Lychee (*Litchi chinensis*) production in south Florida

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Botany

- Sapindaceae
- Important fruit crops within the Sapindaceae include longan, rambutan, pulasan, and akee.
- Origin – subtropical areas of southern China, northern Vietnam, and Malaysia.
- Center of diversification believed to be the highlands of southern China.
- Evolution – feral trees found in southern China in lowland and elevated rainforest.
- Distribution – throughout the subtropics and tropical highlands.

Botany – 3 subspecies

- *Litchi chinensis* subsp. *chinensis* – indigenous to southern China
- *L. chinensis* subsp. *philippenensis* – indigenous to the Philippines and Papua New Guinea at high elevations
- *L. chinensis* subsp. *javenensis* – indigenous to the Malay Peninsula and Indonesia

Lychee production areas

Lychee is grown in a range of areas with subtropical climates.

- Mediterranean, semi-arid, winter rainfall pattern areas (California, Israel).
- Humid to dry subtropical areas with summer rainfall pattern (South Africa, China, Taiwan, Mexico, Florida).
- High elevation areas in tropical areas (Philippines, Thailand).

Botany

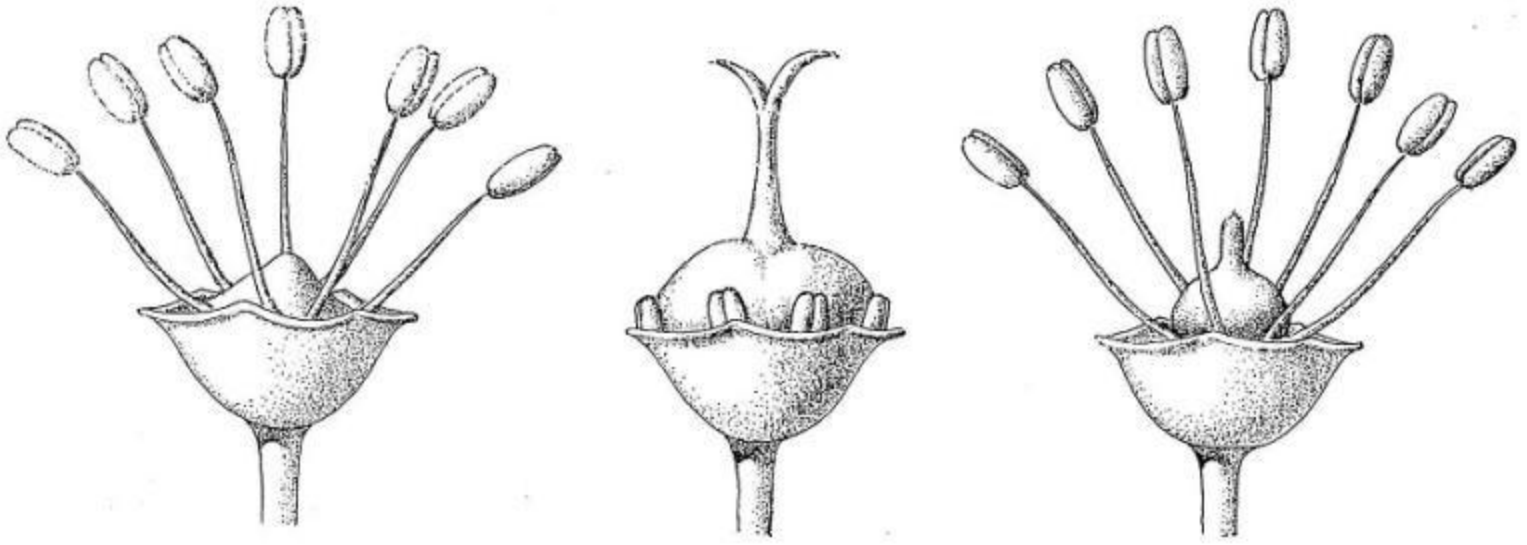
- Medium to large trees to 10-30 m tall.
- Seedlings have a deep tap root system with secondary and tertiary laterals. Air-layered trees have a shallow root system; most of the fibrous root system within 30-45 cm soil surface.
- Evergreen – leaf abscission rate is influenced by climate, disease pressures, and flowering.
- Leaves are compound and take about 40-50 days to mature.
- Multiple many branched panicles (thyrses) are produced at the terminal of recently matured stems. Flowers are small, white, apetalous, and are functionally male or female. Female flowers have a superior ovary. Anthesis occurs over a 6-12 week period.

Botany

- All 3 flower types are found on each panicle. There may be ~180-3000 flowers per panicle.
- M1 – functional male (3-65%).
- M2 – functional male with some nonfunctioning female flower parts (22-82%).
- F – functionally female flowers with nonfunctioning male flower parts (9-67%).

<u>Sequence of flower opening</u>

- M1 – open ~10 days
- M1 and F – open ~2-3 days
- M2 – open ~2 days
- F and M2 – open ~2-3 days
- M2 – open ~7-10 days



M1-male Female M2-male

Fig.2 - LITCHI FLOWER TYPES

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M1-male and female bloom

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Fruit set and early fruit development

Botany

- Lychee fruit is a drupe with a thin, leathery exocarp (peel) with small protuberances surrounding a translucent white, subacid flavored flesh (aril). The flesh surrounds a single seed. Fruit may be round, oval, or heart-shaped. The peel may be yellowish-green to pink to dark red. Fruit may weigh up to 30 g (usually 15-20 g).

'Brewster'

‘Hak Ip’

‘Mauritius’

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Climatic adaptations - optimum

- Shoot growth, >52°F (>11°C) required, >68°F to 86°F (>20°C - 30°C) best.
- Root growth, 55°F to 82°F (13°C to 28°C) best.
- Floral induction occurs during exposure to 2-5 months of fall-winter temperatures 68/59°F (20/15°C) (day/night) or less following the cessation of summer vegetative growth.
- Floral initiation is reduced when trees are exposed to winter maximums >75°F (>25°C) and minimums 68°F (>20°C).
- Floral initiation occurs when temperatures increase above ~68/59°F (~20/15°C).

Climatic adaptations - optimum

- Optimum temperatures during flowering ~68-75°F (~20-25°C); excessively high temperatures 75-86°F: >86/75°F/day-night (25-30°C; >30/25°C/day-night) may result in leafy (mixed) panicles, decrease the percentage of F flowers, and revert some floral buds to vegetative.
- Optimum temperature for pollination is 66-72°F (19-22°C); temperatures <55°F (<15°C) inhibit pollen tube growth.
- The number of days from flowering to harvest varies with cultivar and weather conditions during fruit development; range 65-90 days.

Optimum climatic scenario

- Optimum flowering and fruiting occurs in climates where vegetative growth ceases after summer vegetative flushing due to cool temperatures (dry conditions are beneficial and enhance the subsequent flowering), exposure to 1-5 months of cool temperatures <68°F(<20°C) followed by moderately warm temperatures in spring during the flowering period, followed by moderately high temperatures during fruit development.

Lychee flowering study
Background

- The two main environmental factors which influence the potential for mature lychee trees to flower are ambient temperatures and available soil moisture. However, among lychee researchers world-wide, there is agreement that exposure of quiescent lychee trees to cool non-freezing temperatures during the winter is the dominant environmental factor required to induce consistent lychee flowering.
- Previous research has determined that lychee flowering and fruit production occurs most reliably after exposure to cool non-freezing temperatures.

Term: quiescent – to be dormant due to environmental conditions not physiological dormancy.

Background

- Investigations with containerized lychee trees under controlled conditions and field observation have suggested temperatures below 15-20°C (59-68°F) are necessary for flowering.
- Furthermore, the effect of cool temperatures on the ability of quiescent lychee trees to flower appears to be cumulative i.e., intervening warm temperatures do not reduce the effect of previous cool temperatures, as is the case in temperate fruit crops. However, the precise temperatures and hours of exposure to flower inductive temperatures may vary by cultivar and influenced by local climate and current weather patterns.

The south Florida estimate purpose of investigation -

- With this in mind we investigated the effect of hours per year below specific ambient temperatures (hours below 7°C to 21°C; 45°F to 70°F) on subsequent 'Mauritius' lychee yields from the 1998-99 to the 2002-03 seasons in Homestead, Florida.

Materials and Methods

- Records of continuous temperature data from the University of Florida's Florida Agricultural Weather Network located at the Tropical Research and Education Center (TREC; 25.5^{o}N, 80.5^{o}W) along with yield data records from 8 to 12 'Mauritius' lychee orchards in the Homestead production area were used to investigate the relationship between November through January temperatures and crop yields from 1999 to 2003.
- The lychee orchards ranged in size from 0.3 to 14 acres and trees ranged in age from 4 to 19 years old. All yield data was normalized by calculating yield on a per acre basis.

Materials and Methods

- Regression analysis.
  - The relationship between hours below 7°C to 21°C (45° to 70°F in 5°F increments) and average crop yield per acre from the 1998-1999 through the 2002-2003 harvest season was determined by nonlinear regression using TableCurve 2D (Systat Software, Inc., Richmond, CA). The individual data points along with the standard error of the mean and regression line developed from the equation is also shown.

Materials and Methods

  - Also the 30 year mean monthly temperatures (1971-2000; S.E. Regional Climate Center, Columbia, SC) for TREC for Nov. through Jan. was plotted on the same graph as the mean monthly temperature for Nov. through Jan. for the 1998-1999 to 2002-2003 seasons and notating the average yield per acre.
- Factors such as tree age, plant growth stage during cool inductive temperatures, and cultural practices (e.g., fertilizer and water management) varied among the 8 to 12 orchards because they could not be controlled.

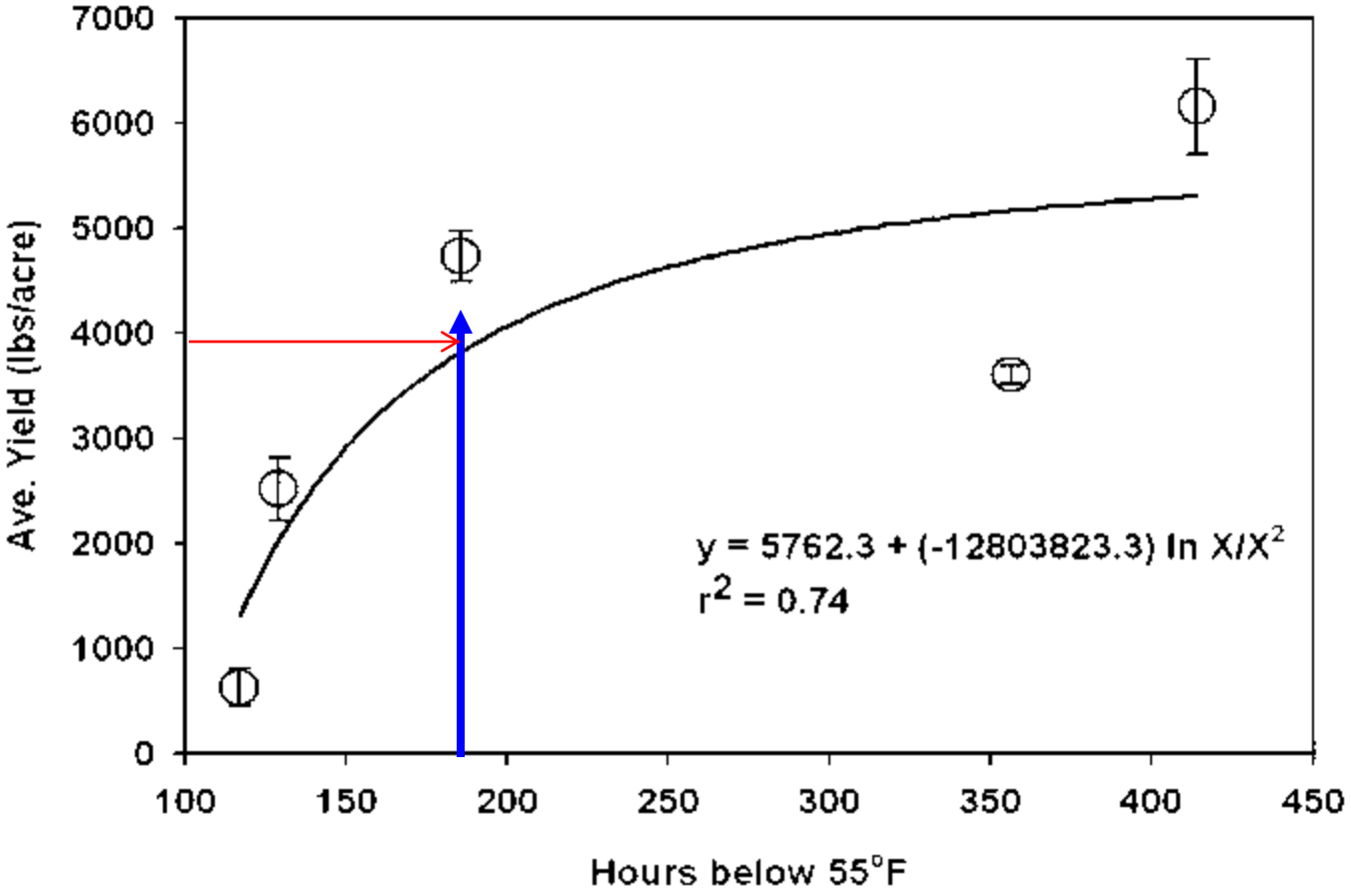
Results

- The best equation describing the relationship between hours below specific ambient temperatures and lychee yield was:

$$Y = a + b \ln x/x^2$$

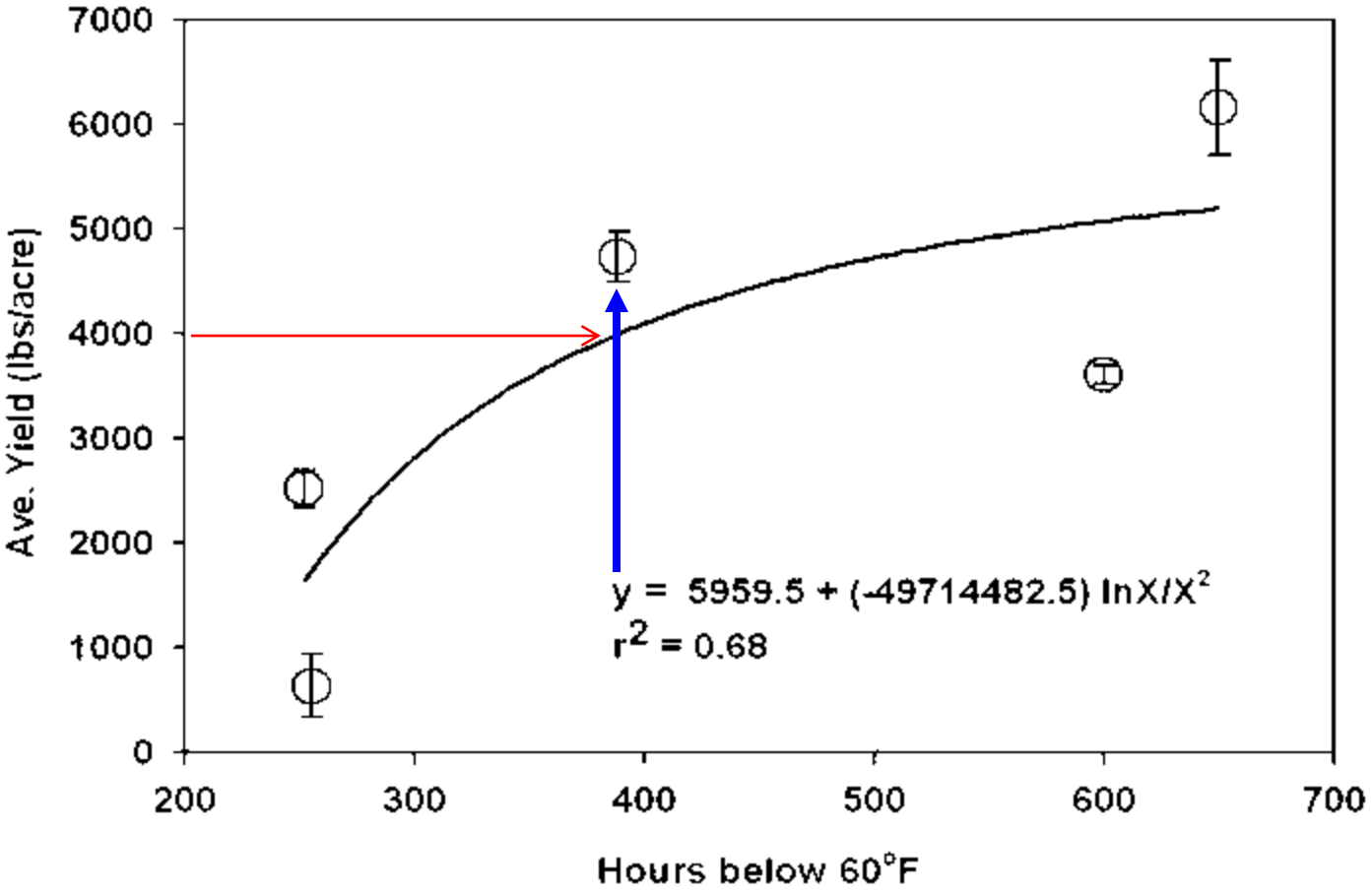
•Hours below 13°C (55°F) was the most highly correlated with the average yield Using 5.3 MT/ha (~2.4 tons/acre) as a baseline yield, it appears that after about 180 hr below 13°C (55°F) moderately good crop yields occurred.

Results



Hours below 13°C (55°F) on average yield of 'Mauritius' lychee in Homestead, Florida from 1998-99 to 2002-03 crop season.

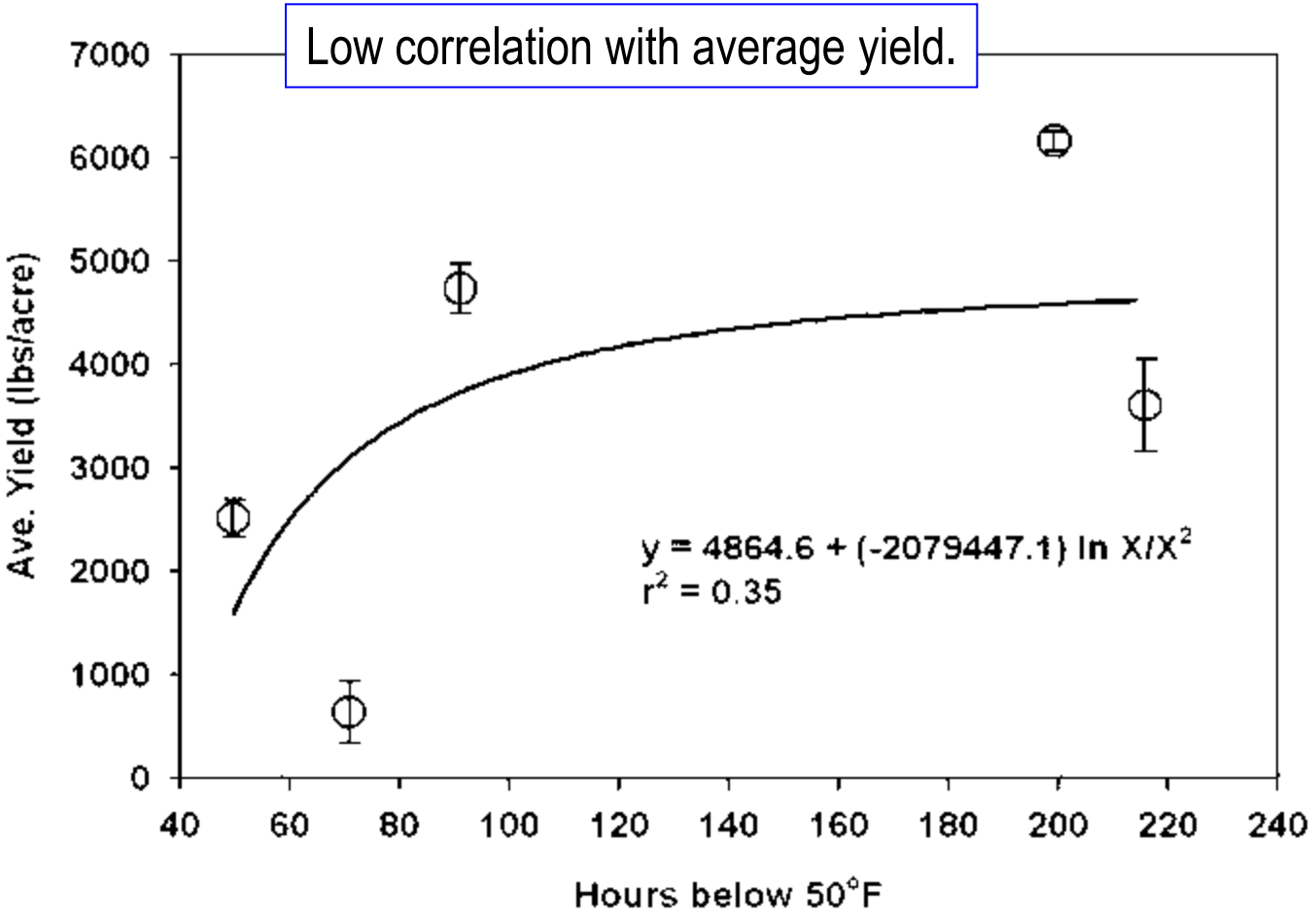
•Hours below 15.5°C (60°F) was the 2nd most highly correlated with the aver. Yield Using 5.3 MT/ha (~2.4 tons/acre) as a baseline yield, it appears that after about 390 hr below 15.5°C (60°F) moderately good crop yields occurred.



Results

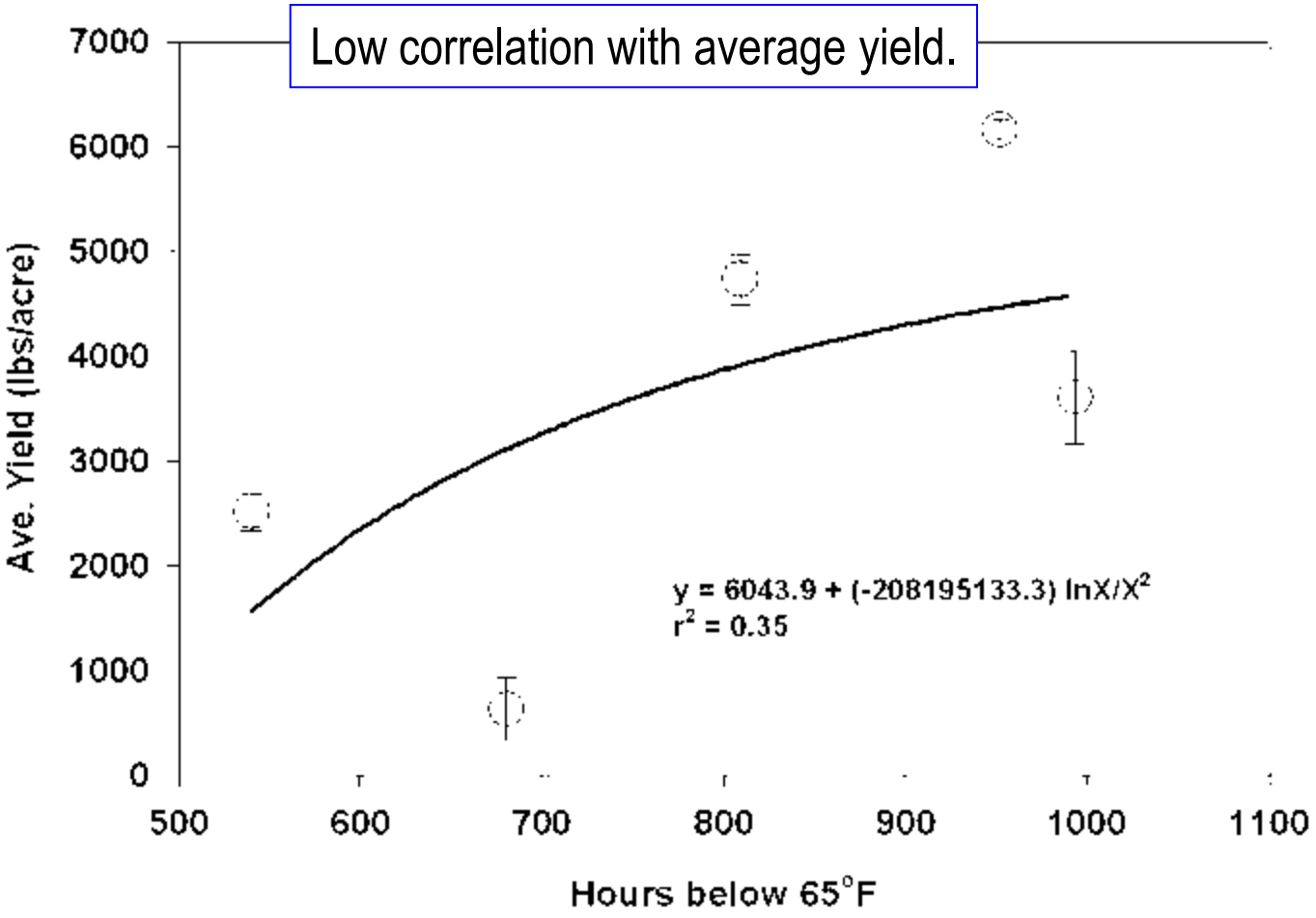
Hours below 15.5°C (60°F) on average yield of 'Mauritius' lychee in Homestead, Florida from 1998-99 to 2002-03 crop season

Results



Hours below 10°C (50°F) on average yield of 'Mauritius' lychee in Homestead, Florida from 1998-99 to 2002-03 crop season.

Results



Hours below 18°C (65°F) on average yield of 'Mauritius' lychee in Homestead, Florida from 1998-99 to 2002-03 crop season

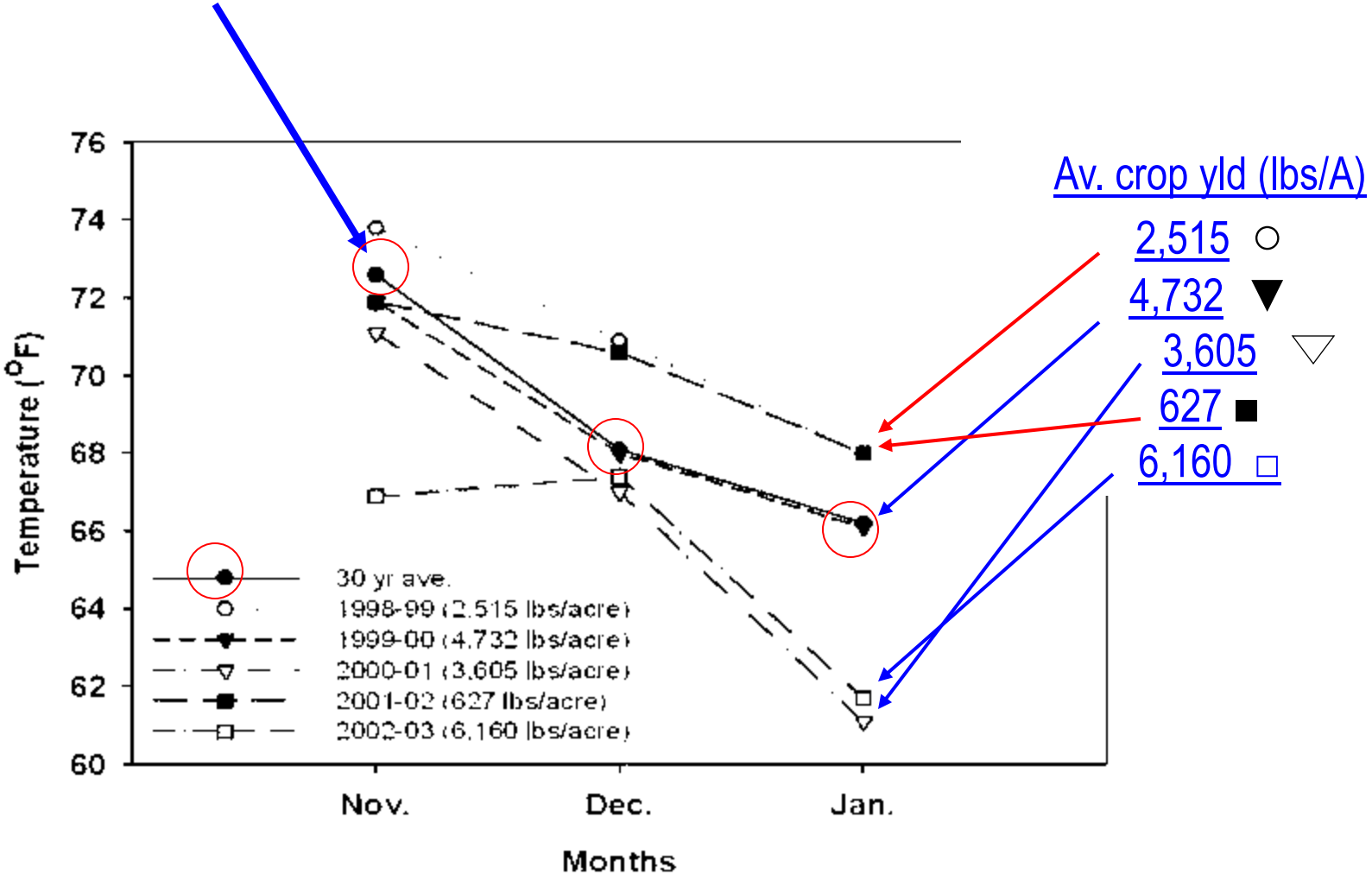
Results

- The correlation (r^2) between the average yield and hours below 21°, 7°, and 4°C (70°, 45°, and 40°F) were very low (<0.30). The r^2 for 10° and 18°C (50° and 65°F) were also low (0.35).
- The fact that the number of hours below 15.5°C, 18°C, and 21°C (60°F, 65°F and 70°F) was not well correlated to crop yields suggests that there was little effect of temperatures above 15.5° to 21°C (60° to 70°F) on flower induction in the Homestead area.
- The fact that the number of hours below 4°, 7°, and 10°C (40°, 45°, and 50°F) is was not well correlated with crop yield may be due to the very low number of hours of these temperatures experienced in Homestead; thus making it hard to draw any conclusions on their effect on lychee flowering in the Homestead area.

Results

- The fact that hours below 13^{o} and 15.5^{o}C (55^{o} and 60^{o}F) were best related to crop yield agrees with controlled studies and field observations – i.e., that as the number of hours of cool temperatures increased subsequent crop yield potential increased.

30-year average



The 30-year (1971-2000) mean monthly temp. from Nov. through January (●) compared to the mean monthly temp. from 1998-99 (○), 1999-00 (▼), 2000-01 (▽), 2001-02 (■) and 2002-03 (□).

Results

- Plotting the 30-year average along with the seasonal average temperatures and noting the average crop yield provides further evidence that an increase in the number of hours of cool temperatures is related to increased crop yield. Higher than average temperatures from the November through January period during the 1998-1999 and 2001-2002 seasons resulted in less crop yield per acre than the 1999-2000, 2000-2001, 2002-2003 crop seasons.

Overall conclusions

- The relationship among hrs below 13^{o} and 15.5^{o}C (55^{o} and 60^{o}F) and 'Mauritius' lychee crop yield was moderately well correlated (i.e., r^2 = 0.74 and 0.68, respectively) for Homestead, Florida.
- Moderate crop yields resulted after about 180 hr below 13^{o}C (55^{o}F) and/or 390 hr below 15.5^{o}C (60^{o}F.
- Years with average or below average Nov. to Dec. temperatures had higher 'Mauritius' lychee yields than years with above average Nov. to Dec. temperatures.

Orchard/grove infrastructure

- Land preparation – clearing, leveling or sloping and/or bedding, ditches/canals.
- Grove layout – NS is preferred for optimum duration of light exposure.
- Many well drained soil types, pH 4.5-7.0, with poor to moderate fertility.
- Irrigation system(s) installation – for watering and possibly fertilizing; microsprinkler or drip; for cold protection use high volume.
- Wind machines for cold protection in areas with predominantly radiation type freezing events.

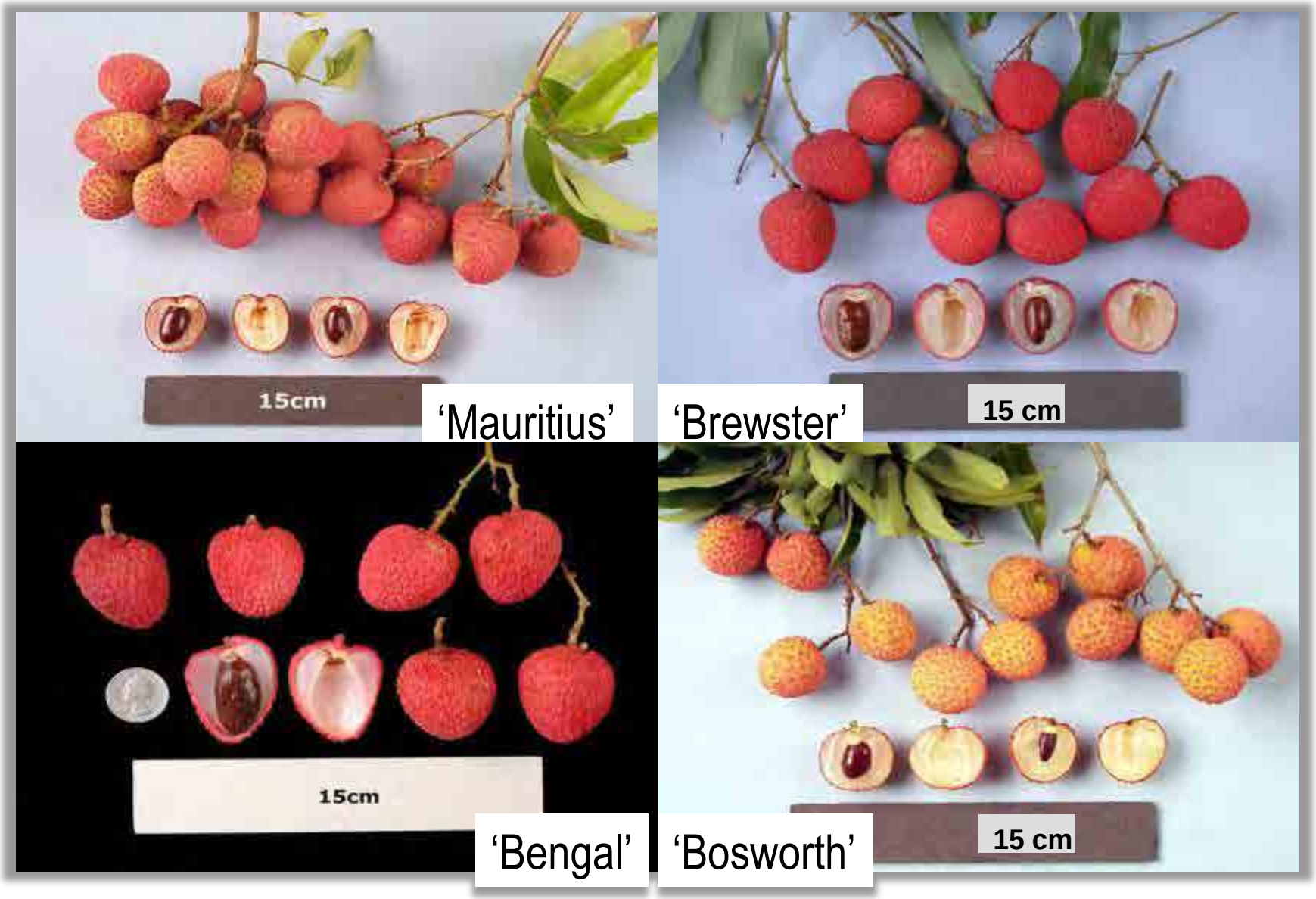
Florida cultivars

- Florida season is May-June. There are two main cultivars, ‘Mauritius’ (early) and ‘Brewster’ (late). Numerous cultivars have been tested to extend the harvest season.
- Percent fruit set varies greatly from 0-50%.
- Fruit maturity is determined by color, size, taste, and sweetness (°Brix).

‘Mauritius’

Cultivars in Florida

- Bengal
- Kwai Mai Pink
- Brewster
- Early Large Red
- Emperor
- Groff
- Hak Ip
- Kaimana
- Yellow Red
- Garnet
- No Mai Tum
- Sweetheart
- Kwai Mai Red
- Mauritius
- No Mai Chee
- Ohia
- Salathiel
- Sweet Cliff
- Wai Chee
- Hanging Green
- Amboina
- Gee Kee
- Peerless
- Seymour
- Shan Chi



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‘Early Large Red’

‘Emperor’

‘Garnet’

‘Gee Kee’

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‘Hak Ip’

‘Hanging Green’

‘Kaimana’

‘Kwai Mai Pink’

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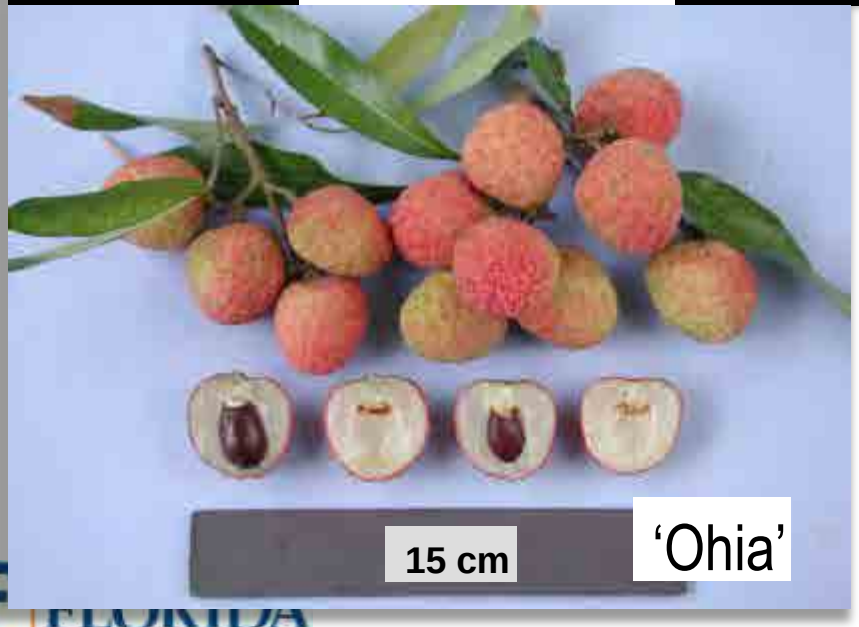
'Kwai Mai Red'

'No Mai Tum



'Ohia'

'Peerless'

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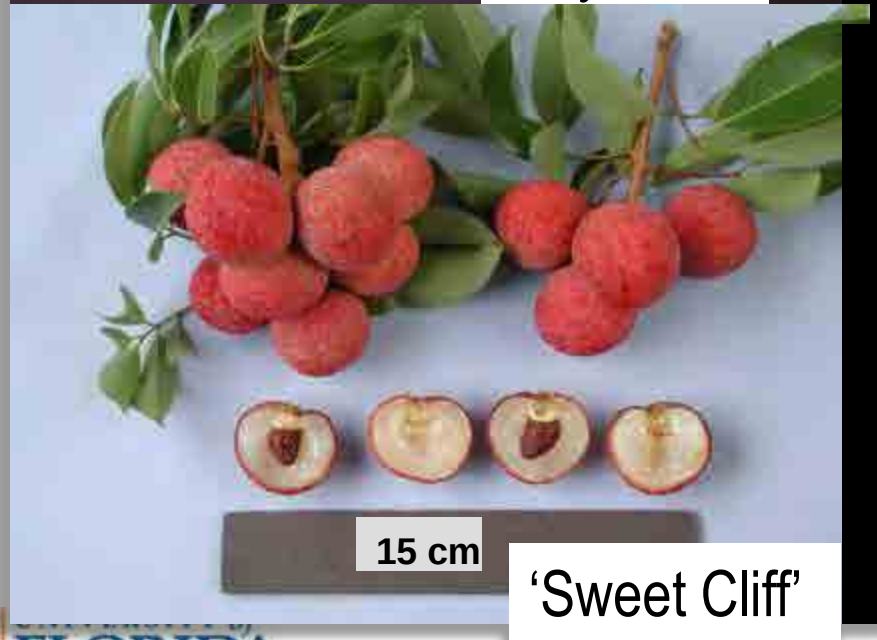
‘Seymour’

‘Shan Chi’



‘Sweet Cliff’

‘Yellow Red’

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Plant spacing in Florida

- Factors
  - Life expectancy of the grove
  - Climate
  - Tree vigor
  - Ultimate tree size desired
  - Presence of irrigation system

- Range 4.6 m to 7.6 m in-row (15-25 ft); 5.5 m to 9.1 m between-row (18-30 ft).
- Recommended: 6.1 m to 7.6 m in-row (20-25 ft) and 6.7 m to 7.6 m between rows (22-25 ft).
- In general, trees can be grown closer together in cool climates.

Requirements for optimum flowering and fruiting

- Exposure to cool (<65°F; <18°C) non-freezing temperatures during fall/winter to induce cessation of growth; dry weather enhances the quiescence, flower induction, and subsequent flower intensity.
- Warm (~mid to upper 20°C) temperatures late winter/early spring to induce flower initiation (flowering) and "good" fruit set; nonlimiting soil moisture.
- High temperatures (>upper 20°C to mid 30°C) during fruit development and nonlimiting soil moisture.
- One to two vegetative flushes after harvest then cessation of growth to optimize carbon assimilation and storage for flowering the next year.
- Interplanting rows of cultivars with overlapping flower period may enhance percent fruit set.

Late fruit set problem

Pollination

- Lychee flowers are predominately pollinated by insects – mostly honey bees.
- Hives are place in the groves during the flowering period.

Crop production strategy

- Time N fertilizer applications to support flowering and fruit development and postharvest A and carbohydrate accumulation.
- Do not to over apply N which results in excessive vegetative over reproductive growth. Recommended no N applications after July-August.
- Maintain all other nutrients at nonlimiting levels.
- Maintain nonlimiting soil moisture from flowering through harvest.
- Allow postharvet flush(es) to harden and for A and carbohydrate accumulation
- Reduce or cease irrigation from Oct. until signs of flowering.
- Appropriate tree size control program to maintain canopy light exposure and crop production.

Crop production strategy

- Water stress (drought) acts to synchronize vegetative dormancy before exposure to low inductive temperatures during the winter.
- A period of drought stress –
  - Reduces the number of growth flushes after harvest.
  - Reduces stem circumference.
  - Synchronizes the shoots phenologically.
  - Increases the amount of flowering and may increase yields.
  - Does not induce flowering if plants are exposed to continuously warm temperatures (86/75^{o}F; 30/25^{o}C); conversely well-watered plants exposed to inductive temperatures (<65^{o}F; <18^{o}C).

Asyncrhonous growth

- When individual shoots are in different stages of growth
  - New flush
  - Mature/dormant
  - Recently matured
- Results in
  - Poor flowering
  - Low yields

- Solution:
  - Prune trees annually
  - Prune only small diameter wood (<2.5-3 cm dia.)
  - Restrict or eliminate N applications
  - Emphasize micronutrients
  - Restrict or eliminate irrigation

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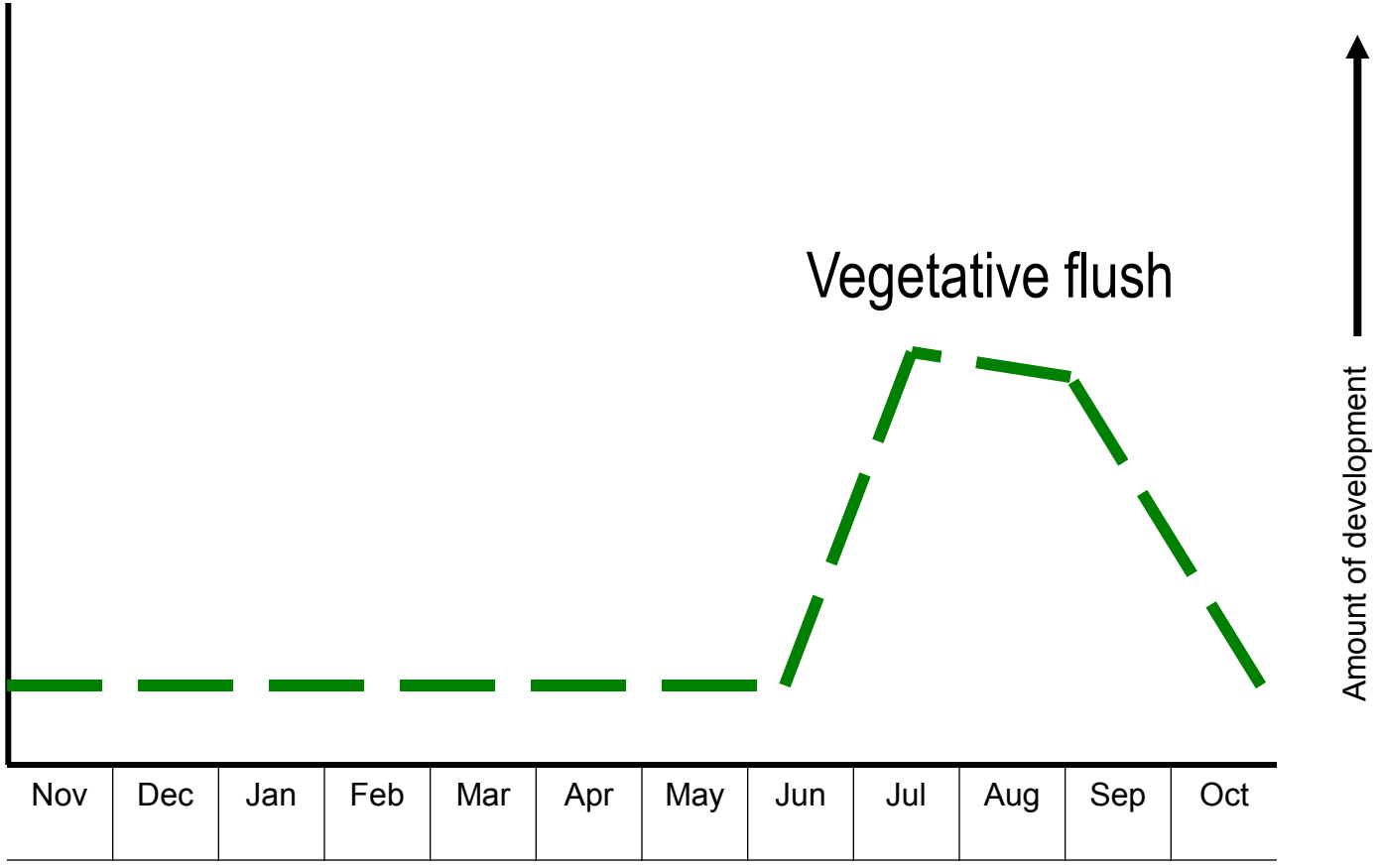
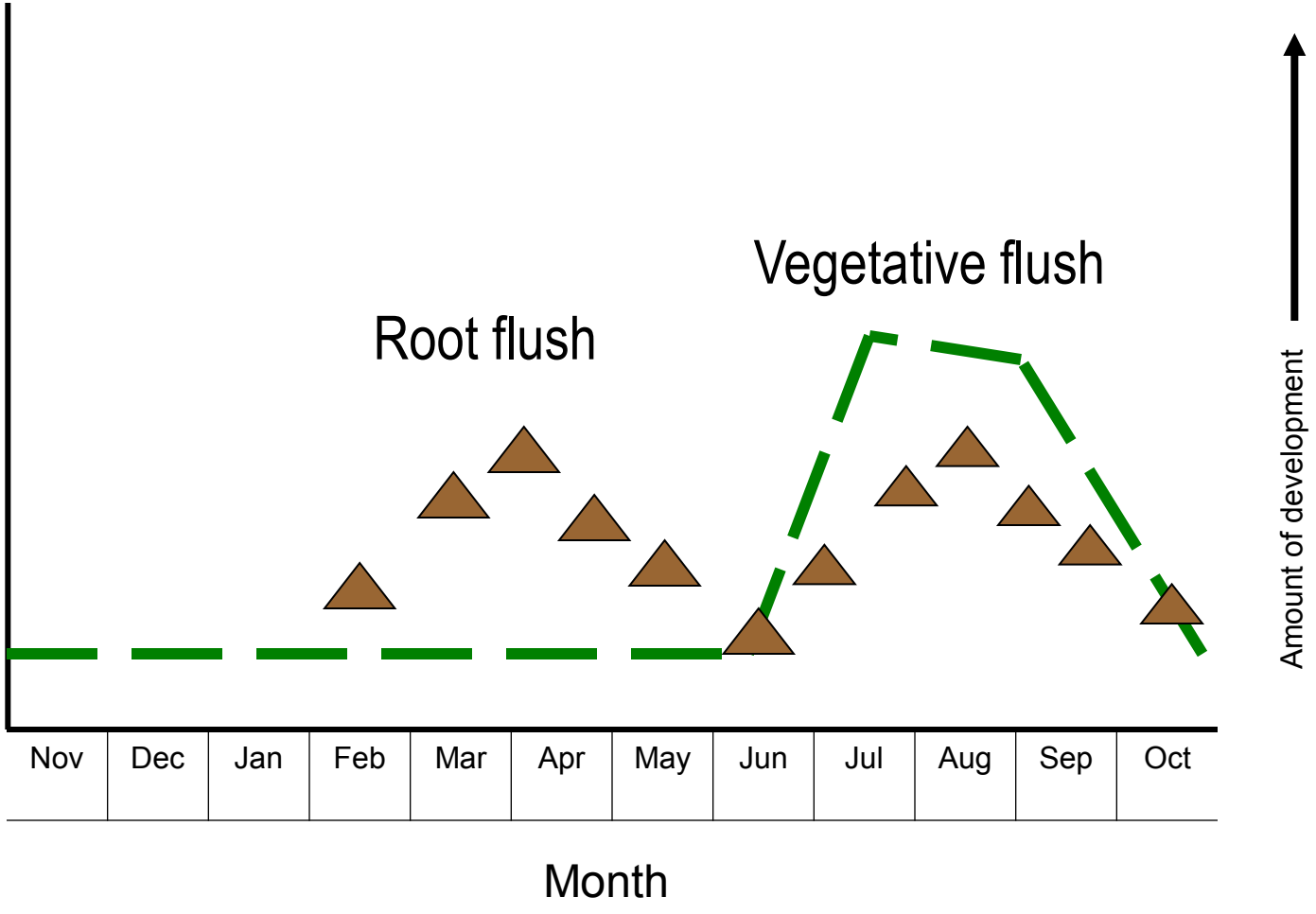
Plant nutrition

- Moderate to poor soil fertility.
- Leaf litter and/or mulching is beneficial.
- Apply 9-45 kg ha^{-1} yr^{-1} (20-100 lbs N $acre^{-1}$ yr^{-1})?
- Base fertilizer applications on leaf analysis.
- Split nitrogen applications into 2-4 application per year; prior or at bloom, and mid- to late fruit development period.
- Avoid N applications after August/Sept. as this may cause excessive and repeated flushing.
- Secondary and minor elements should be applied on an as needed basis or maintenance level to maintain tree health.

Lychee phenology



Lychee phenology



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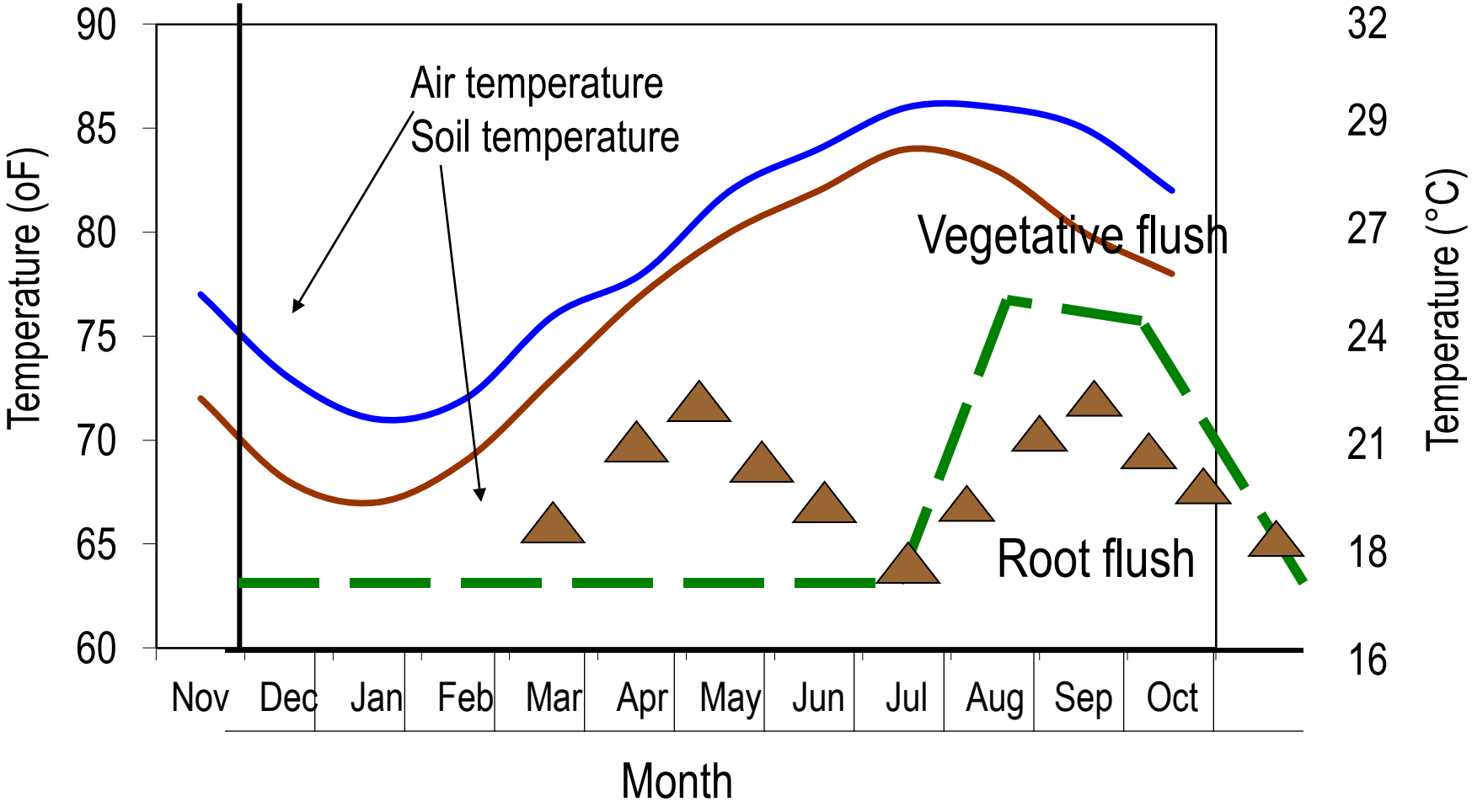
Lychee phenology



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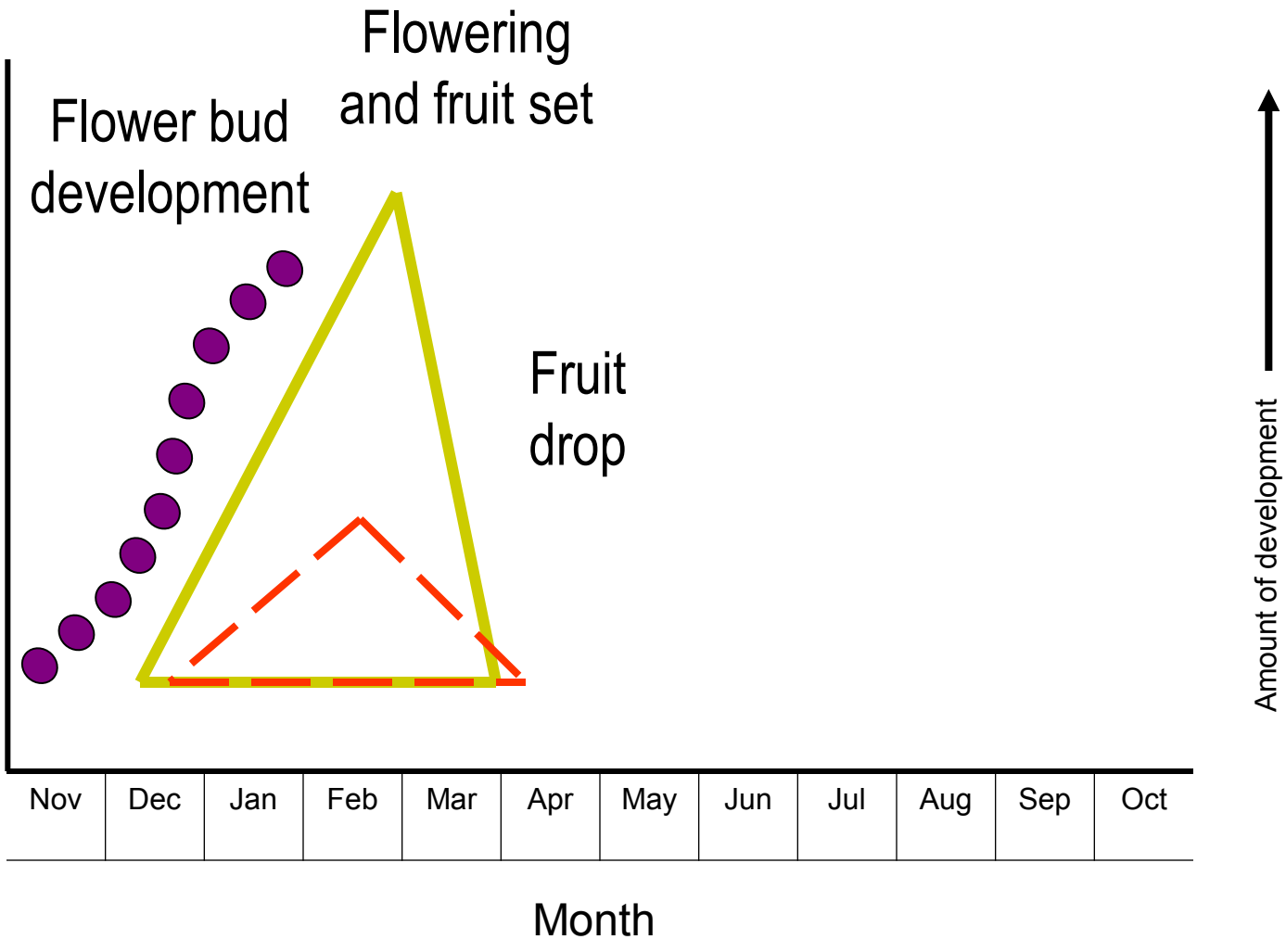

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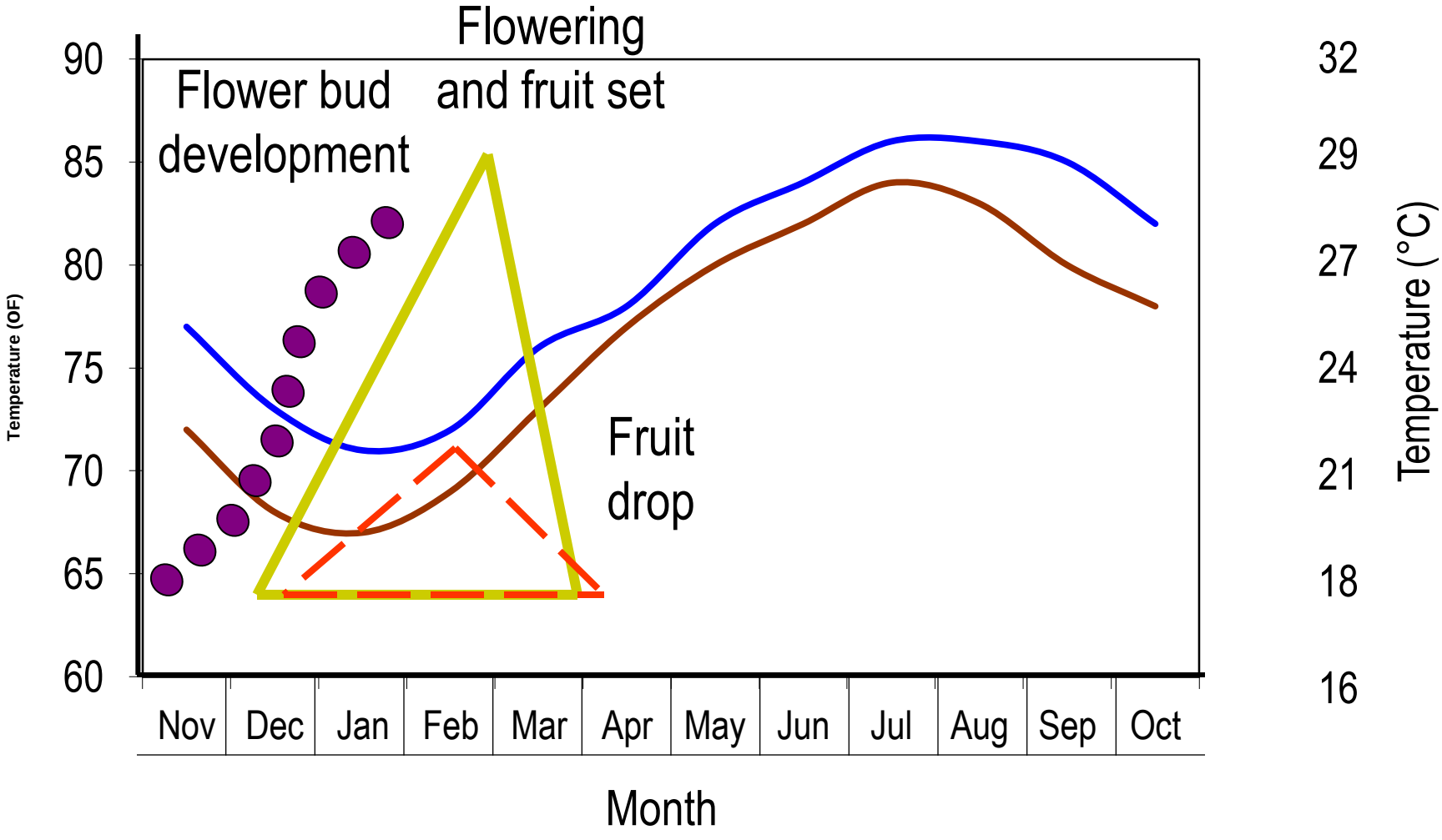

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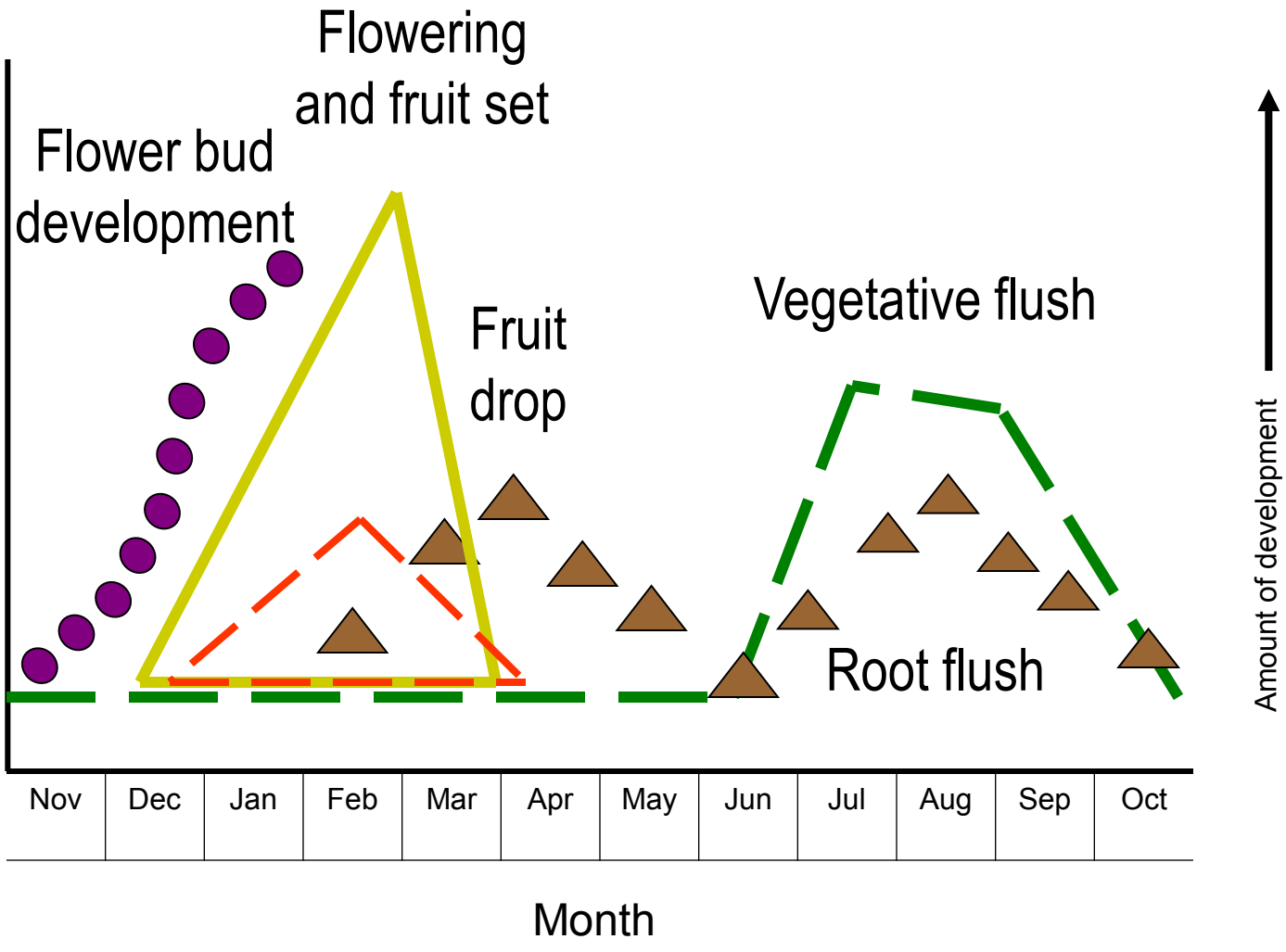

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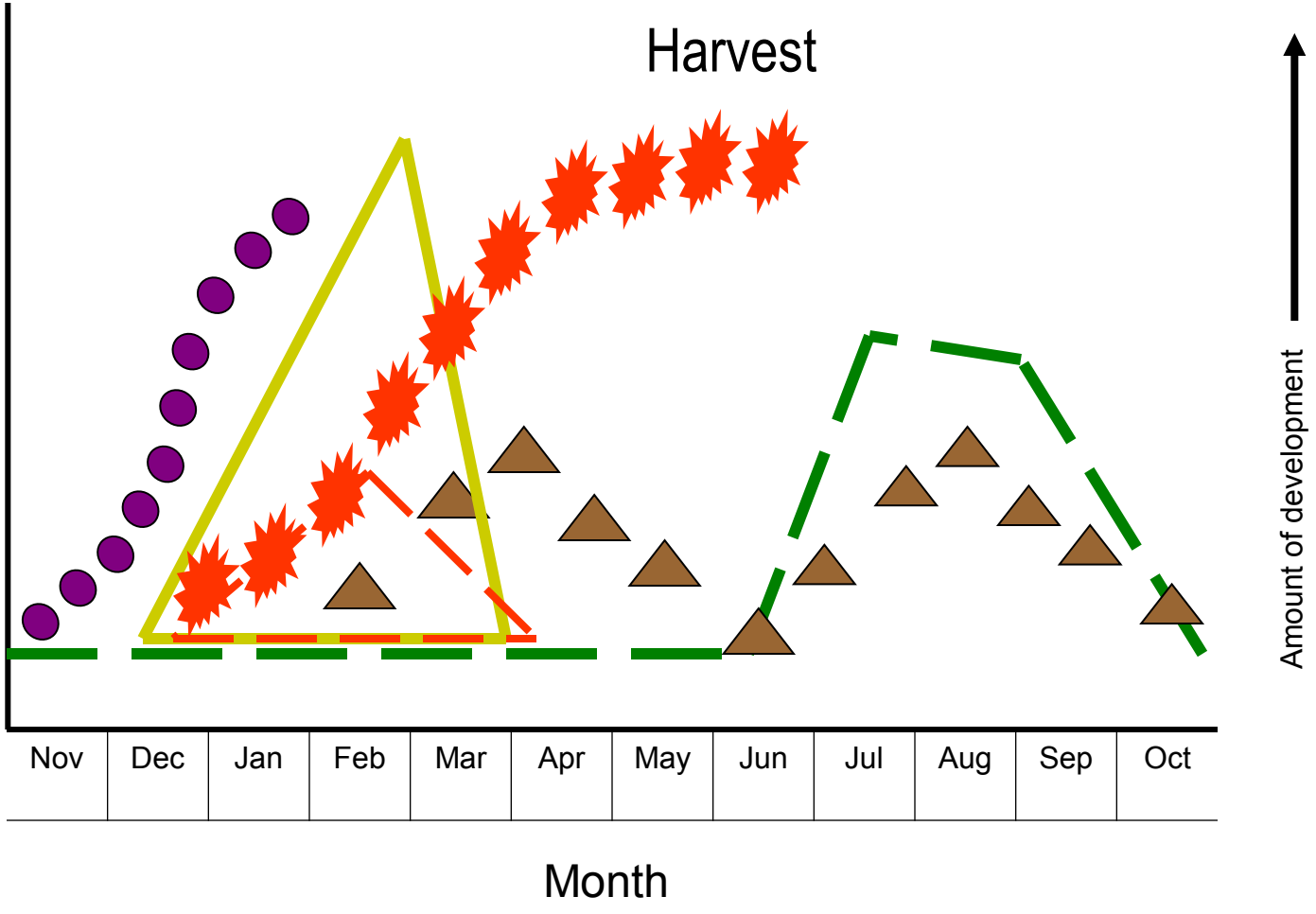

Lychee leaf nutrient levels

Element	Symbol	Unit	Range for mature trees		
			Australia	So. Africa	Israel
Nitrogen	N	%	1.50-2.00	1.30-1.40	1.50-1.70
Phosphorus	P	%	0.14-0.22	0.08-0.10	0.15-0.30
Potassium	K	%	0.70-1.10	1.00	0.70-0.80
Calcium	Ca	%	0.60-1.00	1.50-2.50	2.00-3.00
Magnesium	Mg	%	0.30-0.50	0.40-0.70	0.35-0.45
Sulfur	S	%	0.11-0.14	no data	no data
Boron	B	ppm	25-60	25-75	25-75
Iron	Fe	ppm	50-100	50-200	50-200
Manganese	Mn	ppm	100-250	50-200	40-80
Zinc	Zn	ppm	15-30	15	12-16
Copper	Cu	ppm	10-25	10	no data
Sodium	Na	ppm	<500	no data	300-500
Chlorine	Cl	%	<0.25	no data	0.30-0.35

Production practices for Florida lychee.

Operation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Disease[1]	Anthracnose →											
Insect[2]	—	—	—				—	—	—	—	—	—
Fertilizer:												
General[3]		—	—		—	—	—	Do not apply nitrogen containing fertilizers				
Micronutrient[4]	- -	- -	—	—	—	—	—	—	—	—		
Iron[5]			—	—	—	—	—	—	—	—		
Weed control:												
Mow	X		X		X	X	X	X	X	X		X
Herbicide Contact	- -	-	—	—	—	- -	- -	- -	-	—		
Irrigation[6]	Little to none - begin irrigating at panicle emergence through harvest - little to none →											
Harvest					—	—	—					
Hedge and topping[7]						—	—					
Frost protection	—	—	—								—	—
Operation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

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Critical periods for irrigation

- At flowering and fruit set.
- During fruit development.
- During the cool period, if severe drought, limited irrigation is justified.
- Irrigation rate (amount) varies with tree size, climatic demands, soil type and depth and should be determined with soil moisture monitoring.

Critical period for dry soil conditions

- During late summer/fall to limit vegetative flushing
- During the fall/winter exposure period to cool temperatures

Tree training and tree size control

- In general, the warmer the climate the more vigorous tree growth is.
- In general, for terminally bearing species, pruning of large diameter stems/wood results in excessive and/or continuous vegetative flushing.
- The wider the spacing the longer it takes to require regular pruning. The closer the plant spacing the earlier a pruning program is required and the more frequently trees are pruned.
- In general, designing a pruning program for cultivars with a vigorous, upright growth habit is more difficult than for less vigorous, spreading growth habit cultivars.
- Recommendation for Florida, top trees to 4.6-6.7 m (15-22 ft) and maintain a 1.8-2.4 m (6-8 ft) middle.

Tree training and tree size control

- Observations have suggested shade reduces panicle size and fruit per panicle.
- Selective pruning to thin-out inner canopy limbs will increase light penetration, help maintain lower productive canopy, and improve air movement to reduce fruit/leaf disease problems.
- Mechanical pruning to synchronize growth and limit tree size.

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- Young trees begin to produce on a commercial scale after 3 to 4 years.
- Yields from mature trees average 23 kg per tree (~50 lbs) however, 45-182 kg per tree (100-400 lbs) are possible.
- Lychee production is erratic although attention to the fertilizer and irrigation program increases the probability and reliability of cropping.
- Yields of 60-70 kg (130-155 lbs) per tree is considered good and up to ~1000 lbs; ~450 kg per tree have been reported from other production areas.

Lychee crop production in Florida

Harvest indices

- Picked ripe based on -
- Taste (flavor, sweetness)
- Fruit color
- Fruit diameter
- Fruit weight
- Fruit aroma

Lychee harvest

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Lychee harvest

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Postharvest handling

- Pick carefully and place bins in shade immediately.
- If available hydrocool or force-air cool.
- Sort and pack in polyethylene-line boxes and place in cold storage immediately.
- Optimum storage temperature varies with cultivar: ‘Brewster’, ~3°C (38°F); ‘Mauritius’, 5°C (41°F).

Harvest, postharvest

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Harvest, postharvest

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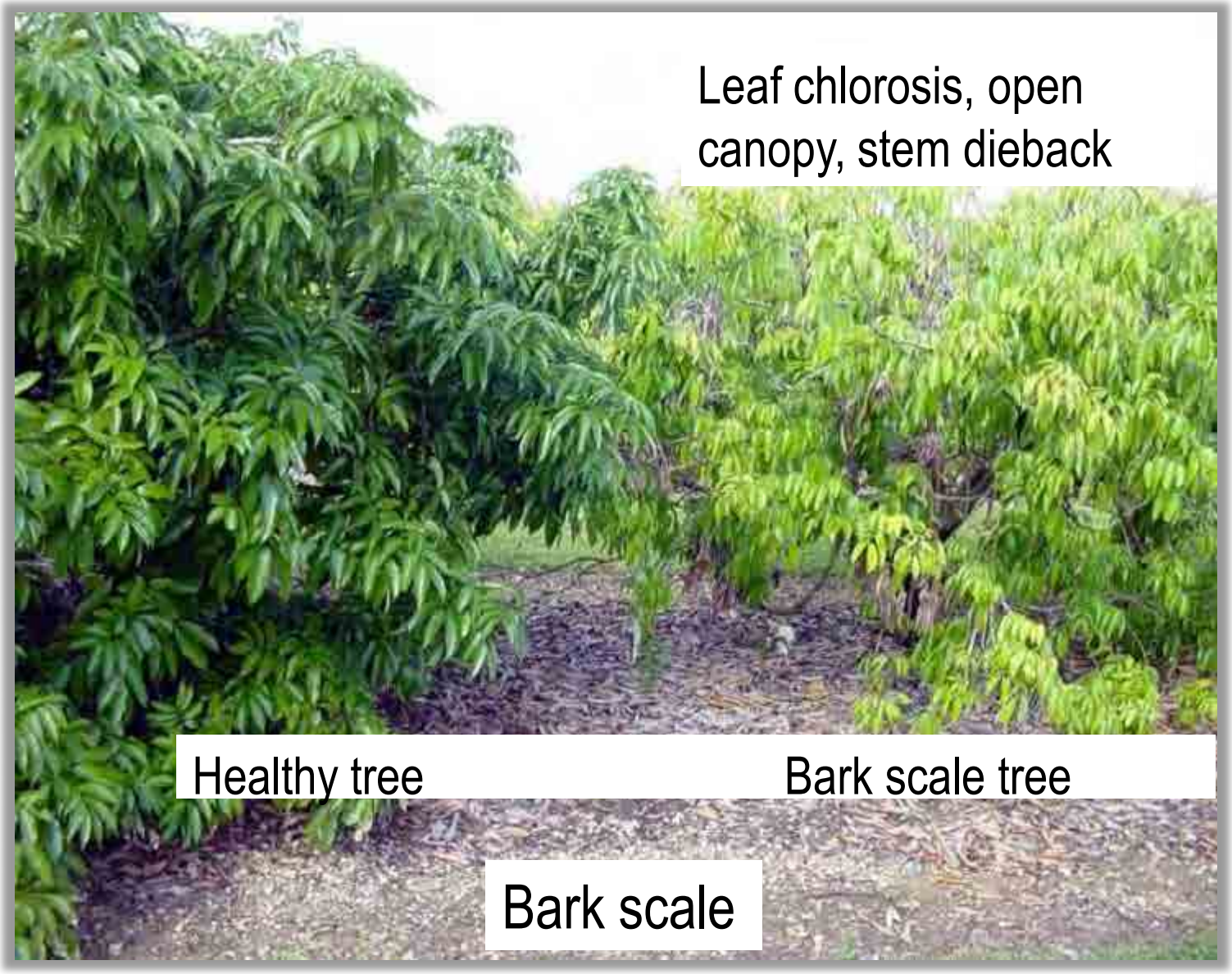
Major diseases and insects of lychee in Florida

- Anthracnose (*Colletotrichum gloeosporioides*) attacks fruit – periodic fungicide applications, air movement.
- Mushroom root rot (*Clitocybe tabescens*) – not common.
- Red alga (*Cephaleuros* sp.) attacks shoots and limbs – copper fungicides.
- Lychee webworm (*Crosidesima* new species) attacks emerging panicles and vegetative growth.
- Lychee bark scale (*Andaspis punicae)*
- Mealybug and mites.
- Allow “natural” predators to work,, scout/monitor grove continuously and use least disruptive insecticide materials as needed.



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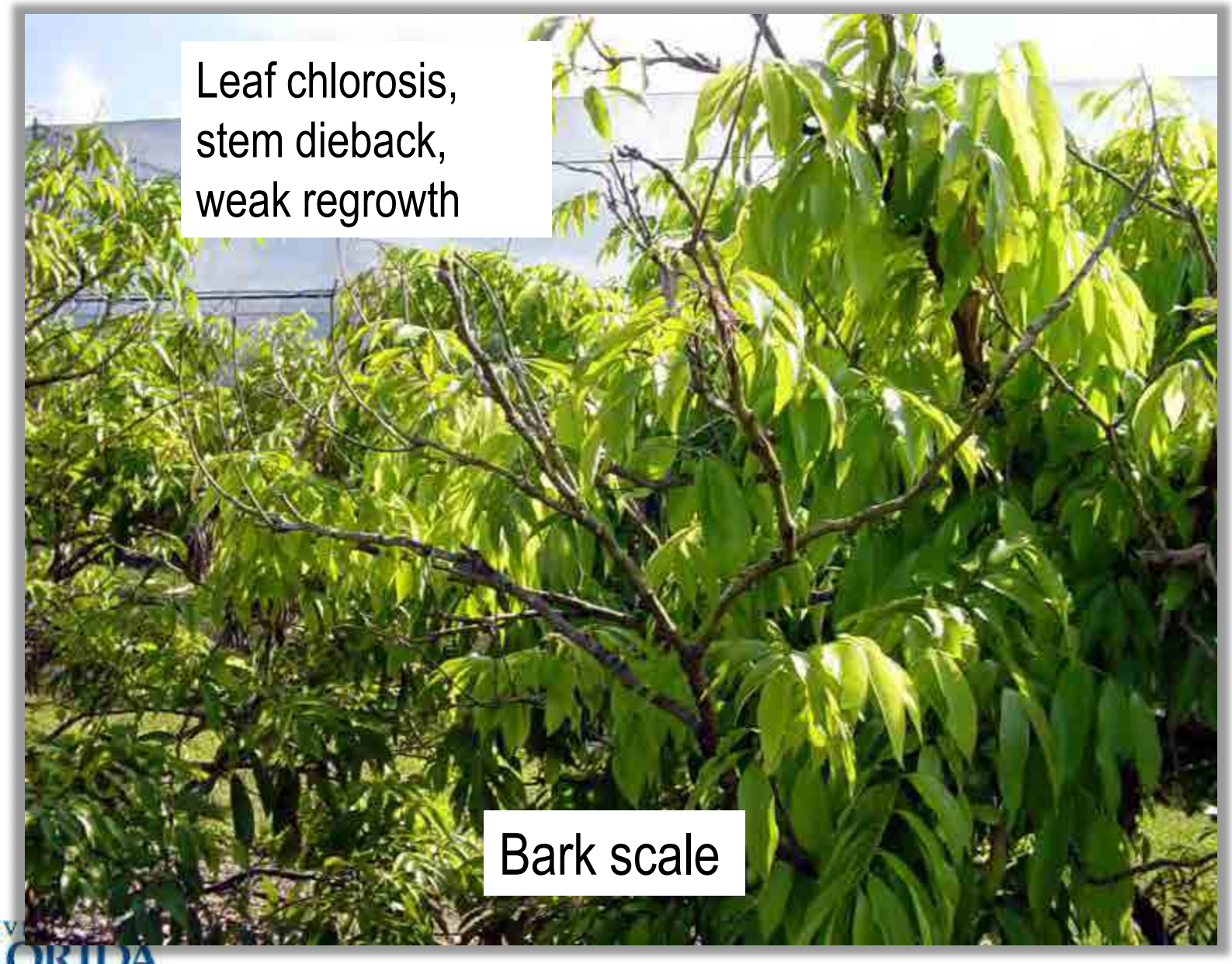
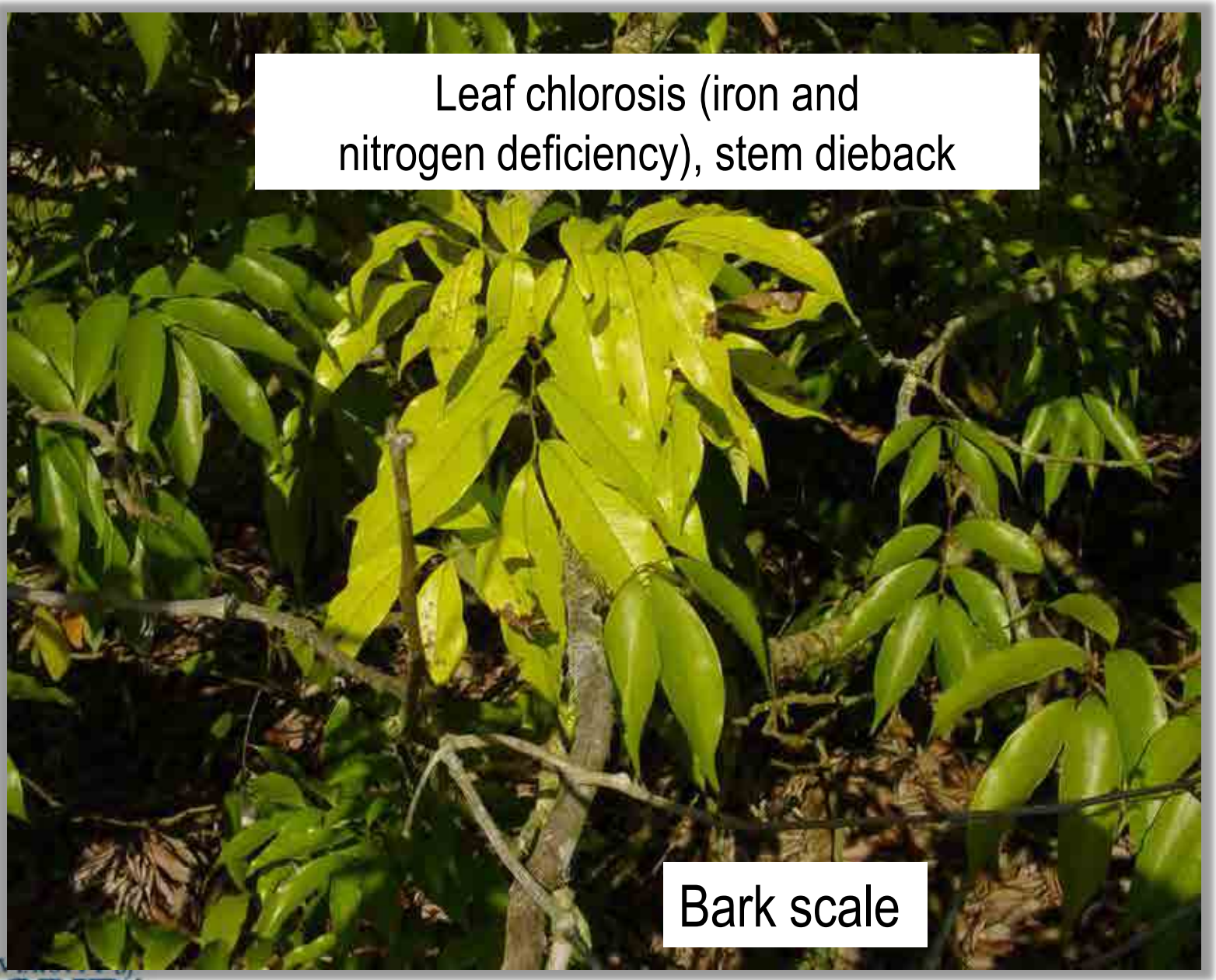
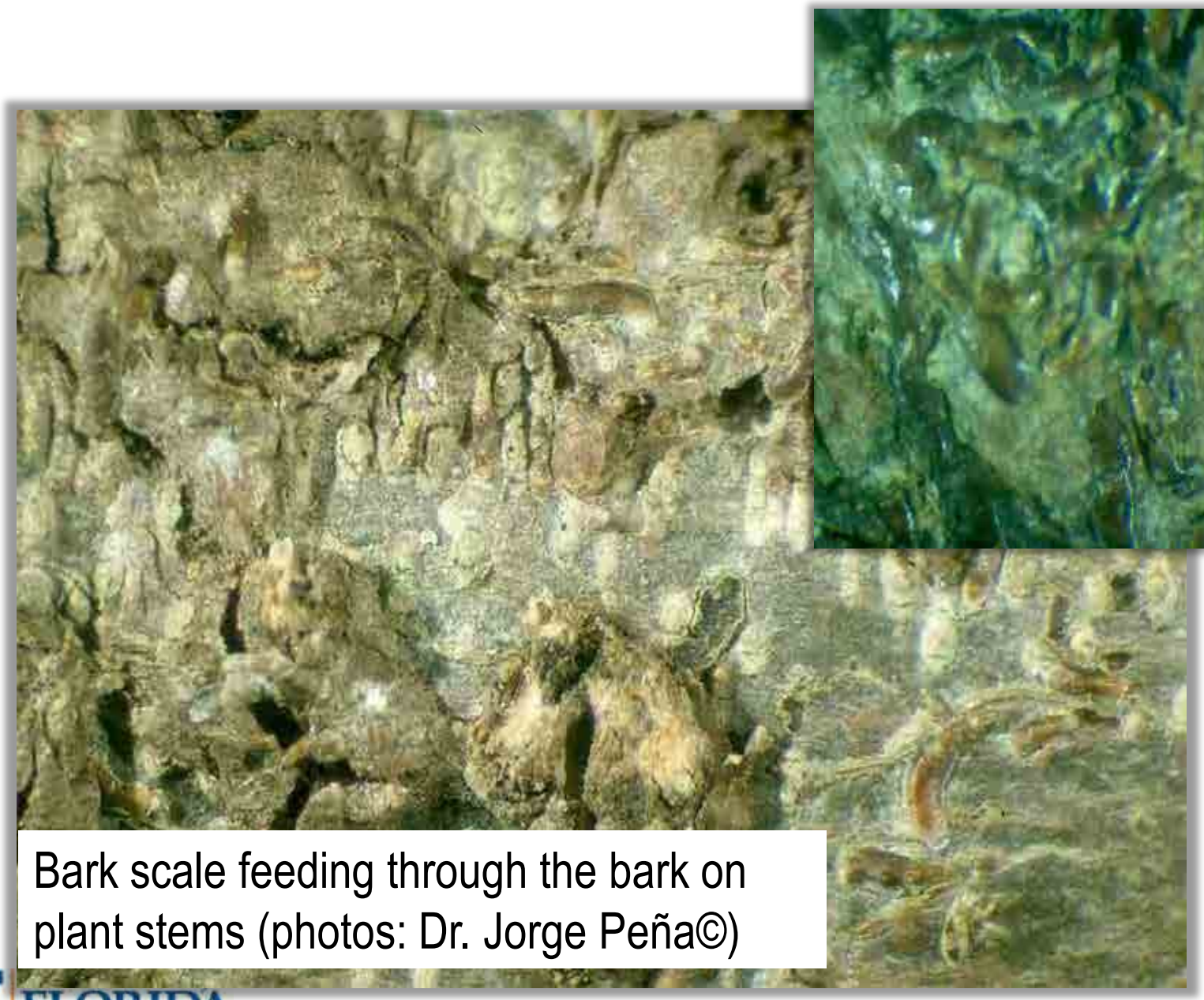

Leaf chlorosis,
stem dieback,
weak regrowth
Bark scale


Leaf chlorosis (iron and nitrogen deficiency), stem dieback
Bark scale



Bark scale feeding through the bark on plant stems (photos: Dr. Jorge Peña©)

Bark scale
stem bark symptoms
(photos: Dr. Jorge Peña©)

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Corky (Scaley) bark

- Scaley bark caused by *Dolabra nepheliae* and sometimes infested with a bark miner – *Marmara* sp.

Brown scale

Mealy bug

LYCHEE WEBWORM (*CROCIDOSEMA* SP.) AND DAMAGE

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Red mites

Litchi erinose mite (*Aceria litchii*)

(origin China, picture from Spain)

Psocids - b
lice, cause
damage to
tree

Bird damage

Bird netting

Anthracnose (*Colletotrichum gloeosporioides*) damage on fruit

Coffee stain (unknown cause)

Anthracnose

Coffee stain

Parasitic lichen

Fruit cracking – physiological problem

Lychee environmental stress and management

Moderate tolerance

- Drought – leaf wilting, chlorosis, desiccation, and abscission; reduced fruit set, fruit drop, reduced fruit size; stem and limb dieback; reduced crop yields; tree death.
- Solutions - wide plant spacing, deep rooting, mulching, irrigation.

Moderate tolerance

- Flood – leaf wilting, chlorosis, desiccation, and abscission; fruit desiccation and abscission; stem and limb dieback; severe crop loss; tree death.
- Solutions – site selection, tolerant rootstocks, mounding, bedding, ditch/canal/ contour, subsurface drainage, hardpan disruption.

Lychee environmental stress and management

Moderate tol. to intolerant

- Freezing – leaf wilting, water soaking, desiccation, abscission; stem and limb dieback; fruit drop; tree death.
- Solutions – site selection, cold tolerant cultivars, high volume irrigation, wind machines.

Low tolerance

- Salinity – marginal and tip necrosis on leaves; stem and limb dieback; reduced fruit size, fruit drop; tree death.
- Solutions – site selection, water quality and quantity – flushing soil profile periodically; tolerant rootstocks.

Freeze damage
(photos S. Goldweber)

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Lychee environmental stress and management

Tolerant-intolerant

- Wind – leaf damage/ deformation, abscission; stem, limb breakage*; toppling, windthrow, stumping*; tree death.
- Solutions – site selection, wind breaks; tolerant cultivars; facilitate deeper rooting for improved root anchoring; regular pruning program.

Moderate tolerance

- High pH, calcareous soil – nutrient deficiencies, especially iron, zinc, manganese, and magnesium.
- Solutions – rootstock, frequent foliar applications of minor elements (Zn, Mn, Mg) and chelated Fe materials.

Salinity stress

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Lychee fruit nutrient content – value per 3.5 oz (100 grams) of fruit

- Water, 82%
- Calories, 66 kcal
- Protein, 0.83 g
- Total lipid (fat), 0.44 g
- Vit. C, 71.5 mg
- Folate, 14.0 mcg
- Vit. E, 0.07 mg
- Vit. B-6, 0.10 mg

- Thiamin, 0.011 mg
- Niacin, 0.603mg
- Calcium, 5 mg
- Magnesium, 10 mg
- Phosphorus, 31 mg
- Potassium, 171 mg
- Sodium, 1 mg
- Antioxidants/phenols

Source, USDA

Uses of lychee

- Fresh
- Sorbets
- Cooking (toppings)
- Wine
- Liqueurs
- Dried
- May be frozen whole, thawed and used