

# Pineapple News

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## Abstracts of the 7<sup>th</sup> International Pineapple Symposium July 13-15, 2010 at Johor Baru, Malaysia

### Abstracts of Oral Presentations

#### Session 1: Industrial and Trade

##### Global overview and trade of the pineapple industry

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World production of pineapple made up about 25 percent of the total production of tropical fruits, which was estimated at over 82.7 million tonnes in 2008. The global production of fresh pineapples had increased by 44.8 percent during the last 11 years, increasing from 13.23 million tonnes in 1997 to 19.17 million tonnes in 2008. In 2008, global production was dominated by Brazil which accounted for 13.0 percent of total global production, with a production of 2.49 million tonnes. This was followed by Thailand, Philippines, and Indonesia at 2.28 million tonnes, 2.21 million tonnes and 1.62 million tonnes, respectively. The export of fresh pineapple increased by 179% from 901,694 tonnes in 1997 which was valued at \$369.1 million to 2.52 million tonnes with a value of \$ 1.39 billion in 2008. The fresh pineapple export market was dominated by Costa Rica, Philippines and Belgium. Costa Rica recorded an exceptional increase from 250,100 tonnes in 1997 to 1.35 million tonnes in 2007 with a value of \$ 486.9 million. The Philippines exported 270,054 tonnes valued at \$ 147.3 million while Belgium exported 263,811 tonnes valued at \$ 268.8 million in 2007. The major importing countries are the USA, Belgium, Netherlands, Japan and Germany. Total imports by these countries in 2007 amounted to 2.50 million tonnes, valued at \$2.06 billion. Overall, the global demand for fresh pineapples increased by 1187 percent from 0.87 million tonnes (valued at \$525.7 million) in 1997 to 2.50 million tonnes (valued at \$1.81 billion) in 2007. The global export of canned pineapple increased by 46.6 percent, from 799,878 tonnes (valued at \$538.2 million) in 1997 to 1.17 million tonnes (valued at \$870.3 million) in 2007. Thailand, Indonesia and the Philippines are the major exporters of canned pineapple accounting for 69 % of the export volume with an estimated. Thailand, Indonesia and Philippines exported an estimated total value of \$ 603.2 million in 2007. Global demand for canned pineapple had increased by 38.9 percent, from 898,315 million tonnes (valued at \$750.1 million) in 1997 to 1.2 million tonnes (valued at \$979.7 million) in 2007. In 2007, the total imports for canned pineapples were 665,421 tonnes valued at \$ 479.7 million. The major importing countries were USA, Germany, Russian Federation, Netherlands and Spain. While the global market for pineapple seems to indicate a positive trend, issues producing countries have to contend with include cost effective production methods, value chain efficiency and enhancement of distribution networks.

##### Rejuvenating the pineapple industry and trade in Malaysia

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In Malaysia, pineapple is the first crop grown as a commodity or industrial crop with high export potential. The local pineapple industry took off during late 60s and early 70s and Malaysia was the number three exporter in the world for canned pineapple. However, the ability to remain competitive suffered tremendous setback. Slight increment in the average planting area in estate and small holders for the past five years is due to the fruits demand from factories for canning processed. Fresh pineapple production involves only the smallholders with combined area of about 1,200ha constitute more than of all producers. Roughly 89% of the production is destined for fresh consumption, while the rest is mainly for processing (especially canning). In estate sector, the planted area have increased slightly by 211 ha, but had remained static at 5,000 ha from 1990 to 2004. Yield production from estate growers was quite consistent which is around 60,000 tonnes metric per year. However, for small growers, problems occurred on planting effected the consistency of the production had decreased from 10,000 tonnes metric to 8,000 tonnes metric in the year 2000 until 2003 before it bounced again, with increment of 20,000 tonnes metric in the year 2005. This trend of production shows the correlation and close connection between factor of the acreage of planting and total of yield production. This paper addresses the strategies of rejuvenating the pineapple industry in Malaysia.

##### The Philippine pineapple industry

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As a leading exporter of fresh and processed pineapple products in the world next to Thailand, the Philippine's export industry is increasing. There are a number of processing plants in the Philippines, some of these are owned by multinational companies: Dole Philippines and Del Monte Foods. Dole Philippines is one of the largest multinational companies in the Philippines, operating on approximately 20,000 hectares of land. In 2009, Dole had 57.8 and 47.6% shares in US market for canned and fruit cup products, respectively, while Del Monte only had 9.0 and 36.7% market shares for same products. Biggest fresh pineapple exporters were Dole, Del Monte Philippines and a farmers' cooperative in Basud, Camarines Norte. Importing roughly 65% of fresh pineapple shipment from Philippines. Japan serves as the biggest export market for the Philippines. The huge demand in China and South Korea for fresh pineapple prompted Mindanao-based agribusiness companies to expand their capacities by 10 to 20% this year. A new variety called Queen Pineapple from Camarines Norte had generated interest of buyers overseas and recently, trial shipments were made to South Korea. According to Department of Agriculture's Agribusiness Marketing Service study, prospects for Philippine pineapple industry are bright with domestic demand estimated over the next 10 years to be growing by an average of 4 to 7 percent every year. Other export markets for fresh Philippine pineapple are Middle East (Sharjah, Jabel Ali, Abu Dhabi, Qatar and Kuwait), New Zealand, Hong Kong, Canada, Guam, Russia and Germany.

### **Current situation of pineapple production in Taiwan**

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The pineapple (*Ananas comosus*) is an important tropical fruit crop in Taiwan. A wide selection of cultivars have been planted, including 'Smooth Cayenne', 'Winter Honey', 'Ice Cream', 'Fragrant Apple', 'Perfume' and others. Depending on varieties, pineapple can be cultivated throughout the year with major production months from March to November. There were 11,510 hectares pineapple planted with a total production of 450,000 metric tons in Taiwan in 2008. Total soluble solids averaged at 12-13° Brix. Most of the production is consumed fresh; however, processed products are also popular. A small percentage of the fruit has been exported to nearby markets, such as Japan and Korea.

### **Status of pineapple industry in Thailand**

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More than 95% of pineapples production in Thailand is for processing which is destined for export. Only about 5% is grown for fresh consumption since it requires higher cost from more intensive production technique. The main production area is in the central region closer to the processing plants and sea ports. The fruit are available year round with two peaks; one between April and May the other in November. Less fruit are available in July and August. Ninety percent of the pineapples are produced by small holders who have about 6.5 acres per household. The production cost for the fruit is approximately US\$ 0.12 per kg, which is about a third of canned pineapple cost. Another third is for can and another third for other costs. At present, among more than 30 processing plants, they are using only about two third of their combined capacity. The main problems facing the industry are the irregular supply of pineapples, the shortage of labor, and the declining production area, due to the expanding of rubber and oil palm plantation.

### **Pineapple cultivation in North East India. A perspective venture**

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North-Eastern (NE) region of India comprising of eight states with a total geographical area of 2.62 lakh km<sup>2</sup>, is a highly potential region for pineapple cultivation in India. The region has remarkable advantages of fertile and organically rich soils, ample rainfall, water resources and great climatic diversity supporting diverse cropping possibilities. With the progress already made and the potentials of the region already demonstrated on a sustain basis by adopting modern technological approaches viz., Staggering techniques, HDP, Organic cultivation, and certification that has boosted pineapple industry with better yield and quality, cultivation of pineapple in the region is undoubtedly a very perspective venture. Government of India having identified the potentiality of NE region for horticultural crops started a project 'Horticulture Technology Mission' in 2001. This has resulted in substantial increase in area and production of pineapple to the tune of 140.72 % increase in area (Directorate of Horticulture, 2007). The region produces more than 40% of the total Pineapple of the country and almost 90-95% of the produce is organic. The common varieties grown are Giant Kew & Queen. Pineapple produced from this region are qualitatively different and is said to be among the "Best in the world as they are very sweet (high TSS) with less fibre". In the context of tremendous national and global market demand for organic pineapples as well as low volume concentrated products, NE states of India is an idle potential area to explore for pineapple cultivation. The region being an agrarian society with an average of 80 percent tribal population, this venture will result in a breakthrough of social empowerment of the tribal people of the NE states of India.

### **Improvement of Indonesian pineapple competitiveness through the empowerment of small scale farmers**

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Indonesia is among the top three pineapple producers in the world and the fourth of top of processed pineapple exporters. Generally, export of processed pineapple has been done by multinational plantation company that own large farms. To have better share in international markets, Indonesia has increased its efforts to improve production capacity and quality of pineapple by empowering of small scale farmers through institution strengthening, quality improvement and partnership development. For institution strengthening is focused to drive farmers to develop farmer groups that moving toward to form growers' association. For marketing purposes farmers are encouraged to establish farmers private enterprise that fully managed by farmers, with main tasks are to develop partnership with the exporters as well as establish better communication and coordination with farmer groups and farmer association. To improve quality of the produce is conducted by implementation of Good Agricultural Practices (Indo-GAP). Partnership with exporters is aimed to develop mutual understanding and transparency along supply chain from farmers to exporter, including guaranteeing supply continuity of produce.

## **Session 2: Biotechnology and Breeding**

### **Review of genetic improvement of pineapple**

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World consumption of fresh pineapple has quadrupled in less than 15 years. This phenomenal event started around 1996 when the first dedicated fresh market pineapple; 73-114 was released by Del Monte. This was the culmination of somewhere in the vicinity of 34 years of breeding and selection and comprised 24 individual parent combinations. World consumption of this variety is now in excess of 1.9 MT. This demonstrates the difficulty of breeding new pineapple varieties but also the value of a successful program. The success of 73-114 and the competitive nature of world pineapple markets have provided impetus for pineapple breeding programs to obtain quick results. However, the highly heterozygous nature and self-incompatibility of pineapple limit progress. This review looks at the collective experience in pineapple genetic improvement, both conventional and using tools of biotechnology, with an emphasis on fresh market pineapple. It covers relevant pineapple reproductive biology, breeding strategies, parent varieties and the relevance of biotechnology.

### **Pineapple breeding- Fulfilling the requirements of the global supply chain**

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Pineapples breeding, as in breeding of many other fruit species, usually have selection criteria based on conventional traits like high yield and fruit quality. In modern day production from farm to fork for the global markets, however, the selection criteria is expanded to an integrated system of good agricultural practices. This becomes more complicated as the breeder has to address the demands at each segment of the whole global supply chain. At the very beginning (upstream) of the supply chain is the production of bona fide, disease free planting materials that is important for start up of the pineapple farm. For the breeder, the variety should be selected with consideration of production of at least one or two suckers for continuity in propagation. New varieties should have consistent and high, early yield, stability in performance over environments and seasons and pest and disease resistance that reduces the use of chemical pesticides. In the midstream, the demands will be on fruit configuration for efficient packing, good ripening characteristics, extended shelf life and ability of the fruits to withstand specific sanitary and phytosanitary (SPS) requirements demanded by some importing countries. At the downstream marketing end, the extended shelf life for a longer display window is important, as is the cosmetic appeal of the fruit on display. Finally, the consumers' demands on organoleptic traits like freshness, flavour (balance of sugar and acid for e.g.), sweetness, texture and visual traits like fruit cosmetics and colour have to be satisfied to ensure repeat purchases. Convenience in serving such as the peeling eye pineapples and mini core varieties for fresh cut (minimally processed) pineapples to make consumption more ubiquitous should also be addressed. Many global markets are now demanding for food safety through Good Agriculture Practices and varieties should be able to adapt to such cultural methods (low pesticide use, organically grown etc.). Lately, consumers are starting to recognize the role of tropical fruits as functional foods with high vitamins, antioxidants and other health attributes for wellness. Breeding therefore should address the improvement of these nutritional contents as well.

### **Pineapple breeding for quality improvement in South of Vietnam**

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Systematic research for improvement varieties was initiated at Southern Fruit Research Institute (SOFRI), Vietnam. At the initial stage, priority was given on field collection of local and introduced pineapple varieties, characterizing and evaluating available genetic resources. Four Queen pineapple local varieties were selected viz. CDD-11.55.01, CDD-12.55.02, CDD-33.55.03, CDD-27.55.04 with better fruit quality and high yield capacity, adaptability under acid sulfate soil of Mekong Delta. A follow up breeding program put emphasis on fruit cylinder shape, large size, shallow eye and eating quality using 'Cayenne TL2' x 'Queen III-1', 'Cayenne TL2' x 'Queen II-6', 'Cayenne GU114' x 'Queen II-6'. Several hybrid plants were planted and screen in the field. Among of these, three hybrid plants were better in term of fruit cylinder shape, fruit weight (1500-1760g), total soluble solids (18.4-19.4%), the edible portion (56.3-75.4%), colour of flesh was intermediate yellow to yellow. The advances obtained from this breeding work are being evaluated for development of suitable varieties for local and processing markets.

### **An electrochemical DNA sensor for the detection of ATP synthase gene expression in freshcut pineapple**

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ATP synthase is an indispensable enzyme in ATP production in living cells. Any cell deprived of its ATP synthases, does not survive. In order to monitoring the deterioration of cells in the fresh-cut pineapple tissue using ATP synthase as an indicator. A technique for the semi-quantitative determination of ATP synthase gene expression in fresh-cut pineapple based on electrochemical biosensor was developed. This technique employed RT-PCR amplification of a specific domain corresponding to a target ATP synthase gene and a common housekeeping 18S rRNA gene. Signals of gene expression was measured based on a phenomenon of DNA aggregation induced by Hoechst 33258 in conjunction with changes in anodic current peaks measured via a carbon screen printed electrode on linear sweep voltammetry. Anodic current peaks of the resulting cDNA products from fresh-cut tissues during storage were between 1.12-2.13 A. Semi-quantitative analysis for the level of ATP synthase gene expression was measured using the comparative ratio between copy numbers of ATP synthase gene and a housekeeping 18S rRNA. When this was used to monitoring the cells deterioration in fresh-cut pineapple, it was revealed that expression levels of ATP synthase were down to 10% of the originals upon deterioration and this was in correspondence with the results obtained using gel visualisation of RT-PCR products. The technique provided several merits especially on its rapidity and simplicity in monitoring the freshness based on semi-quantification of ATP synthase gene expression.

### **Session 3: Plant Physiology and Cultural Practices**

#### **Ecophysiology of pineapple**

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Pineapple leaf photosynthetic rates are determined primarily by average temperature and the highest rates occur at temperatures between about 20 and 25 °C. Irradiance likely influences leaf photosynthetic rates, but few data are available because effects cannot be easily measured on leaves that assimilate carbon via the crassulacean acid metabolism pathway. Across the range of environments where clonally propagated cultivars of pineapple are grown, limited data and casual observations suggest that leaf photosynthetic rates determine such parameters as type and availability of planting material, plant population density, rate of vegetative growth, sensitivity to forced and natural induction of reproductive development, rate of fruit development, initiation of shoots used to produce planting material or a ratoon crop, fruit weight to plant weight ratio, fruit quality and the ability to produce a profitable ratoon crop. Collecting confirming data is a major challenge that likely will

require a joint public-private effort. The principle value of such data would be an increased understanding of basic processes and the education of young scientists.

#### **Innovative cultural practices of planting pineapple on tropical peat lands**

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Most of the tropical peatland is found in Southeast Asia where it occupies about 20 million hectares, mainly concentrated around the Sunda Flat of Malaysia and Indonesia. The area has been an important rain forest ecosystem which is very sensitive and very fragile. As a result of population pressure, some of these areas had been converted to agriculture, industrial and settlement sites. Utilisation of peatland for agriculture requires innovative activities. Peatland needs to be drained properly for pineapple farm development. However, upon drainage the peat shrink and subsides and thus to sustain its usage in the long run will be difficult to accomplish. A number of perennial or semi perennial crops have been grown on tropical peatlands. Of these, pineapple (*Ananas comosus*) has been an excellent crop being cultivated, because it both flourishes in the acid conditions prevalent in peat soils, and it is relatively low growing and not susceptible to being uprooted at maturity. For a sustainable cropping, an appropriate cultural practices need to be adopted and practiced. A wise use of the tropical peatlands for planting pineapple is therefore encouraged. This paper highlights some of the important innovative cultural practices for planting pineapple on tropical peatland with special emphasize to the Malaysian experience. The Malaysian pineapple industry is based predominantly on deep oligotrophic peats, and has been in existence for more than a century. Cultural practices especially those related to water management in relation to crop moisture requirements, tillage and land preparation, liming or acidity control, fertilizer use, crop protection and as well as the flower induction methods will be discussed. The main issue for any pineapple planting on tropical peatlands is the water management, due to the high rainfall status and as well as its high humidity. The subsequent cultural practices will depend on this single factor. Normally, poor cultural practices are due to lack of proper knowledge or from bad traditions. Many farmers grow pineapple of different varieties without considering the crop's requirements for the optimal space, plant nutrition and pest control. Another limiting factor for adopting the cultural practices used on mineral soils for planting pineapple on tropical peatlands is the inability to mechanize farm operation; several innovative activities are currently adopted using lighter and smaller machineries. The paper will also look into the aspects of innovations related to the conduct of good agricultural practices especially the emphasis on the proper handling of pesticides and proper pesticide disposal methods. S3 3

#### **Sunn hemp cover cropping and solarization as alternatives to soil fumigants for pineapple production**

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A field trial was conducted to compare the impacts of preplant treatments: 1) sunn hemp (SH) planted for 6 months, 2) solarized (Sol) for 3 months, 3) SH planted for 3 months followed by 3 months of solarization (SH+Sol), or 4) fallow with weeds (C) on plant parasitic nematodes, weeds and soil health conditions. Pineapple slips were planted subsequently. Soil collected at 3 months after pineapple planting (MAP) revealed that SH reduced numbers of reniform nematodes compared to C, but SH+Sol did not improve the reniform nematode suppressive effect of SH. However, SH+Sol suppress weeds more effectively than SH or Sol alone. Nematode community indices were used to evaluate soil health conditions across geographical areas. At 3 MAP, an additional set of soil samples was collected from a nearby commercial pineapple field with same pineapple planting date as the experimental site but the field received standard plantation practices (SPP) prior to pineapple planting. These practices included fumigation with 1,3 dichloropropene, pre emergence herbicides application, and etc. Standard plantation practices severely disturbed soil community, but Sol only temporary disturbed soil health for less than 3 months. Whereas, SH enriched soil nutrient, enhanced bacterial and fungal feeding nematodes, and soil microarthropods that involved in soil nutrient cycling compared to C and SPP. Therefore, planting of SH before pineapple crop improved soil health conditions.

#### **Recent research on AVG prevention of natural induction**

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The naturally occurring non protein L amino acid AVG (Aviglycine HCl, Aminoethoxyvinylglycine HCl) temporarily inhibits ethylene biosynthesis in plants by competitively inhibiting the pyridoxyl phosphate dependent enzyme ACC Synthase, a key enzyme in the ethylene biosynthesis pathway that catalyzes the conversion of S adenosylmethionine to the ethylene precursor 1-aminocyclopropane-1-carboxylic acid. AVG reduces endogenous ethylene production, but does not affect the plant's sensitivity to ethylene. The commercial AVG product, ReTain Plant Growth Regulator has been registered and commercialized in many fruit producing countries and is listed for use in organic farming in the United States. Natural induction (NI) of flowering in pineapples is a very serious problem for growers, especially for those growing highly sensitive cultivars. NI occurs when endogenous ethylene is released by the pineapple plant in response to stresses such as chilling, short day length and low light intensity. Individual incidents of NI can be unpredictable, occurring multiple times within the same field, causing a large proportion of the plants within the area to begin blooming at various times, thereby disrupting production schedules. ReTain is very effective in preventing NI when applied to pineapples prior to any occurrence of NI, and at frequent intervals thereafter up to the scheduled date for induction of flowering. Application of ReTain allows more plants to reach optimal production size before bloom, enables accurate scheduling of harvests, more concentrated flowering, and more uniform plant crop and ratoon harvests. The successful use of ReTain on several pineapple cultivars and by various application methodologies will be reviewed in the presentation.

#### Pre and post harvest metabolism of pineapple crown leaves

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As the pineapple crown is a continuation of the vegetative stem leaves, and the spirally arranged leaflets have a similar morphology, one might expect a similar metabolism occurred in these leaves. The functioning of the crown leaves remain unexplored. Leaf damage, occurring as brown spots on the crown leaves, are causing import financial losses. The brown spots on pineapple crown leaves occurring after transport were caused by physiological disorders similar to described leaf damage in ornamental CAM bromeliads (Londers et al., 2005; De Proft et al., 2007). Gas exchange analyses and organic acid content confirmed a CAM activity of the crown leaves for intact plants as well as for crown leaves of cut fruits kept under dark/light conditions. During continuous dark at 10°C (transport conditions), the acidity levels in the crown leaves increase while those in the fruit remain constant. This suggests that organic acids are translocated from the fruit into the leaves. This long time malate exposure of leaf cells causes cell wall weakening and bursting in the chlorenchyma layer. A better understanding of these processes inside the crown leaves might lead to improvements of the transport chain of fresh pineapple fruits for overseas markets.

#### Session 4: Pest and Disease Management

##### Overview of the pineapple integrated pest management

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Implementing the pineapple IPM activities has enabled 47% reduction on the use of herbicides, 37% on insecticides and 20% on fungicides. Besides reducing production costs, the decrease on use of pesticides contributed also for environmental protection and food safety. The pineapple IPM guidelines used in Brazil, monitoring techniques and results already achieved are described.

##### Further characterization of pineapple mealybug wilt associated viruses in Hawaii

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The genomes of *Pineapple mealybug wilt associated virus 1* (PMWaV-1) and PMWaV-3 were sequenced. Sequence analyses indicated that these viruses are unusual for ampeloviruses. Unlike other ampeloviruses, PMWaV-1 and PMWaV-3 lack an intergenic region between the RdRp and p6 open reading frames (ORFs), contain an ORF encoding a relatively small coat protein (CP), and lack an ORF encoding a coat protein duplicate (CPd). Phylogenetic analyses place these viruses and some grapevine leafroll associated viruses in a distinct clade within the genus *Ampelovirus*. In addition, the genome of a new pineapple badnavirus was sequenced from pineapple in Hawaii. The 7451nt pineapple badnavirus genome possesses three ORFs encoding putative proteins of 20 (ORF1), 15 (ORF2), and 211 (ORF3) kDa. ORF3 encodes a putative polyprotein that includes a putative movement protein, and viral aspartyl proteinase, reverse transcriptase, RNase H, and zinc finger regions. Phylogenetic analyses firmly place this new virus from pineapple in the genus *Badnavirus*. A reliable, rapid, and sensitive real time RT PCR (qRT PCR) assay based on TaqMan chemistry was developed to detect and quantify PMWaV-2 in pineapple plants. Oligonucleotides used for the assay were designed from the coat protein regions of PMWaV-2. Absolute quantification of PMWaV-2 was achieved by generating standard curves from RNA transcripts cloned from the selected target of the PMWaV-2 CP gene. PMWaV-2 concentrations are higher in the white basal portion of leaves compared to other parts of the leaves. PMWaV-2 levels are higher in younger leaves compared to older leaves on the same plant. Virus titers are significantly higher in PMWaV-2 infected pineapple roots compared to the leaves. PMWaV-2 infected plants with mealybug wilt of pineapple (MWP) symptoms have higher virus levels than those without wilting symptoms.

##### Development of degenerated primers to detect different viruses associated with mealybug wilt of pineapple

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Pineapple (*Ananas comosus* var. *comosus*) is propagated vegetatively which facilitates the production of planting material but leads to dissemination of viruses. Mealybug wilt of pineapple (MWP) is a devastating disease of pineapple worldwide. The disease is characterized by severe leaf tip dieback, wilting of the leaves and can lead the plant to die. The MWP is associated with three *Ampelovirus* species, Pineapple mealybug wilt associated virus-1 (PMWaV-1), PMWaV-2, and PMWaV-3. Besides to the direct damage on plant production, there is great difficulty to select plantlets for planting because some infected plants exhibits no symptoms. The virus can be detected by RT PCR using specific primers; however for phytosanitary purposes, it's interesting to screen plant material for all viruses simultaneously in order to save time and cost. With this objective, degenerate primers were designed and tested to detect PMWaV-1, -2, -3 in pineapple hybrids of Embrapa breeding program. Using the degenerate primers in a RT PCR, it was possible to amplify a fragment of the expected size only in infected samples. Also, the reverse degenerated primer was combined with each of the forward specific primers in order to identify the PMWaV species present in infected plant. These two approaches led to detection of PMWaVs in 20/27 asymptomatic hybrids, with higher prevalence of PMWaV-1 (12 plants), PMWaV-2 (10 plants) and PMWaV-3 (7 plants). A total of 12 plants present mixed infections. The results show that degenerated primers provided a reliable alternative to plant material certification with about 30-40% on cost reduction and short period of indexing.

##### A bait and trap method for sampling symphyliid populations in pineapple

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We developed a standardized method to monitor the Symphyliids (*Hanseniella* sp) populations in pineapple using bait and traps. Two methods for symphyliid extraction and enumeration were tested. Two statistical methods, the "variance/mean" ratio and a spatial analysis (Moran



and Geary indices) were used to describe the type of spatial distribution of the populations. This bait and trap method allows a good evaluation of the symphylid populations. The ratio between adults and larvae may be used as an indicator of the population growth statute. Data collected on a rotation crop for pineapple, *Mucuna pruriens* var. *utilis*, showed that symphylids populations are highly aggregated following a negative binomial distribution. Finally, the method has been validated on 'MD-2' pineapple plots to monitor the symphylids populations at different stages of development of the crop.

#### **Rearing mealybugs for efficacy studies with pesticides**

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A method of conducting efficacy studies for pesticide screening was developed for control of pineapple mealybugs, *Dysmicoccus brevipes* and *D. neobrevipes*. Sectioned crowns were planted individually in pots, grown for 2 to 4 months and inoculated with mealybug crawlers at 2 months and grown for another 2 months or 6 to 8 weeks. Individual infested plants were taken out doors and sprayed with test pesticide and observed for mealybug mortality over a period of 6 weeks.

#### **Nematode suppression and yield improvement potential of organic amendments in pineapple (*Ananas comosus* L. (Merr.)) production**

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A factorial experiment was conducted in 2009 at Komenda, a prominent sugar loaf pineapple variety growing area in the Central region of Ghana. Three organic amendments; ground cocoa shell, ground citrus waste and compost were investigated for their nematode suppression and yield improvement potential in pineapple production. The purpose was to introduce pineapple farmers in the catchment area to organic system of farming to keep them in the international trade in the pineapple industry. Two of the candidates, cocoa shell and citrus waste demonstrated significant nematode suppression activity. Cocoa shell recorded 83%, 75%, 85%, 87% and 77% reduction in *Helicotylenchus multicinctus*, *Meloidogyne* spp., *Pratylenchus brachyurus*, *Rotylenchulus reniformis*, and *Tylenchulus semipenetrans* over the control treatment respectively during the first six months of application of treatments. However at harvest of the main crop, citrus waste recorded 60%, 96%, 53%, 96%, 91% and 88% reduction in *H. multicinctus*, *Hoplolaimus* spp., *Meloidogyne* spp., *P. brachyurus*, *R. reniformis*, and *T. semipenetrans* over the control treatment respectively. Yield of the main pineapple crop from citrus waste treated plots recorded 49.12 tons/ha whilst the control treatment recorded 38.92 tons/ha out yielding the control treatment by 26%. There were no yield differences between cocoa shell, compost and the control treatments.

#### **Vermicompost tea and BTH effects on pineapple Heart Rot**

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Vermicompost tea and BTH (Actigard) were evaluated for control of *Phytophthora nicotianae*. Hybrid 73-50 crowns were dipped in 100 ppm BTH, 0.29 kg Aliette/100 L water or water. Vermicompost tea or water was applied as a 500 ml/crown drench after planting. Crown death was recorded 3, 6, 9, and 12 weeks after planting. The test was repeated. In the untreated plots, 16% and 66% of the plants died in the first and second tests, respectively, whereas only 2% and 24% death was observed in Aliette treated plots. BTH protected the plants better under the reduced pressure in the first test (only 8% dead) compared to the second test (52% death). During the first 9 weeks, BTH performed similar to Aliette. In the first test, the tea increased heart rot over the untreated plants (38% vs. 16%), whereas plant mortality was similar to the untreated plots (64% and 66%) in the second test. The vermicompost tea was not an acceptable alternative to Aliette for the control of heart rot. BTH might prove to be an alternative for *P. nicotianae* control.

### **Session 5: Postharvest Handling and Product Development**

#### **Quality maintenance of pineapple in postharvest handling**

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The quality of fresh fruits is a combination of characteristics, attributes and properties that give the commodity value for food. Various ways to indicate degree of excellence including market quality, edible quality, dessert quality, shipping quality, table quality, nutritional quality, internal quality, appearance quality and safety. For pineapple, quality is always associated with excellent appearance, freshness, taste, colour and aroma, besides being free from injuries and disorders. Effective postharvest handling should begin with excellent quality fruits at harvest. Pineapple for long distance markets should be able to withstand long distance transportation and still remain in excellent condition after reaching the destination. Effective maintenance of quality in pineapple incorporates good handling practices including the use of cold chain, grading, suitable packaging and the right treatments.

#### **Handling of fresh cut pineapple for fresh consumption**

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Pineapple is one of the popular fruits served in fresh cut form. At ambient temperature and without protective treatments, cut pineapple turns slimy and deteriorates rapidly, resulting in off flavour and off odour development within a day. Fresh cut pineapple sustains substantial tissue injury during processing; the disruption of tissue and cell integrity often increases respiration rate, ethylene synthesis, enzymatic browning and development of physiological disorders with associated increases in rates of other biochemical reactions responsible for changes in colour (including browning), flavor, texture and nutritional quality (sugar, acid and vitamin contents). The damaged plant tissues also provide a nourishing medium for microbial survival and growth. Effective use of chemical treatments by using sodium chloride, calcium chloride and ascorbic acid were used to improve the taste, flesh firmness and overcome the browning problem to the cut pineapple cv. Josapine. Rigid

polypropylene containers were used for the packing system. Oxygen absorbant was inserted in the packing system for the quality enhancement which allows fresh cut pineapple to be stored for 2 weeks at 20°C, 1 week at 10°C and 2 days at 25°C. Such storage periods provide sufficient time for fresh consumption of fresh cut pineapple at the market shelf. This paper elaborates the handling operations, packing systems and storage requirements for fresh consumption of the fresh cut pineapple. Issues involved in maintaining both quality and safety will also be emphasized.

#### **Pineapple leaf fibres. Composites applications at macro and nano scales**

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Cellulose nanofibres were extracted from the agricultural residues, pineapple leaves by hydrothermal chemicomechanical technique to examine their potential for use as reinforcement fibres in biocomposite applications. The morphological structure of the cellulose nanofibres was investigated by Environmental Scanning Electron Microscopy (ESEM), Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM). The obtained pineapple leaf nanofibres were determined to have diameters in the range of 5–20 nm and lengths of 200–250 nm. Chemical characterization of the PALF nanofibres confirmed that a sharp increase in cellulose content was observed by steam coupled acid treatment. FTIR spectroscopic analysis of the prepared fibres demonstrated that this chemical treatment also led to partial removal of hemicelluloses and lignin from the structure of the fibres to obtain highly pure cellulose. PXRD results revealed that this resulted in enhanced crystallinity of the fibres. The thermal properties of disintegrated and individualized nanofibres were studied by the TGA technique and found to increase dramatically. The degradation temperature of the developed nanofibre reached beyond 400 °C. This value is reasonably promising for the use of these nanofibres in reinforced polymer manufacturing. Mechanical properties indicated that the use of PALF cellulose nanofibres induced a mechanical percolation phenomenon leading to outstanding and unusual mechanical properties through the formation of a rigid filler network in the matrix. X-ray diffraction proved significant change in the crystallinity of the matrix with the incorporation of cellulose nanofibres.

#### **Colorimetric detection of yeast in fresh cut pineapple based on blue silver nanoparticle**

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Yeasts play a crucial role in the sensory quality of a wide range of fruits. They can also be a major cause of fruit and juice spoilage. Most yeast is more resistant than bacteria to low water activity, low pH, high salinity, and chemical preservatives. Employing the use of yeast contamination as an index for fresh cut fruits quality monitoring, a simple colorimetric yeast detection method was developed for fresh cut pineapple based on blue silver nanoparticle. Detection processes were based on an enrichment procedure made directly from fresh cut pineapple to enable DNA amplification without any sample pre-treatment such as DNA extraction and a following step of specific DNA amplification of 26S rRNA gene by polymerase chain reaction. DNA signals were measured visually through a colorimetric change of blue silver nanoparticle (850 nm). The method had a limit of detection at 50 copies of yeast DNA per 50 g of specimen. No cross-reactivity was observed from specimens contaminated with other bacteria. Detection could be completed within 8 hours of operation including the enrichment process. Survey on yeast detection on fresh cut pineapple parlours was also demonstrated.

#### **Improving baking quality of cookies made from pineapple (*Ananas cosmosus*) decanter/agro waste as a novel functional food**

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Pineapple (*Ananas cosmosus*) decanter/agro waste is a by-product of the pineapple processing industry and consists basically of the residual pulp, peels, and skin. Pineapple (*Ananas cosmosus*) waste products are still underutilized while the demand for health-oriented, high-fiber products is also increasing. The study attempts to follow the trend of finding new sources of fiber as ingredients for food industry from pineapple, focusing on the decanter waste of pineapple. Cookies formulated by decanter waste of the pineapple parts and other ingredients were evaluated for crude fiber, protein, fat, energy, width, thickness, spread ratio and overall acceptance. Results indicated that crude fiber was significantly ( $p \leq 0.05$ ) higher ranging from 2.8 to 33.3% but no significant differences in protein and fat from the control (0%) cookies, even though decreasing amounts of protein were detected. The mastication energy (0.72 to 7.02 N.mm) and the thickness of pineapple-supplemented cookies increased (6.55 to 7.65 mm), whereas width (47.52–45.17 mm) and spread ratio decreased with the increasing level of pineapple solids incorporated. The objective of this study is to improve the baking quality of pineapple cookies as a novel functional food. Pineapple cookies results showed significantly ( $p \leq 0.05$ ) different in overall acceptability compared to the control. Therefore, decanter waste of pineapple could be utilized for the preparation of cookies and other food products with improved functional and nutraceutical properties.

#### **Production of pigments from bacteria grown in solid and liquid pineapple waste**

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Awareness on the use of natural pigments has escalated over the years due to stringent environmental standards imposed on synthetic pigments. Natural pigments can be extracted from microorganisms notably bacteria; however, the high cost of the growth medium hampers its large-scale production. In this paper, we report the extraction of 2 pigments, violacein and prodigiosin from *Chromobacterium violaceum* and *Serratia marcescens* respectively grown in liquid pineapple waste and solid pineapple waste. The potential application of these pigments in textile dyeing will also be discussed.

## Session 6: Consumer and Marketing

### Fresh pineapple market from the banal to the vulgar

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Pineapple is a very large fruit crop at the world level. Production totals 20 million tonnes (source: FAO), putting it in seventh position with pear and ahead of peach and nectarine. Production has doubled in the last two decades and quadrupled since the early 1970s. Nearly 90% of production is concentrated in a dozen countries. Traditionally, Asia accounts for more than 50% of production, with five countries in the world's top ten: Thailand (2.3 million tonnes), the Philippines (2.2 million), China (1.4 million), India (1.3 million) and Indonesia (1.3 million). Thailand lost the position of world leader that it had held for decades to Brazil (2.5 million tonnes) and is threatened by the strong growth of the Philippines. Costa Rica is now the world's fourth largest producer with 1.6 million tonnes and is specialized in the fresh pineapple market. It exported a little more than 1.4 million tonnes in 2009, that is to say three quarters of world export supply. World production developed for more than ten years, however, estimated figures for 2009 show that production decreased again after a difficult 2008. If demand has increased favorably in recent years, it is because the fresh fruit segment has fuelled production and world exports. Nevertheless, 2009 marks the end doubtless provisional of an avalanche of good performances. European imports have slipped below the 900 000 tonne mark to 880 194 tonnes in 2009. A growth crisis or a reversal of the trend? It is difficult to tell. The economic downturn can be mentioned as an external factor affecting the sector. GNP decreased by more than 4% in 2009 in EU 27, the greatest fall since the creation of the common market in 1957. So it is not surprising to see repercussions on the pineapple market. One might also have thought that the meteorological shocks of 2008 and 2009 in Central America had reduced the export potential of countries like Costa Rica, Panama or Honduras. However, there is no depression in the United States, the other import market (700 000 tonnes). All that can be said is that there has been no growth. The crisis in value added was more serious than the volume crisis. Unit value fell. In contrast with the possible recovery of volumes, the depreciation of the pineapple market is a weighty trend. The comparative movement of the customs value of imports from Costa Rica and Côte d'Ivoire since 1996 shows that the over valuing of 'Sweet' in comparison with the old 'Smooth Cayenne' standard is ancient history or soon will be. The unit value curves joined in 2009, wiping out ten years of very contrasting trends for the two sources. The driving force behind this ten year interlude is finally very classic. They combine an immoderate increase in volumes resulting from the diversification of sources and operators preceding an overall decrease in quality at the import and retail stages. The fruit became ordinary and thus lost value. European imports increased five fold in 20 years! It has been a while since we could call pineapple a niche fruit or specialised produce. We should rather wonder when EU imports will reach the symbolic million tonne level. In addition to the question of volumes, pineapple has also progressed from niche consumption to mass consumption. Market releases are linear. After a decade of development, the fruit has now become ordinary. Nevertheless, growth potential is still large if only as a result of supply pressure, which is not at all likely to decrease in the coming years.

### SPS requirements with respect to the world pineapple markets

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Every member of World Trade Organization (WTO) recognized the importance of Sanitary and Phytosanitary (SPS) Agreement to help curb the spread of pest and disease through movements of human, animals and plants in international trade. Although the agreement recognize the sovereign right of a country to protect herself from such threat, the agreement specifically stipulate that no country shall impose any measures arbitrarily that could impede the flow of trade between nations. The SPS Agreement has a considerable effect on trade of horticultural produce. As the movement of fruits and vegetable are increasingly seen as a pipeline of introducing new pest into the importing country, more countries are strengthening their SPS regulations. It has now become more challenging in finding new market for Malaysian horticultural produce. Under the SPS Agreement, importing countries should recognize Pest Free Area (PFA) and Area of Low Pest Prevalence (ALPP) for unrestricted trade of horticultural produce. However, if such areas are not feasible to be created, a country is allowed to export by using quarantine treatment or systems approach as mitigating measures to ensure trade is not disrupted. Though many countries may adopt the latter option, establishment of quarantine treatment facilities and the need to provide pest free production infrastructure is financially and technically challenging for Malaysia. Adoption of Good Agricultural Practice (GAP) and adherence to International Standards for Phytosanitary Measures (ISPM) will ensure that farmers practice best farm management which incorporates elements of effective pest control and good post harvest handling that are vital to meeting the SPS requirement.

### Consumer perceptions, utilization and preferences toward pineapple in Malaysia

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A national study involving 1185 respondents was carried out to investigate consumer perceptions, utilization and preferences toward pineapple. The varieties understudied were MD2, Josapine, Maspine and Moris. The study revealed that 92% of respondents preferred fresh pineapple, while the remaining eight percent preferred processed pineapple products. This study also found that majority of consumers part take fresh pineapple in two ways; consume directly as salads (41%) or used the fruit as food ingredient (30%). The processed pineapple products that the consumers utilized the most were jam, followed by juice, canned pineapple and Natta de coco with pineapple flavour. The physical characteristics were found to be important factors that have influenced consumers when they purchase pineapple. Middle size fruit with the average weight of 1.2 kg, cylindrical or ovals shape and fruit with shallow thorn were generally more preferred. The preference towards the fruit depended upon the way the fruit was consumed. For freshly consumed, the characteristics of fruit preferred by consumers were fruits with sweet aroma, sweet, smooth and crunchy textures, small woody stalk, and at 50% yellowish skin. The study also revealed that the variety MD2 generally, rated higher by consumers and was found to be dominant in overall characteristics as compared to Josapine, Maspine and Moris. Consumers perceived that MD2 was sweeter, has better texture color, crunchier, better aroma and juicy. Josapine was ranked second in overall preferences, and followed by Maspine and Moris. The Malays were found to prefer Maspine more than the Chinese and the Indians. The people from East Malaysia, especially Sabah showed significant preference towards MD2 relative to their counterpart from peninsular region. On the other hand, preference for Josapine did not show significant differences amongst consumers in all regions studied.

### Abstracts for Poster Presentations

#### Session 1: Industrial and Trade

##### **The better approach to pineapple farming for smallholders A research finding from two case studies in Malaysia**

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Pineapple smallholder farmers in Malaysia from research and observations throughout Malaysia do not actually received a fair share of the income cake. On average they are just getting between 6 to 10 percent of the whole revenues throughout the value and marketing chain of the product from input, planting and processing and marketing of the product. The biggest share since to be monopolized by the wholesalers. There are plenty of cases that we found out do not repeat planting pineapple for the second harvest just because they are not given subsidy by the Government. Even though they are people are hardworking, yet the majority of them still considered within the group of sustainable of income. In respond to this situation, we did a research on two groups of smallholders. The first case is in Tanjung Sepat, Selangor which is being managed by cooperative body and the second case is in Batu Pahat, managed by LPP (Farmer's Organization Authority). Apparently, the researchers found out that the rate of the production and the quality of the fruits in these two case studies performed much higher when farmers are on their own individually. These findings lead us to make various deductions and implications that may affect the policies of the pineapple industry in Malaysia.

##### **Measuring competitiveness of Malaysia's pineapple trade market: A comparison between the selected exporting countries measuring**

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The major purpose of this paper is to assess Malaysia's competitiveness in pineapple's trade market as compared to other selected exporting countries comprising Philippines, Thailand, China and Indonesia since Malaysia have faced a growing competition in pineapple export market for decades. Carraresi and Banterle (2008) stated that an analysis of competitiveness is usually carried out by assessing trade indices, comparing trends and countries in the international markets. Thus, the analysis of trade indices includes export market share (EMS), relative export advantage (RXA), relative import advantage (RMA), relative trade advantage (RTA), revealed competitiveness (RC), and net export index (NEI) are used in this study. The annual time series data starting from 1961 to 2008 published by the United Nations Commodity Trade Database and Food and Agriculture Organization statistic is analyzed in this study. The trade indices introduced by Vollrath (1987, 1989 and 1990) and Balassa (1965) are considered, and the result shows that the mean values of export market share (EMS) for Malaysia decreased tremendously from 44.9% to 1.1% during 1961 1965 and 2001 2005, periods, respectively. The Philippines has maintained its position as the largest share in pineapple export market since 1980s. However, the positive values of both relative trade advantage (0.854 to 2.123) and the revealed competitiveness (1.378 to 5.533) indicate Malaysia has both comparative and competitive advantage in pineapple sub sector. Also, the logarithmic form of relative export advantage measured the positive values index (0.061 to 1.213) from 1989 to 2007, except in 2004 ( 0.050), and the net export index (0.506 to 0.949) indicates that Malaysia has the competitiveness and comparative advantage in exporting pineapple to global markets.

##### **Pineapple production and research in China**

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Pineapple, ranks next to banana and mango, is the third most important tropical fruit in the mainland of China. The cultivation areas change from 52000 to 65000 ha with a total production 780000 to 920000 ton within this decade. Guangdong, Hainan, Guangxi and Yunnan province are the main pineapple cultivation areas. Especially Guangdong province, it produces 50% 60% pineapple of China. Nearly 85% of the pineapple produce in China goes to the domestic market as fresh fruit. Comte de Paris, which occupies more than 80% pineapple planting area, is the most important pineapple cultivar in the mainland of China. But Yuecui, Tainon No.16 and Tainon No.17 have shown they are the promising cultivars. And the cultivation of these cultivars is keeping increase these years. Although pineapple industry takes an important role in tropical agriculture economy, there were few researches to carry out on pineapple before 2005. Crop management mostly lies on farmer's experience. To promote the development of pineapple industry and increase its competition ability, the Ministry of Agriculture of China started a research program on pineapple since 2006. It includes genetic improvement, studies into high yield and good quality fruit production technique, integrated management of pests and diseases, postharvest handling, utilization of by production and marketing strategy. Some progress has been made from this program, a better understanding on the role of nutrient needed and uptaken by the cultivars Comte de paris and Smooth Cayenne, on sugar metabolism and accumulation during fruit development, on the ability in bacillus killing and/or inhibiting and smell reducing of leaf fibre. Techniques have also been developed in leaf fibre abstracting and processing.

##### **Pineapple Production in the CNMI**

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Pineapple (*Ananas comosus* L. (Merr.)) is high valued crop in the Commonwealth of the Northern Mariana Islands. Low maintenance, typhoon tolerant, source of income generation and high vitamin C content properties of pineapple makes favourable horticulture crop of farming community. Smooth Cayenne (Pinan Hawaii), Red Spanish (Pinan Chamorro), and Queen (Pinan Aleman) are the three main varieties of pineapple widely grown in the CNMI. Pineapple production is severely affected in recent years by the introduction of diseases and pests, dwindling economy, high costs of labor, fertilizer, pesticides and irrigation. Islands' dwindling economy, natural disasters, and paucity of quality planting material have also considerable constraints on pineapple production in the Commonwealth. Nematodes, mealybugs, rodents, snails are major insect pests attack pineapple in the CNMI. Mealybugs cause wilting disease. Fungal rot, crown rot (Phytophthora), and wilting are among

the diseases caused severe damage to the crop. Due to high cost of farm chemicals and restrictions, botanical pesticides such as neem leaves extract and soap solution increasingly used by farmers to control insect pests and diseases. Commercial growers use 'force' flowering in pineapple by apply chemicals. Conventional method of planting pineapple in the Commonwealth is through crowns, slips, suckers, and ratoons. Cooperative Research, Extension and Education Service Dept. of the Northern Mariana College introduced tissue culture program in the CNMI in 2006 for the cultivation of improved varieties and quality planting material of fruits and vegetables. This paper describes cultivation practices, varieties, propagation and constraints of pineapple production in the CNMI.

## Session 2: Biotechnology and Breeding

### Micropropagation of Maspine pineapple treated with 6 benzylaminopurine through in vitro technique

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In Malaysia, Maspine pineapple is currently the most preferred variety due to its applicable for canning. Large quantities plant materials are needed to fulfill the demand. Therefore, in vitro procedure was developed as an alternative method to improve upon the multiplication rate of this variety. The cultures required 5 mg/L of BAP to significantly increase the shoot development for the initial culture. The cultures subsequently sub cultured on medium with 1 mg/L BAP, resulting in the highest number of proliferated plants (64 plants) compared to other concentrations or treatments. About 95% of the in vitro regenerated shoots rooted on MS hormone free medium within 2-3 weeks of culture and 85% of the micropropagated plantlets could be successfully established in soil, where the plant grew normally.

### Pineapple (*Ananas comosus* (L.) Merr.): Isolation, identification and screening of bacterial endophytes from pineapple for cytokinin like compounds

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Endophytes are the microorganism that reside inter or intra cellularly in most of the plant tissues without causing any visible disease symptoms. Endophytes are known to produce plant growth promoting compounds. Cytokinin is a group of plant growth regulators (PGRs) and known to play an important role in converting etioplasts into chloroplasts, and could be used to increase the shelf life of leafy vegetables, flowers and fruits. The objective of this study is to isolate endophytic bacteria from pineapple (*Ananas comosus* L. (Merr.)), family of Bromeliaceae) and to screen them for cytokinin like compounds using cucumber cotyledon bioassay. Field grown, pineapple plant leaf samples were collected from various parts of peninsular Malaysia and putative endophytes were isolated from leaf tissues using the standard isolation method. Polymerase chain reaction (PCR) was carried out using bacterial lysate and 16S rDNA gene specific primers (Bak11W F and Bak R). The amplified PCR products were purified; and DNA sequencing was carried out using forward primer, Bak11W F. By using the blastN analysis of 16S rDNA, putative endophytes were identified. Well isolated single colonies of putative bacterial endophytes were grown separately in Luria Bertani (LB) medium and diluted cell free broth was used in the cucumber cotyledon bioassay. The total chlorophyll content in cucumber cotyledon samples was estimated by spectrophotometry and compared with positive and negative controls used in bioassay. The results of identification and screening of bacterial endophytes isolated from pineapple leaves will be discussed in this paper. This project work is fully supported by a grant from the Ministry of Agriculture & Agro Based Industry (MoA) of Malaysian Government [Grant Code: 05 02 16 SF1001].

### Identification and characterization of differentially expressed microRNAs during fruit ripening in pineapple (*Ananas comosus* var. *comosus*)

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MicroRNAs (miRNAs) are a class of small, non coding, endogenous RNA that negatively regulates gene expression by cleaving or repressing the translational process of protein coding mRNA transcripts. In order to provide evidence for the elucidation of gene regulation associated with pineapple fruit development and non climacteric ripening mediated by miRNA, the detection and quantification of pineapple miRNAs by comparing fruit at two different development stages, pre ripening and post ripening stage using RT qPCR were carried out. This paper reports the expression profiles of 13 miRNAs namely miR156, miR157, miR159, miR162, miR164, miR165, miR167, miR168, miR169, miR170, miR171, miR172, and miR390 in pineapple. Among these 13 miRNAs, three miRNA genes (miR168, miR390, and miR164) displayed clear differential expression during pre ripening and post ripening stages of the fruit. During the post ripening stage, miR168 and miR390 were up regulated 1.79 and 2.64 fold respectively, while expression of miR164 dropped down to 0.07 fold compared to the pre ripening stage. The discovery of miRNAs from this study together with its stage regulated expression profiles are excellent candidates for further investigation into pineapple crop improvement through functional genomes.

### Potential pineapple for landscaping in Malaysia

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The interest in using pineapple as ornamental plant is increasing world widely. However, in Malaysia decorative pineapples are being planted only by a handful of hobbyists and so far no work has been done to promote pineapple as an ornamental crop. A number of plants in MARDI's pineapple germplasm are found suitable as landscape plants. These include the variegated red leaves *Ananas comosus* var. *bracteatus* and the miniature *Ananas nanus*. The former is more suitable to be grown as bedding plant on raised bed, while the miniature could be grown in pots. In addition, generated materials from breeding program also showed some ornamental values. Distributed among the population F1 progenies developed from piping leaf are genotypes with fan like crowns, multiple crowns and those with numerous slips. Some of these off types

showed some potential as landscape plants. In addition, tissue cultured pineapple population is also a good reservoir of pineapples with unique and interesting characteristics. These somaclonal variations including the prettily coloured and ‘snaky plant’ with creeping growth habit could be used for landscaping too. The introduction of these ornamental pineapples will add more choice to the Malaysian landscape industry which is currently being dominated by evergreen trees, shrubs and ground covers. It is timely therefore to promote pineapple as an ornamental crop.

#### **Difference in sugar content and enzymes related to sucrose metabolism of pineapple different sections**

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The sugar accumulation of various sections was different for a given ‘Comte de paris’ pineapple. During the fruit maturation, the sugar content was the highest in the basal section of riped fruit, followed by the medial section, basal section and fruit core. Changes in activity of acid and neutral invertases (AI and NI respectively) and sucrose phosphate synthase (SPS) corresponded to changes of sugar concentration gradient within various sections during fruit development. These results suggested that the higher activity of invertase in the basal section of fruit played a role for rapid cleavage of sucrose and helpful to form a sucrose gradient which made sucrose transport from the leaves to fruit, meanwhile, and the higher activity of SPS could promote the synthesis of sucrose, which indicated that the difference between activity of invertase and SPS resulted in the difference of sugar accumulation among the various sections. The relations between the content of sucrose and the enzymes activities were different among the various sections, the activities of sucrose phosphate synthase (SS) and SPS had a great impact on the sugar accumulation in the medial and the basal sections of fruit during the period of 70 DAA (days after anthesis), and after then the rapid sucrose accumulation was related with the increase of SPS activity and the reduction of NI activity. The activity of SS regulated the sucrose accumulation in the fruit apical and core section in the period of 70 DAA, and the activities of AI, NI and SPS regulated the sucrose accumulation of the fruit core after 70 DAA, whereas the activities of various sections before 70 DAA, and after then it had less effect. In short, the activity of NI and SPS regulated the sucrose accumulation during the fruit maturation.

#### **Difference in sugar content of fruit harvested in different month pineapple and its relation to sucrose metabolism**

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The fruit growth and development were different among the fruits harvested in different seasons. The growth of fruit harvested in February was a non-typical single ‘S’ pattern (fast-slow model) and the growth of fruit harvested in July presented a typical single ‘S’ pattern (slow-fast-slow model), and the maturation period of the latter was shorter than the former by 40 d. The harvest period had an effect on the ‘Smooth Cayenne’ fruit sugar accumulation. In the winter fruit harvested in February, exhibited the ratio of hexose to sucrose to be 0.37 with mainly sucrose been accumulated. Whereas in summer fruit harvested in July, the ratio was 5.92 and more hexose was accumulated. There was significant different of sugar accumulation and sucrose metabolism enzymes between fruits harvested in February and July. The activities of SPS and SS synthetic direction in fruits harvested in February were significantly higher than those in July, whereas the invertase activities in fruits matured in February was significantly lower than those in July. This profile of sucrose metabolism enzymes was favorable to sucrose accumulation for fruits harvested in February. The ascending invertases made fruits matured in July accumulate less sucrose and more hexose.

#### **Frequency and distribution of simple sequence repeats (SSRs) in pineapple fruit transcriptome**

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Simple Sequence Repeats (SSRs), normally known as microsatellites or Short Tandem Repeats (STRs) are ubiquitous, hypervariable and abundant in many eukaryotes genomes. They are generally thought to differ due to the effect of replication error and unequal recombination. Their distribution varies across genic, intergenic regions and non coding regions of the DNA. SSRs may be predominant in certain regions which may reflect the tendency of mutational processes to create certain repeats patterns under selective pressure. The expansion of repeat motifs in the coding regions of the gene may alter gene expression. This paper reports the discovery of tandem repeats motifs and its frequency in fully ripe pineapple fruit transcriptome generated from contigs derived from paired end Solexa mRNA sequencing. Paired end sequences, with lengths of 75bp each and with insert sizes of 200bp, were assembled using Velvet which generated 28,728 contigs. These contigs were then used to reveal di-, tri-, and tetranucleotide SSR motifs which are present by using SynaRex (Synamatix). Primers flanking the SSR loci were then designed by using the online software PRIMER 3. Mining of the contigs generated showed that only 3.5 % of the fully ripe pineapple fruit transcriptome contained SSRs. Dinucleotides were the most abundant and they account for 498 (49.6%) contigs containing SSR followed by trinucleotides and tetranucleotides with 467 (46.5%) and 40 (3.9%) contigs, respectively. Among the dinucleotide motifs, (TC) and (GA) were the most abundant with 45% and 41.6% occurrences, respectively. For trinucleotide motifs, (GGA), (CTC), (AGA) and (TTC) showed higher occurrences compared to other trinucleotide motifs with 20.3%, 16.5%, 13.1%, and 9.2%, respectively. Of all the contigs containing SSR, only 26.6% were suitable for designing flanking primers for PCR. Of these, 66 contigs were dinucleotide, 190 contigs were trinucleotide and 11 contigs were tetranucleotides. Further validation of the PCR primers will provide wider application in biomarker identification, genome mapping and characterization, phenotype mapping, marker assisted selection and finally in diversity studies of pineapples.

#### **Cluster analysis using quantitative, qualitative and molecular variables for genetic diversity studies in pineapple genotypes**

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Cluster analysis using quantitative, qualitative and molecular variables has been demonstrated to be a useful tool in estimating genetic diversity between genotypes in germplasm collections. The objective of the present study was to carry out a simultaneous analysis of quantitative, qualitative and molecular variables followed by clustering for studying the genetic diversity between pineapple genotypes using the Gower algorithm. Eleven quantitative, five qualitative and forty three molecular characteristics in ninety pineapple genotypes were evaluated. The

cophenetic correlation coefficient of the joint analysis was higher when compared with the individual analysis coefficients. It was observed fifteen groups which indicate higher variability among the genotypes evaluated. The simultaneous analysis of the quantitative, qualitative and molecular variables was efficient in the expression of the genetic diversity between pineapple genotypes when compared to the individual analysis for each type of variable.

#### **F<sub>1</sub> hybrid pineapple (*Ananas comosus* L.) resistant to bialaphos herbicide**

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Weeds are the main factor for pineapple production. Pineapple plantation growers spend at least a half of production cost controlling the weeds. However, all current commercial pineapple cultivars are sensitive or susceptible to biodegradation herbicide. This research project aims to establish F<sub>1</sub> hybrid pineapple variety resistant to herbicide by conventional breeding. Direct and reciprocal crosses between genetically modified pineapple (TP) carrying bialaphos resistant (bar) gene and two commercial pineapple cultivars Pattavia(PV) and Phuket(PK)] was made in 2005 at Faculty of Agriculture, Rajamangala University of Technology Srivijaya, Nakhonsithammarat, Thailand. 1,172 F<sub>1</sub> seeds and 886 F<sub>1</sub> plantlets were obtained from the first crossing of both crosses of PV and TP. However, no seeds could be obtained from either direct or reciprocal crosses of PK and TP. The 886 F<sub>1</sub> plants were studied and evaluated for agronomic characteristics, fruit quality and bialaphos herbicide resistance. Of 886 F<sub>1</sub> plants, 410 F<sub>1</sub> plants showed resistant to Basta X herbicide. Furthermore, there are eighteen potential F<sub>1</sub> plants showing other good agronomic characters and good fruit quality. Three promising hybrids, (PV x TP) 51; (PV x TP) 46 and (PV x TP) 34, showed resistant to biodegradation bialaphos herbicide, a high percentage of Brix (18 22.2°Brix), a fragrant smell, crispy flesh and a smooth leaf with only the tip being spiny. In particular, (PV x TP) 34 hybrids presented pale pink bract and fruit and it gave 22.2°Brix, cylindrical fruit shape, dark yellow flesh, as well as pleasant flavor. These potential hybrids will further be evaluated to confirm the traits and consequently release to farmers.

#### **Gene regulation of fruit development by MicroRNAs**

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MicroRNAs are small RNAs with approximately 21 nucleotides in length. It functions by regulating gene expression of various plant tissues such as leaf, root and embryo through the mechanism of RNAi silencing. Numerous papers have been reported on the role of miRNA in regulating fruit development in tomato, which is a model organism for fruit development and ripening in climacteric fruits. This paper, aims to firstly, identify and characterize the miRNAs in the non climacteric fruit, pineapple, and secondly, to reveal differentially expressed miRNA between pineapples and tomatoes. MicroRNAs from a mature green pineapple were isolated using an optimized small RNAs concatenation and cloning method. A hundred and fifty clones were sequenced resulting in a total of 1,709 small RNAs. These small RNAs were screened for conserved microRNAs from other plants species using miRBase online database. These small RNAs were also screened for differentially expressed miRNA between pineapples and tomatoes using the Tomato Functional Genomics Database (TFGD). A total of 12 conserved microRNA families were identified as regulators of fruit development in pineapples. The most abundant miRNA is miR157, which has 57 copies out of the total small RNAs pool. This is followed by miR396 (5), miR164 (3), miR166 (3), miR827 (3), miR159 (2), miR171 (2), miR319 (2), miR156 (1), miR162 (1), miR395 (1), miR529 (1). However, the TFGD search revealed that only miR529 and miR827 are absent in tomato and have unknown target genes, thus may represent the different mechanism of regulation by microRNA in non climacteric fruits. This is the first paper published on the isolation and characterization of microRNA in pineapples using the conventional cloning method.

#### **The vegetative 'snaky' stem in pineapple: Is it heritable or physiological**

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The long non fruiting creeping snake-like stems of Maspine, because of its capacity to generate numerous plantlets, are often used as common source in rapid multiplication to generate new planting materials. This together with the inconsistency in yields of Maspine crops particularly those crops which originated from materials derived from mass production, has prompted further study on yield performance of tissue cultured materials and a genetic study on non bearing long vegetative 'snaky' stems. A look at the first generation tissue cultured material of Maspine, like most pineapple produced through tissue culture, showed somaclonal variations. The plants with 'snaky' long vegetative stem were the most common, constituting >30 % of the population. In terms of yield performance, the first generation tissue cultured crop recorded considerably low fruiting percentage of less than 20%. The non fruiting characteristic of 'snaky' stem persists even in the second generation populations. Similar phenotypic performance was observed in the second study. The populations derived from suckers of 'snaky' plants consistently recorded low fruiting percentage of less than 30%. This is comparatively lower than the fruiting percentage (> 70 %) recorded in the populations originated from crown or suckers of normal plants. The consistency in low bearing nature of the 'snaky' stems in both studies is conclusive enough to say that long 'snaky' vegetative stem is heritable in nature. Though able to generate more than 300 plantlets, it can be concluded therefore, that long 'snaky' vegetative stem is not a

#### **Root knot and Reniform Nematode resistance bioassays of pineapple subjected to genetic modification and tissue culture**

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Accurate bioassays of root knot and reniform nematode resistance in pineapple have required 9 to 12 months in the greenhouse, respectively. We developed protocols to evaluate genetically modified pineapple for resistance to nematodes using a reproductive factor (Rf=Pf/Pi) that shortened the time to 3 months for *Meloidogyne javanica* and to 6 months for *Rotylenchulus reniformis*. Plants were transitioned from tissue culture into the greenhouse by repotting into individual pots and allowing one month for adjustment before being inoculated with nematodes. We employed this protocol for nine different sets of plants. In the first seven sets of plants, tissue cultured F153 and D10 plants that had not been subjected to transformation were used as controls. The Rf of *M. javanica* and *R. reniformis* on these D10 averaged 5.96 (s=10.37) and 15.65 (s=41.69), respectively. On F153, the Rf was 131.75 (s=137.41) and 32.28 (s=38.69) for *M. javanica* and *R. reniformis*, respectively. For those plants that had been subjected to a transformation process, *M. javanica* Rf averaged 16.20 (s=33.63) and *R. reniformis* Rf averaged

26.66 (s=61.51) over all of the seven sets. In a set of proven transgenic lines, the Rf of *M. javanica* and *R. reniformis* averaged 22.58 (s=24.93) and 3.39 (s=6.54), respectively. The controls in this set were ACC synthase transgenic plants that had an Rf of 18.85 (s=25.14) for *M. javanica* and an Rf of 5.72 (s=10.82) for *R. reniformis*. The variation associated with the bioassays was large making conclusions difficult. The sets were composed of many lines of pineapple, most represented by only a few plants. Plant size was not uniform at transplanting and plant growth was different among lines. Differences arising from the time of year that the assay was conducted may also have contributed to the wide variation. The transformation and genetic modification process appears to alter the host status of pineapple, making some lines more better hosts to the nematodes. Because of the variation, it seems necessary to produce and evaluate multiple plants in a modified line to accurately identify nematode resistance.

#### **Molecular overview of genes involved in pineapple fruit development**

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Pineapple (*Ananas comosus*) is considered a tropical fruit crop of significant commercial value, yet surprisingly little research has been undertaken to understand the molecular basis of pineapple fruit development. The major focus of this project is to bioinformatically identify key genes involved in pineapple fruit development. Microarray and bioinformatic analyses identified approximately 230 clones that are 1.5 fold or more up and down regulated during pineapple fruit development. The genes were annotated and assigned putative functions using tools from NCBI GenBank (BlastX), The Arabidopsis Information Resource (TAIR) database, Database for Annotation, Visualisation and Integrated Discovery v6.7 (DAVID) and Gene Ontology (GO) classification systems. Interestingly, DAVID Functional Enrichment Cluster (FEC) analysis of all 230 genes identified organic acid metabolism, glycolysis, gluconeogenesis, vitamin biosynthesis and cysteine peptidase activity as common pathways and processes with confident enrichment scores indicating functional importance. DAVID Heat Maps, MapMan, and KEGG pathway tools were further used to visually analyse cluster of genes (1.5>fold) involved in common pathways and processes of biological significance during pineapple fruit development. Molecular approaches involving the isolation of a wide range of gene sequences from ripening pineapple fruit would allow the study and identification of changes that occur in gene expression during pineapple fruit development. The metabolic and biological significance of these findings may prove beneficial for understanding the molecular basis of pineapple fruit development. In addition, an understanding of the processes that occur in pineapple fruit ripening and senescence may allow the future modification of fruit characteristics of economic importance.

#### **Phenotypic variability in selected population of hybrid progenies derived from piping leaf base**

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Pineapple (*Ananas comosus* L. (Merr.)) is one of the most important fruit industries, especially canning industry, in Malaysia. Currently the Malaysian pineapple industry is faced with production problems such as deteriorating in yield of the old canning variety and susceptibility to bacteria heart rot (BHR) disease of Josapine when grown on mineral. To boost this flagging industry more vigorous varieties with desirable agronomic characteristics, fruit quality and resistance to prevailing diseases are required. Wide genetic variability was created through hybridization between 'piping-leaf' parents (53-116 and 59-656) and Josapine. The generated variants were subjected to selection process. Selections were made based on plant characteristics including earliness to fruiting, major fruit quality traits and resistance towards prevailing pest and diseases. Earliness in bearing will incur less production cost because of reduction in cost of field maintenance and this will provide a more competitive edge for the industry. More than seven thousand F1 progenies of 'Josapine' x 53-116 and 'Josapine' x 59-656 crosses were first subjected to a step-wise culling process. Six hundred hybrids with 'piping-leaf' were selected and further evaluated in the field. The phenotypic characteristics of these materials were then subjected to cluster analysis. The dendrogram obtained illustrated interesting gene pool with diverse phenotypic variability in agronomic characters and resistance to diseases for future varietal improvement programme. Thirty potential 'piping-leaf' hybrids with diverse phenotypic variability were then selected to be evaluated for further genetic and economic considerations.

#### **Ulam: A novel pineapple variety**

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The pineapple products (fresh, canned and dried) are marketed worldwide. In the late 1980s, a pineapple cultivar 'MD-2' was released. In 2009, Dr. Bartholomew reported that the annual sales of 'MD-2' exceeded 1 billion U.S.\$. Pineapple consumption is increasing in Japan, South Korea, China, Middle East, U.S. and Europe. Brazilian species, varieties and elite selections were used as parents and for Meristem Tissue Culture propagation. After 30 years of breeding, one outstanding plant with pleasing taste, high Brix (18-22°) and desirable horticultural characteristics (tolerant to HRR and yellow flesh) was selected. DUS tests were conducted. The Department of Agriculture awarded a Variety Protection Certificate. Aside from unparalleled sweetness, Ulam has a unique differentiation from other varieties. The core is crunchy. Ulam, a Filipino word for viand, is ready for commercialization, sixty hectares in 3 years and 500 hectares in 6 years.

#### **Session 3: Plant Physiology and Cultural Practices**

##### **Leaf gas exchange of pineapple as influenced by fruit**

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'Smooth Cayenne' pineapple plants were propagated from suckers and grown in containers for leaf gas exchange studies. Following natural flowering and fruit development, net CO<sub>2</sub> exchange was measured in the leaves of the crown and the main plant throughout diel cycles. A non significant increase in maximum net CO<sub>2</sub> exchange of leaves occurred at the flowering stage. Maximum net CO<sub>2</sub> exchange of leaves on the main



plant was  $0.44 \text{ mol m}^{-2} \text{ s}^{-1}$  and did not differ between plants supporting fruits and vegetative plants. Maximum net  $\text{CO}_2$  exchange of crown leaves was  $3.99 \text{ mol m}^{-2} \text{ s}^{-1}$ . The results indicate leaves subtending pineapple fruits do not increase in carbon assimilation during fruit growth as do leaves of other fruit species. Furthermore, crown leaves appear to satisfy most or all of the carbon requirements of the developing fruit based on the gas exchange data.

#### **Observation on flesh cell development of pineapple fruit by flow cytometry and histological analysis**

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More than 80% of the pineapple (*Ananas comosus* L.) planted in mainland China is Comte de Paris'. In order to understand the fruit cell development of pineapple (Comte de Paris), fruits were collected every 15 days starting from 0 day after anthesis (DAA) until maturation (60 DAA). The flesh of second (upper) and sixth fruitlets (lower) were selected for flow cytometry and histological analysis. The results showed that flesh cell areas were the smallest at 0 DAA, which were  $1662.38$  and  $2755.58 \mu\text{m}^2$  for the upper and lower parts, respectively. Thereafter, the upper and lower cell areas increased sharply to  $2630.89$  and  $3465.72 \mu\text{m}^2$ , respectively at 15 DAA. Following that the cell area increment was slower until it reached the peak at 45 DAA, when the upper and lower cell areas were  $3527.50$  and  $3741.33 \mu\text{m}^2$ , respectively. However, after the fruits matured, the cell areas significantly decreased to  $2498.03$  (upper) and  $2650.36 \mu\text{m}^2$  (lower), respectively. On the other hand, flow cytometry analysis showed that the percentages of S phase cells of fruit flesh at 0 DAA was less than 4%. However, this ratio increased sharply until it reached the peak (more than 30%) at 30 DAA. After that, this ratio significantly decreased; until maturation, when the S phase cells were less than 3% both for the upper and lower flesh.

#### **Role of calcium on internal browning of pineapples**

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Internal browning of pineapples limits storage life and transportation potential at low temperature. Queen and Smooth cayenne pineapples harvested from Chiangrai, Rayong, Trad and Nakhon Pathom provinces, had total calcium content in the pulp and cor determined and then were stored at  $10^\circ\text{C}$  for 21 days. It was found that Queen pineapple had higher total calcium content but developed more internal browning than that in Smooth cayenne pineapples. However, within the same pineapple type, total calcium contents were negatively correlated with internal browning. The effect of pre harvest and post harvest calcium applications on internal browning of Trad see thong' (Queen type) pineapple was also determined. Pineapples were sprayed with  $1000 \text{ mg/L}$  calcium boron solution combined with  $150$  kilograms per hectare of calcium oxide exhibited  $47.6\%$  internal browning reduction. However, in another experiment the calcium application was not effective for the internal browning reduction. On a postharvest study, calcium applications by immersion of pineapple fruit stems in  $0$ ,  $1$ ,  $2$  and  $4\%$  calcium chloride solutions at  $25^\circ\text{C}$  ( $80$ – $85\%$  RH) for 18 hours had  $35$ ,  $77$  and  $79\%$  internal browning reduction, respectively. However,  $2$  and  $4\%$  calcium chloride solutions caused a dark brown area in the fruit stem, which extended  $2.5$  centimeters into the core. Repeated experiments could not confirm the result. It was suggested that calcium content was only one of the factors influencing internal browning in pineapples. Further study need to be conducted for confirmation of the finding.

#### **Refining ReTain treatments to control natural induction of flowering of 'MD-2' pineapple in Hawaii**

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Natural induction of inflorescence development (NI) of pineapple is a serious problem in pineapple fields in Hawaii from late November through February. Experiments to test the efficacy of aviglycine in controlling NI were installed in irrigated fields at elevations of  $145$  and  $275 \text{ m}$  on Oahu, Hawaii. Plant weights were about  $2.0 \text{ kg}$  at  $145 \text{ m}$  and  $1.6 \text{ kg}$  at  $275 \text{ m}$  with  $67,925$  plants  $\text{ha}^{-1}$  in both fields. Plots of 'MD-2' pineapple were sprayed with ReTain ( $15\%$  aviglycine) or VBC 30102 ( $20\%$  a.i. in a liquid formulation), in 2008-09. NI in control plots was greater than  $40\%$  in both fields. Excellent control of NI was achieved by weekly sprays of  $100 \text{ mg L}^{-1}$  aviglycine in  $2337 \text{ L ha}^{-1}$  or  $200 \text{ mg}$  in  $1168 \text{ L ha}^{-1}$  with no differences due to formulation. Biweekly sprays of  $100 \text{ mg L}^{-1}$  aviglycine in  $2337 \text{ L ha}^{-1}$  had significantly less NI than the control but significantly higher NI than weekly sprays. Aviglycine had no significant effect on fruit size distribution in the 2008-09 experiment, but delaying aviglycine sprays until after NI occurred resulted in deformed fruit. ReTain is very expensive and NI needs to be controlled for more than the  $10$  weeks currently allowed by the label. To explore ways to reduce costs and extend control, experiments were installed in November of 2009 to evaluate the effects of various combinations of solution concentration and weekly or biweekly intervals for up to  $17$  weeks on the control of NI. ReTain provides excellent control of NI but cost remains an issue.

#### **The effect of NaCl on the mineral nutrient and photosynthesis pigments content in pineapple (*Ananas comosus*) in vitro plantlets**

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An experiment was conducted to determine the effects of salinity induced by NaCl on the mineral nutrient: (potassium, calcium, sodium, magnesium, phosphorus), chlorophyll and carotenoid contents in all varieties of pineapple (*Ananas comosus* L. Merrill) tissue cultured plantlets. Explants sizes  $10$ - $12 \text{ mm}$  were cultured on MS medium treated with  $0$  (control),  $34$ ,  $68$ ,  $103$ ,  $137$ ,  $171$ ,  $205$  and  $240 \text{ mM}$  NaCl. The fresh weight (FW), dry weight (DW) and number of leaves were determined every two weeks during the first two months of culturing. Mineral nutrient, chlorophyll and carotenoid contents were determined once at four weeks of treatment. The result shows that the increasing of NaCl concentration in the culture medium led to reduction of potassium ( $\text{K}^+$ ), calcium ( $\text{Ca}^+$ ), magnesium ion ( $\text{Mg}^+$ ), however sodium ion ( $\text{Na}^+$ ) was increased in tissue of all tested pineapple varieties. The chlorophyll and carotenoid contents were decreased when salinity levels were higher than  $68 \text{ mM}$ .

High concentration of NaCl would influence the uptake and accumulation of major mineral nutrients ion and pigments biosynthesis in pineapples tissues.

#### **Partitioning of dry matter in fruiting and vegetative pineapple plants of homogeneous age**

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'Smooth Cayenne' pineapple plants were propagated from suckers of uniform size and grown in containers. Natural flowering occurred on a portion of the plants at 13 months. When the syncarps developed color, six fruiting and six vegetative plants were bare rooted then partitioned into roots, leaves, stem, peduncle, slips, syncarp, and crown. Leaves were counted and all tissue was dried at 75°C to constant weight. Total dry matter accumulation and the ratio of below to above ground dry weight were not different between the two groups. Plants that did not flower produced about twice as many leaves as did the plants that flowered, but individual leaf weight did not differ between the two groups. Although dry matter partitioning among various above ground tissues has been reported for pineapple, I am unaware of any previous study that has shown the amount of growth above ground was in proportion with growth below ground for plants of same age whether they produced fruit or continued to produce leaves.

#### **New formulation for the flowering of pineapple var. Maspine**

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A study was conducted in MARDI Research Station Kluang, Johor, Malaysia between 2007-2008 on mineral soil (Renggam Series). It was irrigated during dry period especially during early vegetative and fruit growth development. The objective of the study was to determine an ethrel urea borax formulation for effective, consistent and uniform flowering of pineapple var. Maspine. The planting materials were vegetatively propagated by quatering technique from stumps and young suckers. The concentrations of ethrel (10.8% ai) used were 180, 240, 360 and 480 ppm, urea (46% N) were 2 and 4% while borax (15.2% B) was at 0.5%. As the strength of ethrel increased from 180 to 240 ppm at 2% urea, the percentage of flowering increased from 69.90% to 100% and remained consistent thereafter. When 0.5% borax was added to the above mixture, the percentage of flowering increased from 83.33 to 100%. However, the application of 180 ppm ethrel, 4% urea and 0.5% borax resulted in higher percentage of flowering (84.40%) compared to those without borax (26.50%). Hence, the application of ethrel at 240 ppm with 2% urea is sufficient for maximum, consistent and uniform flowering of Maspine. Comparisons were also made for fruit weight (without crown), fruit length, crown weight, crown length, core diameter, sugar content, skin and flesh colour when fruits were harvested at maturity index 3. There was no significant difference at 5% for the above parameters for ethrel at 240 and 480 ppm, urea 2-4% and borax at 0.5%. Throughout the treatments, the fruit shape remained cylindrical. Conclusively, ethrel urea combination should remain at 240 ppm 2% in order to obtain optimum flowering, desirable qualities.

#### **Effect of gibberellic acid and N-(2-chloro-4-pyridyl)-N'-phenylurea treatments on fruit quality of pineapple**

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More than 80% of the pineapple cultivated in mainland China is 'Comte de Paris'. To evaluate the effect of gibberellic acid (GA<sub>3</sub>) and N-(2-chloro-4-pyridyl)-N'-phenylurea (CPPU) on pineapple ('Comte de Paris') quality and production, pineapple fruits were sprayed with GA<sub>3</sub> and CPPU at the rates of 20, 50 and 100 mg/L at days 0 and 15 respectively after flowering. The results showed that all the different concentrations of GA<sub>3</sub> increased the fruit weight significantly, in which the best treatment, i.e. 50 mg/L GA<sub>3</sub> increased the fresh weight of pineapple fruits by 20.3% compared with the control. On the contrary, all CPPU treatments had little increase on pineapple fruit fresh weight. On the other hand, 50 mg/L GA<sub>3</sub> treatment slightly influenced on the total soluble solid and fruit juice pH compared to the control. However, Vitamin C significantly increased from 22.37 to 25.18 mg/100g FW and both the content of total soluble sugar and total titratable acidity decreased; however the ration of soluble sugar and titratable acidity was slightly affected. Histological observation showed that GA<sub>3</sub> caused fruit cells enlargement, which resulted in the increase of fruit fresh weight. Flow cytometry analysis showed although CPPU significantly promoted cell division after its application, the cell size did not enlarge thus there was no significant increase in fruit fresh weight compared to the control.

#### **Outline of pineapple growth model in very clear cut natural conditions of Reunion Island**

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In intensive pineapple production, cultural practices schedules are well established and adapted to the plant needs. But when cultivated away from the humid tropics or equatorial conditions, the pineapple growth rate decreases and the growing cycles gets longer. In Reunion Island, at 750 m above the sea level, forcing on Queen pineapple is usually done at 11 or 12 months after planting, instead of 6 months under tropical conditions at sea level, impacting strongly the schedule of cultural practices. Furthermore, there is inadequate information on agronomic requirements for cultivation under new environments or new varieties. The aim of this study was to confirm that it is possible to design a simple growth model for pineapple where plant weight is a function of temperature by observing pineapples in very different growing conditions in Reunion Island. With such information it would be possible to stimulate plant growth and to propose schedules for fertilizer applications for the various climate environments.

#### **Effects of N and K on plant biomass, yield and fruit quality of pineapple var. Maspine grown on Rasau soil series**

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A study on the nitrogen (N) and potassium (K) requirement of pineapple var. Maspine was conducted in MARDI Bukit Tangga to observe the effects of 16 N and K fertilizer combinations on plant biomass, yield and fruit quality grown on Rasau soil series. Three levels of N and K applied were 0, 200, 400 and 800 kg N and K<sub>2</sub>O ha<sup>-1</sup>, respectively. The study revealed that Maspine showed the best plant biomass performance at

200 to 400 kg N ha<sup>-1</sup> and K<sub>2</sub>O ha<sup>-1</sup>, respectively. Meanwhile, the highest yield (1.88 kg fruit plant<sup>-1</sup>) was obtained from the combination of 200 kg N ha<sup>-1</sup> with 200 and 400 kg K<sub>2</sub>O ha<sup>-1</sup>. It also resulted in the highest total soluble solid (TSS) values ranging from 15-18 °Brix. Correlation coefficient analysis between plant biomass and yield showed that leaf length and weight, both peduncle and stump width and weight, fruit and crown length, including fruit weight and width were positively correlated ranging from 0.81 to 0.99 R<sup>2</sup> values. Furthermore, by using stepwise regression equation to determine the relationship between 9 plant biomass variables with yield, only 4 were significant (R<sup>2</sup>= 0.9801) namely peduncle, stump and fruit width and fruit length. Thus, at the recommended N and K combinations the yield kg plant<sup>-1</sup> (Y) of pineapple var. Maspine can be derived from all significant plant biomass data through the equation  $Y = -1799.16 - 8.93 (\text{peduncle width}) + 15.14 (\text{stump width}) + 4.34 (\text{fruit length}) + 13.77 (\text{fruit width})$  at  $p < 0.15$ .

#### **Living mulch as a management tool for reducing inter row soil erosion in pineapples**

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Pineapple cropping soils are most vulnerable to erosion from the bed-forming stage until canopy closure of the inter row space. One of the main issues associated with pineapple production in Australia is loss of soil and sediment in runoff water. Previous research clearly shows that soil losses are higher in the first 10 to 12 months when the inter-row surface is exposed to raindrop impact prior to canopy closure. Living mulch is a green cover crop established in the inter-row space and on the sides of the bed at the same time as the pineapples are planted, the mulch is killed with weedicide prior to seeding but the leaves and roots remain effective in a protective role for some time. A trial on a sandy loam soil with a slope of 3% used sediment collection troughs to compare this treatment with standard practice. Inter-row cover reduced soil loss by 54 tonnes/ha (68.7 t vs 14.7 t) compared with bare inter-rows over the 17 month trial period. Other apparent benefits of living mulch include better drainage for *Phytophthora* control (the beds retain their height for longer and the inter-rows remain free of silt). The range of species used as living mulch, oats (*Avena sativa*), white French millet (*Panicum miliaceum*) and forage sorghum (*Sorghum bicolor*), are not hosts for nematodes in South East Queensland and they have also demonstrated allelopathic properties against weeds. Cost savings include less work retrieving soil from silt traps.

#### **The potential of Moris cultivar pineapple on mineral soil**

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Pineapple is basically grown on peat soil in Malaysia. An observation study on pineapple cv. Moris on mineral soil was carried out on commercial farms beginning 2006 in the state of Kedah. Before the year 2006, there was an understanding that Moris cv. couldn't be grown in the northern state by portraying unhealthy leaves growth with reddish color and could only bear small fruits. The first harvest of Moris in Pokok Sena, Kedah on an area of about 4.0 hectares has proven that Moris cv. has greater potential and with proper cultural practices can generate better yield in term of bigger fruit size, sweeter, crunchy and produced an aromatic smell as compared to those pineapple growing on peat soil. Through four years of experienced with this cultivar, the Kedah State Department of Agriculture together with the stake holders of Kedah State Government has chosen three (3) pineapples including Moris cv. to be grown on large scale in Kedah.

#### **Pineapple production in Meghalaya (India) Indigenous cultural practices and status**

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Meghalaya is one of the most important pineapple (*Ananas comosus* Merr.) producing State of India. It is situated in the North Eastern Region of India with a geographical area of 22, 489 sq. km. The economy of Meghalaya is basically agrarian and rural based with about 70 % of its population depending on agriculture and allied activities for their livelihood. During the last ten years, there is substantial increase in the production of pineapple. The productivity of pineapple increased from 8,623 Kg/ha during 1998-99 to 9,601 Kg/ha during 2007-08. Presently, pineapple occupies an area of 9,808 hectares with an annual production of 94,170 MT (2007-08). In Meghalaya, prominent pineapple varieties like Giant Kew and Queen are cultivated along the hilly slopes under rainfed conditions. It is consumed fresh or in the form of juice, jam, squash and canned fruit. Various developmental programmes of the Government enabled the pineapple growers in the State to enhance the production and productivity considerably. Use of inorganic fertilizers or chemical pesticides is negligible in the State. In the interior parts of the State, the age old indigenous methods of pineapple cultivation are still in practice. With adequate scientific intervention these areas may be developed into a potential organic pineapple production hub. The paper presents the development of pineapple in the State during the last 10 years and highlights the indigenous cultural practices being followed by the pineapple growers.

#### **Effect of ethrel on fruiting characteristics of pineapple in Cooch Behar District, West Bengal, India**

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A preliminary study was conducted at the University Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India to assess the effect of different concentration of ethrel (25, 50, 75, 100, 125, 150 ppm) on fruiting characteristics of pineapple (*Ananas comosus* (L) Merr.) during December, 2007. Maximum fruit length (15.7 cm) was obtained with ethrel 25 ppm (T1), followed by 15.57 cm with ethrel 50 ppm (T2). Maximum fruit girth (36.67 cm) was recorded with ethrel 25 ppm (T1). Fruit weight was recorded as maximum (1470 g) with ethrel 50 ppm followed by with ethrel 25 ppm (1330 g). Highest total soluble solids (TSS) and total sugar was recorded to fruit treated with 25 ppm ethrel and their values were 14.93°Brix and 6.07 %, respectively. However, highest juice percentage (81 %) was recorded with ethrel 50

ppm. Comparing with mean values for different parameters it was found from the investigation that ethrel 25 ppm showed better result for fruiting characteristics.

#### **Induction of flowering in pineapple (*Ananas comosus* (L.) Merr) by NAA and Ethrel**

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An experiment was conducted at Horticultural Research Station of Uttar Banga Krishi Viswavidyalaya, Cooch Behar (West Bengal), India, to evaluate the effect of seven different doses of NAA and Ethrel on its flowering induction and fruiting of Pineapple cv. Kew with eight treatments. The experiment was laid out in RBD taking eight treatment combinations of NAA & Ethrel viz., NAA @ 10 ppm (T1), Ethrel @ 50ppm (T2), Ethrel @ 100 ppm (T3), Ethrel @ 150ppm (T4) Ethrel @ 50 ppm + NAA @ 10 ppm (T5), Ethrel @ 100 ppm + NAA @ 10 ppm (T6), Ethrel @ 150 ppm + NAA @ 10 ppm (T7) and Control (T8) as water spray in three replications. The shortest flower initiation period and highest flowering were obtained with the application of 50 ppm Ethrel while the longest and lowest duration of flowering was recorded with Ethrel 100ppm + NAA 10 ppm. Highest fruit weight, fruit length, fruit pulp: peel ratio were recorded with NAA 10 ppm application compared to control. The results obtained from the combined application of NAA with Ethrel did not show any significant difference from its sole application because of the adverse effect of higher ethylene production due to their combined application.

#### **Effect of NAA and Ethrel on yield and quality of pineapple (*Ananas comosus* L. (Merr))**

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The responses of pineapple to the selected combinations of Ethrel and NAA with simultaneous variations were studied at experimental farm (Horticultural Research Station) of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, and West Bengal, India during the year 2006-2008. The experiment was laid out in RBD taking eight treatment combinations of NAA & Ethrel viz., NAA @ 10 ppm (T1), Ethrel @ 50 (T2), 100 (T3), and 150ppm (T4) and the combinations of NAA @ 10 ppm with Ethrel @ 50 (T5), 100 (T6), or 150 ppm (T7) and Control (T8) as water spray to evaluate their effects on yield and quality of pineapple cv. Kew. All the chemicals were sprayed when the average number of leaves per plant was 30 to 40 and the time of application was after 5:00 pm during the month of December 2007. Earliest fruit maturity was recorded with T6 application. Maximum yield per hectare (without crown) of 62.46 tonnes was obtained with T1 application while the lowest of 19.95 tonnes was recorded with control (T8). Among the different treatment combinations, highest TSS content was found in T5 (16.22) followed by T3 (16.08) and T1 (16.07). The juice recovery (ml/100 g pulp) was highest in T3 (78.84) followed by T1 (78.16) and T6 (76.12). Highest Ascorbic acid (mg/100 g fruit) was observed in T4 (98.26), followed by T5 (89.35) and T6 (85.36). Lowest acidity were recorded in T2 & T3 application followed by T4 and T5. The lowest and the highest values of these parameters respectively was recorded with control. The maximum fruits as well as higher yield per hectare with crown (82.60 tones) was found under T1, followed by T2 (73.47) and T7 (71.23).

#### **Inducing pineapple mutant by Ethyl Methane Sulphonate (EMS)**

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Mutation-breeding is one important tool in developing better-performing varieties. Pineapple variety Comte de Paris (Queen Group) was famous for its crisp with sweet aromatic flavor in China. This variety had been planted in Zhanjiang, China for more than 60 years. However, its small fruit size, deep eyes, and low yield made it unsuitable for canning. In this study, Pineapple calli, and tissue culture shoots (approximately 1.5 cm high) induced from Comte de Paris, were treated for 1, 3, 5, and 10 h in the presence of EMS at concentrations 0.5, 1.0, 2.0%, respectively. Then, calli transferred to shooting induce medium, and shoots transferred to rooting medium. Survival rate was recorded after subculture for one month. The results showed that the survival rate of calli treated with 1% EMS for 5 h was 56.3% and that of 1.5 cm shoots treated with 2% for 10 h was about 50.1%. Then 1.0% EMS for 5 h treatment was used to construction pineapple mutant population. After subculture two months, the rooted seedlings transferred to greenhouse for further study. Stripe leaf mutants were obviously obtained in M1 generations indicating EMS was effective and can be used in the pineapple mutation breeding.

#### **Performance of pineapple in arecanut based high density multi species cropping system**

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The experiment was conducted at the Horticultural farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during the years 2006-09 with pineapple cultivar Kew as one of the component crop in the three year old arecanut based high density multi species cropping system. The pineapple was planted in the system in three different spacing of arecanut (2.7m X 2.7m, 2m X 2m, 1.75m X 1.75m). Pineapple planted in the wider spacing (2.7m X 2.7m) resulted in higher growth, higher TSS, higher sugar content and lower acidity compared to other spacings confirming better quality owing to more light penetration. In the closer spacing (1.75m X 1.75m) of arecanut and banana all the characters except acidity was lower resulting in moderate size and quality. It is clear that to minimize the ever increasing pressure on land and more area under plantation crops particularly arecanut and coconut should be brought under HDMSCS incorporating banana and pineapple as component crops which grow very vigorously with good quality and fetches lucrative market prices.

### **The effect of application rate and frequency of application of ReTain (aviglycine) on the inhibition of natural flowering of queen pineapple in South Africa**

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Natural induction of flowering (NI) is a severe problem in the production of Queen pineapples destined for the fresh market in South Africa. NI is mainly induced by short days/long nights and low temperatures, but total radiation and extremes in water supply can also play a role. In Northern KwaZulu Natal, NI occurs during the winter months (May, June), yielding an over-production of fruit in December/January with consequently lower market prices. Chemical control of natural flowering with [2-](m-chlorophenoxy) propionic acid] (Swelpine) had the adverse effect of stunting the plants and reducing sucker growth, therefore affecting available planting material. Trials were also done with aviglycine, an ethylene biosynthesis inhibitor. In 2008 it was found that aviglycine at 100 mg L<sup>-1</sup>, applied every two weeks from May to the end of July (6 applications), reduced natural flowering from 33.5% in the control to 1.5%. When aviglycine was applied before and after a predicted cold front (3-4 application), natural flowering was reduced to 2.2%. Two more trials were done in 2009 with 60 and 100 mg L<sup>-1</sup>, sprayed at 7 and 14 days interval. 100 mg.L<sup>-1</sup> at a 7-day interval gave the best results (0.5% and 0%), while 100 mg L<sup>-1</sup> at a 14 day interval reduced NI to 2% (control = 45% and 14%). These application rates are though very costly and therefore more cost effective application rates were evaluated in a third trial.

### **Pineapple cultivation in Hilly Tripura with Year round production: Improving Livelihood Opportunities in Rural Areas of Tripura**

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Pineapple (*Ananas comosus* L.) is a natural crop and most important fruit crops of Tripura, since the diverse agro-climatic condition, fertile soil, slightly acidic, sub-tropical climate and abundance rainfall area enriched with undulating tilla land type with varying degree of slope and play a vital role to check soil erosion and can stand even with minimum care orchard. The two important varieties Kew and Queen are grown in different parts of Tripura. Area under pineapple cultivation in Tripura is 5,180.00ha and production is 1.06 M.T. However, area under cultivation queen variety is more than the Kew. Queen is most popular and excellent cultivar of Tripura for fresh consumption. Pineapple crop does not flower uniformly even after physiological maturity. The 80% of pineapple ready for harvest with short period of 2-3 months (May-June- July) in Tripura with huge production. During the period, huge market glut is noticed in almost all the market places of the state and creates problems as the fruits are highly perishable in nature. During May to July the state usually receives high rainfall accompanied with high relative humidity and temperature which deteriorates the keeping quality of pineapple and because of that the farmers are getting very less price. In order to overcome the problem, Year Round Production by using different planting material like different grade of Suckers/Slips (300g, 600g and 900g), Staggered planting from April to October at monthly interval followed by chemical induction by application of ethrel at 25ppm at 38-40 leave stage affect off season flowering, fruiting, fruit maturity and yield. Moreover, it playing a vital role in nutrition, livelihood opportunity for rural and Tribals areas of state for employment and income generation. This paper would focus the potentials of pineapple and their utility in rural and tribal areas of Tripura.

### **Mechanized system for large scale pineapple production on mineral soils in Malaysia**

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Malaysia is one of the top pineapple producers in the world with the acreage increased steadily from less than 10,000 ha in 2004 to about 16,000 ha in 2007. Within the same period, the national production has increased more than two folds. However, there are issues and problems besetting the pineapple industry with regard to the availability of farm labour and the associated low labour productivity under the manual operation and the high cost of production, impacting the development of the industry. It has been acknowledged that mechanized farm operation is among the best long term options to overcome the above mentioned field production constraints. The introduction of farm mechanization in many crop productions has enabled producers to dispel their worries about farm labour shortage especially during peak hours. More importantly, larger farm are now possible to operate under mechanized operation. The economy of scale in crop production can mitigate the issue of possible unwarranted increase in the production cost accrued with high farm investment under mechanized system. There are numerous pineapple machineries available in the local or overseas markets. However, the operation and working efficiencies of these machineries have not been tested under local climate and soil conditions. MARDI has undertaken a study on the development of a mechanization package for commercial scale cultivation of pineapple on mineral soil from planting to harvesting. The machines have been tested and evaluated in LADANG FIMA pineapple plantation in Kluang, Johor. The study has indicated that the machinery system evaluated can be of some potential for use in large scale production of fresh pineapples for both domestic and export markets. The paper will discuss on the performance characteristics of the various pineapple machinery systems identified for mineral soil conditions.

### **The red soil exchangeable magnesium and effect of magnesium fertilizer on pineapple in red soil region**

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The main upland soils of Guangxi contain 10.9-370.6 mg/kg exchangeable magnesium (Mg). Some soils commonly used for crop production contain exchangeable magnesium under 70 mg/kg. This is true for the lateritic red earth, latosol and silicosol. According to the statistics of 45 field experimental results, effect of magnesium fertilizer for crops with contents of soil magnesium fertilizer for crops with contents of soil exchangeable magnesium negative correlation:  $Y = 10.95 e^{-0.30X + \ln X}$ ,  $r = -0.5777^{**}$ . The response to application of magnesium fertilizer, yields of pineapple increased 6.77-15.62%.

### **Sustainable management of P and K fertilizers in pineapple (*Ananas comosus*) cultivation on tropical peat soils**

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In Malaysia, pineapples are uniquely cultivated on peat soils. However, important nutrients such as P and K requirements based on their use efficiency and loss through leaching for pineapples grown on peat have not been well researched. This paper reports on P and K use efficiency and their leaching losses under a conventionally recommended fertilization regime in pineapple cultivation on a peat soil. The study revealed that P and K recovery from applied P and K fertilizers in pineapple cultivation on tropical peat soil were low. At a depth of 0–10 cm, there was a sharp decrease of soil total P and K, exchangeable P and K, and soil solution P and K days after planting (DAP) for plots with K fertilizer. This decline continued until the end of the study. Soil total, exchangeable, and solution P and K at the end of the study were generally lower than values before the study. There was no significant accumulation of P and K at depths of 10–25 and 25–45 cm. However, P and K concentrations throughout the study period were generally lower or equal to their initial status in the soil indicating leaching of the applied P and K and partly explained the low P and K recovery. Phosphorus and K losses through leaching in pineapple cultivation on tropical peat soils need to be taken into consideration in fertilizer recommendations for efficient recovery of P and K. This is important because it is not possible to build up P and K contents of peat soils by saturating the exchange complex.

### **Quality of organic pineapple produced by using 'pine organic' fertilizer**

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The objective of this work is to monitor the quality of organic pineapples planted by using "Pine Organic" fertilizer. In this case, Maspine type pineapple was selected as a trial plant. The cultivation plot was divided into two plots called 'Control' and 'Pine Organic'. The Control' plot was used a conventional fertilizer while the 'Pine Organic' plot was used a bio organic fertilizer by using Effective Microorganisms (EM) technology. The time duration for the Maspine pineapple cultivation was 1 year and 4 months on the farm. Two parameters to check the quality of the pineapple produced in this work were a plant physical quality and secondly, the chemicals contents of fruits and leaves. The physical qualities analyzed were i) stage of maturity index, ii) color of leaf, iii) number of leaf produced, iv) length of leaf, v) length of root, vi) length of bark and vii) total weight of pineapple plant. The chemicals content quality involved an analysis of macro and micronutrients element, pH level, total soluble Brix level, total titrate acidity level, protein content, vitamin C content from Maspine leaf, fruits and fruit color. The results obtained from the Pine Organic' plot showed a better quality compared by the control plot. In this work, it can be concluded that the best harvest stage for the Maspine cultivation is during the stage of maturity index number 2.

### **Development of bio organic fertilizer from pineapple waste using effective microorganism (EM) technology**

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The development of this bio organic fertilizer was focused on the enrichment of macronutrient elements such as Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg) and Calcium (Ca) and micronutrient elements such as Boron (B), Molybdenum (Mo), Sodium (Na), Iron (Fe) and Manganese (Mn). Two formulations were developed for the bio organic fertilizer. The sources for the first formulation (Formulation A) of the are pineapple wastes (include leaf, bark and root) as a carbon source, rice bran as a trace element supply, quail manners as a nitrogen source, molasses as a glucose supply, Effective Microorganisms (EM) as an activator and water as a media for the bacteria growth in the fertilizer and as an oxygen supply to the EM. The composting activities took place 7 to 10 days to complete. After the composting process, a chemical content analysis has been done to determine the macro and micronutrients elements. This formulation was then compared by the second formulation, Formulation B. In Formulation B, the ingredients were similar with Formulation A with extra addition of 10% (w/w) of burn rice husk. The analysis results showed that the nitrogen content in Formulation A 0.0015% was increased to 0.98% in Formulation B, the phosphorus content in Formulation A 0.00021% was increased to 0.98% in Formulation B and the potassium content in Formulation A 0.00003% was increased to 11.64%. In conclusion, with the enhancement of rice bran, the macronutrient elements can be improved. The bio organic fertilizer by using EM technology was named by MPIB as Pine Organic' for commercial used. From this encouraging result, a research on pineapple waste by using EM technology will be carried out to be more specific for root, leaf and pineapple fruit development.

### **Flower forcing technique by ethephon in pineapple**

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Flower forcing is a crucial in pineapple cultivation, especially for those cultivars which cannot flower regularly and naturally. Ethephon is the most popular pineapple flower forcing agent used in China due to its low price and convenient handleability. For most pineapple cultivars, flowering can be induced effectively by Ethephon and the fruits can be harvested throughout the year. However, the appropriate concentration of Ethephon solution for pineapple flower forcing differed from both cultivars and climates. In this study, experiments were conducted to investigate the forcing technique on various cultivars in different seasons by ethephon, effects of different concentrations of ethephon solutions (100-800 mg/L) and different additives (Urea and  $\text{KH}_2\text{PO}_4$ ) on the fruit size, fruit weight and fruit quality of pineapple. Results showed that for cultivars 'Comte de paris', 'Tainong 20' and Pearl', ethephon solution of 200 mg/L were the best for flower initiation induction in warm season (from June to September) and 400 mg/L in cool season (from October to May), with a flowering rate of 100%; for 'Smooth Cayenne', the concentration is much higher, being 400 mg/L in warm season and 600 mg/L in cool season. For 'Tainong 13', 800 mg/L is the optimum

concentration. Both the fruit size and fruit weight, as well as the D leaf length, D leaf weight and fruitlet number decreased significantly as ethephon concentration increased from 200 mg/L to 400 mg/L. There were no significant difference on the total soluble solids. 1% Urea and 0.4% KH<sub>2</sub>PO<sub>4</sub> applied in the 200 mg/L ethephon solution increased the fruitlet number and fruit weight of 'Comte de paris', resulted in significantly increased yield. There was no significant difference on the total soluble solids.

#### **Effect of planting density on growth, development and yield of cayen pineapple in irrigation procedures in Nghe An province**

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A study on effect of planting density on growth, development and yield of cayen pineapple in irrigated cultivation procedure in Nghe An province was carried out at the Nghe An Fruit Company from July 2007 to October 2009 on Chinese cayen pineapple variety. Planting densities applied in experiments were from 57,000 to 78,000 crowns/ha; fertigation was done through a drip irrigation system of TORO made in Australia. The evaluation results after 2 crops showed that planting density affected growth and yield of Cayen pineapple. In the scope of experimental planting densities, increasing planting density tended to increase plant height and decrease width of leaf D; flowering percentage gradually reduced as treated by calcium carbide in off season condition. When the planting density exceeded 71,000 crowns/ha, obtained mean fruit weight was smaller than lower planting density ones; The highest yield was given by treatment of 66,000 crowns/ha at 85.70 86.32 tons/ha; the lowest yield was given by treatment of 78,000 crowns/ha at 68.91-73.27 tons/ha. Different planting densities did not significantly affect quality criteria of cayen pineapple fruit.

#### **Bioaccumulation of Hg, Pb, As and Cd by pineapple (*Ananas comosus* L. Merr) var Giant Kew and its implication as an agroforestry crop for ex tin mines in Peninsular Malaysia**

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An agoforestry trial was conducted at an ex tin mine located at Research Station of FRIM, Bidor, a selected variety of pineapple (*Ananas comosus*) var. sugarloaf available in the market was planted on sand tailings treated with four factors of soil enrichment including control, mesocarp fiber, good mineral soils and a combination of good mineral soils and mesocarp fiber. A complete randomized design was employed to determine the vegetative growth of pineapple affected by the four treatments, and the finding at 8 months after planting showed that good mineral soil treated plots had significantly greater blade length than others. Pineapples grown on soil alone treated plot significantly differ on all vegetative growth parameters namely leaf number, height of the crown and its crown diameter than those plants grown on pure sand. In addition, soil alone treated pineapple produced significantly heavier oven dry weight of leaf but mesocarp fiber and good mineral soil treated plant had significantly the largest photosynthetically leaf area due to significantly the higher number of leaf. Hence, a combination of mesocarp and soil treated sand tailings would promote vigorous vegetative growth of the pineapples.

#### **Effects of soil treatments on vegetative growth of pineapple (*Ananas comosus*) var. sugarloaf grown on sand tailings**

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An agoforestry trial was conducted at an ex-tin mine located at Research Station of FRIM, Bidor, a selected variety of pineapple (*Ananas comosus*) var. sugarloaf available in the market was planted on sand tailings treated with four factors of soil enrichment including control, mesocarp fiber, good mineral soils and a combination of good mineral soils and mesocarp fiber. A complete randomized design was employed to determine the vegetative growth of pineapple affected by the four treatments, and the finding at 8 months after planting showed that good mineral soil treated plots had significantly greater blade length than others. Pineapples grown on soil alone treated plot significantly differ on all vegetative growth parameters namely leaf number, height of the crown and its crown diameter than those plants grown on pure sand. In addition, soil alone treated pineapple produced significantly heavier oven dry weight of leaf but mesocarp fiber and good mineral soil treated plant had significantly the largest photosynthetically leaf area due to significantly the higher number of leaf. Hence, a combination of mesocarp and soil treated sand tailings would promote vigorous vegetative growth of the pineapples.

#### **Availability of Maintain CF 125 for commercial production of pineapple planting material**

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'Smooth Cayenne' pineapple (*Ananas comosus* L. Merr) is a perennial plant which is grown commercially in Hawaii and other parts of the world. It is self incompatible in producing seedless fruits. In the absence of seeds, pineapple must be propagated from vegetative parts, referred to as slips and crowns. Slips are leafy shoots originating from auxiliary buds borne on the peduncle, and crowns are leafy structures that develop on the fruit. High yielding Smooth Cayenne varieties grown commercially produce very few slips. Therefore, the principal naturally occurring source of the planting material is the crown of the pineapple. The pineapple production systems can be broadly divided into two types, cannery and fresh fruit operations. In cannery operations, crowns are removed from the fruit before processing. These crowns may serve as a source for planting material. In fresh fruit operations, the fresh fruit is sold with crowns and as a result, the pineapple growers must rely on slips as a source for planting material. Maintain CF125 has been found to be very useful for producing the planting material, especially in situations where most of the pineapple production goes into fresh fruit operations. Maintain CF125 (containing chlorfurenol as an active ingredient) is the only commercially available product on the market for the production of sliplets which are used as the pineapple planting material. This product is now registered in the United States, Australia and a few countries in Central and South America. Maintain CF125 is applied at 0.6 to 1.2 kilograms active ingredient in 2000 to 3000 liters of water per hectare to vegetatively mature plants in combination with ethephon. A second application may be made after about 10 days' interval. Maintain CF125 is applied 6 to 8 months prior to desire planting pineapple material. It has been shown that the application of Maintain CF125 would result in the production of uniform and quality planting material which in turn contributes to the quality of the farm operations. Maintain CF125 serves as a critical component in producing high quality sliplets which will

yield superior pineapple fruit in cost effective manner. Maintain CF125 induced production of pineapple planting material is a unique phenomenon in agriculture and is superior to non chemical alternatives such as stump sectioning and meristem tissue culture.

#### **Forcing of Tainon 17 pineapple with calcium carbide (CaC<sub>2</sub>) and/or ice cold stress under field conditions**

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Calcium carbide (CaC<sub>2</sub>) has been used for large scale induction of reproductive development in pineapple. Over application of CaC<sub>2</sub> to ensure synchronized flowering in pineapples grown for fresh markets may increase the cost of forcing, despite posing serious threat to human health. This investigation was aimed at exploring the forcing effectiveness of CaC<sub>2</sub> prepared with ice (0°C) water and compared with that of CaC<sub>2</sub> prepared in tap (25°C) water as indicated by the inflorescence emergence rate. Two applications of CaC<sub>2</sub> solution prepared in ice cold water at a 48 h interval promoted a significantly higher percentage of inflorescence emergences than CaC<sub>2</sub> solution prepared using tap water at 25°C. At 70 days after treatment, plants treated with the tap water solution reached 50% inflorescence emergence whereas plants treated with the ice-water solution had completed inflorescence emergence. We propose that the use of a CaC<sub>2</sub> solution prepared with ice water could reduce the number of CaC<sub>2</sub> applications required to effect forcing in pineapple and also reduce the cost of forcing. In another field experiment (2008-2009 season), reproductive development of Tainon 17 pineapple plants treated 3-4 times with ice water or ice crystals was not induced by the cold stress on days having a mean night temperature of 25°C or above. This observation suggests that a cooler night temperatures, perhaps below 20°C at least for the duration of the ice treatment is necessary for the successful induction of flowering with ice cold stresses under field conditions. Further confirmatory experiments are required to ascertain the exact roles played by day and night temperature on the forcing efficiency of ice treatments.

#### **Micropropagation of pineapple var. Maspine through direct and indirect regeneration system**

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Maspine is a complex hybrid of five varieties of pineapple with various special traits of piping-leaf, high sugar level, yellowish gold colour and resistant to certain plant diseases, Bacterial Heart Rot (BHR). Therefore, Maspine demonstrated high suitability to be planted in certain environmental condition which is conducive towards the BHR. With all the positive characteristics showed by this variety, it will projected the suitability of expanding the Maspine planting area of up to 35,000 hectare by the year 2010 in Malaysia. In order to promote massive planting area with constant quality of plant, tissue culture of Maspine were done using direct regeneration of meristem from slips. Explants were cultured on Murashige and Skoog (MS) supplemented with 3.0 mg/L 6-Benzylaminopurine (6-BAP), followed by monthly subculture onto the same medium every month for 3 to 4 months to obtain multiple shoots. By using this media, a single slip can produce more than 600 plantlets after 5 months of culture. Other than that, indirect regeneration system was introduced to facilitate better and higher production of planting materials. It was done by culturing the leaf base of in vitro shoots which were cut into 5mm x 5mm in size and subjected to callus induction medium, containing MS + 3 mg/L Picloram. From 976 leaf bases, 12.3% produce friable callus, 4.7% scalp-like structure, 3.8% compact callus and 3.1% shoot-like structure. All types of calli obtained were then transferred to solid regeneration medium to regenerate plants.

#### **Session 4: Pest and Disease Management**

##### **Complete lab on a chip system for simple and rapid detection of pineapple mealy bug wilt associated viruses (PMWaVs)**

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Pineapple mealybug wilt disease is a devastating disease caused by pineapple mealybug wilt associated virus (PMWaV). To prevent the disease occurrence and yield decline associated with the PMWaVs, method for a rapid screening of virus is required to eliminate the presence of the virus in infected planting materials. We have developed a simple complete lab on a chip system for a rapid detection of PMWaV through the detection of a specific domain on coat protein gene. The chip was fabricated using PDMS with combining the reaction zone for RNA extraction and amplification with the microchannels for the inlet and the outlet of the reagents. RNA extraction was performed on chip. Trapping of RNA was by magnetic field set at the fore part of the reaction zone. Rapid RNA extraction from apparent lesions was performed based on chaotropic effect of oxide resin trapped at chip's reaction zone, where RNA was amplified through reverse transcription and direct cDNA amplification using isothermal reaction with highly specific primers to six domains of coat protein gene simultaneously upon elution. Resulting fluorescence signals of the DNA was detected visually. All processes were completed within 40 min. The testing on this chip showed high sensitivity, with a detection limit at 50 copies of DNA/reaction. No cross reactivity was observed from the samples of other related viruses. The chip reported here provided a rapid and simple method for the detection of PMWaV.



### **A simple and rapid colorimetric detection of pineapple mealy bug wilt associated viruses (PMWaVs) based on gold nanoparticle**

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Pineapple mealybug wilt disease is a devastating disease found in most areas where pineapples are grown commercially. Strong correlations between disease symptoms and pineapple mealybug wilt associated virus (PMWaV) have been addressed. Since pineapple is vegetatively propagated, therefore a rapid and reliable screening technique of virus is needed. We have developed a rapid colorimetric PMWaV detection method with high degree of accuracy based on gold nanoparticle's plasmon property. Detection processes were based on the specific cDNA amplification of common element in coat protein gene of both PMWaV 1 and 2 at 65°C using isothermal temperature platform. DNA signals were then measured visually through a colorimetric change of gold particle (20 nm) after probe hybridized to the target gene products. The method could detect both viruses and had a limit of detection at 10 copies of cloned viral DNA. No cross reactivity was observed from samples contaminated with other viruses. Detection could be completed within 40 min of operation without the need of thermocycler. This method constitutes a basis for a rapid, simple and accurate detection of pathogenic virus.

### **Development of degenerated primers to detect different viruses associated with mealybug wilt of pineapple**

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Pineapple (*Ananas comosus* var. *comosus*) is propagated vegetatively which facilitates the production of planting material but leads to dissemination of viruses. Mealybug wilt of pineapple (MWP) is a devastating disease of pineapple worldwide. The disease is characterized by severe leaf tip dieback, wilting of the leaves and can lead the plant to die. The MWP is associated with three Ampeloviruses species, Pineapple mealybug wilt associated virus 1 (PMWaV 1), PMWaV 2, and PMWaV 3. Besides to the direct damage on plant production, there is great difficulty to select plantlets for planting because some infected plants exhibits no symptoms. The virus can be detected by RT PCR using specific primers; however for phytosanitary purposed, it's interesting to screen plant material for all viruses simultaneously in order to save time and cost. With this objective, degenerate primers were designed and tested to detect PMWaV 1, 2, 3 in pineapple hybrids of Embrapa breeding program. Using the degenerate primers in a RT PCR, it was possible to amplify a fragment of the expected size only in infected samples. Also, the reverse degenerated primer was combined with each of the forward specific primers in order to identify the PMWaV species present in infected plant. These two approaches led to detection of PMWaVs in 20/27 asymptomatic hybrids, with higher prevalence of PMWaV 1 (12 plants), PMWaV 2 (10 plants) and PMWaV 3 (7 plants). A total of 12 plants present mixed infections. The results show that degenerated primers provided a reliable alternative to plant material certification with about 30-40% on cost reduction and short period of indexing.

### **Effect of methyl bromide fumigation against Mealy Bug on pineapples var. N36 and Josapine**

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Pineapples fruit of N36 and Josapine variety were subjected to Methyl bromide (MB) fumigation of doses of 24, 28 and 32 gm/M for two hour against the pink mealybug, *Dysmoccus brevipes* (Cockerell). Fumigation was conducted during the early morning hour (1.00 am) using tarpoline sheet covered over angle iron rectangular structure where the fruits were housed. Fruits were fumigated while in packing boxes with holes at the bottom and cover ends and the handle. A Box of Josapine pineapple contained 8 fruits while those of N36 variety contained only 6 fruits. The average weight for N36 is 1.8 kg while those of Josapine are 1.2 kg. All the three doses of Methyl bromide tested effectively killed 100% of the mealy bugs present on fruits in the sampled boxes. Both Josapine and N36 were injured by the treatment causing fruits to be blemished and darkened at the core and neck region of the fruits. The details of conducting and handling the fumigation experiments were elaborated and the results affecting both the insects and fruits discussed.

### **Varietal responses to Mealy bug infestation on pineapples grown on peat soil**

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Six commonly grown pineapple varieties namely Gandul, Selangor Sweet, 'MD-2', Josapine and N36 were planted on peat soil of MARDI Jalan Kebun in Selangor. The plants are subjected to standard agronomic practices of planting pineapples, where suckers were subjected to insecticide treatment before planting. The planting distances of 1x2x3 were practiced, where plants were spaced 1 feet apart, 2 feet between rows and 3 feet between planting beds. Fertilizer was applied as according to the standard operational procedures. The plants are allowed to grow until maturity and allowed to flower freely without induction. The plants were weeded manually and no insecticide or fungicide used for pest control. Upon maturity plants were inspected for mealy bug infestation and plant sampled randomly and scored. This paper discusses the level of mealy bug infestation according to variety, the association of ants to mealy bugs, the occurrence of other pests and also beneficial organism in pineapple ecosystem.

### Evaluation of the potential of different rotation crops to control *Rotylenchulus reniformis* and *Hansenella* sp in pineapple

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Pesticides to control soil born parasites (nematodes and symphylids *Hansenella* sp) are no more available in many pineapple production areas due to the market requirements for no pesticide residue in fruit and vegetables. We tested different possible rotation crops for their potential in decreasing the inoculum of *Rotylenchulus reniformis* and *Hansenella* sp, the two main soil-borne parasites on pineapple in Martinique. A description of the experimental design in greenhouse and climatic chamber is given. *Crotalaria juncea* and *C. spectabilis* proved to be the most efficient plants among those tested in reducing both parasites inoculum.

### Occurrence of cucumber mosaic virus on pineapple in Malaysia

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Cucumber mosaic virus (CMV) is a cosmopolitan plant virus with wide host range. A survey to determine the occurrence of CMV on horticultural crops was carried out in 2008. A total of 161 leaves of pineapple showing symptoms of chlorosis, yellow spots, reddening of leaves and necrosis at leaf tip were collected. ELISA and RT-PCR were used to detect for the presence of CMV. Results of the survey showed that 3.1% of the samples collected were found to be infected by CMV. So far, the virus has not been reported in Malaysia. Results of the survey also showed that the virus was only limited to the state of Johore only. Even though, the incidence of CMV on pineapple was low, nevertheless its impact on other crops will be great since it has a wide host range and also the life span of pineapple is about 18 months which can be an effective alternate host for the virus.

### Screening of MARDI's Josapine somaclonal variation in the field for selections that are BHR resistant or tolerant

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Pineapple has been identified as a Malaysian priority crop to increase its production. Therefore, in 1996 MARDI has developed the new hybrid Josapine to cater the market demand. However, bacterial heart rot (BHR) disease caused by bacterium *Erwinia chrysanthemi* is a serious threat that limits the production. It has been recorded that Josapine was very susceptible to the disease. At the time of the disease epidemic, the losses can rise up to 64% for this cultivar. Therefore, in 2004 MARDI has developed a strategy to improve Josapine by exploitation of heritable somaclonal variations using tissue culture technique. This strategy was to obtain a selection of somaclones for BHR disease resistance and with good agronomic traits. Therefore, the present research was to screen the second generation of MARDI's Josapine somaclones in the field at MARDI Kluang, Johor. From these screens, some potential BHR disease resistance Josapine somaclones were selected with good agronomic characteristics such as high total soluble sugar (TSS), reasonable fruit weight, single crown with low number of suckers and good flesh color.

### Effect of *Dicranopteris linearis* debris on weed emergence and pineapple growth in pineapple field

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The project was conducted to study the potential of *Dicranopteris linearis*, an allelopathic plant, as an organic mulching material for weed control in pineapple field. The result revealed that debris of *D. linearis* significantly reduced weed emergence in pineapple field. After 3 months of treatment, the *resam* at the rate of 1.5 kg/m<sup>2</sup> could reduce approximately 95% of weeds emergence. In the field treated with 3.0 kg/m<sup>2</sup> of *resam*, only 1% of weed successfully emerged. *Dicranopteris* did not cause detrimental symptom on pineapple plants. The number and length of leaves and fresh weight of pineapple plants in the *Dicranopteris*-treated areas were higher than those in the non *Dicranopteris*-treated areas.

### Plant parasitic nematodes associated with pineapple in peninsular Malaysia

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A survey was conducted in pineapple field within 10 states in Peninsular Malaysia to identify the predominant plant parasitic nematodes associated with pineapple. Thirteenth nematodes species belonging to nine genera were detected. The predominant nematode species on mineral soil were *Rotylenchulus* and *Helicotylenchus*. While on peat soil, *Paratylenchus* sp. was found in high population and was associated to low yield of pineapple production. Others genus that were found are *Criconeoides*, *Meloidogyne*, *Pratylenchus*, *Longidorus*, *Xiphinema* and *Tylenchorhynchus*.

### Alternative control of pineapple Fusariosis on Irrigated MD-2 cultivar in Brazil

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Pineapple fusariosis is a devastating disease which affects all pineapple producing areas in Brazil. It is caused by the fungus *Fusarium subglutinans* which attacks the slips, the plants and, mainly, the fruits. The spores penetrate the fruits through the natural opening of the flowers. For this reason the traditional control is done with fungicides sprayed individually over each fruit which is being formed during the four week period that the flowers remain open. Once established inside the fruit *F. subglutinans* causes an aggressive rot which takes over the fruit and

causes its complete destruction. The Perola and Smooth Cayenne cultivars are susceptible to fusariosis but the disease can be controlled with fungicides. However, the MD-2 cultivar has been found to be extremely susceptible to *F. subglutinans* with difficult control in irrigated commercial fields. Usually excessive residues of pesticides are found making exportation impossible. Therefore this research had the objective of testing an alternative control of pineapple fusariosis with different dosages of citric extracts, food preservatives, and pyroligneous acid and of tannins of cultivated *Acacia mearnsii*. These tannins are extracted and commercialized worldwide for utilization on the leather and tanning industries. Four experiments involving almost 15,000 plants were carried out in a private pineapple farm located in the semi-arid zone of the state of Bahia, Brazil in 2008. The experimental design was of randomized blocks with 8 treatments and four replicates. The fruits were evaluated immediately after the harvest in search of symptoms of fusariosis rot. Most of the alternative products were inefficient against this disease except for the tannins of *A. mearnsii*. In this experiment the incidence of fusariosis was reduced from 72% in the control treatment to 22% in some tannins treatments.

#### Evaluation of ornamental pineapple hybrids for resistance to *Fusarium subglutinans*

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*Fusarium subglutinans*, the causal agent of the pineapple fusariosis, is the most serious problem of that crop in Brazil. The cultivation of resistant varieties is the most efficient control measure and this concept is also useful to ornamental plants. This work aimed to evaluate ornamental pineapple hybrids to resistance to fusariosis. Forty hybrids from five crosses (FRF-22 x FRF-1387), (FRF-1392 x FRF-32), (G-44 x FRF-1387), (FRF-1392 x FRF-224) were evaluated. Pineapple slips, about 25 cm long, were wounded at their bases with a needle, 2 mm in diameter, and immersed into a conidial suspension for about three minutes and then transferred to a greenhouse. After 90 days, evaluation was performed considering both internal and external symptoms and a scale of notes was applied. The experiment's design was a completely randomized one with six replications and two controls: cv. Perola (susceptible) and PEXSC73 (resistant). The results showed that 13 hybrids were resistant, 7 were moderately resistant and 20 were susceptible. Nevertheless, in the cross FRF-1392 x FRF-224 100% of the hybrids was resistant. The behaviour of the controls was adequate to give support to the results obtained in the present work.

#### Pineapple germplasm and Fusariosis resistance

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Pineapple breeding programs in Brazil are based on genetic resistance to *Fusarium subglutinans* f. sp. *anas* the causal agent of the pineapple fusariosis; the most serious problem in Brazilian pineapple fields. Yield losses due to fusariosis disease vary according to harvesting period and growing season as well. The genetic resistance is considered the most effective and economic measure of disease control. The Pineapple Germplasm Bank at Embrapa Cassava & Tropical Fruits has a total of 616 pineapple accessions of pineapple and related species. Since 80's, several experiments were carried out at Embrapa Cassava & Tropical Fruits, under greenhouse or nursery conditions, in a completely randomized design with five replicates, in order to evaluate the reaction of pineapple genotypes to inoculation, by the wounding and dipping technique, with *F. subglutinans* f. sp. *anas*. A total of 273 genotypes were evaluated for resistance to the pathogen. The reference genotypes were the Smooth Cayenne and Pérola cultivars (susceptible) and Perolera and Primavera (resistant). Evaluations showed that 144 genotypes (52, 7%) showed no symptoms of the disease, while the remaining 129 genotypes (47, 3%) behaved as susceptible to *F. subglutinans* f. sp. *anas*. Among the resistant genotypes, 105 belonged to the *Ananas comosus* var. *comosus*, the species with edible infructescence. All inoculated plants of the Pérola and Smooth Cayenne cultivars, control genotypes for susceptibility, showed fusariosis symptoms at evaluation. These data indicate that resistance to the pathogen is of fairly common occurrence among pineapple genotypes. These genotypes will be submitted to an agronomical evaluation in order to be indicated for use in the breeding program aiming to generate new pineapple hybrids.

#### Nematodes on pineapple grown on peat soil

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Pineapple cultivar Gandul grown on peat soil is the most popular cultivar grown in Malaysia for canning. Since the introduction of this new cultivar, commercial farms have been experiencing yield reduction exceeding 50% after more than several crop cycles. It has been theorized that high rate of leaching of nutrients, inadequate fertilizer regimes and cultivar genetic disruption and degradation can no longer sustain economic yield. After extensive crop and soil sampling and evaluation, the yield reduction had been associated with the nematode *Paratylenchus* sp. Evaluation of some control methods showed that chemical control was not able to reduce the nematode population. Clean fallow for nine months was better than natural fallow in reducing nematode population. Evaluation of the pineapple germplasms showed wide range of associations with this nematode based on the population of nematodes in the soil and roots of the plant. Gandul cultivar is highly susceptible to *Paratylenchus* sp. based on the population level in the soil and roots.

#### Pineapple integrated pest management; an overview

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Consumers are very concerned about food safety and environmental protection as well. Such a situation imposes changes on conventional crop production. Regarding to the pineapple crop, control of pests and diseases all over the world is based on calendar applications of pesticides. On the other hand, pineapple orchards conducted under integrated pest management strategies are in accordance with environmental and food safety concerns. The concept of integrated pest management (IPM) appeared in 1968 and by 1989 it was a common strategy all over the world.

IPM implementation results on reducing the use of pesticides and promotes the use of pesticides approved by governmental agencies. Special measures are also applied to reduce pesticide applications such as: Introduction of predatory wasps and mites; crop rotation to reduce soil pest populations; use of cover crops to attract beneficial insects; monitoring pests and disease development; planting of disease-resistant varieties; and use of biological pesticides. Considering that the success of any IPM program relies on a good understanding of the crop production system as well as of the ecology and biology of each pest or disease, pineapple growers should be continuously trained on IPM procedures.

#### **Pineapple research and development status in Center for Tropical Fruit Studies, Bogor Agricultural University**

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Indonesia is the major production country of pineapple, and in order to improve competitiveness of pineapple industry in Indonesia, Center for Tropical Fruit Studies, Bogor Agricultural University has been conducting comprehensive research from genetic improvement to postharvest handling. Genetic improvement researches consist of germplasm collection and characterization, molecular marker utilization, inheritance studies and new variety development. Research on plant propagation focused on to mass rapid propagation through establishment tissue culture protocols, acclimatization method, and high throughput micro section. Field production research consists of vegetative growth study, nutrient status establishment, flower induction, fruit development, and standard operating production implementation. Integrated pest management covered biology of mealybug (*Desmoccoccus brevipes*), molecular characterization of PMWaV, mealybug parasitoid study, and mealybug wilt control management. Postharvest research comprise of postharvest physiology, postharvest handling and fruit processing.

#### **Beekeeping in pineapple smallholdings: A case of *Apis mellifera***

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Beekeeping, a traditional subsistence industry in coconut smallholdings, has long been ignored by many developing countries as a source of additional income to farmers and as a foreign exchange earner to the country. The industry is not something recent in Malaysia as many farmers and individuals have ventured into this lucrative project as early as in the 1980s. Since then, not many researchers have assessed the profitability of such a project under the incentive program. The states of Perak, Selangor, Melaka, Johor, Sabah and Sarawak have long been the centre for beekeeping activity in Malaysia. There are two main species reared in Malaysia, namely *Apis cerana* (local bees) and *Apis mellifera* (imported bees). The study is conducted to ascertain the benefits to beekeepers in the pineapple smallholdings under the potential incentive for agriculture and agro-based industry. It is an attempt to look at how much a beekeeper can actually earn after taking into account the incentives provided. Data for this study were collected from surveys involving beekeepers rearing *Apis mellifera* in Johor. The methods used include the common project evaluation indicators and its impact on the potential incentive. Since beekeeping project is viable, the introduction of this project to rural farmers will contribute positively to product diversification and rural development.

#### **Transmission characteristics of pineapple mealybug wilt associated virus-2 by the grey pineapple mealybug *Dysmicoccus neobrevipes* in Hawaii**

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Pineapple mealybug wilt associated virus-2 (PMWaV-2) is a mealybug transmitted ampelovirus associated with mealybug wilt of pineapple (MWP) disease in Hawaii. The characteristics of PMWaV-2 acquisition and persistence grey pineapple mealybugs (GPM), *Dysmicoccus neobrevipes* Beardsley, were measured. Some GPM were able to acquire the virus within 36 hours. Transmission efficiency of GPM in groups of 25 was 100% following a 72 hour acquisition access period (AAP). GPM remained viruliferous for up to three days after a 3-day AAP when serially transferred to virus free pineapple plants at 24-hour intervals over a 7-day period. Access to a kabocha squash, a non host of the virus, reduced the transmission efficiency and persistence of the virus. This data shows that PMWaV-2 is transmitted by the grey pineapple mealybug in a semi-persistent manner. A potential management strategy based on these findings is discussed.

#### **Session 5: Postharvest Handling and Product Development**

##### **Effect of maturity stages on chemical properties and sugar contents in Smooth Cayenne pineapple fruit**

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The effect of maturity stages on chemical properties and sugar contents of pineapple (*Ananas comosus* cv. Smooth Cayenne) fruits were studied. The fruits were harvested at 110, 120, 130, 140, 150 and 160 days after full bloom (DAFB) in rainy season crops during June-August 2009. The fruits were evaluated on total soluble solids (TSS), titratable acidity (TA), TSS/TA ratio, pH and sugar contents. The results showed that changing of TSS, TSS/TA ratio and pH were increased with harvesting time. The daily ratios of increases were 0.375 %Brix for TSS, 0.219 for TSS/TA ratio, and 0.0064 mg/100 mg for pH, respectively, whilst the TA ratio decreased at 0.0014 with harvesting time. During the harvesting period of 110-160 DAFB, the chemical properties slightly changes and the sugar contents composed of sucrose (9.2-11.76%), fructose (2.13-3.24%) and glucose (2.11-2.88%). The proportion of sucrose, fructose, and glucose were 5.5: 1.3: 1.1, respectively. It was found that harvesting period had an effect on rate of daily changes in sugar contents of pineapple.

##### **Effect of storage time on physical, chemical properties and sensory attribute of Queen pineapple fruit**

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The Queen pineapple (*Ananas comosus* cv. Phu lae) fruits were stored at 25 °C, RH 80- 85% and evaluated on physical properties (flesh colour; L\*, a\* and b\* value), chemical properties (total soluble solids (TSS), titratable acidity (TA), pH), and sensory. The results showed that

flesh colour on L\*, a\*, b\* value, TA (citric acid), and sensory score were decreased with the storage time, whilst TSS value was increased. Hence, the pH was slightly changes during the storage at day 2 10 of storage time.

#### **Morphology, physical and chemical properties of Queen pineapple fruit**

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The commercial harvesting of Queen pineapple (*Ananas comosus* cv. Phu lae) fruits was evaluated on morphology (fruit weight, size, fruitlet and shape), physical properties (ripening stages, flesh colour as follow: L\*, a\*, and b\* value), chemical properties (total soluble solids (TSS), titratable acidity (TA), and pH). The results showed that the average of fruit weight was 160 g. The fruit width and length were 64.58 mm and 61.26 mm, respectively. The minimum and maximum numbers of fruitlet (eyes) were 37-61 fruitlet/ fruit. The fruit shape was spherical and the ripening stages were 3-4. The lightness (L\* value), a\* and b\* value were 64.40, 9.72 and 36.54, respectively. The chemical properties were 12.39 °Brix for TSS, and 3.15 mg/100 mg for pH, respectively.

#### **Changes and distribution of aroma volatile compounds from pineapple fruit during postharvest storage**

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The aroma volatile compounds in both pulp and core of Tainong 17 pineapple fruit were extracted by head space solid phase microextraction (HS SPME) and analyzed by gas chromatograph mass spectrophotometer (GC MS) during postharvest storage (at day 1, 6, 9 after harvest) at 25 ±1 °C. Eighteen volatile compounds were identified, in which, esters were the most dominant, and butanoic acid methyl ester, hexanoic acid methyl ester and 3-(methylthio) propanoic acid methyl ester were all in both pulp and core. During the postharvest storage, the total content of esters increased from 65.47% to 81.18% in the pulp, but increased at the beginning and then decreased later in the core. At day 1, the content of hexanoic acid methyl ester was highest in all compounds of the pulp and core, followed by butanoic acid methyl ester in the pulp. At day 6, butanoic acid methyl ester was the most dominant and followed by hexanoic acid methyl ester and octanoic acid methyl ester in all compounds of the pulp, while hexanoic acid methyl ester was the highest and followed by octanoic acid methyl ester and butanoic acid methyl ester in the core. At day 9, hexanoic acid methyl ester and methyl-2-Methylbutyrate were the main aroma compounds in the pulp, while butanoic acid methyl ester and hexanoic acid methyl ester in the core. The content of esters increased to the maximum in the pulp (81.18%), but the minimum in the core (47.13%) at day 9, which had been considered as important class of aroma volatile compounds in not only the pulp but also the core.

#### **Surface coating treatments influence fruit weight loss and fruit surface microstructure of N36 and Gandul pineapples**

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Effect of surface coating treatments on fruit weight loss and fruit surface microstructure of N36 and Gandul pineapples stored at 100°C were carried out. The coating materials tested were; liquid paraffin and palm oil and Semperfresh. Hydrophobic emulsion (liquid paraffin and palm oil) were found to be effective in reducing weight loss in pineapples during storage at 100°C for 8 weeks. Environmental scanning electron microscope (ESEM) microstructure analysis also showed that both liquid paraffin and palm oil can effectively cover the stomata and lenticel on fruit skin which possibly reduce the moisture loss of the fruit. Surface coating treatments affect the weight loss of pineapple as significantly (p <0.05) increased weight loss of N36 pineapples was noticeable when the pineapple was treated with Semperfresh. However, significantly (p <0.05) reduced in weight loss was observed when the Semperfresh was treated to Gandul pineapples. The results revealed that the effectiveness of coating materials in the reduction of weight loss in pineapples varies according to fruit variety. Hydrophobic emulsion (liquid paraffin and palm oil) were effective in reducing weight loss in both varieties of pineapples.

#### **Effect of postharvest heat treatments on microstructure changes of N36 and Gandul pineapples**

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Effect of postharvest heat treatments on the weight loss and microstructure changes on the skin and flesh of N36 and Gandul pineapples were carried out prior to storage at 10°C. Different morphology of pineapple effect of HT and CHT on weight loss and microstructure of skin and flesh differ with different morphology of pineapple varieties. Heat treatment alone (HT) significantly (p <0.05) increase the weight loss of both N36 and Gandul pineapples. Percentage of weight loss of N36 was significantly (p <0.05) reduced when heat treatment was combined with surface coating (CHT). However, weight loss of CHT Gandul pineapples were still significantly (p <0.05) higher compared to the control pineapples. Dehydration of fruit surface (skin) and flesh near the skin during heating causes the natural epicuticular wax and surface coating applied to melt and filled the pores and cracks. These were observed in the microstructure study by environmental scanning electron microscope (ESEM). The covering of wounds and cracks by melted wax, following the heat treatment can contribute to the positive effect in protections on the skin against wound pathogens. However it may also cause negative effect to cell collapse leading to serious tissue degradation.

#### **Effect of methyl bromide fumigation on Josapine and N36 pineapples**

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Malaysian pineapple should be fumigated with 32 g/m<sup>3</sup> methyl bromide for a minimum of 2 hours for controlling pest prior to shipment to countries like China, Australia and Iran. The effect of methyl bromide fumigation on two popular cultivars of pineapple was studied. Josapine and N36 were harvested at colour index 2 and required to undergo the normal postharvest handling procedures prior to fumigation treatment. After packing, the pineapple fruits were fumigated with three different dosages of methyl bromide; 24, 28 or 32 g/m<sup>3</sup> for an exposure period of 2 hours before storage at 10 °C. Non fumigated fruits were used as a control. The fruits were removed from 10 °C after day 10 and placed at room temperature (25 °C) for another 7 days. Fumigation treatment by using methyl bromide between 24-32 g/m<sup>3</sup> for 2 hours was found to be affected the quality of both pineapple cultivars.

#### **Quality changes of pineapple (*Ananas comosus* var. Josapine) as affected by controlled atmosphere condition**

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Effect of controlled atmosphere (CA) storage on quality of pineapple (*Ananas comosus* var. Josapine) was investigated during storage at 10 °C. Pineapple fruits harvested at colour score 3-4 were bought from private farm in Johore. Physico-chemical changes were monitored during storage in atmosphere containing 3, 5 and 7% of O<sub>2</sub> with 8% CO<sub>2</sub> (balance N<sub>2</sub>). Fruits stored in the normal atmosphere were treated as control sample. The changes in colour, soluble solids content (SSC), total titratable acidity (TTA), pH, ascorbic acid and total sugar were retarded by CA treatments. There were significantly (p<0.05) differences between the CA conditions on chroma, hue angle, SSC, TTA and total sugar of Josapine during storage at 10 °C for 5 weeks as compared to control sample placed at normal condition. However, there were no significantly (p>0.05) different on lightness, pH and TTA values. The quality of Josapine was maintained and the storage life was extended for a week by CA treatment with 3-5% O<sub>2</sub> and 8% CO<sub>2</sub>.

#### **Pineapple under agri export zone of India**

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Pineapple (*Ananas comosus*) is one of the important tropical major fruits of India. Though Thailand, Philippines, Brazil, Costa Rica are the major producers of pineapple, the area under quality pineapple production is in increasing trend in India. In view of the international demand for fresh and processed pineapple products and also on account of the concentration of pineapple growing in the district of Darjeeling (Siliguri subdivision), Jalpaiguri and Cooch Behar (Sadar subdivision) of West Bengal first Indian Agri Export Zone was announced during 2001 by APEDA. This project entails development of the high value produce through research and extension by a dedicated team of personnel, setting up of processing plants by private entrepreneurs and concerted market efforts with the help of various Government Agencies like Ministry of Food Processing Industry, National Horticulture Board, Ministry of Agriculture and APEDA. High density planting and year round production of 'Kew' pineapple is the most important features of pineapple production in this zone. A few of the farmers generally follow the proper harvesting and post harvest package of practices of pineapple. They poorly handle the fruits during loading, unloading for transport. Due to lack of cool chain a heavy loss of fruits is a common scene in this zone. But with the helps from different agencies the farmers are practicing better harvesting and post harvest packages. Packaging of fresh pineapples in CFB and wooden boxes for national and international market, processing of pineapple for development of value added products are now a days in vogue. To fetch the better market price and also to utilize the market surplus during the seasonal huge production by the farmers are processed by different private companies like Dabur, Calypso to produce quality squash, canned pineapple, frozen pineapple, pineapple jam etc which are coming to the international market. This paper highlights the techniques of quality pineapple production and the post harvest operations by the agri export zones of India.

#### **Effect of temperature on the rheological behaviour of Josapine pineapple pulp (*Ananas comosus* L.)**

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The temperature effect on the rheological behaviour of 30% Josapine pineapple pulp in juice has been determined over a wide range of temperature (5 to 65 °C) by using a rotational rheometer. The speed of the rotating cylinder varied from 1 to 300 s<sup>-1</sup>. These juices, containing pulp, behaved as Non Newtonian with yield stress. The Bingham equation was observed to describe best the relationship between the shear stress and shear rate. The average value of yield stress was 0.566 Pa and plastic viscosity was in the range 0.0312 to 0.0510 Pas. The plastic viscosity decreased with an increase in temperature. The effect of temperature on their plastic viscosity can be described by an Arrhenius-type equation. The values of the Kowas 0.0038 Pas and activation energy (Ea) was 5871.10 J/mol.

#### **Effect on relation of chemical properties and acceptability of 'Smooth Cayenne' pineapple**

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The study on relation of chemical properties total soluble solid (TSS), titratable acidity (TA), ratio of TSS/TA, and pH), and acceptability of 'Smooth Cayenne' pineapple was investigated by path analysis. The results found that only the ratio of TSS/TA contributed to direct effect of acceptability score of consumer. The path coefficient was 0.239 and significant at p≤0.05. The TSS, TA and pH were indirect affected and path coefficients were 0.774, 0.187 and 0.105, with significant at p≤0.05, respectively.

#### **Effect of oxygen scavenger application to the quality fresh cut pineapple**

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The effect of application of oxygen scavenger to the quality of the fresh cut pineapple was investigated during storage at 10 and 2 °C. Rigid polypropylene containers (10 x10 cm) with the lid sealed was used for packing the fresh cut pineapple. Each packing container was inserted with one sachet of oxygen scavenger (FX -2gm). Packing system without the application of oxygen scavenger was treated as control samples. Weight loss, flesh firmness, surface colour (lightness and hue value), total soluble solids (TSS), pH, gases inpackage (O<sub>2</sub>, CO<sub>2</sub> and ethylene), sensory evaluation were determined every 2 days to the fresh cut pineapple stored at 10 °C. However, the evaluation for the samples stored at 2 °C was conducted only on weekly basis. Lower accumulation of O<sub>2</sub> was observed to the fresh cut packed with oxygen scavenger was observed to the samples stored at 10 °C. However, inconsistent values of CO<sub>2</sub> were monitored both at 2 and 10 °C. The sealed lid of the control samples packing appeared to be slightly bloated after day 7 as shown only to the samples stored at the 10 °C. No significant changes was observed to the weight loss, surface colour, flesh firmness, TSS and pH values between the oxygen scavenger packing and the control samples throughout the storage period for 7 days at 10 °C and 21 days at 2 °C.

#### **Effect of citric acid treatment to the quality of fresh cut pineapple**

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Effect of citric acid treatment on the quality of fresh cut pineapple was evaluated during storage at 10 and 2 °C. The fresh cut pineapple was mechanically sliced into small portion (5 cm) and immersed in the citric acid solution at different concentrations of 0 (control), 0.5, 1.0, 1.5 and 2.0 %. Samples stored at 10 °C were evaluated every 2 days. Whereas those samples stored at 2 °C, the evaluation was conducted on every 4 days. Lower pH values of the treated fresh cut pineapple stored at 10 °C, had pronounced effect on the microbial growth as observed on day 6 and 8. Fresh cut pineapple treated with 1% citric acid was more preferred by the sensory panelist due to the combined blend sweet and sour taste. No significant difference was observed to the tissue firmness, weight loss and flesh colour to the treated and control samples as observed both at 2 and 10 °C.

#### **Physicochemical characteristics and acceptability of pineapple salsa**

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Pineapple salsa was prepared using pineapple puree, tomato puree, chili, onion, garlic, capsicum, acid, sugar, salt and water. Ingredients were mixed, cooked and pasteurized before bottling into sterilized glass bottle. The pineapple salsas containing different levels of pineapple puree were then evaluated for the physicochemical and sensory attributes. Samples containing up to 30% added pineapple puree were not significantly different from the control in terms of overall acceptability, taste and colour. The hotness, viscosity and sourness of pineapple salsa contain 20-30% fruit puree were significantly different ( $p < 0.05$ ) compared to control samples. Increasing level of pineapple puree also resulted in increasing the total soluble solids and viscosity of the product. The colour of the product was not significantly increased with ultimate level of pineapple puree. The addition of 20% pineapple puree into the salsa formulation had increased its total dietary fiber and reduced the moisture and fat content in the final product. Pineapple salsa incorporated with 20% pineapple puree was found to be the most acceptable as compared to the other samples.

#### **Development of slicing machine for fresh cut pineapple**

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Preparation of fresh cut pineapple usually conducted manually either cube, semi circle or wedge form using manual operations, the cutting process is not uniform which caused problems during packing. Time consuming was also been raised by the operators especially for the bulk handling. Imported machines for cutting fruits into various shapes are available in the markets. However, high cost of the imported machine hinder the active use especially by small scale fruit operators. Intensive research had been conducted in developing suitable slicing machine to cater the need of local pineapple processors. Development of slicing machine was based on two systems, namely rotary or centrifugal type working condition. This study was emphasized on machine development and also involving the operating system. At normal rate, the machine is capable of slicing 360 fruits per hour. The slicing machine can easily operated, simple design, cost effective and facilitate the cleaning process.

#### **Effect of different storage durations on quality of fresh cut pineapple cv. Josapine**

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Study was carried out on the effect of different storage duration of whole pineapple fruit at 10 °C on quality of fresh cut pineapple stored at 20C. The rationale of this trial is to observe the quality acceptance of pineapple fruit exported by sea shipment which later will be processed for fresh cut processing. 10 °C and 2 °C used in this study is to represent the actual storage temperature of ship container and market retail, respectively. Results showed that firmness of flesh pineapple was slightly decreased during storage at 10 °C and after processed minimally (2 °C). The pH value was higher, whilst the TTA was lowest in minimally processed pineapple. The TSS value was significantly increased, with duration of storage as observed both at 10 °C and 2 °C. From the observation, blackheart symptom was slightly shown in fresh cut pineapple after 2 weeks storage at 2 °C. These were observed for the fruit previously stored at 10 °C for 2 weeks. Symptom for blackheart (50%) was shown to the fruits previously stored for 3 weeks at 10 °C. Symptom of blackheart was also detected to the fresh cut pineapple after 1 week storage at 20 °C. Higher standard plate count (SPC) was observed to be increases with prolong storage of whole fruits at 100C. However, the coliform count was undetectable after 3 weeks removal from 10 °C.

#### **Effect of ozonated water wash on quality of fresh cut Josapine pineapple during storage**

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The effect of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) as sanitizing treatment on qualities of fresh-cut Josapine was investigated during storage at 10°C. Fruits were pre-cooled overnight at 10 °C prior to cutting. The cut pineapples were then treated with 1% and 3% concentrations. Untreated sample was used as control. All samples were packed in rigid polypropylene container and stored at 5 °C for 10 days. The following parameters were monitored during storage; colour, firmness, pH, total soluble solids (TSS), microbiological analysis and sensory evaluation. The results showed that fresh cut pineapple treated with 3% of H<sub>2</sub>O<sub>2</sub> had a positive effect on maintaining the firmness but negatively affect the surface colour becoming pale yellow. There was no significant difference in the sensory attributes, microbial counts; pH and TSS values between the 1 and 3% H<sub>2</sub>O<sub>2</sub> treated samples as compared to the control fruits.

#### **Evaluation of the browning activity of minimally processed pineapple treated with citric acid**

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This study was conducted to investigate the effect of citric acid treatments on the browning activity of minimally processed (MP) pineapple stored at 10 and 2 °C for 7 and 14 days respectively. The MP pineapples cut in longitudinal shapes (5 cm) were treated with different citric acid concentrations; 1% (T1), 1.5% (T2) and 2% (T3). Untreated sample was used as control (T0). Samples were evaluated for colour (L, a, b and hue), pH, total soluble solids (TSS) and total titratable acidity (TTA). Activity of polyphenol oxidase (PPO) was also monitored as to relate with surface browning of the MP pineapple. Lowered pH value was observed to all treated samples (T1, T2 and T3) both at 10 and 2 °C as compared to the control samples. The activity of PPO of the samples treated with 1.5% was lowered as observed to the sample stored at 10 °C. However, inconsistent trends were shown to the activity of PPO throughout the 14 days storage at 2 °C. No significant difference was observed to the TSS, TTA and hue values of the treated and control samples till the end of the storage period both at 10 and 2 °C.

#### **Quality evaluation for fresh cut pineapple in different cutting shapes**

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Quality evaluation for fresh cut pineapple in different cutting shapes was monitored during storage at 2 °C. Samples were evaluated on daily basis for the physical changes (colour), chemical compositions (pH, TTA and TSS), gases (O<sub>2</sub>, CO<sub>2</sub> and C<sub>2</sub> H<sub>4</sub>) and sensory attributes. The pineapple fruits were manually skin peeled and cut into 2 different cutting styles: longitudinal (A) and semi circular (B) shape. The cut pieces were randomly selected for packing in polypropylene container (10 x 12 cm) with lid sealed. The results showed that the different cuttings shapes of the fresh cut pineapple did not significantly affect the physical and chemical changes. The gradual loss of L\* value (from 78.86 to 73.12) was noticeable to the cut pieces which may directly attributed to the translucency phenomenon in the fruit flesh towards the end of the storage period (day 9). The TSS value showed to increase (10 °Brix to 13 °Brix.) whereas a decreasing trend in the pH and TTA values was noticeable to both cutting shapes (A and B). The headspace composition of the fresh cut pineapple in longitudinal cutting (A) had higher percentage of CO<sub>2</sub> and C<sub>2</sub> H<sub>4</sub> as compared to fresh cut pineapple in semi circle cutting (B). However, no significant difference was observed to O<sub>2</sub> composition to both cutting treatments throughout the storage period for 9 days. The longitudinal cutting shape was more preferred by the panellists due to the combines (sweet and sour) taste within one piece.

#### **Microbiological quality of fresh cut pineapple with application of oxygen absorbent in packaged**

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Fresh cut pineapple is one of the perishable packaged foods. Their shelf life is mostly dependent on storage conditions including oxygen concentration. Oxygen is necessary for the growth of most spoilage and many pathogenic organisms including moulds thus shorten the shelf life of the product. This study was conducted to see the effect of the usage of oxygen absorbent in packaged on the microbiological quality (total plate count, coliform count, and yeast & mould count) of fresh cut pineapple from the Josapine cultivar during storage at 2 °C and 10 °C, respectively. After pre cooling at 10 °C for overnight, fruits were peeled manually, immersed in chilled water and cut into longitudinal shapes. Pineapple slices were then dipped into solution containing 1% of calcium chloride and 1% of sodium chloride. After drip drying, the fruits were packaged in polypropylene clip on container, either with oxygen absorbent or without oxygen absorbent (control). The containers were wrapped with stretch film before storage at 2 °C for up to 15 days and 10 °C for up to 8 days, respectively. Results showed that no significant difference (p>0.05) in the total plate count of bacteria and yeast & mould count between oxygen absorbent and control samples stored at 2 °C and 10 °C. The coliform count for both samples stored at 2 °C also showed no significantly different. However, the amount of coliform stored at 10 °C with application of oxygen absorbent in packaged shown to be significantly (p<0.05) reduced throughout the storage period for 8 days as higher counts was noted to the control samples.

#### **Effect of alginate and gellan based edible coatings on quality of fresh cut pineapple during cold storage**

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Pineapple is one of the most important tropical fruits in Malaysia. Consumer demand for fresh cut pineapple is increasing in the world markets. However, its shelf life is limited. The aim of this work was to study the effect of alginate and gellan based edible coatings on changes in colour, weight loss, firmness and respiration rate of fresh cut 'Josapine' pineapple during 16 days storage at 10±1 °C; 65±10% RH. Uncoated fresh cut pineapple at the same condition served as control. The results showed that for colour, the L\* (lightness) and chroma decreased over time



in all treatments. However, L\* and chroma in coated samples were significantly ( $p < 0.05$ ) higher than control. The hue angle of control samples were significantly ( $p < 0.05$ ) lower than coated samples. Weight loss increased over time during storage. After 16 days, the weight loss of control was  $22.39 \pm 0.94$ , but the weight loss of both alginate and gellan samples were significantly lower than control ( $15.44 \pm 0.83$  and  $16.47 \pm 0.56$  respectively). Respiration rate of fresh cut pineapples with alginate or gellan coating were significantly ( $p < 0.05$ ) lower than control during storage. Firmness of coated samples during storage was not significantly different with the fresh sample. However, the firmness of control after 16 days was significantly ( $p < 0.05$ ) lower than fresh sample ( $1.39 \pm 0.19$  N and  $2.54 \pm 0.28$  N respectively). The results obtained in this study indicate that alginate and gellan based edible coatings could significantly reduced weight loss and respiration rate and maintained the colour and firmness of fresh cut pineapple during low temperature storage as compared with control (uncoated sample).

#### **Standard operating procedure on processing and yield assessment of pineapple and other tropical fruit juices using Voran Pressing 500**

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Belt Pressing Machine (Article no: 1641 00 000 Pressing 500) is the equipment used for solid liquid separation. This model combines the grinding unit and the pressing unit in one easy to operate system. This unit dedicated for fruit grinding and juicing, was designed and fabricated by VORAN. The units are widely utilized by small and medium industries in Europe for juicing of fruits such as apples, pears, carrots etc. The premier unit is placed Universiti Teknologi Malaysia by VORAN representative, Euroasiatics (M) Sdn Bhd for trial operation and R&D. The fruits supplies were from Malaysian Pineapple Industrial Board (MPIB) and Ameelia Excelife Resources (AER). Our bio processing team at UTM is operating the unit for local standard operating procedures and processing data collection on its potential to press tropical fruits. The equipment has been tested for juicing of pineapple, guava and sapodilla fruits. The result for 4 runs of the machine at large scale indicating an efficient pressing of the juices. For every kilogram of whole mature fruit pressed, we managed to recover approximately half litre of juice with dry solid waste for easy disposal. The juicing SOP of pineapple, sapodilla and guava is described in this presentation. Based on our study, we found that this unit is easy to operate, easy to clean and deliver the optimum juicing capacity for mature fruits. However, the ripe to over ripen fruits give viscous juice and wetter waste which lead to difficulties in further downstream processing.

#### **Pineapple juice potential as anti cancer agent in A2780 ovarian cancer cell line**

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Pineapple has a wide range of therapeutic benefits. The main component that contributes to the high value of pineapple is bromelain. The purpose of this study is to identify the potential of crude bromelain in juice form as anti cancer agent in A2780 ovarian cancer cell line. The anticarcinogenic activity of crude bromelain from various parts (flesh, stem and core) in A2780 was assessed by MTT assay. The bromelain crude juice showed anticarcinogenesis properties in A2780 cells with an IC50 value of 280.54  $\mu\text{g/ml}$  (flesh), 280.54  $\mu\text{g/ml}$  (stem) and 231.74  $\mu\text{g/ml}$  (core). Apoptotic morphological changes in A2780 were observed microscopically using both inverted microscope and fluorescence microscope. Cells showed apoptotic bodies and shrinkage following acridine orange and ethidium bromide staining. Therefore, these findings suggested the bromelain crude juice from *Ananas comosus* have potent to induce anticarcinogenic activity through an intrinsic apoptosis pathway in A2780 in vitro.

#### **Production and properties of spray dried pineapple juice**

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This study was carried out to determine the effect of different ratios of pineapple juice to maltodextrin (50:50, 40:60 and 30:70) as encapsulating agent with two different inlet temperatures (160 and 170 °C). Observations were made based on yield and physicochemical properties of spray dried pineapple powder. Results showed that the content of protein, crude fibre, fat, ash, dietary fibre, total sugar, starch, carbohydrate, sodium, iron, potassium, calcium, vitamin A and vitamin C in 100 g pineapple powder were 1.62 g, 1.70 g, 0 g, 1.44 g, 0.22 g, 33.47 g, 38.56 g, 92.27 g, 29.86 mg, 1.02 mg, 559.04 mg, 35.28mg, 38.05 mg and 18.10  $\mu\text{g}$ , respectively. The moisture of the pineapple powder was 2.65%, while its bulk density and solubility were 0.801 g/ml and 141.0 second, respectively. These results suggested that the ratio of maltodextrin to fruit juice at 60:40 with inlet temperature at 160 °C, produced the highest powder output which at 84.85% recovery.

#### **Tropical fruits fiber juice drinks**

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Malaysia is rich in tropical fruits such as pineapple, guava, jackfruit and starfruit. Besides eating fresh, these fruits are prepared and processed in form of juices and drinks. These beverages are commercially available and highly acceptable by the consumers. The fibre beverages are still scarce in the market. As a result tropical fruit fiber juice drink from pineapple was developed as it is the best alternative for a convenient, nutritious and healthy straight drink. Pineapple fruit is highly acceptable and easily available throughout the year. Pineapple fiber juice drink was developed using a simple heating technology by mixing fruit juice with commercial fibre, sugar, citric acid and water. The products were homogenized, pasteurized at 80 °C for 5 min and hot filled. These products are preservative free, have good source of fiber vitamin C and antioxidant activity. It is suitable for all age people to enjoy the taste at any time.

#### **Non-destructive sterilization process of pineapple juice**

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Pineapple juice with high bromelain content would be potential as nutraceutical supplement for conditions such as cancer, asthmatic, sinusitis and bronchitis. However, commercially available pineapple juices in Malaysia contain little to non bromelain activity despite the use of natural pineapple juice due to high heat sterilization processing. This study mainly looks into an alternative processing of pineapple juice to maintain the precious bromelain and other nutritional values. Bromelain activity in every stage of processing is measured using CDU method and compared with several commercial pineapple juices. The non destructive sterilization process used in this study shown that bromelain activity in pineapple juice remains approximately 0.785 CDU/ml, TSS 10.0 °Brix, glucose 72.0 mM, pH 4.00 with turbidity 6 NTU.

#### **Food products from *Ananas***

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Pineapple (*Ananas comosus*) is widely available in the local market and it is considered as a popular fruit for dessert and served as fresh cuts but it is a very versatile fruit with the potential of being processed into various food products of commercial value. Fully ripe, but firm and evenly matured pineapples are usually selected for processing as they have strong flavour, better colour and higher product yield. There has been some work done so far in MARDI regarding the utilization of pineapple. Pineapple can be processed into various products such as puree, juice, beverages, jam, confectionery jelly, canned in syrup, fruit roll/leather, breaded, dehydrated candied, pickle, sauce, fruit fillings and powder. This paper will highlight some of the potential products from mature and ripe pineapple and their processing techniques. These products have potential for commercialization.

#### **Processing of dehydrated candied pineapple using candying machine**

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Dehydrated candied pineapple is a product with intermediate moisture characteristics, which can be kept for longer period at ambient temperature without deterioration. The preparation of dehydrated candied pineapple involves peeling, coring, cutting, blanching, syruping and drying. Conventionally, the syruping process of pineapple is carried out manually. The process is delicate, tedious and time consuming. The major constraint in producing dehydrated candied pineapple for commercial production is the syruping process which takes 5-6 days for the fruit cuts to be fully impregnated with syrup prior to drying process. An effective way to solve this problem is to produce dehydrated candied pineapple using a continuous candying machine. By using this automatic machine, the syruping process can be completed only in 5-6 hours for 252 kg fruit cuts. This paper described the processing technique of producing dehydrated candied pineapple using a continuous candying machine, the physicochemical characteristics and sensory attributes of the products.

#### **Quality and acceptability of pineapple pickles**

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Pineapple pickles are processed by fermentation followed by syruping process. Several varieties of pineapple such as Gandul, Morris, Sarawak and Masmerah were found to be suitable for production of fruit pickles. The pickles had good taste, texture and colour. Pineapple pickles from variety Morris were evaluated for their quality during storage. The products were packed in glass bottles. Microbiological, chemical and sensory qualities of the pineapple pickles were determined. Pineapple pickles had very low microbiological counts and the result of sensory evaluation indicated that the pickles were moderately acceptable. There were no significant increase in microbial counts, pH, titratable acidity and total soluble solids. Sensory evaluation indicated that the products were still acceptable in terms of colour, taste, texture and overall acceptability after 6 months of storage at ambient temperature.

#### **Accelerated shelf life studies of high energy pineapple granola bar**

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Shelf life of pineapple granola bar packed in oriented polypropylene/Q5/vapour metallised cast polypropylene (OPP/Q5/VMCPP) of 55 µ thickness stored under laboratory condition (28 °C, 70-80% relative humidity) as well as under accelerated conditions (38 °C; 90% relative humidity) was studied. The shelf life of product was calculated using empirical formula whereby one month storage factor under the accelerated conditions equals to 2.9 months under the laboratory storage conditions (temperature 28 °C, R.H. 70-80%). The actual shelf life of the pineapple granola bar stored under the laboratory condition is equal to 8.7 months (temperature 28 °C, R.H. 70-80%) based on sensory evaluation results of the accelerated storage sample which was only accepted up to three months of storage. Freshly made pineapple granola bar contained initial moisture content 6.16%, water activity (Aw) of 0.58 and free fatty acid of 0.67 %. Chemical quality changes with increased in the moisture content and free fatty acid during storage study were related with the sensory results of the pineapple granola bar.

#### **Production of high bromelain nutraceutical drink**

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Bromelain is a mixture of proteolytic enzymes found in pineapple (*Ananas comosus*). It has pharmacological actions in human diseases, such as treatment of coronary thrombosis and anti inflammatory effects. Bromelain in freshly pineapple juice is highly susceptible to denaturation because of the oxidation of sulfhydryl group at room temperature or elevated temperature. So, there is an idea to exert the antioxidant property on bromelain's reaction sites to prevent oxidation. Many local food plants such as cashew were reported to contain polyphenol and high antioxidant activity. So it can be used to complex polyphenol of plant extract with bromelain in pineapple juice to stabilize the bromelain activity, to produce

a nutraceutical pineapple fruit drink of high, stable bromelain and antioxidant capacity. Besides, during the processing of pineapple fruit juice, heat required in sterilization will denature the bromelain enzyme. The thermal stability of bromelain polyphenol complex has been reported to be improved, so it can reduce the heat damage to pineapple bromelain.

#### **Use of response surface methodology to optimization of extraction of enzymes from pineapple pulp**

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Ready to eat fruits and vegetables that do not contain any artificial preservatives are getting popular amongst consumers. Vacuum frying is a method to produce crispy snacks with good taste and texture and at the same time contain low oil content. Pineapple has the potential to be processed into a snack using vacuum frying and would be an alternative snack product to dried fruit, fruit roll/ leather, candied fruit, confectionery jelly and sweets for the consumers to choose from. Different pretreatments were carried out on pineapple var. Moris to explore the effect of blanching, syruping and freezing on the fried snack produced by vacuum frying. Pineapple snacks produced by blanching, followed by syruping and freezing were much better in appearance and texture as compared to snacks produced without any treatment, blanching alone or a combination of blanching and syruping pretreatments. Some physical characteristics of pineapple var. Moris, organoleptic results on the fried products, recovery and observations are presented.

#### **Effect of pretreatments on sensory characteristics of vacuum fried pineapple snack . A preliminary investigation**

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Ready-to-eat fruits and vegetables that do not contain any artificial preservatives are getting popular amongst consumers. Vacuum frying is a method to produce crispy snacks with good taste and texture and at the same time contain low oil content. Pineapple has the potential to be processed into a snack using vacuum frying and would be an alternative snack product to dried fruit, fruit roll/ leather, candied fruit, confectionery jelly and sweets for the consumers to choose from. Different pretreatments were carried out on pineapple var. Moris to explore the effect of blanching, syruping and freezing on the fried snack produced by vacuum frying. Pineapple snacks produced by blanching, followed by syruping and freezing were much better in appearance and texture as compared to snacks produced without any treatment, blanching alone or a combination of blanching and syruping pretreatments. Some physical characteristics of pineapple var. Moris, organoleptic results on the fried products, recovery and observations are presented.

#### **Effect of polyols and polydextrose on the physical characteristics of sugarless pineapple tart**

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Traditional pineapple tart contains approximately 26.8% of total sugar (as in inverted sugar). Polyols and polydextrose were used in this study to play a role played by sugar. The physical effects of these products were measured via colour and texture measurement. The outer appearance of the product shows no significant differences ( $p > 0.05$ ) between the products. For the inner part of the products, the  $L^*$  value of the treated products doesn't show significant differences ( $p > 0.05$ ) when compared to Control. The  $b^*$  and  $a^*$  value of the inner part of C shows highest value ( $p < 0.05$ ) when compared to SF1 and SFL. The texture measurement of C, SF1 and SFL showed no significant differences ( $p > 0.05$ ) for hardness. The fracturability value of SF1 (11.9g/s) shows no significant differences ( $p > 0.05$ ) between C (11.7g/s) and SFL (11.6g/s).

#### **Dietary fibre powder from pineapple by product as a potential functional food ingredient**

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Tropical fruit juice industries produced an important quantity of by products, which were mainly used for animal feeds, however, because of their high fibre content and antioxidant activity they can be used as ingredients in food processing. The aim of this paper was to determine the dietary fibre contents, physical properties and antioxidant activity of tropical fruit by products namely pineapple. The sample was investigated for water retention capacity, oil retention capacity and, soluble and insoluble dietary fibre contents and, for their antioxidant activity. Water retention capacity was 8.8 g of water/g of fibre. Oil retention capacity was 1.3 g of oil/g of fibre. The soluble fibre content of pineapple by product was 1.60%, while that of insoluble dietary fibre between 63%. The total dietary fibre content was 64.3%. The antioxidant activity of pineapple by product was 85.7 AOA%. The high content of dietary fibre and antioxidant activity of pineapple by product can be of particular interest for further exploitation and utilization as food ingredients.

#### **Proximate composition and physicochemical properties of pineapple gums**

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This study was conducted to determine proximate composition and physicochemical properties of pineapple gums. Pineapple pulp from Josapine variety was used in this study. Results from proximate analysis showed that moisture, ash, protein and fat of the gums were  $10.93 \pm 0.55$  %w/w,  $7.66 \pm 0.29$  %w/w,  $4.21 \pm 0.01$  %w/w and  $0.46 \pm 0.16$  %w/w respectively. Viscosity of 1% of gums solution was found to be 8.80 CPs at room temperature. The swelling capacity, oil retention capacity and water retention capacity of the gums were found to be  $29.68 \pm 0.15$  mL/g,  $1.70 \pm 0.15$  g/g and  $10.75 \pm 0.34$  g/g respectively. Colour of the gums were light brown where the  $L$ ,  $a^*$ ,  $b^*$  values were  $81.77 \pm 0.58$ ,  $+0.82 \pm 0.11$  and  $+13.14 \pm 0.45$  respectively. The particle structures were observed to be sphere in shape and closely attach to each other. Findings from this study provide an insight on the Josapine gums properties. Further study will be carried out to look for its potential as a food ingredient.

#### **Effect of temperature and pH on viscosity of pineapple gums**

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The aim of this study was to assess the effect of temperature and pH on viscosity of pineapple gums (Josapine variety). 1% of gums solution was prepared and the viscosity was measured at different temperatures (10, 30, 40, 50 and 70 °C) and pH (2, 5, 6, 7, 8, 9 and 10). Viscosity of 1% Josapine gums solution was found to be 8.80 CPs at room temperature. The viscosity was varying directly with changes in temperature over a range of 10-70 °C. An opposite trend could be seen between temperature and viscosity of Josapine gums. Increasing of temperature resulted decreasing of viscosity up to 56%. The pH value of 1% Josapine gums solution at room temperature was 6.76. Viscosity of Josapine gums was highest at pH 10 with value of 6.00 Cps. It was found that the viscosity of Josapine gums decreased at more acidic conditions. In conclusion, changes in temperature and pH had influence the viscosity of Josapine gums.

#### **Performance of pineapple leaf fibre (PALF) reinforced high impact polystyrene (HIPS) composites**

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Pineapple leaf fibre (PALF) is obtained from the leaves of pineapple plants. The fibres are strong, white and silky lustre. Rope, broom, mat, nets, and cloths are several products of pineapple leaf fibre. Currently, the utilization of fibre for the reinforcement polymer matrix composites has a great interest to the academicians and researchers. This paper is about the study of the chemical characterization and utilization of PALF for reinforcement high impact polystyrene composites.

#### **Development of biodegradable plastic utilizing pineapple leaf fibre**

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The study looks into the effect on mechanical properties when pineapple leaf fibres (PALF) are reinforced with biopolymer. The growing amount of pineapple in Malaysia will produce large quantities of leaf waste that disposed onto landfill. Instead of disposing those priceless leaves, value added process definitely will help in agriculture diversification while conserving the environment. Furthermore, characteristics of PALF to withstand high temperature and the ability to fortify with polymer resin encourage PALF to be the filler in producing biodegradable plastic. Aiming to reduce the usage of petroleum based plastic, polylactic acid (PLA) has been discovered and largely used in plastic manufacturing. However, production of PLA from corn is a rival to food sector. Solution to this obstacle is cut down the amount of matrix and filled with PALF. The PALF/PLA reinforced composite has proved no loss in mechanical properties compared to neat PLA plastic. PALF/PLA composite behaved as brittle plastic that able to resist flexure strength and impact strength. Since PALF/PLA composite performed identical mechanical behaviors as PLA based plastic, the study delved into the effect of PALF surface modification on PALF/PLA composite mechanical properties. Alkali treated PALF fortified better with PLA thus performing higher flexural strength than PLA sample and untreated PALF/PLA composite. Those flexural and impact strength has certified the formation of PALF/PLA as bio plastic. The advantages of this type of plastic which showed high flexure and impact strength can be used to produce much biodegradable stuff.

#### **Session 6: Consumer and Marketing**

##### **Ex post impact assessment of pineapple technology on peat soil**

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Ex post impact assessment of pineapple technology adopted on peat soil was carried out by using the adapted Sustainable Rural Livelihoods Framework (SRLF). Data was gathered by personal interview involving 100 pineapple growers in four districts in Johor. Results of the study revealed that the adoption of modern variety, crop and resource management, plant health management and post harvest technologies as recommended by MARDI was low. In general the technology for pineapple cultivation on peat soil had given positive impact on farmers' income. The average farm productivity for Gandul and Moris was higher than expected while the average farm productivity of Josapine was lower. The majority of farmers managed to generate average net income  $\geq$  RM3,000 per month as targeted. Unlike Josapine, the crop husbandry technology for Gandul and Moris had been an industry led technology. Any intervention by policy makers should focus on supporting their prices. The technology for Josapine cultivation should be fine tuned after a few decades.

##### **Scenario and prospect of Malaysia's pineapple industry**

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World pineapple trade had shown increasing trend for the past three decades. Malaysia was listed number 15 of the world fresh pineapple exporter, while for canned pineapple Malaysia was listed as number 9. The export trend for Malaysia's canned pineapple was decreasing, while that of fresh pineapple the export volume had increased. The pineapple technologies developed since 1980-es was not able to sustain the pineapple productivity. Changes in policies and organization involving LPNM influenced the productivity of pineapple farms. The BOT action plan for pineapple industry was very much diverted, but the targeted positive BOT materialised. Malaysia has more strength in fresh pineapple production than processing. Consolidation of smaller farms into bigger scale was the right decision to improve farms' productivity and efficiency. Small scale growers should focus on producing pineapple for fresh market that can be sold at higher price. In order to be efficient and competitive, the canning industries should operate their own pineapple estates as sources of raw material supplies.

### **Consumer preferences towards pineapple varieties in Malaysia**

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Pineapple was among the priority crops to be developed under the Third National Agricultural Policy (1998-2010) which emphasized both fresh produce and processed products. Research undertaken by MARDI had produced a number of pineapple varieties for both purposes. This study was conducted to evaluate consumer preferences towards some of these varieties vis-à-vis other varieties that are in the market. Results of this study would provide important input in future breeding work for varietal development. A survey was carried out in the Klang Valley involving 234 respondents. Every respondent was given a set of four pineapple samples (Maspine, Josapine, Moris, and MD-2) and indicate his/her preference. The respondents in evaluating the samples, gave scores from 1 (least preferred) to 5 (most preferred) on specific attributes of the samples. Generally, result showed that the respondents preferred MD-2 followed by Josapine, Moris and Maspine, with mean scores of 4.38, 4.10, 2.67 and 2.63, respectively. Higher consumer preferences towards MD-2 were due to its aroma (4.38), sweetness (4.26) and color (4.25) while Josapine scored less in all the attributes that were listed, with aroma (4.14), sweetness (4.04) and colour (3.95). Even though Maspine and Moris were less preferred by consumers, both of these varieties had higher score in "crunchiness". Between Maspine and Moris, consumers scored Maspine higher on color and juiciness attributes while Moris scored higher on the "crunchiness" attribute. Based on the findings of this study, attributes that contributed to higher overall scores were aroma, sweetness and color was evidently preferred in MD-2 variety. Researchers should produce improved pineapple varieties with MD-2 as a benchmark in the development of future varieties for fresh consumption.

### **Selected fruit characteristics of pineapple base on consumer preference study**

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A survey on consumers' preference towards local fruits was conducted in 2007 by MARDI, involving 951 respondents from all over Malaysia. The survey was conducted using a structured questionnaire. The study emphasised the consumer preferences for pineapple purchased for fresh consumption. From the survey, two factors that had influenced consumers on pineapple purchase were identified. The first factor focused on external characteristics which consist of skin colour, eyes on the skin and skin thickness. The second factor was the internal characteristics made up of fruit fibre, core size and flesh texture. Ten agronomic characteristics of the fruits had been put forward to the respondents. Based on the survey, the most preferred characteristics of pineapples were: medium fruit size (1.0-2.0 kg), (57%), fragrance (84%), sweetness (73%), less fibrous (70%), longitudinal fruit shape (68%), thin skin (66%), small-sized core (51%), half yellow, half green skin colour (47%), soft texture (45%), and eyeless skin (40%). Researchers and planters should give more attention to these characteristics in their future work so that pineapple can be accepted as one of the main Malaysian fruits for fresh consumption.

### **Consumer acceptance towards Malaysian minimally processed pineapple in Singapore food market**

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Minimally processed fruits have been introduced in recent years to fulfill consumers' needs for 'convenience' fresh fruits. These needs among others arise due to more working parents, tight work schedule and increase in household income. Minimally processed pineapple has the potential to be exported in the global market. In 2008, Malaysia exports around 12,930 MT of pineapple, of which more than 90 percent is exported as a whole fruit, and less than 10 percent as processed food. Consumers study was conducted in 2009 involving 359 respondents using structured questionnaire to identify their acceptance and preferences of minimally processed pineapple in Singapore. The study revealed that the average spending on minimally processed fruit in Singapore was S\$52.50 per household a month. Majority of the respondents rated the external (size and type of packaging) and internal (sweetness, freshness and aroma) attributes of the products was good (using Likert Scale). Product attributes most preferred by respondents were semi circle shape with diameter of 3 cm, medium thickness (1.5 cm), firm flesh texture and pack of 150 g using clear plastic container. On the average they were willing to pay S\$1.40/pack of 150 g fruit. Supermarket or hypermarket was the most important marketing channel for minimally processed fruits, followed by fruits shop and wet market. Information gathered from this study would be able to guide Malaysian entrepreneur to produce and market minimally processed pineapple for the Singapore market.

### **Economic analysis of mechanized system for large-scale pineapple production on mineral soils in Malaysia**

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Pineapple is one of industrial crop that being cultivated in Malaysia traditionally in peat soil and increasingly popular in mineral soil condition. MARDI has been working hard in helping to improve the traditional agriculture practice by developing a way that is adaptable to our local industry as well as to increase the income of local farmer. For pineapple production especially on mineral soil, MARDI had tested and evaluated potential mechanization package that may help in the increasing farm production. The machinery packages for pineapple production include of pineapple transplanter, inter row cultivator cum fertilizer applicator, boom sprayer, boom conveyor fruit harvester, pineapple leave slasher and plant mulcher cum shredder. This study was conducted as to evaluate the cost required for the operation and also the potential productivity of the mechanized system. From the testing and evaluation study on FIMA farm in year 2008-2009, it showed that mechanized system for pineapple production in mineral soil may achieved average yield for about 44742.729 kg/ha/hr, equivalent to about 18.9% of loss due to product rejection. Economic forecast has been projected based from this result. With some relevant assumption, the viable acreage for this mechanization package to be implemented on minimum acreage of 40 hectares, will deliver a payback period after 3" years with Internal Rate of Return (IRR) of 36.7% and the Benefit Cost Ratio (BCR) of 1.05. The Nett Present Value (NPV) for the mechanization system on this particular acreage will be around RM 476,732.45.