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AN OVERVIEW OF FLORIDA CITRUS FREEZE SURVIVAL

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Abstract. **Citrus freeze survival in Florida is a complicated venture that challenges the best in entrepreneurial talents. Freeze warning systems are in a state of transition and continue to evolve through private enterprise with help from state and federal systems coordinated through telecommunications. Research on freeze avoidance and ice tolerance mechanisms is largely focused on inherent and altered gene expression during cold acclimation and the use of water in freeze protection. New industry initiatives help to incorporate research observations into practical application and identify specific areas of opportunity. This target-focused effort stimulates technology transfer in addressing freeze disasters that continue to shift prime citrus acreage into non-citrus activities. Exchange of ideas and observations tends to keep options open and help to develop an acute insight to ensure a sustainable citrus industry capable of providing global leadership in the 21st century.**

Introduction

Freezes have always been a risk factor in growing citrus in Florida, and apparently will continue to be regardless of opinions that the world is entering into a global warming period. The impact of freezes are well documented in the Florida State Horticultural Society Proceedings and other industry oriented reports that vividly assess the economic devastation and destruction of people's livelihoods. Attempts to provide relief have been overridden by the onslaught of repeated freezes, totally unexpected in the 1980's, that eventually forced the industry to relocate to warmer southern areas of the State. Florida's loss has been foreign competitors' gain as market advantages changed to meet consumer needs. Increased plantings in southern Florida have dramatically brought production to pre-1980's freeze levels and strategies are changing to address foreign competition in capturing domestic and emerging global markets. At the present time, improved technology in applying water for freeze protection seemingly will help to offset freeze damage, and the degree of success may determine whether Florida can be a sustained leader in citrus production worldwide.

Probability of Freezes and Warning Systems

It is presumed that freezes will always be a significant risk in growing citrus in Florida. The movement of the industry to the southern part of the State does not preclude significant freeze damage attested to in the severity of past freezes (Martsolf, 1990). Pressures from non-citrus interests and global competition for emerging markets seemingly will encourage the industry to revisit frozen-out citrus acreage to recapture world leadership in production and still be capable of addressing needs of a multi-cultural consumer base.

The increase in freeze occurrence during the 1980's (5 major freezes in 10 years) prompted some climatologists to temporarily raise doubts about commercial growing of citrus in freeze-vulnerable areas in Florida (Miller and Downton, 1993). It has been suggested that individuals contemplating growing citrus in freeze-prone areas should be totally aware that freeze frequencies on record do not ensure similar freeze occurrences in future planning schemes; and by acknowledging this uncertainty, growers would be in a better position to offset the investment risk (Downton and Miller, 1993). Downton and Miller also hypothesized that the frequency of Florida freezes may be related to the behavior of the Pacific/North American (PNA) and the North Atlantic Oscillation (NAO) atmospheric circulation patterns. From a more practical view, growers of citrus in freeze-prone areas should be prepared to cope with a severe freeze every year with full understanding of the consequences of doing and not doing cold protection strategies (Martsolf, 1990).

Analyses of weather data to determine freeze probabilities (Bradley, 1975) and minimum temperature cycles (Chen and Gerber, 1985) have been surpassed by infrared digital data from geostationary satellites that provide continuous monitoring of temperatures. The Synchronous Meteorological Satellite (SMS) and the Geostationary Operation Environmental Satellite (GOES) are examples of advances made in freeze forecasting/documentation (Martsolf and Gerber, 1981; Martsolf, 1982). SMS/GOES data help delineate freeze-prone sites over wide areas, and available maps show effects of different soils, water drainage, and bodies of water (Chen et al., 1982). Measuring the economic benefits from improved temperature and frost forecasts is an exhaustive venture, and study proposals that have been developed seemingly were too expensive to fund (personal file, ECON Inc., Princeton, NJ). Regardless of advances made in helping citrus growers lessen their risk in choosing favorable sites, there are no substitutes for a detailed history of freezes in the contemplated site (Rogers and Rohli, 1991). Such information is not a guarantee that the same pattern of freezes will continue to exist, but odds are reduced in taking on an unacceptable risk. However, there are times when statistical trends create false security. It has been expressed that Florida's citrus growers are vividly aware of risks in site selection, and their investments will tend to reflect their evaluation of devastating events that resulted from abrupt changes in micro-and macro-environments (Miller, 1991).

Improvement, Choices, and Genetic Advances in Planting Stock

The most sophisticated freeze forecast/warning system and the best available choice of site in a freeze-susceptible area can be nullified with poor selection of planting stock. What sells and for what price can sway the investor to plant cultivars that may not be the most suited for the site because of horticultural deficiencies or cold sensitivity. Choices are not easy, especially if available trees are limited to a few scion/rootstock combinations in insufficient numbers. The situation is further complicated if growers have little time to prepare for new plantings, and the wanted cultivar has virtually no significant performance record in the field. Such risks have been reasonably tolerable in the past, but recapturing and sustain-

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ing world leadership in citrus production may no longer be possible due to factors other than freezes.

Certification of trees against infectious or debilitating agents, of known parentage and origin, good form and structure, and horticulturally suited for a specific site, helps growers to minimize their risk at the very beginning. This investment into more expensive trees presumably will pay dividends as the trees mature and offset initial costs. Cooperative quality tree programs (QTP) have been proposed by the Florida Citrus Nurserymen's Association (FCNA) and the Florida Citrus Production Managers' Association (FCPMA), in order to provide the best planting trees for the industry (Rucks, 1994). There are also new thoughts on how one may quantify the relative profitability and risk associated with a particular cultivar/region/market combination (Muraro and Ford, 1990). Pre-planting profitability analyses seemingly would help to focus risk accountability associated with a particular cultivar/site/market. The concept of "distance learning" or "distance education" through computer networking seemingly is a powerful tool to bring relevant information almost instantly to growers in order to expedite management decisions (Martsolf, 1994).

Formal citrus breeding programs do much to provide growers with options on which cultivars to plant for different needs. Florida has been fortunate to have one of the most continuous breeding programs in world citriculture that was developed by the USDA/ARS in cooperation with the University of Florida (IFAS/CREC) and the citrus industry. Periodic new citrus releases developed at the USDA/ARS A.H. Whitmore Foundation Farm near Leesburg, Florida, have significantly added to the citrus inventory since 1931 (Hearn, 1992). 'Ambersweet' (*Citrus reticulata* Blanco × [*C. paradisi* Macf. × *C. reticulata*]) × *C. sinensis* (L.) Osb., a 1989 USDA release, is the most recent new "cold hardy" type whose inherent ability to cold acclimate probably does not exceed that of 'Valencia' sweet orange (Yelenosky et al., 1991). Methods to develop new orange cultivars continue to be focused on standard hybridization techniques followed by natural mutations, and induced mutations largely through irradiation with x-rays, thermal neutrons, and gamma rays (Hearn, 1994). The performance of 'Ambersweet' has not been up to expectations in some commercial plantings and is an example where the haste to plant may need to be more conservative in order to avoid poor early production and fruit quality and possibly, extra costs to replant. However, the risk associated with haste to plant can be justified on the expectation of commanding premium prices for the first selling of new fruit in major markets.

'Sunburst' [*C. reticulata* × (*C. paradisi* × *C. reticulata*)], another semi-cold hardy type, has performed relatively well since its release in 1979 (Hearn, 1981). 'Fallglo', also a mandarin type hybrid, is less cold hardy with highly colored juice and some resistance to sour orange scab (Hearn, 1987). The release of 'Fallglo' in 1987 was accompanied by releases of 'Sunstar', 'Midsweet', and 'Gardner' oranges which are apparently more cold hardy than 'Pineapple' orange (Hearn, 1988). 'Page' orange, a hybrid of Minneola tangelo × Clementine tangerine, a cold hardy type that was released in 1963 continues to be limited in planting because of small fruit size (Reece et al., 1963). If size of fruit could be increased to commercial standards, 'Page' orange would be a likely candidate to recapture frozen citrus acreage lost in the freezes of the 1980's.

There are other new selections that are being considered for release in 1-3 years. One of the candidates is a cold hardy tangerine that apparently has the hardiness of 'Satsuma' mandarin and is reported to be the most cold hardy scion hybrid ever considered for release by the USDA/ARS breeding program (Hardy, 1996). Yields of medium-size fruit have been good to excellent with deep orange juice color and brilliant orange peel surface. Another possible release is a mid-season orange that has done well in cold acclimation trials and is considered by some juicers to have an exceptionally high juice quality. Potential releases also include a Navel orange, a seedless white Duncan type fruit, a seedless 'Fallglo' type tangerine, a dwarf tangerine, and a pink-flesh Pummelo hybrid for special markets.

Rootstock releases have been considerably less than scion types. One of the more significant releases was Swingle citrumelo (*C. paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.) in 1974 (Hutchison, 1974). The rootstock has been widely accepted in the industry, and today is one of the more favored rootstocks for citrus in Florida. It has been a viable alternative to sour orange as a cold hardy stock that also expresses resistance to tristeza. Swingle performed well as a rootstock for 'Valencia' orange trees during the 1981 freeze when temperatures as low as -13C (8F) were found in low lying areas on USDA/ARS A.H. Whitmore Foundation Farm (Yelenosky et al., 1981). Other stocks noted were Citangor and an Eremocitrus experimental hybrid. Rootstocks continue to be evaluated in the field for tree damage during freezes (Rouse et al., 1990), and frequent parentages are citrumelo and trifoliate orange (Wutscher and Hill, 1995). Field evaluations are space and time consuming and cooperative research with citrus growers and managers is sorely needed to do what is required during years of observations (Adams, 1992). Testing some new experimental scion/rootstock combinations during controlled freeze trials suggested that Lee × Nova on Sun Chu Sha mandarin rootstock may be a cold hardy combination that merits consideration for additional study (Yelenosky et al., 1995). Sun Chu Sha is a 1988 USDA rootstock release that is apparently suited for magnesium deficient soils and shows tolerance to tristeza, blight, and foot rot. Another experimental rootstock that performed well under freeze tests was Sunki mandarin × Beneke trifoliate orange which seemingly has drought and salt tolerance and compares well with Swingle citrumelo.

Advances in biotechnology are providing new ways to develop rootstocks, and protoplast culture has led to new somatic hybrids that have been propagated and entered into commercial rootstock trials in Florida (Grosser et al., 1994). In other approaches, a bacterium is used as a carrier to transmit new genes into citrus material (Moore et al., 1992), and successful transfer of genetic traits is expressed through biological indicators (Niedz et al., 1995). It is expected that continued refinement and creative innovations along these lines of research will reinforce standard breeding techniques in customizing citrus to meet challenges in production and marketing (Gmitter Jr., 1994). One of the first steps is well underway in the mapping of molecular sites where cold acclimation is occurring in citrus (Cai et al., 1994). How soon this new science will lead to significant increases in cold hardiness in citrus is yet unclear. Many obstacles have to be overcome, costs will be high, and progress probably will be slow (Guy et al., 1995).

A USDA release of an intergeneric citrus hybrid, US 119, in 1989 offers some hope that the cold hardiness of trifoliate orange can be retained and still achieve edible fruit. US 119 originated from a 1973 cross of [*C. paradisi* cv. Duncan × *Poncirus trifoliata*] × *C. sinensis* cv. Succory (Barrett, 1990), and is a new stage in developing cold hardy trifoliate orange hybrids that have edible fruit. Whether the fruit of US 119 can be progressively improved to commercial standards with further hybridizations without losing cold hardiness is a challenge that may require new science to accelerate progress. Some assistance may be gained from a more recent USDA release, US 145, a seedling pummelo (*C. grandis* Osbeck) which seemingly has superior combining ability for achieving edible fruit in inter-generic crosses with trifoliate orange

(Barrett, 1994). Citrus has the ability to supercool which provides some freeze protection as freeze avoidance; however, the trait is too unpredictable and limited to have practical value (Yelenosky, 1991a; 1991b). Cold hardening citrus fruit, which apparently has no potential to cold harden, is virtually a non-issue except in developing early maturing hybrids that escape freezes because of pre-freeze harvests.

Freeze Protection

Most of the standard freeze protocol is in place and available to the industry as information on soil banks and tree wraps to protect the bud union, wind machines to take advantage of inversions and bring upper warmer air to tree level during radiation freezes, locating plantings south of large bodies of water, avoiding pockets of cold air that drain into low lying areas, wind breaks to disrupt the flow of cold air, using the latent heat of freezing water in various sprinkler technology, closer tree spacing, and much more contained in the Cold Protection Guide, University of Florida, IFAS, Gainesville.

The abandonment of petroleum-type heaters in the late 1970's (Yelenosky and Hearn, 1990), largely because of unacceptable cost increases and decreased availability of fuel in conjunction with enactment of stringent air quality standards, focused on the use of water as an alternative approach through improvements in sprinkler irrigation systems. Improvements continue to be made in this approach, and elevated microsprinklers are being evaluated in commercial plantings as a viable cold protection method (Parsons et al., 1991). The technology is not yet adequate to keep producing trees free from damage, but protection is adequate to ensure survival and quick recovery of trees within two to three years. There are concerns about the influence of wind, low relative humidity, and tree variability on maximizing protection during different types of freezes (Martsolf, 1993). In addition, rapid urban growth in Florida may initiate possible legislative regulation to limit the use of water for certain agricultural pursuits (Bouis, 1990). However, water continues to be a favored citrus cold protection method, especially for resets and young plantings.

Cold Acclimation. All citrus basically are equally susceptible to freeze damage when they are actively growing. The distinction between cold tender and cold hardy citrus is possible because of inherent differences in their degree of response to temperatures usually between 20C (70F) and 0C (32F). It is unclear how this response to colder temperatures (cold acclimation) develops in different cultivars, and only through advances in technology are molecular sites of responsiveness being identified (Cai et al., 1994). Apparently, these sites will be connected to carbohydrate accumulation, decreases in water content, binding of water molecules, membrane permeability, lipid composition, amino acids and proteins, and anatomical differences which are some of the factors associated with cold acclimation and freeze survival in citrus. Response mechanisms through clearer understanding of gene expressions and interactions apparently will be uncovered sufficiently to explain the differences in freeze survival of different citrus cultivars (Guy et al., 1995). The search for fundamentals in order to understand how to "engineer" a superior commercial citrus cultivar with the least amount of dependency on cold acclimation temperatures to survive Florida freezes will require exceptional support, dedication, and persistence.

'Valencia' orange apparently has the inherent ability to survive -6.7C (20F) for 4 hours immediately after cold acclimation of 5 to 6 continuous weeks of 10C (50F) in controlled conditions (Yelenosky, 1978). In the field, it was estimated that for excellent cold hardening to occur, accumulated hours of 10C (50F) or below would have to average 60 hours per week for 11 continuous weeks immediately prior to a severe freeze (Yelenosky et al., 1984). Such favorable cold acclimation conditions are highly unlikely to occur during Florida winters and increases concern about the risk of annual freezes. The degree of cold protection that was acquired in potted trees during five weeks of acclimation in controlled conditions could be lost within one week after acclimated trees were returned to non-acclimating greenhouse conditions (Yelenosky, unpublished data). This rate of losing cold hardiness 5 times faster than it was acquired makes trees again more vulnerable to freezes after one week of warm weather. Multiple freezes during one year are of additional concern based on observations that slightly freeze damaged citrus trees are likely to be severely damaged under similar freeze conditions. This increase in damage may be partly due to earlier ice formation in the tissues which increases ice duration which increases potential for greater damage. Freeze damaged citrus do not cold acclimate nor supercool as well as non-damaged trees (Yelenosky, unpublished data). Seemingly, the greatest freeze tolerance in citrus is before the first freeze. Once trees are freeze damaged, their ability to cold acclimate decreases regardless of favorable cold acclimating temperatures between freezes. It is not known how long it may take for once-freeze-damaged trees to regain their pre-injury potential to cold acclimate. In back-to-back freezes on succeeding nights, it may be more appropriate to use limited one night heat protection resources during the second night rather than the first night of a 2-day freeze provided the first night is warmer than -5C (23F), and the second night is predicted to be as cold or colder. The general thought that more damage occurs during the second night of a two-day freeze because colder radiation conditions may also involve greater damage due to the damage that occurred the first night. Parts of trees that were not damaged the first night will be damaged the second night although freezing profiles are similar. Reasons for this apparently are in how ice stresses develop throughout a citrus tree once the first ice crystal is formed. There is considerable need to clarify acclimation/deacclimation levels for different citrus cultivars in order to improve upon freeze management decisions.

There is little that one can do to improve upon the cold acclimation process. Gene insertion/expression is apparently years away, standard hybridization is also a long and unpredictable path, there are no "magical" fertilization techniques or formulations, cryoprotective sprays are, at best, highly experimental, and weather control is a nonentity. The concept of "healthy" cold-hardy trees with full, clean canopies growing in weed-free soils in warmest sites available seemingly is a good starting point to benefit from whatever cold acclimation may develop during the winter season. Improvements in horticultural spray oil apparently will make it less restrictive as a pre-winter spray to help maintain healthy trees (Lee and Knapp, 1992). Stressed trees are poor risks to appreciably cold acclimate, and resets with excessive bark splitting probably should be replaced to minimize future costs in rehabilitating damaged groves. Severe "buckhorning" is also questionable in lieu of options open in today's competitive market, availability of new cultivars, and intensive irrigation and nutrition programs to optimize tree growth.

Freeze Damage

Freeze damage is largely a function of ice that presumably causes dehydration and membrane damage which disrupt the function of cells and tissues to sustain life. Without ice, there is no significant damage within the limits of Florida's freezes, except possibly for chilling injury of grapefruit. The ability of ice to cause increasing damage as temperatures fall and durations increase provides the basis for managing freeze strategies according to freeze profiles from on site and weather station reporting data. Without knowledge of how freezes are developing, there are no guidelines to protect efficiently with available resources. Even if no protection is used, information on freeze severity helps to formulate contingency plans to deal with expectations in a timely fashion to ensure minimal impact under the circumstances. Cooperative efforts between state and private enterprise apparently are in position to fill any voids created by federal agencies because of shifting priorities (Fisher, 1993; Klein, 1990).

Expectations of first freeze damage possibly could be lowered by 1C (2F), from -2C (28F) to -3C (26F), without much risk except for flowers and succulent new growth. In these instances, using 28F would probably be better, especially if there is visible frost which may induce damage at 1C (30F). At these relatively mild freeze temperatures, duration is the primary concern in doing damage because of increasing risk of ice forming inside the tissues which is lethal to flowers and succulent new growth within one minute. How long new growth and flowers can remain unfrozen at freezing temperatures (supercooling) is unclear, but under controlled conditions, 'Valencia' flowers have the potential to reach -5C (23F) without freezing (Yelenosky, 1988). Open flowers are more vulnerable to early freezing than closed flowers, but the time difference of 15 minutes or less is of no practical significance (Yelenosky, unpublished data). Once ice forms in flowers, open or closed, death apparently results within one minute. Succulent new growth is also quickly killed, usually within 1 to 3 minutes after ice is detected, and one-day-old leaves are more likely to remain unfrozen than one-week old leaves. The reason for this is suspected to be an immature vascular system which, when fully developed, is known to express early freezing. Non-acclimated leaves and stems, 3-months and older, tolerate ice as long as 15 minutes without appreciable injury at mild freeze temperatures. With acclimation, ice tolerance can be as high as 4 hours at -6.7C (20F) without apparent damage (Yelenosky, 1978). The ability of young citrus trees in pots under controlled freezes to remain unfrozen during otherwise lethal temperatures is not evident in the fruit. Fruit has the ability to supercool, but it is less important than the size and juice content of the fruit which help to lose heat slowly and delay the onset of lethal temperatures (Yelenosky, unpublished data. Once ice forms, the latent heat of freezing of the juice keeps temperatures for hours above ambient conditions. This helps to keep the fruit vesicles from turning into "slush" and increases the time frame to salvage the frozen fruit which is now increasingly vulnerable to dehydration (Carter and Knobel, 1977; Syvertsen, 1982).

Differences in mass that reflect size and age, and differences in water content that reflect degree of succulence, are also partial explanations why citrus trees tend to incur freeze damage from the outside to the inside and from the top to the rootstock. Differences in mass are especially evident in observing greater freeze kill to resets and new plantings than to the older, larger, and more heavily canopied trees. None of these variables would be relevant if there were answers to sustaining supercooling or developing cold acclimation without depending on naturally occurring cool temperatures that do not exceed 15C (60F) for at least one month immediately before freezes.

Eliminating external agents that cause early freezing, such as ice nucleating bacteria (Yelenosky, 1983), does not seem to be warranted from observations of field trials and controlled environment tests. Extra costs to conduct sanitary practices cannot be justified as yet, and there is ample suspicion that eliminating ice nucleating agents would not be relevant during severe freezes that reach -5C (23F) because of internal sites of freezing in the tree which are totally divorced from external agents. These sites do not appear to be fixed because initial nucleation can vary from point to point during controlled freezes (Yelenosky, 1991a). The "trigger" that causes the first ice crystal to form inside different parts of the citrus tree has yet to be determined. Eliminating or circumventing the "trigger" would establish supercooling as a significant freeze avoidance factor in reducing devastating freeze losses.

It is not known whether ice starts to form at one point and spreads throughout the tree in a "domino" fashion or whether there are many starting points and multiple paths of ice spread. In tests with young potted trees during controlled freezes, the "domino" theory prevails in that freezing is first detected at some random point in the tree and progressively spreads throughout the tree at rates that can exceed 10 inches per minute (Yelenosky, 1991a). It matters little whether ice starts at a single or multiple sites since spread is too rapid to do anything, there do not seem to be any internal stops, and the end result is apparently the same. The extent of freeze kill does not reflect the limits of ice spread which is essentially throughout the tree, even in the rootstock which is often the last part of the tree that survives during severe freezes. The extent of freeze kill seemingly is a progressive drying out of the tree, much like drought stress, caused by the dehydrating action of ice. The ability of ice to impair membrane function essential for physiological functions supporting life is an added effect that makes freeze injury largely irreversible once critical stress limits are reached. Suspicions on how cells in cold acclimated citrus tolerate ice for as long as 4 hours at -6.7C (20F) range from increases in solutes, which tends to slow dehydration, to increases in membrane stability that is crucial for cell function. Temperatures that continue to decrease at freeze levels lead to greater ice volume that becomes progressively more damaging the longer it persists in citrus cells. Anything that shortens the duration of ice or prevents the freezing of all available water in citrus cells increases their chance for survival. The presence of ice in citrus at temperatures at -2C (28F) presents little risk for damage other than some bleaching of leaves because of chlorophyll destruction or some bark splitting during 6 hours or longer durations. New growth, flowers, and fruit are exceptions, but even these can be protected with sprinkler irrigation that takes advantage of heat released during the continuous application and freezing of the water. In controlled freeze tests with young potted trees, the faster the temperatures are decreased and the faster frozen trees are thawed, the less damage to the trees (Yelenosky, unpublished data). Trees frozen at -6.7C (20F) that are immediately placed in full sunlight during a summer day survive while the trees that are slowly thawed from -6.7C to 10C (50F) at a rate of 1C (2F) per hour are killed. There apparently is little reason to suspect that bright full sunlight on frozen citrus after a freeze night increases the freeze injury other than expressing the injury sooner than if conditions were overcast. Applying water through irrigation systems during thawing (shortly after sun rise) does not help reverse the damage that has already occurred, but it does help shorten the duration of ice, which probably is not significant at this stage of the freeze where temperatures are above freezing and thawing is rapid without water. Total damage will not be evident for weeks, but some hedging of costs can be achieved by delaying fertilizing, irrigating, and heavy pruning (Holland, 1990; Davies and Maurer, 1990). Some weed control will help if there is reasonable expectation of rehabilitating the trees to prefreeze levels.

Assessing Freeze Damage

Federal crop insurance programs are becoming more available and probably should be considered in risky freeze prone areas (Aylsworth, 1996). Assessing freeze damage is difficult and often involves a number of variables that require patience and persistence to fully evaluate. Various methods have been proposed and most are based essentially on some sort of measure for fruit and canopy loss (Stricklen, 1985). Progress in video technology and automated data analyses probably will provide quicker and more efficient assessments. Assessments probably should be delayed until the final damage is evident. This may take as long as 6 months after the freeze.

Summary Perspective of the Florida Citrus Industry

The Florida citrus industry apparently is in a state of transition largely brought about by the devastating freezes in the 1980's. Regardless of devastating losses experienced, the industry is well positioned to recapture the world leadership in citrus production and open up new markets with aggressive initiatives in political involvement (Bouis, 1990) and the anticipation and accommodation change (Wells, 1994) through unified approaches (Stuart, 1993). Grouping the industry into six separate yet interdependent parts (growers, fruit dealers/intermediate handlers, non-brand citrus processors, juice marketers/brands, fresh fruit packers, and gift fruit shippers) apparently has much potential to stimulate production, distribution and marketing for evolving the $4+ billion industry into the 21st century (Morris and Morris, 1996). Technological advances in automated systems and telecommunications will help balance production with domestic and emerging global markets. Research efforts, which have shifted in response to grower concerns (Ferguson et al., 1995), are benefitting greatly because of a new marketing order in 1991 that allowed a tax on production for targeting research to special needs (Jackson and Alexander, 1995). Industry support for targeted research will contribute much to sustaining and advancing citriculture in Florida, and advances in biotechnology have potential to develop new insight into more efficient growing of high quality of fruit for diverse markets. Recapturing acreage lost to freezes apparently will be partially successful with new and improved planting stock. However, increased urbanization and alternative investment opportunities available to citrus owners will continue to erode prime citrus land from Florida's agricultural land bank. For the industry to significantly revisit former producing areas in north central Florida will require acceptance of the risks evident in freeze management strategies (Miller and Downton, 1993). The growth and development of the Florida citrus industry will be challenged on many fronts during the 21st century, and the reality of freezes will continue to be part of the price for growing citrus in Florida (Garner, 1994).

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