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Orchard Floor Management: An Overview

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One of the authors (Skroch) has been asking himself since the early years of a long-term study initiated in 1966 (77) "What is a weed to a tree?" Apple trees in the mowed grass check plots grew less than in plots with woody vines. In another test comparing mowed sod, contact herbicide, and residual plus contact herbicide, trees having an herbicide program yielded 400 bushels/acre more fruit in the 5th year than those without. Apples in another orchard were of higher grade in plots with over 50% trailing blackberry (*Rubus* sp.) and poison ivy (*Rhus radicans* L.) ground covers than those from an area with a mowed-lawn appearance. The practice of frequent mowing, which increased grass covers in the 1960s, may have been a factor in the small fruit problem of the 1970s.

These studies led to participation in the IPOMS project (Integrated Pest and Orchard Management Systems in North Carolina), which paralleled the Huffaker project and was followed by the CIPM project (Consortium for Integrated Pest Management) sponsored by the USDA. Objectives of the IPOMS project were to a) reduce the cost of pest management practices without loss of fruit quality and yield, b) develop pest management techniques for reducing amounts of pesticide used, and c) optimize orchard management practices (73). These are our goals in developing orchard floor management systems in North Carolina (76).

Worldwide, similar research goals and concerns over IPM, minimum tillage soil conservation, agroecosystem analysis, and optimum production through high-density plantings have generated interest in orchard floor management (3, 19, 40, 50). These are not new concepts and were studied scientifically in the early 1900s (13, 14, 93). In particular, Woodbury et al. (93) said considerable controversy surrounded soil management practices and studied the particular factors responsible for the effects of tillage with summer cover crop, mulch, and sod on apple trees. They made measurements on growth, mineral nutrition, water use, soil microflora, moisture availability, soil temperature, and soil physical and chemical properties. They concluded that mulching increased apple growth 45% over trees in sod and the main factor was increased available soil moisture. In 1919, Bedford and Pickering (13) concluded from their studies that fruit tree vigor was reduced in an inverse relation to grass vigor. These results and conclusions have been reaffirmed repeatedly by other authors in apple (2, 8–12, 17, 22, 26, 28, 33, 35, 45, 54, 74, 75, 79) and other (16, 29, 58, 62, 66, 69, 74, 82, 90, 91) orchards. For some reason, however, many growers in the eastern United States still use either one overall natural sward composed of bluegrass (*Poa pratenis* L.) fescue (*Festuca elatior* L.), and orchardgrass (*Dactylis glomerata* L.) (3 of the most vigorous grasses), or a strip system of these grasses in alleys between bare rows maintained with herbicides. Other systems recommended are overall bare soil with a moss-enhancement program (7) and a legume cover crop (19, 78). Each of these systems has its advantages and disadvantages, so the controversy continues as to which is the optimal cover or system. We need to look closely at the benefit:risk ratio of each system and to review, in particular, the effects of these systems on the tree, yield, and economics. After all, what is a weed?

We are interested in continued studies of orchard floor management systems because several problems exist with present systems, and we may as yet be unaware of some of the benefits of each system. Species resistant to applied stresses, particularly to herbicides, become dominant in an orchard (77), making weed control difficult. Even sod alleys in a strip system can interfere with tree growth (3, 9). Cultivation of the soil breaks down the soil structure (34, 42, 78). Bare-ground orchards may be difficult to enter with heavy equipment during wet conditions. Herbicide registrations increase flexibility in style of management, with a vast array of options. Swards of various species have beneficial aspects in harboring pest predators (92). Ground covers also can reduce winterhardiness of apples (60, 89). The cost of grass seed for use in orchards is limited by economics. Also, some grass covers are difficult to establish or maintain as monoculture (or may even have too much vigor), with a spreading habit that makes the grass difficult to manage within the plant-free tree row. Certain species may be allelopathic (49). Changing economics may allow greater input into floor management, especially since intensive high-density orchards are being recommended (1, 6, 85). Present systems may not be optimal, and new technologies may provide new solutions.

We need to look at how ground covers affect an orchard through soil properties, water, nutrients, temperature, pest interrelationships, and allelopathy in order to develop benefit:risk ratios for the different systems and particular plant species. Interference includes direct interactions (such as the competition for water or nutrients and release of phytotoxic chemicals) or indirect interactions (such as modification in microclimate and hosting of pest organisms). Beneficial aspects include the same or similar interrelationships (i.e., harboring of beneficial insects or enhancement of the microclimate).

Soils

Ochse et al. (67) wrote "the most important phase of soil management and probably the outstanding problem in general is the control of erosion," and recommended several soil-terraining methods and cover crops to reduce erosion. Soong and Yap (78) stated that ground cover plants reduce erosion, limit the extremes of climatic conditions, control the rate of decomposition of organic matter, and retard the leaching of nutrients. These effects result in a recycling of nutrients and an increase in organic matter, which they thought was the most important attribute of a ground cover. They particularly recommended the use of creeping legume covers rather than grass swards in Malaysian rubber plantations, because the legume cover increased rubber tree root density; yield; soil aggregate stability, permeability, and porosity; and decreased soil bulk density. Broughton (19) concluded that legumes grow faster and have a greater nutrient content than grasses. They thus recycle more nutrients in the soil, and beneficial aspects, such as increased yield, remained many years after the legumes were shaded and killed.

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Goode and White (34) showed that cultivation leads to a loss of soil aggregate stability. Losses were reduced under mulch and under grass due to increases in organic matter. Haynes (42) showed that cultivation leads to decreased bulk density, water penetration resistance, aggregate stability, tree root density, and earthworm activity, but increased porosity and infiltration rate in comparison to grass. Bare ground led to natural compaction of the surface soil, with increased bulk density, penetration resistance, and root density, but reduced porosity, infiltration rate, and earthworm density of the soil. Cary and Evans (21) showed that water infiltration rate and water holding capacity decreased from sod to winter legume to bare surface. Other studies propose that bare ground leads to a decrease in soil pH and base saturation, causing an increase in nutrient (Ca and Mg) leaching, but this did not seem to adversely affect trees planted in bare row–grass alley strip systems (43, 44, 46). Apple root growth can be inhibited by reduced porosity of the soil (86). So, in this respect, the overall ranking of ground cover systems and their favorable effects is legumes > grass > mulch > bare ground > cultivation. However, soil properties as such are not the main determinants of tree growth, since several authors have shown a nonsignificant effect of soil property on actual tree growth (40). These properties nevertheless do affect moisture retention and infiltration, both of which play a major role in ground cover–tree interrelationships.

Water

Several workers have found that the availability of moisture in the soil favored (from most to least) the following culture systems: mulch > bare soil > minimal cultivation > grass > legumes > continuous cultivation (3, 15, 18, 25, 51–53, 56, 74, 83, 93). Mulch promotes infiltration rates and lowers water evaporation from the soil, so that the maximum field capacity is maintained longer at all depths during a drought period. Bare ground retains better soil structure than cultivated soil and retains more water. Both grass and clover will readily deplete available water within their root zone, usually to depths >50 cm. Mowing, however, decreases water use. Swards transpire much more water than cultivated soil, but the latter will lose soil structure and become puddled with rainfall or irrigation after several years. This puddling results in reduced water infiltration and increased runoff, such that lower levels of the soil profile will have less available water than similar strata under vegetation systems. "Trashy cultivation", that is, a spring cultivation with summer weeds, leads to transpiration of more water, thus favoring a greater water depletion than under a grass or clover sward. Atkinson (1, 4) states water management is the best way to alleviate competition from ground covers in English orchards, and the greater the tree density, the more sensitive is the yield to water management.

Fertility

Rogers et al. (74) studied the effects of different ground covers, mowing frequencies, and fertilizer levels in a mature commercial orchard. Grasses caused a decrease in N levels of the trees. Adding N partially overcame this inhibition of growth, although the ground covers also responded to fertilizer and produced greater growth. Disking in of the swards also corrected tree N deficiencies. They concluded that cover crop effects were greater than fertilizer effects. Atkinson (8) and Haynes (41, 45, 48) noted decreases in N and increases in K in trees due to competition with grass swards for these nutrients. The N decrease resulted from a direct competition that caused sizeable reductions in tree growth, whereas the increase in K content was due to a decrease in overall tree growth and thus to a concentration effect. Lack of competition for N (causing high N levels in leaves and fruit) is considered just as bad as low levels, since high N in fruit will prevent good coloration and cause poor storage quality (68, 80, 94). A ground cover growing in midsummer and not in the spring may be beneficial in maximizing N availability during the major thrust of vegetative growth and fruit set, while reducing N availability during fruit growth. The question still remains, however, whether ground cover competition for N can be completely overcome with fertilizers, or whether the fertilizer will simply cause greater competition by the vigorous ground cover.

Microclimate

Ground covers greatly influence—both directly and indirectly—the temperature of the air and soil in an orchard. Woodbury et al. (93) noted that soil temperature was inversely proportional to the amount of either grass herbage or straw mulch in the orchard, and that rains do not influence soil temperature. Two workers (23, 27) reported that plastic mulches increased soil temperatures, while straw mulches and living plants shaded and insulated the soil, thereby reducing temperatures. Plant mulch will minimize the severity of daily fluctuations of soil temperature (23, 27). Since wet soils have a much greater heat of evaporation than dry soil, soils under straw mulch or bare ground will need more radiation to increase soil temperature than a soil planted to sward during a dry period. Rogers et al. (74) and Leyden and Rohrbaugh (57) noted that the use of swards compared to a cultivated soil or nontilled plots could lower minimum air temperatures by 0.5–1.0°C on nights with radiational cooling. This temperature reduction could make a big difference in bloom survival. In a report on frost protection, Hamer (36) recommended "keeping risk to a minimum during blossom time by removing weeds and keeping grass cut short", since ground vegetation limits heat absorption during the day and, therefore, the heat available to be reradiated to the cold night sky. The presence of a bare, compacted wet soil has been reported to raise minimum orchard air temperatures by as much as 2° on cold nights (50).

Several people (26, 64, 65) have reported that apple seedling rootstocks grew better at temperatures up to 27°C, while some dwarf rootstocks grew best at 14° and even died at the higher temperatures.

Pests

Ground covers indirectly influence the orchard by harboring or attracting beneficial and pest organisms, including nematodes, mites, insects, and rodents. Dandelion (*Taraxicum officinale* Weber) blossoms compete for bee attention at blossom time, thus reducing interpollination of apple trees (30). Fye (31) showed an increase of lygus bugs in orchards with broadleaf weeds. Dandelions, chickweed [*Stellaria media* (L.) Cyrillo], and red sorel (*Rumex acetosella* L.) can act as hosts of the tomato ringspot virus, which causes brownline necrosis in apple and stem pitting in peaches (70, 71). Broadleaf winter annuals are reported to increase insects that cause catfacing of peaches (61). Hayne (38) obtained a high correlation between biomass density (especially grass) of the orchard floor and vole numbers. An increase in the presence of phytophthora fruit rot was associated with bare ground in wet years, since crates and fruit tend to be splashed with wet soil, an excellent phytophthora inoculum (37). Ground covers, compared to bare or cultivated soil, have other benefits including an increase in earthworm activity. An irrigated grass cover, compared to bare ground, was related to an increased infection by vesicular arbuscular mycorrhizae of field-grown fruit trees, resulting in an increase in leaf P levels (5). William (92) presented a case for ground covers that harbor beneficial insects and noted that cover crops reduced nematode infestations in peach, verticillium wilt in olive, and insect pests in peach, apple, walnut, pecan, citrus, grape, tea, and oil palm. Also, a ground cover reduces dust on tree leaves, which, in turn, reduces mite infestations. Tamaki (81) showed that infestations of green peach aphid were reduced when grass replaced broadleaf weeds. In a citrus orchard (55), more mites were found in a strip system than in overall bare ground.

Allelopathy has not as yet been proven to be a significant inhibitor of orchard trees, but it cannot be ignored. Horowitz (49) demonstrated inhibitory responses of citrus to 3 ground covers — bermudagrass [*Cynodon dactylon* (L.) Person.], nutsedge (*Cyperus esculentus* L.), and Johnsongrass [*Sorghum halepense* (L.) Person.]. He suspected an allelopathic response, since inhibition was not correlated with ground cover biomass and could be only partially overcome with fertilizer treatments. Inhibition was not associated with nutrients or water availability in a field study of peaches with increasing levels of bermudagrass density, thereby implying allelopathy (87).

DISCUSSION

A partial answer to the question "What is a weed to a tree?" includes a summary of the desirable qualities of an orchard floor management system. Desirable components should include easy establishment and maintenance, minimal interference with the crop, and an advantage in developing maximum sustained yield. An orchard floor management system should reduce erosion; improve soil structure; recycle nutrients (particularly N) at appropriate times of the season; retain soil moisture in dry seasons and remove water during wet periods; require minimal levels of money, time, and energy; take abuse and retain roadability; enhance beneficial organisms and discourage pests; reduce fire hazard; enhance orchard operations; and perhaps use plants that provide a 2nd source of revenue. Each system needs to be evaluated individually for an overall benefit:risk ratio. Let us not lump together "grass sod" or "sward mix of grass and clover". Many nontraditional species of ground covers, such as red sorrel, nimblewill (*Muhlenbergia schreberi* J. F. Gmel.), and dwarf turfgrass cultivars have possibilities. Chemical vegetation suppressants add another dimension to an arsenal of herbicides and plant growth regulators that could reduce mowing and thatch. Nearly all plant species can be controlled in orchards, and our challenge is to develop skills in using these technologies. The techniques are available to do multifactor experiments in the field, greenhouse, and phytotron to quantify interference. Maintenance practices that enhance desirable over undesirable plants need to be studied.

Another consideration in orchard floor mangement may be to minimize living ground covers, since any plant other than the tree will interfere at some level, hence being defined as a "weed". Bare ground is not difficult to maintain. It increases erosion potential, but moss and algae often become established. These plants could reduce erosion and allow orchard operations when the ground is wet. In high-density plantings, where traditional orchard traffic could be eliminated, gravel, concrete, or plastic travel strips for over-the-row equipment could be feasible. Other possibilities include woven plastic mulches or limited quantities of straw, wood chips, or other organic materials, or even a live winter mulch that is killed in early spring, either naturally or with herbicides.

Economics is the least documented aspect of orchard floor management. When comparing cultivation and herbicides to achieve bare ground, Tucker (84) found one herbicide equal to 5 cultivations in weed control effectiveness, with the economic costs about equal for the 2 systems. The energy costs were much greater for cultivation than for herbicide application, and the fruit yield and quality better in the herbicide system. Carlson and Perez (20) are continuing work on a complete economic analysis of apple growing. Floor management comprises a substantial part of the money and labor budget of overall management. The question arises as to "How much dollar return can a grower earn on a dollar input into orchard floor management?" We can develop new systems, new ground cover species adapted for each area, and proper fertilizer and watering schedules, but what is economically feasible?

In Europe, high density systems with intensive management and dollar investment are being strongly recommended. Are these conditions similar to those in the United States? Can a high-density system support an intense ground cover management system? These questions are still unanswered and need to be studied.

Some noteworthy recent advances are the studies of recycling nutrients in orchards (32, 47), optimal inputs (6), vegetation modeling and sampling (24, 63, 88), modeling of competition (39, 59), and use of allelopathy (72). These studies not only are allowing us to understand interrelationships between ground cover systems and orchard trees, but also are taking us a step further to quantify the factors of interaction and to evaluate systems as a whole in order to integrate them into a total management system where we can make calculated judgements to reach our goal of optimum return on investments.

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Grass Interplanting in Horticulture Cropping Systems

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Of the 5000 grass species identified worldwide, more than 1400 may be found in the United States (17). The potential benefits of interplantings in horticultural crops justifies the effort to identify the most appropriate grasses for this practice. Grass interplantings are used to reduce erosion, increase water infiltration into the soil, improve traffic-carrying ability, improve soil structure, limit weed invasion, moderate soil temperatures, and reduce soil contamination of crops. Disadvantages in using grasses for interplantings include increased competition for water and nutrients, harborage of pests, and expense of establishment and maintenance.

Desired characteristics of grasses for horticultural interplantings include low growth, fast germination and cover, dense and weed-resistant cover, drought and shade tolerance, and wear-resistance. Turfgrasses often exhibit more desirable characteristics for horticultural crop interplantings than cereal and forage grasses. Disadvantages of cereal and forage grasses include a tall, upright growth habit and the fact that many are annuals. Occasionally these characteristics may be desirable, and cereals and forages may be used for interplanting.

The success of grass in interplantings depends upon satisfaction of its environmental requirements. Based upon temperatures for most-active growth, turfgrasses are divided into 2 broad groups. Cool-season turfgrasses have a temperature optimum of 16° to 24°C while those with an optimum of 27° to 35° are warm-season (3). Also, the latter become dormant and top growth turns brown at temperatures near freezing.

Cool-season turfgrasses, such as Kentucky bluegrass (*Poa pratensis* L.), fine fescue (*Festuca* spp.), and tall fescue (*F. arundinacea* Schreb.) are grown as interplantings across the northern two-thirds of the United States and into Canada. The zone of adaptation for warm-season turfgrasses, such as bermudagrass (*Cynodon* spp.) and zoysiagrass (*Zoysia* spp.), is primarily the southern one-third of the United States. There is a transition zone of varying width across the United States in which both cool- and warm-season turfgrasses are common. This zone has a climate not especially suited for either warm- or cool-season turfgrasses, and weed problems are frequently serious because of poor turfgrass performance. There are, of course, some major exceptions to the typical pattern of occurrence of warm-season grasses in the south and cool-season grasses in the north. For example, buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], a native warm-season grass of the High Plains in the United States, may be found growing from Mexico to near the Canadian border.

Selection of the most appropriate grass for interplanting requires consideration of numerous characteristics. In some instances, a blend (cultivars of the same species) or mixture (a combination of 2 or more species) of grasses may be needed to offset problems such as the lack of tolerance of buffalograss (when used as a monoculture) to heavy shade. A review of some of the more important characteristics involved in selecting grasses for interplantings will follow. One or 2 of the traits enumerated will likely be given high priority on any site. Only the more common turf and forage grasses are mentioned, and there may be other grasses of equal or greater value in meeting local needs.

Rate of establishment

A major concern when choosing grasses for interplanting is ease of establishment. Seeds of many commonly grown cool-season turf and forage grasses are readily available. Warm-season grasses, such as St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] are established almost totally by vegetative plantings, while others, such as Japanese lawngrass (*Zoysia japonica* Steud.), centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.], common bermudagrass [*Cynodon dactylon* (L.) Pers.], bahiagrass (*Paspalum notatum* Flugge.), and carpetgrasses (*Axonopus* spp.) may be established by seed or vegetatively.

Rapidity of germination and initial growth (seedling vigor) of a grass is exceedingly important for erosion and weed control and for equipment access. Erosion is often severe in the tropics and subtropics, and rate of establishment of a cover can be of primary concern. Conditions needed for success in seedling establishment are vigorous (adapted) seedlings and a favorable environment (24). Grass seed may germinate in a few days or it may take several weeks or months. Pregermination of seed before planting may speed establishment. Turf and forage grasses usually require only a few days to germinate with good growing conditions. For instance, annual ryegrass (*Lolium multiflorum* Lam.) germinates in 5–8 days, red fescue (*F. rubra* L.) 5–12 days, tall fescue 6–12 days, and Kentucky bluegrass 6–30 days (22). Perennial ryegrass (*L. perenne* L.) planted in late summer and irrigated may emerge in 5 to 6 days. Many horticultural crops are row-, drip-, or furrow-irrigated, and establishment of interplanted grasses is given secondary consideration. Thus, germination may be greatly delayed and establishment poor.

Many commercially available, turf-type perennial ryegrasses are desirable for interplantings because of extremely fast germination and establishment rates and resistance to weed invasion (6). Range grasses such as buffalograss and another warm-season grass, blue grama [*Bouteloua gracills* (H.B.K.) Lag. ex Steud.], have desirable traits for interplantings, but can be quite slow to germinate and establish a cover under natural conditions.

Height and spreading characteristics

Tall growing grasses [e.g., smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), and timothy (*Phleum pratense* L.)] require frequent mowing, while low- and intermediate-height grasses (e.g., buffalograss, Kentucky bluegrass, and zoysiagrass) may need only infrequent cuttings for weed control or to reduce fire hazard. Tall-growing grasses are likely to attract rodents and shelter them from predators unless maintained at a low height. Mice prefer vegetation about 30 cm high (7).

Grasses used for turf are selected for low growth and they are maintained to keep a low sward. Forage grasses are normally tall-