

APPENDIX 1: RESULTS FROM 2020 IRRIGATED AGRICULTURE SOIL HEALTH SURVEY

Information Collection

A survey was sent to the Irrigated Agriculture listserv managed by Washington State University Extension on February 13, 2020 and was closed on March 7, 2020. 147 crop growers/producers, 54 crop consultants and 16 livestock producers participated, for a total of 217 respondents across production systems.

Crop Grower/producer	147
Crop consultant	54
Livestock producer	16
TOTAL	217

Since soil health issues and approaches can vary substantially based on production system, survey responses were divided by primary crop identified by survey participants. Results by crop type are detailed elsewhere in this report.

	Total	% of total	Crop Grower/producer	Crop consultant
Tree fruit	60	31%	48	12
Blueberries or other small fruit	3	2%	3	0
Grapes, wine or juice	23	12%	21	2
Hops	4	2%	1	3
Potatoes	32	16%	16	16
Sweet corn, green peas or other vegetables	12	6%	9	3
Hay or other forage crops	18	9%	13	5
Corn, grain or silage	6	3%	4	2
Wheat	9	5%	5	4
Dry beans	2	1%	2	0
Other (multiple crops, onions, bareroot perennials, horticultural crops, onions, carrots, Douglas fir trees, hemp, Kentucky bluegrass)	26	13%	2	4
TOTAL	195		124	51

Importance of issues related to soil health – All respondents

	High	Mod	Low	High	Mod	Low
	Totals			Percentages		
Nutrient cycling	133	55	3	70%	29%	2%
SOM level	128	60	6	66%	31%	3%
Soil tilth	117	63	13	62%	34%	5%
Water infiltration	117	64	9	61%	33%	7%
Water-holding capacity	112	68	10	59%	36%	5%
Soilborne disease	107	63	19	57%	33%	10%
Compaction	95	80	15	50%	42%	8%
Parasitic nematodes	84	71	33	45%	38%	18%
Drainage, ponding, runoff	79	76	35	42%	40%	18%
Wind erosion	69	66	53	37%	35%	28%
Crusting	48	87	52	26%	47%	28%

Interest in soil health improving practices – All respondents

	High	Mod	Low	High	Mod	Low
	Totals			Percentages		
Cover crops	107	66	14	57%	35%	7%
Compost application	104	57	26	56%	30%	14%
Green manures	89	64	32	48%	35%	17%
Reduced tillage	68	65	44	38%	37%	25%
Manure application	64	58	61	35%	32%	33%
No-till	63	52	66	35%	29%	36%
Double cropping	47	52	79	26%	29%	44%
Livestock integration	44	49	80	25%	28%	46%
Intercropping	39	49	83	23%	29%	49%
Strip-till	32	61	80	18%	35%	46%
Relay cropping	23	46	99	14%	27%	59%

Importance of challenges to improving soil health – All respondents

	High	Mod	Low	High	Mod	Low
	Totals			Percentages		
High cost of soil improvement practices	113	57	16	61%	31%	9%
Logistics of using soil improvement practices	83	75	25	45%	41%	14%
Lack of information	56	88	38	31%	48%	21%
Rotation restrictions	51	57	68	29%	32%	39%
Sandy soils	51	57	68	29%	32%	39%
Required tillage	48	69	60	27%	39%	34%
Short term land leases	47	53	80	26%	29%	44%
Managing high levels of crop residue	44	72	61	25%	41%	34%
Low residue crops	41	72	62	23%	41%	35%

Importance of research or additional information – All respondents

	High	Mod	Low	High	Mod	Low
	Totals			Percentages		
Strategies for improving soil health	157	24	7	84%	13%	4%
Benefits of soil health	133	41	11	72%	22%	6%
Monitoring soil health	124	56	9	66%	30%	5%
Economics of soil health	119	58	9	64%	31%	5%

APPENDIX 2. TREE FRUIT INDUSTRY RESPONSES TO 2020 SOIL HEALTH INITIATIVE SURVEY

37 respondents representing more than 8,170 acres of apples, pears and cherries.

How would you define soil health?

- Diverse microbial life, abundant organic matter, good water-holding capacity/soil structure, ability to sequester carbon
- Good
- The state at which available nutrients are readily available to the plant
- Group of soil characteristics that enable the sustained growth of trees, organisms and life
- Microbial diversity and abundance.
- Healthy soil feeds itself through a diverse microbiome. The healthiest soils require minimal inputs, other than replenishment of organic material.
- The ability of the soil to continuously maintain a healthy population of diverse beneficial soil microbes and flora to suppress pathogens and mineralize/produce nutrients for the crop.
- Good - but that is an uneducated assessment
- Somewhat okay
- Soils ability to retain and deliver nutrients for healthy crop production.
- sufficient nutrients in the right chemical state, maintained by the biological community in the soil to feed the plant at its optimal desire.
- Balance of nutrients and microbes to allow us to grow good fruit/ plants
- Not affecting fruit quality
- The virility and vitality of soil environment.
- Good soils would have a active microbial population. For what I grow in it a mid 6 pH is desired. Minerals available.
- Productive healthy living soils
- Poor
- The ability of the soul to provide an environment conducive for the healthy development of plants with an abundant and thriving rhizosphere.
- How well the tree is able to extract nutrients out of the soil, how well it holds water and moisture, biologicals available in the soil.
- humus, PH, texture (sand gravel Loam) microbes, the balance of these with necessary elements.
- Microbial activity is an indicator of soil health.
- How erodible soil is. Microbial activity. Water holding ability. Ability to provide water and nutrients.
- How soil benefits the growth of the trees. Biodiversity.
- Soil that can support plants. Soil holds the tree in place and holds nutrients and water.
- Good organic and microbial population.
- Organic matter.

What are the most important challenges from low soil health to our industry's orchards?

- Replant disease
- Diseases and therefore huge expenses due to outside inputs, low nutrient dense fruit
- PH
- The ability to quickly, inexpensively and accurately diagnose the issue with the soil health and what specifically to do to achieve a desired outcome.
- Productivity
- Restoring carbon and life to the soil.
- System approach and demands of industrial agriculture ROI push farmers to high input, super high-density systems. These systems are designed to extract resources from the soil, not replenish them.
- Reduced yield potential, seriously reduced fruit quality, increased soil pathogens and diseases, reduced tree health, reduced nutrient efficiency & utilization, all "requiring" more conventional fertilizers and 'crop protection' which increases the problems rather than correcting them.
- Pests and nutrient depletion
- it may be organic material in the soil
- Poor industry understanding of basic soil chemistry that has been foisted on industry for generations
- They are not defined and are hard to see..... do they exist
- Rethinking there is more to soil health than just enough nitrogen
- Supplement testing by university.
- Compaction. Infusion of organic matter (lack of).
- What to correct.
- Chemicals for everything
- Developing consistent and uniform crops.
- There are farmers that need to learn to take soil samples and analyze what is happening to their soil, instead of just pumping tons of nitrogen because it is common practice.
- nutrient availability with proper water level and PH.
- Light soils. Can't incorporate cover crops into the system because of the traffic from sprayers etc. Too much compost can lead to high K. There is not enough biomass available to add for carbon. We can't just add compost because of the P&K.
- Bitter pit. Low yields. Replant disease. Variability in blocks.
- With weak varieties we can't afford to let them stop growing, they need to make it to the top wire.
- Nutrient retention and biodiversity.
- Nutrient build-up possibilities.
- Production on hillsides.
- Old lead [arsenic] soil.

What are the most important functions/benefits soil health can provide for our industry's orchards?

- Cycling nutrients
- Healthy trees that need little ag inputs to resist disease and pest pressures, producing fruit that tastes great and has nutritional value.
- Good tree health by keeping nutrients available to the trees.
- To increase profitability back to the land and create sustainability for generations to come.
- Nutrients, water, mineralization, support, filtering
- Fertility and moisture absorption/retention. Natural fertility.
- The question is backwards - the question is what can our industry's orchards do for the soil. Different systems (rootstock selection, design/layout) are likely required to optimize for soil health. We've worked very hard for the past century towards driving costs down and packout up for financial performance. Permanent crop farming has the potential to build soil much more quickly with far less inputs, if addressed properly.
- Increased tree health, especially the root systems. Increased efficiency of nutrient uptake and utilization, significantly reduced disease and pathogen pressures. All allowing reduction of commercial fertilizer rates and pesticide usage. Significantly increased fruit quality, uniformity, and more consistent reliable yields. Increased storage life and retail shelf life of fruit. Increased nutritional content of the fruit as well.
- This is all conditional on proper pursuit and methods of increasing soil health.
- Stronger, healthier soil will strengthen trees and produce and simultaneously replenish nutrients
- Less stress on the trees and a better crop
- Soils are foundation for producing nutrient rich nutritious food. Current emphasis is on volume and cosmetics...
- nutrients out of balance can cause fruit quality problems
- Provide long term benefits to soil and grower so that with good soil balance there is less need for fertilizer, water and pesticides
- HIGHER PROFITS. NO A PROFIT !!
- Reduction in use of fertilizers and other synthetic amendments. A more naturally produced product.
- Productivity and quality
- Learning demonstrations and education
- Healthy plants and trees should be more productive
- Less water consumption and usage. Having healthy soil eliminates the need to constantly irrigate and replenish moisture and nutrients. When you over irrigation you move nutrients out of the roots profile zone. It would lead to better quality fruit too.
- Better tree health will produce better quality fruit and higher production.
- Yield. Fruit quality. Optimum fruit size. High pack out (quality).
- Promote good plant growth.
- Reduce fertilizer, pesticide and irrigation use.
- Improved production.
- Save on inputs.

What are the most important functions soil health provides to the environment?

- Health trees more clean breathable air and quality fruit available to people on earth.
- Sustainably
- Water holding and movement
- Carbon sequestration and retention. Reduced soil erosion. Larger healthier crops. Natural disease resistance.
- Orchardling in particular has the potential to perform quite well in terms of carbon sequestration. Also, more opportunities for cross-functional use: interstitial cropping, orchard grazing, etc. These provide additional opportunities to improve soil health and reduce inputs. Storing more carbon, while reducing input costs (also carbon-intensive) is an attractive proposition to weigh.
- Increased water efficiency & uptake, reduced runoff, reduced commercial fertilizers and pesticides. More truly sustainable, regenerative crop eco systems.
- Naturally cleaning water and air while providing a more effective nutrient for trees
- Longevity, many years of providing food with lots of nutrients.
- Balance. Hard to do when it's being used as dumping ground by urban areas in Western Washington...i.e. municipal sludge.
- I think it is not defined.
- Basically same as above.
- So it does its part.
- Healthy fruit that isn't on drugs
- Proper reading of nutrients so that we are not over applying fertilizer or nutrients and leaching them into drinking or river water.
- Erosion control. Reduction in leaching.
- Plants that harbor beneficials.
- Low toxicity.
- Clean air. Clean water.

What are some information gaps related to soil health in our industry?

- What makes quality soil? How does one attain healthy soil?
- If information is available it is not communicated in an effective manner. If the information is not available then it needs to be researched.
- Correlation with productive parameters
- Unsure
- Microbiology - the microbiome is not well understood. We have done a great job of evaluating tree nutrient needs by leaf assays. We can quickly, cheaply and easily sample the soil to determine which elements are missing. But the microbiome is an incredibly powerful ally that we've largely killed with chemical application (including fertilizer). Specifically the mycorrhizal interactions.
- Industry suppliers, consultants, agronomists, and academics are highly resistant to any information from "alternative" (non-university) sources. Insistent on years of replicated trials before considering anything outside of the conventional status quo. Many of the soil health/crop health answers they "seek" have been well established and even researched by previous generations of academics for many years. One of the biggest problems is lack of research \$ for "natural" product trials because the chemical companies provide most of the research funding. Why would they want affordable natural competition to their expensive patented products?
- For me it is how to replenish the nutrients in my small orchard's soil

- Understanding what to do in small areas.
- Once again... piss poor fundamental soil chemistry, biochemistry and plant nutrient practices. Seems to be a lot of fairy dust being marketed to growers.
- Are we doing things that we think are good which are bad.
- Beneficial Microbes and how they improve yield and disease resistance
- How to keep it balanced/correct while growing tree fruit crops. How to avoid replant issues.
- How to improve and maintain soil health. Understanding the definition of soil health and how to determine it in a quantitative way.
- Not fully understanding what is happening with nutrient uptake. Also the research to be a lot more clearer for farmers to understand.
- Water systems and application especially in gravelly sandy locations with areas of heavier soils in the same row.
- We need to know what is below ground. How does transition to organic effect health, specifically not using herbicides?
- Correlating a soil test with a fruit analysis. Correlating soil health to fruit pack outs and how well fruit stores.
- How long to organic amendments last, e.g. compost, fertilizers?
- Testing opportunities and results.
- How soil works.
- Soil testing.
- Getting information out to growers.

What are your top research priorities related to soil health?

- Keeping soil health so it strengthens the trees.
- Cheap soil analysis that can be done in the field by the farmer or foreman with simple action steps to take after analysis show deficiencies.
- Amendments that can improve organic matter from different sources; residues from wine, hop, juice etc
- Unsure
- Optimization of ectomycorrhizal networks in orchard systems. Carbon sequestration potential. Biochar - impact on tree health, nutrient buffering, fungal biome health, etc.
- Academic proof that green manure crops, bio-stimulants, & beneficial microbial inoculants do significantly improve soil & crop health, fruit quality, and reduce chemical input requirements, providing increased grower ROI. I have personally seen this in many different crops but sadly “proof” by academics is needed for alternative practices to be seen as legitimate programs.
- A better balance between natural soil health and controlling damaging pests while still producing healthy trees and safe produce; without simply taking nutrients out.

- Not sure
- Developing improved soil tilth which encompasses a process of implementing amendments which support nutrient cycling, soil microbiology and in my case irrigation water quality for the benefit of plant growth
- Show the difference between good and poor soil health
- More work done on crown rot- where is it coming from and how to prevent/ treat
- How plants and soils
- How to create a healthy
- Moisture, nutrient uptake and the plants health.
- For me water application in an area of mixed sandy and heavier loam soil in the same row, how do I apply enough in one end of the row without shorting the other end.
- How do the herbicides we use effect soil health? What are the effects of the tillage we use in organics (how much damage to microbiome)? More information on the critters that live in the duff?
- Education about soil types and how to manage them.

What core investments should be made to move the goals and priorities of your industry forward?

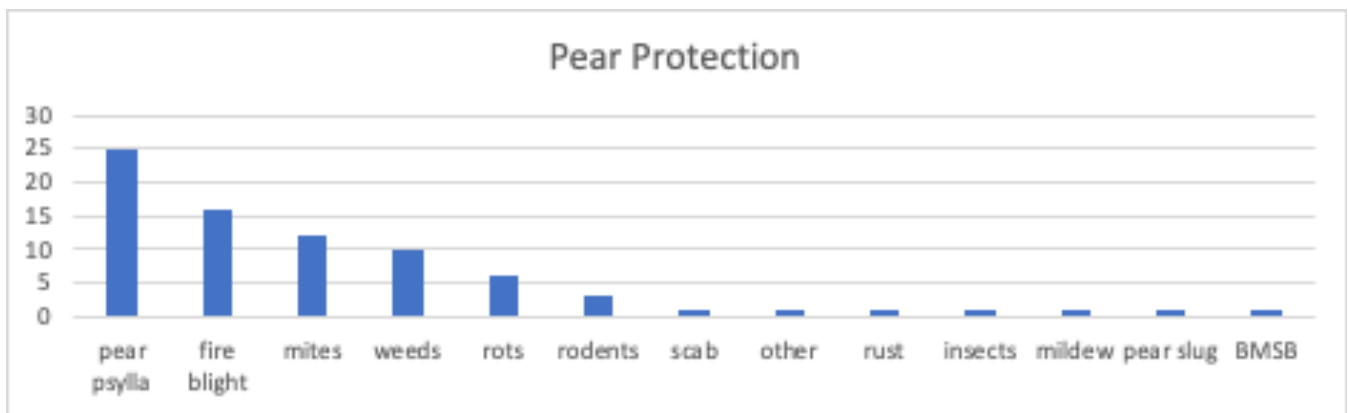
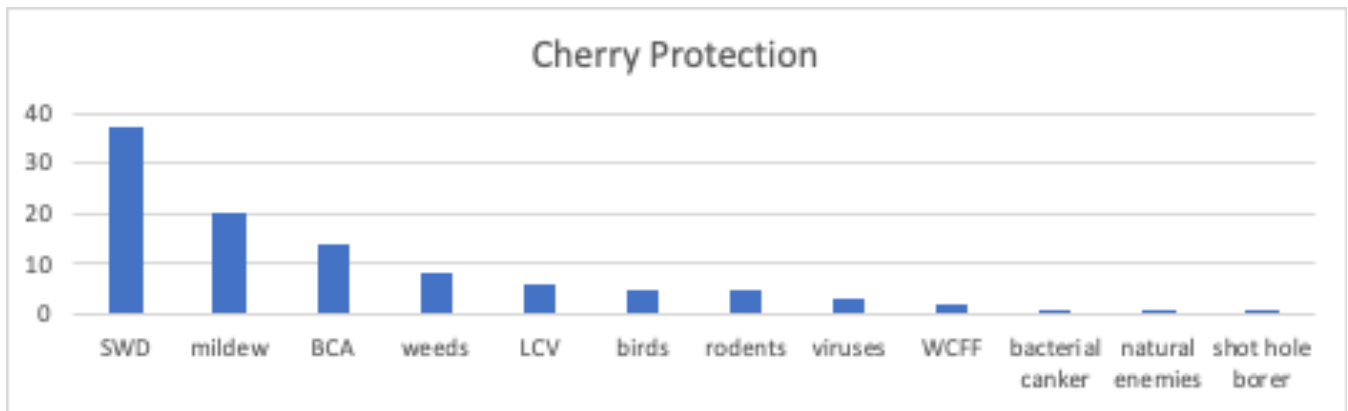
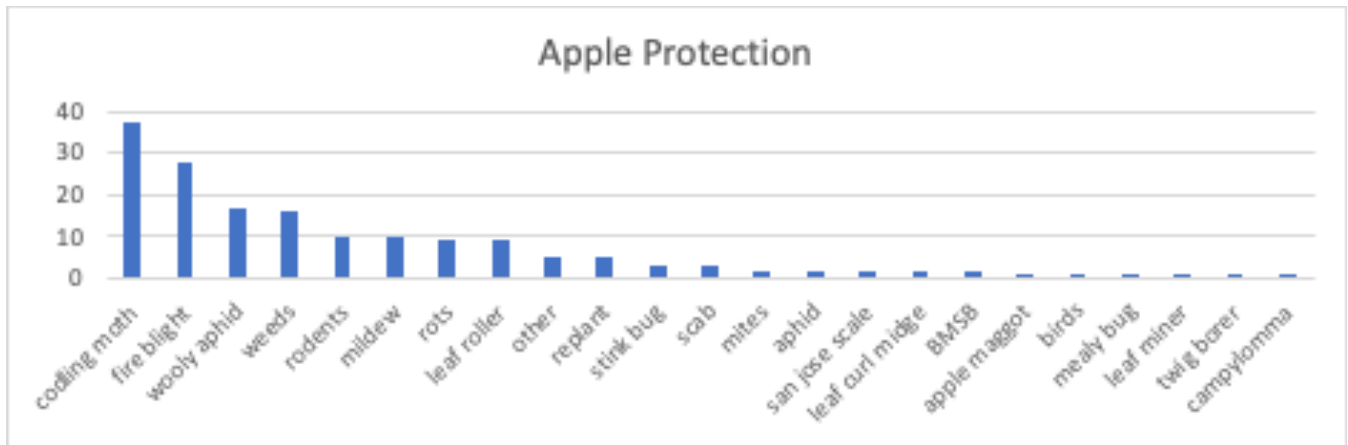
- Continuing education and lab testing to maintain healthy Orchards!
- Not sure where the research is at this point to give a good recommendation
- Funding for competitive projects for long term studies
- Unsure
- Field trials - more research.
- Significant research needs to be done on more 'natural' alternative materials and programs instead of on the latest chemical "tools".
- Buyers should be willing to pay a premium for higher quality fruit to reward growers who invest in systems that increase fruit quality, nutrient levels, shelf life, etc..
- Education to change the cycle of stripping the soil and replacing with chemical fertilizers and defolients.
- Put back in the soil what is needed
- Not enough space here...
- Researchers to do the work
- More crop diversity and sustainable practices
- Need a nation-wide apple promotion program to increase per capita apple consumption. Growers must have a realistic chance of achieving their full cost of production before they can afford to further enhance, both society and the environment.
- How to fortify nutrients to plants/fruit that soils are unable to provide as environmental changes occur.
- Hire the Endowed Chair in Rhizosphere Ecology that is already funded.
- Show the benefits for everyone when you watch soil health. How taking care of your soil can have a big impact on your yields, costs ect.
- Have a test which will really indicate what is going on with soil health.

What are our three important milestones we should reach as an industry and how long would you expect each to take (5, 10 , 20 years for example)?

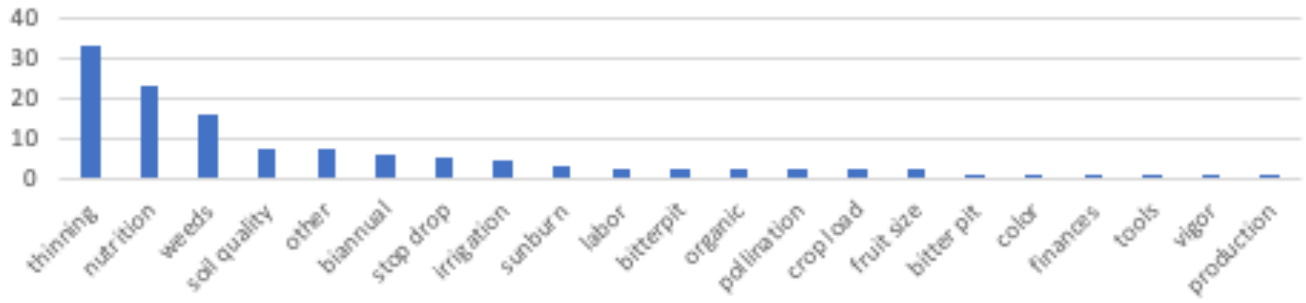
- PH-7
- Minerals in balance
- Fertilizers and leaf feeds that keep soils and trees healthy
- Not enough knowledge to give accurate milestones
- Unsure
- Reducing chemical input application by 50% or greater. Rootstock research - deeper rooted trees would help with nutrient uptake and irrigation expense (dry farming will be more important as climate changes). Working to identify climate change pressures on industry (pest, temperature/drought, chill hours, etc.) - what shifts will be required. Apple orcharding in W. WA - limited resources compared to E. WA climate. Cider apple production system approaches (may be substantially different than dessert apple)
- As one who has been teaching/coaching soil/crop health for over 30 years, I am at a loss how to answer this. It has been agonizingly slow to see any progress in this direction until very recently and now most seminars on 'soil health' are so basic and simplistic it is sad. Reams of research on the subject has been done many decades ago and has continued around the world to this day. For some 'unknown' reasons, it does not disseminate across American agriculture except for a few consultants and small independent companies who produce exceptional 'alternative' products & programs.
- I have no idea how long it will take established eco-agriculture principles to reach any mainstream modern research or industry acceptance.
- Education (as a new orchardist I need this the most) 1-4 years
- Return to a Natural process of pest control and fertilization - don't know timeline
- Return more acreage to plant production and reclaim pasture land
- Not sure
- 1). Understand soil chemistry 2). Understand soil microbiology 3). Understand irrigation water quality and it's impact on soil health
- we have soils in tree fruit for over 130 years. is it depleted or sick??? we need a definition
- Don't know
- Full cost of production returns from the market place. 5 years.
- Replant disease issues.....Keeping soils healthy.....How to be better producers
- Hire Endowed Chair- immediately. Awareness of importance by the industry-5 years.
- Establishment of best practices and SOP's for optimal soil health-15.
- Water conservation, especially with recent past issues of drought and not enough snow fall. 5 years.
- Proper soil analysis, test your soil and understand what is happening so that you do not over apply fertilizers and spend extra money. 20 years.
- Pesticide use to avoid killing natural occurring biologicals in the soil that keep the soil healthy. 10 years.
- Soil tests which take into account the biology in the soil. Building a database of soil tests and fruit quality so we can look at correlations. Make sales not commission based (on fertility) so they are looking at long term benefits. In 20 years be able to look at limiting factors other than just nutrients AND fix them.

APPENDIX 3. ORGANIC TREE FRUIT PRODUCERS NEEDS ASSESSMENT 2017

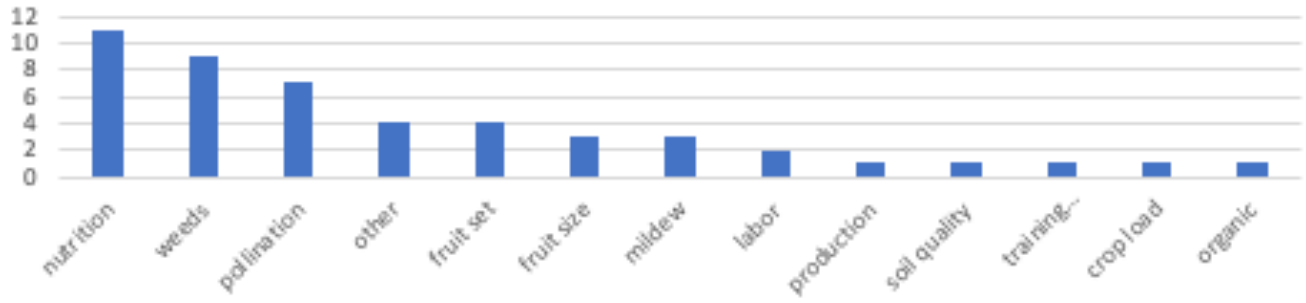
A survey of organic tree fruit producers was conducted in January to March 2017 by the WSU Tree Fruit Extension team. Producers were asked to list the most challenging issues they face for each organic crop they grow in the areas of crop protection and crop management. Listed below are preliminary results of this survey which had 104 individual respondents.



Apple Management



Cherry Management



Pear Management

