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Strategies for Managing Soil Fertility and Health in Organic Orchards – A Fact Sheet

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Introduction

Soils in the Intermountain West are typically shallow, calcareous and are low in native organic matter. Low organic matter translates to less nutrient reserves for plants. Calcareous soils have a relatively high pH that can lead to trace element deficiencies. Some Utah soils have a high salt content that can be toxic to plants. These potential constraints require the organic fruit grower to pay particular attention to soil health and fertility. Utah State University faculty at the Utah State Horticultural Research Farm in Kaysville have been conducting research on transitioning to organic management and in improving orchard soil health. A primary focus of this research is to provide growers with locally adapted advice and solutions for managing soil fertility in certified organic stone-fruits.

Transitioning to Organic Management

Organic certification requires a three-year period of organic-only management prior to organic labeling. A sufficient supply of soil nutrient reserves is necessary to a successful organic soil fertility management plan. In organic systems, nutrients are made available to the plant through the process of organic matter mineralization. Mineralization is the break down of organic residues into readily available nutrients (such as ammonium, nitrate, phosphate and potash) for plants. When transitioning to organic practices it is important to build up organic matter levels in the soil. When soluble fertilizers such as urea or ammonium sulfate are withdrawn from a system, trees can rapidly become nutrient deficient and stop growing if there is insufficient mineralization of soil organic matter occurring to fill the gap (Figure 1). This is known as the transition effect. Ideally, a grower would start adding compost to the tree row a year or two before starting the transition process. The exact rate of this mineralization process can be difficult to predict because it depends on soil type and native soil organic matter levels, the type of organic inputs used, soil moisture levels, and soil temperature.

Figure 1. Conventional trees in the first year of transition to organic compared with conventional trees in the background. Note the yellowing leaves indicating nutrient deficiences. Special care needs to be taken to build soil organic matter prior to transition on soils low in native soil organic matter.

Very young trees require fewer nutrients, so soil fertility can be built up over two or three seasons as they grow. A young orchard can be established in a former pasture or hayfield in order to eliminate the need to actively build soil fertility prior to the organic transition period. Soil organic matter and soil structure are always greatly improved after a period in pasture or hay. The growth and decay of perennial roots effectively builds organic matter deep in the soil profile and loosens dense layers.

Once soil organic matter is sufficient to sustain vigorous tree growth the orchard enters a maintenance phase. Organic matter and nutrients need to be added in sufficient proportions to maintain growth and avoid deficiencies but avoid excess nutrient buildup. This can prove challenging at times with limited budgets, product availability and time. Hence, the importance of developing a long-term soil health management plan based on product availability, budgets and soil conditions.

Building Soil Organic Matter and Providing Appropriate Nutrients

The six major nutrients derived from the soil are nitrogen, potassium, phosphorus, sulfur, calcium and magnesium. The nutrients needed in the largest quantities for crop growth are nitrogen, phosphorus and potassium. The most important of these is nitrogen, especially on sandy or gravelly soils where deficiency is more prevalent.

Cover crops, mulches, and composts are important organic amendments. They can provide all of the major and minor nutrients necessary for tree growth, and buffer roots against extreme weather conditions such as drought and excessive rain. In order to support soil health; i.e., beneficial organisms that maintain nutrient mineralization and soil structural properties, it is helpful to reduce practices that harm soil structure, such as tillage. Tillage can reduce weed pressure and enhance the availability of nutrients. However, overtime it disturbs soil aggregates and compacts the soil, which reduces aeration, water holding capacity and compromises soil biodiversity (Thomsen et al. 2017).

Organic amendments should also not be overapplied. Conventional agriculture is often blamed for inefficient or excess use of fertilizers which can lead to runoff and leaching loss to the environment. However, organic agriculture can also result in water contamination from runoff and leaching, and nutrient deficiencies/excesses when organic composts and fertilizers are applied in large ammounts. It may take a few years to build up the necessary nutrient reserves for competitive crop growth when switching to an organic operation from a conventional one. However, once nutrients, in particular phosphorus, are sufficient, fertilizers should be applied only at a maintenance level to avoid excessive build up of nutrients in the soil. In dry climates such as in Utah and the Intermountain West, excessive use of composts and manures can also rapidly contribute to salt buildup in the soil with negative effects on crop growth. Check the nutrient status and salinity of your soil with regular soil tests.

Nitrogen

Nitrogen is commonly the most limiting nutrient for trees. A deficiency in nitrogen will cause stunted growth and yellowing of older leaves. Manure, compost and nitrogen fixing cover crops such as peas and alfalfa are a few examples of nitrogen rich materials to incorporate into a management plan.

In conventional agriculture, nitrogen is typically applied in its most soluble form--urea or ammonium sulfate ranging from 30-40% available nitrogen. In comparison, organic fertilizers contain only 1-15% total nitrogen with an even lower percentage of that nitrogen immediately available for crop growth.

Due to the limited amount of nitrogen readily available to plants in organic materials upon application, it can be a common mistake to apply these fertilizers in excess in order to ensure the crops immediate needs are met. Over application of nitrogen fertilizers—such as compost and manure--in dry climates such as Utah and the Intermountain West, can leave soils with excess salts. This can contribute to impaired nutrient cycling, and overall reduced crop production (Stamatiadis et al. 1999). The ratio of nitrogen to phosphorus of many organic fertilizers is also often mismatched to plant needs. Plants typically require five parts of nitrogen for every part of phosphorus. However, many organic fertilizers such as manures and composts have a nitrogen to phosphorus ratio of two to one or less. Applying compost and manure to meet nitrogen levels can quickly lead to excess phosphorus buildup in the soil, as well as other nutrients, which creates more nutrient problems to resolve for crops and trees, and will be discussed more in the sections below.

When choosing a nitrogen source, consider the percentage of nitrogen, the ratio of nitrogen to other nutrients, and the immediate, short and long-term availability of nitrogen. The availability of nitrogen to plants is dependent on multiple characteristics including soil type and weather, so this factor is relatively variable and challenging to predict. Typically the organic fertilizers with the highest total nitrogen and lowest carbon to nitrogen ratio will also release the most nitrogen into the soil over time. Typically the higher the C:N ratio, the longer it takes for the materials to break down and the nitrogen to be released. If the ratio exceeds 25-30:1, it does not provide adequate nitrogen in the short-term. The nitrogen will actually be immobilized by soil organisms using it to decompose the carbon. Such materials are best composted or applied to the surface of the soil as mulch. Table 1 provides typical C:N ratios for common organic materials. For exact soil measurements send compost to a certified soil testing lab.

Chicken manure often contains substantial levels of soluble nitrogen that is readily available. Alfalfa hay is also commonly found to contain relatively high amounts of total nitrogen (Sideman 2007). Growing alfalfa or other taprooted legumes such as Birdsfoot trefoil in the alleyways next to the tree rows is a great way to make use of this great nitrogen source; more about this will be discussed in later sections. Feather meal and blood meal have some of the highest proportions of readily available nitrogen per pound among organic amendments. These products are often more expensive, hence are likely best used as a supplement to other fertilizer sources. Table 2 shows the nitrogen, phosphorus and potassium ratios as well as typical cost, both on a total and per pound nitrogen basis. Note that if raw manure is used in an orchard it must be applied 90 days prior to harvest or 120 days prior to harvest for a crop that comes in contact with the ground, to avoid bacterial contamination and meet organic certification requirements.

Phosphorus

Phosphorus is also needed for plant and tree growth in relatively large quantities. A deficiency in phosphorus will stunt growth, limit yields and fruit quality. Chicken manure and bone meal are both good sources of available phosphorus.

Table 1. Common organic materials and their C:N ratios.

Product	C:N
Food Scraps	15:1
Alfalfa Hay	18:1
Grass Clippings	19:1
Oak Leaves	26:1
Varied Leaves	60:1
Corn Stalks	60:1
Straw	80:1
Pine Needles	85:1
Alder Sawdust	134:1
Newspaper	170:1

Note: ratios taken from Washington State University extension- http://whatcom.wsu.edu/ag/compost/fundamentals/needs_carbon_nitrogen.htm

Table 2. Typical organic fertilizers with average nutrient contents and costs per pound product and unit N.

Product	N	P2O5	K2O	Dollars per pound	Dollars per pound N
Alfalfa Meal	2.5	0.5	2.0	0.70	28.00
Blood Meal	12.5	1.5	0.6	1.19	9.52
Corn Gluten Meal	9.0	0.0	0.0	0.77	8.56
Cotton Seed Meal	6.0	0.4	1.5	0.70	11.67
Feather Meal	13	0.0	0.0	0.66	5.08
Composted Chicken Manure	3.5	2.0	2.0	0.07	1.71
Composted Steer Manure (Miller's)	2.0	0.8	0.8	0.07	2.80
Composted Yard Waste	1.2	0.2	0.2	0.05	3.33
Alfalfa Hay	2.5	0.5	2.0	0.05	2.00

Note: Fertilizer nutrient estimates are sourced from the Oregon State University Fertilizer Calculator or from analyses conducted at Utah State University. Prices are quotes obtained from local suppliers in Logan Utah.

Phosphorus is known to accumulate in soils over time with excess use of composts and manures. It is important to switch to a fertilizer with less phosphorus once soils have an adequate supply. Phosphorus in excess can cause nutrient deficiencies; essentially it can block the plant from absorbing key elements such as zinc and iron (Provin and Pitt, 2005). Growing nitrogen fixing cover crops is an effective way to supplement soil nitrogen without building up phosphorus levels. If nitrogen needs are high the affordability of applying fertilizers with zero or limited phosphorus can be a challenge. Table 2 indicates that composted manure has the highest amount of phosphorus compared to nitrogen or the lowest nitrogen to phosphous ratio. Products with the lowest amount of phosphorus to nitrogen include feather meal, and corn gluten meal. Both products are comparable in terms of their cost, with feather meal generally costing slightly less than corn gluten meal. Products with lower ratios of nitrogen to phosphorus can be used to largely meet phosphorus needs, while products with little to no phosphorus can be used to fulfill the plants remaining nitrogen needs. In summary, an effective organic management plan will balance phosphorus rich organic inputs with additonal nitrogen from nitrogen fixing cover crops and or organic fertilizers low in phosphorus.

Potassium

Potassium aids the plant’s ability in regulating efficient water use, and CO_2 uptake. Potassium levels in unleached Intermountain desert soils tend to be high, yet can become depleted as plants use it and in heavily irrigated areas. Generally, providing sufficient nitrogen and phosphorus for crop growth through organic fertilizers will also provide sufficient potassium. Potassium can also build up due to excess additions of organic matter, including mulches, which can interfere with calcium uptake by trees, negatively affecting fruit quality. The amount of potassium in the soil and the need for inputs is best determined by a soil test.

Secondary Nutrients and Trace Elements

Sulfur, calcium, and magnesium are secondary nutrients and boron, iron, manganese, copper, molybdenum, chlorine, and zinc are needed in trace amounts. The most common micronutrient deficiencies on alkaline soils in the Intermountain west are zinc, iron and manganese (Swift, C.E., 2009). Organic amendments typically will have sufficient levels of all of these nutrients needed for crops. However, it is still a good idea to obtain soil tests to expose any nutrient deficiencies as trace elements can be limiting in high pH soils. Trace element deficiencies can be most easily improved through foliar feeding and products that meet organic certification requirements are available. It is also important to recognize that additions of excessive amounts of organic matter can lead to nutrient imbalances and trace element deficiencies.

Soil Testing

Soil testing is the best way to find out exactly which nutrients are needed and to prevent nutrient deficiencies or surpluses from negatively impacting the crop. Regularly checking the nutrient status of cropland soils is the best way to save money from unnecessary amendments or diagnose potential deficiencies before they start to impact crops. For example, an excess of phosphorus can promote deficiencies of other nutrients, like iron and zinc. Adding iron and zinc to the soils, will not remedy the problem of deficiencies in the trees. If soil phosphorus becomes excessive it is advisable to replace manures and other phosphorus rich fertilizers with fertilizers low in phosphorus such as feathermeal and bloodmeal or nitrogen fixing cover crops, until soils return to equilibrium. In cases where trace elements are severely limiting, zinc and iron foliar sprays will need to be applied. Another very important reason for soil testing is to ensure that excessive nutrient loads do not contaminate local water supplies.

Most nutrients can be easily determined from a soil test. Some nutrients, such as nitrogen are better tested through foliar tests or samples of root zone soil. Surface soil samples don’t adequately identify the availability of nitrogen due to the fact that nitrogen is readily mobile in the soil. Since the mobility of phosphorus and potassium is significantly less than nitrogen, effective monitoring of these elements can be done through soil tests alone.

Cover Crops

Cover crops or living mulches can reduce dust and mud, increase soil stabilization, suppress weeds, add organic matter (Hartwig and Ammon, 2002) and improve soil biological activity (Hoagland et al., 2008). Legume cover crops fix atmospheric nitrogen and can reduce the need for purchased nitrogen inputs considerably (Reeve et al., 2017). Applying organic fertilizers based on phosphorus needs and using nitrogen fixing cover crops to supply the additional nitrogen needed may be the most cost effective and ultimately sustainable approach to organic soil fertility management.

The timing of the nitrogen release from the legumes is also important. The release of nitrogen from the legume cover crops takes place all season. Delayed tree dormancy is a possible outcome of this late release of nitrogen. This could be less of a concern in Utah, especially on shallow soils low in soil organic matter. In Utah, it's common for growers to apply some nitrogen after harvest to increase tree vigor.

Mulches

Non living mulches have potential to control weeds, contribute to long-term soil nutrient reserves, and potentially conserve soil moisture. Depending on local availabiity, they may be expensive, however.

- Applying recycled paper decreased weed pressure, according to Hogue et al. (2010), and had a positive effect on tree growth and yield. However, similar research in Utah found that paper mulch decreased tree growth under organic management due to nitrogen immobilization.
- Wood chips have been shown to reduce water loss and increase tree growth, yet have also been found to reduce available nitrogen in the soil (Hoagland et al. 2008), in addition to being a potential source of imported weed seed (Rowley et al. 2011)
- Alfalfa Hay Mulch – Stefanelli et al. (2009) found an increase of foliar nitrogen and higher cumulative yield in apple (compared to flame burning and shallow strip tillage using the Swiss sandwich system).
- Weed fabric has been shown to be a great weed suppressant for sweet cherry (Nunez-Elisea et al., 2005) although Nielsen and Hogue (1992) found that it created dramatic reductions in potassium in apple orchards. Research in Utah has shown excellent weed suppression and tree growth with weed fabric, although it must be removed from the bases of young trees in winter to prevent girdling by rodents.
- Straw mulch—may provide moisture retention as well as a slow release of nutrients to the tree. No benefits in terms of tree growth and water use were observed using straw mulch in Utah over the course of a six-year study, so the cost may not be justified. If using straw, obtaining a weed free source is important and can be a challenge.

Possible Organic Management Systems

At the Organic Systems research plots at the Utah State University Horticultural Research Farm in Kaysville, Utah, researchers are developing management strategies for the production of stone fruits in the Intermountain West. Cover crops were used initially for building the soil at the USU Organic Research plots prior to the establishement of the peach orchard. Broadleaf, grass and legume cover crops were grown in order to increase soil organic matter.

After the succession of cover crop plantings, the area was tilled, and trees were planted. Six different treatments were implemented: 1) straw mulch in the tree row with a grass alleyway 2) straw mulch in the tree row with a legume (birdsfoot trefoil, *Lotus corniculatus*) alleyway; 3) living mulch (low-growing shallow rooted alyssum, *Lobularia maritima (which quickly transitioned to mowed weeds*) in the tree row with a grass alleyway; 4) living mulch in the tree row with a legume alleyway; 5) woven plastic mulch in the tree row with grass alleyway; 6) tilled tree rows with a grass alleyway.

All treatments with mulches in the tree row used the so called swiss sandwich tilling system—a 12 inch tilled strip separating the tree row from the alleyway (Figure 2). Compost and feathermeal were applied directly to the tilled strips and incorporated, allowing the tree to readily access these nutrients without leaving too much bare soil exposed to the processes of erosion.

Birdsfoot trefoil grown in the alleyway as a cover crop in combination with mowed living mulches or weeds in the tree row was one of the most favorable management strategies used at the USU Organic Research Orchard in Kaysville (Figure 3). Tree growth in this system was similar to plots with good weed control (tillage and weed fabric) and exceeded tree growth in plots with grass alleyways and straw or living mulch in the tree rows. (Reeve et al., 2017).

Figure 2. The Swiss sandwich system, with a narrow tilled strip seperating the tree row from the alleyway for incorporating nutrients

Figure 3. Trees grown with Birdsfoot trefoil in the allweyway (yellow flowered plant in forground) with mowed in row vegetation were as large as trees grown with tillage or fabric mulch in the treerows. Trees with grass alleyways and mowed treerows were smaller (see plot beyond pink flags).

Legume cover crops provide nitrogen to the trees in addition to weed suppression and keeping soil structure intact. Previous research has shown legumes to be competitive with trees when planted within the tree rows with grass alleyways. Grass alleyways have been shown to restrict tree root growth to the tree row making weed control much more critical (Black et al. 2010). Taprooted legumes such as alfalfa and birdsfoot trefoil may be much less competitive with tree roots. In an organically managed orchard at Capitol Reef National Park, alfalfa was shown to contribute to soil nitrogen when direct seeded into an established grass canopy (Thomsen et al. 2016).

Nitrogen fixing cover crops, especially alfalfa may use more water than grass, however (Rowley et al. 2011a). Birdsfoot trefoil can be difficult to establish due to very slow early growth, but it is more shade tolerant than alfalfa and persists better in the orchard environment. Woven plastic mulch was another favorable strategy as tree growth in fabric plastic mulch plots was equivalent to tree growth in tilled plots (Figure 4). The disadvantage to fabric plastic mulch is the upfront cost. It can also be labor intensive to manage. At the USU Organic Research Orchard plots the fabric plastic mulch is rolled back every November to prevent rodent activity and put back into place in March after fertilizer has been applied. Organic herbicides were found to be ineffective against the perennial weeds typical at the USU Organic Research Orchard (Rowley et al. 2011b). Organic herbicides are contact herbicides and generally much less effective on perennial weeds than conventional herbicides, as well as much more expensive.

Figure 4. Trees grown with fabric mulch in the treerow.

Chicken and or steer manure compost was sed to meet nitrogen needs of the orchard in the early years. Due to rapidly rising phosphorus levels in the USU Orgnaic Research Orchard in Kaysville, the amount of compost was limited to 3-5lb dry weight per tree after the third year. Supplemental nitrogen was supplied in the form of an organically approved feather meal product (Reeve et al., 2017). The feather meal used has an N:P ratio of 13:0, making it a very valuable resource for producers who may have adequate to high levels of phosphorus in their soils. Ongoing research will determine whether nitrogen from Birdsfoot trefoil is sufficient to meet the needs of mature peach trees when planted in the orchard alleyways. Table 3 shows the percentage of nitrogen, phosphorus and potassium in the compost applications for three years. It also gives the carbon and nitrogen ratio. In 2008 the crabon to nitrogen ratio was the lowest, meaning the nitrogen would become available for plant uptake more quickly. Table 4 shows the sources and amounts of nitrogen inputs per tree in each orchard floor treatment.

Table 3. Compost characteristics used in the USU Organic Research Orchard at Kaysville from 2008 to 2011 2008=chicken manure; 2009,2010,2011 = composted steer manure

Characteristic	2008	2009	2010	2011
Total N	1.89	1.46	2.25	2.18
C:N Ratio	7:1	13:1	12:1	12:1
P2O5	-	0.34	1.00	0.66
K2O	-	0.64	1.63	1.60

Table 4. Average nitrogen inputs to the USU Organic Research Orchard in 2011 for compost, feather meal, and alleyway biomass amendments for six different orchard floor treatments: living mulch tree row with grass (LG) or legume (LL) alleyway, non-living mulch tree-row with grass (NG) or legume (NL) alleyway, and tillage (TG) or weed fabric (WG) with grass alleyways.

Orchard floor treatment	Compost N per tree (lb.)	Feather meal N per tree (lb.)	Biomass N per tree (lb.)	Total average N inputs (lb.)
LG	0.11	0.170a	0	0.282b
LL	0.11	0.146b	0.229	0.487a
NG	0.11	0.152ab	0	0.265b
NL	0.11	0.141b	0.238	0.492a
TG	0.11	0.099c	0	0.212c
WG	0.11	0.110c	0	0.223c

Note: Different letters indicate significant differences at $p \leq 0.05$.

Conclusion

There are many possible ways to successfully manage orchards organically in the Intermountain West. The dry climate reduces pest pressure and the warm days and cool nights provide perfect conditions for growing high quality fruit. Careful consideration should be given to crop nutrient management and be tailored for each specific site in question.

Covering the tree rows with non-living mulch such as straw or woodchips provides a good alternative to weed management and may increase moisture retention in this arid environment. The downside is that mulches can be expensive and not always effective at preventing weeds in the late season. They can also be a source of new weed seed imported into the orchard. Planting legumes in the orchard alleyays, perhaps, is the most affordable and least labor-intensive method of increasing soil nitrogen and tree growth. Incorporating compost into small tilled strips (the Swiss Sandwich system) next to the trees to supply the additional nutrients needed, will limit disturbance to the soil structure. To further save on costs, source locally abundant inputs. Regular soil testing will help prevent nutrient deficiencies and excesses that may negatively affect crops and/or pollution to the surrounding environment. Consider testing for soil health using locally adapted on site soil health tests to monitor the long-term impacts of your management system (Thomsen et al. 2017). See the factshhet by Knudsen et al. 2016 for information on costs and returns for a peach orchard in Northern Utah.

Organic agriculture in the Intermountain West is expanding. Markets are growing and locally adapted best management strategies approaches are being developed. There are many new avenues for growth and new market niches to be explored.

For more on Floor Management of Orchards, visit: http://extension.usu.edu/files/publications/publication/Horticulture_Fruit_2012-01pr.pdf

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