# Intensive Sweet Cherry Orchard Systems—Rootstocks, Vigor, Precocity, Productivity and Management

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While the apple growers of the world have moved headlong into intensively managed orchards of small trees during the late 20th century, the concept of growing sweet cherries in a similar manner has lagged far behind. In some respects, ideas and practices developed for dwarf apple orchards can be applied indirectly to the development of intensively managed sweet cherry orchards, such as optimization of light interception and distribution throughout smaller tree canopies. On the other hand, some aspects of high density apple orchard management relative to usefulness for establishing dwarfing and intensive sweet cherry orchard practices may be as futile as comparing apples and oranges.

The overriding reason for the current difference in state-of-the-art orchard management systems between apples and sweet cherries is the absence, until the mid-1980s, of suitably dwarfing cherry rootstocks. While high density apple systems of 4000-plus trees/ha (1620-plus trees/acre) are now common, sweet cherry orchard densities only recently have approached 500-plus trees/ha (202 trees/acre). Efforts to breed dwarfing commercial cherry cultivars have been largely unsuccessful, so the genetic control of tree vigor via rootstocks has been a critical and long-awaited initial step in developing intensive sweet cherry orchard systems.

Given the recent advent (Perry et al., 1996) and ongoing evaluation (Kappel et al., 1998) of such suitable cherry rootstocks (discussed in detail below), there remain several potentially key differences between apples and sweet cherries that create challenges to simply adopting intensive apple orchard techniques for sweet cherry orchards.

Among these are a greater sensitivity of cherry to debilitating diseases (e.g., bacterial canker [*Pseudomonas syringae*], silverleaf [*Stereum purpureum*]) that can arise from pruning, training and/or trellising decisions; a far shorter period of fruit development (60 to 90 days for cherry compared to 120 to 180 days for apple), which places increased importance on storage reserves to fuel fruit growth and probably results in differences in carbon partitioning between vegetative and reproductive growth as well as to storage reserves; and the response of each fruit species to unbalanced (heavy) cropping. That is, overcropped apple trees tend to become biennial in fruiting with compensatory vegetative growth during the off year, while overcropped cherry trees tend to promote an even heavier return bloom the following year and therefore suffer further insufficient vegetative growth.

Consequently, the efforts of my sweet cherry research group at Washington State University (Prosser) during the late 1990s have been to deconstruct and evaluate potential intensively managed orchard system components to better understand the roles, limitations and optimizations of each in eventually developing suitable management techniques for high density sweet cherries.

Certainly the idea of breaking orchard systems down into components is not new and has been illustrated nicely by the "jigsaw puzzle" concept used by Barritt (1992). The components to be discussed in the following forum include rootstock vigor and precocity effects, canopy architectural effects, pruning decisions (type and timing) and crop load management.

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## ROOTSTOCKS AND VIGOR

The importance of appropriate rootstocks to be integrated into intensive management systems for sweet cherries cannot be underestimated. First and foremost, they are one of the most effective ways to provide varying levels of control of vigor in a tree that would grow naturally to be 10+ meters tall (30+ ft). With a rootstock to hold the tree within a smaller allotted space in the orchard, growers can plant more trees per hectare to reach full production more quickly without concerns about tree crowding later in the life of the orchard. Further, with less emphasis on routine pruning simply to contain tree size, growers can focus more attention on precise placement of leaves and fruit-bearing sites throughout the canopy to optimize yields of uniform fruit quality. Smaller trees clearly have the further advantages of more efficient use of labor (less time wasted on ladders), less pesticide use per application and easier protection from some potential production risks (e.g., netting for birds, covers for rain).

Second, since sweet cherries on seedling rootstocks often exhibit a significant period of vegetative growth characterized by little or no flower bud initiation, and thus require 5 to 7 years to come into production, vigor-controlling rootstocks that impart precocious flower bud induction are extremely valuable. The ability to develop a positive cash flow between years 3 to 5 on a precocious rootstock dramatically alters the economic picture for both growers and their financial lenders, usually more than offsetting any higher initial plant costs (Seavert, 1997). The challenge for growers with such rootstocks is to prevent early cropping from reaching levels that might stunt subsequent tree growth and health. This will be discussed further under intensive orchard management.

Third, rootstocks that control vigor and induce precocious fruiting must also retain adequate productivity. Of the new sweet cherry rootstocks investigated thus far, this is generally not a problem. In fact, excessive productivity with standard commercial cultivars, like Bing and Van, has been more of a challenge. In addition to these three common traits that rootstocks should possess for use in a high density, intensive orchard, further traits of interest are particular tolerances to problematic sites (e.g., sandy or heavy soils) and resistance or tolerance to problematic pests (e.g., common diseases, insects, root-eating mammals, etc.).

The first widespread North American trial of cherry rootstocks having significant potential to control tree vigor and/or precocity was planted in the NC-140 regional project in 1987-88 (Table 1), followed in 1998 by a second group (Table 2). Dramatic and distinct differences are readily apparent among the rootstocks in the first trial (Perry et al., 1996), and such differences in the second trial are just beginning to be manifested. However, it also has become apparent that a significant number of these rootstocks are unlikely to be adopted into commercial cherry production due to their sensitivity to one or more of the pollen-borne viruses, prune dwarf (PDV) and *Prunus* necrotic ringspot (PNRSV) (Lang et al., 1997, 1998). These viruses are relatively common around the world and are often found in wild stands of *Prunus* species as well as in commercial cherry blocks, since *Prunus avium* (sweet cherry cultivars and Mazzard rootstock) and *Prunus mahaleb* (Mahaleb rootstock) all tolerate infection by these viruses with only minor effects that often go unnoticed.

These viruses can spread, albeit slowly, by bee transmission of infected pollen from one tree or orchard to the next. To examine tree reaction to a known infection, Lang et al. (1997) bark-graft inoculated either virus into year-old shoots of sweet cherry in late spring, finding evidence (graft union gumming) that the virus moved from the young shoots to the graft union of mature trees within 10 weeks. On hypersensitive rootstocks, premature leaf senescence and abscission were seen within 12 weeks of inoculation, whereas sensitive rootstocks exhibited only reddening or bronzing of leaves in the fall (about 16 weeks after inoculation).

During the next growing season, hypersensitive rootstocks exhibited twig dieback, scaffold collapse, and tree death, while sensitive rootstocks exhibited minimal new growth. During the third year after inoculation, even trees on sensitive rootstocks collapsed and died (Lang et al., 1998). Of the 37 different rootstocks tested in the two NC-140 trials, 15 have been characterized as having sensitivity or hypersensitivity to PDV and/or PNRSV in the inoculation tests (Lang, 2000).

Consequently, only rootstocks that, thus far, appear to be virus-tolerant will be discussed from here on. Happily this list still includes rootstocks with various levels of vigor control. Using tree vigor on Mazzard as a 100% control, the best rootstocks from the 1987-88 NC-140 trials for vigor control and/or precocity were Gisela 5 (Gi 148/2), Gisela 12 (Gi 195/2), and Gisela 6 (Gi 148/1).

Gisela 5 provided a dwarf tree about 50% of the vigor on Mazzard, and Gisela 12 provided a semi-dwarfing tree about 75-80% of the vigor on Mazzard.

Under irrigated conditions on good soils in the high light environment desert climate of the Pacific Northwest (PNW), Gisela 6 provided a tree (using Bing) with the same vigor level as that on Mazzard, yet much more precocious and productive.

Under non- or partially irrigated conditions on poorer soils in the lower light environment of the Great Lakes region, Gisela 6 provided a tree (using Hedelfingen) that was dwarfing to semi-dwarfing. Hence, cultural practices and scion varieties may affect overall tree vigor in ways that have yet to be fully characterized in these early trials.

Thus, the potential for genetic control via rootstocks of sweet cherry tree vigor is much more promising than it was merely a decade ago. There are alternatives to rootstocks for vigor control, such as deficit irrigation (effective only in dry climates), root restriction or root pruning (difficult to manage, may affect fruit size negatively), limb bending or summer pruning (labor intensive) and/or growth regulators such as Cultar, Ethrel or Apogee (availability may be restricted and/or the cumulative economics and effects on tree and fruit growth of such annually repeated applications are not yet known).

TABLE 1

**Cherry rootstocks in the 1987-88 North American NC-140 regional project trial (Perry et al., 1996), listed by experimental test number and by cultivar name, as appropriate.**

Mazzard seedling, Mahaleb seedling
Colt
Gembloux [GM] 9 (Inmil), 61/1 (Damil), 79 (Camil)
Giessen [Gi] 148/1 (Gisela 6), 148/2 (Gisela 5), 148/8 (Gisela 7), 148/9 (Gisela 8), 154/4, 154/7, 169/15, 172/7, 172/9 (Gisela 1), 173/9 (Gisela 10), 195/1 (Gisela 11), 195/2 (Gisela 12), 196/4
Mazzard x Mahaleb (MxM) 2, 39, 46, 60, 97

## PRECOCITY AND PRODUCTIVITY

Perhaps the most outstanding trait conferred by some of the new cherry rootstocks, such as the Gisela series and Tabel Edabriz, is significant flowering in the 3rd or 4th year in the orchard (that is, the 4th or 5th leaf). Depending on the inherent precocity of the variety, this is 2 to 4 years earlier than cherry trees on Mazzard would tend to begin cropping (Perry et al., 1996). Data from one of our WSU trials in a commercial Bing cherry orchard, in the 5th year, yielded 6 kg/tree of fruit on Mazzard, 23 kg/tree on Gisela 5, and 24.5 kg/tree on Gisela 6. During the first 10 years of the 1987-88 NC-140 trial at WSU/Prosser, Bing trees on Gisela 5 outyielded trees on Mazzard through 7 years, then essentially equaled Mazzard yields for years 8-10. Trees on Gisela 6 outyielded Mazzard across all 10 years.

This increased productivity tends to be due to both precocious flower bud and spur formation and to a greater number of flower spurs that develop per length of shoot. As can also be derived from the yields reported above, a dwarf tree on Gisela 5 that is allowed to yield at levels similar to a full-size tree on Mazzard during years 8-10 is likely to have a much lower leaf-to-fruit ratio, with subsequently smaller fruit size due to simple limitations in total photosynthesis, carbon acquisition and resource partitioning. Consequently, some highly productive varieties, especially those with moderate size (e.g., Chelan) or self-fertility (e.g., Lapins, Sweetheart), may tend to overcrop severely on highly precocious and productive rootstocks like Gisela 5, 6, or 12 if the crop loads are not reduced in some way. Conversely, however, productivity of lower-cropping varieties can be improved significantly on stocks such as Gisela 5, 6, or 12. If the low-cropping variety has the genetic trait of extraordinarily large fruit, such as Tieton, productivity often can be improved while still retaining large fruit size.

## INTENSIVE MANAGEMENT

Since capital investment increases dramatically with higher planting densities, and earlier productivity intensifies how quickly growers must switch from a “fill the orchard space” frame of mind to “produce high quality fruit” frame of mind, it is clear that management decisions take on added emphasis from the moment the idea of a future orchard is first conceived. Site selection, while always critical, becomes more so since rootstock vigor must be matched appropriately with soil type and orchard training system. Likewise, since sweet cherries are particularly susceptible to spring frost damage, small trees bear a greater proportion of the crop closer to where the coldest air settles near the ground, increasing the importance of selecting frost-free sites and/or protective spring heating strategies.

Early limb development and placement become critical if a viable crop harvest is planned for year 3 or 4; when sweet cherries on seedling rootstocks were not expected to bear for 5 or 6 years, early mistakes in scaffold and limb placement were readily corrected before fruiting commenced. With precocious rootstocks, the new growth that is developed and trained during the 1st and 2nd year in the orchard will create the bearing surface for the crop that is harvested in the 3rd and 4th years, respectively, making it more difficult to correct early mistakes.

Nary a grower likes to remove early cropping wood to re-structure a tree canopy. Once the tree begins cropping, it diverts fewer resources to new growth, thereby taking longer to correct early canopy developmental mistakes. In fact, experience in the NC-140 trials and models of precocious cherry fruiting demonstrate that canopy management decisions in the 2nd and 3rd years will determine whether overcropping and poor fruit quality result in the 4th and 5th years when the trees are most at risk of losing the balance between vegetative and fruit growth. That is, before the first flowers and crop are even seen (potentially, the 3rd year), future crop loads must be envisioned throughout the anticipated canopy in order to make pruning and training decisions that are critical to balancing future cropping levels in year 4 and beyond.

Precise placement of scaffolds and fruiting shoots on young trees can be accomplished by heading cuts to create branching, by pre-budbreak use of Promalin to induce lateral buds to elongate into shoots, by selected notching or scoring of the bark above lateral buds targeted for elongation with a small sawblade, or by removal of all lateral buds except those targeted for elongation.

Heading cuts tend to delay fruiting and moderate subsequent floral bud or spur development, which has some advantages for precocious, productive rootstocks. However, the new shoots that result from heading cuts tend to be vigorous, have acute angles, lack precision in their placement or orientation and usually are clustered near the site of the heading cut (vs. being distributed widely below the cut). Where spring temperatures are warm and fairly uniform, Promalin applied in a paint can induce a high level of lateral shoot elongation over a wide region below the terminal, generally with wide angles and horizontal growth patterns. However, cool weather following application may render Promalin inactive. Further, shoots that are induced by Promalin can lack precision in their placement or orientation, with greater shoot formation often near the terminal or on the side of treated scaffolds having southern exposure. When Promalin works too well, the high number of resulting shoots may be excessively weak and/or require thinning out by follow-up pruning.

Two techniques that are more intensive, yet generally result in more precise placement of limbs, involve selecting the exact bud to become a future shoot.

The first induces elongation by cutting through the bark and cambium just above the targeted bud to the wood, thereby releasing it from the inhibitory flow of natural plant hormones from the terminal which normally suppresses growth of lower buds. This is done from the “greentip” stage of bud swelling through budbreak, resulting in precisely placed shoots of generally wide angle.

The second induces elongation by removing all or most competing buds, leaving only those buds that are desired for development into new shoots. This is also done from “greentip” stage through budbreak or slightly beyond, resulting in precisely placed shoots that tend to be a bit more vigorous (with somewhat less obtuse angles) than those from notching. This technique reduces early leaf area due to the removal of all other buds destined to break but not elongate; however, it also reduces excessive early spur and fruit formation on precocious rootstocks since non-elongating growing points generally become reproductive the following year. Both of these techniques have some risk of increasing bacterial canker infection where canker

### TABLE 2

**Cherry rootstocks in the 1998 North American NC-140 regional project trial (Kappel et al., 1998), listed by experimental test number and by cultivar name, as appropriate.**

Mazzard seedling, Mahaleb seedling
Tabel Edabriz
Giessen [Gi] 148/1 (Gisela 6), 148/2 (Gisela 5), 148/8 (Gisela 7), 195/20, 209/1, 318/17, 473/10 (Gisela 4)
Weiroot (W) 10, 13, 53, 72, 154, 158
P-50

is prevalent due to variety susceptibility and spring climate.

As the canopy architecture of the young cherry tree fills its orchard space and cropping approaches mature levels, the focus of management continues to be on balancing crop load and vigor while periodically renewing fruiting shoots to distribute young wood and large leaves throughout the canopy. While experience with mature sweet cherry orchards on dwarfing, precocious rootstocks is practically nonexistent due to the their recent availability and adoption, one may postulate the importance of a few fundamental management techniques. Since sweet cherry fruit growth occurs over a relatively short timeframe (~60 days following bloom), early fruit growth is very dependent upon stored carbon and nitrogen reserves. Late summer or early fall fertilization (such that new growth is not stimulated or cold acclimation delayed) is probably more important to early fruit growth than spring fertilization. Thinning cuts to promote light distribution throughout the canopy following harvest are likely to be critical for maintaining a good distribution of both flower buds and storage reserves throughout the canopy. Heading cuts tend to reduce excessive spur formation and stimulate new shoots and greater leaf area close to existing spurs, helping to maintain the balance between fruiting and shoot growth.

Few, if any, comparisons of different canopy architectures suitable for high density sweet cherry orchards have been documented. In research trials at WSU/Prosser and in collaborative trials in commercial PNW orchards, productivity of intensive cherry orchards with various canopy architectures has been studied through the 6th year (7th leaf). In general, thus far no one specific canopy architecture has been clearly superior in terms of sustainable productivity and fruit quality. Rather, the differences in management techniques have tended to dominate the cropping results. Training systems that incurred the least amount of pruning (e.g., some central leader/spindle-type systems, a trellised palmette system) generally have had the highest yields but the smallest fruit size. Training systems with a higher proportion of pruning, particularly heading-type cuts (e.g., multiple leader/bush architectures), generally have had lower yields but larger, sweeter fruit (Lang and Ophardt, 2000).

As the trees have reached maturity and filled their space, differences in productivity have decreased even as some differences in fruit quality have continued due to prior histories of crop loads that were allowed to become unbalanced with vegetative growth. Table 3 depicts the average yield/tree and average size/fruit of a 5th year Bing orchard in Pasco that has had minimal heading cuts and two consecutive years of overcropping, compared to a similar orchard in Moxee planted at the same time but subjected to more heading cuts and lower earlier yields that promoted a better leaf area distribution. In the latter orchard by the 5th year, the non-precocious trees on Mazzard were still yielding significantly less than the comparable trees in Pasco, but the precocious trees on Gisela 5 and 6 had total yields comparable to the same trees in Pasco and fruit size was as much as 40% larger, presumably due to a better current and prior balance between vegetative and reproductive growth. In both orchards, the precocity of trees on Gisela 5 and 6 was orders of magnitude higher than on seedling Mazzard.

## CONCLUSIONS

Intensive sweet cherry orchards are clearly on the horizon for progressive growers like those of the IDFTA. While the most important component of such intensive systems, vigor-controlling precocious rootstocks, is now available and selection is expanding, the other components of the puzzle have yet to be studied extensively by tree fruit scientists or tested widely in commercial orchard settings. Much will be learned during the next 5 years with regard to basic pruning techniques, canopy architectures, crop load limits and fertility management of today's common variety/rootstock combinations. Tomorrow continues to hold the promise of better information about matching these new rootstocks to particular varieties, soils and climates.

## TABLE 3

**Average yields and fruit size of 6th leaf (5th year in the orchard) Bing sweet cherry on Gisela 5, 6, and Mazzard seedling rootstocks, managed by commercial growers in Pasco and Moxee, Washington.**

| | Pasco Orchard | | Moxee Orchard | |
|---|---|---|---|---|
| **Architecture:** | **Dual leader 'V' trees** | | **Multiple leader "bush" trees** | |
| **Pruning:** | **Mostly thinning cuts to promote vertical growth, early cropping, light distribution in canopy** | | **Mostly heading cuts to promote bushy shoot growth, thinning cuts for light distribution in canopy** | |
| | **Yield (kg/tree)** | **Size (g/fruit)** | **Yield (kg/tree)** | **Size (g/fruit)** |
| Mazzard | 10 | 8.9 | 4 | 9.3 |
| Gisela 5 | 28 | 6.0 | 23 | 9.8 |
| Gisela 6 | 28 | 6.5 | 27 | 10.2 |

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