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Importance of orchard floor management in organic fruit growing (nutritional aspects)

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Summary: Worldwide research goals and concerns are to soil conservation and improve. This conception is mostly actual in horticulture where the numbers of high-density plantings are continuously increasing. High-density orchards cause more intensive nutrient and water uptake. So that the preservation of soil moisture and nutrient level are key factors in qualified fruit growing. On the other hand due to the climatic changes the water supply of trees will be satisfied among worse conditions than some decades ago. Appearance of water supply problems and water stress is increased in organic growing, where the number of corrections is limited anyway. Furthermore, floor management is a successful tool in weed management which causes many problems for organic growers due to the prohibition of synthetic herbicides. This paper will mainly focus on the nutritional aspects of methods of orchard floor management for growers adopting organic fruit management to make their production profitable.

Key words: floor management, mulching, weed control, organic growing

Introduction

Preserving soil moisture as well as weed control are in focus of organic production all over the world. The practise of ground cover is suitable to solve these problems simultaneously.

According to *Libik & Wojtaszek* (1973) the practise of mulching, well known to horticulture, is perhaps as old as agriculture itself. Mulching with organic materials is highly beneficial in many orchard crops because it is a traditional weed control method that offers important potential benefits by maintaining a high quality soil environment (*Hogue & Neilsen*, 1987, *Holb,* 2002, 2005, 2006).

Moreover, mulching has used generally in organic fruit farming all over the world due to benefits of it (*Skroch & Shribbs*, 1986).

Mulches are not only highly effective in checking evaporation and in preventing weed growth, but also have influence on several processes in the soil. The benefits are variously attributed to the suppression of weed growth, to the conservation of moisture by reducing evaporation and run off, to protection from erosion, to increased infiltration of water, to the increase or decrease of soil temperature fluctuations, to the enhancement of mineral nutrient availability, to the enhancement of nitrification, to additional nutrients and organic matter derived from a decomposing mulch, or to the preservation or improvement of soil structure (*Merwin et al*., 1994). Moreover, mulching has a positive effect on nutritional and biological factors as well (*Faust*, 1989). On the one hand mulching produces an increase in the nutrient content of the soil by leaching of nutrients from the mulch, but at the same time the entire condition of nutrient availability may be modified for better or worse by changes induced by the mulch in the moisture and temperature regimes of the soil. On the other hand applying mulches increases root length density and brought the roots closer to the surface (*Merwin and Stiles*, 1994). In a review of orchard floor management, *Skroch and Shribbs* (1986) provide some general guidelines for several aspects, including soil quality, water relations, and microclimate. They statement that the favourable effects on soil quality can be achieved in the following order: legumes > grass > mulch > bare ground > cultivation (*Skroch and Shribbs*, 1986).

Role of floor management in weed control

To grow large fruit, trees must be unstressed and provided with adequate water and nutrition. Weeds can compete with fruit trees for both water and nutrients. Research has demonstrated that weed competition in young fruit trees reduces tree growth and efficiency, and therefore decreases fruit production and fruit size (*Merwin and Stiles*, 1994).

Therefore weed control is essential to young tree establishment and good tree growth and has an important role in organic production where the methods of it are strongly limited.

Moreover, it is no doubt that the organic fruit production is increasing in Hungary in the last few years, but the production is limited by a lack of effective weed control methods. When weeds are not managed, reductions in yield and fruit size occur. Despite of it, currently, organic growers have few alternatives for weed management and lack information on which alternatives are most effective. Growers need much more information on the effectiveness of weed management strategies in order to maximize yield and fruit quality.

Furthermore, weed control, particularly in the tree row, is also more labour intensive in organic orchards. Some growers report twice as much labour for weed control than in conventional systems, while other only require slightly more (*Granatstein*, 2000b).

Methods of weed control

Current widely used strategies of floor management era in use, including mechanical tillage, mulching, flaming, cultivation, living mulch, cover crops and mowing (*Table 1*). Each method has disadvantages that determine whether or not they will be adopted by growers.

Furthermore weed control can be started prior to orchard establishment and when you have an existing orchard.

Table 1. Commonly used mulching materials

Organic materials	Inorganic materials
Straw	Breakstone
Straw with manure	Plastic foil
Manure	Agro-textile
Sawdust	Shredded paper
Bark mulch	
Turf	
Cover crops (grass, legume, hay etc.)	
Natural weed cover	
Green manure	

Source: basic on *Hrotkó* (2003)

Weeds can be controlled mechanically or by manual cultivation, but control is usually delayed until after unfavourable weed competition has occurred. Tillage incorporates crop residues and other organic wastes into topsoil. However, deep tillage is deleterious to tree roots and soil moisture relations and should be avoided except in serious cases of soil compaction. Frequently, very shallow tillage is recommended to control weeds without damaging tree roots and without causing undue soil drying. This shallow tillage permits good water penetration without exposing additional weed seeds from deeper levels of the soil, thereby reducing weed pressure over time.

Mowing of sod middles, with shallow tillage along the tree rows and/or mulches beneath the tree, reduces soil compaction and erosion and fosters soil microbes and macrobes. However, sod middles compete for available water and nutrients. Electrical or flame weeding equipment can also be used, but may not be practical or safe under orchard conditions. Careless or uncontrolled fire can kill fruit trees rapidly (*Daar*, 1987).

Weed Management Prior to Orchard Establishment

It is an old statement that easier to manage weeds before an orchard is established. Cover crops produce a thick stand that will shade or choke out weeds. Combined with a well-planned sequence of tillage, cover cropping is an effective pre-plant weed suppression strategy that also contributes to soil fertility and stable humus. The basic strategy begins with plowing under or disking the existing vegetation, ripping to loosen compaction, planting a cover crop to suppress weed growth, mowing down and tilling under the cover crop(s), and finally planting the fruit crop (*Kuepper et al*., 2004).

Specific cover crops and management strategies must be varied with location and purpose. The length of the warm season may allow more than one cover crop to be grown in succession. Some cover crops may also be cut and allowed to regrow.

Legume cover crops of purple hull peas (cowpeas), crotolaria, and sesbania all demonstrated good-to-excellent weed suppression, while supplying nitrogen and biomass to the soil.

Weed management an established organic fruit orchard

Very important to maintenance orchard floor management during growing season to can be control erosion, improve the soil, and provide beneficial insect habitat.

The orchard floor – the tree rows and alleyways – can be managed in a variety of ways, using tillage or mowing with cover crops, grazing, or mulching.

A system that provides full ground-cover provides the best protection against erosion. However, a ground cover that is actively growing in the summer uses up water. This is a severe disadvantage in irrigated orchards where water is limited and expensive.

Where they are adapted, orchard grass, fescue, and other cool-season grasses are practical fruit crop for water. With proper fertility management, these grasses can also provide plentiful mulch. Likewise, grasses are a good choice in apple orchards, for example, where the excess nitrogen provided by legumes can actually reduce fruit yields.

Many warm-season legumes are deep-rooted and compete with the trees for water. Normally, they should not be allowed to grow under the tree canopy. However, leguminous ground covers can provide significant nitrogen to fruit trees or vines (*Haynes*, 1980). Grass and legume ground covers alike promote water infiltration and hold the soil in place during the rainy season. Ground covers help maintain and increase soil organic matter, which increases the soil's ability to retain moisture. Cool season legumes, such as bell beans, vetches, and clovers, also can achieve these goals (*Kuepper et al*., 2004).

Cover crops

Orchard cover crops can perform four main functions. They prevent soil erosion and reduce soil compaction from equipment; improve soil quality and nutrient cycling; and improve orchard. A good cover crop might be considered one that has limited competition with the tree, is a poor habitat for rodents and other pests while being a good habitat for beneficial species, and can improve soil quality (*Granatstein*, 2000a).

When you managing a ground cover you should state your objectives and take into the following considerations and aims in order of priority:

- suppress weeds,
- break up soil compaction,
- add organic matter to the soil (increase tilth, water infiltration rates, and water-holding capacity),
- enhance soil fertility (nitrogen fixation),
- attract and sustain beneficial insects,
- serve as a trap crop for pests.

In addition, you must take into account the climate, rainfall pattern, soil type, and potential for soil erosion because these parameters basically determine your choosing.

Characteristics of cover crops should be considered before using. The main questions are the following:

Does this cover crop have a tap root? Will it regrow if mowed? Does it fix nitrogen? How much biomass does it produce? Is it fibrous? How long will it take to break down? Will I need to mow or chop it to speed its decomposition? When should I incorporate it? Will it reseed itself? What is its potential to become weedy if it goes to seed? Does it attract insects? What kinds? Will it serve as beneficial insect habitat? Is it a host for pests? Can it be used as a trap crop? (*Kuepper et al*., 2004).

Animal manures

Animal manures are the most common amendments applied to the soil. In floor management they are used as laying down on the soil surface. The quantity of nutrients in manures varies with type of animal, feed composition, quality and quantity of bedding material, length of storage and storage conditions (*Dewes and Hunsche*, 1998; *Loch*, 2000).

A typical application of 10 t ha^{-1} of farmyard manure from housed organic cattle will contain 30 kg of N, 35 kg of P_2O_5 and 60 kg of K_2O (*Loch*, 2000). In organic systems it is particularly important to conserve manure nutrients for both economic and environmental reasons. Composted manure thus has a more long-term role in building soil fertility, and has been shown to be more effective in building soil microbial biomass and increasing activity than uncomposted manure. Livestock manures influence soil fertility by two major routes, through physical effects associated with organic matters and also through the return of nutrients in dung and urine.

Mulches

Mulching is a powerful weed management strategy that can also contribute to good soil management, if appropriate natural materials are used. After a planting is established, weeds can be suppressed by applying thick layers of mulch. Organic mulches are usually applied in a circle around tree trunks or vines, and down the whole row.

Schupp, 2004 reported that a three- to four- foot-wide weed-free strip under the trees is maintained to lessen the competition between trees and weeds. This is particularly important during the first several seasons of the orchard. Newly transplanted trees have impaired root systems and this further weakens the ability of the trees to compete with weeds. An effective weed management program fosters rapid early tree growth and early fruit production, resulting in a faster return on investment.

Mulch materials may include straw, spoiled hay, leaves, yard trimmings, woodchips, and sawdust. Many of these materials are inexpensive. Still, it's wise to weigh the benefits and risks of each, including hauling costs and the risks of their containing impurities and prohibited materials (*Kuepper et al*., 2004).

Because organic mulches decompose over time, they require periodic re-applications in order to continue suppressing weeds. Mulches can provide adequate weed control if renewed every one or two years, but are expensive, and create a favourable habitat for voles and rodents.

Further advantage of mulching is that their decomposition provides other benefits. The decomposition of mulches contributes organic matter to the soil in the long term, but ties up mineral nutrients in the short term, especially N, the lack of which can be limiting to tree growth and productivity. Coarse shredded bark or woodchip mulch will decompose more slowly than finer materials and is less favourable to voles (*Merwin*, 1995). Bark or woodchip mulch should be supplemented with hand or flame weeding when the trees are young (*Schupp*, 2004).

Mulching with organic matter enhances soil aggregation and water-holding capacity (*Haynes*, 1980). Researchers from 1937 to the present have consistently found that mulching is the best orchard-floor management system for retaining moisture (*Skroch & Shribbs*, 1986).

Kesner (1989) pointed out that mulching was as effective as irrigation in encouraging tree growth.

Figures 1. and 2.: Mulching in young non bearing pear orchard (Tedej) (left) (P. T. Nagy)
Mulching in peach orchard (Siófok) (right) (T. Lang)

Mulching reduces the soil temperature as well, which has other aspects on growing. Growth in the spring could be delayed, and transient micronutrient deficiencies do occur under cold soil temperatures. Cooler soil temperatures are not particularly favourable for freeze-prone or frost-sensitive crops, as lower soil temperature means less energy in the soil to warm trees on cold nights. Too, mulches inhibit the release (as well as the absorption) of radiant energy, which could be important on cold nights. Thus, mulches should be applied to cold- sensitive crops only after the danger of late frost has passed (*Sauls* et al., 2005).

Organic mulches can have positive effects on tree growth, with improvements in soil quality and shifts toward beneficial nematodes (*Granatstein*, 2000a).

Organic mulches provide slow-release nutrients for the long-term health and fertility of the soil. Research indicates that potassium, phosphorus, and nitrogen (primarily from the slow breakdown of the mulch) are more available in mulched systems than in non-mulched systems (*Haynes*, 1980). Some growers express concern that sawdust may acidify their soil or bind nitrogen in the soil. However, these effects are minimal if the sawdust is not tilled into the soil.

Wood chips have been used as successful mulches. However, since wood chips have a high carbon:nitrogen (C:N) ratio, their breakdown in the soil may immobilize nitrogen reducing its availability to the trees. We suppose that this effect may be minimal because the sizes of wood chips are large enough that they are not rapidly incorporated into and decomposed within the soil.

One main problem of mulching is to ensure sufficient mulching material. Raising organic matter on the plantation is one way to ensure sufficient, clean mulching material. Farm-raised hay grown outside the orchard can provide weed-free mulch. Cover crops may be grown between tree rows, mowed, and gathered around the trees. Some small-scale growers use the biomass from orchard alleyways, cutting cover crops with a sickle-bar mower and hand-raking the material under the trees. Larger-scale operations often use forage wagons, straw-bale spreaders, or specialized equipment to mechanize mulching jobs.

Another problem is the monitoring system of incoming production. Gowers must monitor the incoming product and remove any trash to keep undesirable material out of their fields. Growers should ask compost producers about the sources of their materials and any pesticides that may persist in them. Of particular concern are clopyralid and picloram, herbicides that are extremely resistant to breakdown, even after composting. The sale and use of these materials is restricted in most of areas.

Geotextiles, foils

For suppress weed growth geotextile mulches, paper or woven plastic fabrics are using generally. While they allow

Figures 3. and 4.: Use of black foil in sour cherry plantation (Újfehértó) (left) (P. T. Nagy)
Grass between rows in an apricot plantation (Boldogkőváralja) (right) (P. T. Nagy)

some air and water penetration, they may reduce water infiltration, whereas organic mulches increase infiltration (*Granatstein*, 2000). Geotextile mulches do not provide the advantages of adding matter and nutrients to the soil, and if synthetic, they must eventually be removed. Geotextiles have a high intial cost, though this may be partially recouped in lower weed control costs over the materials expected field-life – 5 to 10 years for polyester fabric; 2 to 3 years for paper weed barriers. Still, some growers find them useful for weed suppression in orchard, tree plantations, and cane fruit culture.

Weed barriers by sheet mulching: laying down layers of cardboard or newspaper and covering them with organic material has also widely spread in the USA. Sheet mulching increases the efficacy of organic mulch as a barrier against emerging weeds. Organic growers should avoid cardboard that is waxed or impregnated with fungicide, as well as colour print and glossy paper (*Kuepper et al*., 2004).

In a mulching study (*Hogue*, 1998) found that several organic mulches had positive impacts on water infiltration and retention while a geotextile mulch reduced infiltration.

Cultivation

Cultivation – using mechanical tillage – is the most widely used weed-management practice in fruit production. Some fruit growers have practiced “clean cultivation,” eliminating vegetation throughout the orchard, but this system has many disadvantages, even if accomplished with allowed tillage practices instead of organically prohibited herbicides. In system cultivation may be limited not reaches the tree row under the dripline. A bare orchard floor is prone to erosion, gradual depletion of organic matter, increased soil compaction, and reduced water infiltration. It’s also difficult to move equipment through the orchard in wet weather.

Flame Weeding

Flame cultivation uses directed heat to kill weeds. It works not by burning the weeds but by searing them and causing the plant cells to rupture. Farmers began using tractor-mounted flamers in orchard and row crops in the 1940s (*Daar*, 1987, *Holb*, 2005). Technology and technique have both been refined considerably in recent years. Several tools now commercially available, including flame, infrared, and steam weeders, make heat a viable option for some weed management applications.

Nutritional aspects of floor management

As sources of available mulches have diversified, a revival of interest in this method has recently been documented (*Merwin* et al., 1995). Several recent field trials in humid regions have identified beneficial effects of mulching on apple tree performance (*Merwin & Stiles*, 1994), soil moisture content (*Merwin* et al., 1994) and biological activity in orchard soils (*Hartley* et al., 1996). Moreover, there is little information available concerning the effects of mulching in high density orchards in irrigated regions where daily irrigation and fertigation might be expected to reduce potential nutrient and water stresses. Of particular interest would be the effect of mulching on several problems associated with fertigation of coarse-textured soils, including acidification (*Neilsen* et al., 1999) and the development of nutrient deficiency (*Neilsen* et al., 2000).

Also of interest would be the effect of using mulches in association with organic waste amendments. Biosolids and other biowaste amendments have improved the growth of annual horticultural crops in sandy soils, but their effects in perennial cropping systems have received little attention (*Neilsen* et al., 1998).

Nielsen et al., 2003 pointed out that no increases in leaf nutrient concentration were consistently associated with improved tree performance. Notable effects included in creased leaf P concentration associated with biosolids application, increased leaf K concentration after alfalfa mulch application and temporary in creases in leaf Zn and Cu concentration associated with application of biosolids high in Zn and Cu. Use of both mulches and biosolids amendments benefits growth of trees in high density plantings de spite daily drip irrigation and annual fertigation.

Mulch application most consistently affected tree growth, as indicated in a long term field trial where cumulative yield after 5 crop years was increased by surface application of shredded paper, alfalfa and biosolid mulches. Soil nutrient status and soil biological activity were altered by surface mulching and at another site trees were buffered against moisture stress. Initial growth stimulation from mulching was not sustained at a site where excessive irrigation reduced N availability. Rotovation of a biosolid-amendment to 0.3 m depth prior to planting improved the P-nutrition and initial growth of apple. Amendment treatment did not always affect apple tree performance (*Nielsen* et al., 2004).

Mulch increased root length density and brought the roots closer to the surface. The mulch also increased the concentration of calcium, potassium, and magnesium in the soil and the soil’s cation exchange capacity (*Lang* et al., 2001).

Marsh et al., 1996 reported in a long term experiment that after four years, the tree row mowing treatment had significantly increased soil pH, available P, K, and Ca, and total N. Soil organic carbon was 4.4% with the tree row mowing and 2.8% with the in-place control. The choice of cover crop had less of an influence on soil fertility, and there were no yield differences. However, fruit quality characteristics (bitterpit, fruit Ca, background color, fruit firmness) were influenced by the treatments, in part likely due to changes in N timing and amount.

The concentrations of soil biomass C, biomass N and respiration rates were consistently greatest under the straw mulch and contact herbicide, suggesting that C and N was incorporated into the soil biomass most efficiently under these treatments. The soil solution nitrate concentrations also were lowest under straw mulch and contact herbicide. The straw mulch increased the concentration of K in the surface soil (0-15 cm) compared to the other treatments, and was reflected by consistently higher concentrations in the leaves of trees. The contact herbicide treatment had lower leaf concentrations of N in most years. The fruit mineral concentrations reflected leaf mineral concentrations. The trees growing in the straw mulch had the greatest shoot growth and those in the contact herbicide treated soil had the least. These increases are ascribed to the greater conservation of moisture within the profile during the shoot extension period. The differences in harvest yield between treatments were generally small in individual years, however cumulative differences occurred over 6 crops. The trees in the straw mulch had the greatest yields and mean fruit weights. The ground vegetation management systems did not influence fruit quality except in the second harvest, when yields were low and the individual fruits were large (*Hipps* et al., 2004).

Regarding plant uptake several authors stated that there were no significant differences in any leaf or fruit nutrients in long term floor management experiments (*Shribbs & Skroch* 1986; *Lang* et al., 2001; *Hipps* et al., 2004).

Nagy et al., 2009 different livestock manures (cow, horse and pig) and different mulch-matters (straw, pine bark mulch, black foil) were applied to the surface to test the effectiveness of these materials. Applied treatments were divided into two groups according to origin and effect. Their results can be summarized as follows:

- Our results pointed out that used ground covering matters divided into more categories regarding its effect.
- Available N, P and K content of soil was mostly increased by applying manures.
- Effectiveness of straw, mulch and mostly black foil was lower.
- Differences were found between nutrient supplying treatments and those treatments which did not supply nutrients.

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