Labor Management in Modern Orchards and Opportunities for Mechanization

Karen M. Lewis, Washington State University Extension

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The most important thing you can do to manage labor-related risks in tree fruit production is to commit to simple, narrow, accessible and productive orchard systems. When established with the right genetics in the right location, these systems set you up for high early yields and high yields at maturity and high quality fruit from the top of the tree to the bottom of the tree over the life of the orchard. Transitioning to high density narrow architectures will put growers in the best position to take advantage of new labor reducing/ fruit quality enhancing technologies as they are developed. Orchard operations that have at least a portion of their acreage planted to simple and narrow canopies are more competitive for labor, contract services and warehouse relationships. The labor that is hired can be successful with fewer skills and experience if you limit the complexity of the system and the variability within the system. Blocks trained to these systems are both people and machine friendly. And interestingly, sunlight and humans have about the same reach – light becomes limiting and arms run short after penetrating a canopy to a depth of about 1 meter.

<u>Simple, Narrow, High Density</u>
Canopy thickness: 20 - 90cm
Tree height: 2.7 to 3.5m
Row spacing: 3-3.5m
Tree spacing: 0.75 – 2.5m depending on system

Labor –related risks

Labor –related risks in tree fruit production are many but the most prevalent and usually the most critical are; 1) getting the job done 2) getting the job done on time and 3) getting the job done correctly. Basic best management practices and labor relation guidelines have in the past been sufficient to get the right people for the right job at the right time. Things like being respectful, asking for input, paying competitive wages, having incentives in place, being open to negotiation are standard operating procedures on competitive orchards in 2015. The economy of the world has changed and this has changed what employees need to get from employment and what employers need to get from employees. “Workers Needed” spray painted on the side of a bin placed on the highway is no longer sufficient to attract the labor force we need. It is not a “sign” of a competitive orchard. A common thread in the global fruit growing community is labor shortages and increasing labor costs. From South Africa to South America, from the South Pacific to Asia, Europe to the Americas, we are all in this together. Higher wages through pay scale and work load, incentives to stay for entire season, on – farm housing, - these are just a few ways to be competitive in recruiting and retaining a crew. We must engage workers in the process of growing quality fruit – explain why XYZ needs to happen, why it needs to happen a specific way and why it needs to happen within a specific time period. Don’t confuse how with why… they are not the same.

So, we can regulate and educate and move people all around the globe but at the end of the day, this will not lead to a sustainable operation or industry. We need to engineer solutions to mitigate our labor-related risks and we need to optimize the new normal: high early yields, high mature yields, reduced variability within the orchard and high fruit quality. The time is ripe to engineer solutions to mitigate our labor-related risks. I believe with available and emerging genetic selections and horticultural

practices, and off the shelf technologies, we are on a shared path to change the way we grow and harvest perennial tree crops. In Washington State, with $35-40K / 0.4ha invested at year 3, the risks are both high and concentrated. The orchard system drives the opportunity to mechanize orchard operations. And I would caution letting mechanization or engineering drive the orchard system.

"We have invested in and succeeded with high density narrow systems. We now need the engineering solutions to optimize the horticultural system and our investment" – Scott McDougal, McDougal and Sons, Wenatchee, WA.

Mechanization

With current labor shortages and demographic trends, there is renewed interest in developing engineering solutions for perennial tree fruit production. There is a lot of time and money being spent in both the public and private sector to develop machinery, automated systems and tools. Small market size limits the number and size of companies that are working on our unique needs and it limits the amount of money available to take a concept through research and development and on to product commercialization. Fortunately, there are individuals and small companies willing to take the risk and expend the energy to undertake the process. When I scan the R and D arena in both the public and private sectors, I see more effort directed at tools for simple narrow canopies than for tools that would be a good fit in standard 3D or complex architectures even though the vast majority of all species of perennial tree fruit worldwide are trained to 3D or rather complex architectures.

There are systems being developed that won't see the light of day because of lack of robustness, poor design and most importantly poor return on investment. The adoption of technologies for mechanization requires a positive return on investment, proven reliability and local serviceability. The equipment must be safe, simple and scalable. Successful integration of the technology requires a desire to make it work, and it needs to be the right fit between orchard system, people, machine, and task.

When surveyed about mechanization, North American fruit growers ranked mechanical harvest as the number one need for mechanization. Thinning, pruning and mowing followed mechanized or augmented harvest. Growers also report that while you need a positive return on your capital equipment it might not always be found in increased efficiencies. In the case of mechanical thinning, pruning and harvest, there is value in removing ladders from the operation and that value can be captured in being able to cast a wider net for employees and from mitigating the risks associated with ladder injuries and medical claims.

Point to consider: The machine, the tool, the method, the technology must make you money.
Two schemes: Increased productivity that results in a lower per unit cost; or
Increased fruit quality that results in a greater return.

Mobile Platforms

Mobile platforms, including harvest assist platforms, have been around for several decades but for the most part the European labor crisis in the mid 60's was the event that really pushed the manufacturing and tree fruit production sectors to design, manufacture and use platforms for multiple tasks. Platform use for thinning and pruning has been tried and abandoned many times for several decades in Washington State. Today – most orchards in Europe use platforms for some or all tasks. Today – in Washington State less than 20% of our total acreage is suitable for platform work. However, I think it

would be accurate to report that 80-90% of all apple acreage planted in the last 5 years is planted to a simple, narrow canopy and therefore accessible to workers on a platform. To clarify – not all of this newly established acreage is suitable for all platforms or other labor assist/ labor saving machines. In some cases tree row spacing is too narrow for currently available equipment and/ or trellis systems limit access to machines that require clearance. "They" didn't get the memo!

In large part, platforms are built, bought and used for two primary reasons: To increase worker productivity via increased efficiency and/ or to eliminate injuries and related claims associated with ladder use. In addition it has been reported that you can improve fruit quality through enforced quality control measures when you group people on a platform. What has been proven time and time again is that if you offer employment that does not require ladder use, you cast a wider net over the workforce.

Platforms have two jobs: They position workers in the top third of the canopy without ladders and they set up the top third of canopy for additional labor assist mechanization or automation. If you use a platform to thin, prune, tie etc. the top third of the canopy than you should be able to at the very least, harvest the top third of the tree with harvest assist platforms. Platforms come in all sizes, colors and price points. I want reliable, quality materials and construction, high end components, local parts, simple and safe. Platforms that are designed for multi-use, self-steering and have multiple levels are now standard in the Pacific Northwest.

Removing ladders and putting the right people and the right number of people on a mobile platform requires attention. You need to have a near perfect fit to obtain the efficiencies you need. You must carefully select the right number of people and the right people to work together and you need a pay system that gets the job done, gets it done on time and gets it done correctly. I have many tales of two platforms and there are many platforms that were retired early and are rusting away in the equipment yard. Integration is critical and more people have failed than succeeded.

Point to consider: The success of intensively managed orchards (precision orchard management) can be correlated to execution in the field. Success relies heavily on getting the job done, getting it done on time and getting it done correctly.

Platform Efficiencies

Apple – high density, tall, narrow systems

Activity	Efficiency gain platform over ladder
Pruning	+ 25-40%
Tree Training	+ 40-60%
Bloom Thinning	+ 25-45%
Green Fruit Thinning	+ 35-45%
Pheromone Placement	+ 75%
String Tying	+ 65-116%
Trellis Construction	+15-20%

Point to consider*:* The number of ladder sets dictates the amount of efficiency gained with platforms.

REASONS FOR USING PLATFORMS		REASONS FOR NOT USING PLATFORM	
Reason rated "very important"	**Frequency**	**Reason rated "very important"**	**Frequency**
Increased worker productivity	33	Purchase price too high	110
Improved worker safety	22	Maintenance and repair costs too high	44
Ease of operation	18	Limited availability	28
Purchase cost is recoverable	19	Orchard architecture not suitable	152
Improved quality of work	21	No improvement in productivity	62
		Steep slopes	82

Gallardo et al 2010

Point to consider: *Do as much work from the ground as possible.*

Mechanical Pruning

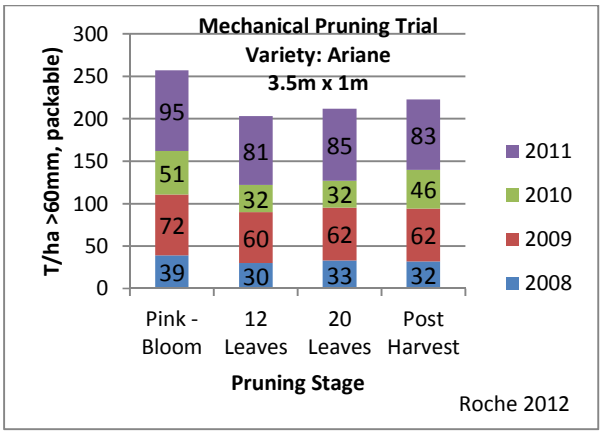
In recent years, Europe has been experimenting and at varying levels adopting mechanical pruning in fresh market apple production. Mechanical pruning is considered a requirement for the development and maintenance of the true fruiting wall architecture. The recommended scheme is to use loppers at dormant stage in establishment years 1-2, 1-3, 1-5 depending on your location, site, vigor etc. and then use the mechanical "hedger" beginning at full production and for the life of the orchard. Manual pruning with loppers – at dormant will be needed to manage bud count and remove wood/ limbs that get too large. Mechanical hedgers can be used with different results at dormant, Pink, 8-12th leaf stage, the 20th leaf stage and post-harvest.

Sickle bar and circular saws are both used with a slight preference to sickle bar in blocks where there is little or no wood over 3cm. In blocks with more than the occasional piece of wood larger than 2.5 - 3cm, the circular saw might be preferred. Single bar and double bar are both common place however most commercially available hedgers are single bar. A few companies such as Fruit Tec and Gillison have designed their systems for both vertical and horizontal operation.

Mechanical thinning was researched and commercially used in the U.S. in the 1960's and 70's with disastrous results. Terrance Robinson of Cornell University points out that orchards in the U.S. are more suited for mechanical pruning today because of dwarfing rootstocks, calmer and better balanced trees and the structural makeup of small pendent fruiting branches.

Research results and commercial operation have been somewhat consistent in Europe and the U.S. Timing matters – dormant timing is a good option to promote shoot growth and to "set the box". Setting the box means dictating or forcing the fruiting area to be defined by hedging to a predetermined canopy depth. Eighth to tenth leaf stage has resulted in a proliferation of spurs and promotion of fruit set. In lower light conditions in the U.S., a later hedging time (20th leaf) has resulted in less regrowth and the development of flower buds on the tips of regrowth. A pioneer in fruiting wall architectures and mechanical pruning, French physiologist Roche reports that pruning a new shoot at the 12th leaf stage

results in a proliferation of inflexible spurs, enhanced floral induction and a long lasting fruiting zone. Mechanical pruning using this strategy saves 80-100 hrs. /ha/year and can increase one worker's productivity from 8ha to 12ha.



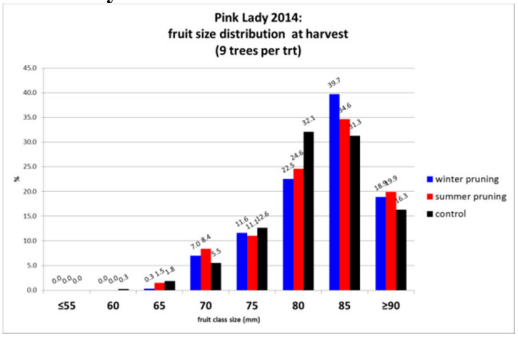
Washington Trials – Apple

- Dormant hand pruning removed 3X more wood than dormant mechanical pruning. Average wood removal by hand was 1.03kg
- Mechanical dormant pruning was 2X faster than hand dormant pruning

Pink Lady/M9-337 – planted 2012. 3 x 1m spacing

Three treatments were tested: winter mechanical pruning (March 2014), summer mechanical pruning (June 2014) and control (March 2014 - traditional hand dormant pruning).
In summer, the mechanical pruner hedged one tree in 1.78 sec, removing 0.32 kg of fresh material/tree (62.5% leaves and 37.5% wood) and an average of 9 fruit/tree.
Fruit size distribution assessment revealed that the mechanical pruning had a positive effect on fruit size in the highest size categories (85 and >90 mm equal to 3.35" and >3.54") in comparison to control. We recorded higher yields for summer timing and dormant timing by lopper when compared to dormant timing by mechanical hedger.
Fruit from trees hedged in summer showed a higher starch degradation, but lower SSC and acidity than the other treatments, while fruit from winter pruned trees were redder with higher vividness.

Pink Lady/M9-337 fruit size distribution



Pink Lady/M9-337 mechanical pruning trial: yield data (Mattawa, WA, Oct. 2, 2014).

Pruning treatments	number fruit/tree		net weight (kg) fruit /tree		TCSA (cm^2)		Avg. fruit weight (g)	Yield efficiency (kg/cm^2)	
Control	42	a	10.4	a	11.9	b	248	0.89	a
Summer pruning	44	a	10.9	a	13.7	a	251	0.82	ab
Winter pruning	34	b	9.0	b	12.4	b	261	0.74	b
Significance[1]	***		***		**		ns	**	

[1] $p<0.05$, *; $p<0.01$, **; $p<0.001$, ***; *ns*, not significant.

Washington Trials – Sweet Cherry

- Hand pruning removed 2X as much wood as mechanical pruning in 'Tieton' sweet cherry trained to the UFO system (postharvest pruning)
- Mechanical pruning was 23X faster than hand pruning (hedging and topping combined) in sweet cherry

Point to consider: The response to mechanical pruning is affected by timing, variety, tree architecture and the distribution of wood age in the existing canopy. Local research is needed to determine when and how to get the response you want.

Mechanical Thinning

Finding labor reducing technologies for fruit thinning at bloom is critical and ranks right behind harvest in several grower surveys. Bloom thinning by hand has become a standard practice with several apple cultivars, new sweet cherry cultivars and all stone fruit cultivars in Washington State. In most apple blocks, chemical thinning at bloom and post bloom followed up with green fruit thinning by hand is standard practice. In cherry we traditionally have not thinned our most common varieties. In stone fruit, bloom thinning with hands, rakes or brushes is common and is always followed up with green fruit thinning. In stone fruit, green fruit timing alone does not give us the size premium we need.
In all species – the need for a large number of people over a short time frame = high risk.

Mechanical thinning got its start in stone fruit with rudimentary rope thinners. Today we have tractor mounted string thinners and handheld string thinners. The tractor mounted systems can be used across all species and are most effective and useful where there is sufficient cord to bloom contact. You can get good to excellent results and a "dialed in" level of thinning if you take the time for thorough assessment and calibration. The tractor driver is a variable and one that needs to be sorted out. String thinners are non-selective thinners. In general they are not a stand-alone tool for thinning to a number or for placement / distribution of fruit. They are good to take bloom to 125-150% or greater.

New to the market is the Automated Ag Systems Bloom Bandit and the INFACO Electroliv or Electroflor. The handheld devices are a non – selective thinner but when you put it in the hands of a trained person, you add selectivity to the process. The other advantage of the handheld is you can penetrate canopies

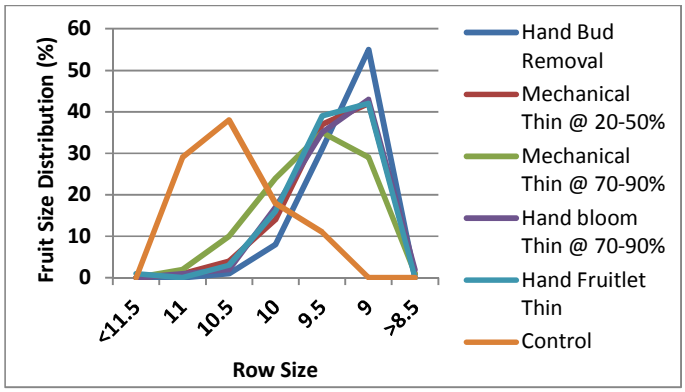
that are 3D and complicated or need to target dense bloom in multiple sections of the tree. In general they are not a stand-alone tool for thinning to a number or for placement / distribution of fruit. They are good to take bloom to 125-150% or greater.

Point to consider: String thinners are just one tool in the crop load management toolbox. In most cases it will be used with other tools such as pruning, chemical thinners, frost, and / or the human hand (bloom and / or green fruit timing) to carry out your crop load management strategy. STONE FRUIT

Sweet Cherry

The extensive planting of new prolific sweet cherry varieties and results from string thinner (Darwin and Bonner) trials in sweet cherry led to the development and validation of the handheld thinning device. There is very small acreage of cherries planted to planer canopies so opportunities to use tractor mounted thinners is very limited. In addition, Darwin/Bonner trials often resulted in over thinning and blank wood. Results were mixed across varieties when thinning was conducted at bloom but results from bud swell timing were positive. Dormant timing is "easier" on the grower and we were able to dial in the desired removal amount more successfully than when we attempted to dial in removal at bloom time. "Easier" should be qualified. If frost or a cold spring is predicted, cherry growers will not touch a thinner at this stage.

Cherry trials with the hand held INFACO have shown mixed results in some varieties. Growers are cautiously evaluating handheld use in cherries but overall, I think hand held devices will be a tool in the crop load management toolbox and become a useful tool in managing crop load in the most prolific cherry varieties grown in the U.S. Below is a fruit distribution curve for Sweetheart on Mazzard under different thinning regimes.



Stone Fruit

Tractor mounted thinners have documented success in nectarines, peaches and apricots trained to a planer system where cord to bloom contact its good. The best results are in blocks where most of the wood is short and stiff or tied to wire. Long whippy shoots are either grabbed by the cord and stripped or missed completely. In systems where trees are planted to open vase, central leader or not supported V's and quads the handhelds are a better option. Replicated and demonstration trials in commercial stone fruit orchards in the USA have shown that bloom thinning with mechanized string thinners improves fruit quality, percent of fruit in first pick, final fruit size and return bloom in stone fruits. Hand

bloom thinning in PNW stone fruit orchards costs between $1000 and $1400 / acre. Mechanical thinning with tractor mounted string thinners costs $55-60/acre. Mechanical thinning with hand held string thinners cost in the range of $250-300/acre. Added savings are captured in reduced follow up green fruit thinning times by 40-65%. In stone fruit there is a concern of late frosts, but without chemical options and the high returns for large fruit (bloom-thinned), mechanical thinning can pencil out.

Apples

In an effort to increase fruit size and ensure return bloom and mitigate biennial bearing, bloom thinning with chemicals became a standard process in the U.S. Chemical options are not easy to dial in and very often underperform or over perform. Of course this performance is affected by numerous variables such as weather, tree vigor, bloom strength and distribution, application rates and methods and so on. Apple growers have been hesitant to use tractor mounted mechanical thinners because of concern about fireblight, over thinning, non-selectivity, potential king bloom loss and reported leaf tearing. String thinners used at bloom in apples has been effective at reducing bloom by knocking off individual flowers or whole clusters. Early trials and demonstrations worked out the many variables that can be dialed in when using tractor mounted thinners in apples. What we have learned in apples thus far: 1) the variables of cord placement and cord number are less important than spindle speed and tractor speed, 2) as number of strings increase, the level of thinning severity increases 3) as spindle speed increased, the removal of the number of blossom clusters increased and the number of blossoms per spur declined, 4) spindle speeds of 200-220 rpm and 5 kph (or 220-240 rpm @ 8 kph) provided the best overall thinning response and minimized injury to spur leaves, and 5) fireblight bacteria can be transferred from tree to tree but in Washington State, 9 years out of 10 the temperatures at bloom are below what is required for active infections.

Hand held devices increase selectivity but like with the tractor mounted thinners, they are not the tool or this is not the method to precisely thin to a specified number of clusters or flowers. Although with an accurate assessment of bloom, solid weather prediction and good calibration you can get close.

A couple 2015 strategies: Mike Robinson, WA. will prune to a bud count of 1.25 in Gala, then string thin with handheld device to 50% bloom at squirrel ear and follow up with bloom thinning by hand to singles at tight cluster. He will green fruit thin as needed. Rod Farrow, NY. - in Gala he will prune to desired tree architecture with no regard for bud count. String thin bud load to 1.25-1.50, and then chemical and hand bloom thin to correct crop load and placement. His strategy for Honeycrisp is to prune to desired tree architecture and a 2.00-2.50 bud number and then lightly string thin with Darwin to encourage return bloom. He will follow up with chemical and hand thinning at bloom to correct crop load and placement. He will green fruit thin as needed.

Mechanical Harvest

Apple

Fully mechanized tree fruit harvesters are on the minds and drawing boards in public and private sector engineering and / or horticulture labs around the world. Several attempts have been made to fully mechanize harvest of apples and pears since the 1960's. Most machines have had a large industrial robotic arm and either a suction, cutting or hand end effector. These projects have failed to make it out of the lab because it is too big, too expensive, isn't fit for duty outside in the elements … or they can't find or pick an apple.

A step in the right direction is the labor/harvest assist platforms. These platforms are used extensively in Europe with units a recent uptick in units sold in all major fruit growing regions in the world (except China) They come in all kinds of configurations, sizes, capacities, complexities and prices. Labor savings can be realized when you remove ladders and put people on platforms or do the work from the ground and bring the bin or conveyor device near the picker. All require workers to find the fruit and pick the fruit by hand. Our initial studies in 3D apple orchards have shown that 35-40% of harvest time is consumed by setting and resetting the ladder, climbing up and down the ladder and walking to/from the bin. This time requirement is reduced by as much as 50% in narrow, simple canopies that have a uniform crop from top to bottom of the tree and top to bottom of each row. European and South African producers report relatively small increases in labor efficiency or productivity on small orchards of mixed varieties and strains and in orchards with noticeable variability. I point this out because in Washington State we tend to have large blocks of single varieties/strains so our expectation and need for efficiency is different than that of smaller European orchards. Fruit size is a factor as well. The best use of this technology in Washington State is to focus on using harvest assist platforms for harvesting the top 1/3 of the tree.

I will limit my comments to machine types/ machines sold in the U.S.

Self- propelled or tractor powered platforms with bin management systems and the use of picking bags/buckets.

Littau Machine "OP"

This machine is designed for 4 platform pickers, 2 ground pickers, 2 sorters and one driver/rover for a total of 9 people. The self-propelled machine shuttles over the empty bin, picks it up and places in a bin-filling mechanism in the rear of the platform. Fruit is picked in "short" picking bags and the four pickers on the machine deliver fruit to a sorting conveyor where culled fruit is dropped through a shoot to the ground. The 2 pickers on the ground self-sort and put fruit directly in the bin. Bruising across all non-bruising susceptible varieties is within the industry tolerance of <5% and <3% downgrade. Efficiency varies according to variety and type of pick but overall, this company is realizing a gain in efficiency from 20-50%. Auvil Fruit Company who co- designed the machine does not use them every year or in every variety. Many factors dictate if they use the platforms.

DBR Conveyor Concepts "DBR"

The DBR harvest assist system is a 4 picking bucket/tube, vacuum tube based delivery system with a dry decelerator and bin filler. It is self-propelled and designed for 4 pickers and 1 rover (to swap out bins etc..) . Two pickers can pick from the ground and 2 from the platform or 4 from the platform. A picker can pick like he does with any bag based system but fruit does need to be singulated going into the tube. Fruit handing is within tolerance in all non-bruising susceptible varieties. Efficiencies are reported to be between 25% and 40% when compared to ladders and bags. Fruit is delivered to the bin via a vacuum tube. Filled bins are placed on the ground when full. Bins are brought into the row on a towable straddle trailer. Bin switch out time is ~ 1 min/ bin. This is a multi-use platform.

Automated Ag Systems "Bandit Express"

The Bandit Express is designed for 4 pickers on a multi-level platform and an unlimited (untethered) number on the ground. The platform is self-propelled. The straddle / lift design allows for empty,

partially filled or full bins to be picked up in front and lifted up to platform floor or passed through to the ground in the rear of the machine. The machine can hold 4 bins at a time. Fields are binned out as they would be for ladder /bag crews. Efficiencies are reported to range between 40% and 65% depending on what is being picked and how it is being picked.

Wafler Machine

In this system, eight workers on multi-level platforms fill five bins at a time, and the five bins move and stay together. The five are offloaded and five empties are loaded in less time that it takes to fill a picking bag. Thus picking is continuous and the bins change out as the machines moves forward. Bins are delivered and returned as a group using a specially designed bin trailer – so rows are not binned out like they would be for a ladder/ bag crew. Reported gain in efficiency is around 40% depending on what is being picked and how it is being picked.

Conveyor – commit to cup platform systems. No bags.

Pluk-o-Trak, Zucal – I have not worked with either of these machines. None are used in Washington State in commercial orchards. Efficiencies gained with this type of machine are going to be less than what can be gained with a system that depends on the traditional method of picking into a bag.

Horizon Harvest Technologies

WSU CPAAS and the Washington Tree Fruit research Commission have partnered to develop a long term strategy for research in 2 distinct core technologies: *Pick in Place and Shake and Catch.*