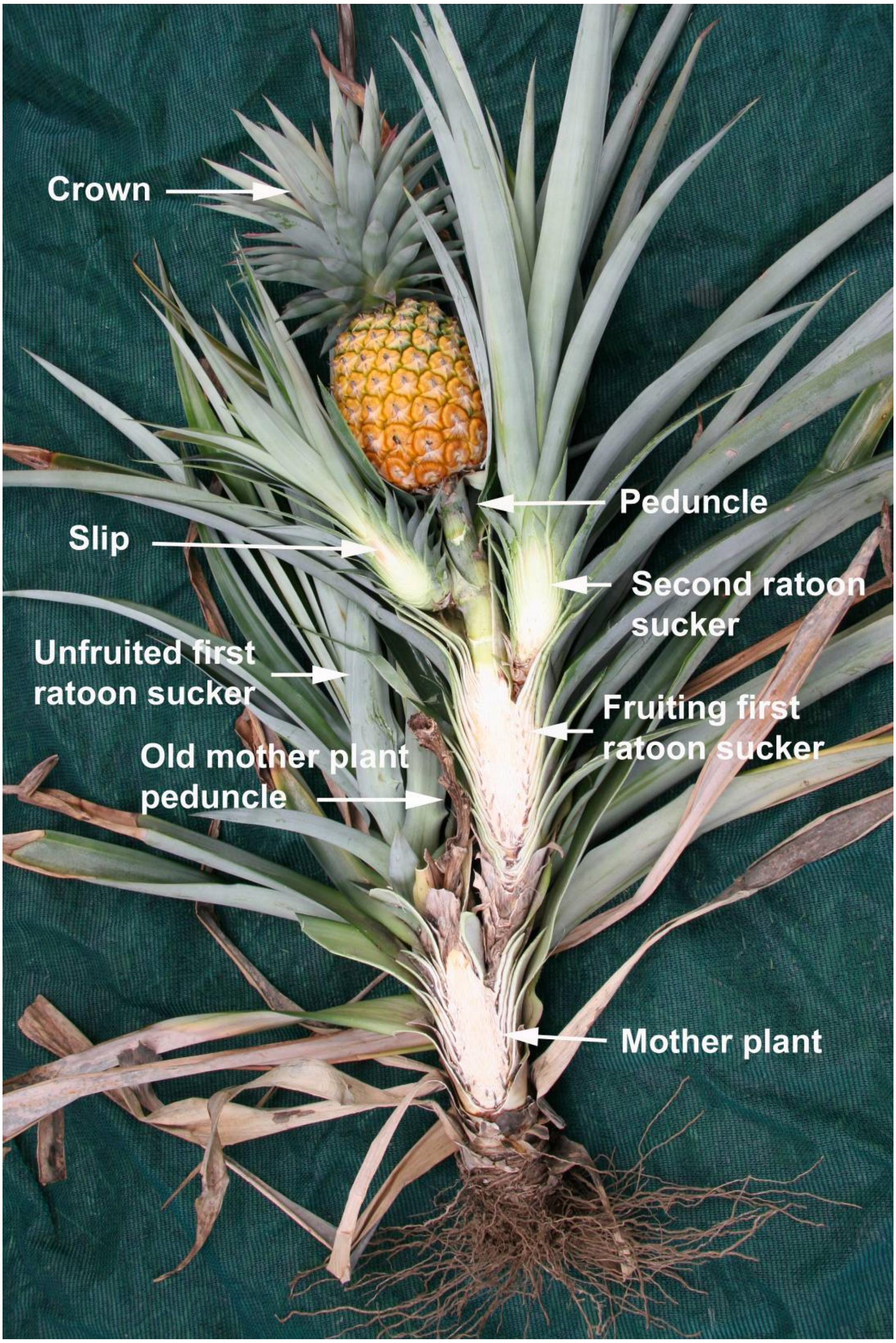
Chapter 01

THE PINEAPPLE



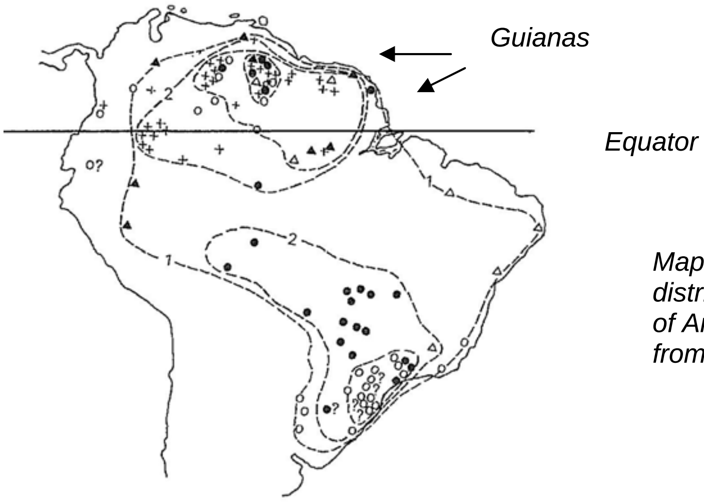
Version 1, 31 August 2009

Vegetative (rounded) growing point (left) and flowering (pointed) growing point (right)

Classification and origins

The pineapple belongs to the bromeliad family, which contains 50 genera and about 2,500 known species, all but one of them from Central and South America. The exact origin of the cultivated species – *Ananas comosus var. comosus* – is hard to pinpoint, but *Ananas comosus var. ananassoides* (with very small, seedy fruit and spiny leaves) is considered a wild ancestor of the domestic pineapple. Its origins are in Brazil/Paraguay straddling the equator between latitudes 15°N & 30°S. (In Australia they are commercially grown between 15° & 27°S, Cooktown to Brisbane). Domestication is thought to have occurred in the Guianas (Duval et al, 2003).

For several thousand years, superior types of pineapples had been selected, domesticated and distributed by native Indians throughout the tropics and subtropics of South/Central America (notably the Guarani in whose language ‘ananas’ meant ‘excellent fruit’).



Map of South America showing distribution of different varieties of Ananas comosus (adapted from Py et al 1987)

Westerners first saw pineapples in 1493 on the island of Guadeloupe during Columbus’ second voyage to “The New World”, and on other islands in the West Indies later. It was recorded that King Ferdinand of Spain was eating pineapples as early as 1530, and the Spanish navigators distributed pineapple plants throughout the tropics so early and widely that it was considered indigenous. Pineapples were in India by 1548, and cloth was being made from pineapple leaf fibres (piña cloth) in the Philippines in the 1500’s.

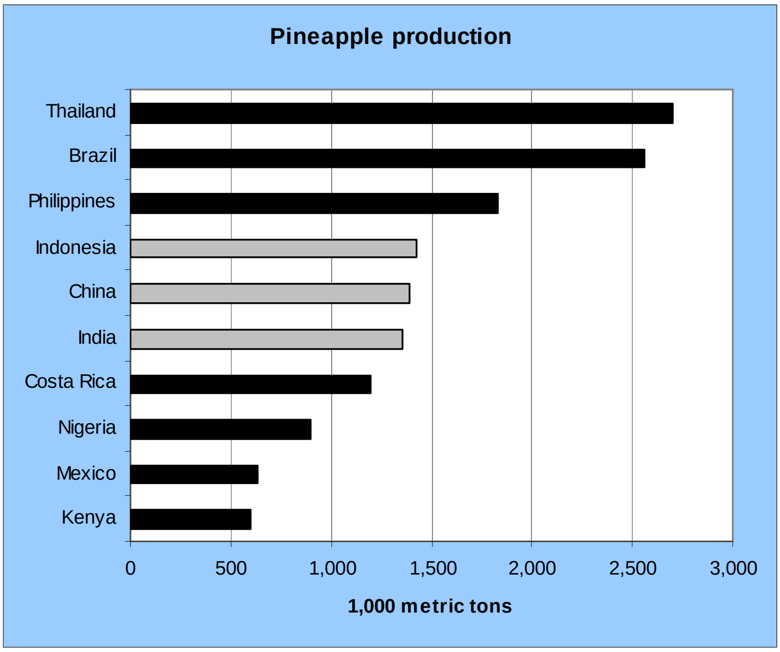
The first pineapples (rough-leafed) are thought to have been introduced to Australia from India in 1838 by a German missionary, although some records indicate that pineapples were grown near Sydney as early as 1824. The first commercial plantings were established in Nundah (now a suburb of Brisbane) in the early 1840’s (Lewcock, 1939). Smooth Cayenne came from Kew Gardens in England probably around 1858 (Collins, 1960). The main pineapple growing areas at that time were Saint Lucia, Fortitude Valley and Kangaroo Point (with its Pineapple Hotel). Production spread to Wavell Heights, Zillmere (there’s still a Pineapple St there) and continued its spread north from there. In Queensland today pineapples are commercially grown from Brisbane to Cooktown and small quantities are grown in Northern New South Wales and the Northern Territory (Darwin). While the pineapple is considered a tropical fruit it has been grown commercially from latitude 27°N (Okinawa & Florida) to latitude 34°S (South Africa), with the great mass of production within the tropics only a few degrees north and south of the equator.

World pineapple production

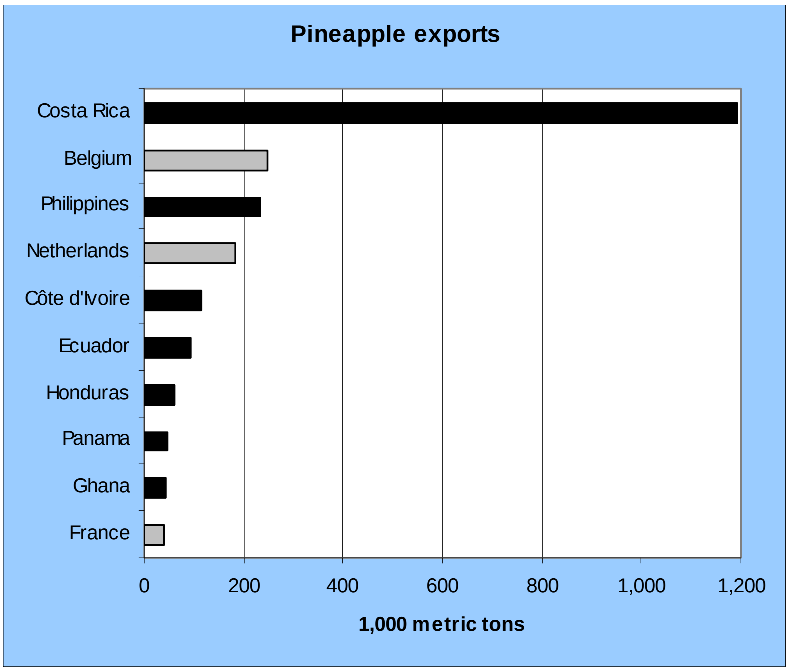
Australian pineapple production reached a peak in 1988 with 154,000 tonnes from 6,660 ha (Castles, 1995). In 2009/10 it is estimated that 90,000 tonnes will be grown of which about 44% is for fresh fruit. It is expected that within a few years that the volume grown for fresh fruit will exceed that for processing.

The following graphs show the top producing and exporting countries of the world.

Top producers of pineapples in 2006 (USDA, Economic Research Service, 2009)



Top exporters of pineapples in 2006 (USDA, Economic Research Service, 2009)



Note: Belgium & the Netherlands do not grow pineapples but import then re-export to other European countries.

Botanical and physiological adaptations

Pineapple is a tropical plant and grows best in a moderately warm climate (16° to 33°C) with low, but regular rainfall. It is estimated that Smooth Cayenne requires only 50mm of rainfall per month for optimum growth. It has some important limitations:

- It cannot tolerate frost
- It is intolerant of high temperatures (in excess of 40°C), and sunburn damage to plants and fruit can be severe
- It has a fragile root system that needs well-drained conditions

Pineapple has several special characteristics that allow it to survive and thrive under low rainfall conditions:

- Leaf shape and orientation that maximises capture of moisture and sunlight most efficiently
- The large cups formed where the leaves attach to the stump are effective reservoirs for nutrient solutions and water
- The ability to absorb nutrients through axillary roots in the leaf bases, and directly through the leaf surfaces especially the basal white tissue
- Low numbers of stomata, and leaves that are insulated to reduce water loss
- Water storage tissue that can make up to half the leaf thickness, and is used during periods of low rainfall to help maintain growth
- A specialised metabolic system (CAM) for capturing carbon dioxide at night for use during the day that greatly reduces water loss

The pineapple's adaptation to dry conditions comes not only from evolving in a dry climate but also from its epiphytic ancestry (epiphytes grow above the ground on other plants for support).

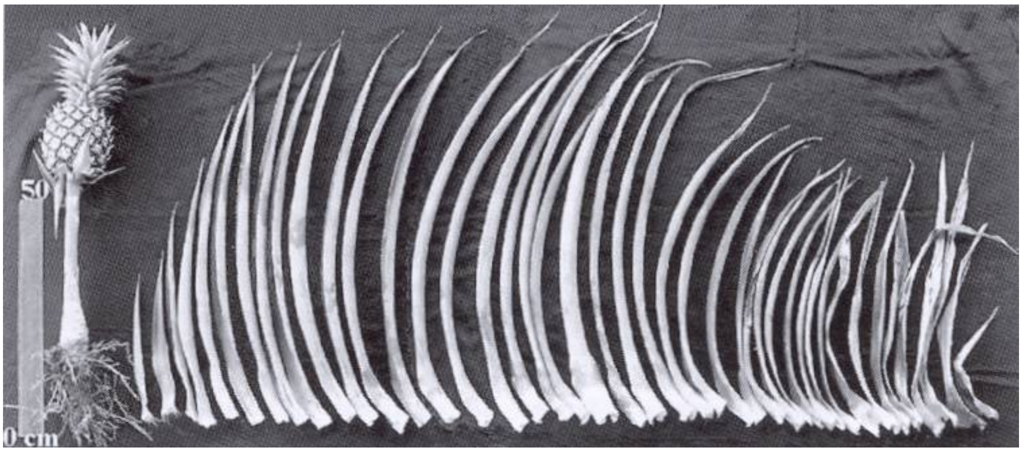
Leaf shape and arrangement.

Pineapple leaves - long, trough-shaped, tapered from base to tip, and approaching horizontal - are arranged spirally around the stump. This plant shape allows for maximum sunlight interception, and highly efficient gathering and movement of rain to the plant's stem and root system. Most of the leaves – especially the leaves at the top of the plant most exposed to the sun are oriented at an angle to the sun (i.e. relatively erect) and this helps reduce leaf temperature and moisture loss.

The leaves are arranged so that it is the thirteenth leaf on the spiral that first actually overlaps and shades a lower leaf on that plant, and because of their long, tapered shape do not shade leaves of neighbouring plants until they are large and mature. A mature plant, weighing 3.6 kg will have a leaf area of about 2.2 square metres.

Axillary root system

In the cup-like leaf axils are rudimentary (partially developed) roots called axillary roots that can absorb moisture and dissolved nutrients directly.



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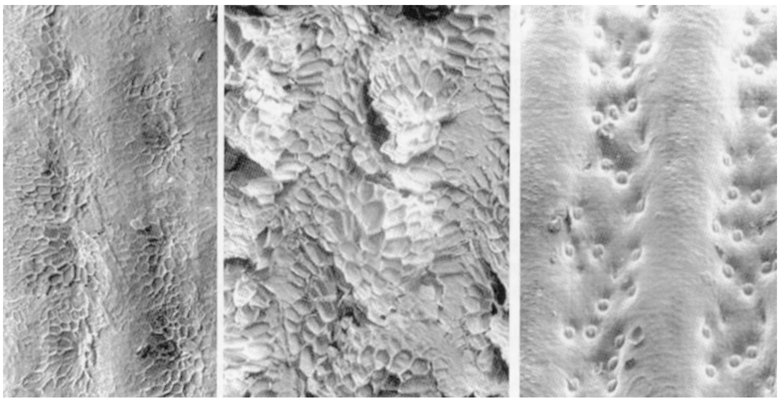
Basal white tissue
This white tissue can absorb water and dissolved nutrients directly. It changes to green tissue as leaves grow and mature.

Stomata
Stomata are pores in the leaves that can open and close to the atmosphere. Carbon dioxide enters the plant through the stomata whilst moisture and oxygen leave through them. There are relatively few stomata per unit of leaf area, plus they are small and situated mainly on the underside of the leaves in depressed channels. Because they are small, deep and protected by a heavy coat of waxy trichomes, the plant has a very low rate of transpiration (water loss).



Electron micrographs of the pineapple leaf surface. Far left: upper surface of the leaf. Centre: lower surface of the leaf showing dense trichome growth. Right: lower surface with the trichomes rubbed off revealing the location of the stomata (leaf pores) in the furrows (from Malezieux et al 2003).

Trichomes ("leaf hairs")
Trichomes are defined as "fine outgrowths from the epidermis (skin) of the leaf". In pineapple the trichomes are multi-cellular, mushroom-shaped scaly hairs that surround the stomata and help reduce water loss from the plants. They are heaviest on the under side of the leaves (the white dust that gets on your trousers) and give the leaves their silvery underside. When trichomes are absent (copper deficiency) or removed by insects (mites and ants) or by urea heart rot, the leaves take on a "polished" look**.** The silvery colour of the leaves (given to it by the trichomes) heightens reflection and helps reduce leaf temperature.

As well as having a covering of trichomes the epidermis (skin) of the upper leaf surface is covered with a thick waxy cuticle which further reduces moisture loss.

Water storage tissue

The cross-section of a mature ‘Smooth Cayenne’ leaf can be up to 4mm thick with approximately half the volume occupied by water-storage tissue. When moisture levels are good, up to half of the 4mm cross-sectional thickness of a mature leaf is made up of specialised water storage tissue. This tissue serves as a reservoir and is drawn upon to maintain plant growth, and even fruit development, during periods of inadequate moisture. After extended dry periods this tissue decreases to near nil – a sign of drought.

CAM photosynthesis

The pineapple has a special photosynthetic pathway called CAM (Crassulacean Acid Metabolism). This is a feature that certain plants including cacti have evolved to conserve moisture. Most plants must absorb carbon dioxide whilst the sun is shining for photosynthesis to take place and produce starch and sugars; therefore their stomata are open in the warmest, driest part of the 24 hour cycle and much moisture escapes from the plant through the open stomata. CAM plants, on the other hand, have the unique ability to store carbon dioxide within the plant (as malic acid), this allows them to keep their stomata closed during the day but to open them at night when the atmosphere is cooler and more humid. When the sun comes out the next day the stomata close but carbon dioxide is released into the plant cells from the stored malic acid allowing photosynthesis to take place. The table below illustrates the benefit of CAM in terms of moisture conservation.

Relative loss of water through stomata

Plant	Grams water lost for every gram carbon dioxide absorbed
Trees and shrubs	450 - 600
Tropical grasses	250 - 350
Pineapple	25 - 150

Even though the actual rate of photosynthesis is slower in pineapple leaves than in other crops, such as wheat and sugarcane, its leaf area index (area of leaf per square metre of ground area) is high and it is also able to keep photosynthesising under conditions that would be too dry for other crops.

Due to its moisture conservation attributes, water use (combined evaporation and transpiration) actually reduces in pineapple as the crop grows larger. Compared to open-pan evaporation, water use in a pineapple field is approximately as follows:

Newly planted tops:	100%
12-months old:	25%
1st ratoon field:	15%

In contrast a grass sod evapo-transpiration rate is essentially 100% of pan evaporation rate from start to finish.

Implications
The many ways in which pineapple is able to conserve water make it very tolerant of periods of low rainfall so it is able to continue to grow under relatively dry conditions.

The shape of the plant and its leaves allow pineapple to benefit from water droplets from whatever source, e.g. rain, heavy dew or high volume foliar sprays (more than 1,000 litres per ha). These are efficiently collected by the spirally arranged rosette of leaves and funnelled into the leaf axil cups for absorption by the basal white tissue and axillary root system. For foliar sprays ensure sufficient volume is used so that spray ingredients reach the basal white tissue and axillary (aerial) roots.

The downside is that it is difficult to reach the soil with sprays once canopy closure has been reached. By the time adjacent plants meet across the beds and walking spaces (8 – 10 months) leaf coverage is so heavy that treatments destined for the soil require high volume sprays (more than 2,000 L per ha, usually about 5,000 L).

Some nutrients can enter directly through the green leaf surfaces (notably urea and iron/zinc sulphates). Low volume sprays (no “run off” – less than 500 litres per ha) are efficient and effective. Since stomata are open at night some sprays may be more effective at night.

Although pineapple has many very efficient moisture conserving systems and has one of the highest water use efficiencies among cultivated crops and can survive severe drought, they still benefit from “good” rainfall/irrigation. Under moisture stress plant growth and yields are significantly reduced. During extended dry periods the plant ‘closes down’ and crop schedules are upset.

Fruit that mature under severe water stress are highly susceptible to cracking if rain occurs near maturity. Losses to yeasty rot can be almost total when this happens.

Another downside is that because the pineapple leaves close their stomata during the day they don’t have the benefits of evaporative cooling! Plants heat up and unless there is a breeze to move the heat out of the field they are prone to plant damage, fruit sunburn and “cooking” or “boiling”. Growth slows when temperatures exceed 36°C and stops at about 40°C.

Life cycle

In our climate pineapple does not have an annual cycle, it is longer than 12 months and flowering and fruit maturity are not tied to seasons. Refer to Appendix I.

Two conditions are required for plants to flower naturally (a) they need to have reached sufficient maturity and (b) some form of stress needs to occur that causes a check in plant growth. Examples of stress include cool temperatures, drought or physical damage such as hail, insect or disease attack.

Tops (crowns) and slips are the normal choices for planting. Slips, which are normally larger than tops, produce a mature plant earlier. In south east Queensland slip plantings are ready for flowering at about 12 months, whilst crowns planted at the same time can be expected to be ready at 14 months.

The time from crop initiation to harvest varies considerably both by time of year and latitude (Chapters 5 and 26 detail these differences). In very broad terms the plant crop is ready for harvest 20 to 24 months after planting.

Normally one ratoon crop is taken following the plant crop but sometimes single crop cycles are used. For ratoon crops the fruit form on the suckers that develop from the stem of the earlier crop. Again the time from plant crop to ratoon crop harvest is highly variable, but generally in the range of 12 to 15 months.

Typically, a two-crop cycle takes four years from planting to planting.

Pineapple is a perennial plant and many successive crops can be taken from one planting. If plants continue to be healthy, second and third ratoons are possible. Fruit size declines with each successive crop.

Stem (butt)

The stem is the storage reservoir of the plant. It can contain up to 11% starch, which is the form of energy stored when photosynthesis exceeds the plants immediate needs. These starch reserves are drawn down when sunlight is limited and they are the source of energy for the early development of suckers.

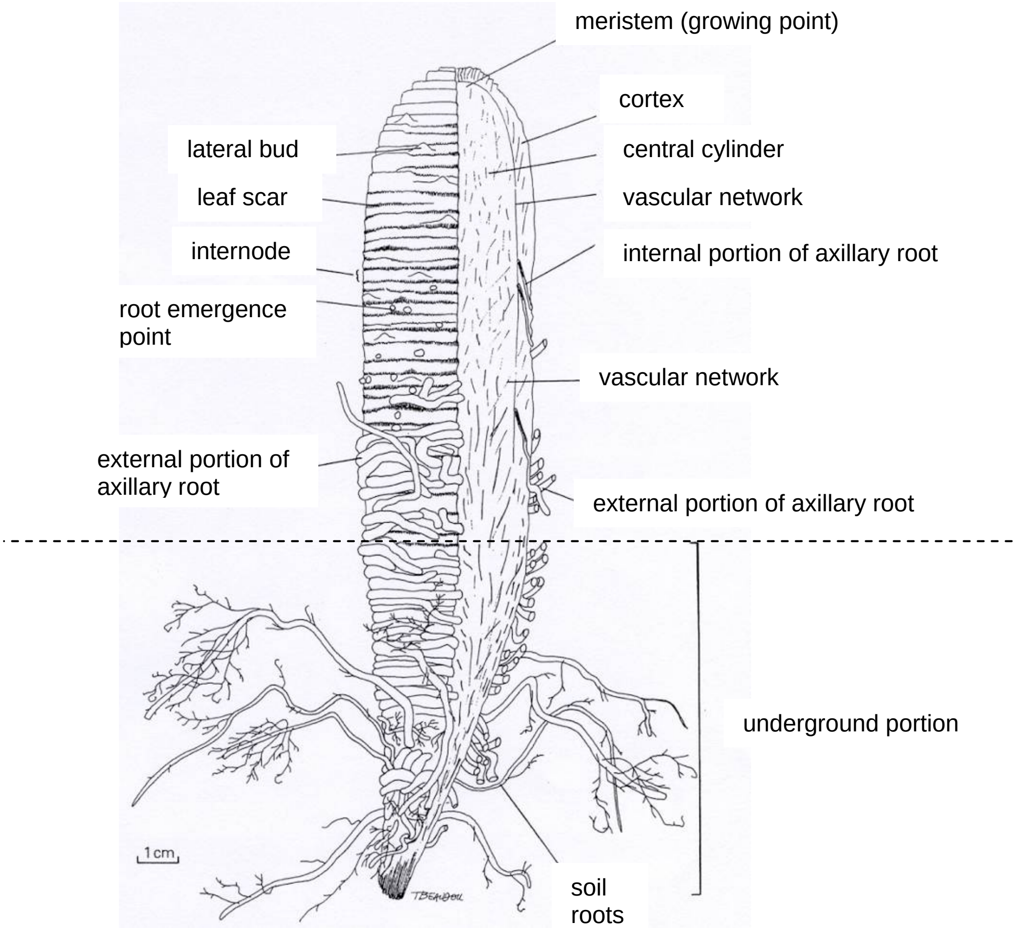
This part of the plant is not visible unless all the leaves are stripped. Understanding its relationships helps to understand the “nature” of pineapple,

- Broad leaves = large stem diameter = large fruit diameter.
- Narrow leaves = small stem diameter = small fruit diameter.
- Fruit with larger diameter are heavier = higher yield

The diagram below shows the stem after all the leaves have been removed. One of the pineapple’s important characteristics is the presence of both soil and axillary (aerial) roots. There are also lateral buds on the stem associated with each leaf, which can form ratoon suckers and become volunteers in replant fields. These have been an important source of planting material in clonal propagation before the advent of tissue culturing. This method of bud propagation is slow, but does not produce off-types.

Implications

It is the size of the stem that is most important when judging how large and well-grown a plant is, not just the size of the leaves & canopy. Very fast growing plants in a very warm tropical environment can produce a lot of leaf but store little starch in the stem and hence may only produce small fruit.



Nutrients and water applied as foliar sprays can be absorbed by the axillary roots on the stem at the leaf bases (as well as via the basal white leaf tissue).

Plants induced too early i.e. without sufficient accumulation of starch reserves, may not develop an adequately sized fruit.

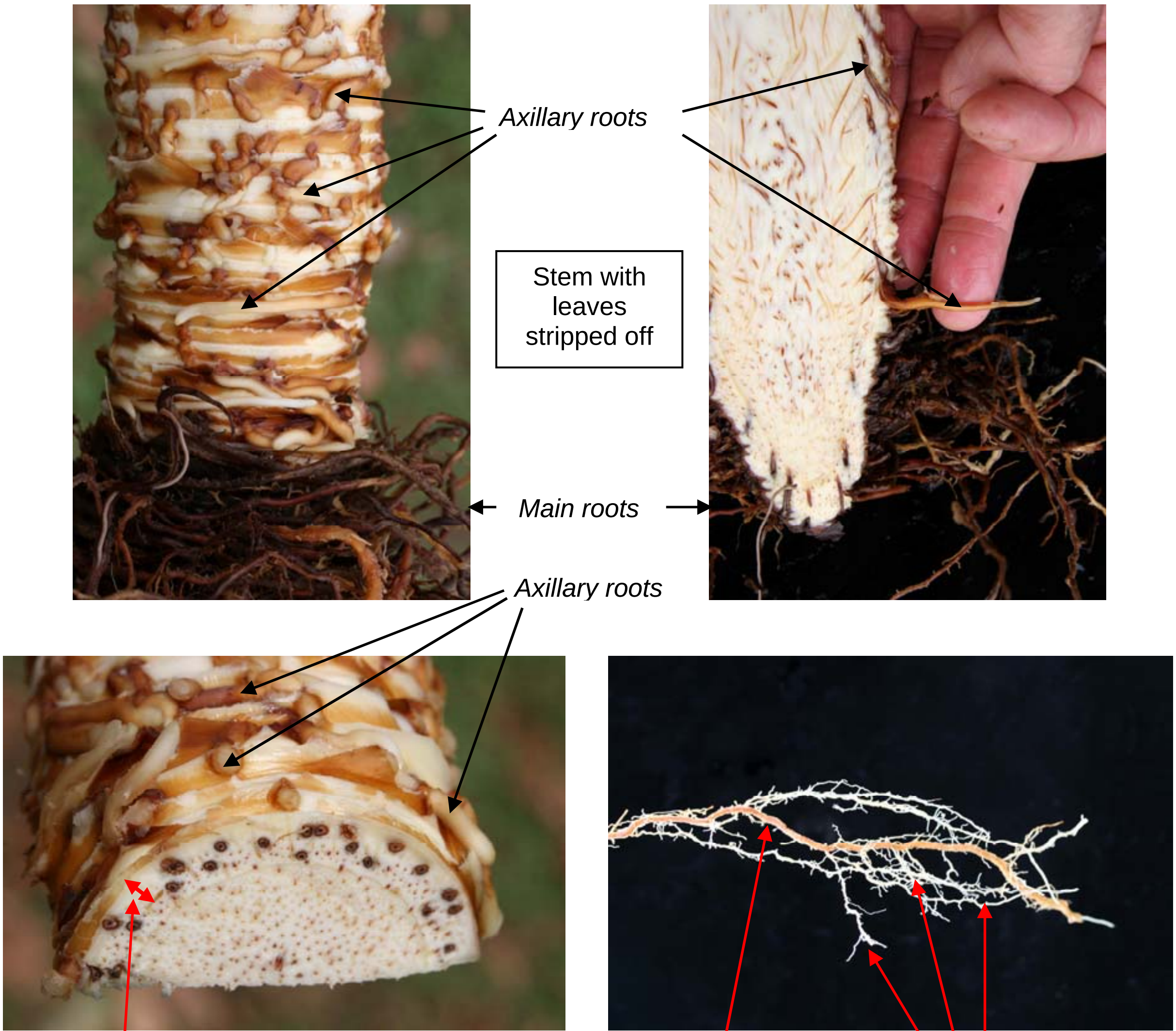
Well grown and mature mother plants are more likely to have sufficient starch reserves to produce robust suckers for the ratoon crop.

Root system

Bromeliads have a weakly developed, fragile root system which perhaps can be traced back to their epiphytic ancestry. The root system of pineapples is usually shallow, spread out and does not regenerate well if damaged by pests or diseases.

Types of roots
All roots originate from just behind the **growing point** of the plant/planting material. They grow downwards and outwards through a narrow layer of tissue called the **cortex** emerging about 1cm below the growing tip on the outside of the plant just below a leaf base. If they emerge below ground or within a centimetre or so above the soil they will grow into the soil and form **main roots**, but as the plant grows the growing tip becomes further away from the soil and the roots will emerge higher and higher above the soil, these roots won't reach the soil and instead will wrap around

the stem becoming **axillary roots**, they have a flattened reddish-brown appearance. The axillary roots and the white basal tissue of the leaves perform an important role absorbing water and nutrients that run down the leaves.



Cortex through which the roots (dark brown in cross section here) grow downwards and outwards before emerging

Main root (light brown, partly suberised)

Lateral roots

Roots that branch off the main roots are called **lateral roots**. Axillary, main and lateral roots have **root hairs** which significantly increase the surface area of root material capable of moisture and nutrient uptake. The formation of root hairs is entirely dependant on the oxygen supply to the roots.

Root Growth

The number of underground roots depends on the weight and type of planting material. Crowns produce considerably more roots than slips or suckers.

Root growth commences soon after planting and continues up until around flowering. Root growth slows but continues throughout winter depending on temperatures and soil moisture. The longest main roots spread laterally out from the base of the plant not far below the soil surface. Roots can penetrate to a depth of 1.5 m but most root development is within the raised bed where the soil is not compacted. Smooth

Cayenne plants can produce a total of around 70 metres of main root over 12 months. There can be around 450 main roots per plant.

N.B. The main root system is not renewed if damaged and no new main roots are produced if any die. New lateral roots will however form behind any damaged main root tips.

Main roots only emerge within the first 12 months or less and they must last until the ratoon crop is harvested. Where the root system has declined, the ratoon crop will depend more on the mother plant for its development. It is important therefore to maintain good root health and to maintain soil around the base of plants.

Note: Trimming of lower leaves on the old mother plant and hilling soil around the stem will induce new main root growth from further up the stem.

Varietal differences

Differences in root growth can occur between pineapple varieties. For example some will produce more main roots than others and some will produce more lateral roots than others.

Uncompacted, well drained and aerated beds are essential and the use of pesticides can rarely be avoided.

Reproduction

Pineapples are normally propagated vegetatively, using tops, slips, suckers and even butts. This means that each plant is a clone (genetically identical copy of its mother). These clones grow true to type and produce predictable and uniform crops**. Note: Occasional mutations (off-types) can occur (common in tissue cultured plants) and must be weeded out (rogued) so they don't multiply and contaminate a good clonal population.**

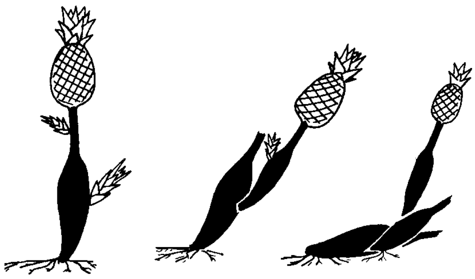


Diagram showing successive vegetative generation in pineapple up to a 2^nd ratoon (from Py et al 1987)

Pineapples are "self incompatible" so rarely produce seed in a field of only one variety. However, if two varieties are grown close together (Smooth Cayenne and a hybrid for example) and they are in flower at the same time, insects can cause cross-pollination. Seedy fruit is not acceptable for either fresh or processing outlets.

Cross-pollination between varieties is practiced by plant breeders to produce new hybrid clones like the "Golds", the seed is germinated under laboratory conditions.

Chlorflurenol (Maintain®) used for propagating slips, can result in thousands of small, undeveloped seeds in fruit if applied too long after fruit initiation (usually because some natural fruiting occurred before chemical forcing). These seeds will not germinate and the fruit must be discarded.

Flowering

Pineapple is an indeterminate flowering plant which means it has no specific flowering trigger like day/night length, for example. Natural initiation of mature plants (12+ months old) for summer harvest is strong because initiation takes place in winter. Natural initiation for winter harvest - while present - is much weaker because initiation occurs in warmer months when vegetative growth is strong.

Because of this “random” nature of flowering, fruiting can be spread out and require many harvest rounds to complete a crop. Good crop control requires careful planning. Uniform planting material type and size (tops, slips and suckers mature at different times), a uniform strike and intelligent use and timing of flower induction treatments will result in more uniform fruiting, and allow for controlled ripening.

Fruit

The pineapple is technically called a sorosis – “a fusing of many fruit together to form one unit”. Each “eye” (fruitlet) is a complete fruit. Flowering starts at the bottom of the sorosis and continues up as a spiral to the last eye. When the formation of fruitlets stops, the growing point reverts to a vegetative state and the top (crown) is formed. A good induction will ensure a large number of fruitlets are formed which, with good cultural care, will all fill out to give a well-shaped, high-yielding fruit.

Because ripening of the fruitlets follows the same pattern as flowering, the bottom portion of pineapples is riper, sweeter and has better flavour than the top. Shorter fruit with little taper (summer plant crop and ratoon fruit) mature more uniformly than larger, tapered autumn to spring plant crop fruit.

Pineapple, like strawberries and citrus fruit, contain no starch reserves so cannot become “sweeter” after harvest like pears, stone fruit, rock melons and bananas.

Nutritional, medical and industrial value of pineapple

The table below provides data published on the nutritional content of pineapples by the US Dept of Agriculture (USDA, 2009). For comparative purposes the content of apples, oranges and bananas is also presented.

The nutritional content of pineapple can vary significantly between varieties as illustrated by the Vitamin C content of the pineapple varieties 73-50, 53-116 and Smooth Cayenne (Clone 13) which were 64.6, 35.8 and 14.6 mg/100mL respectively (Sanewski and Giles, 1997).

In addition to the fruit the pineapple plant also provides fibre (used in clothing and industry) and the enzyme bromelain. Bromelain’s medicinal uses include relief for arthritis sufferers, as a digestive aid, in the reduction of blood clotting, as an anti-inflammatory agent, and for skin debridement of burns. Bromelain also has industrial uses including meat tenderisation, clarification of beer, production of vegetable oils and the dehydration of eggs and soya milk. Bromelain content is known to vary by up to 50% between varieties.

Table 1. Nutrient content of pineapples compared with apples, oranges and bananas (value per 100 grams of edible portion of raw fruit).

Nutrient	Pineapple Smooth Cayenne variety (USDA, 2009)	Pineapple MD2 variety (USDA, 2009)	Apple (USDA, 2009)	Orange (USDA, 2009)	Banana (USDA, 2009)
Non-edible proportion	42% (core, crown, parings)	49% (core, crown, parings)	23% (core & stem, skin)	27% (peel & seeds)	36% (skin)
Water	87g	86g	87g	87g	75g
Energy	190kJ	215kJ	200kJ	197kJ	371kJ
Protein	0.55g	0.53g	0.27g	0.94g	1.09g
Total lipid (fat)	0.13g	0.11g	0.13g	0.12g	0.33g
Carbohydrate	11.82g	13.50g	12.76g	11.75g	22.84g
Fibre (total dietary)		1.4g	1.3g	2.4g	2.6g
Total sugars	8.29g	10.32g	10.10g	9.35g	12.23g
Sucrose	4.59g	6.47g	0.82g		2.39g
Glucose (dextrose)	1.76g	1.70g	3.25g		4.98g
Fructose	1.94g	2.15g	6.03g		4.85g
Starch					5.38g
Calcium	13mg	13mg	5mg	40mg	5mg
Iron	0.25mg	0.28mg	0.07mg	0.10mg	0.26mg
Magnesium	12mg	12mg	4mg	10mg	27mg
Phosphorus	9mg	8mg	11mg	14mg	22mg
Potassium	125mg	108mg	90mg	181mg	358mg
Sodium	1mg	1mg	0	0	1mg
Zinc	0.08mg	0.12mg	0.05mg	0.07mg	0.15mg
Copper	0.081mg	0.113mg	0.031mg	0.045mg	0.078mg
Manganese	1.593mg	0.818mg	0.038mg	0.025mg	0.27mg
Vitamin C (total ascorbic acid)	16.9mg	56.4mg	4.0mg	53.2mg	8.7mg
Vitamin B1 Thiamin	0.078mg	0.080mg	0.019mg	0.087mg	0.031mg
Vitamin B2 Riboflavin	0.029mg	0.033mg	0.028mg	0.040mg	0.073mg
Vitamin B3 Niacin	0.47mg	0.507mg	0.091mg	0.282mg	0.665mg
Pantothenic acid	0.193mg	0.217mg	0.071mg	0.25mg	0.334mg
Vitamin B-6	0.106mg	0.114mg	0.037mg	0.060mg	0.367mg
Folate	11mcg	19mcg	0	30mcg	20mcg
Choline	5.6mg	5.4mg	3.4mg	8.4mg	9.8mg
Vitamin A, IU	52 IU	57 IU	38 IU	225 IU	64 IU
Carotene, beta	31mcg	34mcg	17mcg	71mcg	26mcg
Vitamin E (alpha-tocopherol)		0.02mg	0.05mg	0.18mg	0.10mcg
Vitamin K (phylloquinone)	0.7mcg	0.7mcg	0.6mcg	0	0.5mcg

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