *comosus*, 29 *A. comosus* var. *ananassoides*, 24 *A. comosus* var. *bracteatus*, 5 *A. comosus* var. *erectifolius*, 6 *A. comosus* var. *parguazensis*, and 6 *Ananas* sp. (Souza et al., 2021). These accessions also include traditional varieties collected in Brazil, commercial cultivars, and samples of populations of wild species.


Photos: Everton Hilo de Souza

Figure 2. Genetic variability of Pineapple AGB in the field, revealing the richness of colors and shapes conserved in the germplasm.

Shoot tip culturing for viral cleaning

In the last 10 years, indexation procedures carried out with accessions of the Pineapple AGB have revealed a large number of plants contaminated by the PMWaV viral complex. In view of this, a routine was established both for the cleaning of contaminated accessions and for introduction of new plants into the *in vitro* genebank to guarantee the health of the introduced and preserved plants. For viral cleaning, two strategies have been used, the cultivation of shoot tips with very small sizes (0.2 to 0.5 mm) and cryotherapy based on the cryopreservation method developed for pineapple (Souza et al., 2016; Guerra et al., 2020, 2021). Figure 3 shows the sequence of steps that constitute the routine adopted by the Pineapple AGB curators to clean contaminated accessions using cultivation of shoot tips.

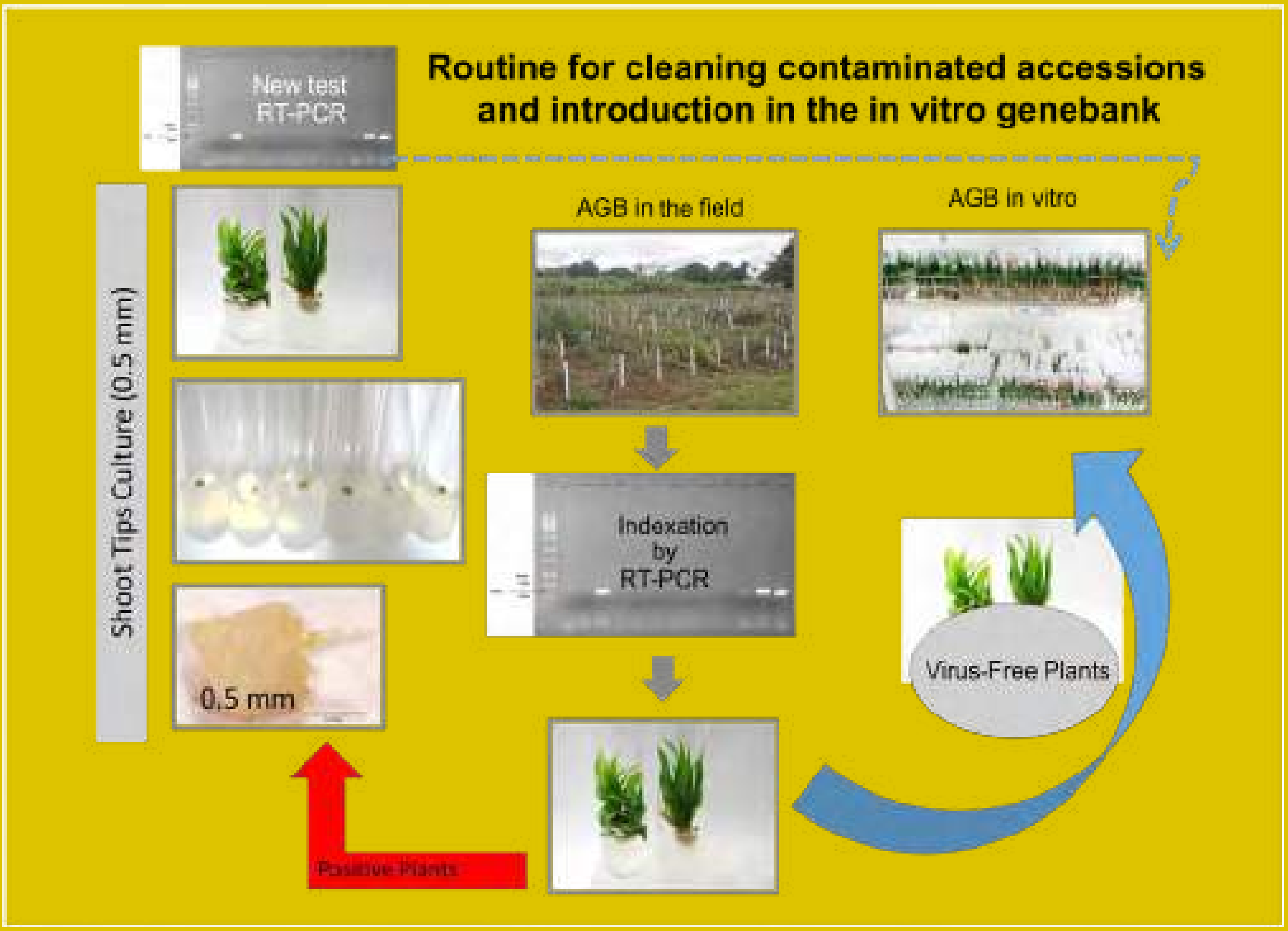

Figure 3. Steps for viral cleaning of contaminated accessions and introduction into the *in vitro* genebank, from indexing the field plant to its transfer either to the *in vitro* collection of the AGB or to the cleaning route by cultivating shoot tips.

Cryopreservation and cryotherapy

Despite the success of our recent *in vitro* conservation of these accessions, we started using cryopreservation techniques to establish another conservation strategy (Souza et al., 2015) and at the same time to produce virus-free plants using cryotherapy (Guerra et al., 2020). This provides an interesting possibility to combine long-term preservation with viral removal of pineapple plants. Achieving an efficient cryopreservation process that guarantees efficient plant regeneration is the base for development of a successful cryotherapy protocol. As a complementary tool for the allele's conservation a protocol of pollen cryopreservation was developed by Silva et al. (2017). Accessions of all botanical varieties were used to study different protocols for freezing pollen, as well as to determine their viability *in vitro/in vivo* during the study and after freezing in liquid nitrogen. It was possible to cryopreserve pollen from all the pineapple accessions studied after dehydration for 6 h on silica gel, with significant *in vitro* germination percentages and production of viable seeds.

The results obtained with the shoot tip culture take into account the less complex cleaning process, resulting in its recommendation mainly for laboratories that do not have infrastructure for the use of freezing techniques. However, in relation to cryotherapy, the possibility to guarantee a virus-free cryopreserved collection is encouraging and leads us to continue using this technique for germplasm preservation of the genus *Ananas*, where the phytosanitary conditions are highly relevant.

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Metabolomics as a tool to discriminate species of the *Ananas* genus and assist in taxonomic identification

In an unprecedented metabolomics study, based on ultra-efficient liquid chromatography coupled to high-resolution mass spectrometry (UHPLC-ESI-HRMS), the metabolic profile of genotypes of the *Ananas* genus at the Pineapple Active Genebank from Embrapa Cassava & Fruits was performed. Data obtained from metabolites of the genus with their respective species and varieties were used to establish a comprehensive chemical characterization of the individuals of this genus, as well as to discuss the current taxonomy based on chemical profiles.

Abstract

The family Bromeliaceae Juss. is a large one, with 78 genera and 3,659 species. *Ananas* is considered the most important genus from an economic perspective, and Brazil ranks third worldwide in the production of pineapple. Fruits of *Ananas comosus* (L.) Merrill) are most consumed and are widely appreciated all over the world. However, the chemical profile of its leaves and the potential for the production of secondary metabolites have been little explored. Further, the taxonomy of the genus is constantly revised due to the agricultural profile of the genus. In this work, for the first time, we carried out an untargeted metabolomic approach based upon liquid chromatography coupled with mass spectrometry, followed by multivariate statistical analysis to obtain the metabolic fingerprints of 35 leaf samples of individuals belonging to *Ananas comosus* and *Ananas macrodontes* and to five botanical varieties of *A. comosus* (var. *microstachys, bracteatus, comosus, erectifolius* and *parguazensis*) from the Pineapple Active Germplasm Bank, located at Embrapa Cassava & Fruits, Brazilian Agricultural Research Corporation, Brazil. The metabolomic data of the 35 samples and their taxonomic information were combined to characterize the genus based on the chemical profile of the species and varieties, and, for the first time in the literature, 46 substances were recognized in the two species. Based on multivariate statistical analysis by Principal Component Analysis and Orthogonal Projections Latent Structures Discriminant Analysis using the metabolomic data, it was possible to discriminate among the species and varieties based on their chemical profiles. Our results showed that the chemical composition of *Ananas* leaves can be used to assist in taxonomic identification.

Cassago, A.L.L., Souza, F.V.D., Zocolo, G.J., Costa, F.B. (2022) Metabolomics as a tool to discriminate species of the *Ananas* genus and assist in taxonomic identification, **Biochemical Systematics and Ecology,** Volume 100.

New promising hybrids under evaluation in Embrapa's breeding program

D. T. Junghans, D. H. Reinhardt – Embrapa Cassava & Fruits

At Embrapa's National Research Center for Cassava and Fruits, Cruz das Almas, Bahia, pineapple is one of the major fruits studied. There is a team, set up by several researchers, to carry out a program on the development of knowledge and technologies focused on the main constraints of this crop in Brazil.

Third-placed in the ranking of pineapple production in the world, Brazil produces pineapples all over the country in several biomes, such as the tropical and subtropical Cerrado (Savanna like conditions), the tropical Atlantic Forest, with its several subbiomes, and the semiarid zone in the Northeast called "Caatinga". However, within these biomes commercially significant volumes of pineapple are restricted to specific regions and districts, where thousands of mostly small growers are responsible for the major part of the country's production.

Some of these regions have more specific challenges in relation to crop management and the production chain of pineapple. However, there are some constraints affecting this crop in most of the regions over the country. The most severe one is the fusariosis disease (*Fusarium guttiforme*), causing very significant losses of fruits, plants and planting material, which may reach levels turning this activity anti-economic even for small growers.

In the 1980s, Embrapa installed a broad collection of pineapple genotypes in Cruz das Almas, Bahia, and started its breeding program. The search for new varieties with resistance to *Fusarium guttiforme* has been one of the major goals of this program. Fortunately, several mostly wild genotypes presented genetic resistance to this fungus. Some of those genotypes were then selected and two varieties were recommended for pineapple growers in 1986: Perolera (from Colombian Andes) and Primavera (from Amazonian Forest). Unfortunately, both didn't adapt to the main Brazilian pineapple producing regions. However, both genotypes and some other ones with resistance to fusariosis were used in crossings with the main commercial varieties in Brazil, the 'Pérola', which still covers more than 80% of the area cultivated, and 'Smooth Cayenne', the main world cultivar, present in a few subtropical production areas in this country.

Seedlings showing superior desired characteristics, including resistance to fusariosis, were selected, cloned (using their slips and suckers) and then evaluated along three sequential cycles for a very rigorous selection. All these steps, typical of the breeding program, have been carried out over the last decades until today. A few cultivars have become available for the growers, such as the cvs. BRS Imperial, BRS Vitória and BRS Ajubá, all three with resistance to fusariosis and agronomic characteristics adapted to different environmental conditions. However, the level of adoption by growers and hence the area cultivated with them is still rather small in comparison to the traditional cultivars Pérola and Smooth Cayenne. Low availability of good planting material has been one of the reasons for that.

In recent years, some new hybrids obtained in Embrapa's pineapple breeding program have been selected over the four plant cycles mentioned above. A low volume of planting material of these hybrids with resistance to fusariosis has been obtained and spread to several pineapple production poles in North, Northeast and Southeast Brazil. In partnership with organizations of growers and local qualified people linked to regional research or educational institutes, the development and agronomic performance of the hybrids has been evaluated along at least two cycles. Observations and data obtained until now have confirmed a favorable performance of at least one or two hybrids in each region. Even in the semiarid region, where pineapple is grown without irrigation due to lack of water with adequate quality, two hybrids have shown surprising results, equaling fruit weight and quality of the very well adapted 'Pérola' cultivar, which, however, presents high fruit losses due to fusariosis.

All the recently selected hybrids are derived from the genotype FRF 632, collected in a tropical rain forest region of the municipality of Manicoré, State of Amazonas. This genotype is resistant to fusariosis and, surprisingly, has presented tolerance to drought conditions of the semiarid region in Bahia. Its fruit is smaller than that of 'Pérola' pineapple with average weight around 1 to 1.2 kg. A study on its quality in different maturity stages was done and an article published with the following reference and abstract:

Viana, E. de S., Sasaki, F.F.C., Reis, R.C., Junghans, D.T., Guedes, I.S.A., Souza, E.G. (2020) Quality of fusariosis-resistant pineapple FRF 632, harvested at different maturity stages. **Revista Caatinga**, v. 33, n.2, p. 541-549.

Abstract

The objective of this study was to evaluate the influence of the harvest maturity stages on the physical, chemical and sensorial quality of the pineapple genotype FRF 632. The fruits were harvested in the maturity stages "green-ripe", "spotted", "colored" and "yellow" and evaluated regarding fruit and flesh mass; flesh yield; fruit and crown length; diameter of the basal, middle and top fruit sections; flesh color; titratable acidity (TA); translucency; soluble solids (SS); SS/TA ratio; and sensory acceptance of the attributes color, aroma, flavor, texture/firmness, overall acceptance and intensities of the attributes sweetness, acidity and firmness, using the just about right scale. There was no difference for the majority of the physical traits of the fruits at the various harvest maturity stages. The fruits had average mass of about 1,100 g. There was a gradual increase in the content of soluble solids and the SS/TA ratio during ripening. The fruits collected at the "colored" and "yellow" stages had the highest approval percentages and were considered to have ideal sweetness and acidity by the majority of consumers in sensorial tests. However, the preference mapping revealed a greater preference for fruits harvested in the "spotted" and "colored" stages for all the attributes assessed, unlike what was observed in the test of average and approval percentage. Therefore, the physical, chemical and sensorial tests indicate that the fruits harvested in the "colored" maturity stage were the most preferred by consumers, since they had high approval percentage, as well as ideal sweetness and acidity.

Development of an organic small-scale production system of pineapple in a tropical highland of Bahia, Brazil

Along the past ten years, Embrapa Cassava & Fruits has done studies to develop and improve organic production systems for pineapple and a few other tropical fruits. The work has been carried out on farms of the company Bioenergia Orgânicos Ltda, in the municipality of Lençóis, in the Chapada Diamantina highlands located in the central part of Bahia, Brazil.

Results obtained over the first period of studies were synthesized in two papers presented at the IHC 2018, Istanbul, Turkey, published in ***Acta Horticulturae*** 1299, 2020. In the following are the bibliographical references and the abstracts of these articles:

Pádua, T.R.P., Matos, A.P., Xavier, F.A.S., Rosa, R.C.C., Cordeiro, Z.J.M. and Reinhardt, D.H. (2020). Development of an organic small-scale pineapple production system in Chapada Diamantina, Bahia, Brazil. 1. From soil preparation to planting. **Acta Horticulturae** 1299, 153-160.

Abstract

In Brazil, the second largest pineapple producer in the world, pineapple production is carried out by tens of thousands of small to medium-sized producers in a conventional system, with use of mineral fertilizers and other synthetic chemical inputs, mainly for the control of fusariosis (*Fusarium guttiforme*) and pests. However, there is a growing national and international market for the consumption of organic pineapple. Embrapa Mandioca and Fruticultura established a technical partnership with the company Bioenergia Orgânicos, aiming to develop technical recommendations for the organic cultivation of pineapple, in the environmental conditions of the region of Lençóis, Chapada Diamantina, State of Bahia. Using several experimental designs, the technical team conducted over five years studies on several aspects of pineapple cultivation, from the production of planting material to fruit harvesting. In this part of that work, results and technical recommendations were obtained for the production of planting material from stem sections, soil preparation and the planting system for the cultivars 'Pérola', which is the most traditional one in the country, and 'Imperial', a cultivar with resistance to fusariosis.

Pádua, T.R.P., Matos, A.P., Cardoso Reis, R., de Souza Viana, E., Fumi Cerqueira Sasaki, F. and Reinhardt, D.H. (2020). Development of an organic small-scale pineapple production system in Chapada Diamantina, Bahia, Brazil. 2. From post-planting to harvest. **Acta Horticulturae** 1299, 161-168.

Abstract

The national market in Brazil presents a wide demand for organic fruits. There is no supply of organic pineapple. Pineapple is produced from the North to the South by tens of thousands of small to intermediate-sized producers, but in a conventional system, with intensive use of mineral fertilizers and other synthetic chemical inputs, mainly for the control of fusariosis (*Fusarium guttiforme*) and other pests. Aware of this research demand, Embrapa established a technical partnership with the company Bioenergia Orgânicos, aiming to develop the organic cultivation of pineapple, in the environmental conditions of the region of Lençóis, Chapada Diamantina, State of Bahia, Brazil. Using several experimental designs, the technical team conducted over five years studies on aspects of pineapple cultivation, from the production of planting material to fruit harvesting. This work will address studies on post-planting crop management of the cultivars 'Pérola', traditionally planted cultivar and 'Imperial', a new cultivar with resistance to fusariosis. The results obtained will allow the establishment of technical recommendations for the control of weeds, pests and organic fertilization. In addition, the feasibility of organic pineapple production will be studied and the technical aspects of cultural management practices improved to enhance production in the region of Lençóis, Chapada Diamantina.

Studies on this issue have been continued during the last few years with some additional results and information:

Control of fruit sunburn in organic pineapple production

T.R. P. de Pádua - Embrapa Cassava & Fruits

The practice most used by Brazilian farmers to control sunburn is to cover the fruits with old newspaper sheets. However, this practice is not allowed in an organic production system due to the risk of fruit contamination by the print chemicals. Looking for an alternative, plant covering with shading nets have been studied. There are screens with different intensities, usually varying from 30% to 70% shading. The initial investment is higher, compared to the use of newspapers or paper bags, but the screens, when handled correctly and stored under appropriate conditions, can be used over several production cycles diluting its cost over time.

In a first trial, four treatments were studied in a 'Pérola' pineapple field: brown paper bags, black screens with 50% and 70% shading, and the control without protection. The second trial had six treatments: black screens with shading of 30%, 35%, 40% and 50%, blue screen with 30% shading and brown paper bags. All treatments were applied right after closure of the last flowers, about 90 to 100 days after flowering forcing treatment. Treatments efficiency on fruit burning prevention was evaluated based on the intensity of external symptoms, expressed by a severity scale with five scores, ranging from complete absence of symptoms (score 1) until the presence of cracks between the fruitlets and black necrosis on the fruit rind (score 5).

In the first trial, unprotected fruits presented a score close to 5, classified as a commercial loss due to intense burning, with cracks between fruitlets and pulp necrosis. The other treatments studied, 50% and 70% shading screens and brown paper bags, showed efficient fruit burning control without losses.

Data obtained in the second trial were analyzed and classified into three groups by the Scott-Knott test. The 50% shading screen gave the most efficient fruit protection, followed by the 40% shading screen. Treatments of 30% and 35% shading, blue screen and paper bag formed the group considered less efficient in protecting the fruits against sunburn. Fruit protection by paper bags was reduced due to damage caused by rains and winds. In addition, paper bags are not easy to be placed over the fruits, requiring much labor force, and cannot be reused.

Fruit quality was not affected by the treatments studied in the first trial and presented small differences in soluble solids and acidity among treatments in the second one. Overall performance in both trials was the best for the treatment using a 50% shading screen as pineapple field cover from flower closure to fruit harvest. This practice has been recommended for use in substitution of fruit by fruit covering with newspaper or paper bags. The screen should be removed at the time of harvest and stored in a protected dry place, without luminosity, in order to be reused when needed in new pineapple fields.

Does shading favor development and productivity of pineapple under semiarid conditions?

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This is a question to be answered by Embrapa's pineapple research team over the following years. Some facts or visual observations made in different regions and environmental conditions have drawn attention to this issue.

Frequently, cv. Pérola pineapple plants show leaf yellowing and symptoms of Mg deficiency during periods of high air temperature and high solar radiation. Another cultivar, the 'Imperial', has shown improved growth when cultivated in the interrow spaces of a cocoa plantation in South Bahia. 'Pérola' plants grown in a field without normal weeding practice presented improved development in comparison to those plants in the neighboring "clean" field during the high summer period in Maranhão State, Northeast Brazil. In Mexico, INIFAP has developed a large research program and defined a complete system for MD-2 pineapple cultivation under shading net in the field.

Motivated by all these aspects, studies have been started on this issue in the semiarid region, where 'Pérola' pineapple plant leaf yellowing and appearance of visual symptoms of Mg deficiencies are common during hot and dry periods. The studies are being carried out in partnership with a local pineapple grower in the municipality of Itaberaba, at 12°38'28" latitude South, 40°14'44" longitude West and 275 m altitude. Itaberaba has an annual production of about 30 million 'Pérola' fruits by more than 700 small growers. This region has a typical semiarid climate of a BSh type according to Köppen-Geiger, with average annual temperatures of 24.4 °C, average minimum of 16.6 °C in July and average maximum of 31.4 °C in January. The daily temperature amplitude is 10 °C to 11 °C throughout the year, and the average annual rainfall is 747 mm, with monthly volumes of less than 40 mm from May to October. From October to April, over autumn and summer, temperatures are above 30 °C during a major part of the day and insolation is very high, as there is a low formation of clouds during long periods.

In randomized block designs and four replications and use of at least 80 plants per plot, treatments are being studied using 30% and 50% black shading net, applied during the vegetative and reproductive phases of the plant cycle. In a separate trial, with similar design, the shading effect is sought by spraying over the leaves, at different cycle phases and frequencies, a product, developed by a private start-up company, which has shown a solar radiation mitigating effect in some other fruit crops.

Black shading screen has been previously studied on its effect on pineapple fruit protection during pre-harvest stages. Results have been positive, demonstrating efficient protection of fruits against sunburn, maintaining fruit quality and in some cases, increase of fruit size.

Cover crops intercropped with pineapple

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Abstract

The pineapple crop has a slow initial growth. The use of intercropping in the first months of pineapple cultivation is important for soil conservation, as long as there is no high competition for nutrients and light. The objective of this work was to evaluate the effect of cover crops intercropped with pineapple on the characteristics of the 'D' leaf, on yield and fruit quality of pineapple cv. Pérola. Massai grass, yard grass, jack bean and spontaneous plants were evaluated as cover crops intercropped, in comparison with pineapple grown in monocrop system. During the vegetative cycle biometric evaluations were done on pineapple 'D' leaves. Just before the treatment of flowering forcing, 'D' leaves were sampled for foliar analysis. At harvest, yield, fruit size and quality were determined. Intercropping with jack bean had a negative effect on pineapple plant growth, fruit size and quality, but increased the ammoniacal nitrogen content in 'D' leaves. Massai grass, yard grass and spontaneous vegetation as soil cover presented smaller biomass accumulation than jack bean, and had only slight effects on pineapple growth and production.

Keywords: *Ananas comosus var. comosus*, soil management, mineral nutrition.

Introduction

The state of Tocantins has been one of the main pineapple producing States in Brazil. In 2020, 98.5 million fruits were harvested in 4,727 ha, with a yield of 20,843 fruits ha^{-1} (IBGE, 2021). A major part of this production occurs in an off-season period, with low offer and higher fruit prices and improved farmer profit. The largest pineapple producing poles in Tocantins are located in the central region. Most fruits are sold in the national market, but a small part is exported with higher profitability (EMBRAPA, 2014; Araújo et al., 2018).

Tocantins is located in the center of Brazil, presenting environmental conditions that favor the production of high quality pineapple fruits, as described by Pereira et al. (2009). However, good agricultural practices must be used to meet the increasing standards required by consumers (Neves, 2006). In Tocantins, pineapples are cultivated in a double row system with 1.2 m between double rows. Under regional environmental conditions in rainfed pineapple fields, plant growth is rather slow and the interrow space remains uncovered for at least six months. The intercropping with adequate cover crops could protect the soil from high insolation and major erosion.

The use of intercropping is not a common practice among the pineapple growers. In Tocantins, pineapple is grown as monocrop and weed control, usually performed up to six months after planting, is based on pre-emergent herbicide application and/or manual hoeing, causing soil surface exposure favoring loss of soil, organic matter, and nutrients. Intercropping with cover crops may mitigate those losses, conserve moisture and improve physical, chemical and biological properties of the soil (Araújo et al., 2018; Bezerra et al., 1995; Cunha, 2004; Perin, Guerra and Teixeira, 2003; Siebeneichler et al., 2019).

Intercropping can be done with short-cycle food crops such as beans (*Vigna* and *Phaseolus*), peanuts and others. Intercropped plantations are best recommended for small areas, and can also be used between the lines of tree or shrub species, such as acerola, cashew, cassava, banana and citrus, among others (Matos e Sanches, 2011).

Adequate biomass production is one of the important aspects to be considered when choosing a plant to cover the soil, in addition to the time for nutrient cycling, release of C-CO_2, and its capacity for mineralization (Araújo Neto et al., 2014).

Despite the existence of some reports on pineapple grown in intercropping system, little is known about benefits or interferences of such a practice on pineapple development and yield. Just like weeds, cover crop plants may compete for nutrients and light, delaying pineapple plant development and yield (Maia, Aspiazú, Pegoraro, 2018; Reinhardt and Cunha, 1984). For this purpose, plants must be identified that provide soil protection without negative effects on fruit quality and productivity of the crop (Andrigueto, 2002). The objective of this study was to evaluate the effect of cover crops intercropping on 'Pérola' pineapple growth, yield and fruit quality**.**

Materials and Methods

The experiment was carried out in the Cedro farm, located in the municipality of Miracema do Tocantins, TO, at 09°30' to 10°20' South and 48°00' to 48°50' West, and an altitude of 197 meter. The climate is a tropical one, with total yearly precipitation of 1,534 mm with a wet season from October to April (1,447 mm) and a dry season from May to September (77 mm). The average monthly minimum temperature varies from 21 to 23°C and the maximum temperatures from 30 to 35°C (site www.climatempo.com.br).

The experimental design used was a randomized blocks one, with five treatments, represented by four cover crops and pineapple grown in monocrop system, and four replications. Each plot consisted of five double rows, each double row with 30 pineapple plants, spaced at 1.40 x 0.5 x 0.45 m. Data were collected from 74 plants of the three central rows.

The experiment was planted during the rainy season, using pineapple slips (400 g average weight). The cover crops intercropped with pineapple were the following: 1) Massai grass (*Panicum maximum* x *Panicum infestum*) sown between the pineapple double rows, in an area of 3.6 m^2, with a total of 413 plants/m^2; 2) Yard grass (*Eleusine indica*) sown between the pineapple double rows, in an area of 3.6 m^2, with a total of 1,770 plants; 3) Jack beans (*Canavalia ensiformis*) planted in a spacing of 0.2 m x 0.4 m, with seven plants per linear meter, in a total area of 2.4 m^2; 4) Spontaneous plants grown without any control between each double row in an area of 3.6m^2. In the pineapple monocrop treatment the space between the double rows was kept weed free throughout the cycle. As for the consort plants, they were sown 15 days after planting the pineapple seedlings and were cut before the pineapple induction, so the total period of the consortium was around twelve months.

The monthly dry mass production of the cover plants was evaluated by randomly throwing a square with the internal dimension of 0.0625 m^2 and cutting the shoot of the plants within this square. The material was placed in a paper bag and dried in a forced circulation oven at 70°C for 72 hours, then weighed on an analytical balance. Such a procedure was repeated three times in each plot for each evaluation time. Data were collected every 30 days until 210 days after planting (DAP).

Throughout the pineapple cycle, 'D' leaves were sampled for evaluation of dry mass content and determination of macro and micronutrients levels. 'D' leaf sampling occurred at a two months interval, starting four months after planting and ending at the flowering induction treatment. Pineapple flowering forcing was done at thirteen months after planting, using calcium carbide diluted in water. Fruits were harvested five months later and evaluated for the following variables: fruit circumference (cm) in the central part of the fruit; fruit size with and without crown (cm); fruit weight with crown (g); yield (Kg ha^{-1}); titratable acidity (TA), expressed in % citric acid; total soluble solids content (TSS, °Brix), using a portable refractometer; and the TSS/TA ratio. Data were submitted to analysis of variance and means were compared by the Tukey test at 5%, using the statistical program SISVAR (2003).

Results

As expected, 'D' leaves dry mass increased with pineapple plant development along its vegetative cycle, in all treatments, with higher values obtained for the monocrop treatment (**Figure 1**). Jack beans as intercrop determined a larger reduction of pineapple 'D' leaf dry mass over the entire evaluation cycle. 'D' leaves are the leaves physiologically most actives and hence are used for pineapple plant development measurements during the vegetative period (Cunha and Cabral, 1999; Vilela, Pergoraro, Maia, 2015).

In comparison to the other cover crops studied, jack beans presented higher dry mass content over the entire evaluation period (**Figure 2**).

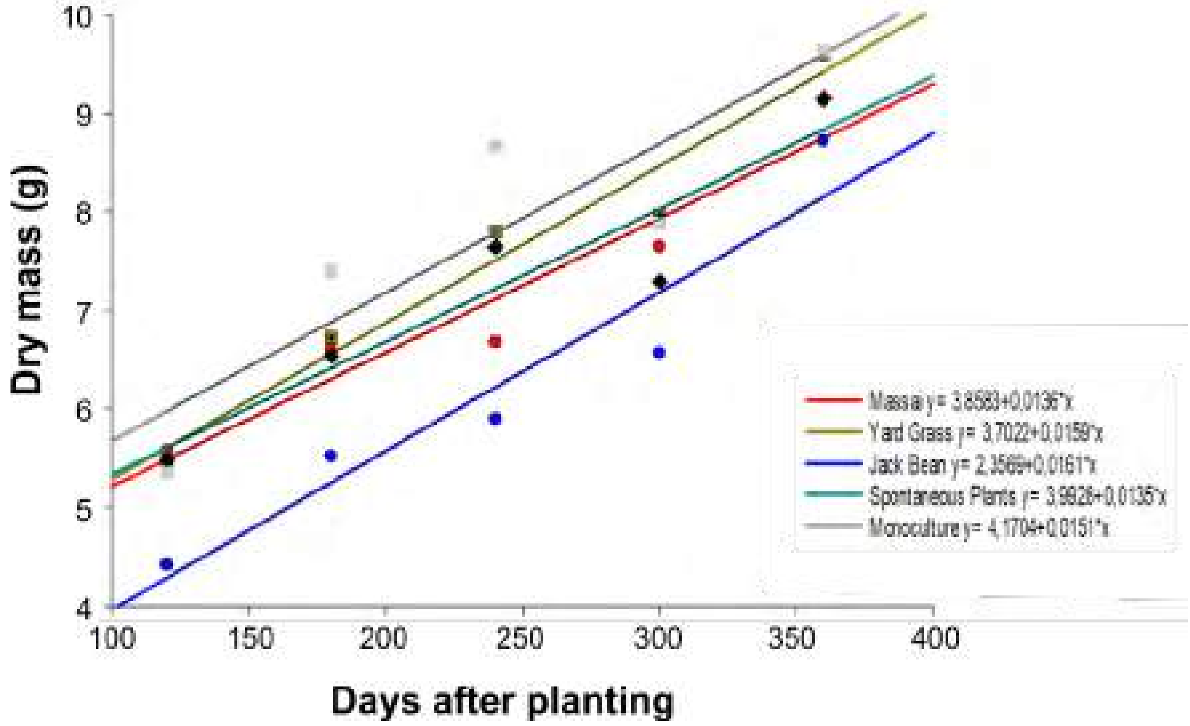

Figure 1. Dry mass content of pineapple 'D' leaves collected throughout the plant development cycle, from four months after planting up to the flowering induction treatment.

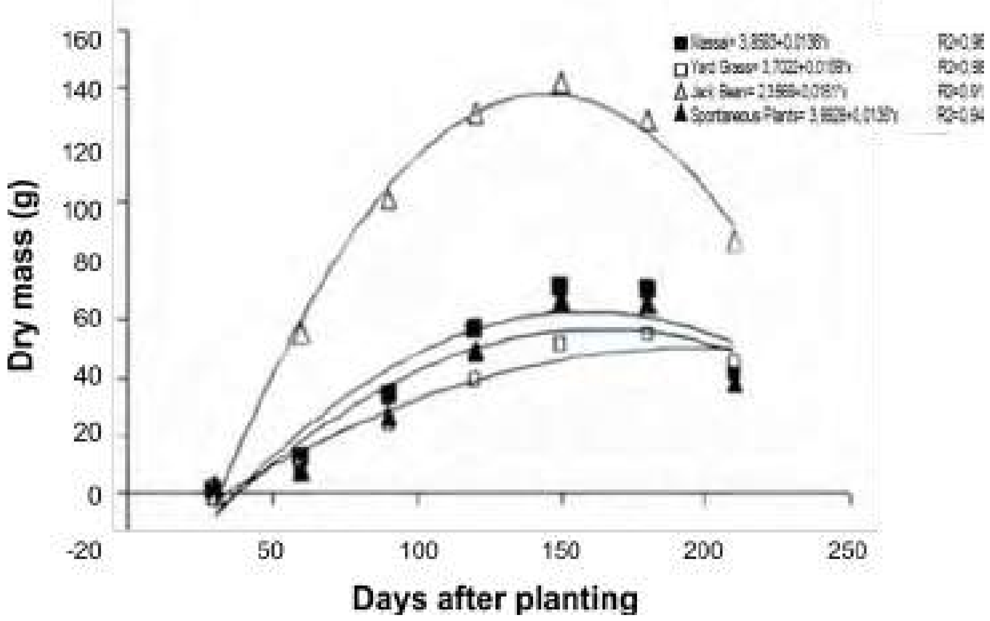

Figure 2. Dry mass content (g) of the cover crops grown in the interspace of pineapple double rows.

There was no major significant effect of the cover crops on the macro and micronutrient levels shown by the pineapple 'D' leaves (**Table 1**). However, the ammonia-N content was higher for pineapple plants intercropped with jack bean and massai grass. And the chloride values were higher for 'D' leaves of pineapple plants intercropped with massai grass, yard grass or spontaneous vegetation.

Table 1. Pineapple 'D' leaves contents of macro and micronutrients as influenced by the intercrop cover crops massai grass (Mg), yard Grass (Yg), jack Bean (Jb) and spontaneous plants (Sp), in comparison to the pineapple monocrop (Mono).

Treat	N-NO$_3$	N-NH$_4$	P	K	Ca	Mg	S	B	Cl	Cu	Fe	Mn	Mo	Zn
		g kg^{-1}							mg kg^{-1}					
Mono	0,72	9,29	0,74	14,3	5,38	2,49	0,73	19,6	4,10	6,4	291	138	0,72	10,9
Mg	0,65^{ns}	10,2^{+}	0,82^{ns}	16,5^{ns}	5,04^{ns}	2,52^{ns}	0,82^{ns}	20,1^{ns}	5,50^{+}	6,6^{ns}	236^{ns}	122^{ns}	0,32^{ns}	11,5^{ns}
Yg	0,73^{ns}	9,70^{ns}	0,78^{ns}	16,5^{ns}	5,41^{ns}	2,60^{ns}	0,71^{ns}	20,4^{ns}	5,12^{+}	6,41^{ns}	233^{ns}	138^{ns}	0,71^{ns}	11,0^{ns}
Jb	0,69^{ns}	10,2^{+}	0,74^{ns}	15,9^{ns}	4,90^{ns}	2,30^{ns}	0,84^{ns}	20,0^{ns}	4,60^{ns}	6,34^{ns}	218^{ns}	123^{ns}	0,57^{ns}	10,6^{ns}
Sp	0,66^{ns}	9,59^{ns}	0,79^{ns}	17,4^{ns}	5,51^{ns}	2,60^{ns}	0,77^{ns}	19,9^{ns}	4,96^{+}	6,4^{ns}	188^{ns}	126^{ns}	0,30^{ns}	10,7^{ns}

Ns=not significant; +significant difference in relation to the monocrop value.

Pineapple fruit weight was significantly reduced when the plant was intercropped with jack beans (**Table 2**). The other treatments studied caused a slight, statistically not significant reduction in comparison to the monocrop treatment. Jack beans intercropped determined a reduction of fruit circumference and length without crown, whereas Massai grass caused reductions of fruit length with and without crown and length without crown. There was a statistically not significant reduction of pineapple productivity for all cover crops treatment studied, with jack beans determining the lowest value (Table 2).

Table 2. Circumference, fruit length with and without crown, fruit weight and yield of pineapple grown intercropped with Massai Grass (Mg), Yard Grass (Yg), Jack Bean (Jb), Spontaneous vegetation (Sv) as cover crops and in monoculture (Mono).

Treatments	Circumference	Fruit length with crown	Fruit length without crown	Fruit Weight	Productivity
	cm			g	Kg ha^{-1}
Mg	36,1 a	31,3 b	16,8 b	1.236ab	21.832 a
Yg	35,9 ab	32,1 ab	17,4 ab	1.237ab	21.703 a
Jb	34,9 b	31,6 ab	16,5 b	1.117 b	18.305 a
Sv	36,1 a	32,2 ab	17,2 b	1.255 a	22.749 a
Mono	36,6 a	32,9 a	18,2 a	1.326 a	24.197 a

Means followed by the same letter do not differ from each other by Tukey test at 5%.

Pineapple fruit quality was not significantly affected by the intercropping treatments studied (**Table 3**). The soluble solids (SS) contents ranged from 12.9 to 13.6°Brix, titratable acidity (AT) from 1.01 to 0.96 % citric acid (rather high for 'Pérola' fruits) and SS/AT ratio from 13.32 to 14.08 (rather low).

Table 3. Soluble Solids (SS), titratable acidity (TA) and SS/TA ratio of pineapple fruits from plants intercropped with massai grass, yard grass, jack bean and spontaneous vegetation (Sv) as cover crops, compared to monocrop (Mono).

Treatment	Soluble Solids (ºBrix)	Titratable Acidity (AT)	Ratio (SS/AT)
Massai grass	13,58 a	1,01 a	13,44 a
Yard grass	13,31 a	0,99 a	13,37 a
Jack beans	13,41 a	0,97 a	13,83 a
Sv	13,59 a	0,96 a	14,08 a
Mono	12,94 a	0,97 a	13,32 a

Means followed by the same letter do not differ from each other by Tukey test at 5%.

Discussion

The negative effect of jack beans on pineapple plant development and yield may be due to the competition of that cover crop for productions factors over the pineapple cycle, especially during the initial stages of the pineapple development (Cunha and Cabral, 1999). Jack beans accumulated higher shoot dry mass contents (Figures 1 and 2), indicating to be more competitive than the other cover crops studied. Lisbon-Silva et al. (2015) reported similar results showing that jack beans, used as cover crop intercrop, affected pineapple plant growth, nutrient supply and fruit development. Siebeneichler et al. (2019) also observed a reduction in pineapple fruit size, when the plant was intercropped with another legume, *Vigna* beans, indicating that legumes may not be a good alternative for intercropping with pineapple.

The other cover crops studied, which were Massai grass, yard grass and spontaneous vegetation, affected much less pineapple development and yield, and may be better alternatives for this purpose than jack beans. One favorable aspect of jack beans intercropping was the increase in ammonia-N in the 'D' leaves of pineapple, an effect certainly related to the capacity of biological nitrogen fixation by a legume like jack bean. The N accumulated in its tissues, after its decomposition, may release the nutrient to the soil, becoming available for absorption by pineapple plants (Auras; Zilli, 2018; Burle et al., 2006). The higher ammonia-N in the 'D' leaves of plants intercropped with massai grass may be due to better nutrient cycling. It is inferred that these species have retained this element in their straw and, during its decomposition process, it was absorbed by the pineapple plant (Epstein; Bloom, 2006).

According to Embrapa's soil and plant chemical analyses handbook (EMBRAPA, 1999), some values found for nutrients in this study are below the standards established for pineapple. Boron, copper and manganese values were within the standards in all treatments. Phosphorus was within the required standard only when massai grass was used as cover crop intercrop, and iron was within standards in the treatment with spontaneous vegetation, but for the other treatments, it showed values higher than the required ones. When compared to the values reported by Tavares et al. (2015), the values are equivalent, except for K and S. Regarding to micronutrients, the levels reported by Tavares et al. (2015) were lower than those found in this study.

Siebeneichler et al. (2002) obtained higher values for nitrogen, phosphorus, potassium, sulfur, zinc, iron and manganese in pineapple plants grown in the northern coastal region of the State of Rio de Janeiro, Brazil. However, the fruits produced in the two regions have similar weight, suggesting that plant nutrition values vary from one region to another, probably due to soil and climatic conditions.

Fruits harvested in this study presented higher acidity and lower SS/TA ratio than usually observed for fruits produced in the State of Tocantins. Pereira et al. (2009) reported SS/TA values varying from

20.3 to 40.4 for fruits marketed in that State. The SS contents were also lower than desired for fresh consumption in Brazil, which correspond to values between 14 and 16°Brix (Chitarra & Chitarra, 2005).

Conclusions

The intercropping of pineapple with jack beans as cover crop, in spite of increasing ammoniacal nitrogen content of pineapple 'D' leaves, had a negative effect on plant growth, as expressed by reduction of 'D' leaf dry mass, on fruit size and yield.

Massai grass, yard grass and spontaneous vegetation as soil cover presented smaller biomass accumulation than jack bean, and had only slight effects on pineapple growth and production.

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L-PIÑA: computer system under development to simulate pineapple growth

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Keywords: *Ananas comosus var. comosus,* L-System, 3D model, plant modeling.

Abstract

Studies on pineapple cultivation in the Brazilian semiarid region have been carried out since 2005 by the research group from the State University of Montes Claros and partner institutions. This work resulted in a robust database that allows modeling studies on the pineapple growth and development as influenced by different cultural practices. Based on the L-System plant growth method (Prusinkiewicz & Lindemayer, 1990), crop simulation models have emerged that provide interaction with the system in a virtual environment, demonstrating the results of variations in biotic and abiotic factors in several stages of plant growth and development in a visual/graphic (3D) manner. L-Peach (Lopez et. al., 2010) and L-Almond (DeJong et al., 2017) can be cited as examples. The software under development will be open source and available in a Web environment (https://l-pina.guanambi.ifbaiano.edu.br/) and presented according to the characteristics that interfere with pineapple growth. In the user's interaction with the software, it will be possible to visualize the pineapple plant individually, where only one plant is used to perform the simulation (**Figure 1**), or by population, where several plants are grouped in a population to simulate a real crop. Based on the grammar of the L-System (Prusinkiewicz & Lindemayer, 1990), specific algorithms are being developed for the generation and growth of pineapple using the 3D modeling technique known as blend shapes. In this way, it will be possible to generate the graphic object in real time and more precise modifications of it using mathematical formulas. This software will have practical and theoretical applications in teaching, research, and extension.

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Figure 1. Visual comparison of field-grown pineapple image (left) and L-PIÑA graphic output (right).

Reduction of the water footprint of pineapple cultivation in semiarid region

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Keywords: *Ananas comosus var. comosus,* mulching, shading screen, water-absorbing polymer.

Introduction

The pineapple (*Ananas comosus* var. *comosus*) is a tropical fruit appreciated worldwide due to its characteristic aroma and flavor. It can be consumed in natura or processed. The pineapple world production was 28 million tons in 2019. Costa Rica was the main producer, followed by the Philippines and Brazil. The world average pineapple yield reached 25.04 t ha^{-1} in 2019. In addition, the highest yields ranged from 128.32 to 68.67 t ha^{-1} obtained by Indonesia, Costa Rica and Ghana. In Brazil, the pineapple has been cultivated in more than 70,000 hectares and the average yield was 36.12 t ha^{-1} (FAOSTAT, 2021).

Although pineapple is a crassulacean acid metabolism plant, for commercial production the crop needs at least 50 mm of monthly rainfall or irrigation depth, which can reach 75 mm in regions with hot climates (Jimenez et al, 2018). Even considering the relatively low water requirement of pineapple, the inefficient water use in irrigation systems is a problem requiring more research efforts focused on technologies to reduce water loss by evaporation and leaching in the soil, as well as to increase water use efficiency by the plants.

Among those technologies, the use of mulching, shading screens and water-absorbing polymers can be mentioned. The individual or combined adoption of these technologies in pineapple cultivation can contribute to yield increases and improved fruit quality together with lower use of water and other inputs.

This study aimed to evaluate the effects of water-absorbing polymers, mulching, and shading screen on the reduction of the pineapple water footprint in a semiarid region.

Materials and Methods

The study was carried out in an experimental area located in the municipality of Janaúba, Minas Gerais State, at 15°43’48”S, 43°19’23”W and altitude of 533 m. The regional climate is classified as “Aw” according to Köppen, although it is inserted into the semiarid region. The soil is classified as Eutrophic Red Latosol.

The treatments were arranged in split plots, in a randomized complete block design, with three replications. The plots consisted of the following treatments: control (control); plastic mulching (PM) (white plastic 200 micras); organic mulching (OM); organic mulching + 50% red shading screen (OMS), plastic mulching + 50% red shading screen (PMS). The subplots presented two treatments: absence and presence of water-absorbing polymers placed into the planting hole (0.5 g per plant). The experimental plot consisted of two double rows each three meters long, spaced 0.9 x 0.4 x 0.3 m. Selected slips, about 40 cm long, of the variety IAC Fantastico were planted in January 2020.

The following variables were determined: percentage of plants with natural flowering (FN), leaf area index (LAI), D-leaf leaf area (DLA) and total leaf area (TLA). To determine the LAI, an AccuPAR ceptometer model LP-80 was used, operated according to the manufacturer’s specifications, between 10h00 a.m. and 02h00 p.m., in each subplot; three readings were done, below and above the canopy, for each plant. The percentage of natural flowering was calculated from the number of plants that flowered before flowering forcing. The ‘D’ leaf area (DLA) and total leaf area (TLA) were determined according to the methodology described by Santos et al. (2018).

Data were submitted to univariate analysis of variance and the means compared by the Tukey test at 5%. Statistical analyses were done using the R statistical software (ExpDes.pt package).

Results and discussion

The use of water-absorbing polymers did not influence the percentage of natural flowering (FN) of the plants **(Table 1).** The treatments with the lowest means of natural flowering (FN) were organic mulching + red shade net (OMS) and plastic mulching + red shade net (PMS), which did not differ statistically from each other. The highest percentages of natural flowering were observed in the control treatment, plastic (PM) and organic mulching (OM) (**Table 1**).

Table 1 - Percentage of natural flowering and vegetative characteristics in pineapple plants as a function of the use of mulching, red shading screen and water absorption polymers (WAP).

Treatments	Natural flowering		*LAI	
	With WAP	Without WAP	With WAP	Without WAP
Control	58,3 Aa	50,0 Aa	4,9 Bb	5,1 Ca
PM	50,0 Aa	41,6 Aa	5,1 Ba	4,9 Ca
OMS	04,1 Ba	00,0 Ba	6,6 Aa	6,1 Bb
PMS	12,5 Ba	08,3 Ba	6,4 Ab	6,7 Aa
OM	50,0 Aa	45,8 Aa	5,0 Ba	4,6 Cb
CV (%)	28,2	20,1	4,7	2,1

Treatments	'D' leaf area		Total leaf area	
	With WAP	Without WAP	With WAP	Without WAP
Control	710,3 Ba	690,4 Ba	12743,5 Ba	12397,1 Ba
PM	685,4 Ba	702,9 Ba	12310,9 Ba	12614,7 Ba
OMS	710,1 Ba	694,1 Ba	12740,2 Ba	12462,1 Ba
PMS	895,0 Aa	820,7 Ab	15962,7 Aa	14667,9 Ab
OM	694,2 Ba	658,6 Ba	12462,9 Ba	11843,4 Ba
CV (%)	8,9	5,1	8,7	5,0

The means followed by the same letters, lowercase in the lines and uppercase in the columns, do not differ from each other by the Tukey test ($p<0.05$). Treatments: Control, plastic mulching (PM), organic mulching + 50% red shading screen (OMS), plastic mulching + 50% red shading screen (PMS) and organic mulching (OM). *Significant effect for the interaction between the treatments and polymers.

Natural flowering of pineapple is stimulated by endogenous and exogenous factors. Pineapple is considered a quantitative short-day plant. The low nocturnal temperatures (< 20°C) associated with the shortening of days (< 11.5 hours) observed in the southern hemisphere, in the months of June, July and August, are the major environmental stimuli for natural flowering of this species (Cunha, 2005; Bartholomew, 2014; Bartholomew and Sanewski, 2018). This phenomenon, however, is undesirable because it results in non-uniformity hindering adequate cultural practices during the reproductive period, spreading the harvest and affecting fruit quality.

The effect of inhibiting or reducing natural flowering in treatments with red shading screens can be understood as the response of phytochromes to the wavelengths (irradiance quality) that reach the leaves and are perceived by those pigments.

There was no significant interaction between the main treatments and the use of polymers for the vegetative growth variables 'D' leaf area and total leaf area. However, there was an interaction for the leaf area index (LAI) (**Table 1**).

The plastic mulching + 50% red shading screen (PMS) treatment presented significantly higher averages for 'D' leaf area and total leaf area. In this same treatment, the use of the polymer determined higher DLA and TLA values, but a lower LAI. Some other effects of the treatments studied are shown in **Table 1**, but there is no clear evidence for a significant positive effect of the use of polymers in this study.

Red shading screens transfer more light from the red wavelength spectrum and diffuse the light that passes through the mesh, with positive impact on plant development (LI, 2006). This possibly promoted the preservation of moisture and reduced soil temperature, favoring plant root growth. In addition, the plastic mulching used reflects the light that reaches its white surface, thereby returning to the plant canopy contributing to plant light absorption for photosynthesis. These positive effects of plastic mulching, in interaction with the red screen, on plant growth and development agree with results reported by Oliveira et al. (2021) in a study on 'Vitória' pineapple. The use of plastic mulching together with the shading screen probably determined a microclimate with some thermal comfort, favoring vegetative growth.

Treatments like these that determine faster vegetative growth, make it possible to force earlier pineapple plant flowering, shortening the crop cycle, another factor that may help to reduce crop water consumption improving its water footprint. And shading screens can be reused for at least two pineapple production cycles, reducing its cost.

Conclusions

The use of red shading screen associated with plastic and organic mulching reduced natural flowering rates of the pineapple plants.

Plastic mulching associated with red shading screen increased the vegetative growth of the pineapple plants. In this treatment, there was also a positive effect of the use of water-absorbing polymer at planting.

The combined use of plastic mulching with red shading screen and water-absorbing polymer may contribute to a significant reduction of the water footprint of a pineapple crop under semiarid conditions.

Acknowledgement

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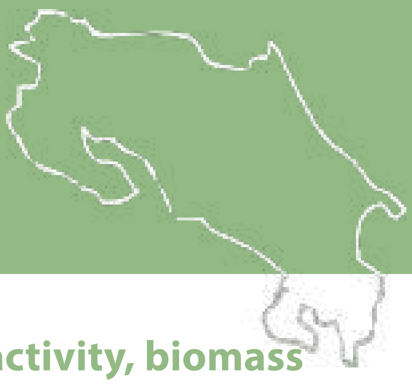

News from Costa Rica

*Effect of temperature and solar radiation on CAM activity, biomass accumulation, sensitivity to natural induction and harvest index of 'MD-2' pineapple in Costa Rica.

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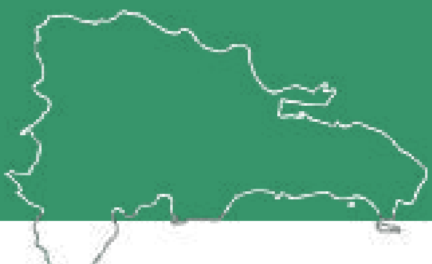
Most studies of the CAM photosynthetic pathway have been "pathway-focused " while few have examined the productive implications of CAM in commercial crops such as pineapple. As a result, there are knowledge gaps on specific physiological processes of agronomic interest, such as natural induction of fruiting and the crop harvest index. Research to narrow the knowledge gaps will be focused on understanding the ecophysiology of the 'MD-2' pineapple cultivar. The objectives include a study of CAM photosynthate production and allocation to growth and glucans storage reserves. This study will be carried out in contrasting natural conditions simultaneously at masl of 90 (dry tropic), 175 (humid tropic) and 1570 (very humid temperate cold) at different sowing dates and tissues will be sampled at different phenological states that have been developed. The main hypothesis is that differences in temperature and solar radiation under mentioned natural conditions affect the plant's reserve capacity. The study of the plasticity and allometry of allocation has important implications for plant production systems. Therefore, improving the understanding of relationships "potential of the source and strength of the sink" by quantifying metabolites (glucose, sucrose, fructose, and glucans) in leaves and stems associated with phenologycal stage, will provide a better physiological understanding of mentioned phenomena's, which depend of the glucans reserve capacity of the plant.

*Abstract presented at the XXVII Seminário Internacional en Ciencias Naturales para el Desarrollo, Universidad Nacional de Costa Rica

Natural flowering of 'MD-2' pineapple. Main agronomic challenge of Pineapple Agroindustry in Costa Rica.

News from Dominican Republic



Traffic light methodology for the application of Good Agricultural Practices (GAP) in agroecosystems with pineapple (*Ananas comosus* L. Merrill): Results in pineapple plantations of ASOPROPIMOPLA, Dominican Republic

Hermann A. Jürgen Pohlan, Dennis José Salazar Centeno, Manuel Ramos Quezada, Joelin Santos Contreras

The principles of Good Agricultural Practices (GAP) are basic tools and guides for successful agricultural and livestock production and guarantee high standards in the agronomic management of crops and their post-harvest. These are carried out in harmony with the economic, ecological and social conditions in the agroecosystems and in each farm. In all cases, it is essential that production techniques and methods can be identified that guarantee the viability of these activities within the integrated crop management, so that they contribute to the safety and traceability of pineapple in its production chain.

In the pineapple plantations of ASOPROPIMOPLA (Asociación de Productores de Piñas de Monte Plata), whose production area covers 233 ha, this methodology was applied for the first time in the Dominican Republic. First, it was necessary to adapt the standard methodology to pineapple cultivation and site conditions. This resulted in a total of 13 pillars, such as: 1) History and organization of the farm by lot; 2) Soil management and conservation; 3) Origin of planting material and cultivars; 4) Management of in-vitro cultures and propagule quality; 5) Pineapple planting systems; 6) Management of intercropping, the mulch system and different life cycles; 7) Weed management; 8) Nutrition management; 9) Pest and disease management; 10) Irrigation and management of floral stimulation; 11) Management of fruit harvest, storage and packing; 12) Management of the processes of fruit selection, packing and transport to the ports; 13) Social care, capacity building and training. Each pillar presents several components (a total of 55), whose purpose is to document, evaluate, monitor and improve the state of the art of Good Agricultural Practices by fruit growers.

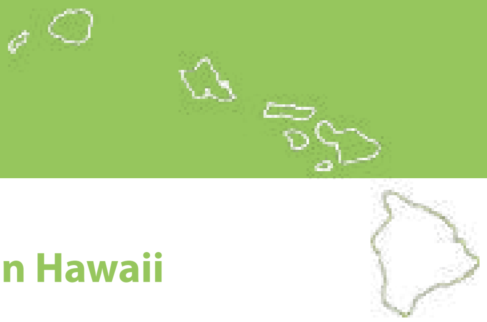
The traffic light methodology works in such a way that its lights or bulbs for the respective components exist as a model before evaluating an agroecosystem with its respective lots. In the case of the pineapple agroecosystem, there are 16 components in red, 16 in yellow and 23 in green (**Figure 1**).

Figure 1. Complete set of 55 control points for horticultural agroecosystems with pineapple.

The results obtained reflect a high standard in pineapple production in ASOPROPIMOPLA. Its 13 farms with 571 lots, which produce a very juicy pineapple with impeccable flavor, will be programmed in a defined system for the 52 weeks of the year. Especially for pillars 1, 3, 5 and 10, methodologies were developed, whose objective is a decisive improvement of Good Agricultural Practices (GAP) in the pineapple plantations of ASOPROPIMOPLA. The current situation shows only two components with a red light and four components with a yellow one, which should be fixed soon.

This research will be presented in more detail in the Dominican Republic, which has the pleasure of presiding the X edition of the International Pineapple Symposium, which will be held in 2023 with the theme “Protection and Management of Biodiversity: A Concern for Agriculture of the 21st Century”. This event will be held in Uvero Alto, La Altagracia province in the east of the Dominican Republic. The Pineapple Symposium is an activity of the Tropical and Subtropical Fruits and Nuts Division of the International Society of Horticultural Sciences (ISHS).

News from Hawaii



A review of bacterial heart rot of pineapple in Hawaii

L. Wong, A. Alvarez, R. E. Paull, and B. Sipes

University of Hawaii at Manoa

The first record of pineapple in Hawaii dates to 1813 in Don Francisco de Paula Marin's diary which implied that pineapple had already been in Hawaii for quite some time (Bartholomew et al., 2012). Between 1886 and 1893 James Kidwell and other growers collected many different varieties of pineapple worldwide and planted them in Hawaii. As the importance of pineapple increased in Hawaii, the Territorial Legislature passed a law in 1941 prohibiting the import of all bromeliads into Hawaii except by permit to prevent disease outbreaks that could impact the pineapple industry. Despite the long history of pineapple cultivation in Hawaii, no incidents of bacterial pineapple heart rot were recorded until 2003.

The pathogen

Bacterial heart rot and fruit collapse in pineapple was first observed in Malaysia in 1935 (Thompson, 1937; cited in Lim and Lowings, 1979). Symptoms include heart rot **(Figure 1A**), necrotic water-soaked lesions with gaseous bubbles under the leaves (**Figure 1B**), a foul odor, and rotted fruit. Decay may progress up the peduncle and into the fruit **(Figure 1C)**.

(Photos: L. Wong)

Figure 1. Disease symptoms of bacterial heart rot of pineapple: heart rot (A), gaseous bubbles and water-soaked lesions (B), and progression of rotting tissues into the peduncle (C).

The bacterial pathogen associated with this pineapple heart rot was first identified as *Erwinia carotovora,* a gram negative, peritrichous, rod shaped, soft rot pathogen (Johnson, 1957; cited by Lim and Lowings, 1979), but was later reidentified as *E. chrysanthemi* (Lim and Lowings, 1979). When bacterial pineapple heart rot appeared in Hawaii in 2003, the pathogen was identified as *E. chrysanthemi*, but in 2005 all *E. chrysanthemi* strains were reclassified into six separate *Dickeya* species (Samson et al., 2005). All Hawaiian strains were considered *Dickeya* sp. until they could be reclassified using molecular genetic methods. In 2013, a multi-locus sequence analysis (genetic classification method) showed that *Dickeya* strains isolated from infected pineapple in Hawaii were closely related to the original Malaysian pineapple strain, and both groups were most closely related to *D. zeae* although the pineapple strains were sufficiently distinct to warrant classification into new species (Marrero et al., 2013). As phylogenetic analysis of bacterial pathogens advanced over the next 8 years, new *Dickeya* species were described, among them *D. oryzae*, a pathogen of rice (Wang et al., 2020). In a thorough phylogenetic study of the pineapple strains, Boluk et al. (2021) documented that the pineapple strains were closely related to *D. oryzae*. In the face of rapid taxonomic changes, this pineapple pathogen is often referred to as *E. chrysanthemi* by the industry and as *D. zeae, D. oryzae,* or simply *Dickeya* sp. in scientific literature.

Setting the stage

As the pineapple industry in Hawaii transitioned from canning to fresh fruit, planting material of the Pineapple Research Institute's low-acid hybrid lines 73-50 and 73-114 was needed. In 2001, planting material of 73-114 was imported from Costa Rica by permit and planted directly into Hawaii fields (Bartholomew et al., 2012). By the spring of 2003, Hawaii had fields planted with 73-114 imported from Honduras, the Philippines, and Costa Rica (Bartholomew et al., 2012).

A bacterial heart rot outbreak

In December 2003, several specimens of diseased pineapples were sent to the University of Hawaii for diagnosis (Vine et al., 2005; Kaneshiro et al., 2008). Originally suspected to be an aggressive outbreak of *Phytophthora*, the causal agent of the observed disease was instead identified as *Erwinia chrysanthemi* before the genus was reclassified to *Dickeya* (Samson et al., 2005). Bacteria isolated from pineapple caused raised, water-soaked blisters following reinoculation onto pineapple leaves. Strains isolated from irrigation water on Oahu and Maui also caused blisters and necrotic lesions on pineapple leaves, but they were not inoculated into pineapple crowns, thus the entire disease syndrome was never observed for the irrigation water strains (Sueno et al., 2014).

Pineapple fields on Oahu continued to be monitored from 2003 to 2008 for bacterial heart rot. The irrigation water was also monitored for *Dickeya* sp. (Kaneshiro et al., 2008). In 2006 and through 2008, monitoring was expanded to Maui but no heart rot disease outbreaks were observed on that island (Sueno et al., 2014). Surveys were continued on Oahu from 2009 to 2011 but no additional diseased plants were detected. The monitoring indicated that two separate introductions of bacterial heart rot had occurred, the first outbreak in 2003-2004 and a second outbreak between 2006-2008 (Sueno et al., 2014). Pockets of diseased plants occurred in different fields on the same farm **(Figure 2).**

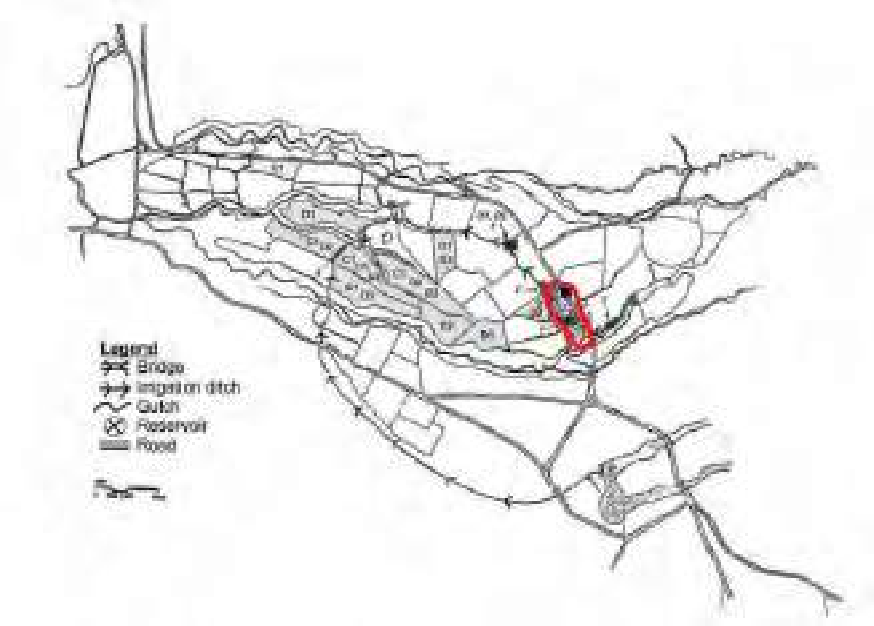


Figure 2. Fields on an Oahu farm showing bacterial heart rot. The area of the initial outbreak in 2003-2004 is circled in red. The shaded fields highlight areas where the second outbreak occurred between 2006 and 2008. C1, D1, D2, D3, and E represent different haplotypes of *Dickeya* sp. recovered during subsequent surveys.

Possible origin of the outbreak

In the first outbreak, *Dickeya* strains isolated from infected pineapple were genetically distinct from *Dickeya* strains isolated from irrigation water, indicating that bacterial strains in the irrigation water were not the most probable cause of the initial bacterial heart rot outbreak in Hawaii (Sueno et al., 2014). Reference strains of *Dickeya* sp. from pineapple fields in the Philippines and Malaysia were genetically distinct from strains isolated in Hawaii based on their Box-PCR haplotypes, indicating that strains from the first outbreak did not originate from either of these countries. The first outbreak of bacterial heart rot was limited to fields planted with suckers of the low acid pineapple hybrid 73-114 originally from Costa Rica and Honduras suggesting that the disease outbreak was caused by an introduction of the pathogen from Costa Rica or Honduras (Sueno et al., 2014).

Strains of *Dickeya* recovered from pineapple plants during the second outbreak were a distinct haplotype from those found in irrigation water, except for a few strains isolated from one reservoir on a pineapple plantation (Sueno et al., 2014). *Dickeya* strains isolated from pineapple during the second outbreak were characterized by haplotypes that were distinct from strains recovered in the first outbreak and distinct from the Malaysian reference strain (Sueno et al., 2014). This difference in genetics suggests a second introduction of bacterial heart rot into Hawaii from plants imported from the Philippines.

Disappearance of bacterial heart rot

No further reports of bacterial heart rot in pineapple were documented in Hawaii after 2008, coinciding with a transition from the low acid pineapple cultivar 73-114 to 73-50 on most plantations. The low acid pineapple hybrid 73-50 provided better fruit and growth characteristics in the cooler tropical environment of Hawaii and this became the preferred hybrid (Taniguchi et al., 2008). The low acid pineapple hybrid 73-50 did not form water-soaked blisters following inoculation with *Dickeya* sp. in detached leaf assays and appeared to be more resistant to bacterial infection compared to the low acid pineapple hybrid 73-114 (Alvarez, unpublished). Although the disease was not a significant factor in driving the transition, 73-50 may have contributed to the decline in serious disease outbreaks after 2008.

In many pineapple production areas, bacterial heart rot is a serious disease. However, losses in pineapple production directly attributed to bacterial heart rot were less than 1% in Hawaiian fields infested with the pathogen (Taniguchi et al., 2008). While this pathogen caused several years of local market disruption and quarantine of pineapple movement between islands in Hawaii, the disease has not been a continuing problem faced by pineapple growers in Hawaii (Sueno et al., 2014; Taniguchi et al., 2008). Bacterial heart rot of pineapple has not been detected on Maui nor reported on pineapple grown on other islands (Sueno et al., 2014; Paull and Sipes, personnel observation). However, *Dickeya* sp. from pineapple also infects corn, taro, and ornamentals in Hawaii (Sueno et al., 2014) and pineapple strains are genetically similar to *Dickeya* strains recently isolated from taro (Boluk et al., 2021).

Summary

Bacterial heart rot of pineapple has a limited history in Hawaii. The disease was not recorded in the pineapple fields of Hawaii for nearly 190 years of pineapple production. When the disease appeared on Oahu in 2003, bacterial heart rot was restricted to one island and although the disease caused much concern for 5 years, its overall impact on pineapple production in Hawaii has been minor. The pineapple cultivars affected by bacterial heart rot in Hawaii were grown only for a few years before being replaced with a cultivar (73-50) that appears to be more resistant to this disease. Desirable growth characteristics of 73-50 prompted replacement of 73-114 and may have coincidentally limited the spread and severity of bacterial heart rot of pineapple in Hawaii. Through several name changes from *Erwinia chrysanthemi* to *Dickeya* sp., and more recently to *D. oryzae* based on phylogenetic studies, the pineapple strains form a significant group of bacteria. This group of bacteria remains in the environment and causes diseases of taro, ornamentals, and corn. Pineapple growers in Hawaii should remain vigilant and be prepared for potential bacterial heart rot outbreaks.

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New approach to extracting irrigation tubing from pineapple cultivation

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Abstract

A new approach to removing plastic irrigation tubing from pineapple fields after crop termination is described. The process involves dessication via herbicide followed by mowing with a heavy duty tractor drawn flail mover. After mowing, equipment designed by Andros Engineering is used to lift the hose out of the soil and laid on top of the ground. The hoses are then collect and bound up in large rolls where they are recycled at a processing facility.

Introduction

In drier climates, like Hawaii, pineapple production is irrigated to ensure good production. Irrigation is done via drip irrigation, which is installed 5 to 10 cm below the surface of the planting bed. In Hawaii, each planting bed has two rows of plants and the drip tubing is placed between the two rows. The drip tubing is made from a thin wall plastic, normally 8 mm thick and has drip emitters approximately every 30 cm. Each drip emitter allows for a slow release of low volumes of water. Drip irrigation allows growers to inject fertilizers, nematicides or fungicides directly to the root-zone where they may be uptaken by the plants more effectively.

An emerging issue in Hawaii has been the retrieval of this plastic tubing after crop termination. Historically, the drip tubing was either burned or chopped up in the land preparation cycle, however both of these practices are discouraged as they have negative environmental effects.

Initial attempts to retrieve the drip tubing proved difficult. In Hawaii, pineapple is taken through a ratoon crop and the large amount of above ground biomass made accessing the drip tubing very hard. A disk harrow is normally used to "knock down" the crop after crop termination. However, the disk harrow often cuts into the planting bed, which cuts the drip tubing into small pieces. High labor costs in Hawaii have prevented hand retrieval of the drip tubing or hand removing the plants from the field to access the drip tubing.

After much trial and error a method to successfully extract the drip tubing was developed. The method described below is a 4-step process, 1) Desiccation, 2) Mowing 3) Extraction 4) Retrieving and binding.

Process description

- **Desiccation**

  Desiccation via herbicide is done after the final crop harvest. At Dole Hawaii a mixture of glyphosate and 2,4-D is applied with standard pineapple spraying equipment. The herbicide has an added benefit of killing difficult weeds like morning glory (*Convolvulaceae* var). Paraquat is likely a preferable herbicide for desiccation but is not allowed for use in Dole.

- **Mowing**

  Approximately 4 weeks after the desiccation step, a heavy-duty shredder is used to mow the pineapple plants. A second pass with the shredder is sometimes needed depending on the amount of biomass per field.

- **Drip Tubing Extraction**

  In Hawaii, a custom designed and built Andros DYNAMO extractor sled, which mechanically removes shallow buried drip tubing from the field is used. A few of the unique features of the Dynamo extractor include an adjustable tensioning system, which allows for maximum pulling force without breaking the drip tubing, and the pinch tires extractor design that removes water and dirt from the drip tube. This Dynamo extractor is configured to extract two lines of drip tube per pass and utilizes rigid discs to cut plastic and trash in the field for easier extraction.

The sequence of steps for drip tube extraction is as followed:

1. The operator drives the tractor into the field and lowers the extractor to the operational height. The ground helper places exposed drip tube lines into the extractor heads and then closes each head. The operator engages the hydraulics of the implement and then drives forward at a predetermined speed.

2. As the tractor advances through the field, the rigid discs or coulter wheels cut open the mulch plastic covering the beds and the spring-load undercutters (shanks) disrupt the soil just below the drip tube line, helping to make lifting the drip tube to the surface easier for the extraction heads. The drip tube is then pulled through the extractor heads and gently laid on top of the ground behind the tractor.

3. At the end of the field, the drip lines are fed completely through the machine. The tractor is now ready to turn around and start the next pass of the field.

- **Drip tube retrieval and binding**

An Andros Mega Binder retrieval machine is designed to collect multiple drip tube lines simultaneously and create a large, condensed roll of plastic weighing approximately 500 kg. Completed rolls are transported to the Andros Wahiawa facility where they are stored to facilitate appropriate recycling of Mega Binder rolls. Rolls are currently being sent to China for recycling.

The sequence of steps for mega binding are as followed:

1. The operator's first step is to install two twine lines on machine spool, which will be used once the roll is complete.

2. The second step is to place two to three drip tube lines into the machine. The operator feeds the drip tube lines through the guide rollers and wheels of the level-wind system. Next, the spool is opened and the drip tube lines are positioned in between the open spool so that when the spool is closed, the lines are held in place by the spool. The operator closes the spool and the machine is ready for operation.

3. The operator moves the control level of the hydraulic valve so that the spool rotates, and the level-wind system moves back and forth. The Mega binder is designed to collect 8-12 lines at time, depending on field conditions, so the operator will add additional drip tube lines by tying them to the lines that are already being collected. As individual tube lines are completely collected, the machine is moved down the fields to allow for additional lines to be collected.

4. When the roll is complete, the operator turns off the hydraulic valve and checks if all loose tube is secure within roll. Then, the two twine lines installed on the unit are each tied around the roll. The hydraulic control arm is opened, and the Mega roll is ejected from the machine. The operator can now move to the next set of lines or field to be collected and the process repeats.

Photos by Barber and Cotton

Figure 1. Mowing pineapple with flail mower.

Photos by Barber and Cotton

Figure 2. Another view of mowing.

Photos by Barber and Cotton

Figure 3. Lifting/extracting the tubing out of the ground.

Photos by Barber and Cotton

Figure 4. View from behind the extractor machine.

Photos by Barber and Cotton

Figure 5. Drip tube retrieval machine.

Photos by Barber and Cotton

Figure 6. Another view of the drip tube retrieval machine.

Photos by Barber and Cotton

Figure 7. Pineapple field after extraction and retrieval of tubing.

Photos by Barber and Cotton

Figure 8. Final product after binding to be recycled.

News from Mexico

Pruning and plant growth regulator to reduce natural flowering in MD-2 pineapple

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Abstract

One of the main constraints in pineapple cultivation in Mexico is a high rate of plants with natural flowering. This causes an overproduction of fruit, from the second half of May to July, and a shortage in September and October. The objective was to prevent natural flowering of 'MD-2' pineapple by pruning leaves, using shade mesh and applying the plant growth regulator 2,3-chlorophenoxypropionic acid (commercial product Fruitone CPA 8%), in order to harvest fruit out of season. The experiment was installed in July 2019, in a randomized blocks design with four replications. At beginning of November 2019, plant, leaf and stem weights were measured and the treatments of leaf pruning, shade mesh covering, and application of the growth regulator started. The percentage of flowering and non-flowering plants, and fruit harvest dates were determined at the end of March, just before artificial flower forcing. Plant shading did not prevent natural flowering. However, natural flowering rates of pineapple 'MD-2' reduced by more than 90% in response to 30% pruning of the leaves in combination with the supply of the growth regulator at 66 mg L^{-1} in a single application. Plants that did not flower until then, were artificially forced to flowering in March. Thereby much less fruits were offered during the period of oversupply and a significant number of fruits could be harvested in September 2020, an out of season period.

Keywords: *Ananas comosus* L. Merr., flowering differentiation control, out of season production.

Introduction

Natural flowering is a problem in pineapple cultivation. This phenomenon occurs mostly when low temperatures and short photoperiod are present, mainly during the winter. Mexico's pineapple planting region presents an average minimum temperature of 17.5 °C, from November to February. In that region, there is a difference of 2 hours and 10 minutes between the maximum day length in June (13h13min) and the minimum in December (11h03min). Under these environmental conditions, on average, around 25% of plants in pineapple fields show natural flowering, what determines a fruit production concentration, especially in June and July, period of lower fruit prices in the national market and a low offer of fruits in September and October, period of higher prices. In addition, natural flowering affects crop management programs and harvest planning and major difficulties for sales commitments, especially for the export market (Rebolledo *et al*., 2016; Uriza *et al*., 2018).

As Mexico is located in the northern hemisphere, natural flowering of pineapple generally occurs between the last week of November and the second week of February (Uriza *et al*., 1994), at variable rates depending on the weight and age of the planting material, the planting date and the occurrence of low temperatures (Reyes, 1992). In Australia, at higher latitudes than in Mexico, natural flowering may affect between 50% and 60% of pineapple plants (Scott, 1992).

To reduce this problem to a minimum, the effect of different inhibitors, which block the ethylene biosynthesis chain and consequently flowering, has been evaluated (Sanford and Bartholomew, 1981; Scott, 1992). It has been shown that six applications of silver nitrate in concentrations of 30 to 180 mg/L, at intervals of 15 days, from two months before the critical time of floral differentiation, reduce or delay flowering. This same result could be obtained with silver thiosulfate, which is cheaper but has a phytotoxic effect on the crop (IRFA, 1987). In Mexico, silver nitrate inhibited only 47% of natural flowering of 'Smooth Cayenne' pineapple plants, while gibberellic acid and bromacil did not show any inhibitory effect (Rebolledo *et al*., 1998).

Scott (1992) evaluated the effect on flowering inhibition of 2,3-chlorophenoxy propionic acid (Fruitone CPA) and paclobutrazol at different doses. The best treatments of both products presented only 8.2% and 28% of plants with natural flowering, respectively, while in the control treatment flowering rates varied between 48% and 55%. For the conditions of Queensland, Australia, the author recommended to apply Fruitone CPA in mid-March at a rate of 50 mg L^{-1} using 3,000 L of water per hectare.

In Mexico, it has been possible to inhibit up to 90% of flowering in the Smooth Cayenne cultivar, with 100 mg L^{-1} of Fruitone CPA, divided into three applications at 15 day-intervals, with more favorable responses in higher planting densities, younger and better nourished plants (Rebolledo *et al*., 1997; Rebolledo *et al*., 2000). Wang *et al.* (2007) evaluated doses of aviglycin (AVG) as an inhibitor of ethylene biosynthesis and found a reduction in the rates of natural flowering from 95% to 51.3% in response to application of 500 mg L^{-1}.

In Australia, genetic engineering has been used to produce pineapple plants with lower susceptibility to natural flowering. The ACC synthase gene was cloned from pineapple, expressed in meristems and activated under environmental conditions that induce natural flowering (ACACS1). Genetic constructs produced ACACS1 contents in sense and orientation to induce gene silencers by co-suppression mechanisms. Transgenic plants were produced and conducted in fieldwork for four years to study their characteristics. Several transgenic lines with lower susceptibility to naturally induced flowering were identified (Trusov and Botella, 2006).

Another way to avoid natural flowering is to shorten the crop cycle to only one year and produce pineapple fruits in the low offer season, without the application of any plant growth regulator. Several technological components must be combined with the maximum possible precision (Rebolledo *et al*., 1998). Suckers weighing 500 g should be planted in densities of 30,000 to 45,000 plants ha^{-1} in September and October, on beds protected with plastic mulch; if planting is delayed to November, heavier suckers (700 g) must be used. Fertilizers are applied in the drip irrigation water, at weekly intervals, totalizing 15-8-15-4 g of N-P-K-Mg per plant per cycle (Rebolledo *et al*., 1998), from planting to flowering. Flowering forcing treatment is done at six or seven months after planting, from mid-March to early May.

The pruning of the leaves of the pineapple plant is an unstudied practice and may have a potential to contribute to reduction of natural flowering since the plant, when pruned, initially weakens, but later develops with less stress since the physiological rhythm is reduced (Uriza *et al*., 2018). This practice is unusual, and the results of its use are variable, so it is necessary to study this factor of interaction with other crop management practices.

In 2005, based on information available at that time, Cunha emphasized that natural flowering continues to be one of the main problems in pineapple cultivation, even in carefully planned and managed plantations. And this is still true now in 2022.

The works on this topic have been carried out mainly with the Smooth Cayenne cultivar. However, in Mexico the area cultivated with the MD-2 hybrid is increasing, especially in the production with mostly international fresh fruit market destination. Therefore, this study was carried out on 'MD-2' pineapple plants with the objective to reduce natural flowering rates by combining treatments of leaf pruning, shading and application of plant growth regulator, and hence obtaining fruit harvest out of season.

Materials and Methods

The experiment was carried out in the Papaloapan Basin, where 80% of Mexico's pineapple is grown, in the municipality of Isla, Veracruz, on the "Las Maravillas" farm, located at $18^0$06' N and $95^0$34' W and 50 m altitude. The climate of the region is Aw_0, classified as the driest of the sub-humid ones

(García, 1988) with a mean annual temperature of 24 °C, an average of 19 °C in the cool period from December to February, and an average maximum temperature of 37 °C in the hot period, from April to June. The soil is of a predominant sandy-loam texture, poor in organic matter and nutrients, with pH varying from 4 to 4.5.

The genetic material used was the pineapple MD-2 hybrid, one of the two most important at the national level and the most widely accepted by the market for fresh export. The land preparation began in June with the passage of two disc-harrowing and one subsoiling; In the second half of July, the plantation beds were made with a center-to-center distance of 1.1 meters. Planting was carried out the last week of July, using suckers selected individually by weight (800 g) and planted at a density of 50,000 plants per hectare.

The experimental design used was a randomized blocks one with four replications, studying leaf pruning treatments, use of 50% shade mesh and the growth regulator Fruitone CPA 8% (active ingredient 2,3-chlorophenoxypropionic acid). Leaf pruning was done manually reducing by horizontal cutting leaf mass at levels of 30% or 95% (almost at plant apical meristem level). Shading was done with a black 50% shade mesh cover placed over the pineapple plants. Fruitone CPA and fertilizers were applied with backpack spray pumps in total spray with 60 mL of the solution per plant, at 15 day-intervals, in concentrations according to the treatments.

The following treatments were studied: 1) 66 mg L^{-1} of Fruitone CPA, in two equal applications and 30% leaf pruning; 2) 66 mg L^{-1} of Fruitone CPA, in one application, and a shade mesh cover; 3) 66 mg L^{-1} of Fruitone CPA in two equal applications, 30% leaf pruning and shade mesh cover; 4) Control; 5) Shade mesh cover; 6) 30% leaf pruning; 7) 95% leaf pruning; 8) Urea at 3% + Calcium nitrate at 3% + amino acids, in three applications and 30% leaf pruning; 9) 35 mg L^{-1} of Fruitone CPA, in three applications and 30% leaf pruning; 10) 35 mg L^{-1} of Fruitone CPA + amino acids in three applications and 30% leaf pruning; 11) 35 mg L^{-1} of Fruitone CPA + Urea 3% + Calcium nitrate 3% + amino acids in three applications; 12) 35 mg L^{-1} of Fruitone CPA in three applications. The treatments were started at begin of November 2019. At the end of March 2020, the plants that did not flower naturally were induced to flower by the application of ethylene gas (2 kg ha^{-1}), with the use of a high-volume sprinkler. The variables plant, leaves and stem weights were determined at the beginning of November. Rates of plants with and without natural flowering were determined at the end of March 2020, and fruit harvest dates were registered along the study.

Results and Discussion

Plant weight did not vary significantly at the beginning of the application of the treatments with an average value of 1.95 kg **(Table 1)**. Leaves and stem weights represented, respectively, 79% and 14% of total plant weight.

Table 1. Organ weight of 'MD-2' pineapple plants at the beginning of treatments studied - leaf pruning, shading and plant growth regulator.

Treatment*	Plant (kg)		Leaves (kg)		Stem (kg)	
1	2.3	a	1.9	a	0.29	a
2	1.8	a	1.46	a	0.26	a
3	1.8	a	1.45	a	0.29	a
4	1.9	a	1.54	a	0.31	a
5	2.1	a	1.58	a	0.29	a
6	1.8	a	1.43	a	0.26	a
7	2.1	a	1.66	a	0.28	a
8	2.1	a	1.58	a	0.26	a
9	2.1	a	1.61	a	0.3	a
10	1.8	a	1.46	a	0.25	a

Table 1. Organ weight of 'MD-2' pineapple plants at the beginning of treatments studied - leaf pruning, shading and plant growth regulator.

Treatment*	Plant (kg)	Leaves (kg)	Stem (kg)
11	1.8 a	1.41 a	0.26 a
12	1.7 a	1.4 a	0.25 a
Mean	**1.95**	**1.54**	**0.28**

*Treatments: 1) 66 mg L^{-1} of Fruitone CPA + 30% leaf pruning; 2) 66 mg L^{-1} of Fruitone CPA + shade mesh; 3) 66 mg L^{-1} of Fruitone CPA + 30% leaf pruning + shade mesh; 4) Control; 5) Shade mesh; 6) 30% leaf pruning; 7) 95% leaf pruning; 8) Urea + Calcium nitrate + amino acids, three applications + 30% leaf pruning; 9) 35 mg L^{-1} of Fruitone CPA + 30% leaf pruning; 10) 35 mg L^{-1} of Fruitone CPA + amino acids + 30% leaf pruning; 11) 35 mg L^{-1} of Fruitone CPA + Urea + Calcium nitrate + amino acids; 12) 35 mg L^{-1} of Fruitone CPA. Same letters represent non-significant statistical difference.

As shown in **Figure 1**, the highest rates of natural flowering inhibition were obtained in treatments 1, 3 and 8, with rates above 90%. In treatments 2, 6 and 7, flowering inhibition rates were close to 80%, also a rather interesting effect. Comparing all these values obtained, can be observed that the most critical treatment to get high inhibition of natural flowering was the application of the growth regulator, which is known to act in the plant tissue reducing the synthesis of ethylene, the main hormone responsible for the initiation of flower differentiation in pineapples. However, the growth regulator used was only effective at the higher concentration studied (66 mg L^{-1}). The lower one (35 mg L^{-1}), divided into three equal applications, did not reduce the natural flowering rate (Figure 1, treatment 12). This result is consistent with those reported by Rebolledo *et al* (1997) in studies with 'Smooth Cayenne' pineapple, indicating the concentration of 100 mg L^{-1}, divided into three equal applications, as the best treatment.

The positive inhibitory effect observed for treatment 8 is probably largely due to pruning, as shown the results obtained for this practice in other treatments in this study. Nitrogen application may favor the vegetative growth of plants and, as more developed plants are usually more sensitive, contribute to flowering; however, in several studies no influence of this factor on flowering has been observed, but the authors suggested to continue exploring the application of different nitrogen sources (Cunha, 2005; Rebolledo et al., 1997).

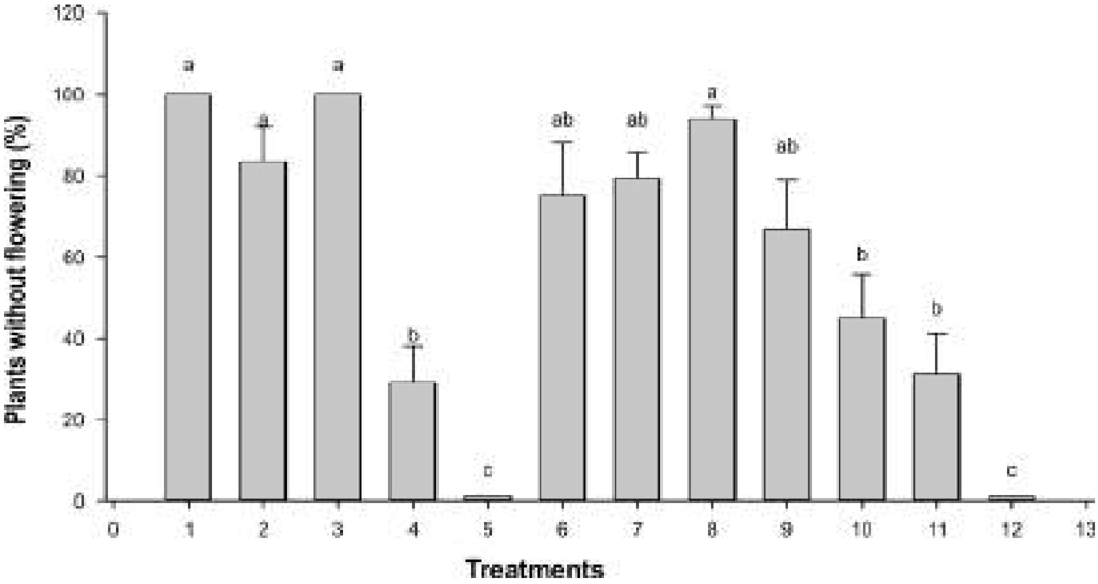

Figure 1. Rates (%) of plants without flowering in response to leaf pruning, plant shading and use of growth regulator. Bars ± standard error. Different letters represent significant statistical difference (Tukey, 0.05).

*Treatments: 1) 66 mg L^{-1} of Fruitone CPA + 30% leaf pruning; 2) 66 mg L^{-1} of Fruitone CPA + shade mesh; 3) 66 mg L^{-1} of Fruitone CPA + 30% leaf pruning + shade mesh; 4) Control; 5) Shade mesh; 6) 30% leaf pruning; 7) 95% leaf pruning; 8) Urea + Calcium nitrate + amino acids, three applications + 30% leaf pruning; 9) 35 mg L^{-1} of Fruitone CPA + 30% leaf pruning; 10) 35 mg L^{-1} of Fruitone CPA + amino acids + 30% leaf pruning; 11) 35 mg L^{-1} of Fruitone CPA + Urea + Calcium nitrate + amino acids; 12) 35 mg L^{-1} of Fruitone CPA.

Plant shading alone had no effect on the reduction of natural flowering (Figure 1, treatment 5). In addition, shaded plants presented thinner and longer leaves with an intense green coloration. This is probably caused by the reduction in solar radiation at the time of year with the lowest light intensity, from November to February.

Leaf pruning at 30% and 95% reduced significantly flower differentiation (Figure 1, treatments 6 and 7). However, when combined with an application of Fruitone CPA at the higher concentration (T1), floral inhibition is further reduced. Even though 95% pruning of leaves had a significant positive effect on reduction of natural flowering, this severe pruning was observed to cause a slower growth of the plants.

Partial leaf pruning showed interesting potential as a management practice to reduce natural flowering of MD-2 pineapple plants. This positive effect may be explained by the fact that the plant reactivates its vegetative growth by having better light conditions, and when combined with good nutrition, it improves its metabolic functions and reduces capture of possible environmental stress signals. The flowering reduction effect is increased by the supply of the plant growth regulator (Fruitone CPA), which helps to inhibit ethylene synthesis, as found by Rebolledo et al. (1997) and Scott (1992).

All plants without natural flowering were submitted to artificial flowering forcing treatment at the end of March 2020, when average plant weight was 2.7 kg. The fruit harvest was carried out during the last days of August and the first week of September 2020. Fruits from all treatments could be harvested at the same period, which in Mexico is an out of season time with low offer of pineapples on the markets.

Conclusions

Application of the growth regulator Fruitone CPA (i.a. 2,3-chlorophenoxipropionic acid) is known as an alternative management for reduction of pineapple natural flowering rates, especially when using a concentration of 100 mg L^{-1}. Partial leaf pruning (30%) showed to be an additional practice with potential for reduction of natural flowering in MD-2 pineapple plants. Its use enabled to get high inhibition rates when combined with a concentration of 66 mg L^{-1} of Fruitone CPA. This practice allowed harvesting fruits in an out of season period. Plant shading did not present favorable results on the inhibition of natural flowering of MD-2 pineapple plants.

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Graphic review: Uses and benefits of the 50% Black Plastic Shade Mesh, in pineapple cultivation under the agro-ecological conditions of Mexico.

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Background

After 15 years of carrying out a continuous series of research and validation work in the field and laboratory to solve the serious problem of soil deterioration due to water erosion and reduce the damage to pineapple plants, fruits and propagules caused by excessive radiation that occurs in the pineapple-producing regions of Mexico, the Pineapple Research Group of Inifap-Papaloapan, finally integrated in 2008 the management technology called "Intensive System in Protected Environment" (SIAP) **(Figure 1)**. This system brings together the best principles of the "Natural Protected System" (SNP) **(Figure 2)** and the "Hawaiian Intensive System" (SIH) **(Figure 3)**. Soil and humidity are protected by means of Plastic Mulch in full coverage (APT) (black polyethylene/150 caliber/penta-layer) and plantations are protected by means of Plastic Shade Mesh (MSP) (black polypropylene/50% shade/ hybrid type), synthetic materials that simulate the plant cover of the soil and the shading of the tree canopy, as occurs naturally in the SNP.

It is estimated that the SIAP, in contrast to the SIH, reduces soil erosion by 95%; prevents the weed growth and reduces the weedicide application by 90%; and that of fertilizers and other supplies of chemical, biological and organic origin, by 40%, due to greater efficiency; saves 60% of irrigation water; reduces by 60% the occurrence of premature winter blooms; shortens crop cycles by 2 to 4 months; two additional ratoon crops are achieved in an uninterrupted manner and with greater safety and profitability; 25 to 50% higher performance and productivity is obtained; the fruit is better shaped and uniform in color, of higher external and internal quality, more innocuous and with at least seven days longer shelf life, obtaining a higher market value. In addition, it leads to a physical, chemical and biological soil improvement, as long as it is correctly applied. However, this system requires that agro-plastic waste must be managed in an ecological manner, for recycling or use as an energy source.

Under the SIAP **(Figure 1),** the yield, depending on planting density, is equivalent to 45-50 tons of fresh fruit/ha/year, in plant crop cycles of 12 to 16 months. Due to the conditions of greater vigor and health with which the mother plants end up in the first cycle, the uninterrupted production of a two ratoon crops, using the same APT and MSP, is the most frequent and profitable. The ecological disposal of the residues of these agro-plastics used, at the end of their "useful life", is an obligation of the users.

In the SNP **(Figure 2),** also called Agroforestry, the average unit yield is very low, being equivalent to 4 or 5 tons of fruit/ha/year (Ríos and Uriza, 2005; Rosales et al., 2014), in uninterrupted cycles of 16 to 18 months, in practically organic plantations being established and harvested for more than 50 years. Although agronomic improvements can be made to increase its productivity, this system is not viable to satisfy the current and future demand for pineapple in the country and the world.

Figure 1. The **“Intensive System in Protected Environment”** (SIAP) protects soil and humidity through the APT and protects the crop and fruit against excessive solar radiation through the MSP. SIAP improves irrigation performance, whatever its modality. Losses due to erosion of 10 tons of soil/ha/cycle are equivalent, on average, to only 0.3 kg of soil per kg of harvested fruit.

Figure 2. In the “Natural Protected System” (SNP), which persists in Nayarit and other states of western Mexico, “Criollas”, “Castilla” or “Mountain” pineapples are produced. Losses due to erosion of 5 tons of soil/ha/cycle are equivalent, on average, to 1.0 kg of soil/kg of harvested fruit. (Credit: Rosales et al., 2014).

Meanwhile, under a strictly applied **SIH (Figure 3)** where the crop is established on bare soil and develops in open air, the yield, depending on planting density, is equivalent to 25-35 tons of fresh fruit/ha/ year, in a two-year plant crop cycle. The degree of water erosion is extreme; the loss of inputs applied to the crop is high by leaching and very polluting to the ecological environment; and high radiation damage is serious. Due to the fact that the mother plants, at the end of the first cycle, present aspects of obvious conditions of general deterioration, the possibilities of achieving at least one ratoon crop cycle are reduced to a minimum, since it is mostly unprofitable. This forces the producer to have to prepare the land again, sow new suckers and cultivate them in this ecologically destructive and cyclical way (Uriza et al, 2018).

Figure 3. In the "Hawaiian Intensive System" (SIH) (bare soil and open sky), the insufficient incomplete techniques of prevention and control of erosion result in erosive events of 50 to 250 tons of soil/ha/cycle, accelerating degradation of soil physical, chemical and biological characteristics, with or without planting beds, even on slight slopes. Losses are equivalent on average to 2.5 to 3.0 kg of soil/kg of harvested fruit.

The adoption of SIAP technology occurred in different pineapple regions of Mexico spreading within 10 years (years 2010-2020) to an area harvested of 8,500 ha, that is, 40% of the country's total yearly harvested area. 85% of the SIAP area is cultivated with 'MD2', 14% with 'Smooth Cayenne' and 1% with some other cultivars such as 'Champaka', 'Cabezona' and ornamental pineapples. About 500 of the total of around 1,500 pineapple growers in the country are SIAP users, especially large exporting companies and their multiple suppliers (medium and small producers, specialized through training and advice by company technicians).

Without a doubt, the SIAP technology is fully applicable to all types of producers, from those who only have 0.5 ha to those who harvest 1,000 ha or more per year. There are no technical-ecological justifications for not applying it, but there are financial ones, due to its relatively high initial investment costs [APT ($1,200 US$/ha) and MSP ($4,000 US$/ha)]. However, these costs will need to be prorated, as they are good for multiple cycles of continuous production [APT, at least three cycles; MSP, at least ten cycles, with services of six months per cycle]. A special case occurs with the MSP, which is no longer used due to the risk of theft, such as when the pineapple plantations are far away and unattended. There are also a few places in Mexico, with unique agro-ecological or topographical conditions, where producers say that, apparently, the MSP is simply not necessary.

Although the APT and the MSP, individually, determine significant increases in fruit yield and quality, in addition to benefits to the soil, water and the environment, interacting together, their benefits are potentiated, achieving 40% lower environmental impacts (ecological load or damage) in pineapple production than the SIH (Uriza, 2011; González, 2014; Espinoza, 2015; Crivelli, 2017; Uriza et al 2018).

This graphic review summarizes, chronologically, advances and results of formal research work carried out by the Inifap in the field, laboratory and in validation plots for technology transfer, from 2002 to 2021. It also includes aspects and information coming from the experiences of growers and technicians who use plastic shade mesh in their plantations. Among others, those experiences include extreme weather events, as for example hailstorms and heavy rains that showed other important functions and benefits of the MSP, still not formally evaluated.

Most of the information presented has its corresponding technical support, which may be more detailed in future contributions of the author(s) to Pineapple News or other vehicles. There are strong technical reasons for the **plastic shade mesh** to be one of important tools to reduce the negative consequences of the imminent climate change, under the environmental and agro-ecological conditions of the pineapple regions in Mexico.

High values of solar radiation during the year that damage the pineapple crop.

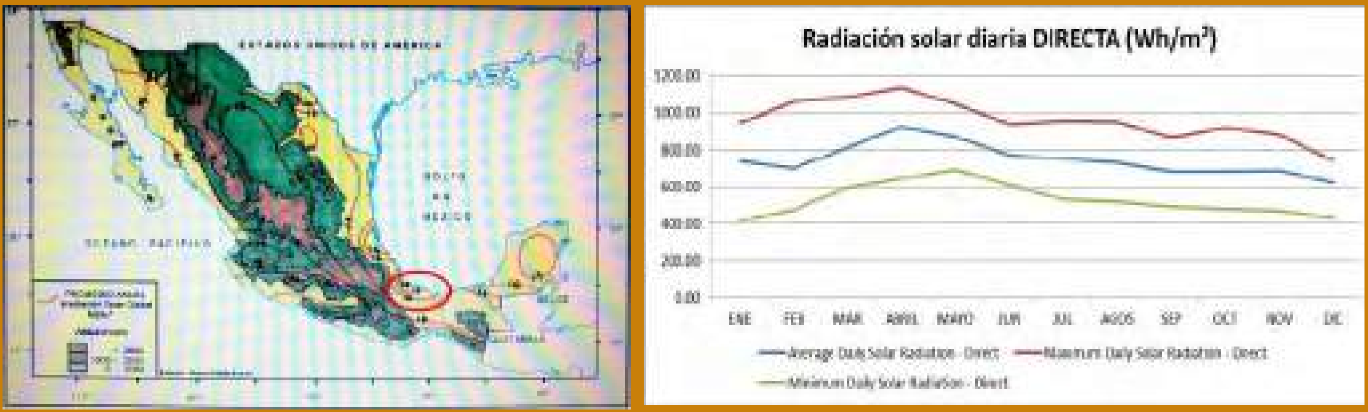

Figure 4. Annual average of Global Solar Radiation in Mexico, ranging between 16 and 18 Mega Joules/m^2 in the pineapple zone of Papaloapan (red circle). Daily Direct Solar Radiation Values (Average, Maximum and Minimum) at the José Azueta Weather Station, Veracruz, Mexico, located in the center of the Bajo Papaloapan pineapple region, reach average values (not absolute maximums) of up to 1,100Wh/m^2.

Determination of the type, color and shade degree of MSP for its use in pineapple

Figure 5. In at least five works of the Inifap-Papaloapan, **types of MSP** were evaluated (photos from left to right): A) Rashel flat woven ribbon; B) Monofilament round thread, and C) Hybrid extended flat ribbon crossed with round thread. Subsequently, **degrees of shade** were studied (35, 45, 50 and 65%) of MSP Rashel vs MSP Monofilament, but only in two fruit harvest seasons: Late Winter and Mid-Autumn. The MSPs were installed one to two months before flowering forcing; the control was the regional fruit protection practice of tying the leaves with plastic raffia over the fruit. It was concluded that the black Hybrid MSP (C) is the most suitable one due to its resistance, ease of handling and cost, especially in high-density plantings in first and second ratoon cycles, where the protection of the fruits with conventional methods is impractical and unaffordable. 50% shading turned out to be more convenient and useful for the whole year. In spring-summer time, a period considered more critical for medium to large fruits, harvested at intermediate to advanced maturity degrees (2, 3 and 4), shading up to 65% may be required. However, in plantations with fruits destined for the fresh export market (with densities of 60 to 70,000 plants/ha), this high degree of shade may reduce fruit weight by 5% when harvested in autumn and winter, what is considered to be a small inconvenience, when compared to the advantages achieved with the MSP in relation to the other regional methods.

Protection of plants during the early stage of vegetative development

Figure 6. In a Smooth Cayenne pineapple field planted in January 2017, serious damage to leaves due to excess solar radiation occurred early. Given this, the Inifap-Papaloapan evaluated the protective effect of the MSP 50% Hybrid type in an early stage of vegetative development. A) (Photo above, on the left) On April 12, an Observation Plot was established with plants covered with 50% MSP and plants without protection, under the same management conditions. B) (Photos above on the right and below on the left) In September, the protected plants reached 3.5 kg of fresh weight (ideal weight for flowering forcing) and 95% of active chlorophyll surface in their most exposed leaves (leaves 'A', 'B' and 'C'), while, the unprotected plants (open sky), only reached 2.5 kg of fresh weight, that is, 30% less than the protected plants, in addition to only 30% of active chlorophyll surface. C) (Photo below, on the right) Top view of protected vs. unprotected plants, 60 days after placement of the 50% MSP.

Soil protection and erosion in plantations of early vegetative development

Figure 7. This aspect or variable has not been formally evaluated by the Inifap-Papaloapan, but it is fully detected by researchers, producers and technical users of MSP 50% in plantations that develop exclusively on bare soil, without APT and in an early stage of vegetative development, when the foliage of the plants has not yet "closed". The evidence indicates that, under these conditions, the MSP 50% reduces the deflocculation of soil particles (which initiates the erosion process https://www.dgcs.unam.mx/boletin/bdboletin/2021_600.html), as the MSP 50% receives the strong impact of raindrops or irrigation flushes, dispersing them into small drops with less kinetic force. What is observed in runoff during each rain is a smaller amount (not yet quantified) of fine soil particles washed away, surely with organic matter and nutrients, fertilizers and granular nematicides applied.

Greater efficiency of irrigation and rain water

Figure 8. The study "Pressurized irrigation with the use of renewable energy in pineapple MD2", carried out by the Instituto Mexicano de Tecnologia del Agua (IMTA) (2013) with the participation of the Inifap-Papaloapan, concluded that: to maintain the available humidity at an acceptable level for the crop, the following levels of daily irrigation are necessary, according to the management condition of the plantation: A) 3.5 mm (100%) in bare soil and open sky (SIH); B) 2.4 mm (70%) on a soil with total plastic cover, and C) only 1.5 mm (40%) for a soil with total plastic cover and plastic shade mesh (SIAP). The savings for the use of MSP individually are 1.0 mm/day and together with the APT, 2.0 mm/day, that is, 30 and 60% less expense, respectively, than in the conventional Intensive Hawaiian System (SIH).

Winter premature blooms (Photo A, on the left) reduction by plastic shade mesh

Figure 9. In November 2009, the Inifap-Papaloapan installed an Observation Unit with the objective of evaluating the efficiency of the plastic shade mesh in the reduction of premature winter blooms in a MD2 pineapple crop planted in bare soil in September 2009, with large suckers (Treatments I and II) and small ones (Treatments III and IV), at a density of 50,000 plants/ha. The treatments were the following: I) No MSP or "open sky"; II) MSP type rashel 50%; III) MSP monofilament 40% and IV) MSP 50% extended flat belt. The surface of each plot/treatment was 225m^2 (15m x 15m), with 1,125 plants each, representative of the microclimate conditions generated under the MSP in commercial plantations. The results as of March 30, 2010 indicated that the three MSPs evaluated, resulted in average percentages of premature flowering 80% lower than the uncovered treatment without MSP (20% premature flowering). As a complement to the main work, between December 2009 and January 2010 (delayed in time), another four Observation Lots with MSP 50% rashel type were installed in different representative regional locations. Average percentages of premature flowering were, respectively, 30, 40, 40 and 55% lower than those observed in the controls without MSP (90, 100, 40 and 55% of premature flowering). Other observations showed that for the interaction total plastic mulch (TPA) + MSP 50% the premature flowering reduction can be 80%, or even higher, if you add: Pre-winter pruning in October + N, Ca and B 20 days later + four fortnightly applications of chlorophenoxypropionic acid (CPA) (medium doses) from November to December (Photo B, on the right).

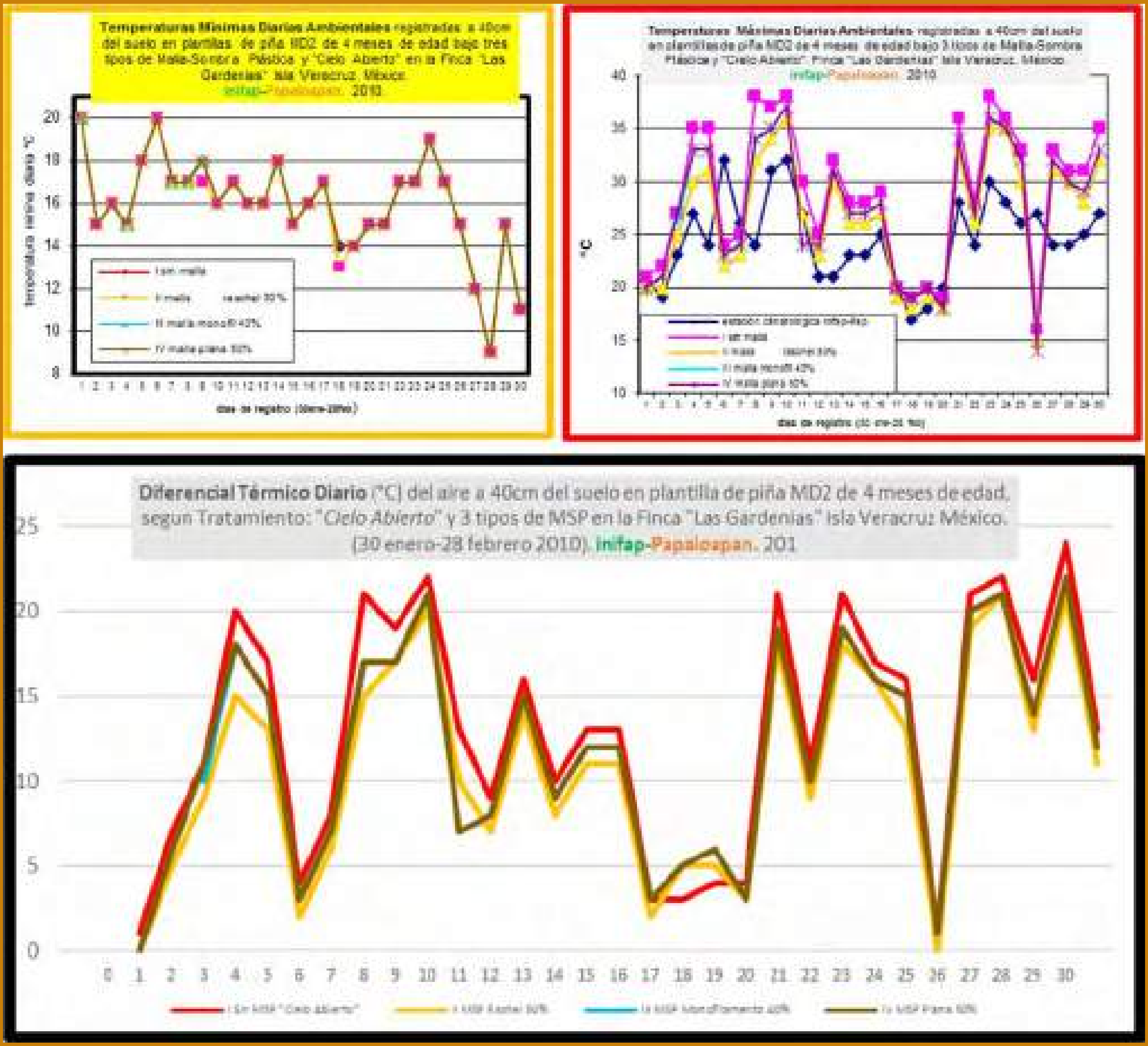

Figure 10. Regarding temperatures taken by Inifap-Papaloapan through portable thermographs, thermal differentials of up to 22°C were recorded on the same day. There were no differences for minimum temperature between treatments (Graph above, on the left), but for the maximum the treatment of MSP Rashel type presented temperatures of up to 5°C lower than those of the "open sky" control (graphs above, on the right, and below). The protected treatment also showed a moisture availability [from the Permanent Wilting Point (6%) to Field Capacity (11%)] that was 15 to 74% higher than in the control, with greater efficiency of water use (irrigation or rain) and reduction of water consumption by evapotranspiration estimated in 30% on average. These more favorable conditions for plant development may reduce stresses that induce premature flowering.

Plant and fruit protection against excessive solar radiation from the pre-induction

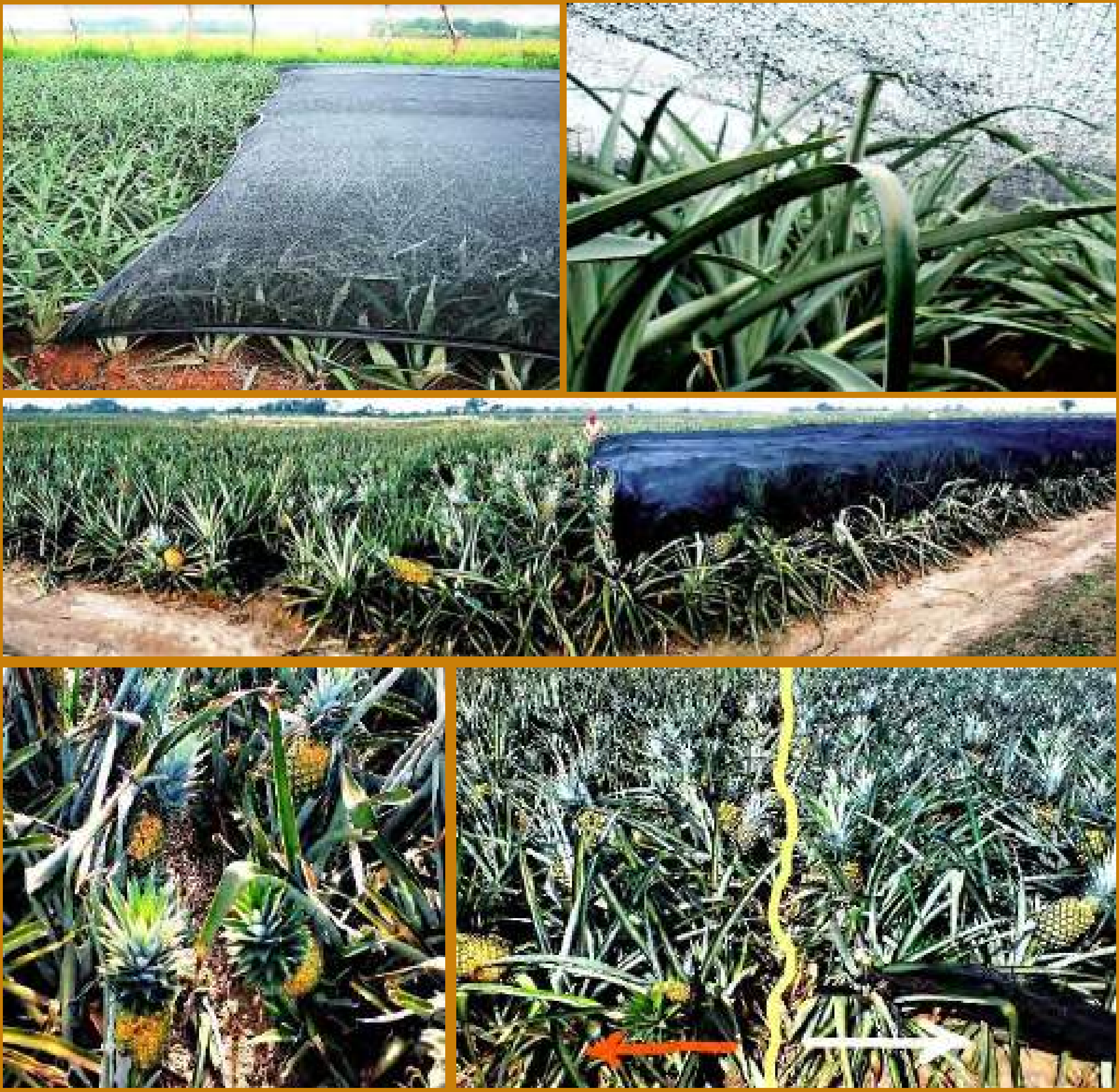

Figure 11. At the beginning of 2008, the Inifap-Papaloapan installed an experiment in the farm “La Algodonera” of Isla Veracruz, Mexico, to evaluate the protective effect of the MSP 50%, installed 50 days before the flowering forcing treatment, on fruit yield and quality of MD2 pineapple for fresh export (Photos above). The crop, with 43,400 plants/ha, was planted in July 2007, the 50% MSP was installed in January 2008 and plants were induced to flower on March 19, 2008, without removing the MSP; in the control treatment, fruits were protected from about 35 days before harvest by tying leaves with raffia over the fruit, the typical regional practice. Fruit harvest was at the end of August 2008, however, during the previous 15 days there were several storms with strong rains and winds, which caused many fruits of the control treatment to remain “uncovered”, a very common problem, so that 44% of them presented mild to severe burns at harvest, while only 2% of fruits covered with MSP 50% presented symptoms of sunburn. The period from induction to fruit harvest occurred during spring and summer, the most critical season in terms of excess solar radiation, high temperature and low humidity in the soil, air and plant. MSP 50% determined temperature up to 5 °C lower and a soil moisture up to 30% higher than in the control. In addition to the large difference in fruit sunburning, other results emphasized the importance of plant and fruit protection by MSP 50% in comparison to the control treatment without MSP and with regional practice for fruit protection: 95% vs. 41% of commercial fruits; 2% vs 16% of fruits with multiple crowns; 20% higher fruit fresh weight (Photos in the middle and below).

Figure 12. The results showed that the more favorable microclimatic conditions established by MSP 50% improved the performance of the protected plants (see photos A and B, on the right side) in comparison to the unprotected ones (A and B, on the left side, and C). The reduction of the excessive direct solar radiation may have increased the number of effective hours of stomatal opening and favored higher photosynthetic activity. Other positive effects may also have contributed to plant performance, especially an improved availability, supply and translocation of nutrients and hormones. Inifap-Papaloapan studies have shown that the occurrence of multiple crowns is favored by low availability of Ca. Its incidence varied from 50 to 65% in summer harvest, depending on the severity of solar radiation and temperature. Rains that reduce direct solar radiation usually contribute to lower percentages of multiple crowns and to some increase of fruit weight.

Efficacy, efficiency and quality of floral induction treatment with MSP 50%

Figure 13. Efficacy, efficiency and quality of flowering forcing treatments in commercial plantations protected with MSP 50% from its pre-forcing stage, have not been formally evaluated by Inifap-Papaloapan, but important inputs have come from other researchers, growers and professionels. In general, independent from the flowering forcing methods applied, in fields protected with MSP have been observed higher induction percentages (95 vs 85), higher uniformity in inflorescence emission and also a higher number of flowers per inflorescence. These aspects contribute to yield and fruit value increases, a more concentrated harvest period. In fields with MSP has been observed that the application of the inducing solution with high volume sprinklers gives better results, as this ensures a more intense atomization of the drops with an improved penetration through the shade mesh and more efficient distribution over the plants. (Crop image credit: Tec. Obet Hernández Romero).

Figure 14. These positive results obtained in response to plant protection with MSP 50%, applied from 60 days or only 10 days before flowering forcing, are a consequence of the improved microclimatic conditions established by the MSP protection. The mitigation of air and soil temperature and humidity, in addition to protection against wind strokes, enable that improved plant performance under those conditions in comparison to the traditional "open sky" cultivation of MD2 pineapple.

Fruit protection against excessive solar radiation

- Inflorescence emergence and early stages of fruit development

Figure 15. The sprouting stage of the inflorescence and the first phases of fruit development entail a high risk of damage to the fruits and crowns due to excessive solar radiation. It occurs when the cells are in intense multiplication (prior to anthesis) and the internal and external tissues are tender and very susceptible to damage. These risks can be: physiological, such as the destruction of chlorophyll and anthocyanins in bracts of the berries and in leaves of the most exposed crowns; and morphological, such as deformation, growth reduction or even death of the apical meristem (A) that result in fruits with multiple crowns, or very reduced and deformed ones. The damage occurs throughout the year, but mainly in spring-summer, in plantations that grow in "open sky" conditions (B) and are not protected with MSP 50% (C) before their emergence. Figure 15-B shows the different, bright reddish color of the inflorescence in the middle plant, which is shaded by neighboring plants, while the other two plants, with more exposed inflorescences, present evident damages due to this factor. In counts carried out by the Inifap-Papaloapan in non-protected commercial plots, from the inflorescence appearance in the plant axis until the "dry flower" stage (anthesis), 30% of inflorescences and fruits presented damages, whereas no damage was detected in plants protected with MSP 50% (C).

- Pre-harvest stage of the fruit

Figure 16. From 2004, Inifap-Papaloapan has carried out several studies to evaluate some methods for fruit protection against excessive solar radiation, specifically during the last 60 days before harvest, both for fruits destined for the national fresh market (planting at low and intermediate density, mid to large-size fruit, at mid to high natural maturity stage) and those directed to fresh export (high density planting, small to intermediate fruit-size, at low to intermediate maturity levels). It was concluded that the MSP 50% hybrid black color is the most suitable for both types of fruit destinations, due to its resistance, ease of handling and cost measured for MSP/ha and for protection/fruit. MSP 65% showed to be interesting in spring-summer period, especially for fruits harvested at intermediate to advanced maturity stages (2, 3 and 4) directed to the national fresh market. The alternative of using micronized kaolinite or calcium oxide powders with adherents have not been effective in protecting the fruit when applied at different maturity stages, but they can help reduce damages, in spite to a lesser degree, if applied in other stages, from pre-flowering forcing to a stage before physiological fruit maturity.

Efficiency, efficacy and quality of the fruit harvesting process

Figure 17. Manually "covering" a lot of 1,000 fruits with one of the conventional protection methods, 2 months before harvest, implies a cost of US$ 12.5, equivalent to US$ 750 for 60,000 fruits/ha, 60 kg of raffia and transportation of at least 60 specialized workers and a working day of at least 6 hours, in addition to at least 2 or 3 repassing. Meanwhile, installing MSP 50% to protect 1.0 ha of plantation (either 25 or 70 thousand plants/ha), either from 2 months before the flowering forcing or before the harvest, 6 people and 8 kg of plastic raffia are enough to install, in a 6-hour shift, to which must be added an amortization cost over 5 years of useful life, of 10 "uses" during 6 months in pre-flowering forcing or from 20 to 30 uses in periods of only 2 months before the harvest. Another additional cost of the conventional methods is, at harvest, the need of "uncovering" each fruit protected with newspaper or with leaves tied with raffia, and to "recover" many of them if they have not reached the wanted maturity stage based upon rind color. The MSP is removed for the harvest in each section, and once completed, re-installed for protection of the still unharvested fruits. According to the Inifap-Papaloapan recommendations, MSP 505 is the most practical, effective and profitable fruit protection in plant and ratoon cycles of high-density plantings.

Fruit protection against pests

Figure 18. Physical and Ethological Control of fruit pests. Since the massive commercial use of the 50% MSP began in total coverage (left), not just superficial (middle), field technicians, growers and researchers from the Inifap-Papaloapan have reported a significant drop in fruit damage by *Stroma basalides*, *Elaphria*, weevil, cricket and birds, all invasive pests that arrive by air at the plantations, in search of emerging or flowering inflorescences or fruits at different degrees of development and maturity. Everything indicates that, when the MSP 50% is placed in a timely and correct manner, in addition to being a physical barrier that prevents these agents from accessing the plants, it also prevents the insects from detecting the attracting colors of the flowers and fruits. In commercial practice, the application of agrochemicals at these plant developmental stages is reduced by 40 to 70%. In addition, MSP also provides protection to the chemical, organic or biological insecticides used, so their effect tends to last longer and to be more efficient than in plants under "open sky" condition.

Protection of the fruit against extreme climatic events

- Dry and high intensity winds

Figure 19. Due to its location in the central part of the Coastal Plain of the Gulf of Mexico, pineapple plantations, especially those with fruits close to harvest, are affected to different degrees by frequent and strong winds in autumn-winter season, usually from November to February, but sometimes extending from September to May. “North Winds” occur 30 to 40 times on average per season, frequently at intermediate to high intensity, half of them are dry ones while the rest are humid ones bringing rain. The “South Winds” are less frequent and less intense (up to 80 km/hour) and occur from January to May, always prior to “North Winds””.

In “open sky” plantations, strong winds (up to 100 km/hour) cause physical damage (friction) to the longer leaves of the plants (photo on the right). Winds often cause fruits to lay down (photo on the left), unwrap or remove the conventional protection (newspaper, grass stubble or leaves tied with raffia around each fruit) and being damaged by exposure to direct solar radiation. Dry winds cause moisture loss and fruit skin cracking (photo in the middle), which increases their susceptibility to fungal diseases, loss of internal liquids and reduce their shelf life to an undesirable minimum. If winds are associated with very high temperatures, they can dry out the apical part of the most exposed leaves of the plants (photo on the right) and the crown of the fruit, affecting the general development of the crop and its commercial value. These problems do not occur or are significantly reduced in plants and fruits protected with 50% MSP, which enables an micro-environment where temperature, solar radiation, air speed, environmental humidity and soil availability are more stable.

Girdled fruits, brown spot, fungal and bacterial diseases and "water shocks" due to heavy rains during the dry season of the year

Figure 20. "Crazy rains" are heavy uninspected rains that happen in restricted areas during dry periods, mostly in spring and part of the summer, that cause a hydric and thermal shock in the affected pineapple fields, especially when falling during the hottest daily hours around noon. These rains have caused several types of damages depending to the developmental stage of plants in their reproductive phase. Some disorders caused are shown in the photos above: A) (Photo on the left) "Girdled" fruits, probably due to the burning of their fruitlets with extremely hot water, drained from the leaves and deposited at the level of the bud of the plants, when the inflorescences are in the process of emerging from the rosette; B) (Photo in the middle) Fruitlets with internal dark, "chocolate" or "coffee" like spots, and C) (photo on the right) Water-soaked fruits, the latter both physiological disorders probably caused by the sudden change in temperature and humidity, in external and internal fruit parts at advanced stages of fruit development, the first related to the oxidation of compounds in the pulp and the second by breaking down tissue cell walls. In addition, these disorders in response to water differentials between the outside and inside of the fruit, may favor the entry of fungal and bacterial diseases. According to available information collected informally in the field, these problems showed a 60 to 80% lower incidence in fields protected with MSP 50%, in comparison to unprotected ones. However, the quantitative and economic impact has not been formally determined.

Hailstorms

Figure 21. Hailstorms fortunately are of low incidence in the Bajo Papaloapan pineapple region. However, when present they may cause significant damage whose magnitude depends on its intensity and the plant developmental stage during the cycle. One important hailstorm occurred in the Los Tigres-Huayacanes sub-region (200 to 250 masl), in a single event. Not protected pineapple fields presented extreme damages in several developmental stages. Fruits affected lost their commercial values and were sold as waste fruits. Plants affected in the vegetative cycle took about four months to recover, increasing production cost and showing lack of uniformity. On the other side, fields protected with MSP 50% did not show any damages (see photo above, on the right, showing both protected and unprotected plants). Their fruits reached high values assuring returns that recovered all investment done with MSP.

Uniformity of the external and internal color of the fruit

Figure 22. Although the traditional fruit cover with leaves of the plant tied around it with plastic raffia (photo on the left) has some advantages in relation to other conventional alternatives, it is not good practice, since there is still a high risk that sunburns may affect some unprotected parts of the fruit. In addition, fruits protected in this way often present on their rind green stripes alternating with yellow ones (photo in the middle). Fruits may also show small cracks or fissures on their surface, making their acceptance difficult in the American fresh market. Meanwhile, fruits protected with MSP 50% (photo on the right) have a bright and uniform colored rind and usually present longer shelf life.

Uniformity of fruit shape

19.1cm/21.2cm=**0.90**
Without protection
(Control)

22.0cm/23.9cm=**0.92**
Protection with paper
(Regional)

22.8cm/24.3cm=**0.94**
Protection with
MSP 50%

Figure 23. In 2012, researchers from the Inifap-Papaloapan carried out a study in the "La Víbora" site, in Veracruz, Mexico, located close to the sea where the pineapple leaves are short and the fruits are more exposed to direct solar radiation than in other regions. In comparison with the control treatment with fruit protection done with old newspaper, the MSP 50% protection systems was studied. Both treatments were done 50 days before harvest. MASP determined a more uniform shape of MD2 fruits (C), with a symmetry index (Sun Face Length/Shadow Face Length) closer to 1.00 (0.94) than in fruits protected with newspaper (B - 0.92) and not protected fruits (A - 0.90). In addition, the fruits protected with MSP presented better external and internal characteristics and lower sunburn percentage. Fresh pineapple exporters are very clear about this benefit, which increases as the protection is provided earlier to the plant and the fruit, that is before the flowering forcing, or at least before the inflorescences emergence.

In Synthesis:

- Current evidence indicates that the 50% MSP is the most practical, efficient, and profitable method of protecting plants, fruits, and shoots against excess solar radiation in the short, medium, and long term.
- This system allows the investment to be recovered (US$4,000/ha) in about four "layings" of six months each, if we consider the additional value of the crops due to the extra quality achieved thanks to the protection of the fruit, and the cost of possible losses due to sunburns in the field and reduction in the value of the product due to malformations, multiple crowns and "tabby" appearance, all causing export rejections, which would have occurred, for not using it.
- "Covering" one hectare (55,000 plants/ha) manually with conventional methods (newspaper or leaves and raffia), costs around US$ 750 and implies the support and transfer of at least 55 workers and a 6-hour shift; while, to install MSP 50% for the same area, 6 days are enough in the same 6 hours. It allows a greater opportunity in the application of the protection, since, in case of urgency, with those same 55 days, 9.0 ha of MSP 50% could be installed in 6 hours/day or 2.75 ha in a single hour.
- The diversity of functions and benefits that its use is proving to have, allow to recover the investment with greater safety and speed. Decreasing the percentage of premature blooms, increasing available soil moisture, reducing the frequency and use of water in irrigation, achieving a higher growth rate of protected plants in all stages of the cycle, possibly also reducing erosion by avoiding the direct hit of the rain on the soil and improve the conditions and response of the plants when they are protected in advance and during the process of flowering and fruit development,

higher yield, better fruit quality, shape and shelf life, among others, are visible advantages that need to be more accurately quantified to give them their value and weight in the financial context.

- The problem for further expansion in its use lies mainly in the fact that the investment for its purchase is very high for many growers, since it represents the equivalent of just over half of the investment for a hectare of Smooth Cayenne pineapple or a third of that of MD2 pineapple. Another problem is the risk of theft under conditions of distance from the plantation and lack of permanent surveillance.
- Agronomically and economically, the application of this technology is feasible and favorable to cultivation under the environmental conditions of pineapple in Mexico. Probably, the 50% MSP will not provide these same benefits in other pineapple regions with rather different characteristics. However, it is worth to be tested using several degrees of shade at different stages of the growing cycle and seasons of the year.

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News from Netherlands

Temperature fluctuation can be reduced in containers with a special floor cover

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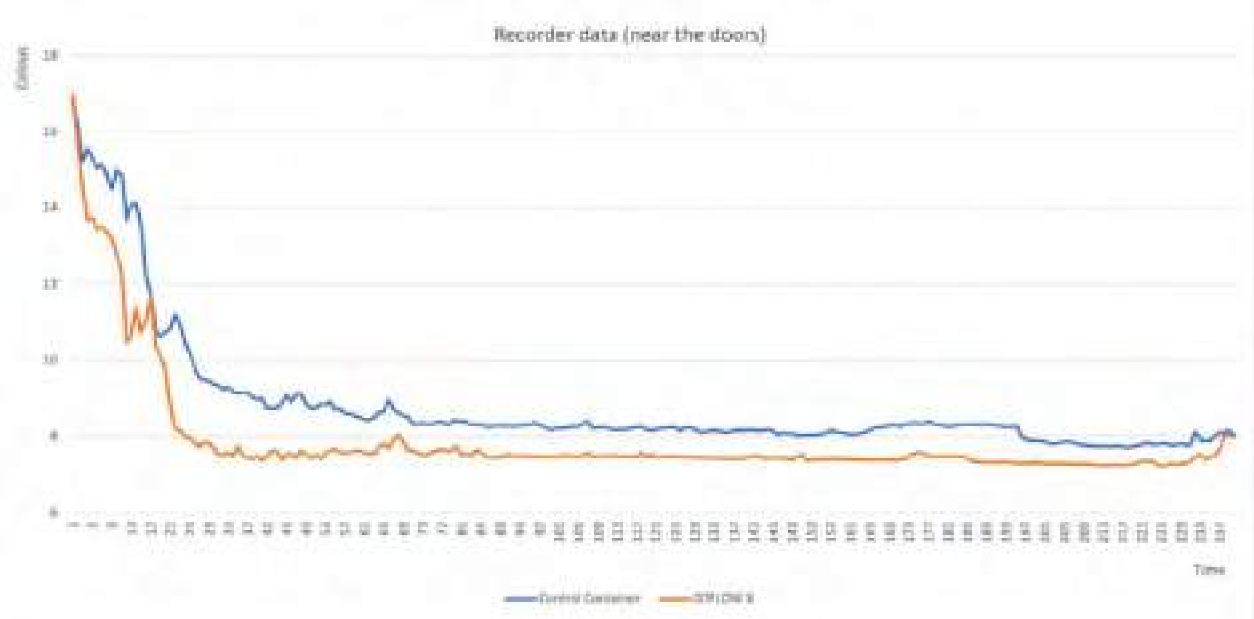
In international trade, many pineapples are exported in refrigerated containers on vessels. For this fruit, the quality is well-conserved if the storage temperature is between 7°C and 10°C. In practice, however, there are rather significant temperature fluctuations, frequently reaching levels above 10ºC, causing damage to the fruits. As a result, there have been many exporters' claims on fruits because of temperature control issues.

The University of Wageningen and Otto de Groot, a Dutch senior fruit consultant, developed a floor cover for refrigerated containers called OTFLOW*. This post-harvest technology was recently tested in a study carried out along with VISA S.A., one of the largest pineapple exporters in Costa Rica. The test was conducted with 50 containers, half of them with the floor covers and the other half without them. Temperatures were measured along with pineapple shipping by multiple recorders in each container, especially to determine differences between the front and back of the containers.

The temperature recorders placed at the doors showed that the containers with the technology reached the set temperature faster than those without them (Figure). Additionally, the temperatures at the doors were always closer to the set temperature than those without the technology. The test showed that the temperature in the 25 containers without the floor cover rose too high (above 10 degrees), 788 times. In those with the floor covers, it was only 311 times, an improvement of 61%. Containers without the technology had a temperature difference of 1.8 ºC on average. Instead, the temperature in containers with the technology registered differences of 0.6 ºC, an improvement of 67%.



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News from Réunion Island / France

A summary of CIRAD research on pest control (*R. reniformis*, nematode, and *D. Brevipes*, mealybug associated with wilt), based on the stimulation of natural defenses of the MD2 pineapple in pesticide-free cropping system.

Alain Soler et al., Cirad, Réunion Island

Introduction

Rotylenchus reniformis are phytophagous nematodes spread over many pineapple production areas as Réunion (I.O.), but also in Hawaii, in Caribbean islands and many other areas. *R. reniformis* are semi-endoparasitic nematodes as their populations grow mainly in the soil surrounding the roots. Only the females attach themselves to the outside of the roots, take on a kidney shape full of eggs, which are laid in the ground. Large infestations reduce the nutrition of the pineapple and consequently can reduce yield by more than 50%.

Mealybugs are present everywhere in the pineapple production areas in Reunion (Nurbel et al, 2020), but also almost everywhere in the pineapple 'world'. In combination with Pineapple Mealybug Wilt associated Viruses (PMWaVs) they induce a disease called 'Pineapple Wilt' that has a strong impact on the yield and quality of fruits produced for export (Hu et al, 2005). Mealybugs and therefore PMWaVs are spread through contaminated plant material harvested from infested fields. The wind can also disseminate the young larvae called 'crawlers' in the fields. Finally, several species of ants have a mutualistic interaction with mealybugs, as they feed on the honeydew produced by the mealybugs; in turn, the ants protect the mealybugs from their predators.

Pineapple MD2 is a good host for both parasites. In conventional production systems, these pests are controlled by chemical applications. Consumers, buyers and authorities out of concern for the protection of health and the environment increasingly criticize these practices. Thus, pesticides are gradually banned in many producing countries, and producers are looking for alternatives to pest control.

Plants have evolved basic defenses against pests. In different plant species, many varieties have been observed to have developed the ability to strengthen these basic defenses against a wide range of pests. Cell surface receptors recognize the presence of a pathogen and, via specific signaling pathways, prepare the plant to react rapidly to new infestations (priming of systemic resistances). Priming can be triggered by the presence of certain parasites or by hormonal elicitation (chemicals or microorganisms). The plant is then able to reduce the ability of parasite populations to multiply and develop by regulating its own defense genes and the production of toxic metabolites. Priming can be induced either as systemic acquired resistance (SAR) dependent on the hormone salicylic acid, or as induced systemic resistance (ISR) dependent on the hormone jasmonic acid. SAR and ISR target interaction against biotrophic or necrotrophic parasites respectively. We hypothesized that priming pineapple plants could contribute to pest control in a more ecological production system based on rotation with cover crops to benefit from a low initial inoculum (Soler at 2013, a). Here, two examples of present experiments show the potential management of *R. reniformis* and *D. brevipes* on the MD2 variety with SAR and ISR induced by appropriate stimulations. The possibility of using them as components of pesticide-free biocontrols is discussed. This is a synthetic presentation of CIRAD's research on this subject; detailed data have recently been published (Soler et al., 2021) or will be published soon, such as during the next ISHS Pineapple Symposium in 2023.

Material and Methods

Vitroplants of MD2 (~100g) and suckers (~150g) from a MD2 nursery were used for separate experimentations for *R. reniformis* and *D. brevipes*. Inocula of 4000 nematodes per plant, and inocula of 5 to 20 individuals of mealybugs inoculated per plant were prepared from populations reared on *Vigna unguiculata* and on small vitroplants of MD2 pineapple, respectively for nematodes and mealybugs. Plant priming was done with salicylic acid (SAL, 1 mM) for SAR, or methyl jasmonate (JAME, 0.1 mM) for ISR, which were used as elicitors of SAR and ISR defense signaling pathways. Counting of populations for *R. reniformis* were made after extraction by an elutriation – sieving method of 50g soil under pineapple (Seinhorst, 1962). Counting of *D. brevipes* populations were done manually under a binocular magnifying device. Greenhouse experiments were done with stimulation repeated three times at 3-day intervals, and field experiments with monthly stimulations (six in total) between planting and forcing. The field experiments were conducted using a rotation with *Crotalaria sp.* in a system of production without pesticide to reduce soil borne parasites and other stresses before planting pineapple. Priming was characterized with three of the enzymatic markers as PAL, PR1 and PR3 for nematode and mealybug experiments, and three molecular markers, AcPAL, AcICS and AcMYB like, for mealybugs experiments.

Result and Discussion

- **An ecological system of production**

An ecological pesticide-free system of production that included rotations with cover crops like *Crotalaria sp.*, minimized inocula of *R. reniformis* populations and other soil pests like symphylidae before planting pineapple. The poor host status of Crotalaria species for the reniform nematodes is known to reduce their populations (Wang et al, 2003). Marie-Alphonsine et al (2017), and Soler et al. (2021) specifically tested *Crotalaria sp.* in pesticide-free production systems including rotation with pineapple to reduce *R. reniformis* but also Symphylidae. The biomass of crotalaria also contributed to high levels of soil organic matter (>50T fw/ha) with high levels of nitrogen (about 3%). They are also good cover crops reducing the impact of weeds on the next crop. We considered that these conditions were a key element of the production system to optimize the effectiveness of systemic resistances against pests because they reduce the stress level of pineapple (Soler et al, 2013a). A high level and/or number of stresses could reduce the effectiveness of systemic resistances by limiting the energy resources that the plant could mobilize to fight against a specific parasite (Choudhary et al., 2012).

- **Systemic resistances against the reniform nematode**

In greenhouse experiments on MD2 tissue culture plants, Soler et al. (2013) showed that the populations (eggs + adult vermiforms) were significantly reduced by both stimulations ISR and SAR, respectively -67.0% and -55.8% compared to controls. It was also noted that on the MD2 controls, nematode populations were higher than on the Smooth Cayenne controls (for example about 3x for eggs). The result indicated that, without priming, MD2 has been a better host than Smooth Cayenne for the reniform nematode.

In the same series of greenhouse experiments, Soler et al. have characterized the establishment of priming of ISR defenses with enzymatic markers such as Lipoxygenase, Superoxide dismutase, Peroxidase or Catalase (oxidative stress), and PAL, PR1 and PR2 (defense). A slight transient change in enzyme activities related to oxidative stress appeared within one hour after application of methyl jasmonate. This transient stress is normally observed with the setup of priming. Then two weeks after inoculation of nematode inoculum, during the multiplication of the reniform nematode, the activities of defense enzymes such as PAL, PR1 and PR3 were higher on the stimulated plants than on control plants (Soler et al., 2013, b). This is also related to an effective priming setup.

In a field experiment without pesticide, eggplants were grown before pineapple to increase the populations of reniform nematodes in the soil. Eggplants helped produce naturally a high inoculum of *R. reniformis (*Soler et al, 2021). The authors tested ISR stimulations (methyl-jasmonate) against *R. reniformis* on pineapple suckers of MD2 on this experimental plot. The results showed that eight months after planting pineapple, *R. reniformis* populations were significantly reduced by -58.4% in this field. The infestations of pineapple were respectively 4302 and 10332 individuals in 100g of soil for stimulated plants and non stimulated ones **(Figure 1)**.

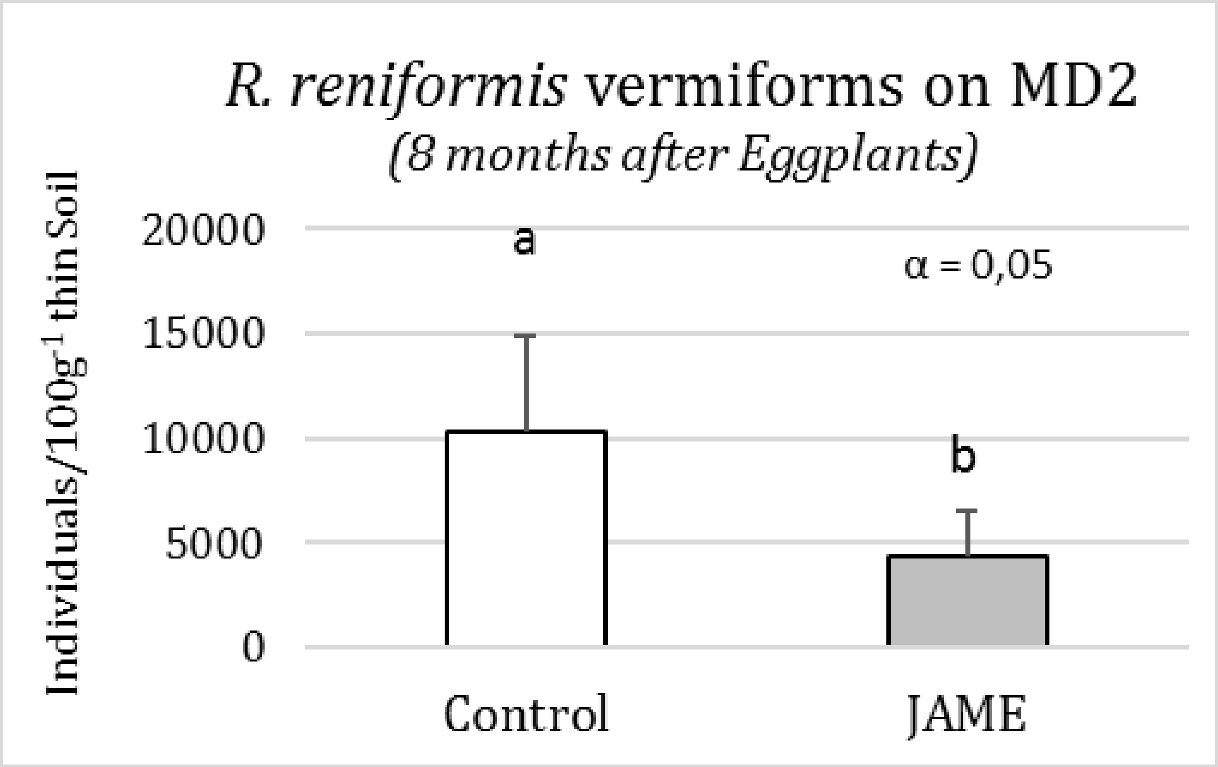

Figure 1. Decrease of populations of R. reniformis on MD2 in field experiment after ISR stimulation. [ISR induced by Methyl jasmonate (JAME) 0.1mM monthly application between planting and forcing (8), control = water; nematodes extracted and counted in 100g of soil. (different letters a,b indicate significant differences at α=0.05)]

In the same experimental field under ecological management with rotation, including *Crotalaria sp.,* before planting pineapple to minimize the nematode inoculum, the same authors obtained a significant reduction of the nematode populations evaluated just before forcing (8 months) on MD2 pineapple after *Crotalaria sp.* compared to populations on pineapple after eggplants. After *Crotalaria sp.* the populations of nematodes on pineapple were much lower, 3550 and 2408 individuals in 100g of thin soil respectively for control and ISR stimulated plants. These levels of nematode infestation were too low to reduce the plant growth as indicated by the 'D' leaves weight.

These results showed that the rotation system with *Crotalaria sp.,* without pesticides, was efficient per se to reduce nematodes populations, but although eggplants produced a higher inoculum in the soil, the ISR was able to maintain low multiplication of *R. reniformis* on pineapple compatible with a commercial production (Soler et al., 2019).

- ***Systemic resistances against the mealybugs D. brevipes associated with the Wilt disease***

In a greenhouse experiment on MD2 tissue culture plants, the SAR defenses induced by salicylic acid (SAL) application before inoculation of mealybugs significantly reduced their multiplication (-91.8%)

compared to the control **(Figure 2).** However, ISR defenses induced by methyl jasmonate (JAME) could not significantly reduce mealybug multiplication. These results were consistent with the trophic status of mealybugs, which, as biotrophic agents, induce and respond better to SAR defenses than to ISR defenses. The last ones are related to necrotrophic agents like caterpillars, or to symbiotic microorganisms like mycorrhiza and several nonpathogenic bacteria.

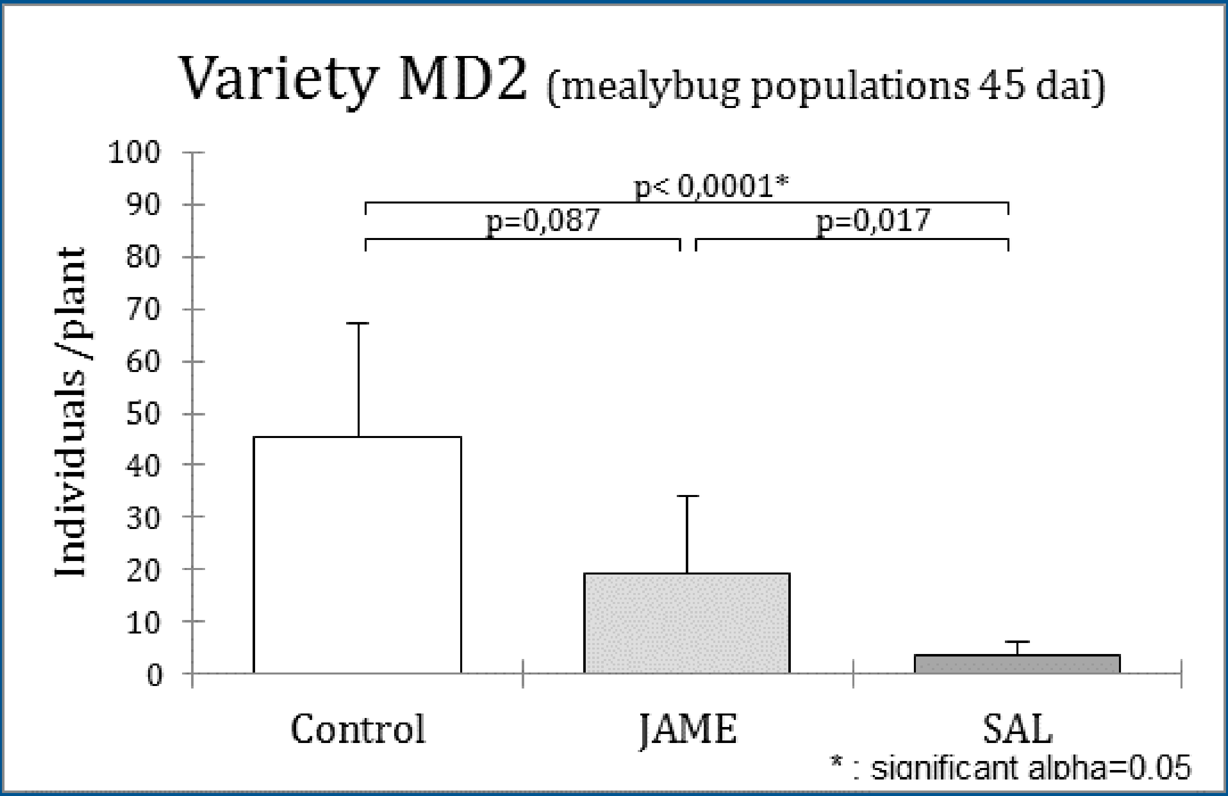

Figure 2. Evolution of D. brevipes populations on MD2 in greenhouse experiment after ISR and SAR stimulations. [ISR by Methyl jasmonate (JAME) 0.1mM, and Salicylic acid (SAL) 1mM, and water (Control) applications; counting 45 days after inoculation.]

Different enzymatic markers characterized the SAR priming and defenses. Activities of Phenylalanin ammonia lyase (PAL), and Pathogenesis related proteins (PR3 and PR1) showed significant differences (α =0.05) between stimulated (S I) and non-stimulated (NS I) plants after inoculation of the mealybugs **(Figure 3)**. PAL is the enzymatic activity responsible of salicylic acid biosynthesis by the plants, and leads to biosynthesis of phenolic compounds. PR3 and PR1 are directly related to the defense of the plants.

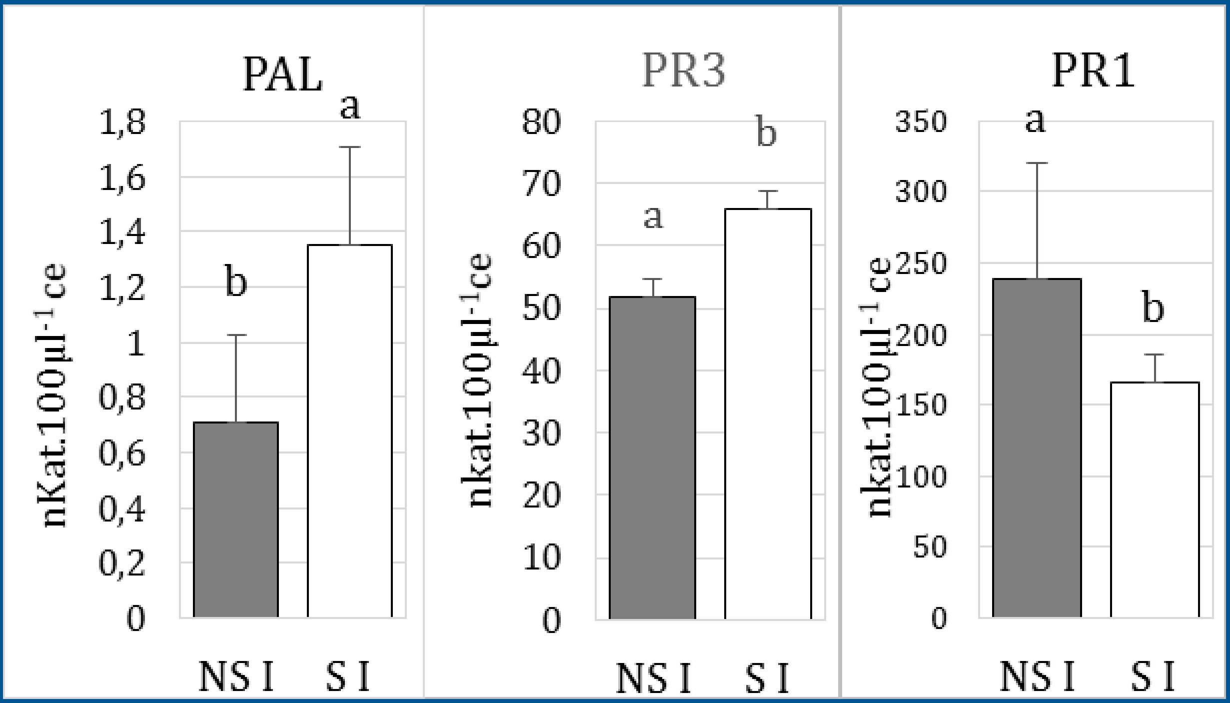

Figure 3. Enzymatic markers of SAR on MD2 pineapple, two weeks after SAR induction and mealybugs inoculation. [SAR induced by salicylic acid (1mM) 2 weeks after inoculation of 20 mealybugs. (different letters a,b indicate significant differences at α=0.05)]

Molecular markers can also characterize the SAR defenses **(Figure 4)**. The regulation, up or down, of the expression of genes of defense such as AcPAL and AcICS2, two genes related to the synthesis of salicylic acid, and one transcription factor AcMYB-like involved in the control of the expression of the AcPAL were evaluated. The results showed that the gene expressions linked to PAL and salicylic acid biosynthesis were strongly upregulated by SAR stimulation of the plants, and the inoculation of the pathogens (S I) compared to the control only inoculated with mealybugs (NS I).

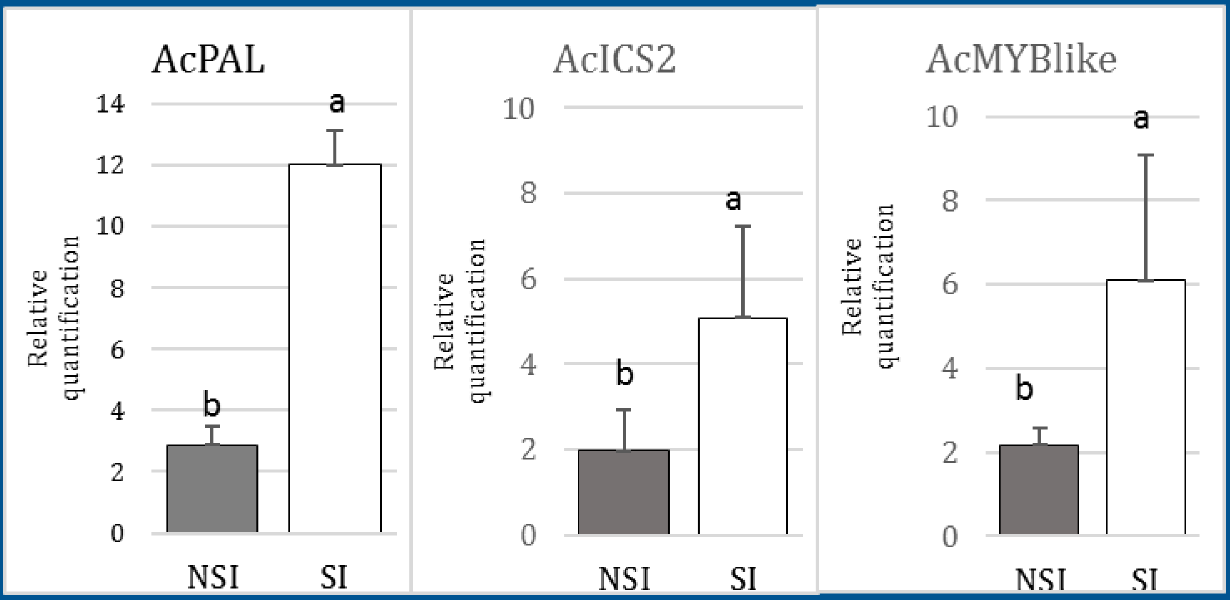

Figure 4. Molecular markers of SAR on MD2 pineapple, one day after SAR induction and mealybugs inoculation. [SAR induced by salicylic acid (1mM), then gene expression analyzed 24h after inoculation of 20 mealybugs/plant. (letters a,b indicate significant differences at α=0.05), SI = stimulated then inoculated, NS I = inoculated control]

These results showed that the priming of MD2 pineapple with salicylic acid induced SAR defenses able to control mealybug multiplication in controlled conditions. Few tests in a rotation system as previously described have been successfully done, but results must be consolidated.

Conclusion

The CIRAD researches presented here show that the management of mealybugs associated with wilt and nematodes by introducing systemic resistance into cropping practices is a promising tool for integrated pest management in MD2 pineapple. Large amounts of pesticide are still currently used on pineapple. Thus, a zero pesticides should be a target for ecological production systems. The inducers of systemic resistances currently tested work at very low concentrations, giving quantities per ha counted in a few g. Ongoing studies focus on the methods of application for producers (number of applications, optimal concentrations of inducers, time of application and others), and the actual effectiveness of systemic resistances in real field conditions. Sources of natural inducers or microorganisms are also targets of current Cirad research. Systemic resistances are involved in the multi-stress tolerance (biotic and abiotic) of plants. Therefore, integrating them into an IPM system without pesticides is necessary for better efficiency of systemic resistances directed against specific pathogens before their populations become too high.

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Multicrop System with pineapple to be studied

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The pineapple sector in Reunion Island is weakened by many factors such as climate change, societal pressure, the increase of pest pressure, less authorized pesticides, or the lack of manpower. It is necessary to change practices to make pineapple production systems more ecological, while maintaining yields and decent incomes for producers.

CIRAD in Réunion is currently working on the design of innovative and more ecological pineapple cropping systems. The focus will be on pest and disease management (weed control and soil borne pathogens) introducing in these new cropping systems a functional biodiversity to reduce the use of herbicides, nematicides, and plastic mulch as well. Functional biodiversity includes all the species in an agroecosystem that contribute to ecosystem services, *i.e.* the benefits that humans can obtain from the environment. These ecosystem services can be provided by crop associations and cover crops *e.g.* to control erosion, improve soil structure and health, regulate pest and disease or suppress weeds.

Experimentations have been designed to evaluate the performances of a multi-crops system that combines banana, pineapple and cover crops. The functional approach by measuring traits of the species like weed cover, light intercepted and agronomic features of bananas and pineapples will help understand the interactions between species and to optimize their spatial arrangement and timing of planting. Further experimentations will study the harmfulness of weeds on pineapple to determine a critical period of weeds interference. It will allow to optimize weed control interventions and reduce the use of herbicide and/or manpower. These trials will also allow to model weeds in pineapple cropping systems in order to better optimize the integration of cover crops in pineapple. Other production systems based on agroforestry will be co-designed with producers as pineapple and/or banana cultivation under lychee and/or mango trees in Cirad Reunion experimental station and at partner producers' sites.

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