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# Quick Guide to Environmental Factors Impacting Subtropical and Tropical Fruit Crops in Florida[1]

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## Introduction

Commercial tropical fruit crop acreage is expanding in Florida outside the traditional extreme south Florida and coastal counties. This largely results from the significantly warmer climate, less frequent freezing events, and less severity and duration of freezing events throughout the state, especially south-central counties. In addition, as the loss of citrus acreage continues, citrus growers and entrepreneurs are seeking alternative crops to remain in business. The successful establishment and maintenance of tropical and subtropical fruit crops in Florida depend on the crop's tolerance to critical abiotic factors, including tolerance to flooded or waterlogged soil conditions, its ability to withstand high soil and irrigation water salinity, and its high and low temperature ranges for growth, flowering, and production. This publication aims to provide commercial growers, Extension faculty, and urban residents with a quick guide to understanding the impacts of environmental factors on subtropical and tropical fruit crops grown in Florida.

## High and Low Temperature Ranges for Growth, Flowering, and Production

Selection of a fruit crop for a specific area should consider the potential high and low extreme temperatures, as well as the general mean temperatures of the area, the known ideal optimum temperatures, and the tolerance for extreme high and low temperatures of the proposed fruit crop.

The optimum growing temperature range is the range of temperatures at which a plant grows best. In many instances, these are the ideal year-round temperatures for the crop (e.g., Annona, dragonfruit, mamey sapote, and papaya). In contrast, some fruit crops (e.g., lychee, longan, and mango) have optimum vegetative growth and fruit development temperatures but optimize their flowering and fruit production only after exposure to environmental conditions that cause them to go dormant (called quiescence). Usually, exposure to cool or cold non-freezing temperatures and/or drought conditions during the fall and winter months induces quiescence.

### Temperatures for Flowering

Fruit trees generally need a period of dormancy to flower and fruit successfully. Dormancy can be defined as a period of no active (visible) stem growth. Dormancy for many tropical and subtropical fruit crops occurs in response to cool temperatures (above freezing but below species or cultivar-specific thresholds). Technically, this dormancy is termed quiescence (i.e., environmentally imposed dormancy). The length of dormancy requirement varies between and within fruit crop species. For example, 'Keitt' and 'Tommy Atkins' mango trees require a longer period (two to four months) of dormancy to flower well compared to 'Edwards' and 'Haden' cultivars (approximately one to two months). Lychee, in particular, needs a long period of dormancy (two to five months) to flower and fruit well and also requires exposure to cool temperatures (upper 40s to lower 60s) just before or during panicle emergence. Because of the generally warmer climate brought on by global climate change, lychee now rarely flowers or fruits well in Miami-Dade County, and trees repeatedly flush vegetatively because shoot growth is not suppressed by cool temperatures. In contrast, summer high temperatures greater than about 92°F may cause flower abortion in passionfruit. Therefore, careful study of the optimum temperatures for growth, flowering, and fruiting, as well as tolerance to high and low temperature extremes, should be investigated when selecting a fruit crop.

### Chilling and Cold Tolerance

Historically, attempts to commercially produce (or at least trial) many tropical and subtropical fruit crops in north, central, and south Florida have shown that successful tropical fruit production was limited to southeastern (Miami-Dade, Broward, Palm Beach [southeastern end of Lake Okeechobee, eastern-to-central Palm Beach County]) and southwestern (Lee County [Pine Island primarily] and Manatee County [Bradenton area]) coastal areas of the state. There are other coastal counties where small plantings of tropical and subtropical fruit crops are grown (e.g., Martin, Indian River, and Brevard Counties). While some tropical and subtropical fruit crops have been harmed by periodic freezing temperatures in these areas, most are severely damaged or killed outside these regions. Indisputably, the general climate has warmed throughout central and south Florida over the past 20 years, and the frequency and/or duration of freeze events have decreased. This has led to new interest in expanding tropical and subtropical fruit production in Florida outside of its historic range. Currently, the acreage of cold-sensitive fruit crops such as guanábana (soursop), caimito, and sugar apple has expanded in Miami-Dade County. Production of these crops has been successful in the area, despite brief cold (e.g., temperatures of 32°F–37°F) and chilling (i.e., temperatures below ~55°F) temperature events, which have caused some crop damage (e.g., defoliation, some dieback). In contrast, the acreage of three slightly less cold-sensitive fruit crops, guava, dragonfruit, and passionfruit, has recently expanded along coastal areas from Sarasota and Brevard Counties south.

### Freezing Temperatures

There are four components to freeze events: 1) the duration (how long an event is at or below 32°F), 2) the frequency (how often the events occur), 3) the depth of the freezing temperatures (the lowest temperature experienced), and 4) when the freezing or chilling temperatures occur (e.g., during bloom or dormancy). For example, chilling temperatures (i.e., above freezing but below ~45°F in 2022 in Homestead) occurred during the mango flowering period, resulting in a drastically reduced fruit set and harvest. Despite the climate warming trend over the past 20 years, freeze events can and do still occur (even in Miami-Dade County). Most disconcerting is the lack of grower planning for potential freeze and/or frost events. Planning includes the establishment of appropriate irrigation infrastructure (e.g., high volume systems) or the establishment of a bedded planting with high-capacity pumps to move water between tree rows (ditch) and to drain the water off quickly. For tropical and subtropical fruit crops, there is limited experience with the use of microsprinkler systems with or without tree trunk covers for young tree freeze protection, and many new plantings only have microsprinkler systems with low pumping capacity that can only irrigate parts of the grove at one time. For more information, see EDIS publication HS1375, "Irrigation System Descriptions for Tropical and Subtropical Fruit Crops in Florida." Prior to purchasing land and/or establishing an irrigation system, producers need to investigate the availability and quality of the water in their water management district. Some areas do not permit the use of high volumes of water, thus limiting the options for cold/freeze protection with water. Producers should know the rules of their district and plan accordingly before establishing a new grove.

## Constant Winds

Some fruit crop species are sensitive to constantly windy conditions, which are sometimes called trade winds. Although the wind speeds may not be great (e.g., 10 to 15 mph or less), they can reduce young carambola, caimito, and Annona tree, passionfruit vine, and papaya plant establishment and growth through their negative effect on leaf water loss, nutrient uptake, and mechanical plant damage. Planting these fruit crops in wind-protected or low-wind-speed areas vastly improves their crop growth and production.

## Tolerance of Flooded or Waterlogged Soils

Higher elevation areas are less prone to flooding than lower elevation areas. The potential frequency and duration of soil flooding or saturation increase in low-lying areas or in areas with a hardpan several inches to several feet down in the soil profile. Flatwoods areas are particularly vulnerable, and the citrus in these areas are planted on beds to elevate the tree roots above moderate flooding depths. Bedding, land contouring, and passive drainage systems should be considered prior to establishing a tropical or subtropical fruit grove in these areas. Also, sufficiently large pumps to move water in and out of drainage ditches should be established prior to planting. Subtropical and tropical fruit crops vary in their tolerance to constantly saturated soil conditions and flooding. In general, flooding is more damaging when combined with high-temperature periods or if the tree has fruit. For example, guava and sapodilla are considered flood-tolerant (i.e., they can survive several days to a few weeks); however, their growth and fruit production may be reduced, and root diseases may result in tree damage or death. Mango, lychee, longan, and carambola are moderately flood-tolerant, but growth and production may be reduced, and root disease may cause tree decline or death. In contrast, avocado, papaya, and passionfruit do not tolerate constantly wet or flooded soil conditions and may be severely damaged or killed after 48–72 hours of overly wet soil conditions. One strategy to reduce avocado tree damage after flooded soil conditions is to prune trees (i.e., remove one-third to half of the canopy) immediately after the flooding event to reduce the canopy demand for water and nutrients. For more information on the flood tolerance of tropical and subtropical fruit crops, see EDIS publication HS957, "Managing Your Tropical Fruit Grove Under Changing Water Table Levels."

## Saline Soils and Water

Very few fruit crops tolerate saline soils and/or water. For example, guava and dragonfruit are considered tolerant to saline soil and water conditions, whereas avocado, mango, and passionfruit are not. For more information on the management of saline soil and/or water, see EDIS publication AE572, "Saltwater Intrusion and Flooding: Risks to South Florida's Agriculture and Potential Management Practices." In some coastal areas (e.g., Pine Island), there is potential for saltwater intrusion into the aquifers and wells, and there are no economic or effective cultural practices to mitigate or prevent crop damage from saline irrigation water. Desalination of saline contaminated soils requires fresh water, and desalination of brackish water for irrigation is expensive. In areas prone to storm surges (from tropical storms or sea level rise), bedding and passive and/or active drainage infrastructure should be established ahead of planting to help reduce the potential for soil contamination by saline water.

## Drought Tolerance

Tropical fruit trees vary in their drought tolerance; however, the growth, production, and fruit quality of even drought-tolerant species may be reduced. For example, mangoes and sapodillas reportedly tolerate several days to weeks of drought, but this may be affected by tree size and the extent of their root system. In contrast, papaya and banana do not tolerate even short-term drought conditions (i.e., they survive a few days of drought, but it may lead to leaf drop and yield reduction), which may result in dramatic delays and reduced flowering. For more information on the drought tolerance of tropical and subtropical fruit crops, see EDIS publication HS957, "Managing Your Tropical Fruit Grove Under Changing Water Table Levels." Optimally, orchards should have an appropriately designed and managed irrigation system to avoid prolonged soil drought conditions, especially from flowering to the harvest period.

The following tables summarize important environmental factors that producers should consider prior to establishing an orchard for commonly planted tropical or subtropical fruits.

## Tables

Table 1. Annona—sugar apple (*Annona squamosa*), guanábana (*A. muricata*), and atemoya (*A. cherimola* x *A. squamosa*).

| Environmental factors | Crop information | | |
|---|---|---|---|
| | **Sugar apple** | **Guanábana** | **Atemoya** |
| Optimum growing temperature range (°F) | 75–86 | 68–86 | 65–86 |
| Freeze damage range (°F) for mature trees | 28–29 | 30–32 | <28 |
| Heat damage range (°F) | >100 | >100 | >100 |
| Sensitivity to constant winds | Intolerant | Intolerant | Intolerant |
| Flood tolerance | Intolerant, rootstock dependent | Moderately tolerant | Intolerant, rootstock dependent |
| Plant and/or rootstock salinity tolerance | Sensitive to intolerant | Not reported | Not reported |
| Drought tolerance | Tolerant | Tolerant | Tolerant |
| Comments:<br>More than a few days of temperatures below ~50°F result in chilling injury.<br>Flood tolerance is moderately rootstock dependent.<br>Atemoya is reported as drought-tolerant, but drought conditions may still result in leaf abscission and reduce growth and yields. Irrigation is common practice. | | | |

Table 2. Avocado (*Persea americana*)—West Indian (WI), Guatemalan (G), and Mexican (M) ecotypes, WI-G hybrids, and G x M hybrids.

| Environmental factors | Crop information | | | | |
|---|---|---|---|---|---|
| | **West Indian ecotypes** | **Guatemalan ecotypes** | **Mexican ecotype** | **West Indian x Guatemalan hybrids** | **Guatemalan x Mexican hybrids** |
| Optimum growing temperature range (°F) | 72–95 | 55–75 | 50–70 | 70–91 | 65–86 |
| Freeze damage range (°F) for mature trees | 25–30 | 21–25 | 18–25 | 24–30 | 20–27 |
| Heat damage range (°F) | >100 | >90 | >90 | >90 | >90 |
| Flood tolerance | Sensitive to intolerant | Sensitive to intolerant | Sensitive to intolerant | Sensitive to intolerant | Sensitive to intolerant |
| Plant and/or rootstock salinity tolerance | Most tolerant | Intermediate tolerance | Least tolerant | Varies | Varies |
| Drought tolerance | Moderately tolerant | Moderately tolerant | Moderately tolerant | Moderately tolerant | Moderately tolerant |

Comments:

West Indian ecotypes are the least cold-hardy type grown in Florida. Guatemalan ecotypes are more cold hardy and have only a few commercial cultivars. Mexican ecotypes are most cold hardy and have only a few cultivars. West Indian x Guatemalan (WI x G) hybrids have variable cold hardiness and are the most common of the cultivars grown in Florida. Guatemalan x Mexican hybrids are generally more cold hardy than WI x G, but most California hybrids have not been extensively tested in Florida.

Sensitivity to constant winds is not reported for any of the ecotypes or hybrids.

Flood tolerance is influenced by rootstock.

Drought tolerance by ecotype is not compared. Irrigation is common practice.

Rootstock affects salinity tolerance (WI>G>M).

Table 3. Banana (*Musa* spp.)—fresh and cooking.

| Environmental factors | Crop information for banana |
|---|---|
| Optimum growing temperature range (°F) | 70–86 |
| Freeze damage range (°F) for mature trees | 28–32 |
| Heat damage range (°F) | >99 |
| Sensitivity to constant winds | Intolerant |
| Flood tolerance | Moderate tolerance to intolerant |
| Plant and/or rootstock salinity tolerance | Low tolerance to intolerant (no rootstocks) |
| Drought tolerance | Intolerant to moderately tolerant |
| Comments:<br>Leaf emergence stops at ~61°F and all growth stops at ~50°F. Chilling injury occurs at or below ~52°F. Temperatures at or below ~61°F can cause fruit distortion, failure of the bunch to emerge from the pseudostem, and increased susceptibility to finger rots.<br>Growth stops at 100°F–104°F.<br>Wind: A small amount of leaf lamina tearing is beneficial for water relations (i.e., improved transpiration and $CO_2$ uptake) and photosynthesis. Too much tearing (shredding, tattering) is not beneficial. Winds greater than ~25 mph can cause plants to topple (uproot).<br>Banana plants may withstand 48 hr of flooding with flowing water but only ~24 hr of stagnant water. | |

Table 4. Carambola—starfruit (*Averrhoa carambola*).

| Environmental factors | Crop information for carambola (starfruit) |
|---|---|
| Optimum growing temperature range (°F) | 70–90 |
| Freeze damage range (°F) for mature trees | 27–32 |
| Heat damage range (°F) | >100 |
| Sensitivity to constant winds | Intolerant |
| Flood tolerance | Moderately tolerant to tolerant |
| Plant and/or rootstock salinity tolerance | Intolerant |
| Drought tolerance | Intolerant |
| Comments:<br>Carambola trees can withstand ~14 days of continuous flooding and recover well once the soil drains.<br>Drought can be used to trigger off-season bloom but may trigger leaf drop. | |

Table 5. Dragonfruit—pitaya (*Selenicereus undatus*, *S. guatemalensis*, hybrids).

| Environmental factors | Crop information for dragonfruit (pitaya) |
|---|---|
| Optimum growing temperature range (°F) | 68–86 |
| Freeze damage range (°F) for mature vines | <26–29 |
| Heat damage range (°F) | >93–104 |
| Sensitivity to constant winds | Moderately intolerant |
| Flood tolerance | Moderately tolerant to tolerant |
| Plant and/or rootstock salinity tolerance | Moderately tolerant |
| Drought tolerance | Moderately tolerant |
| Comments:<br>Chilling injury results from long exposure to 41°F or below. Temperatures above ~92°F begin to cause physiological damage.<br>Plant may tolerate ~1 week of flooding, but flood conditions may increase the potential for stem-root diseases. Constant or strong periodic winds can delay flowering of new vines, reduce flower intensity and fruit yield, and increase wind-scar. | |

Table 6. Guava—guayaba (*Psidium guajava*).

| Environmental factors | Crop information for guava |
|---|---|
| Optimum growing temperature range (°F) | 66–82 |
| Freeze damage range (°F) for mature trees | 25–26 |
| Heat damage range (°F) | >110–113 |
| Sensitivity to constant winds | Moderately tolerant |
| Flood tolerance | Moderately tolerant |
| Plant and/or rootstock salinity tolerance | Moderately tolerant |
| Drought tolerance | Tolerant |
| Comments:<br>Invasive plant status: Guava has been assessed by the UF/IFAS Invasive Plants Working Group as invasive and is not recommended by UF/IFAS for planting in south Florida; guava may be planted in central Florida but should be managed to prevent escape.<br>Tree is tolerant to drought, but drought conditions reduce growth and fruit production.<br>Tree is moderately tolerant to wet soil conditions, but susceptibility to root pathogens increases under constant wet soil conditions.<br>Winds >10 mph distort growth and increase fruit scarring; trees benefit from wind protection. | |

Table 7. Longan (*Dimocarpus longan*).

| Environmental factors | Crop information for longan |
|---|---|
| Optimum growing temperature range (°F) | >60–92 |
| Freeze damage range (°F) for mature trees | 24–27 |
| Heat damage range (°F) | >95 |
| Sensitivity to constant winds | Moderately tolerant |
| Flood tolerance | Moderately tolerant |
| Plant and/or rootstock salinity tolerance | Moderately tolerant |
| Drought tolerance | Moderately tolerant |
| Comments:<br>Low relative humidity (RH) and/or high temperatures may reduce fruit set and the number of female flowers.<br>Fruit should be thinned when pea-sized. Overproduction may lead to tree decline. | |

Table 8. Lychee (litchi) (*Litchi chinensis*).

| Environmental factors | Crop information for lychee |
|---|---|
| Optimum growing temperature range (°F) | 55–92 |
| Freeze damage range (°F) for mature trees | 21–28 |
| Heat damage range (°F) | >95 |
| Sensitivity to constant winds | Moderately tolerant |
| Flood tolerance | Moderately tolerant |
| Plant and/or rootstock salinity tolerance | Intolerant |
| Drought tolerance | Tolerant |
| Comments:<br>Tree requires dormant period and exposure to chilling temperatures (i.e., ≤59°F) to flower well. Temperatures ≥68°F reduce chilling requirement.<br>Low RH and/or high temperatures may reduce fruit set and the number of female flowers.<br>Late season flowers may not set fruit and/or set fruit that develops properly. | |

Table 9. Mamey sapote (*Pouteria sapota*).

| Environmental factors | Crop information for mamey sapote |
|---|---|
| Optimum growing temperature range (°F) | 68–90 |
| Freeze damage range (°F) for mature trees | 28–30 |
| Heat damage range (°F) | No information |
| Sensitivity to constant winds | Moderately tolerant |
| Flood tolerance | Moderately tolerant |
| Plant and/or rootstock salinity tolerance | No information |
| Drought tolerance | Moderately intolerant |
| Comments:<br>Tree may defoliate in response to drought, flooding, and cold/freeze. | |

Table 10. Mango (*Mangifera indica*).

| Environmental factors | Crop information for mango |
|---|---|
| Optimum growing temperature range (°F) | 75–86 |
| Freeze damage range (°F) for mature trees | 25–28 |
| Heat damage range (°F) | >104 |
| Sensitivity to constant winds | Moderately intolerant |
| Flood tolerance | Moderately tolerant to tolerant |
| Plant and/or rootstock salinity tolerance | Intolerant to moderately tolerant |
| Drought tolerance | Tolerant |
| Comments:<br>Tolerance to salinity is affected by rootstock, and typically those rootstocks are not used in Florida. | |

Table 11. Papaya (*Carica papaya*).

| Environmental factors | Crop information for papaya |
|---|---|
| Optimum growing temperature range (°F) | 77–91 |
| Freeze damage range (°F) for mature trees | <30 |
| Heat damage range (°F) | >96 |
| Sensitivity to constant winds | Intolerant, sensitive |
| Flood tolerance | Intolerant |
| Plant and/or rootstock salinity tolerance | Moderately tolerant |
| Drought tolerance | Intolerant |
| Comments:<br>Tree needs at least 73°F for six months for normal flowering and fruit development.<br>Papaya trees stop growing at and below 54ºF. Chilling temperatures at and below 61ºF will reduce growth and production. | |

Table 12. Passionfruit (*Passiflora edulis* forms and hybrids).

| Environmental factors | Crop information for passionfruit |
|---|---|
| Optimum growing temperature range (°F) | 68–86 |
| Freeze range (°F) for mature trees | <28–32 |
| Heat damage range (°F) | >91 |
| Sensitivity to constant winds | Intolerant, sensitive |
| Flood tolerance | Slightly tolerant to intolerant |
| Plant and/or rootstock salinity tolerance | Intolerant |
| Drought tolerance | Moderately tolerant |
| Comments:<br>Tolerance to flooding is affected by passionfruit species, soil, climatic factors, and the presence of disease pathogens in the soil.<br>Vines may tolerate about four days of drought; if more, then drought conditions will stop growth, flowering, and fruit set, and vines may drop flower buds, resulting in reduced yields.<br>Heat damage may reduce or stop vine growth, cause flower bud or flower drop, and result in reduced production. | |

# References by Crop and Environmental Factor

Table 13. Annona citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Higuchi et al. (1998); Nakasone and Paull (1998); Pinto et al. (2005); Rodrigues et al. (2016) |
| Freeze range (°F) | Campbell et al. (1977); Lynch (1940); Nakasone and Paull (1998); Pinto et al. (2005) |
| Heat damage range (°F) | Higuchi et al. (1998); Yamada, Hidaka, et al. (1996) |
| Sensitivity to constant winds | Leal and Paul (2022); Nakasone and Paull (1998); Pinto et al. (2005) |
| Flood tolerance | Fu et al. (2012); Leal and Paul (2022); Nakasone and Paull (1998); Núnez-Elisea et al. (1999); Schaffer et al. (2006) |
| Salinity tolerance | Marler and Zozor (1996); Passos et al. (2005) |
| Drought tolerance | Pinto et al. (2005) |

Table 14. Avocado citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Chao and Paull (2008); Dubrovina and Bautista (2014); Wolstenholme (2013) |
| Freeze damage range (°F) | Arpaia et al. (2012); Campbell et al. (1977); Hatton and Reeder (1963); Krezdorn (1970); Malo et al. (1977); Rouse and Knight (1991); Witney and Arpaia (1991) |
| Heat damage range (°F) | Wolstenholme (2013) |
| Sensitivity to constant winds | Schaffer et al. (2013) |
| Flood tolerance | Schaffer (1998); Schaffer et al. (2006); Schaffer et al. (2013); Sanclemente et al. (2014) |
| Salinity tolerance | Ebert (2000); Schaffer et al. (2013) |
| Drought tolerance | Schaffer et al. (2013) |

Table 15. Banana citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Nakasone and Paull (1998); Stover and Simmonds (1993) |
| Freeze damage range (°F) | Campbell et al. (1977); Nakasone and Paull (1998); Stover and Simmonds (1993) |
| Heat damage range (°F) | Nakasone and Paull (1998); Stover and Simmonds (1993) |
| Sensitivity to constant winds | Nakasone and Paull (1998); Stover and Simmonds (1993) |
| Flood tolerance | Nakasone and Paull (1998); Stover and Simmonds (1993) |
| Salinity tolerance | Al Harthy et al. (2018); Ramteke and Sachin (2016); Wei et al. (2022); Junior et al. (2020); Willadino et al. (2016); Ravi, Mayilvaganan, et al. (2014); Ravi, Vaganan, et al. (2014) |
| Drought tolerance | Santos et al. (2018) |

Table 16. Carambola citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | George et al. (2002); Ngah et al. (1989) |
| Freeze damage range (°F) | Campbell et al. (1985); Campbell et al. (1977); Lynch (1940) |
| Heat damage range (°F) | George et al. (2002); Yamada, Hidaka, et al. (1996) |
| Sensitivity to constant winds | Goenaga (2017); Marler and Zozor (1992) |
| Flood tolerance | Ismail and Noor (1996); Joyner and Schaffer (1989); Schaffer (1998); Schaffer et al. (2006) |
| Salinity tolerance | Marler (1990) |
| Drought tolerance | Al-Yahyai et al. (2005); Ismail et al. (1994); Pingping et al. (2017); Salapetch et al. (1990) |

Table 17. Dragonfruit citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Ben-Asher et al. (2006); Mizrahi (2014); Nobel and de la Barrera (2004) |
| Freeze damage range (°F) | Nerd, Tel-Zur, et al. (2002); Nobel and de la Barrera (2004) |
| Heat damage range (°F) | Nerd, Tel-Zur, et al. (2002); de Oliveira et al. (2020); Le Bellec et al. (2006); Nerd, Sitrit, et al. (2002); Nobel and de la Barrera (2004) |
| Sensitivity to constant winds | Thomson (1998) |
| Flood tolerance | Moderately tolerant ~1-wk. Personal communication with Chugn-Ruey Yen, June 7, 2022. |
| Salinity tolerance | de Sousa et al. (2021) |
| Drought tolerance | Nobel and de la Barrera (2004) |

Table 18. Guava citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Kwee and Chong (1990); Menzel (1985); Paull and Duarte (2012b) |
| Freeze damage range (°F) | Campbell et al. (1977); Paull and Duarte (2012b) |
| Heat damage range (°F) | Menzel (1985); Paull and Duarte (2012b); Yamada, Hidaka, et al. (1996) |
| Sensitivity to constant winds | Menzel (1985); Paull and Duarte (2012b) |
| Flood tolerance | Menzel (1985) |
| Salinity tolerance | Menzel (1985); Paull and Duarte (2012b); Ramteke and Sachin (2016) |
| Drought tolerance | Menzel (1985); Paull and Duarte (2012b) |

Table 19. Longan citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Groff (1921) |
| Freeze damage range (°F) | Campbell et al. (1977); Groff (1921); Groff (1943); Lynch (1940); Paull and Duarte (2010); Young (1963) |
| Heat damage range (°F) | Paull and Duarte (2010); Yamada, Fukamachi, et al. (1996); Yamada, Hidaka, et al. (1996) |
| Sensitivity to constant winds | J. H. Crane, personal communication |
| Flood tolerance | Crane et al. (2016) |
| Salinity tolerance | Mahouachi et al. (2013) |
| Drought tolerance | Mahouachi et al. (2013) |

Table 20. Lychee citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Groff (1921); Groff (1943); Menzel (2001) |
| Freeze damage range (°F) | Campbell et al. (1977); Groff (1921); Groff (1943); Lynch (1940); Lynch (1958); Young (1963); Young and Noonan (1958) |
| Heat damage range (°F) | Paull and Duarte (2010) |
| Sensitivity to constant winds | Groff (1943) |
| Flood tolerance | Menzel (2002) |
| Salinity tolerance | Menzel (2002) |
| Drought tolerance | Carr and Mezel (2014); Stern et al. (1993); Stern et al. (1998) |

Table 21. Mamey sapote citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | J. H. Crane, personal communication |
| Freeze damage range (°F) | Campbell et al. (1977); Ledin (1959); Lynch (1940) |
| Heat damage range (°F) | No information |
| Sensitivity to constant winds | Paull and Duarte (2012a) |
| Flood tolerance | Nickum et al. (2008); Nickum et al. (2010); Nickum et al. (2011) |
| Salinity tolerance | No information |
| Drought tolerance | Paull and Duarte (2012a) |

Table 22. Mango citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Schaffer et al. (2009) |
| Freeze damage at or below range (°F) | Campbell et al. (1977); Schaffer et al. (2009) |
| Heat damage range (°F) | Schaffer et al. (2009); Yamada, Hidaka, et al. (1996) |
| Sensitivity to constant winds | Schaffer et al. (2009) |
| Flood tolerance | Schaffer (1998); Schaffer et al. (2006); Schaffer et al. (2009) |
| Salinity tolerance | Schaffer et al. (2009); Ramteke and Sachin (2016); Ebert (2000) |
| Drought tolerance | Schaffer et al. (2009) |

Table 23. Papaya citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Saran et al. (2016) |
| Freeze damage range (°F) | Campbell et al. (1977); Saran et al. (2016) |
| Heat damage at or above range (°F) | Saran et al. (2016) |
| Sensitivity to constant winds | Marler and Clemente (2006); Saran et al. (2016) |
| Flood tolerance | Rodriguez et al. (2014); Saran et al. (2016); Thani, Schaffer, et al. (2016); Thani, Vargas, et al. (2016) |
| Salinity tolerance | Ebert (2000); Saran et al. (2016) |
| Drought tolerance | Marler and Clemente (2006); Marler and Mickelbart (1998); Saran et al. (2016) |

Table 24. Passionfruit citations.

| Environmental factor | Citations |
|---|---|
| Optimum growing temperature range (°F) | Deshmukh et al. (2017); Paull and Duarte (2012c) |
| Freeze damage range (°F) | Campbell et al. (1977); Deshmukh et al. (2017) |
| Heat damage range (°F) | Campbell et al. (1977); Deshmukh et al. (2017) |
| Sensitivity to constant winds | Deshmukh et al. (2017); USAID (2019) |
| Flood tolerance | Cervantes et al. (2015); Basso et al. (2019); Paull and Duarte (2012c) |
| Salinity tolerance | Ebert (2000) |
| Drought tolerance | Paull and Duarte (2012c) |

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