

FINAL PROJECT REPORT**WTFRC Project Number:** CH-04-410**Project Title:** High Density Orchard Management**PI:** Matthew Whiting**Organization:** WSU-IAREC**Telephone/email:** 786-9260/mdwhiting@wsu.edu**Address:** 24106 N. Bunn Road**City:** Prosser**State/Province/Zip** WA/99350**Cooperators:** Donald Peterson, USDA-ARS; D. Hayden, B. Harris, L. Lancaster, D. Allan**Budget History:**

Item	Year 1: 2004	Year 2: 2005	Year 3: 2006
Salaries	6199	6301	6553
Benefits	1736	1953	2031
Wages	6000	7000	8000
Benefits	960	1120	1280
Equipment			
Supplies	2000	2000	2000
Travel	1000	1000	1500
Miscellaneous			
Total	17895	19374	21364

OBJECTIVES:

1. Develop and evaluate novel production systems including specific training/pruning strategies, cultivars and rootstocks that improve labor efficiency and yield excellent quality fruit
2. Develop and refine training strategies that facilitate mechanical harvest and/or platform assist of sweet cherries for the fresh market.
3. Continue to evaluate the effect of Ethephon on fruit quality, maturity, and retention force of different cultivars
4. Model tree vegetative and fruit growth in relation to genetic and environmental factors
5. Identify grower cooperators to participate in Competitive Orchard Systems 2015 and initiate high density research plantings with growers.

SINGIFICANT FINDINGS:

- Ethephon applications did not elicit a reduction in fruit-pedicle retention force or fruit firmness in all varieties
- Ethephon induced fruit softening is not problematic for mechanical harvest systems nor characteristic of all varieties
- Ethephon did not advance maturity in all varieties
- Ethephon applications to Bing should be made 2 to 4 weeks before harvest
- Skeena may be harvested mechanically without application of Ethephon
- Bing and Tieton appear better suited for stemfree harvest than Benton and Chelan
- early growth of high density orchards is affected by scion variety, training system, and rootstock
- the relative importance related to tree vigor/growth in our experimental orchard is: scion variety>training system>rootstock
- Bing and Tieton were the most vigorous, Sweetheart and Chelan were the least vigorous
- high yields of excellent quality fruit can be grown within angled fruiting wall orchard system
- in our high efficiency orchard system, 4th leaf Skeena yielded ca. 8.4 tons/acre of fruit that was 10.5-row or larger
- highest fruit growth rates occurred during stage I of development
- alternating trees from E to W was more productive system than splitting tree into the traditional Y-trellis system

METHODS:

High density orchard management. A new high density orchard was planted in 2003 at about 5' within row spacing and 14' between row spacing for a density of approximately 580 trees per acre. It is comprised of cultivars that ripen at approximately weekly intervals (Chelan, Tieton, Bing, Skeena, and Sweetheart) on Gisela 5 and Gisela 12 rootstocks. This block is being trained to a y-trellis system in two different ways: (1) trees headed after planting at approximately 20" and alternately tied to opposite sides of the trellis (*i.e.*, three leaders per side in a fan shape) and, (2) trees headed at

approximately 30” and split on the trellis (*i.e.*, two leaders, one per side in a central leader shape). The interactions among training method, cultivar, and rootstock will be evaluated. In the first few years, tree growth and precocity data will be collected, including, trunk cross-sectional area, shoot length, number of laterals, flowering, fruit yield and quality.

Vegetative and fruit growth (when present) in this new orchard will be monitored weekly and related to locally recorded environmental data. Solar radiation, relative humidity, wind velocity, soil and air temperature, and soil water content will be continuously and intensively monitored in this orchard by three AgWeatherNet weather stations located approximately 100’ apart. The ultimate goal of this experiment is to model reproductive and vegetative development of distinct germplasm to environmental phenomena (*e.g.*, fruit development, harvest date, and full bloom by degree days/heat units).

A new high density (*ca.* 530 trees/acre) of Tieton on Gisela 5 was planted in 2003. In this block, trees will be trained to either a central leader or multiple leader bush system. Growth, precocity and fruit quality will be monitored and compared between systems. This research program has shown that excellent quality fruit can be grown on a variety of training systems. Therefore, the costs associated with production on these various systems may be an important factor in determining their commercial potential. Each different system will be evaluated for labor efficiency by timing harvest and pruning events on a minimum of 50 trees per system.

Mechanical harvest efficiency. Mature Bing trees trained to various systems (*e.g.*, y-trellis, bush, central leader) will be harvested mechanically. Entire rows will be harvested and efficiency will be documented as harvesting time per tree and the number of impacts per tree. In addition, the efficiency of fruit harvest will be evaluated by collecting and weighing: (1) all fruit remaining on the tree (*i.e.*, those fruit not removed by the harvester), (2) all fruit on the ground (*i.e.*, those fruit removed but not collected), and (3) all fruit in bins (*i.e.*, ostensible yield). Quality of fruit subsamples harvested from each system will be evaluated, in comparison to stemless fruit harvested by hand and control fruit (with stems, harvested by hand), by an independent lab (Allan Bros.) for bruising, pitting, mechanical damage, and stem-end tears at the time of harvest and after two weeks in cold air storage.

Ethrel effects. Whole trees will be treated with Ethrel approximately 14 days before harvest. Cultivars to be treated include Chelan, Tieton, Bing, Benton, Lapins, and Selah. The following data will be collected on each of 40 fruit randomly harvested just prior to application and at 2 – 3 day intervals following application until commercial harvest: fruit retention force, fruit weight, soluble solids, firmness, and color. Fruit from treated trees will be compared to fruit from untreated control trees.

RESULTS AND DISCUSSION:

Varietal response to Ethephon In the first two years of this research trial, we evaluated the response of many varieties to Ethephon applied at a single rate (3 pt/ac) and a single timing (*ca.* 14 d before harvest). Not all varieties responded similarly to the application of Ethephon. In 2005, Ethephon reduced pedicel-fruit retention force (PFRF) of Bing, Chelan, and Tieton but not of Benton. Tieton and Bing exhibited significantly greater reductions in PFRF than did Chelan. In 2004, each variety tested showed significantly reduced PFRF in response to Ethephon. In 2005, for those affected varieties, the average reduction, measured about two weeks after application, was 35%. Bing and Tieton responded similarly, exhibiting a *ca.* 41% reduction and Chelan was less-affected – PFRF was only 24% lower in Ethephon treated trees. Regardless, for no variety did Ethephon reduce PFRF below the target of 400 for ideal removal by the mechanical harvester. For those treated with

Ethephon, the lowest values were for Bing at 540 g and the highest were from Benton at 850 g. Our data show that stem retention (% fruit which were removed at the pedicel-spur abscission zone) was high (30% - 90%). Even for Bing, at 540g PFRF, ca. 30% of fruit retained their pedicel. Without Ethephon treatment however, pedicel retention was 90%.

In 2006, we conducted a more detailed analysis of PFRF vs. rate and timing of Ethephon for Bing and Chelan. In general, Chelan PFRF was unresponsive to Ethephon (Figs. 1 and 2). Irrespective of timing and rate of Ethephon, Chelan PFRF did not vary significantly from the untreated control levels. At harvest, in our timing trial on Chelan, mean treated PFRF was 0.72 kg vs. 0.84 kg for untreated. In addition, PFRF at harvest from the rate trial was 0.73 kg across rates (which were similar) vs. 0.79 kg for untreated. The inconsistent response between years with Chelan exemplifies the vagaries of bioregulator research in general and underscores the need to develop/utilize genotypes which naturally develop low PFRF at harvest. In contrast to Chelan, Bing PFRF was reduced significantly in response to Ethephon applications (Figs. 1 and 2). In a rate trial, Bing PFRF at harvest was related negatively to Ethephon rate ($r^2 = 0.74$, data not shown). Mean PFRF across rates was 0.33 kg vs. 0.68 kg for the untreated fruit. This ca. 50% reduction is similar to the reduction in PFRF recorded in previous years. In an Ethephon timing trial on Bing, again, PFRF was reduced significantly – mean values for treated, across timings was 0.39 kg vs. 0.68 kg for the untreated. Single applications of Ethephon applied at 4, 3, and 2 weeks before harvest were equally effective at reducing PFRF (Fig. 2). However, applying Ethephon 1 week before harvest did not reduce PFRF below the 400 kg limit for optimum removal for mechanical harvest.

Bing fruit quality was not affected significantly by rate of Ethephon. Compared to quality at the time of Ethephon application in our rate trial, fruit soluble solids increased similarly across all rates (ca. + 31%). Untreated fruit soluble solids increased similarly over the two week period (+ 28%). Average fruit weight increased by ca. 22% irrespective of rate, whereas untreated fruit increased in weight by 18% over the same period. Firmness of treated fruit declined by ca. 11% to 263 g/mm, again, irrespective of rate of Ethephon. Untreated fruit firmness declined over the same period by 16%, to 281 g/mm, a similar reduction to the treated fruit. Chelan fruit quality responded similarly – we recorded no quality parameter that was affected significantly by Ethephon at rates up to 5 pt/ac. For example, firmness of treated fruit, irrespective of rate declined by ca. 26% to 272 g/mm over the two week period between Ethephon application and harvest. Untreated fruit exhibited a similar decline of 27% to 270 g/mm over the same period. These results contradict slightly results from previous years in which we documented a slight but significant reduction in Bing and Chelan fruit firmness in response to Ethephon (ca. 17% reduction, from 416 g/mm to 347 g/mm in 2005). However, fruit from those previous trials were much firmer overall, this may affect the response to Ethephon. It should be noted however, that, in the current trials and previous research, for no variety/rate/timing did fruit firmness decline to levels which would preclude their being marketed fresh. Therefore, Ethephon induced fruit softening is not problematic for mechanical harvest systems nor characteristic of all varieties. Tieton, for example, though not evaluated in 2006 has consistently shown reductions in PFRF in response to Ethephon treatment without any associated loss of firmness (see continuing reports from previous years). While the different responses to Ethephon are not fully understood, we can select varieties better-suited for mechanical harvest based on their response to Ethephon. Overall, these results suggest that Bing and Tieton are better suited for mechanical harvest than the other varieties we have tested (e.g., Chelan, Benton). However, ideally new varieties with inherent low PFRF at harvest must be identified and utilized in future mechanical harvest systems. At WSU-Roza experimental orchards, we are evaluating several candidate varieties which without Ethephon application, possess low PFRF (e.g., Skeena, Ambrunes).

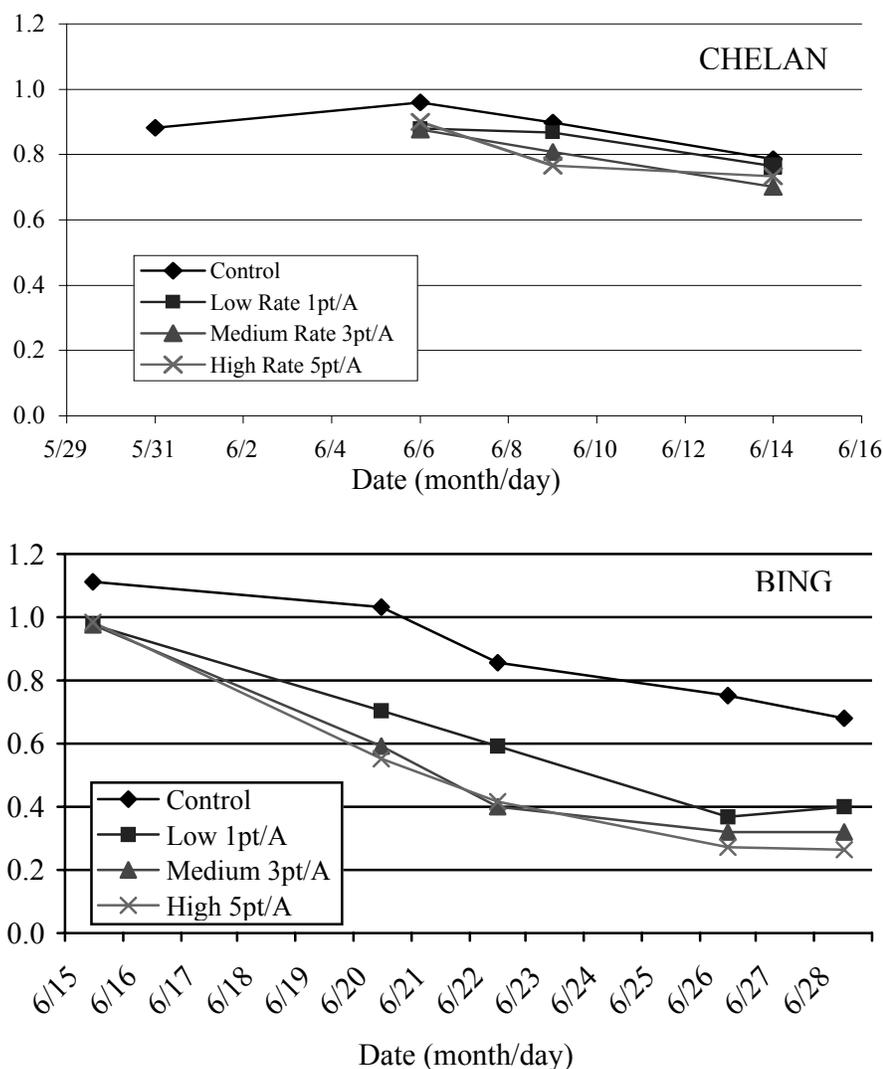


Figure 1. Effect of rate of Ethephon application (applied ca. 14 days before harvest) on pedicle-fruit retention force (kg) for 'Chelan' and 'Bing' sweet cherry. 'Chelan' harvest was on 14 June. 'Bing' harvest was on 29 June. The range between 0.2 kg – 0.4 kg is ideal for mechanical harvest.

Mechanical harvest trials In 2004 we negotiated and signed an agreement with USDA-ARS to transport and house their experimental mechanical harvester in Prosser for a 3-year duration. We will continue to consult with Dr. Peterson and industry cooperators as we refine orchard systems for maximum harvest efficiency. . In 2005 we received funding (ca. \$40k) from the IMPACT center at WSU to study the efficiency of the mechanical harvest system, its impact on fruit quality, and consumers' perceptions of stemfree cherries. These projects will complement each other well and lead to a more efficient and rapid analysis of the mechanical harvest system. In 2006 we harvested Skeena mechanically and observed complete removal of fruit without any application of Ethephon. 'Skeena' PFRF declined linearly with fruit ripening and maturation and reached levels sufficiently low (ca. 0.42 kg on 11 July) to facilitate mechanical harvest (Fig. 3). Mechanically harvested Skeena fruit possessed a complete and dry pedicel-fruit abscission zone and we did not observe any 'leaking' of juice from the fruit. This variety appears to be well-suited for mechanical harvest.

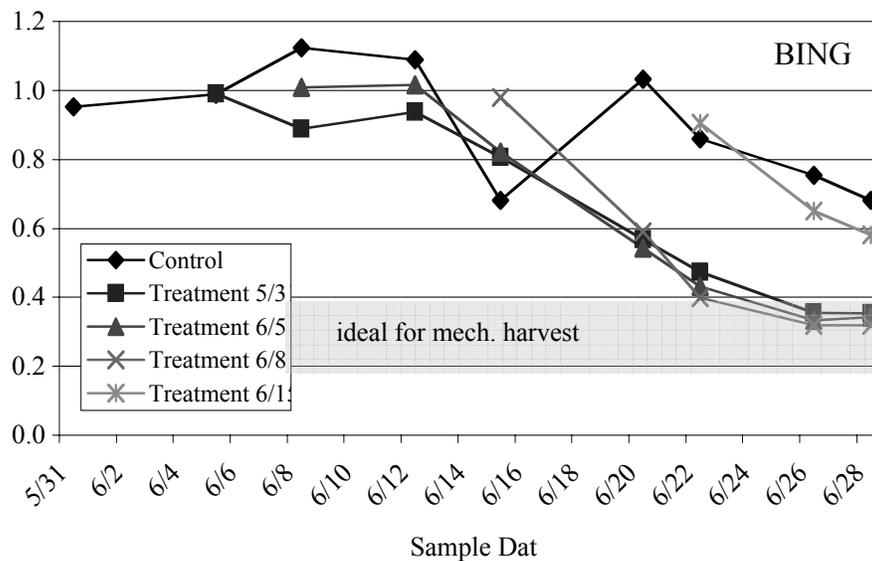
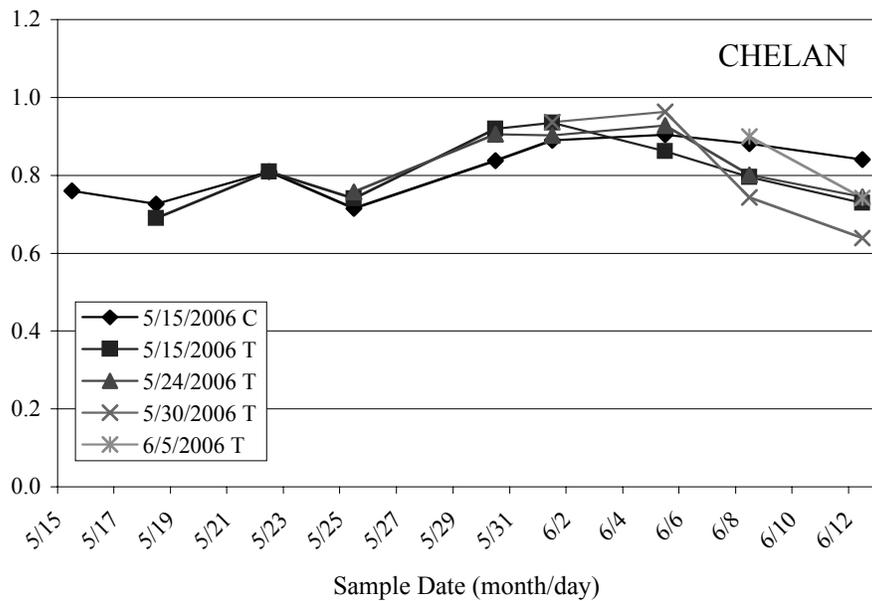


Figure 2. Effect of timing of Ethephon application (at 3 pt/ac) on pedicle-fruit retention force (kg) for 'Chelan' and 'Bing' sweet cherry. 'Chelan' harvest was on 14 June. 'Bing' harvest was on 29 June. The range between 0.2 kg – 0.4 kg is ideal for mechanical harvest.

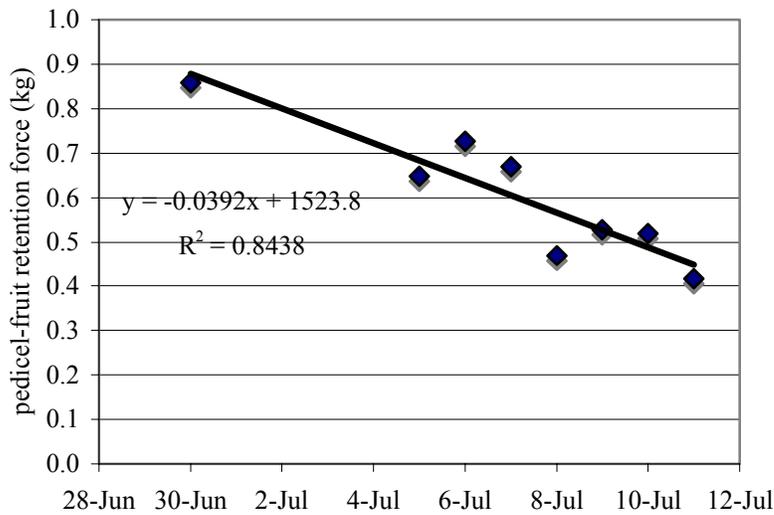


Figure 3. Trend in natural (i.e., without Ethephon) decline in pedicel-fruit retention force of ‘Skeena’ sweet cherry. Fruit were mechanically harvested on 11 July.

High density orchard management In 2006 we continued to refine training concepts to fit the mechanical harvest system and future integration of other mechanization (e.g., platforms). The original concept remains unchanged – develop homogeneous orchard systems comprised of fruiting ‘walls’ rapidly and efficiently while optimizing fruit yield and quality. This approach aims to create a system in which training is systematic throughout. The repeating vertical fruiting uprights become ‘management units’ – structures to be evaluated and treated similarly for crop load management, etc. In the current systems trial we again measured growth and fruiting characteristics of ‘Chelan’, ‘Tieton’, ‘Bing’, ‘Skeena’, and ‘Sweetheart’ on ‘Gisela 5’ and ‘Gisela 12’ rootstocks. From our ongoing studies of training systems for mechanical or possibly, pedestrian or platform-assisted harvest, we have developed the following principles:

- two single-layer fruiting walls per row in a Y-configuration (one/side)
- ca. 60 – 80° between planes (each plane ≈ 50°- 60° from horizontal)
- each plane consists of vertical fruiting uprights (4 – 7/tree and side though this varies with tree spacing)
- fruiting uprights spaced ca. 18” apart
- horizontal growth is eliminated
- fruiting limbs are renewed below first wire (ca. 28 in) with dormant heading cuts
- upright growth to a height of at least 50 cm (≈ 20 in) above soil

In this orchard’s 4th year, yield increased significantly versus 2005. This was predicted due to the dramatic increase in two-year-old fruiting wood present in the 4th leaf trees vs. 3rd leaf trees. Indeed, mean yield per tree across architectures, rootstocks, and varieties was 12.3 kg in 2006 vs. 2.7 kg in the previous season. At 587 trees/ac, this translates into ca. 7.2 tons/ac in 2006. This is excellent productivity for a young orchard and highlights the precocity of the Gisela rootstocks as well as the potential productivity of the Y-trellis system. Overall, rootstock had only a slight impact on productivity. Gisela 12 was about 14% more productive than Gisela 5-rooted trees. This is likely due to greater vigor of Gisela 12 and therefore more fruiting spurs on those trees. In addition, training trees to alternating east and west sides of the trellis vs. the traditional Y-trellis resulted in approximately 10% higher productivity in 2006. Neither rootstock or training system however

affected tree yield as much as variety did. In 2006, 'Bing' was the most productive variety, yielding slightly less than 22 kg per tree (data not shown). The least productive variety was 'Tieton', yielding 6.3 kg per tree. 'Chelan', 'Skeena', and 'Sweetheart' were intermediately productive. The 21.9 kg/tree of 'Bing' translates into ca. 12.8 tons/ac. This again, highlights the potential productivity and precocity of this orchard system. The lowest yielding combination of 'Tieton'/'Gisela 12' yielded 3.2 kg/tree, or ca. 2 tons/ac.

It is not surprising that the lowest yielding system also yielded fruit of the highest quality (data not shown). This research program has documented clearly the negative relationship between fruit yield (canopy fruit-to-leaf area ratio) and quality. 'Tieton' fruit were the largest at 12.1 g/fruit and 100% were 10.5-row and larger. The poorest quality fruit were harvested from 'Chelan'/'Gisela 5' trees – 5.5 g/fruit, 20% smaller than 12-row, though the low fruit soluble solids (ca. 13 °brix) suggests that these fruit were prematurely harvested and had not fully sized. However, 'Chelan' does not possess the genetic potential for size that 'Tieton' does. 'Chelan' on 'Gisela 12' were significantly higher quality fruit (6.3 g, 24% 10.5-row+), suggesting that poor quality on 'Gisela 5' was related to insufficient carbohydrate supply to developing fruit. Indeed, no attempt at crop load management was made on 'Chelan'. In 2007 and beyond, crop load management via chemical blossom thinning and post-bloom thinning will be utilized to balance crop load with low vegetative vigor of this combination. The scion/rootstock combination yielding the most 10.5-row and larger fruit was 'Skeena'/'Gisela 12' – these trees bore ca. 15 kg/tree, of which 92% was 10.5-row and larger (i.e., 14.3 kg/tree). At 587 trees/ac, this translates into ca. 8.4 tons of 10.5-row and larger fruit per acre, in the 4th leaf. The next most productive combinations of premium quality fruit (i.e., ≥10.5-row) were 'Bing'/'Gisela 12' (6.5 tons/ac), 'Tieton'/'Gisela 5' (ca. 5.5 tons/ac).

Clearly, this orchard system design is precocious, productive, and can yield large quantities of large fruit. At this stage, the greatest challenges for most scion/rootstocks is crop load management to prevent over-production, and vigor control to prevent excessive intra-canopy shading. We will begin renewal of fruiting wood in this orchard this winter for most combinations. By design, this is a simple operation comprised of aggressive dormant heading cuts to remove the most vigorous fruiting upright limbs below the first wire (i.e., just above the point of origin of the limb). It will be critical to adopt an aggressive renewal strategy to maintain excellent light distribution, orchard productivity, and high fruit quality.

Since planting and training this test orchard, we have developed an alternative, novel approach for creating either upright or angled fruiting walls. This new approach may facilitate orchard establishment and creates an architecture comprised of two horizontal, permanent scaffold limbs from which fruiting uprights originate (Fig. 4). Similar to the previous configuration, renewal is accomplished via dormant heading cuts removing all but a short stub from each upright. We anticipate that the naturally vigorous upright growth in response to such pruning will expedite the renewal process. We have established in 2006 a new orchard to this design. It is comprised of Bing, Rainier, and Selah on Gisela 6 rootstock and spaced at 4' × 15' and trained to angled fruiting walls at 70° from horizontal.

Vigor varied among varieties most notably in 2006, but also by rootstock and training system. Overall, vigor was lower than in 2005. This is likely due to the significant increase in tree productivity (ca. 6-fold increase in yield vs. 2005) and competition between fruit growth and vegetative growth. Tieton was again the most vigorous variety with ca. 44 cm mean length of new shoots. Bing was similar to Tieton (43 cm). Chelan, Skeena, and Sweetheart were all similar and significantly less vigorous. Mean shoot length for these varieties was ca. 30 cm. This abating in vegetative extension growth will be important for many combinations to minimize intra-canopy shading at the high tree density of the orchard. However, it will be important to keep moderately high

vigor in this orchard to keep canopy leaf area high. In 2006, Gisela 12 was only slightly more vigorous (+ ca. 8%) than Gisela 5, across all varieties. For many scion rootstock combinations, particularly for Tieton and Bing on Gisela 12, trees have completely filled their space and renewal pruning will begin this winter. The least vigorous combinations are Sweetheart and Chelan on Gisela 5. Only with hard dormant heading and prudent water, nutrient, and crop load management will these trees fill their space. Clearly, early growth (first – third leaf) is critically important as trees fill their allotted space and develop future bearing surface. These combinations may never exhibit sufficient vigor to become commercially viable. We will follow the relationships between vigor and precocity and productivity closely in the next few years as some combinations have filled their space and others have not.

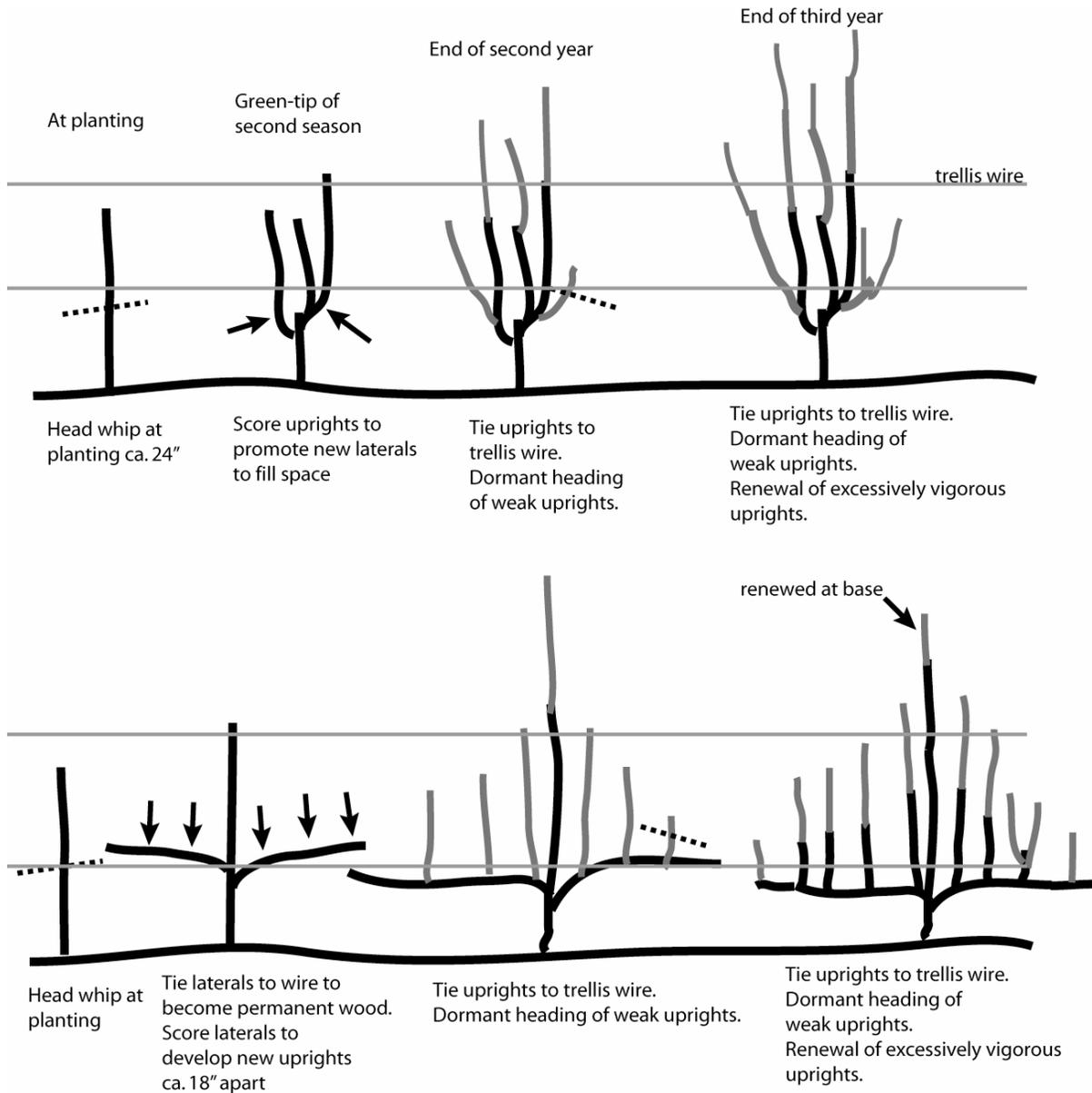


Figure 4. Brief comparison between proposed systems for establishing angled/upright fruiting walls.