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Crop Load Management of Apple Via Induced Plant Stress

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Abstract

Commercial apple (*Malus* × *domestica* Borkh.) growers face economic pressures which compel them to minimize production costs. Effective chemical thinning programs significantly reduce labor expenses and increase financial returns. Research has shown bloom thinning programs based on lime sulfur or oil plus lime sulfur combinations decrease fruit set while increasing fruit size and return bloom. Damage to sensitive flower parts combined with transient depression in carbon fixation likely reduce fruit set to levels beyond those seen with other caustic bloom thinners which do not significantly impact photosynthesis. Implications of stress-inducing chemical thinning programs are discussed.

Like other horticultural crops, apple (*Malus* × *domestica* Borkh.) has a natural tendency to over-fruit and requires careful crop load management to ensure consistent yields of high quality, profitable fruit. Rising labor costs, global oversupply, and increasing competition from foreign producers continue to squeeze margins for profitable orchard operations. Apple growers must cut production costs and maximize returns in order to remain financially viable.

Labor continues to be the greatest expense for commercial fruit growers; these costs are guaranteed to balloon in coming years as minimum wages increase around the nation. In commercial apple orchards, pruning, hand-thinning, and harvest comprise the vast majority of labor expenses, and technology is providing management strategies to minimize these costs. Progressive growers already employ modern approaches to tree training, nutrient and water management, and strategic use of plant bioregulators to reduce pruning costs. A small group of orchard operations currently feature mobile platforms to minimize ladder usage and hold down labor costs. Nearly all growers, however, have adopted chemical thinning programs to minimize hand thinning costs, which, unchecked, can exceed U.S. $2000/ha. Effective chemical thinning also improves economic return for growers by promoting fruit size, quality, and return bloom.

Research has identified some sprayable chemistries which reduce crop load at novel timings, but most commercial products are categorized as “bloom thinners” (applied while blossoms are open) or “postbloom thinners” (applied within 2-3 weeks of petal fall). Materials used in the postbloom window typically mimic the action of plant hormones such as cytokinins, ethylene, or auxins to induce fruitlet abortion. Chemicals applied during bloom are generally caustic in nature, intended to damage viable pollen and/or stigmas to prevent fertilization. New research, however, has suggested that in addition to chemically burning floral anatomy, bloom thinning programs featuring lime sulfur also induce whole plant stress, further decreasing fruit set (8, 10).

The relationship between stress and thinning is well established. Williams (11) suggested that plant stress elevates production of 1-aminocyclopropane-1-carboxylic acid (ACC), in turn inducing increased abscission layer concentrations of ethylene, the phytohormone most closely associated with fruit drop. Suppressed auxin transport in chemically or environmentally stressed fruit trees has also

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been proposed as a potential trigger for increased fruitlet abscission (1). Williams later reported (12) that either high temperatures or plant growth regulators specifically can cause fruitlet abscission due to increased plant stress. Untiedt and Blanke (9) reported temporary depressions of photosynthesis in apple due to application of postbloom chemical thinning agents including NAA, NAD, and ethephon.

Terbacil, known widely as an agent of "chemical shade," is a herbicide which restricts photosynthesis via inhibition of photosystem II in plant thylakoids. Terbacil has been shown to reduce carbon fixation in 'Seyval blanc' wine grapes (5) and apple, where Byers and Carbaugh (4) also observed dramatically reduced fruit set with Terbacil; no fruiting data were taken in the 'Seyval blanc' study. Additionally, Byers et al. (3) identified ten other photosynthesis-inhibiting herbicides which also induce apple fruit thinning.

The correlation between reduced photosynthesis and fruit thinning has been further demonstrated by studies involving artificial shading. Decreased fruit set has been observed when shade cloth was applied to apple trees at various timings during and after bloom (2, 3, 4, 6). Byers and Carbaugh (4) also reported diminished seed counts in shaded fruit which likely contributed to increased rates of abortion. McArtney et al. (6) found temporary shading induced a transient reduction in fruit dry matter accumulation, followed by a subsequent increase for the balance of the growing season. At harvest, fruit size was larger in surviving shaded apples than in untreated controls.

The Washington Tree Fruit Research Commission (WTFRC) conducted more than 200 chemical bloom thinning trials in commercial Washington apple orchards from 1999-2006. Key parameters evaluated in each of those trials included fruit set, harvest fruit size, and return bloom. Macro-analysis of results across all trials reveals that treatments which feature lime sulfur, whether alone or tank-mixed at lower rates with various horticultural oils, consistently outperformed treatments featuring other caustic bloom thinners, including ammonium thiosulfate (ATS) and magnesium/calcium chloride (NC99).

Collaborative studies between the WTFRC and other researchers have shed some light on the success of lime sulfur programs as chemical thinners. Single leaf (8, 10), partial canopy (L. Lombardini, WSU, personal communication), and whole canopy (10, and L. Lombardini, personal communication) gas exchange techniques have all confirmed that application of lime sulfur induces temporal depression of carbon fixation rates. Under Washington conditions, transpiration and net carbon exchange rates typically returned to control levels within 4-10 days of lime sulfur applications (10). Multiple applications of lime sulfur showed additive effects in terms of depressing photosynthesis (L. Lombardini, personal communication); spray intervals of 4-6 days in Washington are most likely to provide maximum impact on carbon fixation, and in turn, chemical thinning (8, 10).

Photosynthesis recovery rates were typically much slower in Pennsylvania and New York trials, often requiring several weeks to return to levels comparable to those of untreated controls (8). This delayed recovery was likely due to additive effects of lime sulfur and shading through depression of photosynthesis in Eastern districts, where cloudy weather is common during late spring. As a result, trial results suggest over-thinning could frequently result from bloom applications of lime sulfur programs for Eastern growers. Because Washington apple production areas typically enjoy copious sunshine during the chemical thinning season, these programs rarely cause over-thinning and frequently reduce crop loads to desirable levels. As a result, commercial use of lime sulfur programs for blossom thinning in Washington has increased dramatically in recent years, with most growers reporting successful results.

Caustic salts such as ATS or NC99 likely rely upon damaging recently opened flowers prior to pollination for effective thinning. Under normal conditions, only a small portion of potential flowers/fruiting sites may be vulnerable at any given time when these

materials are applied. Lime sulfur programs, however, have demonstrated a "kickback" effect in which flowers that have already been pollinated, as well as flowers which have not yet opened, show increased rates of abortion compared to untreated controls (7). Apple growers using lime sulfur thinning programs, therefore, should enjoy greater margins for error regarding their spray timings and better overall results than with ATS or NC99.

Fruit growth rates may lag shortly after lime sulfur application, but similar to effects seen from shading-induced thinning, the resulting reduced sink competition for photosynthates typically translates to superior fruit size at harvest (7). The 2006 growing season in Washington, however, produced isolated reports from several fruit growers of apple blocks thinned with lime sulfur producing smaller fruit than adjoining blocks thinned with ATS. These orchards experienced several days of temperatures near 40°C shortly after bloom thinners were applied; it is likely that lime sulfur-treated trees endured stress well beyond the typical 4-10 day window of photosynthetic depression, and fruit growth was unable to catch up to that of the relatively unstressed neighboring trees treated with ATS.

Plant stress is generally considered something to be avoided in commercial agriculture, but in some cases, can be strategically managed to elicit desired outcomes. Apple chemical thinning techniques based on inducing plant stress have proven effective around the world. Lime sulfur-based programs show promise in research trials and commercial practice on soft fruits, cherries, and pears, providing hope that these crops can also be managed more economically and bolstering the long-term financial viability of tree fruit production.

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