Integrated Weed and Soil Management in Fruit Plantings

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Cornell Cooperative Extension ❦ Information Bulletin 242

This publication is issued to further Cooperative Extension work mandated by acts of Congress of May 8 and June 30, 1914. It was produced with the cooperation of the U.S. Department of Agriculture; Cornell Cooperative Extension; and College of Agriculture and Life Sciences, College of Human Ecology, and College of Veterinary Medicine at Cornell University. Cornell Cooperative Extension provides equal program and employment opportunities. William B. Lacy, Director.

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Produced by Media Services at Cornell University

Printed on recycled paper

142IB242 429/700 1/98 2M GPP MS60567

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Introduction

Growing fruit is a complex, high-stakes enterprise. Crop values can exceed $25,000 per acre, and damage caused by weeds, insects, and diseases can easily make a crop unmarketable. Pest control accounts for a substantial portion of the costs of fruit production, and weed control helps determine its short-term success and long-term sustainability.

Weeds can be controlled by a variety of methods. Growers must decide which controls are best suited to their growing conditions, intended market, and personal preferences. Public concerns and government regulation of soil and water quality and pesticide residues on foods raise additional questions about potential health and environmental impacts of weed control practices. Choosing the best weed and soil management systems is thus an important and complex decision.

This bulletin explains how weed management systems affect fruit crops, soils, groundwater, and some beneficial or detrimental organisms in fruit plantings. The advantages and disadvantages of various methods for managing weed competition are described, and the importance of integrating weed control practices into comprehensive systems for sustainable fruit production is emphasized.

Interactions of Weeds, Crops, Soils, and Water

A weed has traditionally been defined as "any plant growing where it is not wanted," but the same plant species may be a weed during the growing season and a useful ground cover during the dormant season. To avoid unnecessary and wasteful expenditures on weed control, one should distinguish between ground covers (naturally occurring weeds, mulches, cover crops, or turfgrasses that can be managed as a useful part of the crop system) and weeds (undesirable surface vegetation that must be controlled or eliminated).

Growers need to know when control measures are justified by economic returns. For this purpose, a more practical definition of weeds is "nonharvested plants that significantly reduce crop yield or quality by competing for essential resources such as nutrients, water, or sunlight without providing compensatory benefits." This broader definition reflects an important concept of integrated pest management (IPM), which recognizes that weeds and other pests require control only if they are likely to cause economic damage to the crop.

The level of pest infestation at which anticipated crop damage justifies the costs of control measures is called the "damage action threshold" or "economic injury level" for that pest. Advances in herbicide and cultivation technology have made it easier and less expensive than ever to control weeds and manage ground covers, but the potential environmental impacts of any particular technology must be considered when making decisions about pest control. For example, the potential soil conservation benefits of ground covers could be factored into economic damage thresholds for weed control. It is not easy to assign dollar values to natural resources such as soil and water, but everyone recognizes the importance of fertile soil and safe drinking water.

Although surface vegetation in fruit plantings can be eliminated during the entire growing season, doing so may not be necessary or advantageous. Fruit crops require ample nutrients and water for good production, but exposed soil without a ground cover is vulnerable to wind and water erosion. Loss of vital topsoil and organic matter eventually reduces the availability of water and nutrients in the soil and can threaten the quality of groundwater, streams, and lakes. For example, tests in a New York orchard demonstrated that organic matter content in soil increased after six years under mowed sod grass and mulches but decreased when residual herbicides and cultivation were used for weed control (Figure 1). In the same orchard, available nitrogen, phosphorus, potassium, calcium, and magnesium increased under grass, mulch, or residual weed ground covers compared with weed-free herbicide plots or cultivation. Rainfall infiltration and retention were also better under grass, mulch, or killed weed residues in postemergence herbicide strips than in weed-free herbicide or cultivated plots.

Access for equipment during wet weather and visual appeal of plantings for "pick-your-own" customers can be enhanced when turfgrass is maintained in drive lanes between crop rows.

It is important to develop weed control systems that optimize trade-offs between weeds' competition with the crop and their contributions as ground cover to the stability and sustainability of the total fruit planting environment.

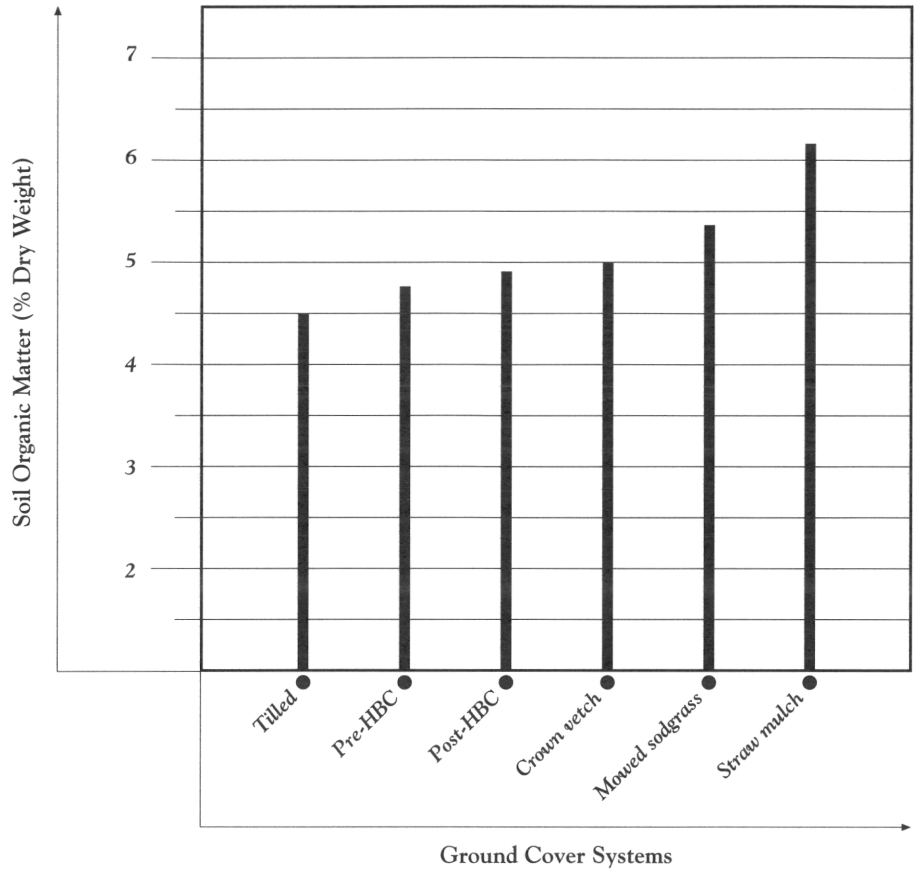

Figure 1. *Organic matter (% dry weight) in upper 8 inches of topsoil after five years under different ground cover management systems. Abbreviations: Tilled = monthly rototilling during growing season; Pre-HBC = preemergence applications of paraquat, norflurazon, and diuron herbicides in April each year; Post-HBC = two postemergence applications of glyphosate herbicide in May and July each year; Crown vetch = "living mulch" of crown vetch; Mowed sodgrass = mowed sodgrass of red fescue and perennial ryegrass; Straw mulch = applications of 4-inch-deep hay-straw mulch each May.*

Integrated Pest Management Systems for Weed Control

Action Thresholds

Researchers have established damage action thresholds for fruit pests such as spider mites, leafrollers, leafminers, apple maggots, and codling moths or for diseases such as powdery mildew, botrytis gray mold, apple scab, and fire blight. Reliable action thresholds have not yet been determined for weeds in fruit plantings or other crops, however, and the usefulness of this concept in weed control is still controversial.

Fundamental differences between weeds and other pests make action thresholds more difficult to use in weed IPM. Unlike that for other pests, natural biological control of weeds is rarely enhanced by delaying or deferring chemical or mechanical controls. In contrast to other pests, which are sporadic and often do not appear in sufficient numbers to cause damage in fruit plantings, the weed "seed bank" in every agricultural soil ensures that plenty of weeds will be present to compete with the crop in every growing season. Strategies for integrated weed management thus differ in some respects from other IPM programs, but an integrated approach to weed and soil management is still worthwhile.

Figure 2. *Dinitroaniline-resistant henbit. Repeated use of the same herbicide can select for resistant weed populations and cause weed control to fail.*

Preventing Resistance from Developing

Integrated management provides many of the same advantages for weed control as it does for other pests, and preventing weeds from developing resistance to pesticides is equally important. Repeated use of the same herbicide eventually creates genetic or ecological resistance in weed populations, leading to control failures and crop loss (Figure 2). Repeated mechanical weed control can have similar consequences because it does not remove deep-rooted, persistent weeds (such as milkweed, dock, or thistles) and weeds that sprout from tubers or rhizomes (such as nutsedge or quackgrass). Some of these weeds are also difficult to control with chemicals and can become serious problems when mechanical tillage is used repeatedly.

Preplant Eradication and Exclusion

Applying systemic herbicides or broad-spectrum soil fumigants before starting new plantings will minimize subsequent weed problems, especially in crops such as strawberries for which only a few effective herbicides are available once the crop is established. Growing preplant cover crops or establishing a dense turfgrass before the fruit crop is planted also helps exclude problem weeds afterward and can increase organic matter content and water-holding capacity of the soil. Finally, a crop's tolerance for weed competition can be maximized by selecting varieties and rootstocks that are best adapted to the soil, climate, and production system at each site.

Ground Covers

Preplant cover crops of marigold or Sudan grass have afforded substantial control of parasitic nematodes in some orchards. Flowering ground covers provide pollen and nectar for insect predators and sometimes help reduce aphid and mite populations in fruit or nut trees. Ground covers also provide a habitat for carabid beetles and other predators that may consume overwintering fruit fly pupae and emerging adults in the soil.

Some ground covers aggravate pest problems. Legumes often increase tarnished plant (Lygus) bug damage to nearby fruit, and aphids or leafhoppers are more likely to infest fruit crops if certain weeds are present. When surface vegetation or mulches create sheltering habitat, populations of meadow or pine voles (*Microtus* spp.) can increase rapidly and severely damage the roots and lower trunks of fruit crops. Many broadleaf weeds are favorable hosts for parasitic nematodes, viruses, and other pathogens that cause problems such as graft-union necrosis, orchard replant stunting, X-disease of stone fruits, and Pierce's disease of grapevines. Selective weed control, such as broadleaf herbicides that help suppress weeds in turf, is essential to remove these alternate host weeds where such pests are a major problem.

Another concern in orchards is the effect of flowering ground covers on honey bees and other pollinators. Parasitic mites and brood diseases are weakening and killing feral honey bee colonies throughout the country so insufficient pollination is becoming a real threat to fruit growers. When dandelions, yellow rocket, or other spring flowers are present in orchards at bloom time, bees and other pollinators may be distracted from visiting blossoms in

the trees (Figure 3). The lack of pollination can substantially reduce fruit set and cropping. Using selective herbicides and mowing the orchard floor during bloom will encourage bees to pollinate fruit trees instead of weeds. Managing tree rows and drive lanes to maintain turfgrasses or other nonflowering ground covers is also important later during the growing season to prevent unintentional harm to bees that are foraging in the orchard when insecticides must be applied to control economic pests.

Figure 3. *Flowering weeds that compete with the fruit crop for pollinators can substantially reduce fruit set. Mowing the orchard floor and treating with selective postemergence herbicides before bloom can minimize this problem.*

In summary, many basic IPM concepts are useful in controlling weeds in fruit crops. Weed control can be deferred when crop damage is unlikely. Herbicide ingredients or mechanical controls can be combined or alternated to postpone development of pesticide-resistant weeds. Health and vigor of the crop can be managed to enhance its tolerance to weeds. Environmental impacts and effects on beneficial insects and wildlife should be considered so as to select the safest effective ground cover management system. Different IPM strategies can be combined as appropriate for each farm, recognizing the complex interactions between weeds or ground covers, the fruit crop and pest complex, and local climate, soil, and water resources.

A year-round weed-free soil surface may not be necessary for optimal fruit crop yields, but there are no simple rules for deciding when and how to control weeds. Growers must consider present and past vigor of the crop, seasonal weather conditions, and the potential for soil or wind erosion. It is important to know which weed species are present and potential difficulties in controlling them, whether plantings must be harvested or accessed during wet weather, and signs of weed interference with the crop.

Competition between Crops and Weeds

Vulnerability of a crop to weed competition depends on soil type, seasonal variation in climate and rainfall, and other site-specific conditions. Newly planted trees or vines, nonirrigated plantings on shallow or droughty soils of low fertility, and shallow-rooted berry crops such as strawberries or brambles are especially likely to be damaged by weed competition and require consistent and effective ground cover management.

By contrast, mature fruit trees planted on fertile soil or during a wet summer might benefit from a competing sod ground cover that limits mud and soil compaction, curtails late-season shoot growth in the trees, and improves fruit

color and firmness at harvest. Just as insecticides and fungicides are no longer applied at fixed calendar intervals, weed controls can be selected and applied on a flexible basis depending on local circumstances in each fruit planting.

Sunlight, soil nitrogen, and water are the essential resources that most often are deficient in crop systems. Weed competition for sunlight is usually negligible in established orchards or vineyards because the crop canopy overshadows all but the most vigorous or shade-tolerant weeds. Newly planted trees or vines and low-growing crops such as strawberries that are shaded by weeds will be severely stunted, however, and may take years to recover if weed control is neglected during the first growing season. Plantings of all types and ages are vulnerable to competition from ground cover for soil nitrogen and water because most weeds take up those resources more quickly and efficiently than do fruit crops. For example, when nitrogen fertilizer is applied to turfgrass beneath fruit trees, most of the nitrogen is first taken up by the grass instead of tree roots.

Supplying additional fertilizers or irrigation to compensate for weed competition offers little or no benefit because without other controls these weeds become more vigorous and problematic for the crop. Low-stature, slow-growing, shade-tolerant ground covers that become semidormant during midsummer probably cause the least competition, but the perfect ground cover that never behaves like a weed remains to be developed or discovered.

Weed Control Area

The roots of trees and vines can extend considerable distances into soil wherever nutrients, water, oxygen, and pore space are adequate for root growth and metabolism. Nonetheless, root proliferation decreases with depth in the soil and distance from the lower trunk or crown region, and the root density of most fruit crops is less than that of common weeds. Therefore, competition for resources between weeds and the crop is most intense in the topsoil within the crop canopy drip line or row.

The size of the weed control area for optimal crop growth and production will depend on the crop's characteristics, including plant age and pattern of root development, as well as characteristics of the soil, such as texture and effective rooting depth, that influence root development and availability of water. For example, competition from annual weeds and grasses can severely limit the growth of newly planted, nonirrigated apple trees in a coarse-textured soil (Table 1).

Trickle irrigation in a fertile, fine-textured soil produced apple tree growth, fruit production, and an optimal cost-benefit ratio for weed control in a 2.5-foot-wide tree-row strip treated with postemergence herbicides (Figure 4). Mature peach trees grown in narrow weed-free herbicide strips may be smaller but equally efficient in yield as more vigorous trees in wider herbicide strips, although peach production is considerably lower for younger trees in the narrower herbicide strips.

Mature or trickle-irrigated fruit trees can adapt to partially restricted rooting in a narrow area of weed control. Young trees and nonirrigated orchards will establish and come into production more quickly, however, if weeds are controlled within a 6- to 8-foot-wide strip along the tree row.

The extent of competition from weeds also depends on the density or biomass of weeds within the crop row. Weed density can be visually estimated as number of weeds or percentage of weed coverage per square foot of soil surface. Small, sparsely concentrated weeds are less likely to pose a problem for the crop than larger, denser ones. Long-term tests have shown no significant differences in tree growth or yield with completely weed-free residual herbicide treatments compared with postemergence herbicide treatments that left killed weed residues on the soil surface and allowed sparse regrowth of weeds during late summer and autumn. A scanty ground cover can provide some protection for the soil surface in dormant-season rains and runoff without causing problems for the crop.

Table 1.
Total shoot growth of apple trees during first year in the orchard in relation to the percentage of weed control within a 6-foot-wide row strip

Weed-free area (%)	Shoot growth per tree (feet)	Growth reduction (%)
100	9.28	0
75	8.40	10
50	7.40	20
25	6.63	29
0	5.77	38

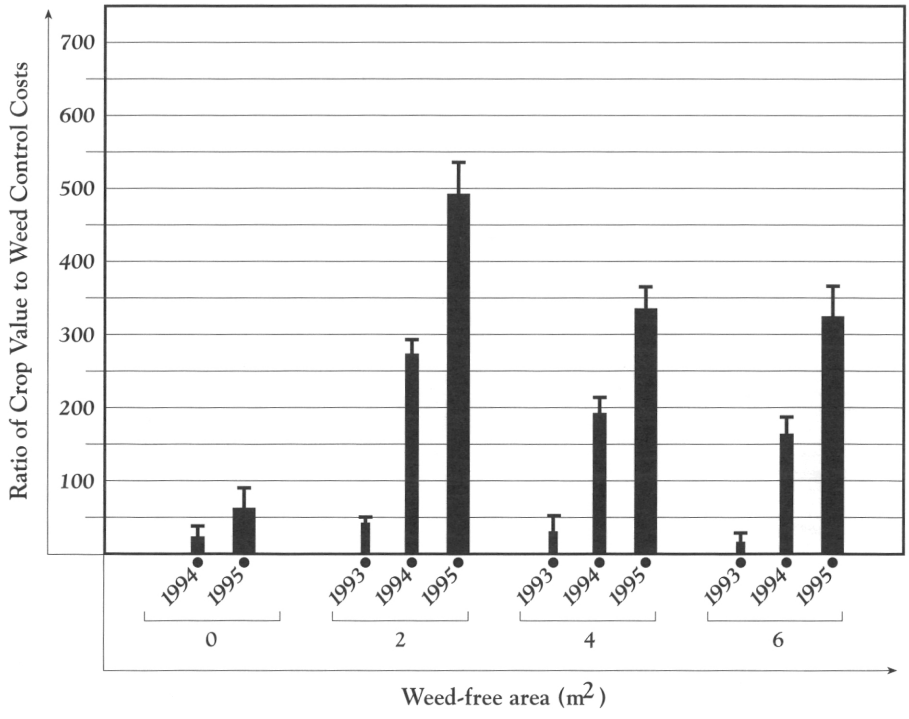

Figure 4. *Ratio of harvested crop value to yearly weed control costs for various weed-free areas (m^2 per tree) in a newly planted orchard during 1993, 1994, and 1995. Standard error bars are for yearly means.*

Timing of Weed Control

When relying on mechanical cultivation systems, it is essential to till early in the growing season so as to conserve soil water reserves and provide nutrients for fruit crops. This practice usually involves turning under a winter cover crop of legumes or annual grasses that was seeded late in the previous growing season. Nutrients are released from the cover crop biomass and soil organic matter that decomposes after each tillage. Early tillage is still common in orchards and vineyards of the southwestern United States.

The advent of long-lasting residual herbicides made possible the year-round eradication of weeds. Applying tank mixes of postemergence and residual preemergence herbicides in the fall, late spring, or early summer can eliminate ground cover vegetation from the crop row for most, if not all, of the growing season. Because of increasing concern about soil erosion and agrichemicals, however, growers are seeking alternatives to weed control methods that leave soil bare and exposed to weathering. Recent research in newly planted orchards and in strawberry beds indicates that weed control using nonresidual postemergence herbicides is also most effective early in the growing season. Crop benefits diminish if the initial weed treatment is delayed until midsummer (Figure 5).

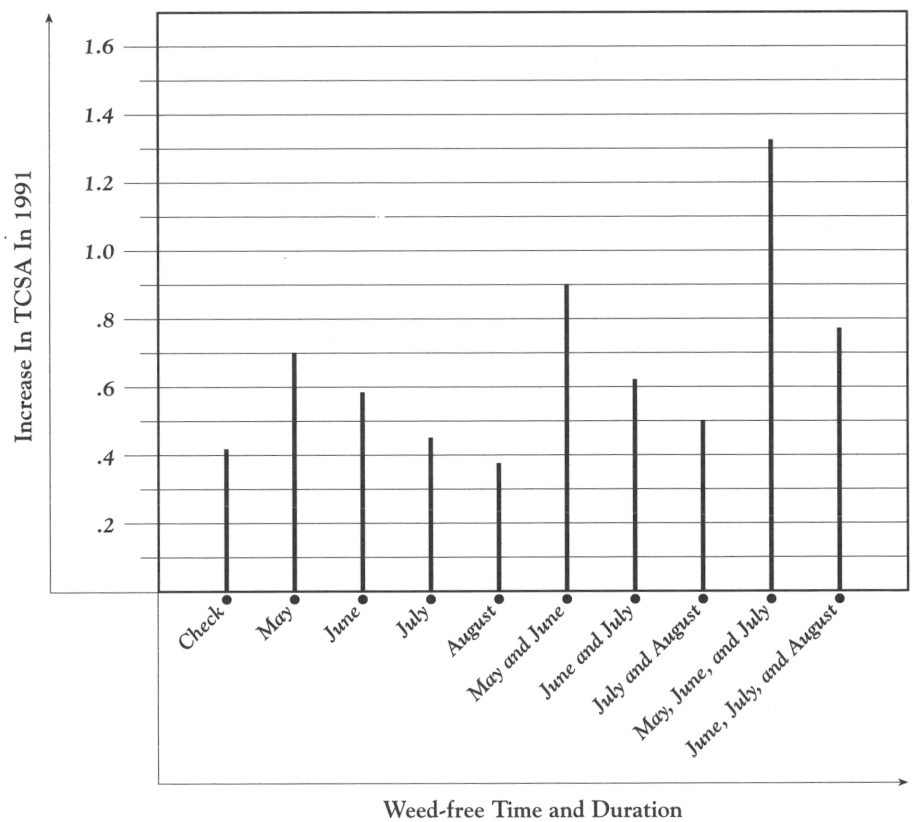

Figure 5. *Effect of different timing and duration of weed control on trunk cross-sectional area (TCSA, in cm^2) of drip-irrigated apple trees during the first year after planting (1991).*

Late Summer Weed Control

Many studies of established bearing apples, grapes, peaches, and other fruit crops suggest that moderate competition from weeds for water and nutrients during certain periods of fruit development or after harvest can be beneficial. Quality of wine grapes and color and storage quality of apple fruit sometimes improve when weeds are allowed to regrow or ground covers are seeded during the final stages of fruit ripening. Size of peach fruit is unaffected, but pruning costs are reduced when ground cover management or deficit irrigation is carefully used to create moderate nutrient or water stress during pit hardening and after harvest. Winter cold tolerance and perennial canker resistance of peach wood and buds may actually improve when late summer shoot growth is restrained by judicious ground cover and irrigation management. Evidence shows that more precise timing of weed control and ground cover management can benefit fruit crops.

Control of Problem Weeds

Certain weeds pose serious threats to human health and make harvest and maintenance operations difficult. Poison ivy, brambles, and horsenettle can scratch or cause dermatitis in workers. Seeds, pollen, or chaff from pigweed or ragweed can be a problem for workers or clients at "pick-your-own" farms. Other weeds such as yellow nutsedge are especially difficult to control and can proliferate aggressively. For these weeds, prompt treatment with systemic herbicides or mechanical removal is essential.

Ground Cover Management Systems

Weed Control Strips with Ground Covers between Rows

Variations on this system offer many advantages and have become popular among fruit growers. Weed control within the crop row may consist of using herbicides, mulches, cultivation, or periodic mowing. The width of the crop row strips can be adjusted periodically in response to crop vigor, soil differences, and climatic conditions. Permanent turfgrasses or other ground covers are usually maintained between the rows to facilitate access during inclement weather or harvest and to minimize soil erosion and compaction from traffic.

Permanent Ground Covers

Turfgrasses are probably the most manageable ground covers to use in fruit plantings. Fineleaf fescues such as red fescue *(Festuca rubra)* or hard fescue *(F. duriuscula)* tolerate heavy traffic, are relatively low-growing, and tend to become dormant during hot, dry weather. Unfortunately, they are also slow to establish and their seed is expensive. Perennial ryegrass *(Lolium perenne)* is less expensive and easier to establish but requires more moisture and nitrogen to compete against invasive weeds. Other grasses such as tall fescue *(F. arundinacea)* and annual ryegrass *(Lolium multiflorum)* are less expensive but more competitive for water and nitrogen and require more frequent mowing. These grasses may also require periodic applications of selective herbicides to control broadleaf weeds.

Figure 6. *The killed sod system. A turfgrass is established the year before planting the fruit crop, then strips are killed with nonresidual herbicides shortly before planting. The trees or vines are planted in the weed residues with minimal disturbance, providing a thin mulch of weed residues that suppresses weeds, protects the soil, and improves water penetration for some time.*

Preplant Cover Crops

The "killed sod" system is probably one of the best ground cover systems for new fruit plantings. A grass is established and strips are killed with glyphosate or other nonresidual herbicides shortly before establishing the fruit crop, which is planted directly into the killed sod with minimal disturbance of the soil. The persistent killed sod residues reduce germination of weed seeds, protect the soil surface, provide additional organic matter, and retain soil moisture during the first years of the planting (Figure 6).

Vetches, clovers, and other legumes are often recommended as preplant or seasonal cover crops. As "green manures" and to improve soil physical conditions, these are excellent ground covers. But these cover crops have many disadvantages in fruit plantings. Legumes have deeper roots and they consume more water than most grasses. In our experience over many years in various plantings, the nitrogen fixed by root nodules in legumes has usually been unavailable to fruit crops unless the legumes were killed and incorporated into the soil, which is often impractical or impossible in perennial fruit plantings. Legumes can also increase populations of parasitic nematodes in the soil, and they serve as alternate hosts for various insects and diseases that affect fruit crops. Finally, most legumes flower during the summer months, attracting honey bees that may be killed by pesticides used to protect fruit crops.

White clover (*Trifolium repens*) is common in the soil seed bank in northeastern soils and often appears naturally in fruit plantings. It is perhaps the least problematic legume ground cover—low-growing, durable, a good companion for many grasses, tolerant of a wide pH range—but it is competitive for soil water.

Natural Ground Cover Mixtures

If no ground cover is seeded, the natural soil seed bank and wind-blown seeds at each site will determine which weeds predominate during subsequent years. Fifteen to fifty weed species are already present in the topsoil of most fruit plantings, and every tillage brings up more seeds of some weeds while burying others. Because so many different species are present, it is difficult to avoid problems with alternate hosts for pests and diseases such as rust fungi and viruses. This is another rationale for establishing and maintaining more desirable ground covers.

Mulches

Before herbicides were developed, mulches were popular for controlling weeds and conserving soil. The current trend toward reducing agrichemical inputs in fruit growing has renewed the interest in mulches. Potential choices for mulch materials have also increased greatly in recent years. We can now choose among a variety of synthetic mulch materials including polypropylene plastics and bonded polyesters, recycled biomass mulches such as wood chips or paper pulp, and traditional mulches such as hay and straw. The costs and availability of various mulch materials are changing as fuel prices fluctuate and recycling waste materials becomes a priority. For example, wood chips and tanbark have long been used to mulch trees and shrubs in urban landscapes but were very expensive in the past. Because many landfills now prohibit dumping of brush or wood, some public utility and tree maintenance companies will arrange to deliver wood chips free to backyard gardeners or commercial fruit growers. Similar changes are likely to occur as communities and corporations around the country seek new ways to recycle paper and other waste products.

Mulches are usually more expensive than conventional weed management systems such as herbicides or cultivation (Table 2). Polyethylene plastics and ground cover fabrics, hay or straw, and wood chips are practical alternatives. Plastic films are widely used as mulches in vegetable and strawberry production. These thin films are relatively inexpensive, and equipment is available for mechanically placing them. Plastic mulches are excellent for conserving moisture. They increase soil temperatures early in the spring, which can be an important advantage with some fruit crops. Plastics add no nutrients or organic matter, but their effects on soil moisture and temperature influence the availability of nutrients. They also protect the soil surface against weathering

Table 2.
Estimated costs per acre of orchard to establish and maintain natural and synthetic mulches, herbicides, grasses, or cultivation in 6-foot-wide strips with 16 feet between tree-row centers, in a New York orchard

System	Materials ($/acre)	Labor ($/acre)	Total ($/acre/year)
Hay-straw mulch	150–400	145	300–550
Woodchip mulch	70 (or free)	295	130–315 (1–3 years)
Weed collar™	9,800	200	10,000
1.2 mil polyethylene	150	35	185
Belton-Sarlon™ plastic	735	5	190–770 (1–4 years)
Agritex™ plastic	980	35	238–1,015 (1–4 years)
Typar™ plastic	1,420	35	1455
Warren's Weed-arrest™	1,800	35	395–1,835 (1–4 years)
Herbicide strip	10–50	5	15–55
Mowed sodgrass	30	40	70–100
Clean cultivation	15	35	50

and erosion. The primary drawback of these mulches is their lack of durability. Most must be replaced annually, which necessitates disposing of the used plastic. Some growers cultivate used mulches into the soil, which leaves unsightly and annoying shreds throughout the fruit planting for many years. Even the so-called biodegradable plastic films will not break down rapidly in the soil; what little disintegration occurs makes removal more difficult.

The ultraviolet-resistant synthetic "landscape cloth" or fabric mulches are more durable and if used for several years substantially reduce their annual costs. Most of these mulches are made from woven or spunbonded fabrics rather than films so they permit penetration of rainfall and may be sturdy enough to be removed intact and reused. The major disadvantage of these fabrics is their high initial cost.

Hay or straw mulches provide partial control of annual weeds and are highly beneficial as a soil amendment, but in recent years the cost of straw for mulch has increased greatly. In areas where waste hay or straw is available at a reasonable price, it should be considered as a mulch. As is true with plastic mulches, straw may increase availability of soil potassium, phosphorus, calcium, and water, and in low-fertility or droughty soils this can be very worthwhile. Natural biomass mulches will also gradually increase soil organic matter and improve pore structure and aeration of the soil.

Unfortunately, meadow voles (*Microtus* spp.) can become a serious problem under straw as well as plastic mulches. Removing mulch and using a rodenticide during winter months when voles feed on roots and bark can provide partial control.

Another serious problem with mulches is excessive soil moisture in poorly drained soils. In such sites, the use of straw mulches can greatly increase Phytophthora root and crown rots and mortality of fruit trees and brambles. Planting on mounds or raised beds so that water does not flood the crown and upper root zone will reduce these problems somewhat, but in poorly drained soils the likelihood of root and crown rots under mulches is substantial.

Wood chips or shredded bark offer several advantages over hay or straw mulches. Hardwood chips contain lignins and other compounds that make them decompose more slowly than hay or straw, reducing the need for annual replacement of the mulch and minimizing problems of excess late-summer release of nitrogen or its immobilization by decomposing mulch material. If an inexpensive source (utility tree crews or sawmills) is available, chips are an excellent mulch. Caution is advised, however: if wood chips are hot and fermenting or composting at the time of application, they may release ammonia or volatile organic acids that can injure lower foliage on canes or vines.

Mechanical Cultivation

Tillage has been popular in fruit plantings for centuries, often in conjunction with winter-grown cover crops, especially in irrigated sites. This management system increases the availability of soil nutrients and water for about one month after each cultivation. Even when cover crops are turned under, however, repeated cultivation of the soil depletes organic matter, causes compaction and collapse of soil structure, and increases the likelihood of erosion. In sites that have restricted rooting depth, particularly with shallow-rooted plants such as brambles, the injury of crop roots that occurs with each cultivation is also a serious drawback.

Chemical Mowing

A few postemergence herbicides are labeled at sublethal rates as "chemical mowers" for vegetation between the tree or vine rows. Low rates of glyphosate (about 10 percent of standard recommended rates) can be applied several times per season, depending on the weed spectrum and the crop. Chemical mowing has not been tested extensively, but it appears to suppress ground cover competition with fruit trees somewhat more effectively than conventional mowing.

Herbicides

Herbicides are the least expensive effective method of weed control and consequently the most widely used by fruit growers. The short-term benefits of herbicide control include conserving soil nutrients and moisture, optimal growth, and early cropping of young fruit plantings. Prolonged use of preemergence herbicides, however, depletes soil organic matter and may leave chemical residues in the soil that can cause problems at replanting time. More subsoil leaching and surface runoff of agrichemicals from fruit plantings may occur where residual preemergence herbicides are applied than when mulches or mowed ground covers are used. Herbicides are most effective when used as one part of an integrated weed management program. Combinations of herbicides or sequential applications may be necessary because of variable weed populations and the need for residual control of weeds in some fruit plantings.

Selectivity of herbicides is based on timing or stage of growth of the crop, tolerance of certain plants or species for the active herbicidal ingredients (as in many graminicides), or physical interaction of herbicide formulations with soil particles and organic matter that prevent the active herbicide from moving down and into the roots of the crop. Tolerance and selectivity usually depend on the dose and vary among soil types and weather conditions during or after treatments. Application of herbicides at higher than labeled rates is therefore both risky and illegal.

Many different herbicides are registered for use in fruit plantings. The lists in Tables 3 and 4 are intended for general information only. Check the current pest management recommendations and read container labels of individual herbicides carefully to determine how they must be used and verify that a particular herbicide is registered for use in your area and on the crop or soil type to be treated.

Weed Control Equipment

Herbicide Applicators

Many different herbicide sprayers are available, including shielded booms, ultra-low-volume sprayers, wipers, and backpack spot sprayers. Equipment is also available for applying granular herbicides. Most herbicides should be applied in a volume of water sufficient to wet a substantial portion of the surface area being treated with minimal runoff. This often requires about 20 to 40 gallons of spray material per treated acre, though substantially less may be required with wiper or ultra-low-volume equipment. The optimal volume of water may also vary with the herbicide being applied. For example, glyphosate is generally more effective when lower volumes of water are used, whereas a greater volume of water increases the effectiveness of paraquat.

Sprayer application pressure should be kept low enough to minimize spray atomization in the nozzles and drift but high enough to produce an even spray pattern in the nozzles and across the desired boom width. All sprayers should

be carefully calibrated. An overdose of herbicide can seriously damage the crop, and too low a dose may not provide effective weed control.

Shielded boom sprayers with shrouds or curtains between the crop and the nozzles provide an extra margin of safety by minimizing drift.

Wipers are used to apply herbicide selectively to one portion of the ground cover vegetation; there is minimal chance of drift or penetration to the crop or desirable species in the ground cover vegetation.

Backpack sprayers are useful where weeds are sparse or scattered, and they are an economical way to use chemicals. Their drawbacks are the potential for uneven coverage, drift, and inadvertent damage to crops.

Between-Row Cultivators

Various widths and designs of disk, tine, rotary hoe, or chisel-tooth harrows can be used, and rototillers are sometimes used between rows of grapes. As many as six cultivations per season may be necessary to control weeds. Perennial weeds may be a greater problem when repeated cultivation is used as the sole weed control method.

Within-Row Cultivators

Many types of in-row cultivators are available, and more are being developed. Available equipment includes rototillers (forward tilling) (e.g., Northwest By-Hoe™), which may trip in and out of the row; horizontal circular tillers that throw soil out of the row (e.g., Weed Badger™, Kimco tiller, Clements tiller); flat blades that cut under weeds and trip out of the row; and the traditional French plow or hoe-plow that trips in and out of the row. All of these implements work close to the tree or vine, and if not properly adjusted or operated they damage trunks and surface roots. In-row cultivation may be done only once in spring, or twice, in spring and summer, before the fruit-laden limbs or canes droop into the operation zone. Preemergence herbicides may sometimes be incorporated during cultivation, when the label says they are permitted.

Mowing Equipment

Mowing is done primarily in the middles of the rows of no-till orchards and vineyards or in older orchards of large apple or cherry trees in humid growing regions. Some mowers cut within the row of trees or vines planted at grade level, but they do not work in raised-bed or berm plantings. Available implements include rotary, flail, and sickle-bar mowers. Some flail mowers are sturdy enough also to grind up tree and vine prunings left on the ground in row middles, providing a thin mulch layer and retaining nutrients in the orchard. Flail and rotary mowers with side delivery chutes can be operated so they place most of the mowings or mulch within vine or tree rows, providing a thin mulch and helping to suppress weed growth.

Flame or Steam Weeding

Flame or steam have not been used much to suppress weeds in fruit plantings because of problems with air pollution, fire hazard, and damage to the trunks and foliage of the crop. Preliminary work with an in-row propane burner in orchards suggests that crop damage can be minimized if the heat source is shielded, but weed suppression by heat has more short-term results than contact herbicides such as paraquat. Steam generators are also being evaluated and may become practical if contact herbicides are scarce or less economical in the future.

Table 3.
Some residual preemergence herbicides used in fruit crops

Dichlobenil—Used primarily for hard-to-kill perennial weeds such as quackgrass and nutsedge and for the reduction of field bindweed. Also effective for control of annuals. Must be lightly incorporated in arid climates or applied in the rainy season for best results.

Diuron—Applied alone for annual broadleaf weeds and grasses or in combination with bromacil for citrus or other preemergence selective materials in some deciduous crops.

Napropamide—Primarily used to control annual grasses and in combination with other selective herbicides to control broadleaf weeds on young trees and vines because of its positional selectivity above the roots. If mixed into planting media, severe root injury can occur.

Norflurazon—Used for long residual on annual grasses and some broadleaf weeds. Sometimes used in combination with other selective herbicides.

Oryzalin—Used for annual grasses and some broadleaf weeds. Often used with other products to broaden the spectrum of combinations. Applied to young trees and vines because its positional selectivity makes it safe for these plants.

Oxyfluorfen—Used as a broad-spectrum broadleaf control material, often in combination with a grass-control herbicide such as oryzalin, pendimethalin, or napropamide. When used on young trees or vines, avoid spraying foliage to prevent contact injury.

Pendimethalin—Used for annual grass and some broadleaf control on young trees or vines, often combined with other herbicides to enhance long-term residual grass control.

Pronamide—For control of annual and some perennial grasses, particularly quackgrass.

Simazine—Used for broad-spectrum control of annual weeds, especially effective on many annual broadleaf weeds and combined with other grass-control materials. Its long residual control has made it a popular herbicide. It has been found in groundwater after long-term use in some locations. At low rates it is an excellent addition to oryzalin, pendimethalin, napropamide, and others.

Terbacil—A long-lasting residual herbicide used for annual grasses and broadleaf weeds in apples and some other fruit crops.

Trifluralin—Used primarily before planting trees and vines to control grasses and some broadleaf weeds. Applied as a continuous band under the soil surface, it is very effective for the suppression of field bindweed in young plantings. Can be incorporated for the suppression of field bindweed between rows in mature orchards and vineyards.

This list is for general reference only and does not imply discrimination or endorsement by Cornell Cooperative Extension.

Table 4.
Some postemergence herbicides used in fruit crops

Fluazifop-P-butyl—For selective control of most annual and perennial grasses.

Glufosinate—Primarily effective on annual grass and broadleaf species, less so on perennials.

Glyphosate—For selective control of most grass and broadleaf species and woody weeds. Injury will occur if sprayed onto leaves or green bark.

Oxyfluorfen—For control of young broadleaf weeds or in combination with other postemergence herbicides.

Paraquat—A contact herbicide used to control grass and broadleaf annual seedlings.

Sethoxydim—A selective herbicide for the control of most grasses. It has little effect on broadleaf weeds.

Sulfosate—A nonselective herbicide for control of annual and perennial grasses and broadleaf weeds. Selectivity is based on the woody outer bark of mature trees and vines.

2,4-D—For the selective control of most broadleaf weeds. Care must be taken to minimize chance of drift onto leaves of crop plants, especially during warm weather.

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Growing fruit is a complex, high-stakes enterprise. Crop values can exceed $25,000 per acre, and damage caused by weeds, insects, and diseases can easily make a crop unmarketable. Pest control accounts for a substantial portion of the costs of fruit production, and weed control helps determine its short-term success and long-term sustainability.

Weeds can be controlled by a variety of methods. Growers must decide which controls are best suited to their growing conditions, intended market, and personal preferences. Public concerns and government regulation of soil and water quality and pesticide residues on foods raise additional questions about potential health and environmental impacts of weed control practices. Choosing the best weed and soil management systems is thus an important and complex decision.

This bulletin explains how weed management systems affect fruit crops, soils, groundwater, and some beneficial or detrimental organisms in fruit plantings. The advantages and disadvantages of various methods for managing weed competition are described, and the importance of integrating weed control practices into comprehensive systems for sustainable fruit production is emphasized.