UNEVEN RIPENING OF 'CONCORD' GRAPES: ENVIRONMENTAL, CULTURAL, AND HORMONAL ASSOCIATIONS

D. L. Cawthon and J. R. Morris, Graduate Assistant and Professor, Department of Horticultural Food Science, University of Arkansas, Fayetteville, AR 72701

Introduction

Uneven ripening of 'Concord' grapes is characterized by a lack of uniformly ripening berries within a cluster and the failure of some berries to ripen even with an indefinite delay of harvest. 'Concord' will often ripen unevenly under the environmental conditions experienced in the warm climate of southern states (8,9,10,29,30,34,39,43). Uneven ripening can be severe and, in many states, prohibits commercial 'Concord' production. Northwest Arkansas is considered the southern boundary for commercial 'Concord' production even though uneven ripening can create severe juice quality problems in some years.

Although uneven ripening of 'Concord' grapes has been well documented as a severe problem in some production areas, little has been done to identify the inherent physiological differences existing between uneven ripening 'Concord' berries. A need exists to examine the basic physical and hormonal changes occurring through maturation and to define differences between normal and nonripening 'Concord' berries before a rationale can be developed to solve the problem. If uneven ripening can be corrected, expansion of the 'Concord' grape industry, increased vine production, and improved quality of processed products are possible.

Environmental and Cultural Factors Related to Berry Development and Uneven Ripening

All environmental conditions will ultimately affect grapevine growth and fruit development and maturation. Temperature, however, may be one of the most important environmental factors contributing to the uneven ripening of 'Concord' grapes since high temperatures during the growing season are associated with 'Concord' production areas encountering this physiological problem.

During maturation of Vitis vinifera cultivars, high temperatures (30 to 35°C) will reduce berry weight (24), soluble solids (23), acidity (22,24) and anthocyanin content (21). Maximum net assimilation rate (as indicated by vine growth) of 'Concord' grapes was found to be at 25°C, while at 30°C, net assimilation was reduced by half (35).

The optimum temperature for photosynthesis in 'Sultana' leaves is estimated between 25°C and 30°C (25,26). However, vine leaves can attain temperatures up to 10°C higher than the ambient temperature (26). Kliewer (20) has suggested that under conditions of high temperature (42°C), vines are not capable of efficiently utilizing radiant energy possibly because degradation of enzymes and chlorophyll exceeds the rate of synthesis. The detrimental effects of high temperatures on photosynthesis may also be due in part to induced water stress (20,25) which has been shown to reduce photosynthetic activity in grapes (26,28).

If photosynthesis is a limiting factor in 'Concord' production contributing to uneven ripening in southern growing areas, then factors which protect or enhance the photosynthetic activity of foliage or increase the supply of photosynthate to the fruit would be expected to reduce uneven ripening problems. It has been shown that increasing the leaf to fruit ratio, shoot positioning, and using training systems which reduce crowding of foliage will increase soluble solids accumulation in the fruit (4,9,34) and will lessen the extent of uneven ripening in 'Concord' (4,8,9,10,34,43). Conversely, overcropping (4,8,29,30), reducing the leaf to fruit ratio (8) and artificially shading grapevines (10,38) increase the severity of uneven ripening.

The fact that only certain berries on a cluster do not uniformly ripen suggests that some selective physiological basis determines which berries will and will not ripen and to what extent they will ripen. The influence of seeds upon the physical development of various fruits is well known. High correlations between grape berry development and seed number and seed weight have been found for several grape cultivars (33) and the periodicity of berry growth resulting in a "double sigmoid" pattern has been attributed to seed influence (44).

Seed content has been related to uneven ripening of 'Concord' grapes. Green berries present at the time of harvest have been shown to contain fewer seeds (37,38,39) and more dead seeds (37,38) than ripe berries. Seeds have been found to have a definite effect upon enhancing the metabolic sink capabilities of grapes (33). If photosynthate is limiting, then berries which do not set an adequate quantity or quality of seeds might lack the ability to attract sufficient metabolites to ripen properly. Hormones are generally assumed to play a prominent role in regulation of metabolic sinks and fruit ripening.

Hormonal Control of Fruit Ripening

Fruit ripening is considered a senescent process and appears to be regulated through hormonal control. Considerable research has been conducted on the effects of plant growth regulators on grape maturation and several researchers have monitored endogenous hormonal changes through the life cycle of the grape berry. However, little
information on endogenous hormonal changes in 'Concord' is available (32) and no work of this type has been conducted in relation to uneven ripening of grapes.

Ethylene

Of the known plant hormones, ethylene is the most prominent in fruit ripening. However, endogenous ethylene appears to play little or no role in normal grape maturation. The highest concentration of ethylene produced in the life cycle of the grape berry is at anthesis (17). After anthesis, endogenous ethylene production rapidly declines (17) and remains at low levels during maturation (7, 15, 17). Application of ethephon can stimulate differential ripening responses in grapes, depending upon time of application. If applied during stage I or early stage II of development, ethephon retards grape ripening (7, 15, 16), possibly by delaying an endogenous increase of abscisic acid (7). If applied during the last week of stage II, ripening can be stimulated (7, 15), possibly due to induced increases in abscisic acid (7).

Ethephon has been used successfully with many *Vitis vinifera* cultivars to improve color (1, 2, 5, 19, 41), soluble solids (2, 5, 19, 41) and ripening uniformity (1, 2, 5) when applied in stage III of development. However, the response to ethephon is cultivar dependent, and many do not respond. *Vitis labrusca* cultivars 'Delaware' (16) and 'Concord' (31) show no beneficial quality response to ethephon when applied during stage III of berry development, even though fruit abscission is easily induced.

Gibberellic Acid

Gibberellic acid (GA) content is high at anthesis but rapidly declines and remains low in grape berries of some cultivars until the end of stage I of development, after which endogenous production increases sharply and subsequently declines throughout stage I (17). Other researchers indicate that GA is depleted in the berry before the start of Stage II (18), and suggest that decreased GA levels may be responsible for initiation of the "lag phase", or stage II of berry development (18).

When GA is applied to fruit, increases in the rate of photosynthate translocation into the berries can occur (42). GA applied to fruit at bloom or shatter can result in increases in the number of berries per cluster (3, 40), fruit size (3, 11, 40) and sugar accumulation (6, 11).

Cytokinins

Little research has been conducted on the effect of cytokinins on grape maturation. However, cytokinin activity is relatively high in early stages of grape berry development, but no activity was found after stage III of development (17). Treatment of grape foliage (36) and fruit clusters (42) near bloom with cytokinin was found to increase metabolic sink capacity of young developing berries.

Auxin

Endogenous auxin levels are relatively high during stages I and II of berry development, but little or no auxin has been found after ripening is initiated (Stage III) (13, 17, 32). Even though auxins applied to clusters near bloom will increase translocation of sugars, organic acids and amino acids into the developing berry (42), auxins applied from the end of Stage I of development through stage III will delay maturation (7, 14, 16), and when applied during stage II of berry development, will delay increases in endogenous abscisic acid (7, 17). The delay in ripening of grapes by applied auxins has been attributed to a lengthening of the "lag phase" (stage II of berry development) (14).

Abscisic acid

Abscisic acid (ABA) is relatively high in berries shortly after bloom (17), then decreases to low levels followed by a substantial increase at veraison (beginning of stage III of development) (7, 12, 13, 17, 27). The ABA increase at veraison is only evident in the berry flesh, with little change of ABA in seeds (7, 27). ABA applied to berries in stage II of development will initiate ripening (7, 16). Once ripening is initiated, endogenous ABA levels generally decline as the grapes become more mature (12, 17).

In summary, the high temperatures encountered in southern growing areas may be detrimental to maximum photosynthesis through stimulation of early leaf senescence and/or by creating moisture stress conditions, both of which would limit the supply of photosynthetic metabolites to grape berries. Competition between individual berries for the available metabolites would probably occur and those berries possessing lesser metabolic sink capabilities might tend to ripen slower, or not ripen at all.

The influence of auxins, gibberellins and cytokinins on enhancing metabolic sink capabilities has been established and the levels of these hormones are relatively high during early development of normal ripening grapes. Since seed number per berry has been associated with uneven ripening of 'Concord' grapes, simultaneously monitoring berry development and changes in endogenous hormones early in fruit development as related to the number of seeds per berry and seed development Would help determine if uneven ripening is associated with seed related metabolic sink capabilities of some berries.
It appears that abscisic acid may have a prominent role in ripening of grapes and that the interrelationship between auxin decline and abscisic acid increase may control initiation of grape maturation. Monitoring changes of endogenous levels of these 2 hormones in ripening and nonripening 'Concord' grapes would help determine if a hormonal imbalance is contributing to the uneven ripening problems associated with production of 'Concord' grapes in southern growing areas.

**Literature Cited**