Biointensive Management of the Orchard Understory

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The concept of "sustainable agriculture" has become widely accepted by growers, consumers, and policymakers as an important guide for the future direction of food production systems. While we cannot know today what will be "sustainable" a century from now, the concept embodies three parts that help shape decisions in the present: economically viable, environmentally sound, and socially responsible. For orchardists, sustainability has mostly taken shape through increased emphasis on biointensive Integrated Pest Management (IPM). In Europe, growers have gone beyond IPM to Integrated Fruit Production, which considers sustainability issues for soil, water, and humans in addition to pests. In our region, the rapid expansion of organic fruit production represents a significant effort to address sustainability.

As we search for systems that are more environmentally benign and still profitable, biology will likely play an increasingly vital role. Growers manage agroecosystems, that while far simpler than most natural ecosystems, are still very complex. We have focused management on specific parts for decades, but are beginning to recognize that the parts interact and through conscious design and management, we can improve both financial and environmental performance. Stuart Hill, formerly of McGill University, proposed three strategies that represent increasing degrees of sustainability (MacRae et al., 1990). The first is efficiency, achieved through such steps as soil testing, pest scouting, and improved sprayers. This is the easiest to achieve but moves us the least towards sustainability. The second step is substitution, where more environmentally sound products and methods are used in place of less desirable ones (e.g. B.t. instead of organophosphate). The third step is agroecosystem design that consciously addresses as many relationships as possible, builds in solutions, and excludes problems. We know the least about this step, which ultimately could deliver the most sustainability. The redesign of the orchard understory represents an opportunity to embody this strategy and provide multiple benefits to the orchard.

Orchard understories perform a number of functions (Table 1). The functions can impact each other (e.g. water relations and gas exchange), and each function is impacted by one or more management decisions made by the grower. 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. For example, favorable effects on soil quality can be achieved in the following order: legumes > grass > mulch > bare ground >

cultivation; a key take-home message is to avoid cultivation. Most management actions involve tradeoffs, and these must be known in order for growers to make appropriate decisions.

Table 1. Orchard floor functions and management impacts.

Functions	***Impacted by:***
Water intake/storage	Understory species
Physical support	Understory canopy
Gas exchange for roots	Irrigation system
Nutrient cycling/storage	Nutrient inputs
Habitat – micro, macro	Spray drip
Micro-climate	Organic inputs

Cover Crops

Ground vegetation, or cover crops, is a standard feature in most modern irrigated orchards. Manipulation of this vegetative cover, in terms of composition, time, location, life cycle, and biomass, offers potential multiple benefits, many of which have not been adequately explored. 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 IPM. 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.

Few contemporary orchards take advantage of these opportunities. Rather they use a relatively undiverse grass planting in the drive row for traction and dust abatement, and keep the tree row devoid of vegetation. With the increased interest in biocontrol, more research and experimentation is occurring with regard to habitat enhancement through the orchard cover crop. Cover crop plantings with increased floral diversity can enhance the presence of beneficial insects, primarily generalists. However, few studies have shown this to result in measurable improvements in pest control. Most of the change occurs on the orchard floor itself (Caprile et al., 1994, Granatstein, 1995). The greatest success has been achieved where a specific pest-predator relationship exists in which the vegetative change directly benefits the predator. Successful examples for pecans in Oklahoma and oranges in China have been reported (Tedders, 1983; Liang and Huang, 199). Researchers in Washington State are currently pursuing this strategy with alfalfa for potential leafroller control.

Weed Control and Mulches

Orchardists regularly employ weed control to minimize competition with the trees for water and nutrients, to discourage rodent habitat, to maintain effective irrigation patterns, and to improve access for workers and machinery. Weed control generally involves creating a biological vacuum in the tree row that nature keeps trying to fill. The actual weed-free area needed to avoid competition is less than the typical herbicide strip and the potential for weed competition declines with tree age and through the growing season (Merwin and Ray, 1997). One alternative weed control strategy that also provides potential benefits is mulching. While the costs of mulching can be much higher than herbicides (Merwin, 1995), new plantings on sandy soil in the Okanagan Valley have shown marked growth responses (Table 2). Certain mulches led to significant improvements in soil quality and surprising shifts in nematode populations that enhanced beneficial nematodes and suppressed parasitic ones (Hogue, 1998). In addition, mulches offer opportunities to manipulate soil temperatures and conserve irrigation water.

Table 2. Effect of orchard mulching on apple tree growth and yield - Summerland, BC. (Hogue, 1998)

	5th Leaf Spartan / M.9	
Treatment	TCSA (mm^2)	Yield (kg/tree)
1. Check (glyphosate)	578 c	5.2 c
2. Biosolids (Vancouver)	596 c	5.8 bc
3. Paper mulch	917 a	7.8 ab
4. 2 + 3	911 a	8.6 a
5. Composted biosolids + 3	840 ab	7.8 abc
6. Alfalfa hay	725 b	8.3 ab
7. Geotextile	726 b	7.5 abc

Mulches are expensive due to the need to ship and handle large volumes of material. One organic grower in Washington State has devised a system of growing the mulch in place and mechanically manipulating it. He grows alfalfa in the drive row instead of grass. A custom-designed mower is front-mounted on the tractor and a Weed Badger and brush rake are used to move the mulch on and off the tree row. Rows are mowed alternately (7-14 days apart) to minimize outmigration of pests such as lygus bug into the trees. This system is less expensive than the tillage-based system previously used, it adds organic matter and improves soil, and it replaces the need for N fertilizer, saving $100-150 per acre per year. As with any system, it has drawbacks including increased rodent habitat, higher humidity and disease potential, and increased light reflection that can sunburn (or conversely, can help color) fruit. The alfalfa system is a good example of a conscious redesign of orchard floor management using biointensive principles.

Soil Fertility

Understory management influences soil fertility and tree nutrition via nutrient cycling, retention, competition, and accumulation. Nutrients brought into the orchard in fertilizers may have little interaction with the cover crop depending on placement and timing. New Zealand researchers have demonstrated large impacts on soil fertility and tree nutrition through manipulation of the orchard understory (Marsh et al., 1998). A block of five-year old apple trees was converted to organic management, with experimental treatments including compost addition (5.6 kg/tree annually), three ground covers (red clover, ryegrass, herb ley), and two mowing regimes (in-place, or mulch to tree row). Soil sampling was done at two depths (0-5 cm, 5-15 cm) and two locations (tree row, drive alley).

After four years, the tree row mowing treatment had significantly increased soil pH, available P, K, and Ca, and total N (Table 3). 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 (Marsh et al., 1996)

Soil Health

The soil provides a number of functions beyond nutrient supply that are commonly referred to as soil quality or soil health. One widely used definition of soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin, 1994). Orchard floor management can influence soil health in a number of ways. For example, in a mulching study at Summerland, BC (Hogue, 1998), researchers found that several organic mulches had positive impacts on water infiltration and retention while a geotextile mulch reduced infiltration. In contrast, mulching in the more humid New York climate led to a dramatic increase in Phytophthora root rot and significant death of apple trees (Merwin and Stiles, 1994). Additions of organic residues to orchard soils in central Washington have led to measurable increases in soil organic matter over periods of 10 years or less (Granatstein, unpublished data), which improves water holding capacity and other soil quality aspects. Conversely, some organic orchardists using tillage to control weeds have experienced decreases in soil organic matter.

Another critical aspect of soil health relates to apple replant problems. Recent work by Mazzola (1999) in Washington State points to the dominance of fungal pathogens as the cause of apple replant disease in that region. He demonstrated that the apple trees themselves create the problem due to the microbial communities that the root exudates favor. Biological and cultural controls are being explored, including the use of wheat and rapeseed cover crops, microbial inoculants, soil disturbance and spatial arrangement. This aspect of soil health is increasingly critical to growers who must replant on shorter intervals to maintain fruit varieties that are viable in the marketplace. And with the likely loss of major tools such as methyl bromide, effective alternatives that are environmentally friendly are needed.

Conclusion

Both current research and grower innovation are uncovering promising new options to manage the orchard understory for multiple benefits that enhance the sustainability of fruit production. More research is needed on both the biology of individual components and the ecology of the system so components can be combined for optimal benefit. This type of research should be a priority for publicly funded research as there is little incentive for the private sector to explore these directions. Such a focus on agroecosystem design for orchards requires multi-year and interdisciplinary approaches that may need to occur on the landscape scale. Despite the challenges, we need to pursue this direction in order to achieve breakthroughs that can address the economic and environmental challenges facing agriculture.

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