Flowering and influences on flowering for tropical fruit crops








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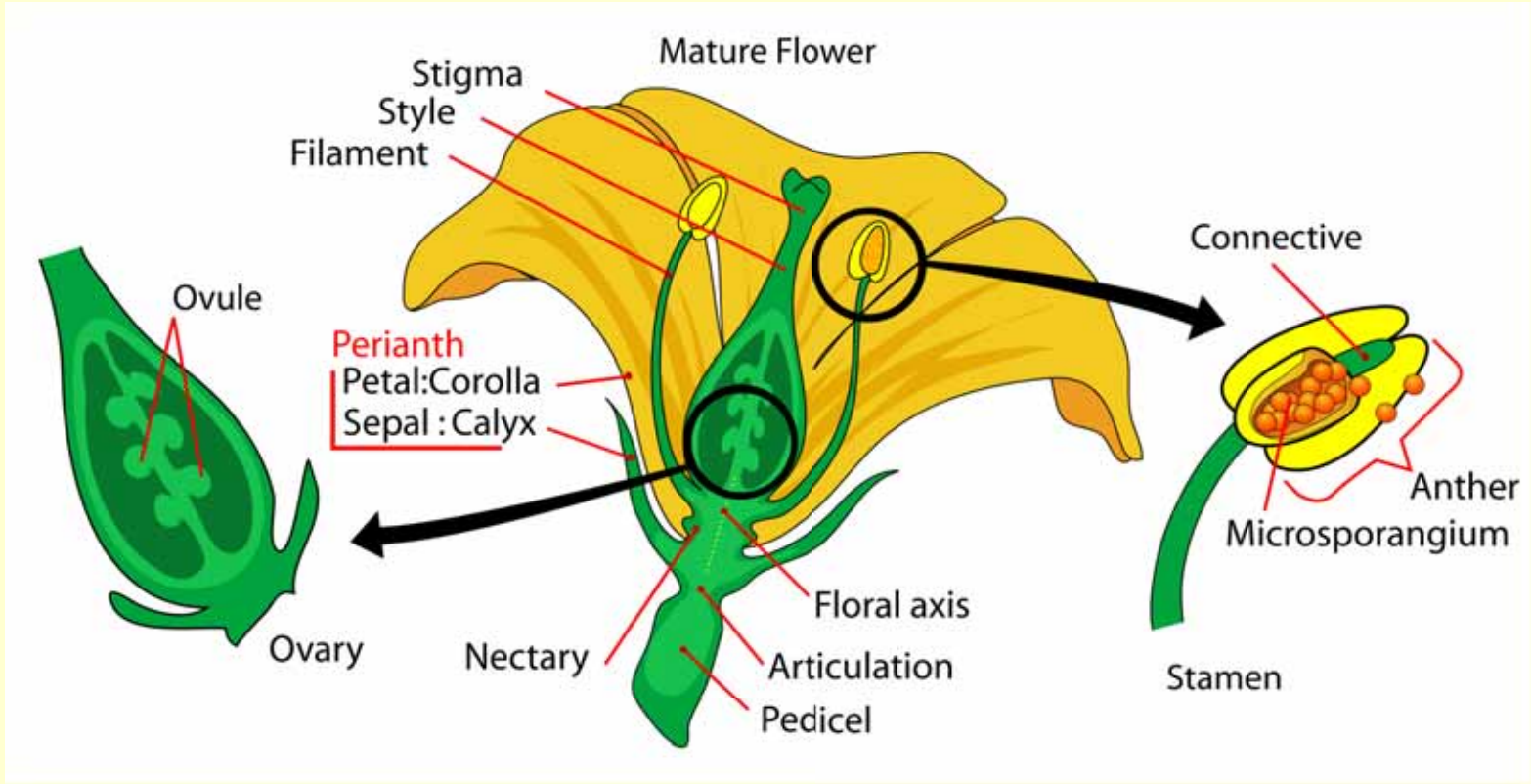
Basic flower morphology



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Pollination and fertilization

- *Pollination is when a pollen grain lands on or is carried to the stigma of a flower, i.e., the flower has been pollinated*
- *Fertilization is when one of the generative (sperm) cells of the pollen grain fuses with the ovum (female egg) now becoming the embryo*
- *The fertilized ovule itself develops into a seed that is contained in the flower's ovary (which ripens into a fruit or part of fruit)*

Why your tree flowered but did not set fruit

- The plant requires cross pollination
- Cool weather (usually in the 40°Fs and 50°Fs) during the flowering period
  - Pollinators cannot fly (honey bees ~56°F)
  - The pollen tube cannot grow quickly enough down the stigma to fertilize the egg
- Desiccation of the stigma by windy dry weather
  - Pollen will not stick or germinate
- Cool/cold temperatures damaged or killed the ovary
- Rainfall during pollen release damages the pollen

Sunlight exposure

- Optimum flowering and fruiting occur in full sunlight for most plants
  - Few exceptions – carambola, pitaya
- Shaded limbs or shoots may not flower or flower but not set fruit
  - For example, avocado, lychee, longan, mango, etc.

Why your tree did not flower?

Potentially

- Too shaded, insufficient sunlight exposure
- Period of tree no-growth (dormancy) was too short (usually cool period not cool enough and/or long enough)
- Nutritional deficiencies
- Excessive nitrogen fertilization
- Too hot (e.g., papaya, passion fruit, pitaya)
- Too cold (e.g., banana, papaya, passion fruit)

Sugar apples and atemoyas

‘Lessard Thai’

‘Gefner’ atemoya

‘Red’

Photos: Ian Maguire©

Sugar apple (*Annona squamosa*) and atemoya (*A. cherimola* x *A. squamosal*)

- Flower location – off of new lateral shoots and small diameter wood
- Flowers bisexual
- Dichogamous
  - At first opening flowers function as females
  - Continued opening – function as males
- Flowering period, 3-5 months
- Flowering to harvest, 5-6 months

New lateral shoot with flowers

Pollinated by Nitidulidae (sap beetles)

- Mostly *Carpophilus* species
- Female stage 18-25 hr
- Male stage ~12 hr
- Sugar apple flowers open early morning (female stage); male stage afternoon or midnight
- Atemoya flowers open in mid- to late afternoon (female stage); about noon the next day male stage (shed pollen)

Carpophilus mutilatus[2]

C. fumatus[1]

Haptonicus luteolus[2]

Photo credits: [1] Lyle Buss, UF http://entnemdept.ufl.edu/creatures/
[2]Mississippi Ent. Museum http://mississippientomologicalmuseum.org.msstate.edu/

Flower inducing conditions

- Maintain healthy leaves after harvest
  - Store carbohydrates
- During winter cease growth due to cool and/or drought conditions
- Exposure to warm (>70°F) temperatures in spring to initiate new growth
- Adequate soil moisture in Spring

Enhancements

- Selective pruning
  - Dead wood
  - Crossed limbs
  - Over/underhanging limbs
  - Reduce long shoots by one-half to two-thirds
  - Results in stronger new shoots and blooms
- Maintain tree height at or below 12 ft

Pruning ‘Gefner’ atemoya in spring at shoot/leaf break

Before

After

Cultural practices

Fertilizer strategy

- No N applications during winter; small dose NPK during leafing/flowering
  - Two-three additional small dose NPK applications
  - Minor nutrient applications important

Irrigation strategy

- Initiate irrigation at leaf/shoot emergence in Spring
- Continue during fruit development period
- Cease irrigation late fall and winter
- To reduce disease pressure do not irrigate foliage

‘Donnie’

‘Monroe’

‘Brogdon’

Avocados

Photos: Ian Maguire©

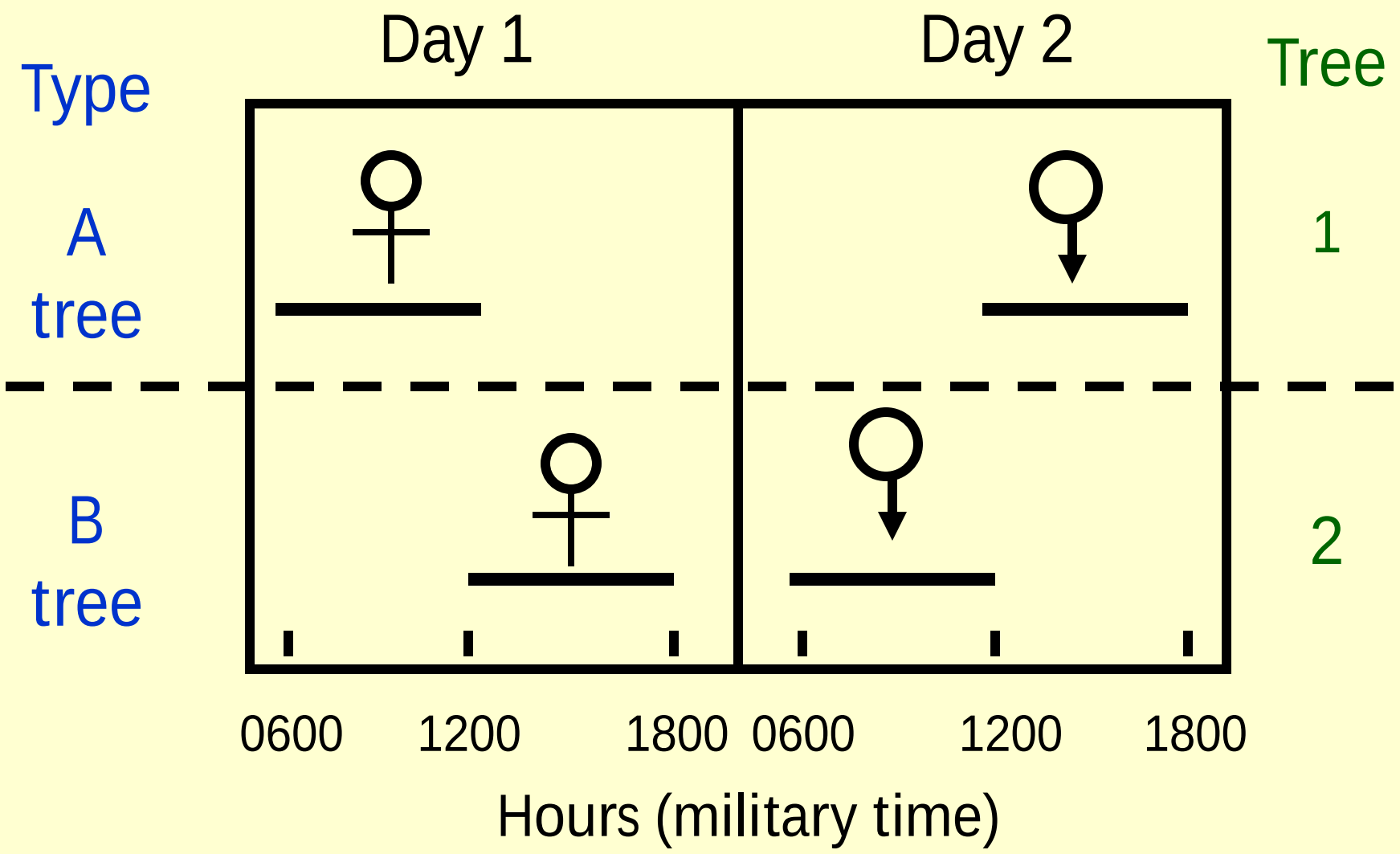
Avocado (*Persea americana*)

- Flowering location – looks terminal, is sub-terminal/lateral
- Flowers bisexual
- Synchronous dichogamy
  - At first opening flowers in female stage
  - Then close
  - At second opening flowers in male stage
- Flowering to harvest, 5-16 months (cultivar dependent)

http://en.wikipedia.org/wiki/Female

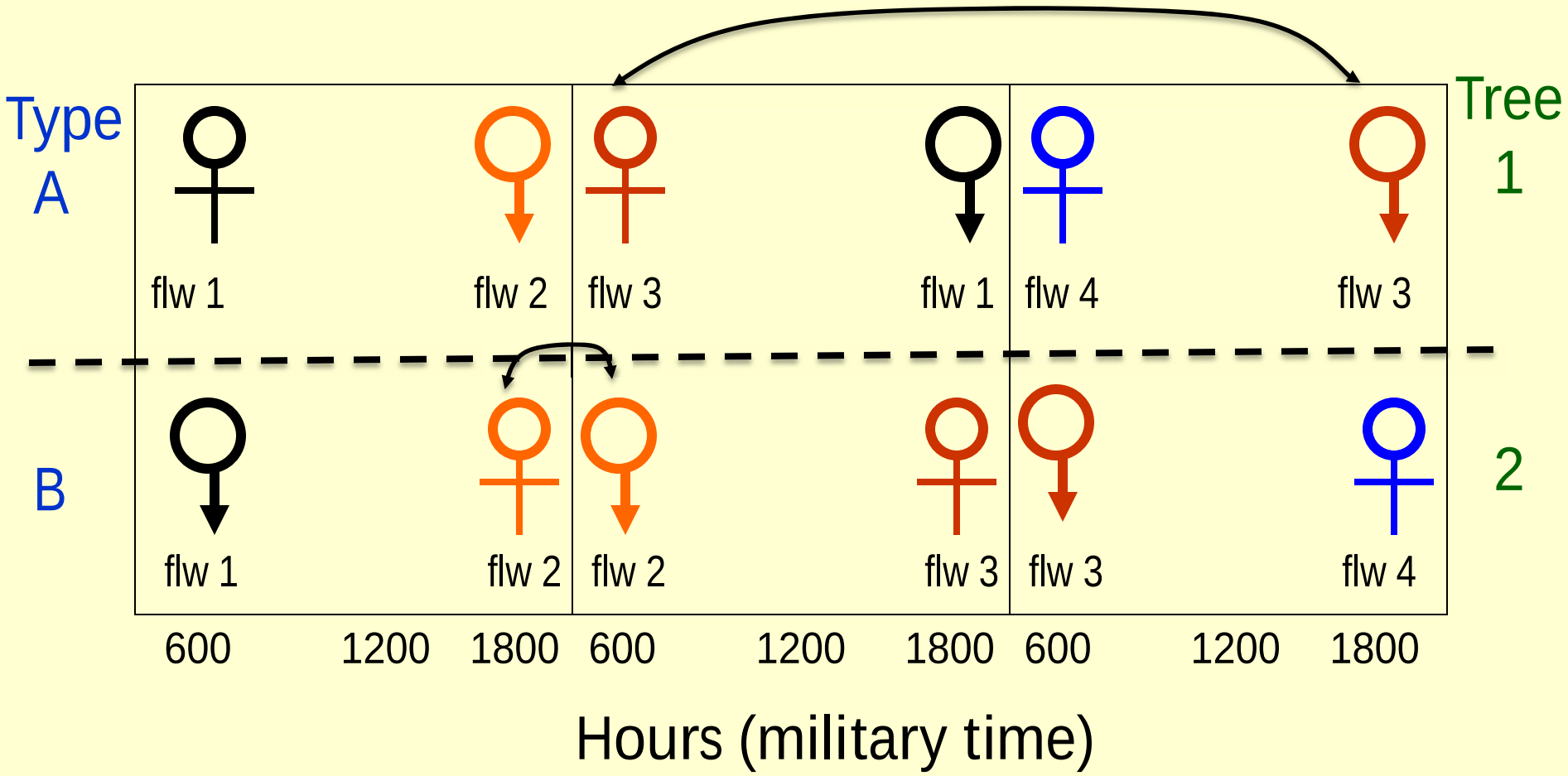
Sub-terminal flowering

Avocado flowering behavior



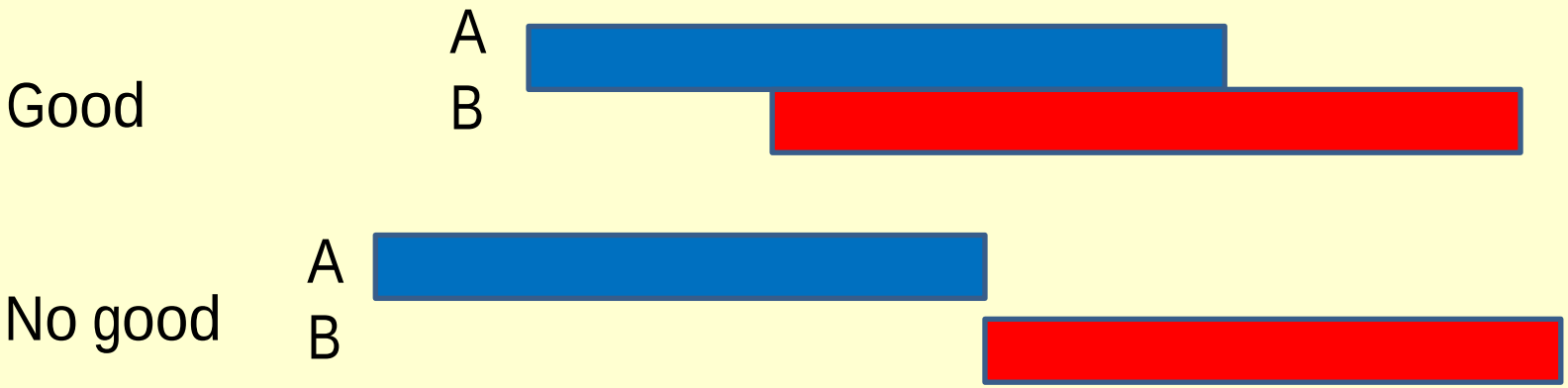
After: Whiley and Schaffer. 1994. Avocado. In: Hdbk of environmental physiology of fruit crops, Vol. II, subtropical and tropical crops. CRC Press, Boca Raton, FL.

Avocado flowering behavior
Overlapping of flowering of Type A and B avocado trees



Avocado flowering behavior

- Avocado cultivars also vary in their period of flowering.
- There are 3 main groups: early, mid-, and late periods.
- To optimize pollination, mix A and B type avocados that bloom during the same period. This will optimize the chances for cross pollination.



Flowering periods

- Example of non-overlapping flowering periods of ‘Arue’ (A) and ‘Beta’ (B) avocado cultivars over a two-year period
- Differences in the length of flowering time is influenced by
  - Ambient temperatures
  - Cultural practices (e.g., irrigation)

‘Arue’ (A)

‘Beta’ (B)

Photos: Ian Maguire©

Pollinators

- Hymenoptera
  - Honey bees (*Apis mellifera*)
  - others
- Diptera (true flies)
- Vespidae and Ichneumonidae wasps

Flower inducing conditions

- Maintain healthy leaves after harvest
  - Store carbohydrates
- During winter cease growth due to cool and/or drought conditions
- Exposure to warm (>70F) temperatures in spring to initiate new growth
- Adequate soil moisture

Enhancements

- Selective pruning to
  - Remove dead wood
  - Reduce canopy height (~15 ft or less)
  - Eventually canopy spread

Tree size control
Full sunlight = full canopy

Before

After

Cultural practices

Fertilizer strategy

- No to very light N applications during winter
  - Maintain foliage during fall and winter to store carbohydrates in stems
- Too much N during fall-winter may reduce subsequent flower
- Three-four NPK and minor element applications from flowering to harvest

Irrigation strategy

- Initiate irrigation at flowering and leaf/shoot emergence
- Continue during fruit development period
- Cease irrigation late fall and winter (if crop harvested)
- To reduce disease pressure do not irrigate foliage

‘Praying Hands’

‘FHIA 3’

Bananas

Photos: Ian Maguire©

Banana (*Musa* hybrids)

- Flowering terminal (end of psuedostem)
- Monoecious – male and female flowers separate on same plant
- Females open first, then transition flowers, then male flowers
- Female flowers set fruit without pollination (parthenocarpic)
- Male flowers are sterile
- Banana plants develop multiple psuedostems from their underground rhizome
- Each psuedostem first grows vegetatively, reaches the appropriate size (# leaves), then flowers and fruits
- The psuedostem then dies

Flowering

Photos: Ian Maguire©

Flower inducing conditions

- Maintain healthy, vigorous plant growth
- Generally each banana cultivar flower flowers after the emergence of so many leaves (usually 20-27)
- Exposure to warm temperatures and available soil moisture is key to banana production
- Flowering to harvest, cultivar dependent, ~3 to 6 months
- Planting to harvest, 14 to 24 months

Enhancements

- Selective removal of all or all but three psuedostems
- This allows all the energy from the leaves and rhizome to concentrate in the remaining psuedostems
  - Reduces time to flowering
  - Enhances fruit and bunch size
  - Removing male bud reduces time to fruit maturity

Photos of mat management

None

Max

Cultural practices

Fertilizer strategy

- During fall/winter when temperatures are below ~50°F reduce NPK applications
- During warm to hot temperatures NPK should be applied every 4 to 8 weeks
- If minor element deficiencies occur apply
- Incorporate lots of compost into the soil
- Mulch around plants 6-8 inch depth

Irrigation strategy

- Irrigate year-round, reduce rates during cool fall/winter conditions
- Depending upon the cultivar – don't irrigate leaves to reduce fungal problems

‘Arkin’

‘Kary’

Carambola

Photos: Ian Maguire©

Carambola (*Averhoa carambola*)

- Flowers bisexual – male and female parts function simultaneously
- Flowers open only once in the morning, if not pollinated they drop
- Not all flowers on a panicle open on the same day
- Some cultivars require cross pollination for good crop yields (e.g., ‘B-17’, ‘B-10’)
- Others (e.g., ‘Arkin’, ‘Kary’) do not

Carambola (*Averhoa carambola*)

Flowering wood

- Long whips
- Short shoots
- Limbs
- Trunks
- Collars

Short shoots

Long shoots

Limbs

Photos: Ian Maguire©

Pollinators

Honey bees

Flies

Wasps

Flower inducing conditions

- Maintain healthy tree canopy
  - Grow in wind protected site
  - Grow in warmest part of property
- Exposure to temperatures >68°F and <95°F
  - Temperatures below about 68°F reduce ability to take up nutrients and water
- Once woody shoots are 3-4 months old they can flower
- Adequate soil moisture is key factor

Enhancements

- Selective pruning to maintain tree height <12 ft
- Bending thin long shoots from vertical to sub-horizontal position, clip 12 inches off terminal
- Prune small shoots back to shoot collar on 2-3 inch diameter wood

Flowering to harvest, 2 to 3 ½ months depending upon temperatures

Pruning to induce flowering and fruiting

Cultural practices

Fertilizer strategy

- Apply frequent small amounts of NPK and minor elements
  - Reduce rates during cool period
- Minor element applications most effective during warm period
- Applications of compost is beneficial
- Three-six inches of mulch is also beneficial

Irrigation strategy

- If well foliated irrigate 1-2 times per week, especially during hot conditions
- If foliage has dropped during winter then reduce frequency and rate of irrigation
- Once tree begins to re-foliate irrigate
- From flowering to harvest trees should be irrigated

Pink type

White type

Guava

Guava (*Psidium guajava*)

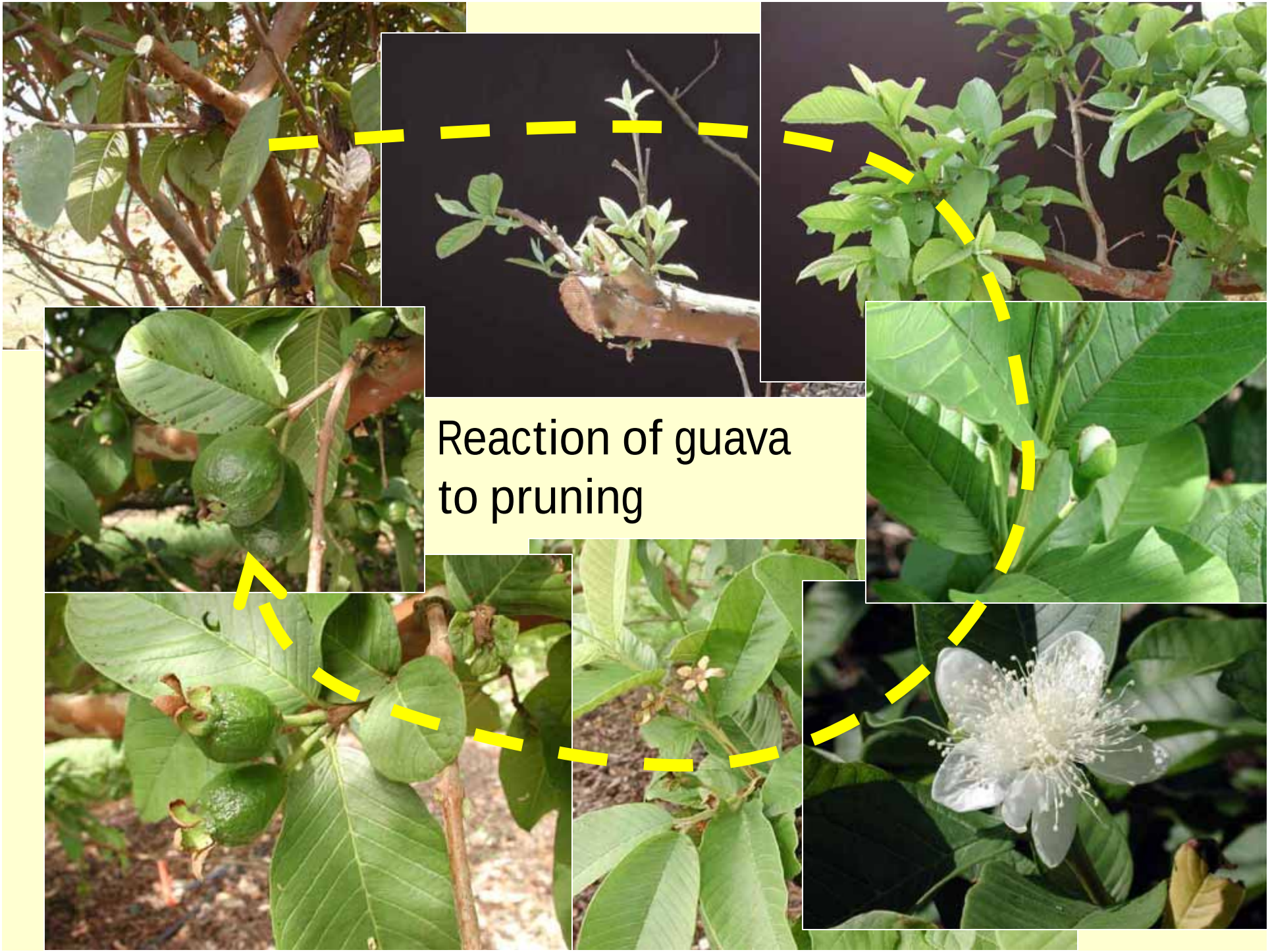
- Flowers off of new later shoots and small-medium diameter wood
- Flowers bisexual – male and female parts function simultaneously
- Flowering to harvest is 3 ½ to 5 months depending upon temperatures
- Cross pollinated

Flower inducing conditions

- Maintain healthy plants
- During drought and/or cool temperatures trees cease growth
- Exposure to warm (>55F) temperatures allows new growth
- Adequate soil moisture
- Flowering to harvest, 4 to 6 months

Enhancements

- Selective pruning
  - Dead wood
  - Head back shoots to induce new shoot and flower growth
  - Prune a few shoots every few months to induce year-round fruit production
- Maintain tree height at 7 ft or below


Reaction of guava
to pruning

Cultural practices

Fertilizer strategy

- Based on previous and current fruit load
- If temperatures warm enough (>60°F) then NPK every other month
- Minor elements 3-4 times per year during warm period
- Benefit from compost and mulch applications

Irrigation strategy

- If foliated then 1-2 times per week
- If defoliated then reduce the frequency and/or rate until beginning to re-foliate then resume more frequent irrigation

‘Tahiti’ or ‘Persian’ lime

‘Tahiti’ lime (*Citrus latifolia*)

- Flowers off of new lateral shoots, laterally adjacent to leaves and at shoot terminals
- Flowers bisexual – male and female parts function simultaneously
- Triploid, seedless, does not need pollination

Flower inducing conditions

- A period of no growth
  - Cool/cold air temperatures
  - Dry soil (drought stress)
- Warm to hot (59°F-90°F) temperatures and adequate soil moisture
- Flowering to harvest, 90-120 days

Enhancements

- General hedge-like pruning after harvest or just prior to the initiation of new growth
- N applications just prior to new growth initiation
- Maintain tree height at or below 7-8 ft

Bouquet and lateral leafy bloom

Cultural practices

Fertilizer strategy

- Apply NPK every 8-12 weeks from flowering to harvest
- Reduce or eliminate N applications during winter
  - Too high N rate reduces flowering
- Apply minor elements 4-8 times per year for best growth and production

Irrigation strategy

- One to two applications per week from flowering to harvest
- Reduce irrigation during cool/cold weather
- To try for off-season fruit, if the tree is healthy with no fruit, eliminate irrigation for 3-4 weeks then fertilize with NPK and water well

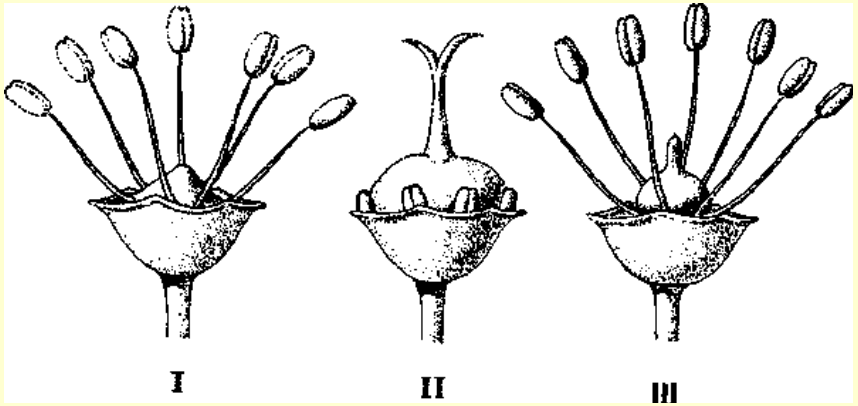
‘Kohala’

Longan

Photos: Ian Maguire©

Longan (*Dimocarpus longan*)

- Flowers at terminals and sub-terminal laterally
- Monoecious – female and male flowers separate on same panicle
- Flowering sequence M1>F>M2+F
  - Some overlap
- Flowering to harvest, 5 to 6 months



- I = M1 male
- I I = Female
- I I I = M2 male

M1, M2 and Female flowers

- Main pollinators
  - Honey bees (*Apis mellifera*)
  - Other bee species
  - Diptera – flies

M2 male

Photos: Ian Maguire©

Flower inducing conditions

- A period of 2 to 6 months of dormancy (quiescence) – no vegetative growth
- Dormancy may be induced by exposure to cool/cold non-freezing temperature
- Drought stress enhances the effect of cool/cold exposure
- No N applications from harvest to flowering
- No irrigation from harvest to flowering
- Depending upon fruit load and tree status (i.e., will not go dormant) N may not be applied
- Dormant trees are induced to flower by warm temperatures and adequate soil moisture
- Prune trees immediately after harvest

Cultural practices

Fertilizer strategy

- No N applications from harvest to flowering
- From fruit set to harvest base rate of NPK on crop load (1-2 applications)
- Apply high K source (0-0-22) after fruit set and two months later
- Apply minor elements during warm period 2-4 times

Irrigation strategy

- Irrigate 1-2 times per week from flowering to harvest
- Reduce/eliminate irrigation during fall and winter

Pruning strategy

- Maintain tree height no more than 15 ft (12 better)
- Maintain lower canopy for fruit production

Show longan decline and thinning

Lack of water and/or fertilizer

Fruit thinning to improve fruit size

‘Kaimana’

‘Mauritius’

Lychee

Photos: Ian Maguire©

Lychee (*Litchi chinensis*)

- Flowers at terminals and sub-terminal laterally
- Monoecious – female and male flowers separate on same panicle
- Flowering to harvest, ~5 months

Female flowers

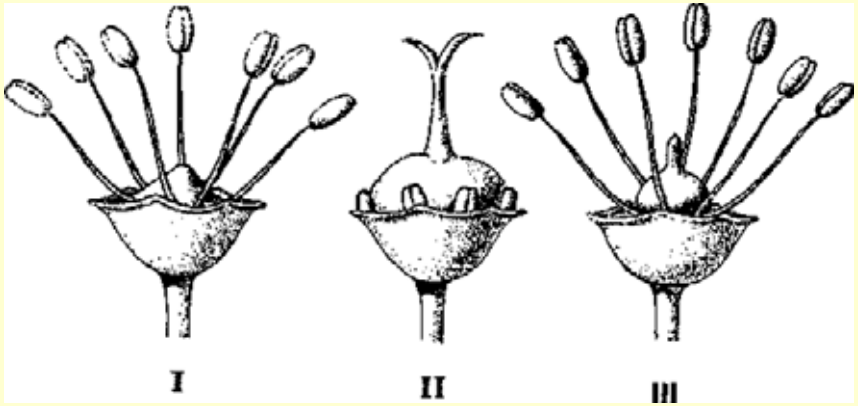
Male flowers

Photos: Ian Maguire©

M1, M2 and Female flowers

- Main pollinators
  - Honey bees (Apis mellifera)
  - Other bee species
  - Diptera – flies

Photos: Ian Maguire©



M1 male F female M2 male

Flowering sequence M1>F>M2+F

Flower inducing conditions

- A period of 2 to 6 months of dormancy (quiescence) – no vegetative growth
- Dormancy may be induced by exposure to cool/cold non-freezing temperature
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- No irrigation from harvest to flowering
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Irrigation strategy

- Irrigate 1-2 times per week from flowering to harvest
- Reduce/eliminate irrigation during fall and winter

Pruning strategy

- Maintain tree height no more than 15 ft (12 better)
- Maintain lower canopy for fruit production

‘Glenn’

‘Valencia Pride’

Mangos

Photos: Ian Maguire©

Mango (*Mangifera indica*)

- Flowers at terminals and lateral sub-terminals
- Monoecious – bisexual and male flowers separate on same panicle
- Flowering to harvest, 5 to 6 months, cultivar dependent

Bisexual flower

Male flowers

Photos: Ian Maguire©

Pollinated by

- Order Diptera – true flies
- Order Hymenoptera
  - Honey bees (*Apis mellifera*)
  - Many others (e.g., *Trigona* sp.)
- Enhance fly population at flowering

Flower inducing conditions

- Healthy tree – no nutrient deficiencies
- A period of dormancy (quiescence) caused by cool and/or dry soil conditions – the length of dormancy required to induce flowering is cultivar dependent
- Excessive N applications may reduce flowering potential and fruit quality
- Exposure to warm to hot temperatures and adequate soil moisture* kicks off flowering
  - * Large mature trees may not need to be irrigated

Cultural practices

Fertilizer strategy

- Little to no N may be necessary – dependent on tree status and size, crop load, and soil type
- Emphasize K applications (at fruit set and during fruit development)
- Apply minor elements 2-4 times per year during warm period

Irrigation strategy

- Little to no irrigation may be necessary – dependent on tree status and size, crop load and soil type, weather conditions
- Keep irrigation water off of foliage and fruit
- Irrigation should be avoided during fall and winter

Pruning strategy

- Maintain tree height no more than 15 ft (6 to 12 better)
- Maintain lower canopy for fruit production

Papaya

Papaya (*Carica papaya*)

- Flowers from leaf axils
- Dioecious – separate female, bisexual and male plants
- Flowering to harvest, 4 to 6 months, temperature dependent
- Pollinators – flying insects, self-pollination

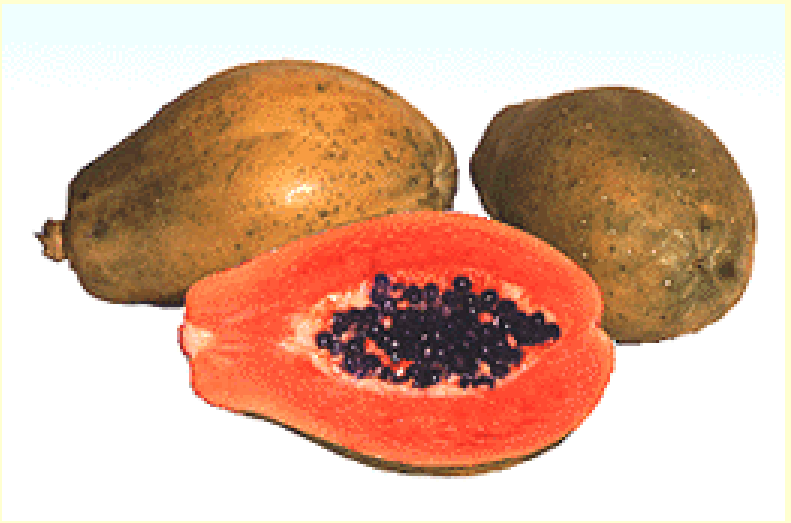
Female

Male

Bisexual

Papaya fruit types

‘Red Lady’
Formosan type
Elongated, 4 lbs to 8 lbs



‘Sunrise’
Solo type
Pear-shaped, 8 oz to 18 oz

Flower inducing conditions

- Healthy trees
  - No restrictions on growth and tree health
- Exposure to continually warm (>55°F) to hot ambient temperatures (<95°F)
- Adequate soil moisture
- Adequate fertilizer
- Once plants become too tall for easy care and harvest they may be cut to about 4 feet
  - Then select 2-3 sprouts (remove the others)
  - Stake sprouts for stability

Cultural practices

Fertilizer strategy

- Small, frequent amounts (1-2 times per month) of NPK
- Reduced rates or frequency during cool/cold periods
- Two to four minor element applications during warm period

Irrigation strategy

- During warm-hot periods every 3-5 days
- During cool-cold periods reduced to 1 time per week

Fall-winter fruiting strategy

- Remove all but 2-3 of the largest (oldest) fruit
- This will enhance their growth, development and sugar content

Pitaya (Dragon fruit)

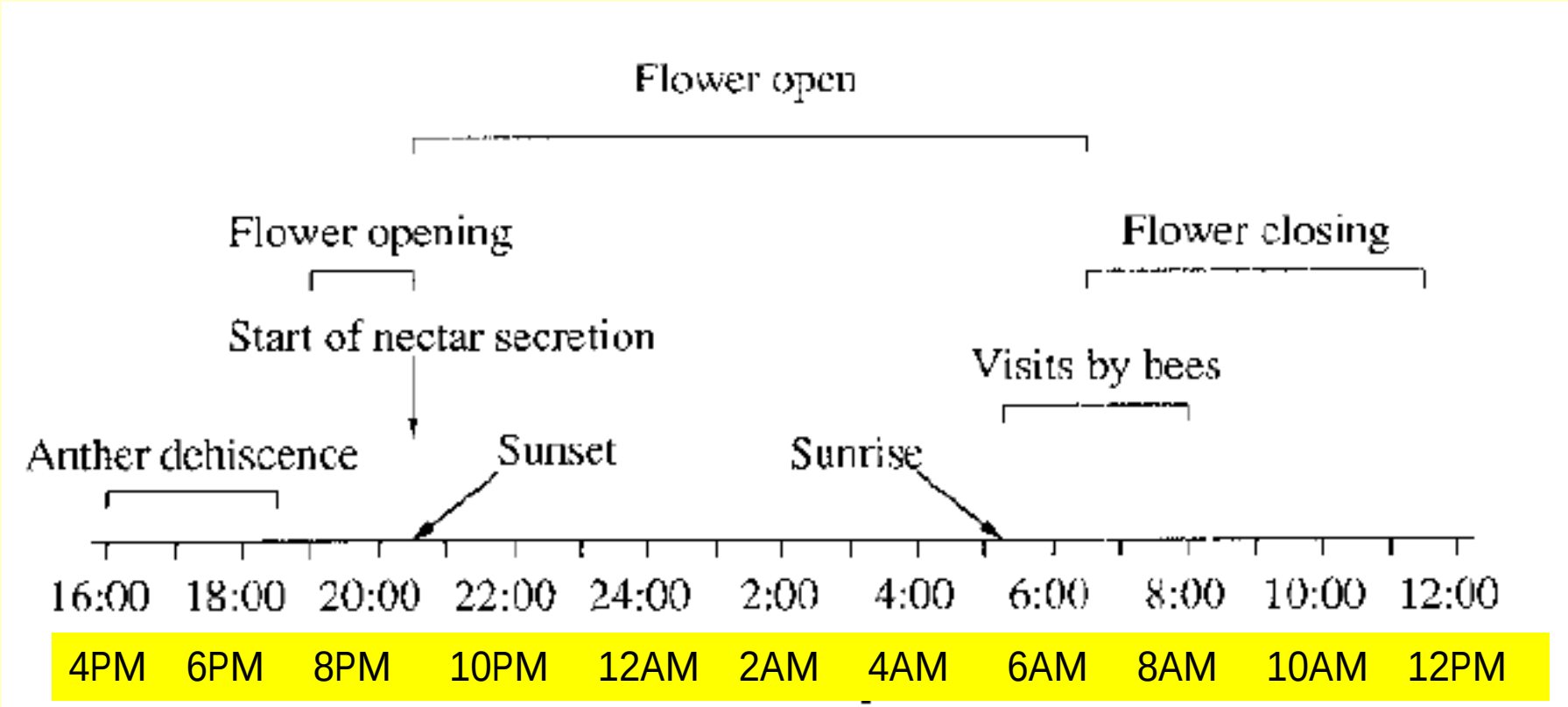
Pitaya (*Hylocereus undatus* and hybrids)

- Flowers laterally along succulent stems
- Flowers bisexual – male and female parts function simultaneously
- From flower bud formation to flowering about 15-20 days
- From flowering to harvest, 30 to 40 days
- Flowers May-October
- Potential for 3-6 waves of flowers per year

Flower inducing conditions

- Increasing day-length
- Dormancy (brief)
- Hand cross pollination results in highest fruit set and fruit weight
- Cultivar and pollination requirements of many cultivars and clones is confused
- Pruning after harvest – branching and flowering
- Natural pollinators – bats and moths
- Bees are not very effective to ok pollinators
- Self pollinating/fertile types and types that require cross pollination to set fruit
- Generally, those with a flower structure where the stigma and anthers are on the same plane may self pollinate

Male and female flower structures separated – self-pollination problem



Time of night and day

Flowering phases and timing

Weiss et al., HortScience 29:1487-1492

Cultural practices

Fertilization

- Benefits from NPK applications (every 4-8 weeks)
- Benefits from compost
- May be fertilized foliarly with dilute nutrients
- Apply minor elements 2-4 times per year

Irrigation

- Irrigate once a week – most important from flowering through harvest
- Adjust rate downward during cool weather

Fruit splitting – uneven irrigation management

Thanks for your attention

QUESTIONS? COMMENTS?





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