placement of the sprinkler head and the amount of water delivered from that sprinkler. Improper placement could lead to severe trunk damage and loss of the all important scaffold limbs and diminish the usefulness of this system. Therefore, extreme care should be taken in the installation and placement of the sprinkler head as to afford the highest degeee of effectiveness. Equally important is the volume of water supplied by the sprinkler head. It is recommended that 1.9 to 5.7 liters·min^{-1} (.5 - 1.5 gal/min) be supplied to the scaffold branch area of the citrus tree during the advent of a severe freeze. The information accumulated during and after the 1989 freeze supports the conclusion that scaffold branch irrigation is a viable system for citrus freeze protection.

Literature Cited

1. Bourgeois, W. J. and A. J. Adams. 1987. Low volume scaffold branch irrigation for citrus freeze protection. HortScience 22:48-50.
2. Bourgeois, W. J., A. J. Adams, and D. H. Oberwortmann. 1987. Temperature modification in citrus trees through the use of low-volume irrigation. HortScience 22:398-400.
3. Braud, H. J., P. Davidson, and P. L. Hawthorne. 1981. Reduction of freeze loss in citrus with water spray. Transactions of the ASAE. Vol. 24:396-400.
4. Buchanan, D.W., F. S. Davies, and D. S. Harrison. 1982. High and low volume undertree irrigation for citrus cold lprotection. Proc. Fla. State Hort. Soc. 95:23-26.
5. Davies, F. S. 1980. High volume undertree sprinkling for citrus cold protection. Proc. Fla. State Hort. Soc. 93:1-2.
6. Davies, F. S. 1981. High volume undertree sprinkling for cold protection. The Citrus Industry 62(7):12-17.
7. Davies, F. S., L. K. Jackson, and L. W. Rippetoe. 1984. Low volume irrigation and tree wraps for cold protction of young Hamlin orange trees. Proc. Fla. State Hort. Soc. 97:25-27.
8. Harrison, D. S. and A. G. Smajstrla. 1982. Irrigation for cold protection of citrus groves and nurseries in Florida. Proc. Fla. State Hort. Soc. 95:26-28.
9. Oswalt, T. W. and L. R. Parsons. 1981. Observations on microsprinkler use for cold protection during 1981 freeze. Proc. Fla. State Hort. Soc. 94:52-54.
10. Parsons, L. R. 1983. Cold protction of young trees with micr sprinkler irrigation. The Citrus Industry. 64(11):4-11.
11. Parsons, L. R. 1984. Use of microsprinklers for cold protection in an advective freeze. The Citrus Industry. 65(12):8-11.
12. Parsons, L. R., B. S. Combs, and D. P. H. Tucker. 1985. Citrus freeze protection with microsprinkler irrigation during an advective freeze. HortScience 20:1078-1080.
13. Parsons, L. R. T. A. Wheaton, and D. P. H. Tucker. 1986. Florida freezes and the role of water in citrus cold protection. HortScience 21:2.
14. Parsons L. R., T. A. Wheaton, D. P. H. Tucker and J. D. Whitney. 1982. Low volume microsprinkler irrigation for citrus cold protection. Proc. Fla. State Hort. Soc. 95:20-23.
15. Parsons, L. R., T. A. Wheaton, and J. D. Whitney. 1981. Low volume microsprinkler undertree irrigation for frost protection of young citrus trees. Proc. Fla. State Hort. Soc. 94:55-59.
16. Parsons, L. R., T. A. Wheaton, and J. D. Whitney. 1982. Undertree irrigation for cold protection with low-volume microsprinklers. HortScience 17:799-801.
17. Wilcox, D. and F. S. Davies. 1981. Modification of air temperature and citrus leaf temperatures with high volume undertree sprinklers. Proc. Fla. State Hort. Soc. 94:59-63.

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FREEZE DAMAGE SUSTAINED BY 27 CITRUS CULTIVARS ON 21 ROOTSTOCKS IN THE BUDWOOD FOUNDATION GROVE, IMMOKALEE

ROBERT E. ROUSE AND EDGAR D. HOLCOMB, JR.
University of Florida, IFAS
Southwest Florida Research and Education Center
P. O. Drawer 5127
Immokalee, FL 33934

DAVID P. H. TUCKER
University of Florida, IFAS
Citrus Research and Education Center
700 Experiment Station Road
Lake Alfred, FL 33850

CHARLES O. YOUTSEY
Citrus Budwood Registration Bureau
3027 Lake Alfred Road
Winter Haven, FL 33881

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Abstract. **Trees 6 and 8 months after field planting experienced temperatures of 24° on 24 & 25 Dec. 1989. Ratings of freeze damage showed differences among scion cultivars and scion/rootstock combinations. 'Star Ruby' grapefruit (*Citrus paradisi* Macf.) and 'Fallglo' citrus hybrid, a cross of Bower mandarin citrus hybrid x 'Temple' tangor, (*C. temple* Hort. ex Y. Tanaka) were the most severely damaged scion cultivars. 'Rohde Red' Valencia orange selection 472-11-43 [*C. sinensis* (L.) Osbeck] was the least damaged scion cultivar. Scions budded to Cleopatra mandarin (*C. reshni* Hort. ex Tan.) and F-80-18 citrumelo [*C. paradisi* x *Poncirus trifoliata* (L.) Raf.] rootstocks were damaged more than scions on other rootstocks. Scions budded to Smooth Flat Seville (*C. aurantium* ?) and *P. trifoliata* x Ridge pineapple sweet orange selection 1573-26 (*C. sinensis* (L.) Osbeck] showed the least damage.**

Visually assessing injury to plants following naturally occurring cold temperatures has long been the basis for determining their relative cold tolerance. Although a general ranking of cold tolerance has been established among most citrus cultivars, the specific ranking can vary considerably when evaluating results following natural freezes primarily because citrus cold hardiness is dependent upon climatic conditions prior to the period of freezing temperatures, and other factors (5). Cold hardiness of citrus is closely associated with dormancy. Trees that are dormant and have been exposed to low but not freezing temperatures for some time often exhibit the most cold hardiness (5). Observations over many years and freeze events indicate that in Florida, mandarins, 'Orlando' tangelo and 'Hamlin' orange are the most cold-tolerant scion cultivars. In descending order these are followed by 'Valencia'

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orange and grapefruit. These are then followed by 'Pineapple' orange, 'Temple' and 'Dancy' tangerine (3, 7, 8, 9, 10). in cold tolerance (2). The least cold tolerant are lime and lemon cultivars (4, 15). However, there have been many unexplained exceptions reported because the genetically controlled ability of a citrus plant to survive freezing and the effect of environment on the acquisition of cold hardiness is not well understood.

A rootstock influence on scion cold hardiness has also been observed (4, 7, 9, 10). Ranking of the most used rootstocks in Florida during the 1960's and 1970's in order of least to most cold hardy would be rough lemon, grapefruit, sweet orange, sour orange, Cleopatra mandarin and the trifoliate selections (8, 16). Among newer rootstocks, trees on Volkamer lemon and *C. macrophylla* would be similar in cold tolerance to those on rough lemon, Carrizo citrange is intermediate with sweet orange while Swingle citrumelo seems similar to sour orange in having the best tolerance to cold (1). However, the ability of the rootstock to impart cold hardiness to the scion is subject to the environmental conditions during hardening period.

Reports attempting to evaluate damage suffered by young 2- to 4-year-old trees on several rootstocks have shown 'Valencia' and 'Hamlin' selections to have less severe foliage and wood kill than grapefruit (12, 13). Trees of 'Star Ruby' grapefruit have been found to lack cold hardiness (13). Trees on some experimental rootstocks, such as hybrids of *P. trifoliata*, have been found to exhibit exceptional freeze tolerance (13).

The Dec. 1989 freeze provided the opportunity to evaluate cold damage sustained by less than one-year-old trees. Twenty-seven commercial cultivars of citrus on most of the commercial rootstocks and several experimental rootstocks were in a single planting site at the time of the freeze. The objective of this study was to visually rate the cold damage sustained by individual cultivars in this planting following the Dec. 1989 freeze.

Materials and Methods

Damage to trees resulting from temperatures of 24°F on 24 and 25 Dec., 1989, was evaluated in March 1990. Actual minimum temperatures recorded each morning were 24°. Two hours were recorded at or below 26 the morning of 24 Dec. and 9 hr on 25 Dec.

Field-grown nursery trees had been planted in April, 1989 and June, 1989 in a citrus budwood foundation grove at the Southwest Florida Research and Education Center at Immokalee. This 20 acre citrus budwood foundation grove is maintained by the combined effort of the Florida Department of Agriculture, Division of Plant Industry (DPI) and the University of Florida, Institute of Food and Agricultural Sciences (IFAS). There are 27 scion cultivars in 3 replications on 21 different rootstocks (Table 1). Trees were 15 x 22 ft on 2-row beds with each row of 66 trees being a single scion cultivar.

Each tree was individually examined to determine the location and severity of cold damage. Ratings of cold damage were: 1 = no damage other than to immature and succulent growth, 2 = foliage loss and dieback on small terminal wood, 3 = bark splits on small and medium interior wood, 4 = split wood on main scaffold, 5 = dead cambial tissue and split wood on the trunk.

Table 1. Scion and rootstock cultivars in the Immokalee Citrus Foundation Grove.

Scions	Rootstocks
1. Fallglo mandarin hybrid	Benton Citrange
2. Grapefruit, Flame	Bittersweet Sour Orange
3. Grapefruit, Marsh	C-35 Citrange
4. Grapefruit, Ray Ruby	Calamandarin
5. Grapefruit, Ruby Red	Cleopatra Mandarin
6. Grapefruit, Star Ruby	Duncan Grapefruit
7. Hamlin 1-4-1	F-80-3 Citrumelo
8. Hamlin 8-1-4	F-80-8 Citrumelo
9. Midsweet Orange	F-80-18 Citrumelo
10. Navel, Cara Cara	*Poncirus trifoliata*
11. Navel 4-2-1	Ridge Pineapple x *P. Trif.* 1573-26
12. Navel 56-12	Rangpur x Troyer
13. Navel 63-18-2	Ridge Pineapple
14. Parson Brown	Ridge Pineapple x Milam 1578-201
15. Pineapple 1-27-11	Sanguine Gross Ronde
16. Robinson Tangerine	Smooth Flat Seville
17. Roble Orange	Sour Orange
18. Sunburst tangerine	Sun Chu Sha Mandarin
19. Tangelo, Minneola	Swingle Citrumelo
20. Tangelo, Nova	Valencia Seedling
21. Tangelo, Orlando	Vangasay Lemon
22. Valencia 1-14-19	
23. Valencia 10-12-7	
24. Valencia 51-3-3	
25. Valencia 55-28	
26. Valencia, Rohde Red 472-3-26	
27. Valencia, Rohde Red	472-11-43

Grove cultural practices from the time of planting have followed standard IFAS recommendations. Care included application of 1.0 pound per tree of 8N-3.5P-6.7K fertilizer with micro-elements applied as a dry formulation five times per year, chemical weed control, and irrigation by a microsprayer system. Rigid thick-walled insulative polystyrene foam trunk wraps with liquid flasks (Reese Citrus Insulators, Inc., Lakeland, Florida) were installed during the winter months. The microsprayer irrigation system was operated during both nights with freezing temperatures, but emitters used caps that directed the water toward the soil and water was not directed into the tree.

Statistical analysis was performed on the data using the General Linear Models Procedure (GLM) with LSD calculated to separate means. Ratings reported for scions and rootstocks are means summed across either all scions or all rootstocks.

Results and Discussion

There were differences in cold damage among scion cultivars and scion/rootstock combinations resulting from freezing temperatures in December 1989 (Table 2). 'Rohde Red' Valencia (DPI selection 472-11-43), and 'Flame' grapefruit were among the least injured scion cultivars. Between the two selections of 'Rohde Red', selection 472-11-43 had less damage than selection 472-3-26.

'Star Ruby' grapefruit trees received the most cold damae and appeared to be least tolerant to freezing temperatures. Yelenosky, et. al. (3) reported 'Star Ruby' to lack cold hardiness following the 1981 Florida freeze. Personal observations in Texas by the senior author following the 1983 freeze also support the susceptibility of 'Star Ruby' to freezing temperatures. In addition to 'Star Ruby', 'Fallglo', Navel 63-18-2, 'Sunburst', Valencia 55-28, 'Cara

Cara' Navel, and Navel 56-12 were also among the worst damaged trees.

Rootstock behavior appeared less clearly defined in respect to their influence scion cold damage (Table 2). Although scions budded to the hybrid of Ridge Pineapple x *P. trifoliata* (1573-26) had the lowest damage rating, there was little difference between trees on this rootstock and those on the other 8 rootstocks with the lowest injury ratings. Similarly, scions budded to the 11 rootstocks with the highest injury ratings were not significantly different.

The interspecific hybrids, Ridge Pineapple x P. trifoliata (1573-26) and Ridge Pineapple x Milam (1578-201) are two of seven selections developed by Ford (6) in an attempt to improve the citrus nematode (*Tylenchulus semipenetrans* Cobb) resistance, and foot rot (*Phytophthora parasitica*) tolerance of Milam lemon (*Citrus* sp.) and Ridge Pineapple [*C. sinensis*]. These selections were found resistant to burrowing nematodes (*Radolpholus citrophilus* Huettel) formerly *R. Similis*, but have not been evaluated for resistance to citrus nematodes (*T. semipenetrans*), foot rot (*P. parasitica*), cold tolerance, drought resistance, or yield and fruit quality of scion cultivars to which they may be budded. The minimum cold damage sustained by scion cultivars budded to Ridge Pineapple x *P. trifoliata* 1573-26 in this eValuation may be an important when considering this rootstock for commercial use.

Table 2. Cold damage ratings for scion and rootstock cultivars in Immokalee Citrus Foundation Grove resulting from the December 1989 freeze. Rated on a scale of 1 to 5 where 1 = no damage.

Cultivar	Damage Rating
Scions	
Rohde Red Valencia 472-11-43	1.87
Flame Grapefruit	2.02
Pineapple 1-27-11	2.44
Minneola Tangelo	2.48
Ruby Red Grapefruit	2.49
Parson Brown	2.54
Hamlin 8-1-4	2.60
Midsweet Orange	2.62
Navel 4-2-1	2.64
Nova Tangelo	2.80
Valencia 51-3-3	2.83
Robe Orange	2.83
Rohde Red Valencia 472-3-26	2.98
Valencia 1-14-19	3.03
Valencia 10-12-7	3.05
Ray Ruby Grapfruit	3.10
Robinson Tangerine	3.14
Hamlin 1-4-1	3.14
Marsh Grapefruit	3.19
Orlando Tangelo	3.22
Navel 56-12	3.33
Cara Cara Navel	3.35
Valencia 55-28	3.38
Sunburst Tangerine	3.56
Navel 63-18-2	3.64
Fallglo Mandarin Hybrid	3.73
Star Ruby Grapefruit	3.77
LSD 5%	0.51
Rootstocks	
Ridge Pineapple x *P. trofoliata* 1573-26	2.42
Smooth Flat Seville	2.48
Duncan Grapefruit	2.51
C-35 Citrange	2.62
Valencia Seedling	2.68
Sour Orange	2.73
Bittersweet Sour Orange	2.74
Rangpur x Troyer	2.78
Swingle Citrumelo	2.86
Poncirus trifoliata	2.94
Ridge Pineapple	3.03
Sun Chu Sha Mandarin	3.04
Ridge Pineapple x Milam 1578-201	3.07
F-80-3 Citrumelo	3.12
Sanguine Gross Ronde	3.13
F-80-8 Citrumelo	3.21
Vangasay Lemon	3.24
Benton Citrange	3.35
Calamandarin	3.39
F-80-18 Citrumelo	3.41
Cleopatra Mandarin	3.41
LSD 5%	0.45

Other rootstocks of interest in this evaluation of cold injury are Smooth Flat Seville and C-35 citrange. Smooth Flat Seville performed as might be expected for a sour orange type. C-35 citrange is a moderately vigorous, high yielding rootstock with potential for Florida. Trees on C-35 rootstock have performed well in California trials. Scions budded to Swingle citrumelo ranked intermediate in cold damage in this evaluation as has been reported previously (1).

Damage ratings for scions budded on Sun Chu Sha and Ridge Pineapple x Milam 1578-201 were not significantly different from the rootstocks that sustained the most freeze damage. Scions budded to Cleopatra mandarin rootstock were among those receiving the most freeze damage, This in contrast to previous reports where scions on Cleopatra mandarin sustained the least damage (8, 16). However, on Cleopatra young trees have been reported to have sustained more damage than other rootstocks in some tests (11). Sun Chu Sha and Cleopatra, often considered similar in many respects, were not significantly different in the amount of cold damage sustained in this test.

In summarizing the results of this evaluation, it is important to note that the trees were exposed to freezing temperatures 6 to 8 months after planting and conditions vary considerably from one freeze to another. Rankings of cold tolerance are usually based on damage and survival of mature trees. Trees in this evaluation were vulnerable in that they were young and more activity growing at the time of the freeze than mature trees. These less than 1-year-old trees in the field had not developed a canopy that could trap radiant heat from the soil and were not large enough to afford protection to each other by close proximity. Statistically, since ratings were done in whole nmbers, only scions and rootstocks with ratings of 1.0 or larger should be considered different. By this criteria scions rated low in Table 2 could be considered to have received less damage than those receiving high ratings. Rootstock differences should not be considered significant without additional reports. There were obvious visual differences in the amount of damage to the different scion cultivars and the results presented represent the situation seen in the field. Although some cultivars experienced unexpected damage, it may be representative of fully-exposed newly planted trees.

Literature Cited

1. Castle, W. S., D. P. H. Tucker, A. H. Krezdorn, C. O. Youtsey. 1989. Rootstocks for Florida citrus. Univ. of Fla., IFAS Pub. SP-42.
2. Cooper, W. C., R. Fenton, and W. H. Henry. 1969. Recovery of

Florida citrus trees from freeze injury. Proc. First Inter. Citrus Symp. 2:565-569.
3. Cooper, W. C., J. Hearn, G. K. Rasmussen, and R. H. Young. 1963. The Florida freeze. Calif. Citrograph. 48:217-220.
4. Cooper, W. C., G. K. Rasmussen, A. Peynado, R. H. Hilgeman, G. A. Cahoon, and K. Opitz. 1963. Freeze injury and recovery of citrus trees as affected by the climate before and at the time of the freeze. Proc. Fla. State Hort. Soc. 76:97-104.
5. Cooper, W. C., R. H. Young and F. M. Turrell. 1964. Microclimate and physiology of citrus: Their relation to cold protection. Agri. Sci. Rev. 2(1):38-50.
6. Ford, H. W. 1978. Burrowing nematode resistant hybrids of *Poncirus trifoliata*, Milam, and 'Ridge' Pineapple. Proc. Fla. State Hort. Soc. 91:20-21.
7. Hearn, C. J., W. C. Cooper, R. O. Register, and R. Young. 1963. Influence of variety and rootstock upon freeze injury to citrus trees in the 1962 Florida freeze. Proc. Fla. State Hort. Soc. 76:75-81.
8. Hume, H. H. 1957. Citrus fruits, p. 260-282. Macmillan Co., New York.
9. Lawless, W. W. and A. F. Camp. 1940. Preliminary reports on varieties and other factors as influencing cold resistance in citrus. Proc. Fla State Hort. Soc. 53:120-125.
10. McCown, J. T. 1958. Field observations of Florida citrus following the 1957-58 freezes. Proc. Fla. State Hort. Soc. 7:152-157.
11. Yelenosky, G. 1979. Bark-splitting from freeze injury of young citrus trees on different rootstocks. Proc. Fla. State Hort. Soc. 92:28-31.
12. Yelenosky, G. and R. H. Young 1977. Cold hardiness of orange and grapefruit trees on different rootstocks during the 1977 freeze. Proc. Fla. State Hort. Soc. 90:49-53.
13. Yelenosky, G., R. H. Young, C. J. Hearn, H. C. Barrett, and D. J Hutchison. 1981. Cold hardiness of citrus trees during the 1981 freeze in Florida. Proc. Fla. State Hort. Soc. 94:46-51.
14. Young, R. H. and E. O. Olson. 1963. Freeze injury to citrus varieties in the lower Rio Grande Valley of Texas. Proc. Amer. Soc. Hort. Sci. 83:333-336.
15. Young, R. H., A. peynado and W. C. Cooper. 1960. Effects of rootstock-scion combination and dormancy on cold hardiness of citrus. J. Rio Grande Valley Hort. Soc. 14:58-65.
16. Ziegler, L. W. and H. S. Wolfe. 1961. Citrus growing in Florida. Univ. of Fla. Press, Gainesville, FL.

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REEVALUATION OF HEATER PROTECTION FOR CITRUS PLANTINGS

G. Yelenosky and C. J. Hearn
United States Department of Agriculture, ARS
2120 Camden Road, Orlando, FL 32803

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Abstract. **The decade of the 1980s was one of the most devastating in citrus losses because of freezes in 1981, 1982, 1983, 1985, and 1989. Abandonment of grove heaters in the late 1970s, largely because of unacceptable cost increases and air pollution regulations is challenging the economic framework of citrus management. The specter of large citrus trees killed to the ground, the mass abandonment of frozen groves once highly productive, and the general reluctance to reinvest in new plantings after repeated freeze kill vividly illustrate the large void brought about by the nonavailability of systems to protect highly valued, producing trees during critical winter periods. Past and present successes in heater protection, introduction of new citrus cultivars and greater competition in world markets suggest that a partial return to grove heating may be a viable option in some instances regardless of stringent DER and EPA regulations and unstable petroleum prices.**

During the past decade, five freezes have largely brought the Florida citrus industry to an uncertain stage of transition. Estimated Frozen Can Orange Juice production losses of 42% for the 1989 freeze alone and at least six counties declared freeze disaster areas (9, 11) reflected economic hardships in the loss of livelihoods and a growing passiveness to regain world leadership in citrus production lost to Brazil. Growers in Citrus, Hernando, Lake, Marion, Orange, Pasco, Polk, Seminole, Sumter, and Volusia counties are making decisions which for the moment they wish they could avoid. Once unthinkable, growers now express sentiments that growing citrus is no longer a viable economic option in counties such as Orange, and that it probably is better to pursue other land uses in view of repeated freeze kills coinciding with accelerating urban growth (6). There are already economic comparisons where "pros" and "cons" are being weighed for growing citrus in the southern vs. northern counties of Florida (10, 23). Evidence is rather overwhelming that growers are faced with extremely complex long-term vs. short investment/management decisions that involve climatic, economic, and political concerns. Decisions, being made every day and for the next 10 years because of the freeze impact, will largely position the industry and set its course into the 21st Century. Whether the path will be one of an aggressive competitor or a passive player in world citrus markets is a troubling challenge to the individual grower. For it is the grower who is the keystone of the Florida citrus industry spectrum that ranges from research to economic vitality.

Grower Concerns

This is not the first time, nor the last time, that Florida citrus growers will be making crucial decisions for world leadership in citrus production. The frequency and severity of freezes in the 1980s were totally unexpected. Predictability was increasingly more difficult because of unusual atmospheric conditions, probability tables were misleading, and freeze protection resources were not adequate at the local, state, nor federal level. Much of the "safety net" disappeared in the late 1970s when the general consensus of the industry was to abandon grove heating because of unacceptable cost increases and unreliable availability of petroleum fuels. This made producing groves in freeze-prone areas extremely vulnerable to freeze damage with only site location, trunk protection measures, and existing scion/

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