

BANANA RIPENING:

PRINCIPLES AND PRACTICE

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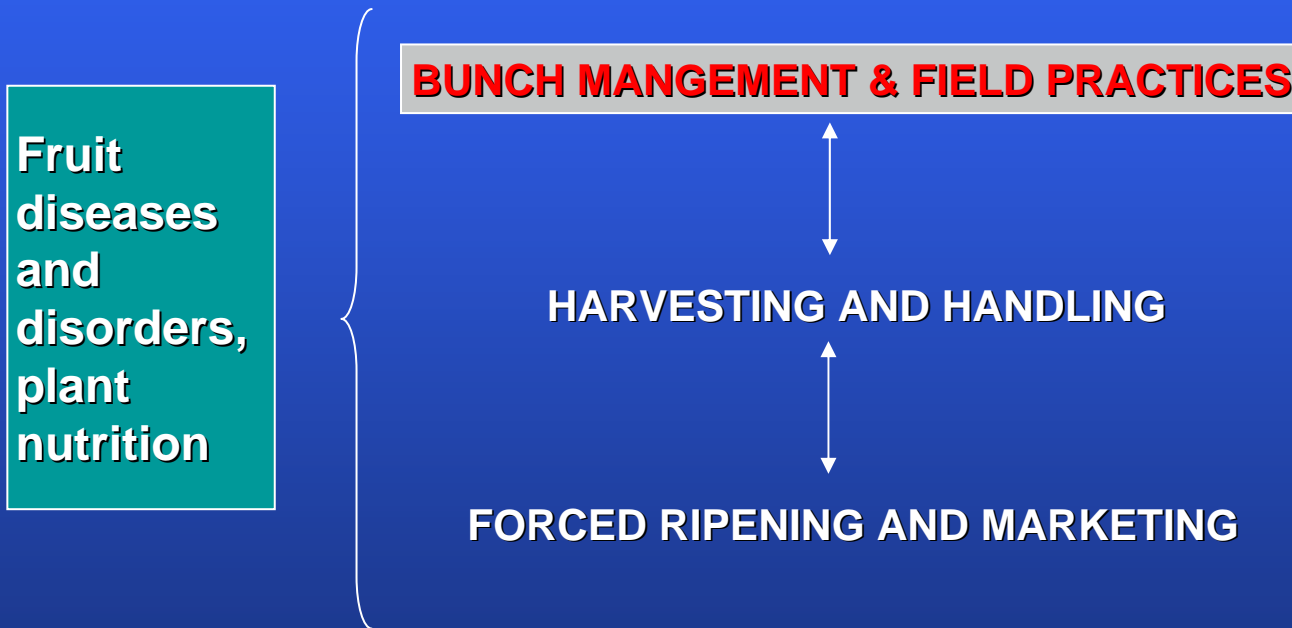
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Presentation Outline:

1. Bunch management and field practices
2. Banana nutrition
3. Harvesting and handling
4. Fruit diseases and disorders
5. Forced ripening

PRODUCING A CONSISTENT BANANA OF HIGH QUALITY EFFICIENTLY, WITHOUT WASTE

Three Phases:



Best bunch management practices:

“quality control from the field to the shelf”

Field practices:

- Leaf removal (diseased leaves, sanitation)
- Deflowering (of individual fingers)
- Bunch spray (to reduce insect and mold)
- Bagging and Tagging
- On-time harvest
- Careful handling & transport to packing house

Packing house practices:

- Good packing house hygiene
- Hang bunches in shade over night to cool
- Careful de-handing (clean cuts)
- Washing
- Drying
- Packing
- Storage (refrigerated), shipping (prompt)



Bunch of bananas

Banana Bunch management in the FIELD:

- ✓ **Leaf removal:** minimizes fruit injury
Remove leaves that rub against bunches
Remove severely diseased leaves (de-trashing)
- ✓ **Deflowering:** reduces incidence of fungus and insect attack; reduces abrasion injury on fruit skin.
- ✓ **Bunch spray** (diazinon, insecticidal soap, BT, copper hydroxide):
reduces pest and disease damage (moth, thrips, sooty mold, etc.)
- ✓ **Field sanitation:** reduces insect and pathogen populations
- ✓ **Bagging and Tagging:** protects bunch; ensures on-time harvest of cohorts
- ✓ **Good cultural practices** (weed, pest, disease management, drainage, fertility, pruning, plant spacing, etc): ensures healthy, consistent fruit
- ✓ **Careful harvesting, handling & transport to packing house:** minimizes fruit injury and bruising.



De-flowering

Female flowers are plucked twice per week
Each bunch is plucked 1-2 times

Flowers are plucked soon after they open up,
while they are still fresh.

Tools: ladder, gloves

After plucking is complete, male flower is cut
off & bunch is sprayed and bagged & tagged
with colored ribbons.

Bagging and Tagging

Bagging is done once per week

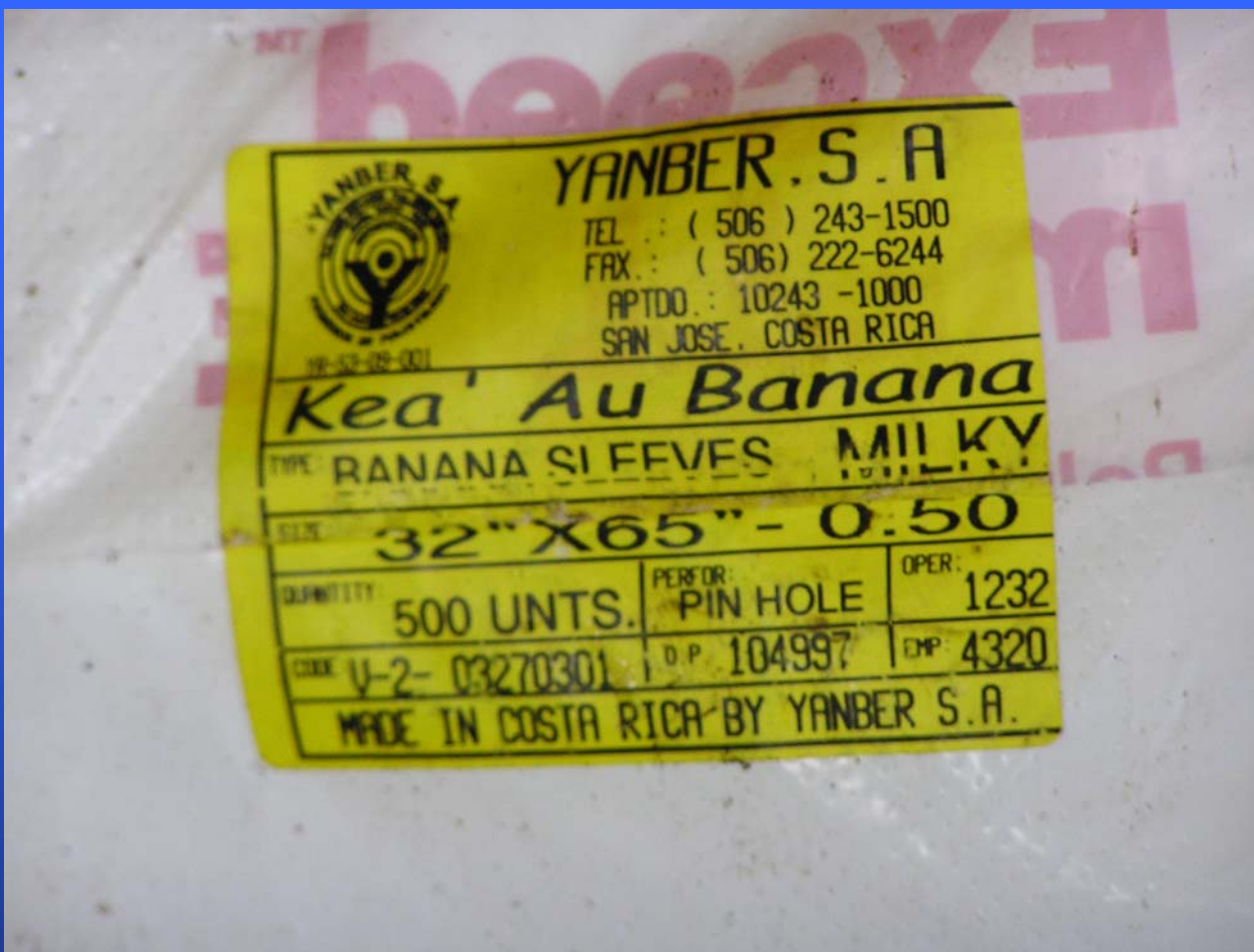
Perforated polyethylene sleeves

Tied at top and bottom

Tagged with bi-colored ribbon



Bagging minimizes sooty mold, insect damage and abrasion injury to fruits.



Banana bunch sleeve manufacturer information

**Identify plants at critical stage of development
and mark the pseudostem with the date**



A simple alternative to Bagging and Tagging

Good cultural practices



Pruning on a regular basis removes unwanted or suckers, keeps production mats in optimum condition, saves fertilizer, reduces pest and disease



Pruned field

Banana nutrition in Hawaii

Nutrient Cycle for Bananas

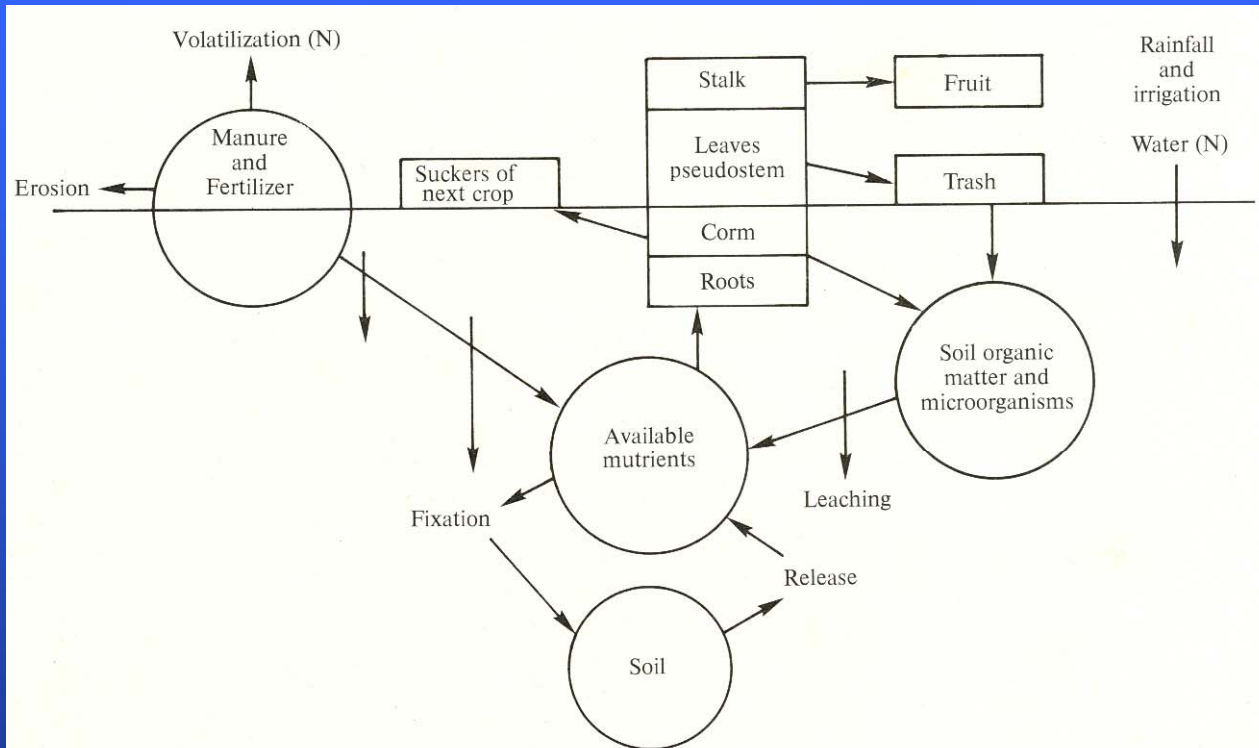


Fig. 8. Schematic representation of the nutrient cycle in bananas. Some nutrients may pass from one crop to another without returning to the soil while the remainder returns through trash and microbial breakdown to the pool of available nutrients in the soil [29, 30, 95].

Nutrient partitioning in Bananas

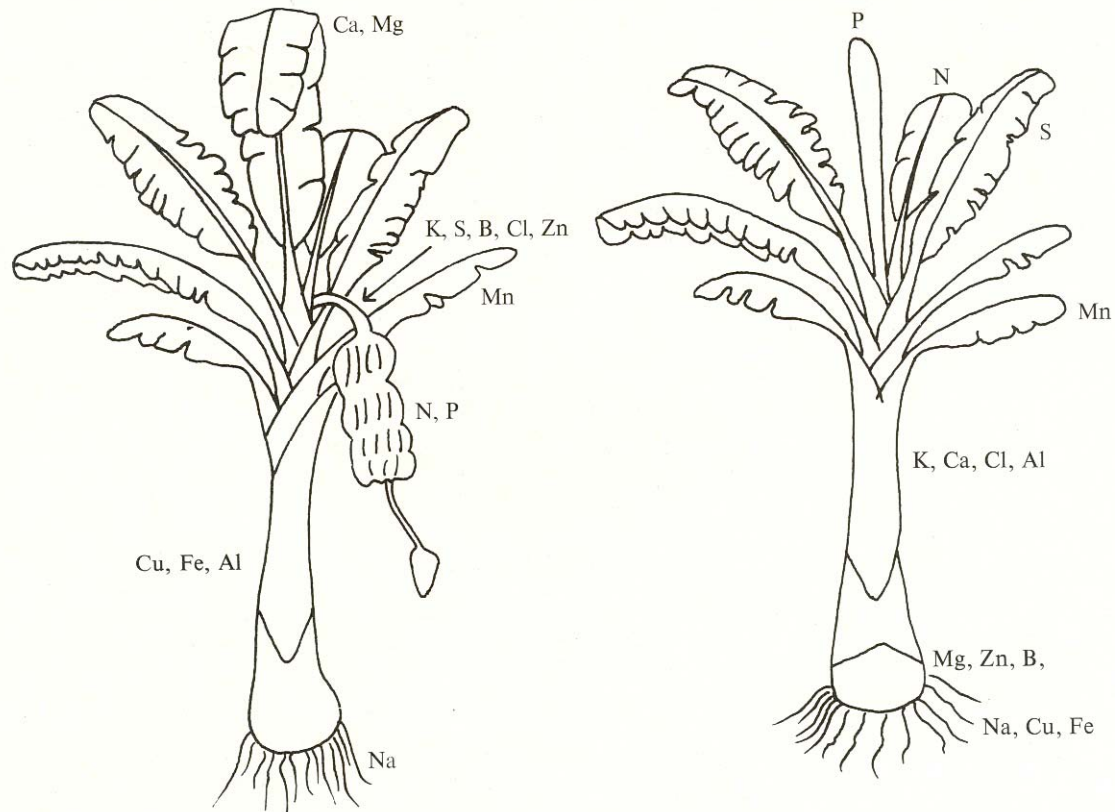


Fig. 9. Highest concentrations of nutrients in various organs in vegetative and fruiting phases of the banana plant.

Element requirements for high-production banana farming in Hawaii

<u>Element</u>	<u>Pounds per acre per year</u>
Nitrogen	300 - 650
Phosphorous	60 - 120
Potassium	600 - 700

Primary fertilizer sources:

“Banana special” 13-3-37 (general N-P-K fertilizer) – about 200 lbs/acre/month

Urea (sulfur-coated or poly-coated) (N)

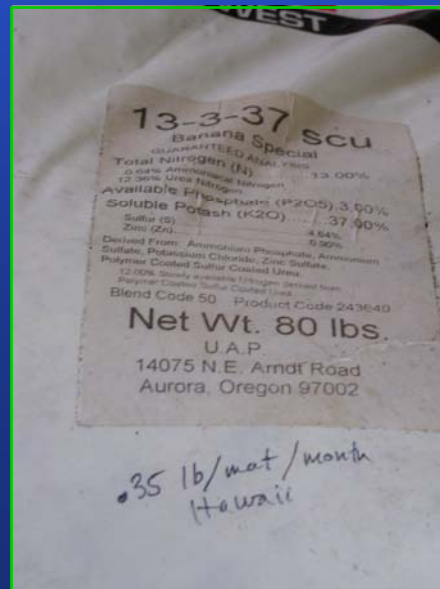
Potash, KSO or KCl (K)

Lime, dolomite (Ca) – fields limed to pH 5.5 – 6.5 up to twice per year

Borax (B)

Zinc sulfate (Zn)

Sulfur (S)



“Banana special” 13-3-37

Crop logging program for banana (Hawaii)

Crop logging is the monitoring of soil and banana tissue data over a period of time to help the grower make better decisions on the type, rate, and interval of fertilizer applications.

Recommended levels of elements in banana leaf tissue in Hawaii.

Element	Symbol	Range (suggested)
NITROGEN	N	2.8 – 3.1%
PHOSPHOROUS	P	0.18 – 0.20%
POTASSIUM	K	3.2 – 3.5%
CALCIUM	Ca	0.6 – 1.0%
MAGNESIUM	Mg	0.3 – 0.6%
SULFUR	S	0.22 – 0.25%
IRON	Fe	50 – 100 ppm
MANGANESE	Mn	30 – 100 ppm
COPPER	Cu	10 – 15 ppm
ZINC	Zn	25 – 40 ppm
BORON	B	15 – 25 ppm

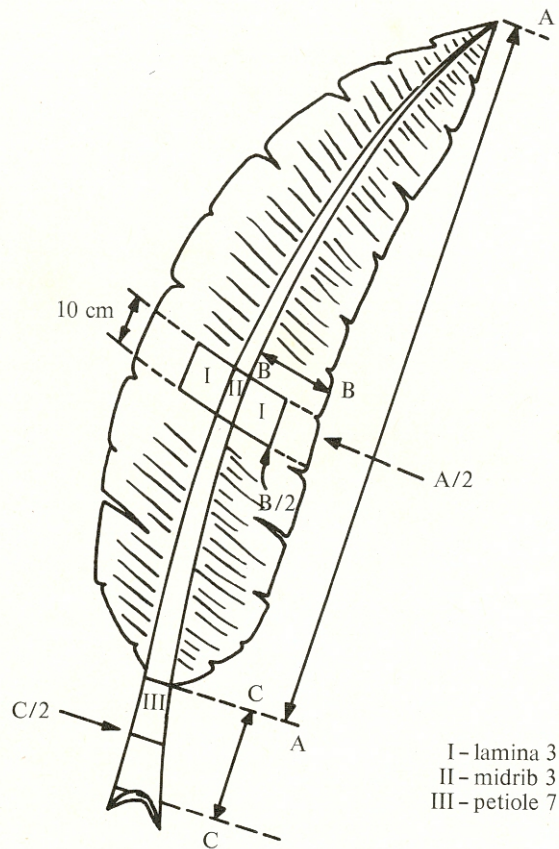


Fig. 14. Sampling procedure for banana leaves.



Banana leaf tissue sampling in Hawaii for nutrient analysis

From: Laha, E., and Turner, D.W. 1989. Banana Nutrition. International Potash Institute Worblaufen-Bern, Switzerland.

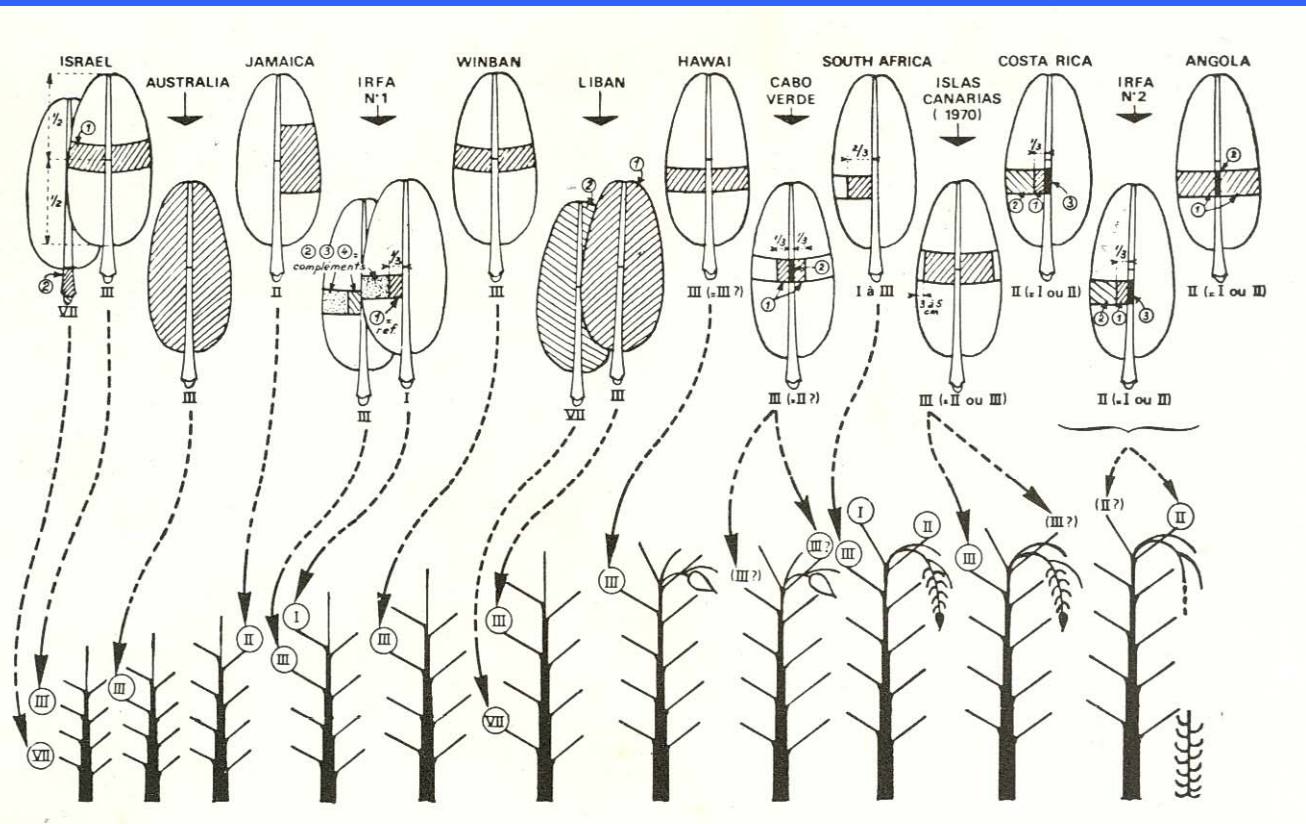


Fig. 13. Sampling methods used in various countries (after *Martin-Prével* [62]).

Advantages of crop logging:

- Quantitative basis for decision making
- Early detection of problems
- Verification of suspected problems and interactions
- Improved yield and quality
- Optimum fertilizer use patterns

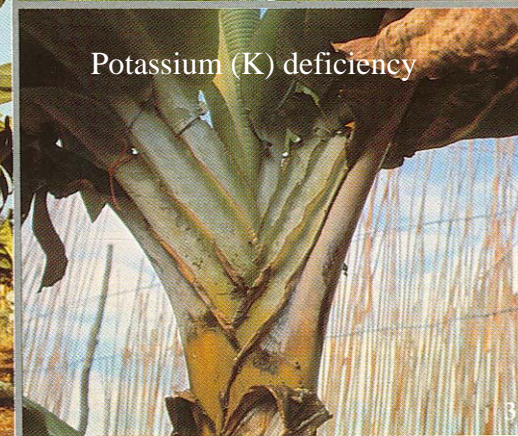
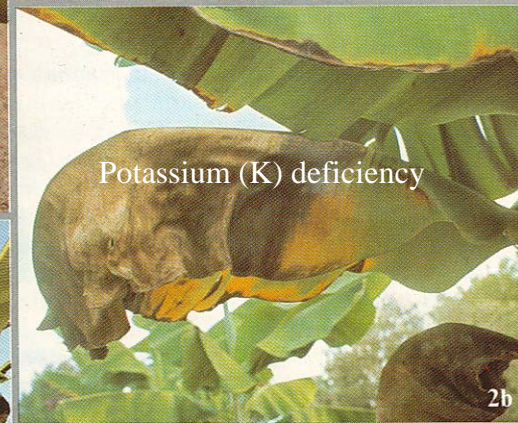
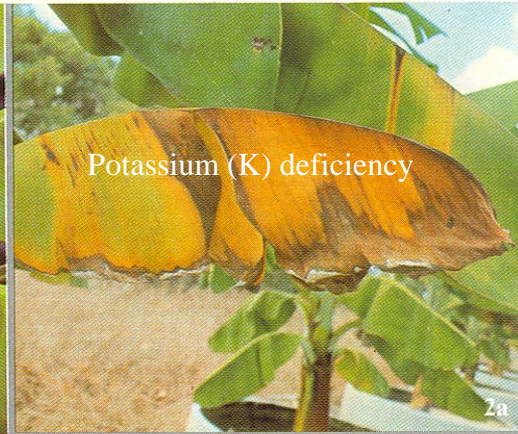
Nutrient imbalance symptoms for banana

Deficient element	Symptoms	Notes
Nitrogen	Generalized chlorosis (more yellowing on older leaves); rose-colored tints on petioles and leaf sheaths; stunting; rosetting; slender pseudostem; small petioles and leaves; reduced life span of leaves; notable reduction in yield.	Banana is more sensitive to a lack of nitrogen than any other element; problem is compounded by dense stands of weeds or grass.
Potassium	Rapid yellowing of oldest leaves which then turn orange and dry up; leaves become tattered and fold downward; crumpled leaves; poorly filled bunch	Responds well to potash applications
Magnesium	Marginal chlorosis of lowest leaves; violet-colored marbling of petioles; fruit may have defective flavor and not ship well.	Magnesium sulphate can alleviate the symptoms.
Calcium	General dwarfing; reduced leaf length; reduced rate of leaf emission; leaves are undulated; tissue near midrib thickens, may turn reddish-brown	Fields should be limes periodically; calcium nitrate can help to correct this deficiency.
Iron	General interveinal chlorosis of young leaves; retarded plant growth; small bunches	Apply iron compounds to soil; foliar sprays of iron compounds can relieve symptoms temporarily.
Zinc	Rosetting and stunting; chlorotic, strap-shaped leaves; leaf chlorosis ion stripes or patches; abnormal bunch and hand characteristics	Problem may be more severe in sandier areas.
Sulphur	Leaves are chlorotic and reduced in size with a thickening of secondary veins; undulating leaf edges; necrosis along edge of lower leaves	Sulphate fertilizers can correct this problem (e.g., ammonium sulphate, potassium sulphate and magnesium sulphate)
Boron	Chlorotic streaking oriented perpendicular to and crossing the primary veins; leaf malformation; interveinal chlorosis	Deficiency can develop over time in mature banana fields in Hawaii

Reference: Stover, R.H. 1972. Banana, plantain and abaca diseases. Commonwealth Mycological Institute, Kew, Surrey, England. 316

Nitrogen (N) deficiency

- Pale green leaves,
- pink-reddish petioles



Potassium (K) deficiency

- Orange necrotic lamina of older leaves
- Leaf curling and desiccation
- “Choke-throat” sucker

Calcium (Ca) deficiency

- “Spike leaf”



Calcium (Ca) deficiency

- collapsed cigar leaf,
- lack of green pigmentation, burned (necrotic) tip of cigar leaf

Calcium (Ca) deficiency

- "Spike leaf"

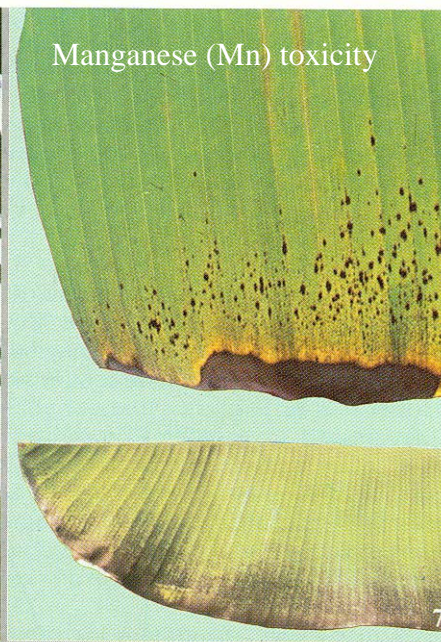
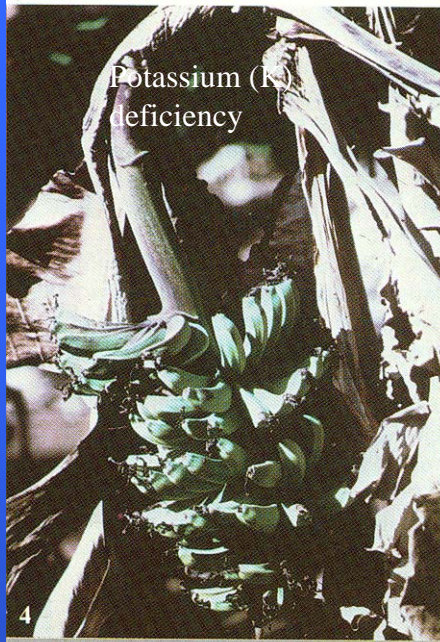


Calcium (Ca) deficiency

- Unthrifty plant growth
- Faint chlorotic yellow stripes parallel to leaf veins

Potassium (K) deficiency

-Bunch failure to fill



Manganese (Mn) toxicity

-Marginal necrosis from fungicide spray (above) or soil (below)

Zinc (Zn) deficiency

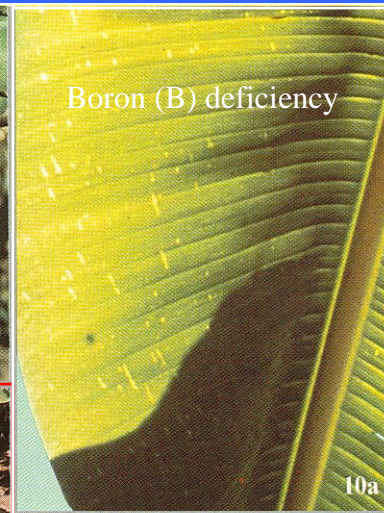
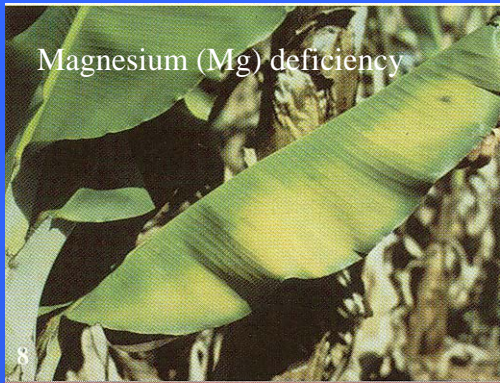
-Anthocyanin pigmentation on underside of lamina of fully mature leaves (left)

-Alternating chlorotic stripes (right)



Magnesium (Mg) deficiency

- Chlorosis of lamina while margins remain green



Boron (B) deficiency

- Stripes perpendicular to veins

Iron (Fe) deficiency on calcareous soils

- Yellow-white complete chlorosis

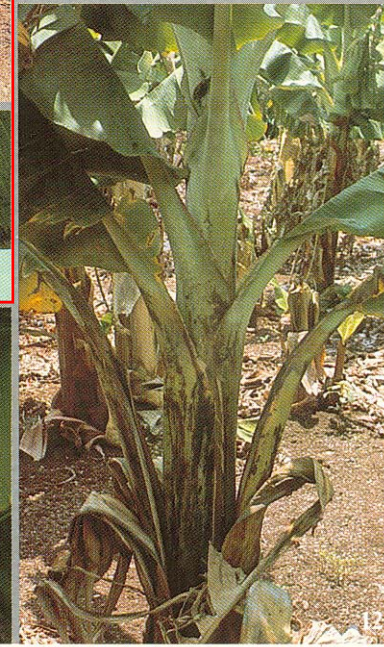


Boron (B) toxicity

- Marginal paling with necrosis

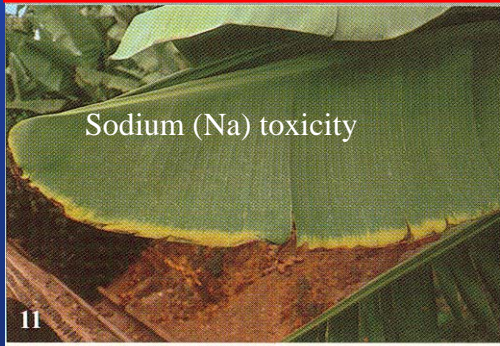
Iron (Fe) toxicity

- Black margins of lamina



Sodium (Na) toxicity

- Marginal chlorosis and necrosis



PRODUCING A CONSISTENT BANANA OF HIGH QUALITY EFFICIENTLY, WITHOUT WASTE

BUNCH MANAGEMENT & FIELD PRACTICES

HARVESTING AND HANDLING

FORCED RIPENING AND MARKETING

Fruit
diseases
and
disorders



Careful harvesting procedure



Notch the pseudostem with a machete while holding the stem of the bunch.



Sever the bunch as it rests on your shoulder and carry to a nearby padded transport vehicle.



Careful handling and transport of bananas from field to packing house
Reduces the injury to fruits.

Bunch management in the PACKING HOUSE:

- ✓ **House hygiene:** minimizes pest and disease; keep packing area clean and free of trash and banana debris
- ✓ **Hang bunches overnight:** allows fruit to cool, reach uniform temperature before dehanding, grading, washing & packing.
- ✓ **Careful de-handing:** minimizes rot of cut ends; use sharp, clean knife and make even (not ragged) cuts.
- ✓ **Washing:** removes sap stains and superficial insects and fungi (water, soap, 0.5 to 1% bleach).
- ✓ **Drying:** air-drying after wash allows dry fruits to be packed (less chance of fungal rots or diseases).
- ✓ **Packing:** sturdy, well-ventilated boxes; careful placement of bunches; use of plastic liner.
- ✓ **Storage, shipping:** depends on market and ripening process.

Hanging on hooks on
rollers and runners



Hanging on pieces of PVC pipe
on greased steel pipe

Hang bunches overnight under cover in a packing house to cool down the banana pulp temperature. Wash and pack them the following day.



Galvanized steel, PVC or ABS pipe, hooks, bolts, washers. This hook has been in use for 15 years.



De-handing with a very sharp, clean blade. Cut surfaces are smooth and even (without ragged edges). A smooth, clean cut reduces the chance of fungal infection. Off-grade fruits are identified at this step.



De-handing knife



Washing in soap and water plus 0.5 – 1% bleach removes latex from hands and helps to remove sooty mold and superficial insects.



After washing, hands are placed on a cushioned, rotating drying table for air-drying. Larger-scale operations use conveyor belts between the wash tank and the boxing area.





Many bananas grown on the island of Hawaii are packed into boxes green and then shipped in refrigerated containers by barge for ripening and distribution in Honolulu (island of Oahu).



Larger banana producers use refrigerated trucks to store and transport harvested or ripened bananas.

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BUNCH MANAGEMENT & FIELD PRACTICES

HARVESTING AND HANDLING

FORCED RIPENING AND MARKETING

**Fruit
diseases
and
disorders**



Banana fruit diseases and disorders

Crown rot



SYMPTOMS: Blackening and rotting of the cut ends of hands. As the fruit ripens, the rot advances rapidly down the fruit stalks. A white or gray fungal growth may be present on the surface of affected crowns.

CAUSE: Numerous fungi including *Fusarium* spp., *Verticillium* spp., *Colletotrichum musae*, and *Acremonium* sp.

CONTROL: Good packing house hygiene (e.g., clean water in the wash tank); approved fungicides; rapid cooling of fruit after de-handing; refrigerate fruit at not less than 13 degrees C during storage and sale.

Anthracnose



SYMPTOMS: Finger rot or blemish of ripening bananas. Initial lesions are lens-shaped to circular, slightly sunken and brown. With time, the spots turn black, enlarge and merge. The original sunken spots become deep depressions covered in pink fungal spore masses.

CAUSE: The fungus *Colletotrichum musae*.

CONTROL: Regular de-trashing; careful fruit handling to minimize abrasions and wounds; keep fruit as cool as possible to slow down the disease; prompt ripening; on-time harvest; good packinghouse hygiene (e.g., clean water and equipment);

Black end



SYMPTOMS: Black decay of the finger stalk and adjacent part of the finger, usually confined to the peel.

CAUSE: The fungus *Colletotrichum musae*; also can be caused by the fungi *Nigrospora sphaerica* and *Fusarium* spp.

CONTROL: Good plantation and packinghouse hygiene; mulch dead leaves; keep packinghouse free of bunch trash and reject fruit; dehand bunches in clean water; keep fruit as cool as possible after harvest (both before and after ripening).

Ceratocystis fruit rot



SYMPTOMS: Crown rot, stem end rot and tip rot of green or ripe fruit. Crowns are soft, black and water-soaked. A mass of dark fungal growth may develop. The stem end turns black and so does the skin. The skin is very moist and becomes covered with tufts of white fungal growth that turns greenish-black. The rot extends to the pulp; finger drop and premature ripening.

CAUSE: The fungus *Ceratocystis paradoxa*.

CONTROL: Good packinghouse hygiene (Clean and disinfect the packinghouse regularly; do not allow rotting fruit to accumulate).

Maturity bronzing



SYMPTOMS: A reddish-brown to brown discoloration of mature green bananas, which develops into scabbiness and cracking.

CAUSE: unclear; appears to be a physiological disorder that is the result of stress in the outer layers of the peel followed by rapid growth of the fruit.

CONTROL: Irrigate to avoid moisture stress when bunches are young. Do not allow bunches to 'over-fill' before harvest.

Scab moth

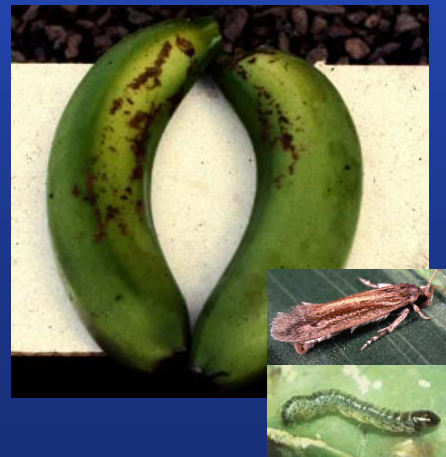


SYMPTOMS: Scars that turn brownish-black on fruit skin.

CAUSE: Banana scab moth (*Nacoleia octasema*).

CONTROL: Bunch injection with registered insecticides where available; fruit bagging.

BANANA MOTH



Sugarcane Budmoth Damage on Banana Fruit

Pest: Sugarcane bud moth, *Decadarchis flavistriata* (Walsingham) [Lepidoptera: Tineidae]

Synonyms: *Neodecadarchis flavistriata* (Walsingham) and *Ereunitis flavistriata*.

Damage: Caterpillars of the sugarcane bud moth commonly feed on decaying banana flowers but occasionally feed on the banana peel which can cause serious fruit scarring (Fig. 1).

Alternate Host Plants: The sugarcane budmoth is also known to feed on decaying sugarcane sheaths and other plant parts, and on the dead leaves of palms, pineapples, and *Pandanus*. Literature reports that numerous caterpillars can be found among the fibrous material at base of palm leaves and the bracts at the base of pineapples (Zimmerman, E.C., Insects of Hawaii).

Field Diagnosis: Monitor fields for damaged bunches on regular basis. Careful attention should be given to the area where the banana fingers meet. Webbing and caterpillar droppings are signs of caterpillar infestation.



Fig. 1. Sugarcane bud moth caterpillar damage

Sugarcane Bud Moth



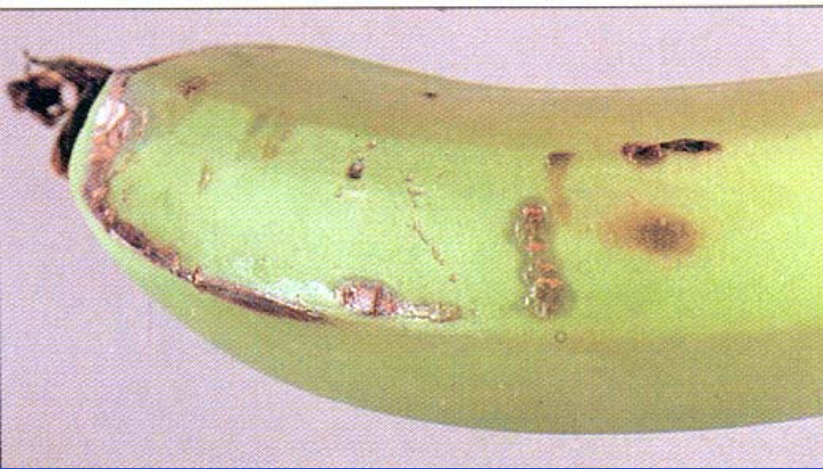
Fig. 2. Sugarcane budmoth caterpillar



Fig. 3. Adult sugarcane bud moth.

Suggested Cultural Control Practices: Debudding (or de-belling) which is the removal of the purple, bell-shaped male bud from the bunch shortly after fruit set will be helpful in reducing the level of damage by this insect. Sampling from an affected field showed that sugarcane budmoth caterpillars were present on the decaying bracts (Fig. 2). It is also very important to pluck the flower remnants from end of fingers prior to bagging.

Sap damage



SYMPTOMS: Stains on skin.

CAUSE: sap contamination of fruit surface.

CONTROL: Soak hands in clean water in a washing/de-sapping tank for enough time to allow fresh wounds to stop flowing sap.

Splitting, finger separation



SYMPTOMS: Longitudinal splits appear in the fruit; ripe fruit separate from hand.

CAUSE: humidity too high (greater than 95%) during the later stages of fruit ripening.

CONTROL: Lower the R.H. to 70-75% during fourth and fifth day of ripening; ensure good aeration in ripening room; restack cartons so that ventilation slots are aligned with each other.

Ammonia injury



SYMPTOMS: Blackening of the fruit skin.

CAUSE: exposure to ammonia gas leaking from refrigeration systems using R717 (ammonia).

CONTROL: R717 refrigeration plants must be properly maintained and tested regularly for leaks.

Senescent spots



SYMPTOMS: Numerous superficial brown spots (less than 1 mm deep) or flecks on the peel. The spots do not enlarge, coalesce or blacken.

CAUSE: senescence of small groups of cells in the outer peel after treatment in a ripening room.

CONTROL: There are no practical means of controlling this disorder, but it appears to be more common when over-mature fruit are sent to a ripening facility.

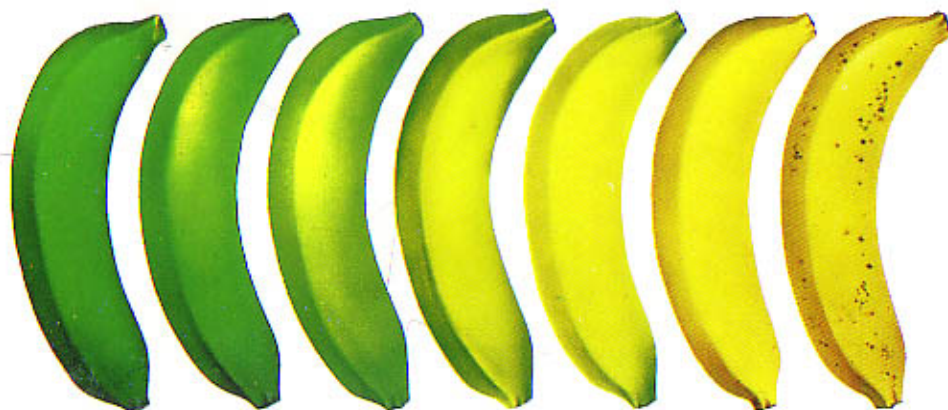
Suggested Guide for Banana Ripening

Pulp Temperatures °F

	Pulp Temperatures °F								
4 Day Schedule	ETHYLENE 64°	64°	62°	60°					
5 Day Schedule	ETHYLENE 62°	62°	62°	62°	60°				
6 Day Schedule	ETHYLENE 62°	62°	60°	60°	60°	58°			
7 Day Schedule	ETHYLENE 60°	60°	60°	60°	60°	58°	58°		
8 Day Schedule	ETHYLENE 58°	58°	58°	58°	58°	58°	58°	58°	
Day	1	2	3	4	5	6	7	8	

Notes:

- Temperatures are °F
- Temperatures are PULP not AIR
- Proper temperature, humidity, time, air circulation, mature bananas and ethylene are required for ripening.
- Use the Super-Ripening Center® and Ethy-Ger® II to hasten ripening.
- Maintain 100-150 ppm of ethylene until color breaks.
- After 24 hour ripening initiation period, vent room for 15-20 minutes with fan on.
- For delayed shipment hold at 58°F.



Color Index No.	1	2	3	4	5	6	7
Peel Color	Green	Green – trace of yellow	More green than yellow	More yellow than green	Green tip	All yellow	Yellow – flecked with brown

Mixed ripe



SYMPTOMS: Ripening (sprung) and colored bananas are found mixed with hard green fruit in the same package or consignment at the markets before commercial ripening.

CAUSE: over-mature bananas; excessive post-harvest temperature; inadvertent exposure to ethylene in exhaust gases; anthracnose wound infections.

CONTROL: Harvest uniform, but less mature, fruit. Improve temperature management after harvest; fungicide dips for anthracnose control; ensure that stacks of fruit are well-ventilated.

Cigar-end rot



SYMPTOMS: Dark brown to black tip rot; pulp characteristically dry and fibrous; gray and powdery spore masses occur on lesions.

CAUSE: The fungus *Verticillium theobromae*.

CONTROL: Frequent removal of dead flowers followed by bagging of bunches with perforated polyethylene sleeves; remove bracts and dead flower parts that accumulate in bags a few weeks after bagging; field sanitation for fruit spot control; packinghouse sanitation; cull infected fruits before placing them in the washing tank; fungicide sprays may be necessary during severe epidemics.

Freckle



SYMPTOMS: Raised black pinpoint spots occurring in groups on the upper surface of leaves and also on the fruit.

CAUSE: The fungus *Guignardia musae* (= *Phyllosticta musarum*).

CONTROL: Remove and destroy infected leaves; use resistant varieties (Cavendish); bag fruit after deflowering; use registered fungicides where available (black leaf streak fungicides are effective)

Corky scab



SYMPTOMS: Superficial scarring; corky scab (slightly raised, discolored, corky skin covering, patchy in occurrence).

CAUSE: banana flower thrips (*Thrips hawaiiensis*).

CONTROL: Monitor crop for flower thrips populations; bunch injections of registered insecticides in some locations; keep plants moist with overhead irrigation during dry periods.

Rust thrips damage

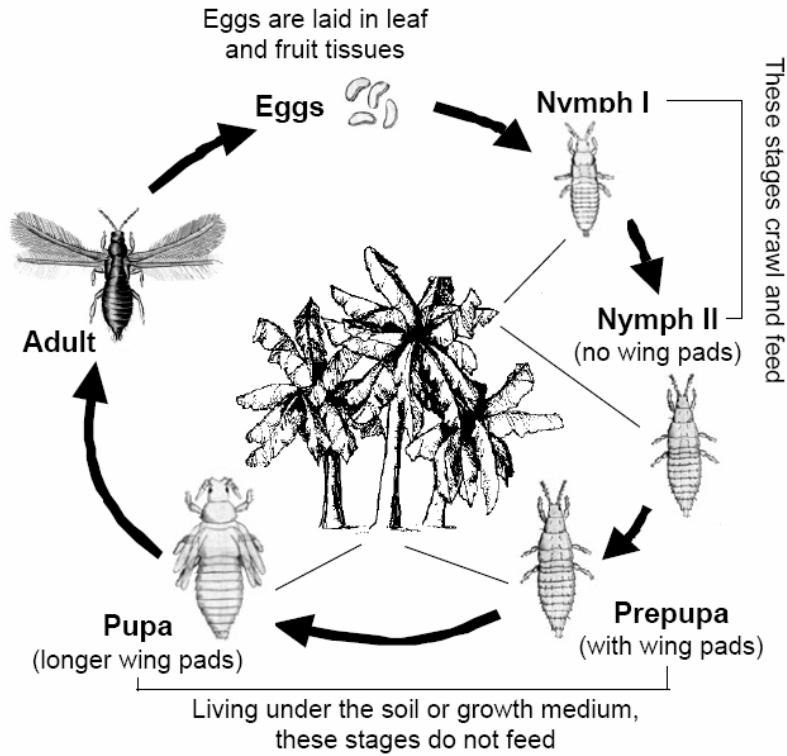


SYMPTOMS: Reddish-brown ‘rust’ areas develop on fruit where two adjacent fingers touch; skin cracking can occur with severe damage

CAUSE: banana rust thrips
(*Chaetanaphothrips signipennis*)

CONTROL: Monitor crop rust thrips activity; apply insecticides to soil, plant and fruit; use thrips-free planting material; destroy neglected plantations; cover the developing bunches with sleeves.

Figure 4. Life cycle of the banana rust thrips.

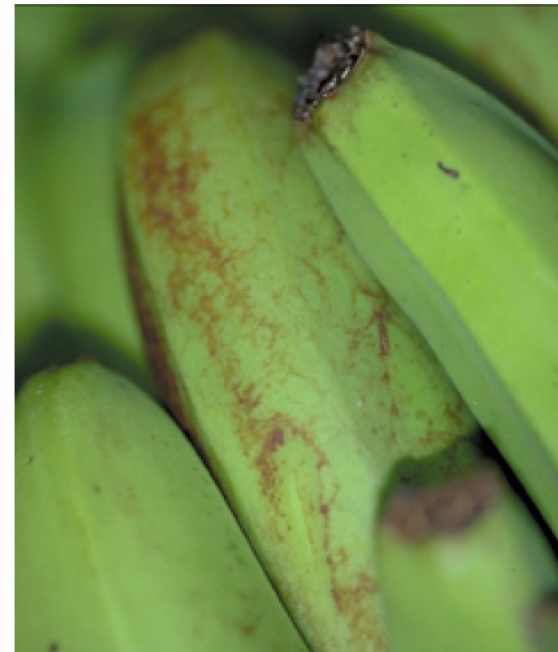


Insect drawings from D. Schulz (see *References*).

Figure 3. Adult banana rust thrips.



Figure 2. Damage to banana fruit by banana rust thrips.



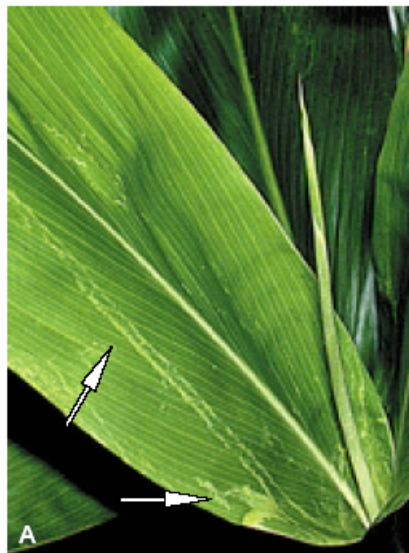
Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

Insect Pests
June 2002
IP-10

Banana Rust Thrips Damage to Banana and Ornamentals in Hawaii

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Figure 1. Feeding damage by banana rust thrips on ti and anthurium: A. Streaks and curlicue markings on opened ti leaf. B. Deformed leaf whorls on red ti that failed to unfurl. C. Deformed anthurium spathe.



Coconut scale



SYMPTOMS: Superficial infestation of banana peel; chlorotic spots associated with feeding; quarantine pest.

CAUSE: Green scale, *Aspidiotus destructor*.

CONTROL: oil sprays

Chilling injury



SYMPTOMS: ‘Salt and pepper’ flecking just below the surface of the green skin and the pulp.

CAUSE: exposure of fruit to temperatures below 13 degrees C before or after harvest.

CONTROL: Bananas in transit and in retail stores should not be stored at temperatures below 13 degrees C. Consumers should not store bananas in the refrigerator for more than a day.



Others fruit pests of banana in Hawaii:

Greenhouse thrips

Rind thrips

Green scale

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BUNCH MANGEMENT & FIELD PRACTICES

HARVESTING AND HANDLING

FORCED RIPENING AND MARKETING

Fruit diseases and disorders



Commercial Ripening

- ☑ Assures good shelf life
- ☑ Provides excellent fruit appearance
- ☑ Provides optimum eating quality
- ☑ Fruit is available when and where required

For bananas, the problem being dealt with is that a banana stalk does not ripen evenly. There can be up to a two week difference between the time the top of the stalk is ready to when the bottom is ready. For the home gardener this may work out quite conveniently. For the larger scale grower, this may lead to marketing problems. Retailers will only buy fruit with predicable ripening times and known shelf life.

Commercial Ripening: four major factors

- ☑ Ethylene gas
- ☑ Temperature control
- ☑ Relative humidity control
- ☑ Adequate air circulation

Because each batch of fruit varies, it is necessary to continuously monitor ripening.

Ethylene Gas

- ⌚ Naturally occurring plant hormone
- ⌚ Produced in all plant tissues
- ⌚ Governs many physiological functions, including senescence and ripening
- ⌚ Produced in greater amounts as plant organs (fruits) mature.
- ⌚ Also ethylene is produced in response to plant stress:

- wounding, sunburn
- infection and disease
- drought

Factors which can contribute to uneven ripening in banana fields.

- ⌚ Ethylene gas is produced by decaying plant material

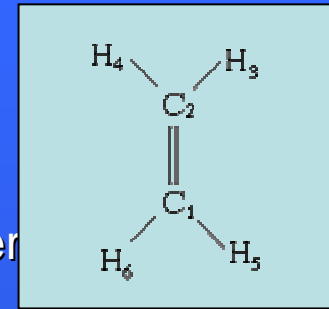
Commercial Ripening: four major factors

☑ 1. Ethylene gas

Colorless gas, slightly sweet odor, soluble in water

Normally produced during banana fruit ripening

If applied to bananas, it initiates ripening and assures even ripening



Only 1 ppm is required to initiate ripening,
but up to 1000 ppm are frequently used.

Banana fruits are exposed to the gas for about 24 hours.

Note: a concentration of ethylene gas higher than 2.7% (27,000 ppm)
can be explosive

The first use of natural ethylene in fruit ripening was described in the Bible. The prophet Amos was described as a "gasher and gatherer" of figs. Gashing figs was known to promote stress ethylene production mimicking the action of the wasps when they exit pollinated fruits, and this triggered ripening. Also in ancient times the Chinese placed weighted lids on growing bean sprouts to promote hypocotyl thickening and crispness (Abeles, 1992). Ethylene was used unknowingly to ripen bananas in both East Africa and Samoa by burying them in fire-warmed pits, thus using residual ethylene from the smoke of the fire as the ripening agent.

RIPENING OVERVIEW

- ⌚ Green bananas in cartons are loaded into the ripening room.
- ⌚ The room is closed and refrigerated for 12 to 16 hours until the pulp temperature reaches 15 to 17°C. Relative humidity is 90%
- ⌚ Ethylene is discharged into the room at a concentration of around 0.1%. The room is then kept closed for 24 hours. The ethylene acts as a catalyst initiating the hormonal process of ripening. Relative humidity is 90%
- ⌚ At the end of this time the room is ventilated to clear the ethylene.
- ⌚ The room is then closed again and the atmosphere controlled at a temperature of 15 to 17°C for three to four days. The fruit pulp may reach a temperature of 32°C during this process and gases, including carbon dioxide, are evolved in substantial quantities. Relative humidity is about 75%.
- ⌚ The room is finally ventilated and the ripe fruit removed. A common way of ventilating involves opening the doors for at least 5, usually 15 minutes before entry is made. Extractor fans may also be used.
- ⌚ The amount of ethylene gas required for a ripening room is normally calculated on the free air space after the bananas have been loaded (i.e., if bananas take up to 35% of the room size, calculate the amount of ethylene required for remaining 65% free air space).

Commercial Ripening: four major factors

☑ Temperature control (pulp temperature)

Without adequate temperature control, bananas can have very short shelf life (as short as 4 days at >73 F)

Fruits ripened at high temperature have poor appearance (dull grey-green) And poor flavor.

Low temperature (less than 55 F) delays banana ripening.

Optimum ripening temperatures are 58 F – 64 F.

Actual temperature used depends on when you want the fruit ready, with higher temperature (64 F) producing ripe fruits most rapidly.

Commercial Ripening: four major factors

☑ Relative Humidity (RH) control

Without adequate relative humidity control, bananas can affect skin color, freshness and may cause splitting, weak necks, breaking, weight loss and may cause existing blemishes to become enhanced.

Ripening RH levels:

Begin ripening: 90% RH (use automatic humidifiers with humistat control)
Color break: reduce RH to 75%

Commercial Ripening: four major factors

☑ Air circulation

Assures uniformity of ripening and prevents buildup of CO₂

Air circulations fans operate continuously while ripening fruit

Fruit boxes are stacked to allow air circulation. Many stacking patterns are available, but a 4-inch air channel is ideal.

Rule of thumb: the discharge from the centrifugal blower in cubic feet per minute should equal the cubic capacity of the ripening room.

A RIPENING SCHEDULE FOR BANANAS

🕒 Ripening time is from hard green to Color Stage 4 (green-yellow with dark green tips)

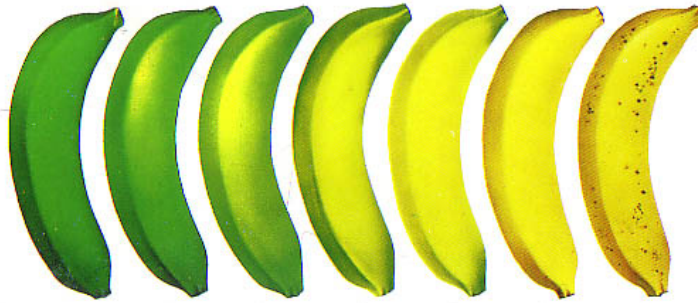
Number of Days to Ripen	Fruit Temperature (pulp) in °F						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
4	64	64	62	60	-	-	-
5	62	62	62	62	60	-	-
6	62	62	60	60	60	58	-
7	60	60	60	60	60	58	58

- 🕒 Air temperatures in ripening room will usually be lower than banana pulp temperatures.
- 🕒 Do not start ripening with ethylene until pulp temperatures stable at desired temperature.
- 🕒 Seal ripening room and gas with 1000 ppm ethylene for 12 to 24 hours.
- 🕒 After initial gassing thoroughly ventilate ripening room with fresh air for 20 to 30 minutes every 12 hours.
- 🕒 Inspect fruit regularly and adjust air temperatures to control pulp temperature in desired range.
- 🕒 Always use a proper pulp thermometer.

Suggested Guide for Banana Ripening

Pulp Temperatures °F

Day	1	2	3	4	5	6	7	8
4 Day Schedule	ETHYLENE 64°	64°	62°	60°				
5 Day Schedule	ETHYLENE 62°	62°	62°	62°	60°			
6 Day Schedule	ETHYLENE 62°	62°	60°	60°	60°	58°		
7 Day Schedule	ETHYLENE 60°	60°	60°	60°	60°	58°	58°	
8 Day Schedule	ETHYLENE 58°	58°	58°	58°	58°	58°	58°	58°



Color Index No.	1	2	3	4	5	6	7
Peel Color	Green	Green - trace of yellow	More green than yellow	More yellow than green	Green tip	All yellow	Yellow - flecked with brown

Notes:

- Temperatures are °F
- Temperatures are PULP not AIR
- Proper temperature, humidity, time, air circulation, mature bananas and ethylene are required for ripening.
- Use the Super-Ripening Center® and Ethy-Gen® II to hasten ripening.
- Maintain 100-150 ppm of ethylene until color breaks.
- After 24 hour ripening initiation period, vent room for 15-20 minutes with fan on.
- For delayed shipment hold at 58°F.



Color index = 7+



pulp thermometer



Commercial, large-scale ripening rooms require forklifts and computerized automation and control.



Banana ripening rooms

- a. The room must be air tight to prevent too much of the ethylene from leaking out.
- b. The room must have adequate refrigeration. Bananas produce large quantities of heat when they are ripening. The refrigeration equipment must have the capacity to accurately control the pulp temperature.
- c. The room must have adequate air circulation. Uniform pulp temperatures depend on circulating air. The room should be constructed so that the air flow path from the cooler, through the load and back to the cooler is unobstructed.
- d. The boxes of bananas should be "air stacked". That is, the boxes should be offset to allow the air to circulate among all the boxes. If the room is designed for "solid stack" palletized ripening, there is no need to air stack.
- e. Maintain proper humidity levels. For best ripening results, humidity should be 85 to 95 percent. If the humidity is too low, wetting the floor of the room with water is often helpful.
- f. When bananas are ripening, they give off carbon dioxide; concentration above 1 percent will retard ripening. Therefore, vent the rooms by opening the doors for 20 minutes every 12 hours, after the first 24 hours of ripening.

Banana ripening room construction follows the principles of ordinary cold room construction:

- ⌚ Insulated
- ⌚ Refrigerated – thermostatic control
 - removes heat of respiration from fruit
 - rapid reduction of room temperature after ripening begins
 - removes heat in-flow from outside (fans)
- ⌚ Heated – thermostatic control (sufficient to raise or lower pulp temperature 1.5 – 2 degrees F per hour)
- ⌚ Air tight
- ⌚ Controllable vents for ventilation
- ⌚ Humidified (mist injectors, dehumidifiers)
- ⌚ Sanitary

METHODS OF INTRODUCING ETHYLENE GAS

Catalytic Generators (e.g., 'Ethy-Gen')

A method by which a liquid concentrate 'Ethy-Gen' is decomposed in an electrically powered catalytic generator, to produce ethylene gas. The 'Ethy-Gen' concentrate is supplied in containers which produce about 12 ft³ (0.33 m³) of ethylene gas. The amount of liquid put in the generator depends on size of ripening room.

Ethylene Cartridges

Each ethylene cartridge contains approximately 51g of pure ethylene and the ethylene concentration in the room may be controlled simply and accurately by using the appropriate number of cartridges. Ethylene is released by piercing the cartridge with a tool which is supplied.

Ethylene and Ethylene/Nitrogen Cylinders

The explosion risk from ethylene can be eliminated by the use of a mixture of gas consisting of 5% ethylene in nitrogen. Pure ethylene and the mixture can be obtained from British Oxygen Company Limited and Air Products Limited.

Pure Ethylene Cylinders

Pure ethylene can be obtained in cylinders.

CATALYTIC GENERATORS



Pour one or two quarts of Ethy-Gen® II and ethylene production begins.

Provides pressureless ethylene on a continuous basis for uniform ripening.

Ethylene output is adjustable for multiple room sizes.

Can work with a computerized ripening room control system.

Available in a wall-mounted version.

Large 2½ quart reservoir.

1,500 cubic foot (43 cubic meters) minimum room size.

Electrical specifications:

120 VAC / 160 W / 60 Hz / 1.2 Amps

OR

230 VAC / 160 W / 50 - 60 Hz / 0.65 Amp

Conversion Rate Settings and approximate room size*:

1: 1 Quart of Ethy-Gen® II every 48 hours; 1,500 to 2,499 ft³ (43 - 70 m³)

2: 1 Quart of Ethy-Gen® II every 36 hours; 2,499 to 4,999 ft³ (71 - 141 m³)

3: 1 Quart of Ethy-Gen® II every 24 hours; 5,000 to 7,499 ft³ (142 - 212 m³)

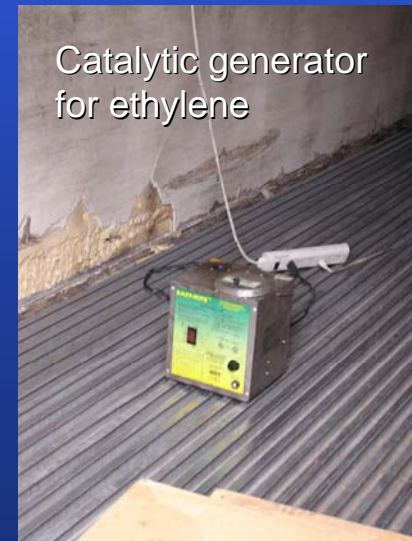
4: 1 Quart of Ethy-Gen® II every 12 hours; 7,500 to 12,000 ft³ (213 - 340 m³)



Fan used while ethylene is being generated



Simple banana ripening in a refrigerated Matson container in Hilo, Hawaii. Capacity: 320 boxes of bananas.



Catalytic generator for ethylene

A simple banana ripening room

- Plywood walls and roof; insulated
- Compressor (air conditioner) on top
- Cement floor
- Temperature, ventilation and humidity controls

Note: it is best to have at least three ripening rooms, instead of just one.

It is also possible to convert existing rooms or structures into banana ripening rooms, depending on scale.

Ethylene gas
from compressed gas cylinders:
two methods



Single shot of gas,
given at one time.

Continuous slow trickle of gas
into the room for 24 hrs.

A method to monitor ethylene concentration should be available.

Alternate ripening methods

ETHEPHON (Ethrel-Union Carbide) is a compound that breaks down to form ethylene. However, this is not currently approved for post-harvest use on bananas. Work done at the University of Hawaii found a 0.33% ethephon spray to be effective in ripening bananas.

CALCIUM CARBIDE breaks down to form acetylene, which at high concentrations produces the same effect as ethylene. This method is widely used in markets in Southeast Asia. About ½ ounces of calcium carbide is wrapped in newspaper. These packets are placed through the banana pile. The bananas are covered with a tarpaulin and the high humidity generated activates the carbide.