Enhanced Pest Management with Cover Crop Mulches

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Abstract

Living and dead plant vegetation on the surface of soils can provide opportunities for regulating pest populations in no-tillage production systems. Cover crops generate substantial quantities of surface vegetation and residue that can be managed to enhance control of pests. Research at the Beltsville Agricultural Research Center has shown that weed germination and emergence is inhibited by high levels of cover crop mulch, that small-seeded annual weeds are particularly susceptible to suppression by mulches, and that herbicide use can be reduced when cover crops are incorporated into cropping systems. Growing mixtures of legume and cereal cover crops is a particularly effective way to produce large quantities of cover crop residue for weed suppression. Mulches with a high surface area-to-soil area ratio and a low amount of internal empty space are most highly correlated with inhibition of weed emergence. Foliar diseases can be reduced by a cover crop mulch, primarily by preventing dispersal of pathogen propagules through splashing and/or wind-borne processes. Cover crops can suppress establishment of soil-inhabiting herbivores such as Colorado potato beetle by disrupting emergence and migration behavior. Reduction of weed and pest populations by cover crops has reduced or eliminated crop yield loss caused by these organisms.

INTRODUCTION

Holistic management principles and a shift to a systems approach for crop protection are vital to combating the escalating economic and environmental consequences of agricultural pests. In conventional pest management strategies, pesticides typically constitute the first line of defense. In contrast, an ecological-based, systems approach focuses on preventive practices and natural processes of population regulation with pesticides used only as therapeutic tools when needed. Emphasis is placed on maximizing the beneficial, desirable ecological processes within farming systems that can maintain weed and pest populations at low, manageable levels. Although agricultural systems are simplified compared to natural ecosystems, there are abundant opportunities to redesign and manage agricultural systems to reduce and eliminate pest outbreaks.

No-tillage production systems offer several opportunities to regulate weed and pest populations. One of the biggest advantages to farming without tillage is the maintenance of plant residue on the surface of soils. The soil microclimate under residue avoids temperature extremes and maintains more uniform soil moisture that favors a wide array of organisms. These conditions lead to improvements in soil structure, tilth, nutrient holding capacity, and water-holding capacity as well as biological activity. These improvements to soil physical, chemical, and biological properties can act in a synergistic manner to create a soil that is more similar to that of natural ecosystems. The live and dead plant material associated with use of cover crops in no-tillage systems are particularly suited to natural suppression of weeds and pests. Generally, a more diverse biological and physical environment at the surface of soils such as that associated with cover crops offers opportunities for regulating and minimizing pest populations.

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PRINCIPLES

Weed and Pest Control by Cover Crops

The degree of weed control provided by cover crops can vary according to cover crop species, residue biomass, and weed species (Liebman and Mohler 2001). Annual weed emergence is reduced according to a negative exponential function of the biomass of residue on the soil surface (Teasdale and Mohler 2000). For various mulch materials, a wide range of mulch mass may be required for any given level of weed suppression depending on the weed species and type of residue. Small-seeded weed species tend to be more sensitive to suppression than large-seeded species. Residue materials with a high area-to-weight ratio generally require less mass for weed suppression than materials with a low area-to-weight ratio. Mulch area index, defined as the area of mulch material per area of soil, is a residue property that is more highly correlated with weed suppression than mulch properties such as mass or height (Teasdale and Mohler 2000). The function

$$E = \exp(-bV^{c}\,MAI)$$

where MAI is mulch area index, V is solid volume fraction, defined as the volume of a mulch filled with solid mulch material, and b and c are coefficients, provided a good overall prediction of weed emergence relative to an unmulched control (E) regardless of mulch type.

Generally, cover crop residue can be expected to provide early-season weed suppression but not full-season weed control. As a result, cover crops can contribute to weed control in reduced-tillage systems but herbicides or other weed control tactics are required for achieving optimum weed control and crop yield. However, cover crops can permit a reduction of herbicide inputs and a shift toward total postemergence herbicide programs. Early weed suppression provided by cover crop residue should permit crops to become established before weeds. Postemergence herbicides can control later-emerging weeds until the crop has grown past the critical period for weed control. This approach has been used successfully with the tomato/hairy vetch system discussed below.

Cover crops also can play a role in reducing foliar diseases thereby offering potential for reducing fungicide use. A wheat cover crop reduced Phytophtora blight of peppers due to reduced dispersal of propagules of the causal agent (Ristaino et al. 1997). A sudangrass cover crop reduced the spread of plant diseases by reducing the dispersal of conidia from soils because of dissipation of rain droplet kinetic energy (Ntahimpera et al. 1998). Therefore, residue can contribute to the design of cropping systems that inherently slow the spread of disease epidemics and improve crop health.

The response of insect pest populations to cover crops is related to herbivore insect responses to increasing ecosystem diversity in general. A survey of this literature (Altieri 1994) suggests that, in the majority of cases, herbivore insect species are less abundant but natural enemies of herbivores are more abundant in diversified systems than in monocultures. In agroecosystems, there are numerous reports of reduced pest incidence in crop mixtures but very few reports of higher pest incidence. Diversification of the agroecosystem with cover crops can provide similar reductions in pest populations. A complex of interrelated processes account for pest reductions in diversified systems (Trenbath 1993; Altieri 1994). Cover crops can interfere with the capacity of pests to colonize hosts by imposing physical barriers, disrupting olfactory and visual cues, and creating diversions to non-crop hosts. Once pests are established in a field, cover crops can interfere with pest populations by limiting dispersal, disrupting feeding, inhibiting reproduction, and enhancing mortality from predators and parasitoids. Management systems for cover crops can be designed to limit pest populations by either disrupting pest colonization of hosts or attracting natural enemies.

Cover Crop Residue Effects on Weed and Pest Microclimate

Winter annual cover crops are typically killed before summer crops are planted and leave residue on the surface of soils during the cropping season. This layer of cover crop residue can influence many factors that, in turn, influence the biological activity of weeds and pests in soils. Residue on the surface of soil can interfere with the establishment of weeds or any pest that emerges from soil by either (1) physically impeding their emergence or dispersal, (2) creating an unfavorable soil meteorological environment, or (3) releasing allelopathic substances. Cover crop-based, minimum-tillage cropping systems that increase soil organic matter and fertility can also reduce damage to crops by weeds or pests by improving the growth and vigor of crop plants.

The formation of a physical barrier by cover crop residue is an important factor that can prevent emergence of weed seedlings or insect pests such as Colorado potato beetles as well as dispersal of pathogen spores. Residue physical properties such area-to-mass ratio, solid volume fraction, light extinction coefficient, and decomposition rates have been shown to influence weed emergence by Teasdale and Mohler (2000) and would be expected to influence activity of most soilborne pest species.

Interception of incoming radiation is one of the most important influences of residue on the microclimate of soil organisms. Interception and reflection of short-wave radiation by mulch elements reduces the quantity of light available to the soil surface, the heat absorbed by soils during the day, and the amount of moisture evaporated from soils (Teasdale and Mohler 1993). These effects can interact with a multitude of weed seed germination or insect emergence requirements to determine the pattern of activity observed in any given season. Many weed species require light to activate phytochrome-mediated germination processes. Emerging weeds also require light for initiation of photosynthesis before seed reserves are depleted. Thus, extinction of light by residue can be an important factor inhibiting weed emergence through residue, consequently, weed suppression is highly correlated with light extinction. In addition, high diurnal temperature amplitude is another factor often required to break the dormancy of selected weed species. Cover crop residue reduces diurnal soil temperature amplitude and, thus, would be expected to prevent germination of weed species with this requirement.

Chemical compounds released from cover crop residue have potential to stimulate or inhibit weed germination and growth (Liebman and Mohler 2001). Research has demonstrated the presence of allelochemicals that inhibit germination and growth of many weed species. On the other hand, nitrates released by legume residues can stimulate germination of selected weed species. In natural environments it is difficult to separate allelopathic effects from the physical effects described above. It also can be difficult to determine whether growth inhibition by residues with high carbon/nitrogen ratios (such as rye residue) is due to allelopathy or immobilization of nitrates.

EXAMPLES OF WEED AND PEST MANAGEMENT WITH HAIRY VETCH

A system has been developed at the Beltsville Agricultural Research Center (BARC) for growing fresh-market tomatoes (*Lycopersicon esculentum* Mill.) in a hairy vetch (*Vicia villosa* Roth) cover crop (Abdul-Baki and Teasdale 1997). Because of yield increases and cost reductions, this no-tillage system has provided substantial increases in economic returns relative to high-input systems based on black polyethylene mulch. This system also has reduced herbicide and nitrogen inputs as well as eliminated the cost of installing and disposing of plastic mulches. Soil and pesticide losses from runoff into the surrounding environment have been substantially reduced by employing a hairy vetch rather than a polyethylene mulch (Rice et al. 2001). Several investigations on weed and pest management using cover crops have been conducted at BARC over the past decade. In the remainder of this paper, we will summarize some of the highlights of this research demonstrating the benefits of cover crops for weed and pest management. Previously unreported reductions in tomato yield loss by these cover crop systems will be presented.

Weed Management with Cover Crop Mixtures

Although hairy vetch has many benefits, it has weaknesses as well. Hairy vetch decomposes rapidly and requires higher initial quantities of mulch relative to other cover crops to suppress weeds. An additional drawback to use of vetch is its inability to capture excess nitrates in soils during fall and winter months. Rye (*Secale cereale* L.) has many characteristics that are opposite and complementary to hairy vetch. Rye is superior at capturing nitrates in fall and winter and provides a more persistent weed suppressive mulch in summer. However, a rye cover crop can remove excess soil moisture and can immobilize nitrogen if left to grow too long in spring; yield losses in corn and tomatoes often are observed with a rye cover crop used alone.

A mixture of hairy vetch and rye can provide a broader spectrum of benefits than either cover crop alone. We conducted experiments from 1995-1997 with various cover crop mixtures both with and without a postemergence treatment of metribuzin herbicide to determine whether cover crop biomass could be sufficiently increased to impact weed control. Details of this research are presented in Teasdale and Abdul-Baki (1998). Mulch biomass was higher in a mixture of hairy vetch plus rye or hairy vetch plus rye plus crimson clover (*Trifolium incarnatum* L.) than with hairy vetch alone (Fig. 1). Higher residue biomass left by these cover crop mixtures resulted in lower weed emergence. Lower weed density in the cover crop mixtures resulted in correspondingly lower weed biomass in the absence of herbicides (Fig. 1). Therefore, cover crop mixtures have proven to be effective at increasing the weed suppressive capability of cover crops as well as maintaining many of the benefits of both species. More research is needed to determine optimum management practices for cover crop mixtures.

Early Blight

Research has shown that tomatoes grown in a hairy vetch mulch maintain a higher leaf area over a longer period of time than when grown in polyethylene mulch or bare soil. One factor contributing to maintenance of a high leaf area is reduced foliar disease. Early blight epidemics of tomato in association with four soil mulching practices on raised beds were studied over three years (Mills et al. 2002). A hairy vetch mulch that completely covered the soil surface reduced soil particle dispersal by raindrops during the early weeks of the season more than dispersal by the other treatments that left part or all of the soil bare (Fig. 2). A similar pattern of response to mulch treatments was observed for development of early blight epidemic on tomato foliage suggesting a causal relationship. Thus, a mulch of hairy vetch residue that provides complete ground cover can reduce spread of foliar diseases by acting as a physical barrier that reduces dispersal of soil and water borne pathogens.

Colorado Potato Beetle Colonization

A study was conducted to compare the effects of black plastic and hairy vetch mulch killed by either mowing with a flail mower or rolling with a drum fitted with angle iron on Colorado potato beetle colonization of and damage to staked fresh-market tomatoes. All plots received herbicide and fungicide applications as needed, but no insecticides were applied to treatments for studying beetle colonization. Over-wintered beetles were collected from other locations and released. Vertical aluminum barrier strips were placed around each block to facilitate beetle establishment. Insects were counted at weekly intervals on all plants in each plot. Colorado potato beetle establishment occurred at a lower rate on tomatoes transplanted into hairy vetch than on those transplanted into black plastic mulch (Fig. 3). Resulting yields were significantly higher with the hairy vetch mulch. These findings illustrate that an additional benefit of the use of hairy vetch in the production of staked fresh-market tomatoes is greater tolerance of the crop to invasion and damage by this pest.

Yield Loss

Weed and pest suppression by cover crops can increase crop growth and yield. In the experiments discussed above, all mulch treatments were tested with or without a pesticide for controlling the target pest. For example, all cover crop mixture treatments were tested with or without a postemergence herbicide application. In the disease experiments, mulch treatments were tested with or without foliar fungicide applications scheduled either by calendar or by the TOMCAST model. In the Colorado potato beetle experiments, tomatoes in mulch treatments were tested with or without a soil drench with imidacloprid insecticide. These pesticide applications successfully eliminated the respective weeds/diseases/pests in these experiments. Since all of these treatments (postemergence herbicide, fungicide by TOMCAST scheduling, and insecticide applied to transplants rather than entire field) represent an approach for reducing pesticide inputs relative to conventional systems, the favorable pest control achieved demonstrates the successful reduction of pesticide requirements in these cover crop-based systems. In addition, pesticide losses to the environment are greatly minimized by cover crop mulches (Rice et al. 2001).

In addition, the weed-free, disease-free, and beetle-free plots derived from these pesticide treatments provided a suitable control against which to test for yield losses from weeds, foliar disease, and Colorado potato beetle in corresponding unsprayed treatments. Tomato yield losses due to weeds ranged from 38% for the hairy vetch monoculture to 23% for the vetch-rye-crimson clover mixture (Fig. 1). Lower weed biomass in the cover crop mixtures was associated with lower tomato yield loss. Tomatoes in a hairy vetch mulch had negligible yield loss from early blight whereas yield loss by tomatoes in bare soil averaged 13% of that obtained in the disease-free plots treated with a weekly fungicide (Fig. 2). Similarly, yield of tomatoes in black polyethylene suffered a 19% loss whereas those in hairy vetch had only a 5 to 7% loss due to Colorado potato beetle damage (Fig. 3). Weed pressure was relatively high in the mixture experiment, thus, yield losses were reduced but not eliminated by these cover crop mixtures suggesting the need for additional weed management. Foliar disease and Colorado potato beetle pressure were relatively low because of dry weather during these experiments suggesting that cover crops may minimize the need for fungicides or insecticides unless more severe conditions for establishment were encountered.

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Figures

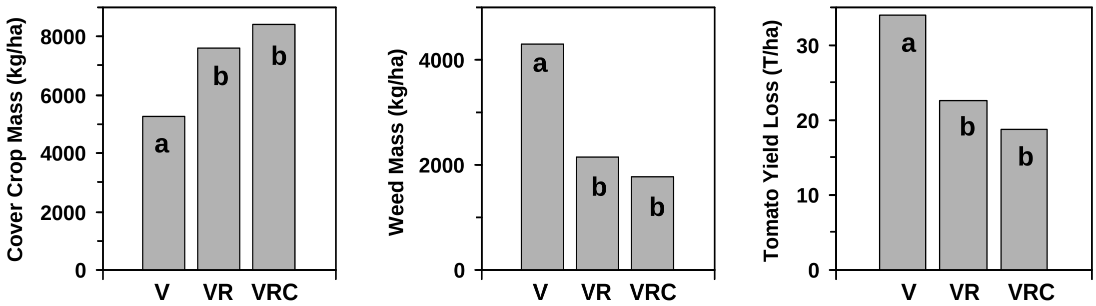

Fig. 1. Cover crop biomass, weed biomass in the absence of herbicide, and yield loss of tomatoes grown with versus without herbicide in hairy vetch (V), hairy vetch + rye (VR), or hairy vetch + rye + crimson clover (VRC). Bars with the same letter are not significantly different (P=0.05).

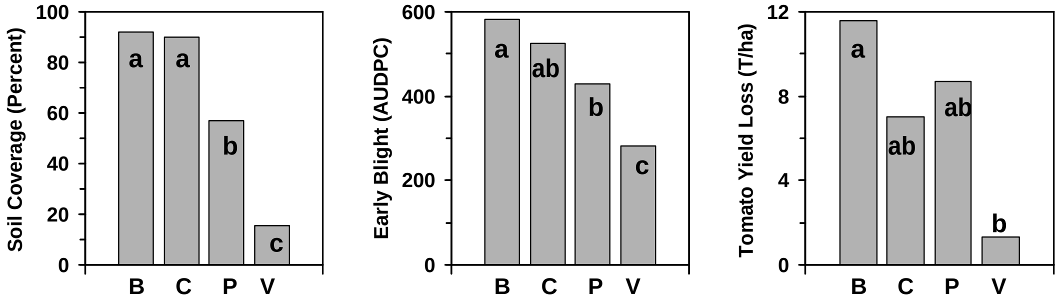

Fig. 2. Coverage of splash panels by soil after rainfall events during the first half of June, area under the early blight disease progress curve for the lower and middle tomato canopy in the absence of fungicide, and yield loss from tomatoes grown with versus without fungicide in beds with bare soil (B), incorporated compost (C), black polyethylene mulch (P), or hairy vetch mulch (V). Bars with the same letter are not significantly different (P=0.05).

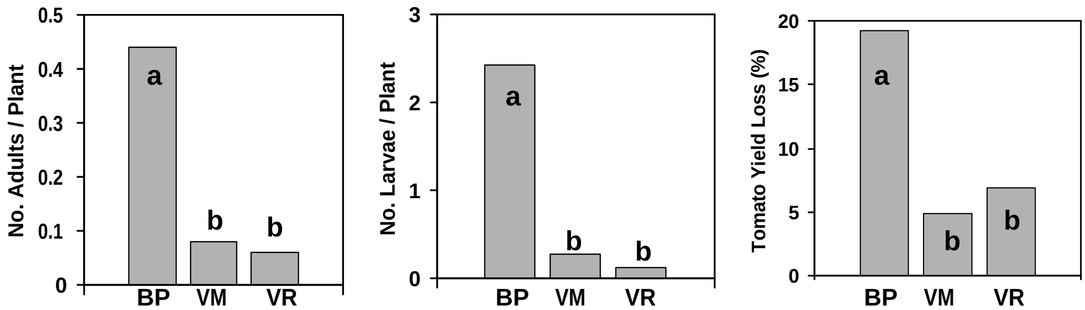

Fig. 3. Effects of black polyethylene mulch (BP) or hairy vetch killed by mowing (VM) or rolling (VR) on establishment of Colorado potato beetle adults and larvae and on tomato yield loss when grown with versus without insecticide. Bars with the same letters are not significantly different (P=0.05).