Critical Concepts for Sweet Cherry Training Systems

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The original working title for this paper, designed to cap the 2001 IDFTA cherry educational session and lead into the panel/audience question and answer period, was "Critical Concepts for the Open Vase/Slender Spindle/Zahn/Brunner/Solaxe/Vogel/Spanish Bush/Steep Leader/Tatura Trellis/HYTEC /Low-Tech/(Your Name Here) Cherry Orchard Training System." Many tree training systems provide important potential management techniques for the sweet cherry grower, some more appropriate than others for certain sites, cultivars, rootstocks or target markets. The fact is that the adoption of high density strategies for sweet cherries is still in its earliest stages, both in research and in practice, and therefore the learning curve remains steep. Trial and error still govern both research and grower implementation, for sweet cherries seem to be fairly sensitive to localized differences in site, climate, rootstock/scion combination and disease pressures. This paper defines a few assumptions regarding the future of sweet cherry production, followed by several critical concepts for growers to consider as they experiment in their own orchards to hasten future production efficiencies and strive to ensure a high quality product.

First, the assumptions: Perhaps the greatest scientific advances that have become available commercially in the past decade have been the increased availability of 1) remarkable new rootstocks that increase productivity, increase precocity, and/or control tree vigor and 2) remarkable new varieties with outstanding eating quality, large and attractive appearance and often self-fertility. Consequently, unlike the prior century of sweet cherry culture, growers will need to learn how to manage trees that can perform quite differently than ever before. For example, earlier flowering and reduced vigor mean earlier, critical impacts on filling orchard space; self-fertility and higher productivity means greater challenges in managing crop loads and leaf-to-fruit ratios (Lang and Ophardt, 2000). Both of these situations lead toward high density orchards to better synchronize the filling of orchard space with early cropping, to provide simplified tree structures to better manage light distribution and crop loads, to use labor and other inputs more efficiently, and perhaps even to provide better protection from environmental or biological challenges like rain-induced fruit cracking or bird damage. In short, these assumptions mean a greater emphasis must be placed on precision in sweet cherry training techniques. This consequently places an increased emphasis on understanding the natural, physiological relationships between fruit bud formation, shoot development and leaf area as well as the roles of seasonal photosynthetic activity and stored carbon and nitrogen in the annual growth cycle.

> *…precision in management… attaining more precise canopy development, more precise cropping levels and more precise management of the various populations of leaves…to optimize… growth and fruit quality.*

TRAITS OF SWEET CHERRY ROOTSTOCKS

Beginning with key traits of the rootstocks likely to be used in the high density cherry orchard of the future, vigor management (i.e., dwarfing) is critical for improving labor efficiency for such a labor-intensive fruit crop as fresh market sweet cherries (Weber, 2001). Elimination of, or reducing the size of, ladders needed for pruning, training and harvest can double labor efficiency—a critical need as labor availability continues to dwindle and become more expensive. Smaller trees require less protective spray volumes, saving both material costs and reducing potential environmental impacts like spray drift. Similarly critical is precocity, the ability to begin significant cropping by year 3 or 4, to achieve earlier positive cash flow as well as to bring exciting new varieties into production sooner to establish and/or capture market niche premiums.

With regard to an increasing array of

rootstocks and varieties that vary in productivity, the decisions made during orchard planning will become more complex but will provide increased possibilities as growers attempt to carve out more market niches to diversify profit potential. The current group of precocious and vigor-controlling cherry rootstocks tends to be very productive; examples such as Gisela 5 or Edabriz promote greater spur formation on scions, a trait that may be particularly important for naturally lighter yielding varieties like Tieton or Regina. Conversely, however, a decision to match rootstocks (that promote earlier, heavier cropping) with varieties that naturally exhibit earlier, heavier cropping, such as Chelan or Sweetheart, will increase the challenges for the grower to adequately manage crop loads and achieve premium market fruit sizes.

Among other rootstock traits that are likely to be of increased importance in future cherry orchards is more uniform potential orchard performance of clonally propagated rootstocks (such as Colt, the Gisela series, the Weiroot series, Edabriz, the MxM series, etc.) compared to rootstocks obtained from genetically unique seedlings (such as Mazzard and mahaleb). As these new rootstocks are used and studied further, their differences in disease tolerance and soil adaptations will also become more powerful tools for growers to utilize on a site-specific basis (Lang, 2000).

CONCEPTS FOR SWEET CHERRY CROPPING

To most effectively implement a sweet cherry training system and manage the orchard under new paradigms inherent to reduced tree vigor and earlier, higher production potential, growers should first fully understand the cyclical timeline of flowering events and the physiological tree processes important to those events. While cropping is an annual event, the physiological factors that influence the development of a single crop actually encompass about a 15-month period, from the initial biochemical signal that begins the formation of flower buds to the final ripening of fruit for harvest. Figure 1 outlines these flowering events and their relative timing for North American latitudes of 44 to 48 EN (e.g., Michigan, Oregon, Washington).

On this timeline, the induction of flower buds for the next year's crop takes place at the same time that new shoot growth occurs during the spring through early summer. Interruption of this shoot growth, as by growth regulators like Apogee or Ethrel, by limb bending, by water stress, etc., tends to increase flower bud formation. During this timeframe, nitrogen uptake and photosynthetic production of carbohydrates is helping to drive growth, thereby establishing both leaf area for the current season and flower bud number for the coming year. As summer progresses, actual microscopic formation of the individual flower parts (e.g., petals, pistils, etc.) begins (Guimond et al., 1998), while shoot growth ceases. The continued uptake of nitrogen and photosynthetic production of carbohydrates then begins a significant shift into storage reserves in the trunk and roots; these reserves will drive growth the coming spring, from bloom and shoot budbreak through early fruit set and growth. Reserve levels may build through autumn until leaf fall occurs and before trees become dormant to survive the winter.

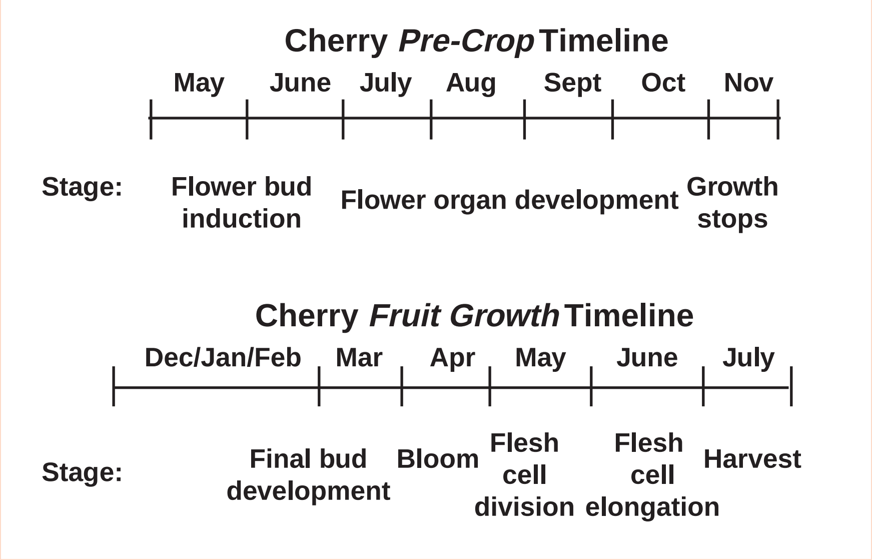
Final flower part development (e.g., individual pollen grains, expansion of the petals and pistil, etc.) occurs in late winter/early spring, leading up to bloom and shoot budbreak. Storage reserves of nitrogen and carbohydrate are critical for these processes and for fruit set. At this time, cell division is occurring rapidly in the young fruits and shoots, thereby setting limits on both future fruit size and future leaf area. This is important because the final stages of fruit growth, leading up to ripening and harvest, involve only the expansion of the existing fruit flesh cells. Similarly, the eventual growth of those cells and the accumulation of sugar into the fruit during ripening are no longer driven by reserve but by active photosynthesis of nearby leaves—the larger the leaf area, the greater the resources available for growth and ripening. Consequently, decisions made during the previous season can affect the early development of the current season crop, while dormant pruning and training decisions can influence the final development of the crop.

PRINCIPLES FOR CHERRY CANOPY MANAGEMENT

Whatever training system is adopted for high density sweet cherry orchards, one of the guiding principles for its implementation should be a goal of *precision in management*—that is, attaining more precise canopy development, more precise cropping levels, more precise management of the various populations of leaves within the canopy to optimize their roles in growth and fruit quality. The shift to smaller trees is a two-edged sword, in that a small tree inherently has a simplified structure (due to fewer growing points to be managed) that lends itself well to increased management precision. However, because the canopy is less extensive than a full-size tree, it is imperative that each branch play an optimized role in this simplified structure, thereby necessitating precision in tree development. The natural growth habit of sweet cherry is that of a competitive forest tree: branching occurs primarily just below the termination of each year's previous growth, leading to a

FIGURE 1

The 15-month sweet cherry cropping timeline, broken into two phases: the Pre-Crop phase during which the potential crop (flower buds) and resources for early growth (carbon and nitrogen reserves) are established and the Fruit Growth phase during which the actual crop (fruit set) and resources for late growth (current photosynthesis and nitrogen assimilation) are realized.



canopy that extends branches as high and as wide as possible to maximize the capture of sunlight on a continually spreading periphery while shading lower and interior growing points (or competing trees). Obviously such a growing habit is inconsistent with maintaining good light distribution throughout a compact canopy area in a high density orchard.

Heading of leaders or scaffolds during tree development does not change this inherent growth habit of sweet cherry; it simply forces it to occur with less primary structure extension (due to partial removal of last year's growth). To change the actual growth habit to more precisely promote a horticulturally optimized canopy, growers must manage at the level of the future growing points, i.e., the buds. Selection of individual buds for development into scaffolds or fruiting branches brings an increased level of precision to tree development and cropping. During structural development, this "precision branching" can be attempted a number of ways, including use of growth regulators such as Promalin, or physical manipulations such as scoring above target buds or removal of unwanted buds to force remaining buds to grow.

Promalin use can alter growth habit remarkably by inducing extensive lateral branch development—*if* conditions for its activity in the plant are optimized. This includes a fairly narrow window of time (bud developmental stage) for its application and relatively warm temperatures following application. Cool spring temperatures during budswell and budbreak may result in poor or variable promotion of lateral shoots. Conversely, too much promotion of lateral shoot formation may require subsequent thinning out of new shoots to achieve adequate shoot growth and light distribution.

Promotion of precision branching by scoring above target buds can be achieved over a much wider window of time, from beginning budswell through budbreak, than by Promalin use. By scoring above only those buds from which shoot growth is desired, the resultant localized branching tends to be more precise as well. Caveats with scoring include the need to create a sufficiently wide interruption in the bark (cambium) above the bud such that healing will not occur until after new shoot growth begins, the risk of shoot breakage in strong winds if scoring cuts extend into the wood and the possibility of bacterial canker (*Pseudomonas*) infection where disease pressures are high.

Promotion of precision branching by removal of unwanted buds (as much as 75% or more) has many of the same advantages as scoring, such as an even wider implementation window (dormant through post-budbreak, though the easiest time to rapidly snap buds off is during budswell) and very localized branching, allowing precise placement of new scaffolds or fruiting branches in specific patterns, such as whorls or tiers, along the year-old wood. Caveats with bud removal include the possibility of bacterial canker and the elimination of summer dormant buds as sites of subsequent leaf area and future shoot or fruiting spurs. However, when using precocious rootstocks, the removal of such future potential spurs during the scaffold and branch development phase of the orchard actually may be beneficial to prevent premature cropping and promote more rapid filling of tree space.

UNDERSTANDING CROP DEVELOPMENT WITHIN A TRAINING SYSTEM

Once the fundamental tree structure has been established within a training system or canopy architecture, the emphasis of high density sweet cherry orchard management should shift from precise branching to precise cropping. One of the key principles is to understand the relationship between shoot age and crop development. On trees with good annual vigor (even trees on dwarfing rootstocks), no fruiting spurs should form on previous season shoot growth (though some solitary, non-spur flowers may form at the basal nodes of such shoots). Rather, most nodes on shoots formed during the previous season will be forming primordial flower spurs during the subsequent season and will actually fruit 2 years after initial shoot formation. That is, during the 2001 growing season, there will be new terminal shoot growth (non-fruiting), there will be primordial flower buds developing on the part of the shoot that formed during 2000, and there will be fruit developing on the older part of the shoot that formed during 1999.

Therefore, it is critical to realize that the first crop is borne on shoots that developed 2 years earlier. For a tree expected to crop in year 3 or 4, training decisions made during year 1 or 2 directly affect that initial crop. Many growers and researchers experimenting with precocious rootstocks such as Gisela 5 have reported serious overcropping in year 4 or 5; "pre-emptive" moderation of such crop loads, then, needs to be anticipated during the second or third year, when those future potential overcropped shoots are either developing or are initiating their flower buds. One suggested strategy is to head-prune previous season shoot growth during the dormant season (or perhaps that same new growth at the end of the summer, prior to dormancy). In preliminary experiments, this has been shown to have the dual effect of reducing the future crop load by direct removal of future fruiting sites as well as the stimulation of more lateral shoots, which may alter the hormonal balance such that subsequent flower bud formation at the remaining sites is somewhat reduced.

The density of flower spurs tends to be greater near the terminus of annual shoot growth. This is due to the general decrease in internode length between future spur sites during shoot elongation later in the season, as well as to the tendency for the number of flower buds per spur to increase on the shoot growth that occurred later in the previous season. Thus, removal of only 10 to 25% of the new shoot growth length, as described above, may serve to directly remove 25 to 50% of the future crop load, due to this disproportionate distribution of future flower buds along the shoot's length. These relationships between shoot length, fruit bud formation and reaction to head-pruning will vary to differing degrees based on rootstock, scion variety, site vigor and climate. Growers must observe the natural (or managed) vigor of their orchard and conduct their own experiments, guided by the above principles, to more precisely manage their own cropping situations, irrespective of training system.

UNDERSTANDING LEAF POPULATIONS WITHIN A TRAINING SYSTEM

Developing a precise tree structure to optimize light interception and distribution in the high density orchard, coupled with understanding shoot growth and fruiting relationships to manage crop loads more precisely, is a critical concept for intensive sweet cherry production. An additional component for optimizing the quality of fruit produced in such intensive systems requires an understanding of the various populations of leaves present in the canopy, how they are distributed in relation to fruit and their various roles in supplying carbohydrates to developing fruits, developing shoots and the storage reserves critical for early growth in spring.

Perhaps the most obvious distinct leaf population is that on current season shoot growth—shoots formed during 2001—having a single leaf at each node. As these leaves form and expand during the active shoot growth phase, initially they are "sinks" in need of carbohydrate imports from elsewhere (storage reserves or nearby mature leaves) for their maturation. At maturity, they begin supplying carbohydrates, via photosynthesis, to nearby new shoot and leaf growth "sinks" and perhaps to distant fruits. Once shoot and fruit growth cease, they may contribute to the storage tissue reserves for next year's initial growth flush. Any removal of portions of this leaf area, as by summer pruning to maintain good light distribution, has a relatively minor impact on the total leaf area of the tree.

A second leaf population is that on last year's shoot growth—shoots formed during 2000—having about 6 to 8 leaves at each node. This, therefore, represents a 6- to 8-fold increase in leaf area compared to the same shoot's leaf area during the year of formation and, consequently, a powerhouse of carbohydrate production. Even more importantly, this segment of shoot is only in the flower bud induction phase of development; there is not yet any fruit to directly support (unless there are the minor solitary, non-spur flowering sites present at the base of the shoot). Consequently, this population of leaves can help supply carbohydrates to nearby new shoots or to the fruits developing farther down the branch on the older wood, as well as to storage reserves when growth demands are satisfied. Thus, this is a major source of actively photosynthesizing leaf area important for all phases of growth, and removal of any portion of it should be minimized (this is the target shoot portion described above for limited head-pruning to promote management of future crop load potential).

A third important leaf population is that on the 2-year-old shoot growth—shoots formed during 1999—having about 7 to 9 leaves at each node, most of which are also fruiting spurs. The primary purpose for this population of leaves is thought to supply carbohydrates directly to adjacent fruits or to those on nearby spurs. If there are only a few fruits per spur, this leaf population generally does an adequate job of supplying the carbohydrate resources needed for the fruits to approach their full growth potential. However, if there is a high density of fruit at each spur, the role of the second leaf population (the 6 to 8 leaves per non-fruiting node on last year's growth) becomes extremely important as supplemental support for fruit growth. The problem with the removal of any of this 2-year-old shoot segment (as for direct reduction of the current season crop load) is not so much the loss of its own leaf area, which may only feed those fruiting spurs also being removed, but with the inadvertent removal of the entire year-old shoot segment and its "free agent" leaf area that contributes supplemental support possibly across the entire remaining crop load.

It is for this reason that flower bud formation on year-old shoots should be anticipated and subsequent efforts made to manage future crop loads, rather than remedial management of current crop loads. The advent of future chemical thinning agents for sweet cherries may reduce the importance of this strategy, but the fundamental principles of understanding crop formation, shoot growth and leaf populations will nevertheless help in the management of intensive, high density sweet cherry orchards and optimization of fresh market fruit quality, irrespective of the initial training system or canopy architecture imposed.

CRITICAL CONCEPT CONCLUSIONS

A fundamental tenet of all high density orchard training systems is to promote both light interception by tree canopies and distribution throughout a compact tree canopy. With the advent of new plant materials for high density sweet cherry orchards, greater precision in tree development and cropping management is possible. Regardless of training system, precise branch development is critical to fill canopy space quickly and efficiently before cropping becomes significant. Since vegetative vigor can slow as cropping begins, particularly on young trees, it is critical to maximize the placement and growth of every vegetative growing point to develop a well-structured tree during the first 2 to 4 years. Once cropping begins, it is more difficult to correct early errors in tree training, such as scaffold placement, canopy light distribution hierarchy and balance between leaf area and crop load.

Early cropping competes not only with tree growth but also with the building of storage reserves necessary for good spring vigor. Young trees have relatively limited root systems and trunk tissues for storage of the carbohydrate and nitrogen "fuel" for spring growth; thus too many growing points (shoots or especially fruits) on young trees can slow current tree growth as well as future tree growth. This is critical for trees on precocious rootstocks, like the Giselas, which can become "unbalanced" between early vegetative and fruiting growth, leading to a prolonged period of "runting out." Trees on non-precocious rootstocks tend to establish significant root systems, canopies and trunk storage tissues before fruiting.

Following development of the main tree structure, precise shoot pruning to optimize leaf area and balance future fruiting spur formation is important for maintaining healthy relationships between shoot growth, "free agent" leaf area, current photosynthesis, annual building of storage reserve and the ultimate realization of good yields of high quality fruit. In general, these plant relationships specific to sweet cherries can guide high density cherry orchard management regardless of the training system or canopy architecture initially adopted.

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