ORCHARD FLOOR MANAGEMENT IN ORGANIC APPLE ORCHARDS

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Introduction

Air, water, sunlight, and soil are the natural resources available to grow fruit crops. For organic farmers, the soil is their most important natural resource, because it is the one that can be most readily improved or damaged by orchard management decisions. In addition, organic farmers do not have the arsenal of chemicals to rely on to maintain crop health and productivity. Orchard floor management is critically important for organic growers, because it is the only tool they have to improve and maintain soil quality.

Organic apple acreage is increasing at a rapid rate both globally and within Washington State. As of 2000-01, the United States led the world in organic apple acreage with nearly 7000 ha, with Europe at 3512 ha and New Zealand at 1163 ha, followed by South Africa, Canada, and Chile. In Washington State, organic apple acreage has increased from only 327 ha in 1993 (representing only 0.6% of total apple acreage in Washington) to 2648 ha in 2001 (representing 3.9% of total apple acreage in Washington). Over the period from 1999-2001, organic apple acreage in Washington State grew at a rate of over 50% per year. The Washington Department of Agriculture, and now the U.S. Department of Agriculture, who oversees organic certification, requires a three year transition period where only certified organic products and practices can be used before a producer can sell their products as certified organic. As of 2001, there were 1383 of these transitional hectares in Washington State. Based on current organically certified and transitional acreage, it is expected that 4028 ha will be organically certified in Washington State in 2003, which would represent 4.7% of total apple acreage in the state. Rapid growth in organic apple acreage is projected for New Zealand and Chile between now and 2005. While this growth has made more organic apples available to consumers, the average price premiums for organic apple cultivars in Washington State have dropped from their peaks during 1996-1998. Although average price premiums for ‘Granny Smith’, ‘Gala’, and ‘Fuji’ have remained relatively stable at 50-80% higher than conventional fruit, ‘Red Delicious’ and ‘Golden Delicious’ price premiums have dropped from their highs at more than 100% above conventional prices to only 40%, and even less than 20%, average price premiums in 2000. The acreage and price data presented above were obtained from Granatstein and Kirby (2002).

Now that the U.S. has national standards for certification of organic raw and processed agricultural products, all importers of organic products into the U.S. must meet the certification standards of the U.S. Department of Agriculture’s National Organic Program (*http://www.ams.usda.gov/nop/*). A list of approved agricultural product categories that can be used in the production of USDA organically certified crops can be found on the Internet at *http://www.ams.usda.gov/nop/NationalList/ListHome.html*. A list of specific commercial products that are approved within these USDA product categories can be found at the Organic Materials Review Institute’s Internet site (*http://www.omri.org/*). In addition, the International Federation of Organic Farming Movements (IFOAM), which provides international organic guidelines and standards, has its own list of approved organic products (*http//: www.ifoam.org/*).

Goals and options in orchard floor management

The goals of managing the ground surface in apple orchards are to: 1) reduce weed competition with the trees, 2) conserve soil water, 3) control nutrient availability to the tree roots, 4) reduce soil compaction, 5) reduce soil erosion, 6) provide a traction surface for equipment, and 7) provide habitat for beneficial organisms. These goals apply to organic, as well as conventional and integrated apple orchards. The orchard floor management options for organic growers fall into four categories: 1) vegetation, whether of planted cover crops or simply managing the resident vegetation; 2) mulches, either of biological origin or synthetic products; 3) physical methods, especially cultivation or tillage, but now newer methods of flaming (burning) or steaming weeds; and 4) chemicals, which are very limited and unproven for organic production. The principal methods for orchard floor management that are available to organic growers are cover crops, mulches, and cultivation or tillage.

Cover crops

Cover crops growing on the orchard floor provide both benefits and disadvantages to the organic apple grower. One of the most important benefits that cover crops provide is organic matter for the soil when their tops are cut and decompose, and when their roots die. This organic matter is probably the single most important factor in improving the quality of soils in organic orchards, because it increases soil microbial activity, which improves nutrient cycling for the trees. Cover crops also improve water penetration and storage in the soil. However, cover crops also use soil water and nutrients, so more nutrients must be provided either by the cut and decomposing cover crops themselves or through other means (such as, compost) so as to supply sufficient nutrients to the trees. Cover crops also reduce soil erosion and improve traction for equipment that are driven through the orchard. Depending on the species of cover crops that are selected, cover crops can increase the diversity and populations of beneficial organisms, such as by providing insectories for pollinators and habitat for predatory or parasitic arthropods. On the other hand, cover crops can increase pest problems, especially of vertebrate pests, such as gophers or voles, for which cover crops provide excellent habitat for these animals if grown in the tree row. Several other potential disadvantages of cover crops are that they can themselves become weed problems, they generally keep the orchard colder thereby increasing frost hazard, and they cost more to seed and maintain than just managing the resident vegetation in the orchard.

Cover crops can be managed in several ways depending upon climatic and orchard conditions. Most commonly they are simply mowed and their cuttings left in place. This is the case whether the cover crop extends all the way to the tree trunks or is confined to only the alleyways, as is generally the practice in apple orchards in Washington State where a weed-free strip in the tree row is maintained. Some organic tree fruit growers who have weed-free strips in the tree rows cut the cover crop in the alleyway either with a mower or sickle-bar and blow or rack the cuttings into the tree row as a mulch. In regions with moderate climates and limited irrigation water, cover crops can be seeded in the fall, grown until spring, and then incorporated into the soil as a “green manure crop”. Some non-competitive cover crops can be left undisturbed, especially those that provide habitat for beneficial organisms. A combination of cut, tilled, and/or undisturbed cover crops can be utilized either as strips within a row or in alternating, entire rows in the orchard. A combination method that has been used by organic tree fruit growers is leaving a narrow uncut strip in the middle of the alleyways or tree rows of cover crop species that provide habitat for beneficial arthropods. When the cover crop is left undisturbed in the tree rows for habitat, the strip must be narrow (10-15 cm) and consist of species that are not aggressively vigorous, so that they do not compete excessively with the trees. In this system, referred to as the 'sandwich system" in Switzerland, weed-free strips are maintained between the narrow cover crop strip in the tree row and the main cover crop in the alleyways.

More and more, organic fruit growers are using mixtures of cover crops, but the selection of species depends on the soil and climate at the orchard. In cool, humid temperate regions of North America, such as New York State, fescue grasses (*Festuca* spp.) plus either clovers (*Trifolium* spp.), vetches (*Vicia* spp.), or alfalfa (*Medicago sativa*) are being used. In hot, arid temperate regions with cold winters, such as Washington State, annual winter ryegrass (*Lolium multiflorum*) plus annual hairy vetch (*Vicia villosa*) and perennial white clover (*Trifolium repens*) are being used. In Mediterranean-type climates, such as California, barley (*Hordeum vulgare*) or oats (*Avena sativa*) plus vetches (*Vicia* spp.) are recommended. As can be seen, these mixtures of cover crops include a combination of both grasses and legumes, and annuals and perennials. All of these annual grasses reliably re-seed themselves. Regardless of which cover crop species combination is used, it should be matched to the soil and climate at the orchard and should be managed to provide the desired benefits (that is, weed control, nutrient availability, water infiltration and soil moisture retention, and improved soil quality).

Generally, it is not advisable to grow cover crops over the entire orchard floor because they impose too much competition on the trees for water and nutrients. In a study (Neilsen and Hogue, 2000) conducted in British Columbia, Canada, plots of white clover or mixed sodgrass of Kentucky blue grass (*Poa pratensis*) and creeping red fescue (*Festuca rubra*) were compared when grown either over the entire orchard floor or just within the alleyways leaving 1.5-meter wide weed-free strips in the tree rows. This orchard of 'Spartan'/M.26 apple trees was planted in 1983 and the entire orchard floor was maintained weed-free for the first two years after planting by cultivation. The treatments described above were established in the orchard's third-leaf. This orchard was planted on a sandy loam soil and was sprinkler irrigated. This trial was not organic, because synthetic fertilizers were used as well as selective herbicides to control broadleaf weeds in the sodgrass and grass weeds in the white clover cover crops. However, it does illustrate the competitive effects of grasses versus legumes and growing cover crops only in the alleyways versus over the entire orchard floor. The six-year cumulative effect on tree size, as measured by trunk cross-sectional area (TCSA), and the four-year cumulative effect on yields clearly showed that when these cover crops were grown over the entire orchard floor, tree size was reduced and yields were 35-50% less compared to only growing cover crops in the alleyways. Compared to control plots that were maintained entirely free of vegetation, the white clover and sodgrass plots with weed-free tree rows produced similar cumulative yields. Tree size was identical between the control plots and white clover plots with weed-free tree rows, however, the trees in the sodgrass plots with weed-free tree rows were slightly smaller. The white clover plots with complete orchard floor coverage produced larger trees and cumulative yields than the sodgrass plots with complete orchard floor coverage. These differences in tree size and yields between the white clover and sodgrass plots is probably due to the added nitrogen provided by the clover legume, however, differences in water use between these two types of cover crops could have affected the results as well.

Cover crop species may also affect disease-causing soil microorganisms. In another study (Utkhede and Hogue, 1999) conducted in British Columbia, Canada, different cover crop species and management practices were compared for their potential control of crown and root rots (*Phytophthora* spp.) of apple trees. Cover crop plots of perennial ryegrass (*Lolium perenne*), annual ryegrass (*L. multiflorum*), oats (*A. sativa*), and canola (*Brassica napus*) were seeded in a sandy soil in 1988. Rootstocks of M.26 were planted in these plots and budded with 'MacSpur' in 1989. After the perennial ryegrass was established, it was cut each spring, and used as mulch around the trees. The other cover crops were incorporated into the soil in the spring of 1989 after being established around the trees. During the remaining years of the trial, these cover crop plots were left fallow. Plots free of any cover crop were maintained by hand weeding and shallow rototilling as a control. Annually in mid-June over five years, the soil around each tree was inoculated with *Phytophthora cactorum*, the disease-causing fungi of crown and root rots of apple. All plots were sprinkler irrigated. The cumulative mortality of apple trees to crown and root rot was measured over five years. Only the annual and perennial ryegrass plots had lower tree mortality (about 30% mortality), while all of the other cover crop plots had tree mortality similar to that of the cover crop-free control plots (that is, 60-75% mortality). It is likely that the perennial and annual ryegrasses, whether used as mulch each year or merely incorporated into the soil during the first year of the trial, contain some compound that somehow inhibits *Phytophthora cactorum*. These types of compounds are referred to as being allelopathic and this phenomenon is referred to as allelopathy. It is surprising that canola, a member of the *Brassica* genus, which is known to contain species with allelopathic effects, did not provide any protection against crown or root rots in this trial. Despite the fact that the annual ryegrass provided protection for five years after only being incorporated into the soil during the first year of the trial, this may be the reason why the canola was not effective.

Bugg and Waddington (1994) reviewed studies of the effects of cover crops on arthropod pests in orchards. They reported on one study from apple orchards in Ontario, Canada, where a diverse understory of intensely flowering plant species resulted in increased parasitism of codling moth and tent caterpillar larvae by parasitic wasps. The diversity and growth habit of plant species in this study were so great that the need to accomplish other orchard management practices might necessitate that some of these plant species be planted in hedgerows surrounding the orchard, while other species could be planted in cover crop strips within the orchard. In another study of diverse flowering understories in apple orchards, no biological control of red spider mite, leafminer, aphids, and leafrollers was provided by the understory species, whereas the plant bug pest *Lygus pabulinus* increased. In a study from northern California, USA, an organic apple orchard with a cover crop of bell beans (*Vicia faba*) had 36% of the apples infested with codling moth, whereas a clean-cultivated organic orchard nearby had 45% fruit loss from this pest. While 35% fruit loss is still too great for even an organic apple grower to accept, other more effective means of organically approved codling moth control are available, such as pheremone mating disruption. It was also reported by Bugg and Waddington (1994) that perennial white clovers (*T. repens*) harbor few beneficial insects compared with annual clovers (*Trifolium* spp.) and vetches (*Vicia* spp.).

It is apparent from these studies that the effects of cover crops in orchards can be complex and many differences are expected when using different combinations of cover crop species grown in different climates and soils. Unfortunately, little research has been conducted on the many possible combinations of cover crops that could be used in organic apple orchards. Nevertheless, the best source of information on cover crops in orchards and vineyards is the University of California's Sustainable Agriculture Research and Extension Program (SAREP) Cover Crop Resource web page (*http://www.sarep.ucdavis.edu/ccrop.index.htm*). This valuable internet site contains a list and database of cover crop species, a slide show for orchard crops, downloadable research papers and books that can be purchased, and links to other internet sites dealing with cover crops.

Mulches

Recent studies on mulches in apple orchards have been conducted in Wenatchee, Washington and Summerland, British Columbia, Canada. Since these sites are located within the interior Pacific Northwest of North America, their climates are similar and they both have light loamy-sand to sandy soils with low organic matter and water-holding capacities. In all of these studies various mulches have been compared to a conventional Roundup (glyphosate) herbicide strip. Two of the most successful mulches have been wood chips and shredded paper, both of which provide good weed control. However, since the wood chips have a high carbon:nitrogen (C:N) ratio, their breakdown in the soil may immobilize nitrogen, reducing its availability to the trees. This may be minimal, however, because the wood chips are large enough that they are not rapidly incorporated into and decomposed within the soil. The main problem with the shredded paper is its tendency to be blown away from the tree rows by the wind. Therefore, a binding material is being incorporated with the shredded paper in order to minimize this tendency.

In a recent short-term study (Granatstein et al., 2001) compared various mulches and cover crops, established in 1999, in an ‘Red Delicious’/M.26 orchard planted in 1995 and located in East Wenatchee, Washington. Over two years, the shredded paper mulch provided absolute control of grass weeds, whereas the wood chip and chopped alfalfa hay mulches kept grass weeds to about 20 weeds/m^2, which was about half the density of the Roundup control plots. Cover crops in the tree row of either annual ryegrass (*L. multiflorum*) or a mown dwarf perennial white clover (*T. repens*) also provided good control of grass weeds. An oriental mustard (*Brassica* sp.) cover crop in the tree rows provided the poorest control for grass weeds of any treatment. Broadleaf weeds in the Round control plots were especially troublesome (nearly 350 weeds/m^2) in the first year, so perhaps a pre-emergent herbicide, such as simazine, should have been used. While broadleaf weeds also reached high numbers (nearly 150 weeds/m^2) in the first year in the plots mulched with chopped alfalfa hay, good broadleaf weed control was provided by the wood ship and shredded paper mulches, and the mown clover cover crop. The ryegrass cover crop provided intermediate broadleaf weed control. The thickness of the mulches in this trial was not given, but presumably this would influence the effective of weed control by mulches.

Tree growth (measured as percent increase in TCSA), yields per tree, and fruit maturity from the mulch and cover crop plots in this ‘Red Delicious’ apple orchard were measured in 2000. Tree growth was greatest in the mulched plots of shredded paper and chopped alfalfa hay and in the plots of mustard and clover cover crops. Fruit yield was much higher in the mulched plots of chopped alfalfa hay (27.7 kg/tree) than in any other mulch or cover crop treatment (which ranged from 15.0 to 18.6 kg/tree) or in the Roundup control plots (15.5 kg/tree). There were no statistical differences in fruit weight (range of 207 g/fruit for mustard cover crop to 233 g/fruit for the chopped alfalfa hay mulch) among the treatments. The alfalfa mulch resulted in the highest apple leaf nitrogen concentration in both 1999 (2.8%) and 2000 (2.5%), which may explain the good tree growth and larger yields of this treatment. Although the 2.5% leaf nitrogen concentration in 2000 is not considered excessive, fruit from the alfalfa-mulched trees had lower fruit firmness and less red color than did fruit from the other treatments. It could be concluded that given the soil fertility and tree vigor of this trial, the alfalfa mulch provided more nitrogen than was necessary for optimal fruit quality.

Another advantage of mulches is that they can reduce water use and thus conserve soil moisture. At least this was shown for smaller apple trees in Summerland, British Columbia, where mulched trees with trunks only 2 cm thick used less than half the water of non-mulched trees, but mulched trees with trunks 4 cm thick used only 13% less water (Granatstein and Hogue, 2001).

While compost, either of animal and/or plant origin, may also be used as mulches, they are usually prohibitively expensive in the quantities needed to provide adequate weed protection. In addition, composts may provide too much nitrogen to the trees too quickly, depending on their C:N ratios.

Mulches made of woven polyester or other synthetic materials may also be used, however, weeds will grow through any gaps or breaks in the woven fabric and it has to be fastened securely to the ground in order to prevent it from being disturbed by wind or machinery. There may also be higher vertebrate pest activity and tree bark injury when synthetic fabrics are used as mulches, as was shown for pine voles (*Microtus pinetorum*) in second- and third-leaf 'Empire' trees on Mark rootstock in New York State (Merwin et al., 1995). Merwin et al. (1999) also found high cumulative tree injury by meadow vole (*Microtus* sp.) in second- to eighth-leaf 'Empire' and 'Jonagold'/MM.111 apple trees in plots maintained with 15-cm deep straw mulch (62% of trees damaged) and in plots of a crown vetch (*Coronilla varia*) cover crop (47% of trees damaged), which were established in the tree rows at planting. In this study, the cumulative tree damage by meadow voles in the herbicide-treated tree rows was only 9%. This same 15-cm deep straw mulch treatment resulted in 35% of the trees becoming diseased with *Phytophthora* crown and root rots during the second- to fourth-leaf, whereas no trees in the crown vetch plots and only 6% of the trees in the herbicide control plots became diseased (Merwin et al., 1992).

Cultivation or tillage

Although cultivation or tillage of the orchard floor in organic apple orchards causes soil disturbance that may damage tree roots and results in the loss of organic matter by increased oxidation, this method of orchard floor management has certain positive aspects. It usually results in fewer vertebrate pest problems, as was shown by Merwin et al. (1999), where only 5% cumulative tree damage by meadow voles was measured over seven years. In contrast to the results of Utkhede and Hogue (1999) in Canada, described previously in the section on cover crops, Merwin et al. (1992) observed only 4% cumulative 'Empire' and 'Jonagold'/MM.111 apple trees diseased with *Phytophthora* crown and root rots during the second- to fourth-leaf in cultivated plots in New York State. The striking difference between the results of these two studies may be because in the Canadian study unnaturally high levels of *Phytophthora cactorum* were imposed by artificially inoculating the soil around each tree over a five year period, whereas in the New York study the effects of only the resident fungal populations were evaluated. In addition, in the New York study the cultivated plots were rototilled 8-cm deep monthly from May through August, whereas in the Canadian study the plots were only hand-weeded and shallow rototilled. Despite the fact that the heavier and wetter clay loam soil in New York would be expected to present greater risks of crown and root rots than the lighter, sandy soil in Canada, the frequent, deep cultivation around the trees in New York may have dried the soil sufficiently to significantly reduce fungal populations. However, in neither study were the actual populations of *Phytophthora* in the soil measured. One other possible explanation for the differences found in these studies may be that the MM.111 rootstock used in New York is less susceptible to crown and root rots than the M.26 rootstock used in Canada.

Economic analysis

In a cost of production analysis of organic and conventional apple production systems in Washington State, we found that the annual per hectare costs for materials, application, and maintenance of the tree rows in the organic plots with a wood chip mulch (assuming a 4-year life) was $US117, with a woven polyester fabric mulch (also assuming a 4-year life) was $US135, and by cultivation with a “grape spade” was $US173 (Glover et al., 2001). Using glyphosate (Roundup), simazine, and norflurazon (Solicam) in the conventional plots, the costs of weed control in the tree rows was $US83/ha/yr. In New York State, an analysis of annual per hectare costs of materials and labor found that a wood chip mulch cost only $US35, the identical brand of synthetic fabric mulch as was used in the Washington State study cost $US152, cultivation by monthly rototilling cost $US283, and Roundup and simazine herbicides cost $US30 (Merwin et al., 1995). Greater differences in the prices for wood chips are expected because there are many types available in different locations. The cost of the synthetic fabric mulch is comparable between the Washington and New York studies. The higher cost for cultivation in New York is due to differences in the number of cultivations per year and the methods used (rototiller in New York versus “grape spade” in Washington). The higher costs for weed control by herbicides in the Washington study may be due to differences in the weed species and populations present at the two sites and/or to differences in herbicide resistance by the resident weed species.

New methods of weed control

The most promising new method of weed control for organic tree fruit growers is flame weeding, which damages the resident weeds by burning and/or steaming them. Most of the flame weeders used in orchards are prototypes mounted to tractors or pulled by small all-terrain vehicles (ATVs). In these prototypes, multiple propane burners are targeted toward the surface of the weeds in the tree rows. One of the most important design features of these prototype flame weeders is the presence of shields to prevent excess heat from damaging the tree trunks or rising into the tree canopies. Another factor affecting the amount of heat applied to the weeds and potentially the adverse effects of heat on the trees is equipment speed. Faster speeds result in less heat accumulation and transfer to both the weeds and the trees. In Washington State, we run the micro-sprinkler system while operating the flame weeding equipment, which because of the angle of the burners has the effect of cooling the tree trunks by evaporation and damaging the weeds more effectively by steam. When flame weeding is first introduced into an orchard, it can take many repeated applications per year to get the weeds under control, however, it is not necessary to use flame weeding to remove all weeds from the tree rows, only to maintain them in a non-competitive condition. Estimated costs for flame weeding are currently higher than for other methods of weed control.

Few chemical options are available to control weeds in organic orchards. New products are being developed, such as BurnOut from St. Gabriel Laboratories, which is a blend of lemon and vinegar juices. The efficacy of this product has not been tested under commercial orchard conditions and the effects of these weak acids on soil pH are unknown. Perhaps, given more research some chemical options for weed control in organic orchards will be developed.

Conclusions and recommendations

Controlling weeds and vertebrate pests in organic apple orchards are the main difficulties in managing the orchard floor. Cover crops, mulches, and cultivation, or a combination of these methods, are the main tools available for organic tree fruit growers to manage the orchard floor. If cover crops are used in arid regions such as Cuauhtemoc, they should have low water-use requirements, or cover crops should be planted in the fall, grown off-season, and incorporated into the soil in the spring as a “green manure crop”. Mulches should be used that are readily available locally, so that material and transportation costs can be minimized. While cultivation is the easiest and most straightforward method of orchard floor management, it is not as beneficial to the soil in organic orchards as are cover crops and mulches.

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