Breeding Fruit Crops for Cold Climates: Introduction to the Colloquium

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Low-temperature injury is one of the most important limiting factors in the production of fruit crops. This is true for some subtropical fruits, such as citrus, as well as for temperate fruit crops that often experience temperatures below – 20C. Injury may be manifested as a mild stress, predisposing the plant to secondary stresses that reduce yields, or as a severe stress, generating crop loss due to flower bud injury, trunk damage, or plant death. Fruit crops have been disseminated far beyond the natural ranges of the progenitor species and into new, often colder climates. The desire to optimize production and minimize losses due to low temperatures has focused attention in many fruit breeding programs on selection for resistance to cold damage (Quamme and Stushnoff, 1983).

Cold injury is a consequence of a complex of events. Cellular changes include loss of membrane fluidity, which causes ion leakage and loss of compartmentation. At extremely low temperatures, plants have evolved mechanisms to either avoid or tolerate ice formation within their tissues. Intracellular freezing is always lethal, while extracellular ice formation may be tolerated. Efforts to breed for cold tolerance are hampered by the complexity of the phenomenon. Different plant tissues and organs respond differently to the same temperatures. A breeder's proficiency in selecting for cold-hardy genotypes is governed by his ability to measure the rate of fall acclimation, the maximal level of hardiness in midwinter, the ability of these plants to remain acclimated during warm periods in midwinter, and the rate of de-acclimation in the spring. The application of selection methodology depends on: a) the ability to differentiate resistant from susceptible genotypes, b) the ability to score this trait in large populations, and c) minimizing time and expense (Quamme and Stushnoff, 1983).

This colloquium was developed to provide a resource to horticulturists committed to developing fruit crops that resist damage due to low-temperature stress and to provide a forum for the exchange of new ideas and information. A desire to keep abreast of recent advances in this field led to the development of this colloquium by members of the Fruit Breeding Working Group. A discussion of the physiology of cold damage sets the stage for presentations on two significant applied breeding efforts concentrating on the development of fruit crops for cold climates. Further details are offered on laboratory techniques widely used to determine cold tolerance of various fruit tissues. New methods in genetic technology have elicited deliberations on an entirely new breeding approach involving attempts to clone genes for factors relating to fruit quality for later insertion into cold-hardy cultivars. This colloquium speaks to all of the above areas.

Ashworth and Wisniewski's essay provides an update on the nature of freezing injury and its anatomical and cellular limits. Dormant buds, xylem, phloem, roots, and other tissues may be damaged at different temperatures. Studies related to cryopreservation of fruit crop tissues, presented by Stushnoff, help to enrich our basic understanding of the mechanism of cold damage and its prevention. Efforts to preserve the genetic resources available for cold-climate breeding cannot be overemphasized. The use of germplasm for interspecific and intergeneric hybridization in efforts to enhance the cold tolerance of various fruit crops is underscored in the contributions by Luby from Minnesota and Hiirsalmi and Sako from Finland. The applied breeding efforts of these two regions show some commonality in their reliance upon long-term program support, use of diverse sources of hardy germplasm, and testing for cold hardiness in the laboratory, as well as in field trials at multiple locations. The discovery of the phenomenon of deep supercooling in fruit crops has led to the use of thermal analysis to measure precisely, in a laboratory setting, the temperature at which freeze injury occurs. This research has facilitated a wide variety of investigations that have enhanced our capability to select cold-hardy genotypes. The paper by Quamme gives an excellent review and update of this important area.

Fruit breeders, beset with problems of long generation intervals, are always drawn to new approaches that may shorten the breeding process or provide the ability to accomplish objectives not attainable by conventional technologies. The contribution by Callahan et al. is stimulating with its description of an entirely new approach that may lead to the development of more cold-hardy cultivars. This process involves cloning genes for high fruit quality characteristics that can then be inserted, via genetic transformation technology, into a cold-hardy cultivar lacking certain fruit quality features. Through an understanding of the physiology of cold hardiness, and with an appreciation for the possibilities for progress through classical as well as novel approaches, it will be possible to accelerate the rate of progress toward the production of cold-hardy germplasm and cultivars. The proceedings of this colloquium provide an excellent update on recent advances, as well as a sound review of classical approaches.

Literature Cited

Quamme, H.A. and C. Stushnoff. 1983. Resistance to environmental stress, p. 242-266. In: J.N. Moore and J. Janick (eds.). Methods in fruit breeding. Purdue Univ. Press, West Lafayette, Ind.