Morphological Characteristic, Chemical Composition and Sensory Quality of Pineapple Fruit in Different Seasons

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ABSTRACT

Pineapple fruits were harvested at 110, 120, 130, 140, 150 and 160 days after full bloom from summer, rainy season and winter crops of 2002/2003. Crops from different seasons were evaluated for their physical characteristics, chemical compositions and sensorial attributes. A relationship between eating quality and different crop season was examined in terms of appearance, color and firmness of rainy season, summer and winter crop. Significant differences (P≤0.05) were found between fruit weight, size, shape and shell color, flesh color, total acidity and pH among three crops. For sensory evaluation, there were significant differences in flesh color, flavor, odor and acceptability. Taste panelists preferred the appearance, color and firmness of rainy season and summer crop more than winter crop.

Key words: Pineapple, *Ananas comosus*, Crop season, Quality

INTRODUCTION

Statistics on world pineapple production are collected by the Food and Agriculture Organization of the United Nations (FAO). According to FAO statistics (Baker, 1990; Anon, 2002), the leading pineapple-producing countries are Thailand, the Philippines and Brazil. The pineapple industry is the largest fruit industry in Thailand. The variety of pineapple used in commercial cultivation for fresh fruits as well as for the processing industry is Smooth Cayenne or Pattawia. Pineapple fruits are consumed locally and exported especially to Europe, Singapore, Japan and the Middle East but the economic production of pineapple from Thailand for export has been limited by quality factor. There were few definitive data on the effects of climatic factors on inflorescence or fruit development of pineapple (Bartholomew et al., 1977). The rate of fruit growth over time apparently was determined primarily by temperature. After flowering, fruit size may increase somewhat with increasing sunlight (Monselise, 1986). In two studies where pineapple was planted at different times of the year and fruit development was forced with a growth regulator, fruit development was slower during seasons with cool temperature (Moreau and Moreuil, 1976; Smith, 1977). In South Africa, it was shown that fruits which developed during cooler months were smaller than fruits on plants of comparable size which developed during warmer months (Smith, 1977).

In Hawaii, for the fresh fruit market, the summer crop is harvested when the eyes have light-pale green color. At this season, sugar content and volatile flavors develop early and steadily over several weeks. The winter crop is about 30 days slower to mature and the fruits are picked when there is a slight yellowing around the base (Morton, 1987). In Taiwan, which is located in the sub-tropic, results have shown a fairly-clear temperature difference between summer and winter. During winter (monthly average 17°C), fruits are sour and lack sweetness and vice versa for summer fruits (Lin and Chang, 2000).

A crop of pineapples can be produced to mature at any time of the year with suitable size of planting material, planting time and flower induction but the physiological characteristics and eating quality vary widely with season. Thus, it is necessary to characterize and determine the quality changes of pineapple fruits during maturation and harvesting at different growing seasons of the year.

The objectives of this study were to determine and compare the morphological characteristic, chemical composition and sensory acceptability of Smooth Cayenne pineapple fruits of three seasons in year 2002 and 2003.

MATERIALS AND METHODS

Fruit sample

Pineapple cv. Smooth Cayenne was planted in a private farm at Thasadet village, Muang district, Lampang province. After full bloom and fruit set, 500 similar fruits were selected and tagged. Thirty fruits were harvested at maturity stages of 110, 120, 130, 140, 150 and 160 days after full bloom (DAFB) in summer season (April–May, 2003), rainy season (June–July, 2003) and winter season (November-December, 2003). After harvesting, the fruits were transported immediately to the Postharvest Institute Technology laboratory, Chiang Mai University. Upon arrival, the fruits were unloaded and prepared for experiment.

MORPHOLOGICAL AND PHYSICAL PROPERTY ASSESSMENTS

Size and shape

The pineapple fruits were measured for fruit weight (g); fruit size: fruit length and fruit diameter (cm); crown weight (g); shape: 1 = spherical (small), 2 = cylindrical (medium) and 3 = conical (big). The shape was determined as follow:

Shape	∅ Top: ∅ Base of fruit	Fruit length: ∅ Base of fruit
Spherical (small)	More than 0.965	Less tan 1.321
Cylindrical (medium)	More than 0.965	More than 1.321
Conical (big)	Less than 0.965	More than 1.321

Color

The harvested pineapple fruits were evaluated for shell color score as follow: CS1 = green, CS2 = breaker, CS3 = 25% yellow, CS4 = 50% yellow, CS5 = 75% yellow and CS6 = 100% yellow. The fruits were then sliced into 3 parts (basal, medial and top–each 3 cm in thickness) after being cut from the center towards the base and the top 4.5 cm, with the top and base pieces discarded. The core diameter was measured for each slice. Flesh color of pineapple was measured with a portable Minolta colorimeter, model Pr–100. The instrument was calibrated against the standard white reflective plate, using CIE Illuminant D65 with a 2° Standard Observer. Other coordinates calculated from the CIELAB a* and b* value were chroma ($c^* = [a^{*2} + b^{*2}]^{1/2}$) or saturated index (intensity or purity) and the hue angle ($H_{ab} = tg^{-1}\ b^*/a^*$). Each value represents a mean of a duplicate determination of three different samples. Results were reported as average of individual values as L* (lightness), a* (+a = red, -a = green) and b* (+b = yellow, -b = blue).

For pigment analysis, a portion of the shell and flesh from 3 parts of slices about 5 grams weight was cut finely with hand shears and added 20 ml alcohol 95%. The sample was kept in refrigerator overnight and filtered through a filter paper Whatman No.1 and the supernatant was taken for determination of optical density at 420, 447, 474, 645 and 663 nm by Spectrophotometer UV-VIS Unicam 500.

The chlorophyll content was calculated as total chlorophyll, chlorophyll a and chlorophyll b components (mg/g) as follow:

Total chlorophyll = $(20.2D_{645} - 8.02D_{663}) \times V / 1000W$
Chlorophyll a = $(12.7D_{663} - 2.69D_{645}) \times V / 1000W$
Chlorophyll b = $(22.9D_{645} - 4.68D_{663}) \times V / 1000W$

Where D = value of absorbance optical density at 645 and 663 nm
V = volume of pigment solution (ml)
W = Fresh weight of sample (g)

The amount of carotene concentration was calculated as β-carotene components (mg/g) as follow:

$$C = A \times 454 / 196 \times L \times W$$

Where C = carotene concentration (mg/g) in original sample
A = value of absorbance optical density at 420, 447, and 474 nm
L = cell length in cm
W = g product/ml final dilution
Converted by C x 0.22

Texture

Texture evaluation was carried out using a Texture Analyzer TA-TXT2i. A force of 500 kg was applied at 10 mm/s pre-test speed, test speed, and post-test speed. Slices (3 cm thick) were used to measure force in compression, option return to start, auto-25g trigger type, data acquisition at 200pps and 6mm cylinder (P/6) probe type. The mean value for maximum force was calculated. The result was reported as resistance to shear in Newton.

PHYSICO-CHEMICAL DETERMINATIONS

Soluble solids

Soluble solids were measured in the juice from ten grams pineapple fruit with an Atago PR-101 digital refractometer. Results were reported as degree Brix.

pH

Ten grams of pineapple fruit sample was juiced and measured for pH at room temperature with a Satorius Professional Meter PP-50 operation manual pH meter.

Titratable acidity

The portion of 5 ml of juice extract was diluted with 45 ml distilled water and titrated with 0.1 N NaOH up to 8.1 pH. The results were expressed as percentage of citric acid (g citric acid/100 g fresh weight).

Sensory analysis

A 10-trained-member panel was selected to evaluate the pineapple fruit quality. The sensory laboratory complied with UNE norms (1976). A 1–5 structured scale was used for visual, flavor, odor, color, firmness and overall acceptability of small pieces of sliced pineapple fruit. For *visual*: 1, bad; 2, slightly bad; 3, acceptable; 4, fairly good; 5, good; *flavor*: 1, sour; 2, fairly sour; 3, sweet-sour; 4, fairly sweet; 5, sweet; *odor*: 1, off-odor; 2, slightly ripe odor; 3, ripe odor; *color*: 1, pale yellow; 2, slightly yellow; 3, bright yellow; 4, deep yellow; 5, brown; *firmness*: 1, soft; 2, slightly firm; 3, fairly firm; 4, firm; 5, very firm; *overall acceptability*: 1, dislikes; 2, dislikes slightly; 3, accepts; 4, likes slightly; 5, likes very much.

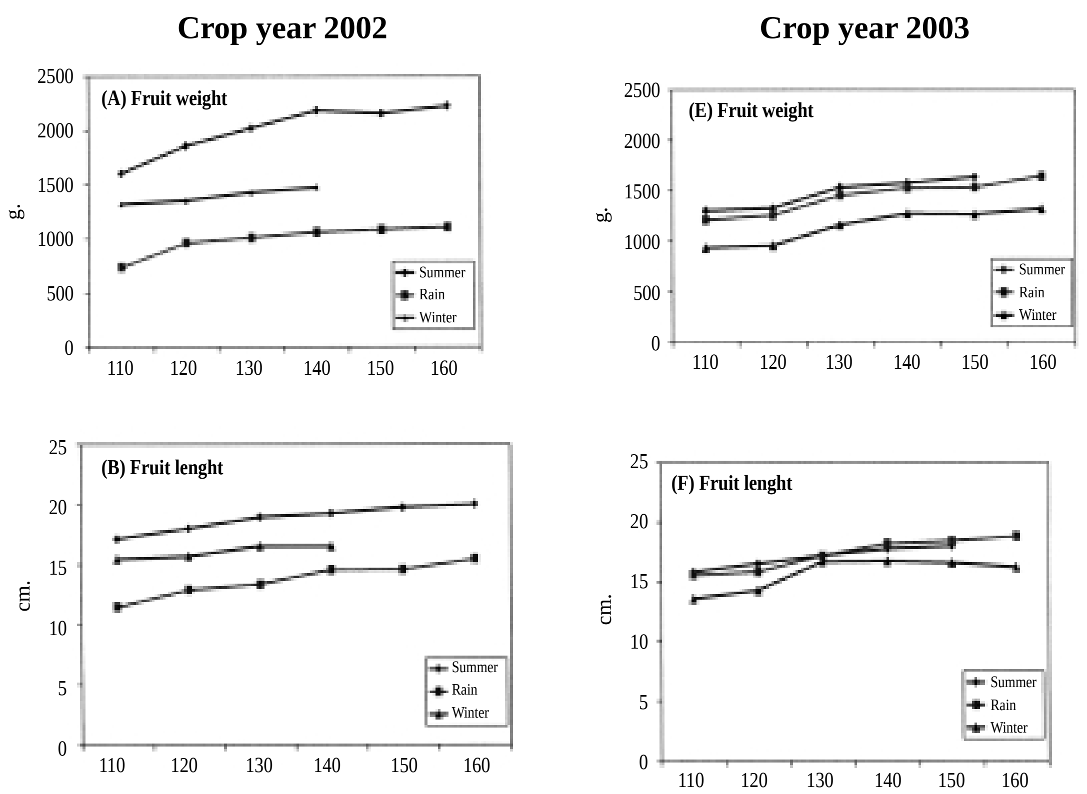
Statistical analysis

Data were statistically analyzed by an analysis of variance (ANOVA) and means separation by Duncan's multiple range tests at $P \leq 0.05$. Significant differences were indicated by different letters in the same row.

RESULTS AND DISCUSION

Fruit weight

Weight of fruit and its components increased during the first 2–3 weeks before harvesting period (Figure 1 (A) and (E)). Sideris and Krauss (1938) described that the growth pattern of pineapple fruit was of sigmoid curve. Nakasone and Paull (1998) showed that after the inflorescence was initiated, the weight of fruit and its components increased in a sigmoid pattern.



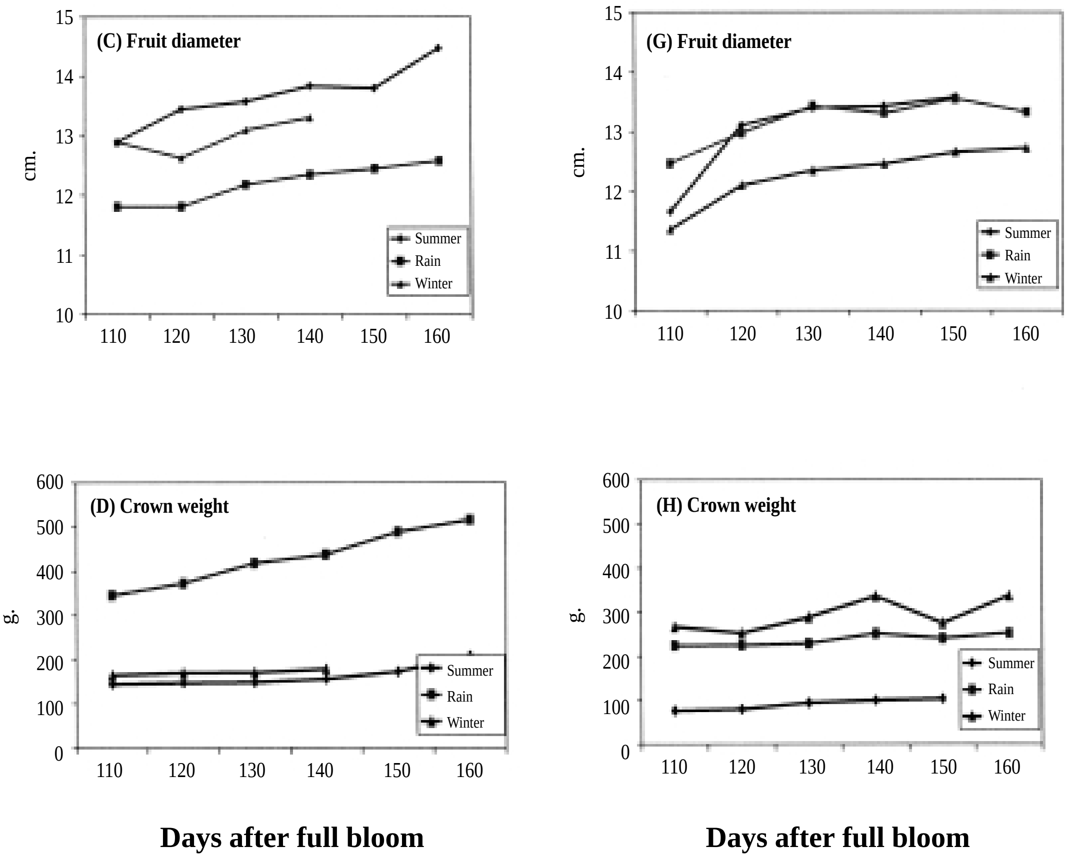


Figure 1. Fruit weight, fruit length, fruit diameter and crown weight of pineapple fruit grown in summer, rainy and winter season 2002 and 2003.

There was significant difference in weight of fruit growing in different seasons. In crop year 2002, the fruit weight of summer season was highest and the fruit weight of winter season was higher than rain season (Figure 1 (A)). In crop year 2003, the fruit of summer season showed highest weight similar to crop year 2002 but the fruit of rain season was higher than that of winter season (Figure 1 (E)).

The effects of climatic factors on fruit weight of pineapple were temperature and rainfall (Hepton et al., 1993; Bartholomew and Malezieux, 1994). In summer crop, the average of day temperature was higher and night temperature was lower than other season (Figure 7) which is optimum factor for the photosynthesis of pineapple mother plant and affected fruit development resulting in high fruit weight. While in rainy season crop and in winter crop, the average of day and night temperature was higher than summer crop which might lead to a decrease in the accumulation of photosynthetate of pineapple mother plant. Hepton et al. (1993) reported that in high temperature area, pineapple mother plant had increased number of leaves which affected food storage of stem and caused the decrease in fruit weight and yield production. Bartholomew and Malezieux (1994) showed that in cases of drought or heavy rainfall during the fruit development, the pineapple fruit growth also decreased. The drought directly affected fruitlet enlargement and fruit weight while the heavy rainfall affected root growth and function which might cause a decreased photosynthesis of pineapple mother plant.

Fruit length and fruit diameter

Fruit length and fruit diameter of pineapple at each maturity stage of each crop season increased until the last maturity stage. Summer-season crop showed highest fruit weight, fruit length and fruit diameter compared to other seasons (Figure 1 (B), (C), (F) and (G)).

Fruit shape

Both years, the percentage of distribution of three types of fruit shape (conical, cylindrical and spherical) was significantly different in all crop seasons (Table 1). In crop year 2002, in summer season, the percentage of distribution of fruit with conical and cylindrical fruit shape was higher than in rainy and winter season. While with rainy and winter seasons there was high percentage of fruits with spherical shape (Figure 2). The percentage of fruit with conical shape in summer 2002 was higher than summer 2003. The application of chemical forcing was unsuccessful in summer 2002 and the inductive forcing was delayed until 5 weeks later and the pineapple mother plant became bigger in size which might have caused to produce more fruit with conical shape and higher weight than summer of 2003.

Table 1. Physico-chemical properties of pineapple fruit at harvesting date (120 DAFB) in summer, rainy season and winter crops.

Assay	Season 2002			Season 2003		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Fruit shape (%)						
Spherical (small)	16.67	100.00	70.00	53.33	60.00	93.33
Cylinder (medium)	23.33	0.00	26.67	43.33	36.67	6.67
Conical (large)	60.00	0.00	3.33	3.33	3.33	0.00
Texture (N)	11.19[a]	10.47[a]	11.17[a]	10.66[a]	9.11[a]	10.50[a]
Total Soluble solids (°Brix)	12.50[a]	12.66[a]	14.38[b]	12.45[a]	14.56[a]	15.51[b]
Titratable acidity (g citric acid/100g f.w.)	0.53[b]	0.52[b]	0.36[a]	0.32[b]	0.50[b]	0.38[a]
TSS: TA ratio	27.16[a]	27.57[a]	41.78[b]	39.01[a]	29.86[a]	43.94[b]
pH	4.24[c]	3.85[b]	3.69[a]	3.69[c]	3.78[b]	3.72[a]

f.w. = fresh weight.
Sample harvested at 120 days after full bloom.
Different letters in the same row indicate significant differences, *P 0.05*

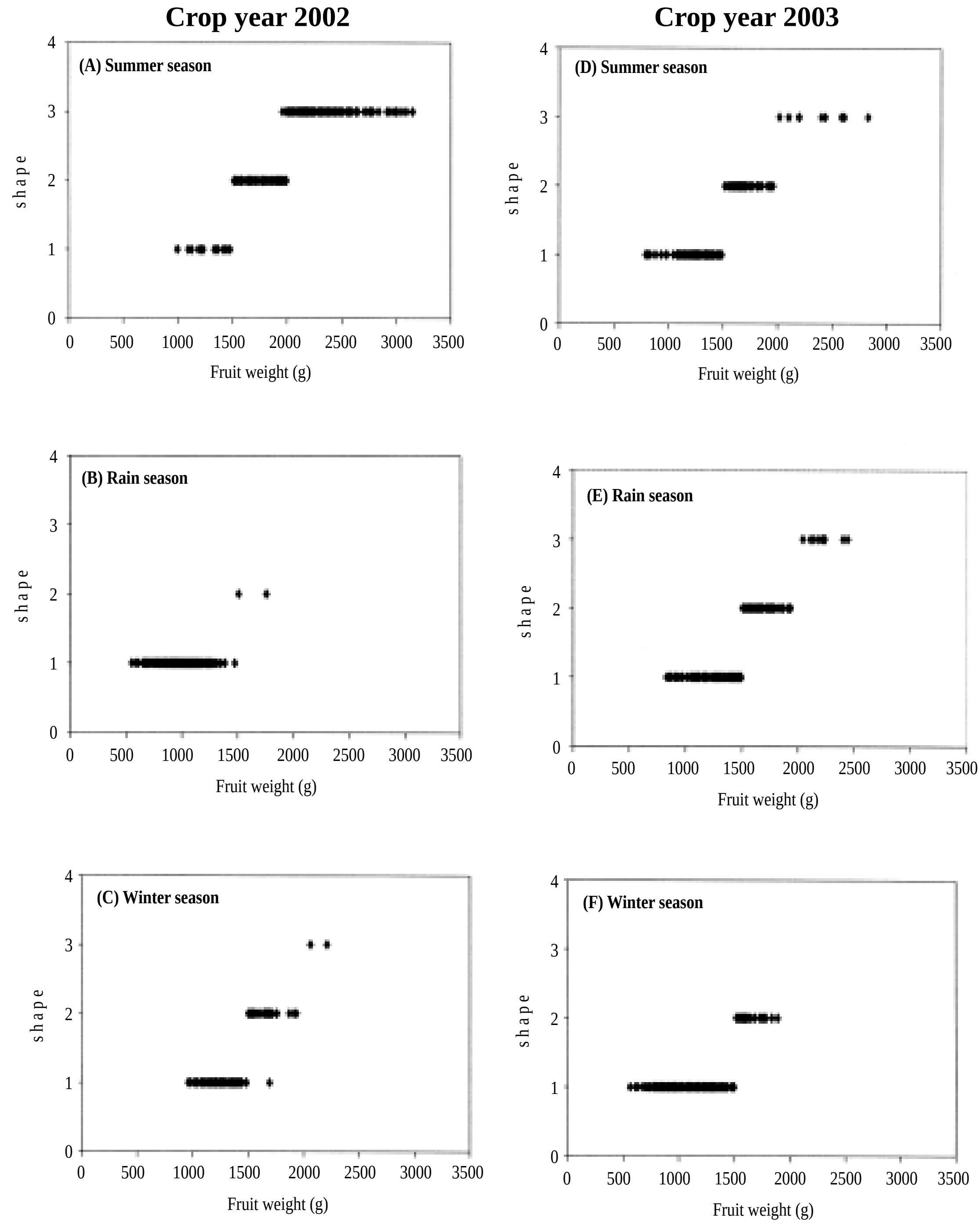


Figure 2. Relation of fruit weight and shape of pineapple fruit and percentage of fruit shape distribution.
(A) summer season, (B) rainy season, and (C) winter season of crop year 2002
(D) summer season, (E) rainy season, and (F) winter season of crop year 2003
Shape 1: spherical (small), 2: cylindrical (medium) and 3: conical (large)

The cylindrical fruit shape is the dominant character of Smooth Cayenne variety (Bartholomew, 1977). However in our experiment, the percentages of fruit with spherical shape were higher than the other shapes in rain and winter crop. The average day and night temperatures were higher than other season and also fruit development occurred during rainy season which might cut down light radiation, resulting in the reduction of fruit size and the increase of percentage of fruit with spherical shape compared with other shapes. In rainy season of 2002, most of the fruits were also of spherical shape which might be also due to the higher average day and night temperatures with incident of rain during fruit development (Figure 7) which probably caused the reduction of the number of fruit with cylindrical shape.

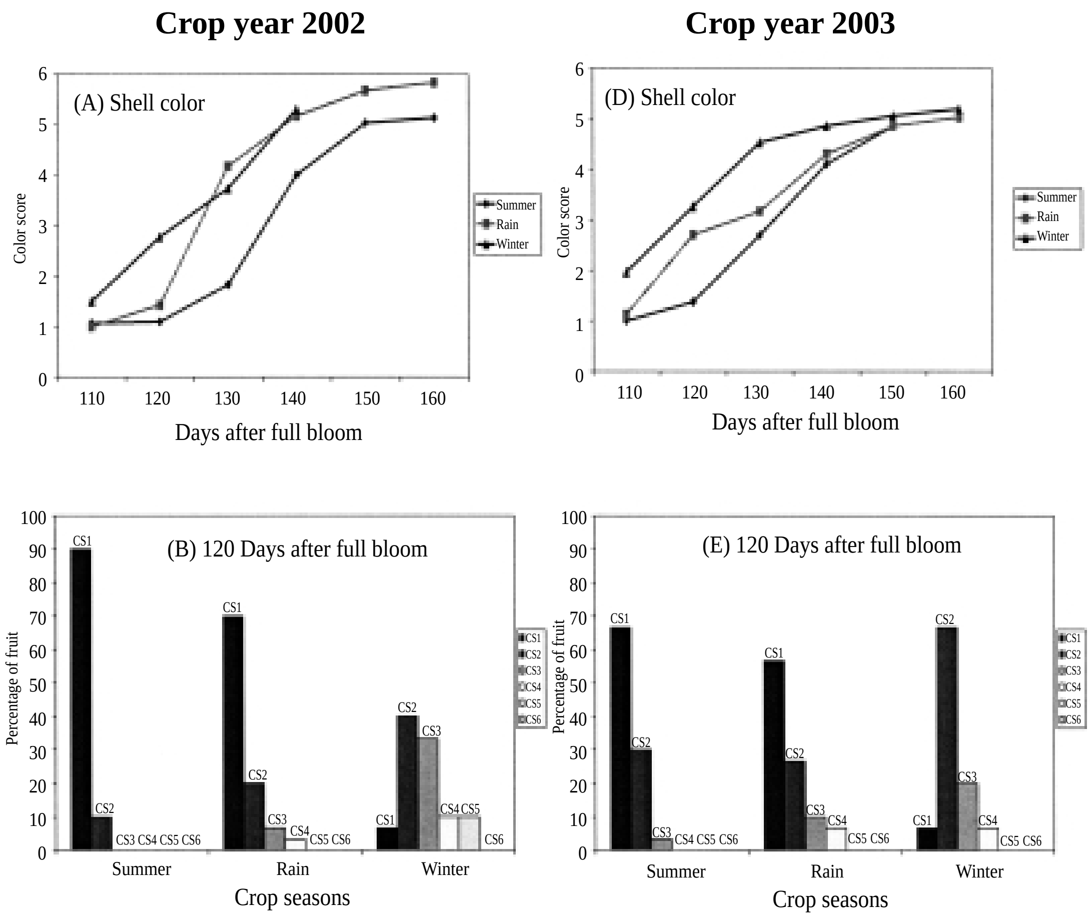
Fruitlet number

The total fruitlet number of pineapple fruit was not significantly different in summer, rainy season and winter crops of both years. The range of fruitlet number was about 99 to 105 per fruit. Fruitlet number per pineapple fruit was established at induction which thereafter determined fruit growth and final size. The number of florets varies considerably with the variety of pineapple, the size of the pineapple mother plant at induction, plant population density and the quality of forcing (Bartholomew, 1977; Wee and Rao, 1979).

Crown weight and crown length

The crown weight and crown length were significantly different between different seasons and increased to follow up with maturity stages. Crown weight and crown length of summer season was lower than rain and winter seasons (Figure 3). Most of all crowns in summer crop were rosette form and crown in rain and winter crop were elongated normal form (Figure 4).

The crown is made up of a bunch of crown leaves which morphologically behaves like vegetative leaf. Growth of the crown is of sigmoid pattern which is the same as in the fruit. Crown growth increases about 30–45 days after fruit growth had commenced. The crown has been reported to have no direct effect on the development of the fruit, although crown removal early in fruiting leads to greater fruit weight (Paull, 2000).



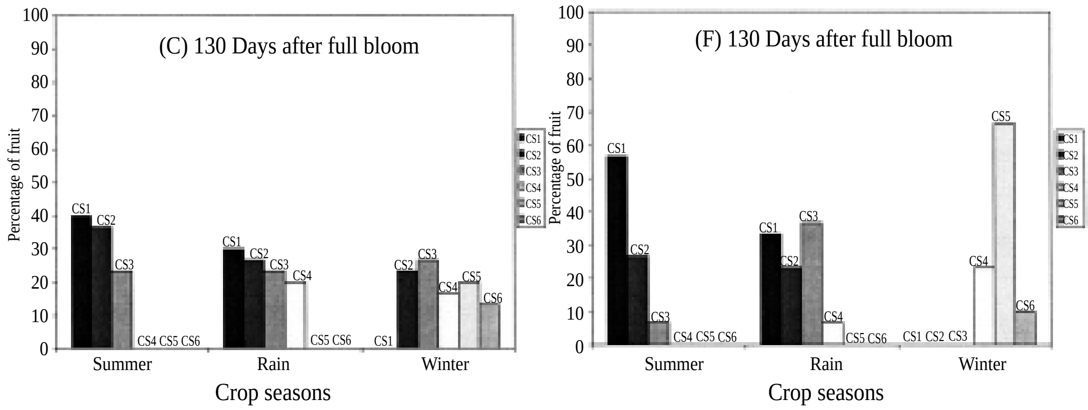
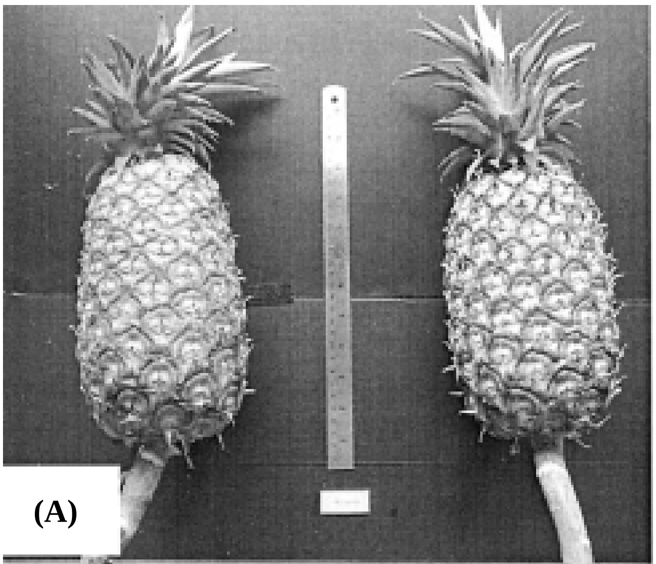
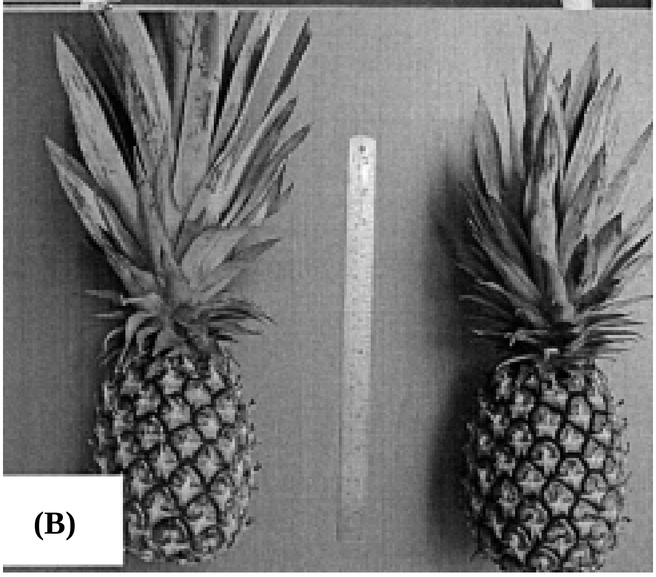


Figure 3. Average shell color score changes during harvesting period in summer, rain and winter crops of year 2002 (A) and 2003 (D) and percentage of pineapple fruit with different color score when harvested at 120 DAFB and at 130 DAFB of year 2002 (B, C) and 2003 (E, F).
Color score (CS): CS1 = green, CS2 = breaker, CS3 = 25% yellow, CS4 = 50% yellow, CS5 = 75% yellow, CS6 = 100% yellow.



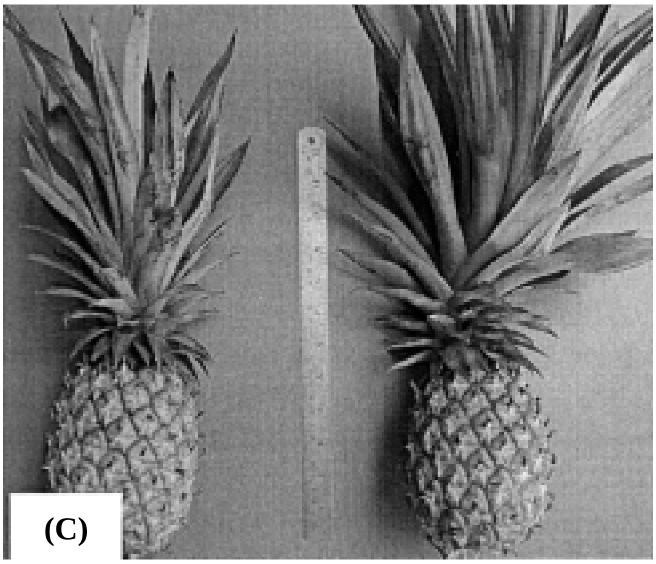
(A) Summer crop

: Conical shape
: Rosette crown
: Green shell, light yellow flesh
: TSS a verage 12.48 °Brix
: TA average 0.48
: pH average 4.15
: Slight sweet taste



(B) Rainy crop

: Cylindrical shape
: Elongate crown
: Green shell, yellow flesh
: TSS average 13.56 °Brix
: TA average 0.50
: pH average 3.66
: Sweet & slightlyt sour taste



(C) Winter crop

: Spherical shape
: Elongate crown
: Yellow shell, pale yellow flesh
: TSS average 14.95 °Brix
: TA average 0.66
: pH average 3.49
: Sour & slightly sweet taste

Figure 4. Characteristics of pineapple fruit of three different growing seasons.

Shell color

The shell color of pineapple fruit changes from green to yellow (color score 1 to color score 6) during maturation. Fruit began to change color at 120 DAFB (days after full bloom) but the change pattern of shell color depends on growing season. In summer crop season at harvesting date of 120 DAFB, when the fruit was ready for consumption, the shell color of most of fruits (85%) was still green (Figure3 (A)). Compare with fruit of winter season, 40% of the fruit changed the color to color score 3 (two lower rows of eyes become yellow). At the optimum harvesting date 130 DAFB (Figure 3 (B)), more than 75% of the summer fruit were ripe which green shell color (color score 1 and 2), while the same percentage of the winter fruits turned their color to yellow of color score 3–4 (Figure 3 (B)).

The result shows the pattern of delaying in shell color change of summer crop season. High night temperature of summer season might have delayed shell color change. The night temperature of summer crop in 2002 and 2003 was as high as 31°C and 23°C respectively while the winter crop night temperature in those years was of average lower than 23°C and 15°C. The low night temperature especially in year 2003 caused rapid color change of the fruit and most number of fruits were 75% yellow (color score 5) compared to the year 2002 which showed higher night temperature and caused 70% of fruit still being at the breaker stage (color score 2) at harvesting time. Smith (1984) reported that the degree of skin yellowness (skin color) present at optimum ripeness varied with season, rainfall, microclimate and field aspect. At various times of the year, the flesh of fruits with a dark green skin can be over-ripe while at other times, completely-yellow fruits can be under-ripe.

Figure 3 shows the pattern of shell color change in second year 2002/2003. Comparing the rate of color change of winter crop season year 2002 and 2003, the winter crop 2003 changed color more rapidly than the previous year. Incidence of rain during harvesting period might be the cause of delay in color change of first year winter crop.

Flesh color

There were significant differences in the flesh color of fruit at each of the maturity stage. The flesh color score showed increases in a*, b* and chroma value and decreases in L* and hue angle value. The flesh color changed from white to bright yellow in the later-harvested fruits, indicated by the decrease of its hue angle, L* and increasing a*, b* and chroma values (data not shown). The b* value of rain crop season was higher than winter and summer crop seasons in both years (Figure 5 (A), (B)). So the yellow color of flesh in rain crop season was more intense than summer and winter crop seasons, although no significant statistical difference was detected in flesh carotenoid content

In our experiment, flesh carotenoid increased at harvest time but it was not significantly different during 3 weeks before harvesting period until overripe. This result was in agreement with the increase of flesh carotenoid during ripe and overripe stages. Gortner (1965), Teisson and Pineau (1982), Py et al. (1987) found that flesh carotenoids increased during these final ten days before the fully-ripe stage and a similar increase in flesh carotenoids occurred in harvested fruit (Dull et al., 1967; Chen and Paull, 1995).

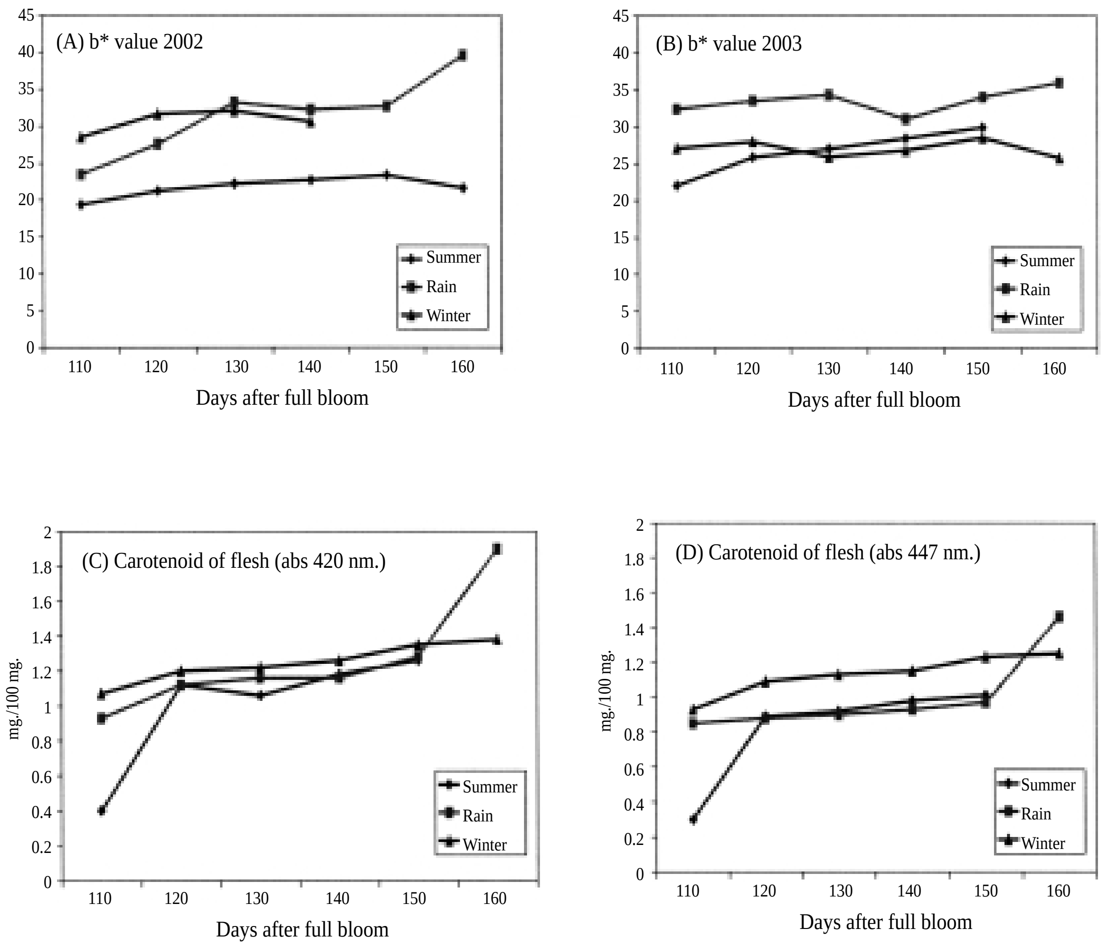


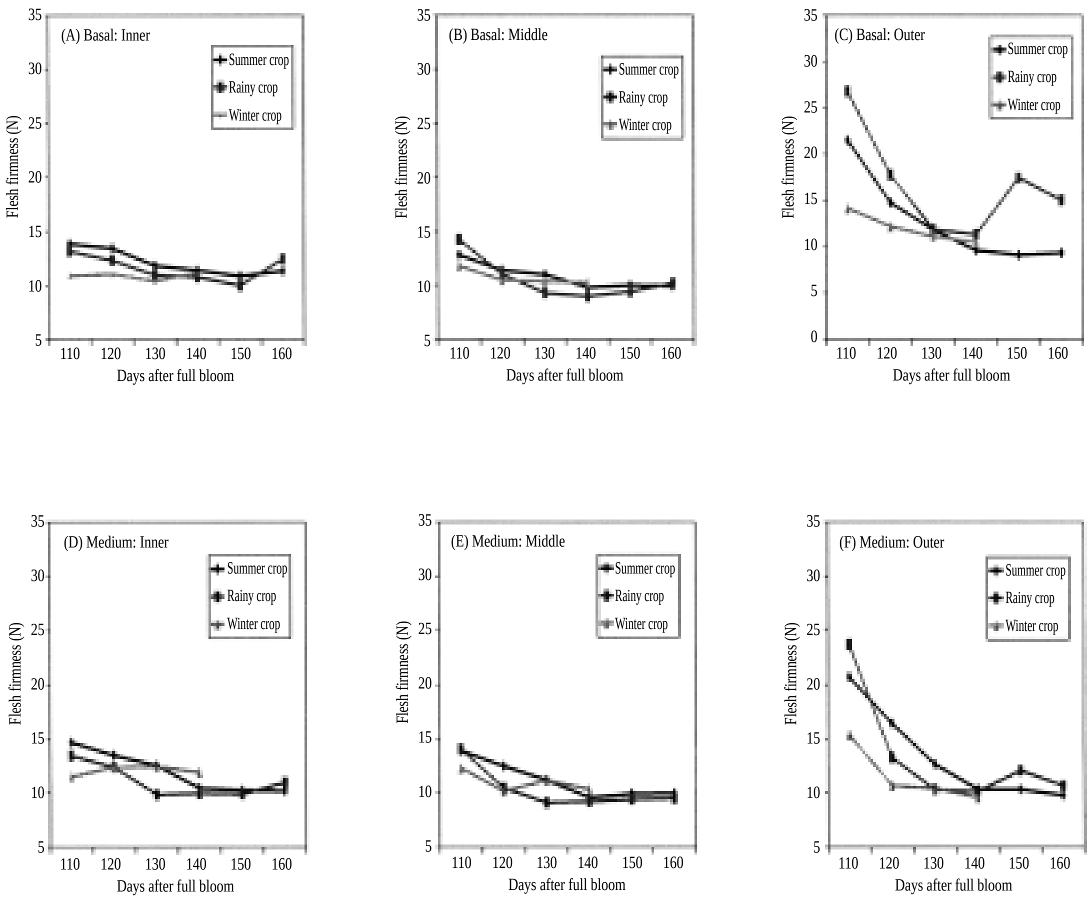
Figure 5. Average changes of b* value of pineapple fruit of 3 different seasons in crop year 2002 (A) and 2003 (B) and carotenoid content of flesh of pineapple fruit during harvesting period. The amount of carotenoid was measured at absorption wavelength of 420 nm (C) and 447 nm (D).

Total soluble solids (TSS), Total titratable acidity (TA), TSS: TA and pH

In both years, there were higher levels of TSS and lower amounts of TA in flesh of winter crop pineapple which caused its TSS/TA ratio to be higher than other crop (Table 1). Although the winter crop showed lower acid content, its pH value was significantly lower than the summer crop. The low pH value might have caused the panelists to distinguish a sour taste for winter crop.

Fruit firmness

The fruits from all harvested seasons showed significant difference in flesh firmness between parts (basal, medium, top) and positions (inner, middle, outer) of the fruit but there were no significant differences in the flesh firmness of the fruit between seasons (Figure 6). The flesh firmness of basal part was lower than medial and top parts. The fruit body comprises of many fruitlets where maturity gradient exist within fruit; fruitlets in the lower portion of a fruit are more mature or ripe than the upper portion (Tay 1976; Ramlah, 1981; Abdullah and Rohaya, 1997). So the more mature, basal tissues of fruit tend to be ripe faster than other parts and show less flesh firmness than those near the crown end (Miller and Hall, 1953). The inner and outer positions of all parts were high in firmness compared to the middle position. All parts of inner position show higher firmness values compared to middle positions due to complex tissues and hardness. Similar to outer positions, firmness values were higher as affected by the shell structure (Okimoto, 1948). All parts of middle positions showed consistent flesh firmness value due to homogeneous ovary and sepal tissues. Therefore the middle position of fruit can be the representative position for fruit firmness measurement.



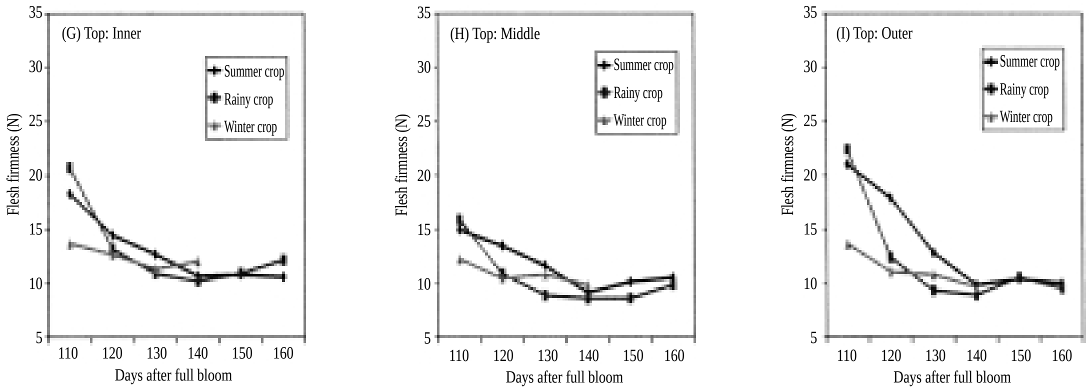


Figure 6. Flesh firmness of parts (basal, medium, top) and positions (inner, middle, outer) of summer, rainy season and winter crop in 2002.

Sensory quality

Visual, odor and firmness values of the flesh were similar in three seasons of both years. Flavor, color and acceptability of pineapple fruit from summer and rainy season crops were higher than winter crop (Table 2). Panelists were able to distinguish the sweet flavor and fairly sweet taste of the flesh of summer and rainy season crops fruit while winter crop showed sweet sour. Regarding color, panelists considered that rainy season crop was bright yellow and summer crop was slightly yellow, while the winter crop was pale yellow. This result agreed with b* value changes of all crop seasons. Acceptability of rainy season and summer crop was higher than winter crop. Smith (1988) showed that TSS and eating quality of the summer and autumn crop were higher than winter crop but the winter crop showed higher TA than other crops. The panel rated the eating quality of summer, autumn and winter crop to be 5.3, 6.2 and 3.4 respectively on hedonic scale.

Table 2. Sensory qualities of pineapple fruit at harvesting date (120 DAFB) in summer, rainy season and winter crops.

Assay	Season 2002			Season 2003		
	Summer	Rainy	Winter	Summer	Rainy	Winter
Visual	3.03±0.41[a]	3.06±0.44[a]	2.80±0.48[a]	2.96±0.31[a]	2.96±0.31[a]	2.83±0.46[a]
Flavor	4.46±0.68[b]	4.03±0.76[ab]	3.80±0.71[a]	4.20±0.71[ab]	3.90±0.80[a]	3.86±0.77[a]
Odor	2.26±0.44[a]	2.33±0.47[a]	2.43±0.50[a]	2.23±0.43[a]	2.36±0.49[a]	2.50±0.97[a]
Color	2.83±0.79[bc]	3.00±0.74[c]	2.30±0.91[ab]	2.80±0.84[abc]	3.06±0.82[c]	2.23±0.97[a]
Firmness	3.06±0.63	3.00±0.74	2.80±0.71	3.03±0.71	3.06±0.82	2.73±0.69
Acceptability	4.23±0.85[ab]	4.36±0.66[b]	3.70±0.83[a]	3.96±0.85[ab]	4.06±0.82[ab]	3.66±0.80[a]

Different letters in the same row indicate significant differences, P0.05
Visual: 1 = bad, 2 = slightly bad, 3 = acceptable, 4 = fairly good, 5 = good
Flavor: 1 = sour, 2 = fairly sour, 3 = sweet-sour, 4 = fairly sweet, 5 = sweet
Odor: 1 = off-odors, 2 = slightly ripe-odor, 3 = ripe-odor
Color: 1 = pale yellow, 2 = slightly yellow, 3 = bright yellow, 4 = deep yellow, 5 = brown
Firmness: 1 = soft, 2 = slightly firm, 3 = fairly firm, 4 = firm, 5 = very firm
Acceptability: 1 = dislikes, 2 = dislikes slightly, 3 = accepts, 4 = likes, 5 = likes very much

Data of total rainfall, relative hamidity, maximum-mimimun temperature during September, 2001 to December, 2003.

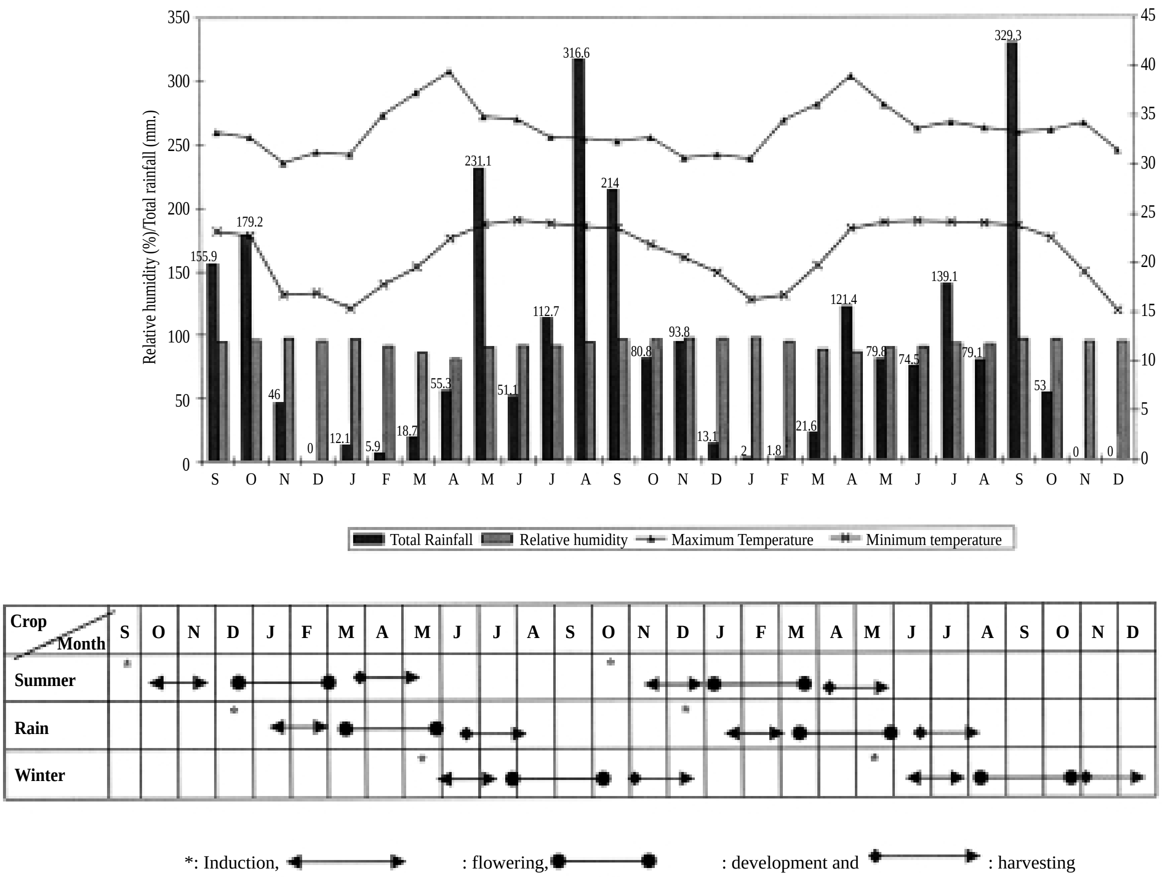


Figure 7. Total rainfall (mm.), relative humidity (%), maximum and minimum temperature (°C) during flowering induction, fruit development and harvesting of summer, rainy season, and winter crops during year 2002 and 2003.

CONCLUSION

The pineapple fruit characteristic and quality, affected by the difference in growing season, were fruit weight, fruit size, fruit shape, shell color, size and shape of crown, flesh color, flavor and taste. The summer crop was highest in fruit weight and the fruit was mainly of conical shape with rosette crown and mostly with green shell. In contrast, fruits of rainy and winter crop were cylindrical and spherical in shape with elongated crown and green shell in rainy crop but yellow shell in winter crop. For flesh qualities, summer and rainy crop had yellow color flesh and sweet flavor taste, while flesh of winter crop was pale yellow and had sour flavor taste. Although the TSS was not significantly different in crops from all seasons, winter crop had higher acid content than other crops.

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REFERENCES

Anon. 2002. FAO STAT database. Food and Agriculture Organization of the United Nations. Rome, Italy.

Abdullah, H., and M.A Rohaya. 1997. Influence of maturity stage on quality of stored pineapple (*Ananas comosus* cv. Mauritius). J. Bioscience. 8(2): 119–126.

Anupant, P., P. Chairidchai, A. Kongsawat, S. Isawilanon, S. Subhadrabhundu, and S. Siripat. 2000. The pineapple industry in Thailand. In S. Subhadrabhundu and P. Chairidchai. (eds) Proceeding of the Third International Pineapple Symposium. International Society for Horticultural Science. Pattaya, Thailand.

Baker, B.1990. World pineapple production. United State Department of Agriculture, Foreign Agricultural Service, Washington, DC.

Batholomew, D.P. 1977. Inflorescence development of pineapple (*Ananas comosus* L. Merr.) induced to flower with ehtephon. Botanical Gazette 138: 312–320.

Batholomew, D.P., and E.P. Malezieux. 1994. Pineapple. p. 243–291. In B. Schaffer and P.C. Anderson (eds) Handbook of environmental physiology of fruit crops. Volume 2, Subtropical and Tropical Crops, CRC Press, Boca Raton, Florida, USA.

Chen, C.C., and R.E. Paull. 1995. Effect of waxing and storage on pineapple quality. Proceedings International Symposium on Postharvest Science and Technology of Horticulture Crops, 27 June–1 July. Beijing, China.

Dull, G.G., R.E. Young, and J.B. Baile. 1967. Respiratory patterns in fruit of pineapple, *Ananas comosus*, detached at different stages of development. Physiology Plant 20: 1059–1065.

Gortner, W.A. 1965. Chemical and physical development of the pineapple fruit. IV, Plant pigment constituents. J. Food Science. 28: 191–192.

Hepton, A., J.L. Ingamells, E. Macion, J. Gonzales, and D. Sampongse. 1993. Pineapple plant and fruit growth and development in fertilized native soil and artificial root medium. Acta Hort. 334: 131–139.

Lin, C. H., and C. C. Chang. 2000. Pineapple production and industry in Taiwan. In S. Subhadrabhundu and P. Chairidchai (eds) Proceeding of the Third International Pineapple Symposium. International Society for Horticultural Science. Pattaya, Thailand.

Miller, E.V., and G.D. Hall. 1953. Distribution of total soluble solids, ascorbic acid, total acid, and bromelin activity in the fruit of the Natal pineapple (*Ananas comosus* L.Merr.). Plant Physiology 28: 532–534.

Monselise, S. P. 1986. Pineapple: Handbook of fruit set and development. CRC Press Inc.

Moreau, B., and C. Moreuil. 1976. Ananas dans la region de tamatave (cote est de Madagascar). Contribution a la connaissance de sa vegetation en conditions naturelle et dirigee. Fruit 31: 21–30.

Nakasone, H.Y., and R.E. Paull. 1998. Tropical fruits. CAB Intl. Wallingford, UK.

Okimoto, M. C. 1948. Anatomy and histology of the pineapple inflorescence and fruit.Botanical Gazette 110: 217–231.

Paull, R.E. 2000. Pineapple and papaya. In G. Seymour, J. Taulor and G. Tucker (eds) Biochemistry of fruit ripening. Chapman & Hall, London.

Py, C., J.J. Lacoeuilli, and C. Teisson. 1987. The Pineapple, cultivation and use. Editions G - P, Maisonneuve, Paris. 568 p.

Ramlah, M. 1981. Fruit ripening studies on pineapple cv. Mauritius Meru, Mauritius Jalan Kebun and Mauritius Pontian. MARDI (Jln. Kebun) Technical Paper No.20: 7p.

Sideris, C.P., and B.H. Krauss. 1938. Growth phenomena of pineapple fruits. Growth 2: 181–196.

Smith, I.E. 1977. Seasonal variations in fruit growth of the pineapple (*Ananas comosus* (L) Merr. cv Smooth Cayenne) in the Eastern Cape. Gewasproduksie 6: 105–110.

Smith, L.G. 1984. Pineapple specific gravity as an index of eating quality. Tropical Agriculture, Trinidad 61 (3): 196–199.

Smith, L.G. 1988. Indices of physiology maturity and eating quality in Smooth Cayenne pineapples. 2. Indices of eating quality. Queensland Journal of Agriculture and Animal Science 45 (2): 219–228.

Tay, T. H. 1976. Fruit ripening studies on pineapple. MARDI Res Bull. 4(2): 29–34.

Teisson, C., and P. Pineau. 1982. Quelques donness sur les dernieres phases du development de l'ananas. Fruit 37: 741–748.

UNE. 1976. Guide for installation of the tasting room. Standard No. 33:119–76.

Wee, Y.C., and A.N. Rao. 1979. Development of the inflorescence and crown of *Ananas comosus* after treatment with acetylene, NAA and ethephon. Amer. J. of Botany. 66: 351-360.