Sustainable Agriculture Farming Systems Project

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Pesticide Use Reduced by 50-100% in Low Input and Organic Tomato and Corn Cropping Systems

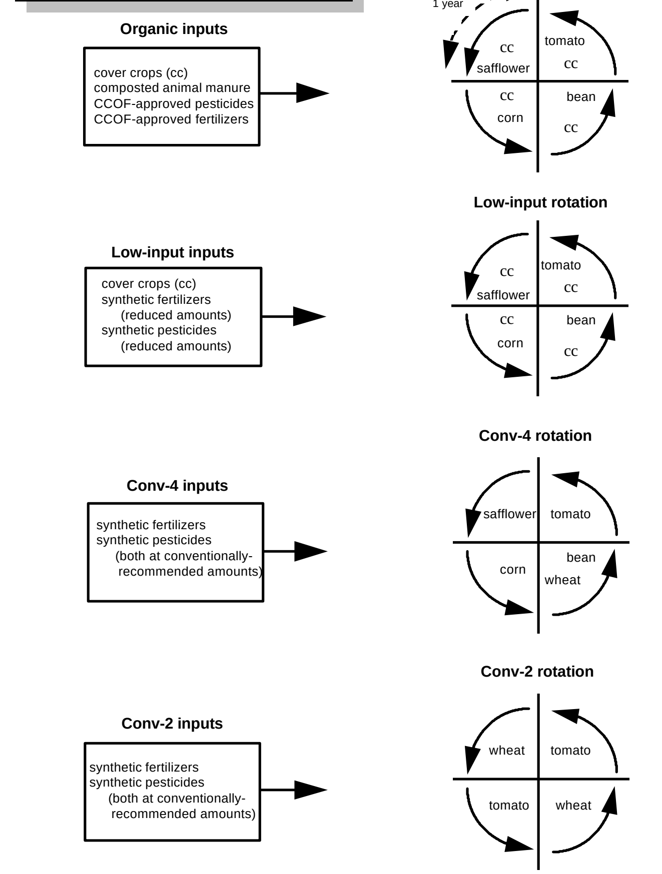
Overview

Reducing pestidide use is a widely acknowledged goal for improving agricultural sustainability. Although there is no national policy for pesticide reduction in the United States, the federal government has set a goal to bring 75% of agricultural land under integrated pest management (IPM) by the year 2000. In addition, voluntary pesticide reduction programs have been initiated at the state and regional levels by government institutions and nongovernmental organizations. In conventional agriculture the decision to use a pesticide is generally based in its effectiveness against particular pests, application costs, the economic value of the crop, and the relative risks to the crop of using it (phytotoxocity, resistance, etc.) versus not using it (pest outbreak). With high-value crops growers may be more inclined to use pesticides as “insurance” even when pest populations are below economically damaging levels. Moreover, farmers may be directly or indirectly encouraged to apply pesticides by pest control advisors working for agrichemical distributors. The potential environmental and health hazards associated with pesticide use are considered less often. By contrast, a principal aim of organic and low-input agriculture is to avoid environmental degradation and health risks by reducing or eliminating the use of synthetic chemical pesticides.

The SAFS Experiment

The Sustainable Agriculture Farming Systems (SAFS) project, an interdisciplinary, experiment station-based study of conventional, low-input, and organic farming systems provided a unique opportunity to assess the consequences of synthetic pesticide reduction or elimination on yield, pest abundance, and pest management costs at the field and farm scale. The SAFS project was established in 1989 to study agronomic, economic and biological aspects of conventional and alternative farming systems in California’s Sacramento Valley. The study consists of 2 conventional and 2 alternative systems which differ primarily in crop rotation and use of external inputs. These include 4-year rotations under conventional (conv-4), low-input, and organic management and a conventionally-managed, 2-year rotation (conv-2)(Figure 1). In the conv-4 treatment, beans are double-cropped with a winter wheat crop, while in the low-input and organic treatments, beans typically follow a biculture of oats and vetch which serves as either a cover crop or cash crop. The conv-2 treatment is a tomato and wheat rotation. Here we focus on pest management and pesticide use in the tomato and corn crops from 1989-1996, the first two rotation cycles.

Figure 1. ***SAFS Experiment Treatments and Rotations***



Pest Management Aproaches

During the 8-year period, all systems used “best farmer management practices” which were determined through consultation with project investigators, farm advisors, and growers cooperating on the project. Thus, management decisions on crop variety selection, agronomic practices, and pest management were based on market demand and current practices in the region. The conv-4 and conv-2 treatments were managed with practices typical of the surrounding area, which included the use of synthetic chemical pesticides. In the low-input system, external inputs were reduced primarily by using legume cover crops to maintain/improve soil fertility, and mechanical cultivation for weed management. The organic treatment was managed according to the regulations of California Certified Organic Farmers. Thus, no synthetic chemical pesticides or fertilizers were used in the organic system.

Pest Abundance

Populations of twenty one pests were monitored and studied at the SAFS site between 1989 and 1996. Significant treatment differences were found in the levels of a variety of pests, either consistently or occasionally, but only weeds were associated with lower yields. These data indicate that weed competition was partially responsible for reduced crop yields in the alternative systems relative to the conventional systems. They also suggest that dependence solely on mechanical weed control, including cultivation and hand hoeing, is somewhat less reliable than using a combination of mechanical and chemical control. In the low-input corn system cultivation has been the primary means of weed management, though herbicides have been used in 4 of the 8 years. The level of weed control achieved with this approach in the low-input system has been as effective as that in the conv-4 corn system which has used 3 times more herbicide.

Insect and mite pests tended to vary more with year than with cropping system treatments. This is not particularly surprising considering the small size of the plots relative to the potential mobility of the insects studied. Furthermore, the infrequent need for chemical arthropod control was possibly a consequence of the high degree of vegetative diversity created by the randomized patchwork of crops. Spatial diversity is well known to influence the abundance of arthropod pests and their natural enemies, with greater diversity usually being associated with reduced pest levels. Insecticides were applied to control potato aphid, armyworm, and/or tomato fruitworm in the conventional and low-input tomato systems during the first 3 years of the study (1989-1991). In the organic system insecticidal soap was applied to control potato aphids in 1989 and *Bt* was applied for tomato fruitworm in 1991. Other pests which were occasionally problematic in tomato included russet mites, stink bugs, and lygus bugs. Insect-infested fruit at harvest was at acceptable levels (below the 2% grade standard) in all treatments throughout the study.

Corn Pests Monitored

Arthropods	Aphids Spider mites Corn earworm	1989-1995
Weeds	Total weed cover Total weed biomass	1990-1996
Nematodes	Root knot nematode Root lesion nematode	1988, 1990-1995

Among the corn pests monitored, only spider mites necessitated chemical control, which was applied in 1989 and 1990 in the conv-4 system. The organic and low-input systems were left untreated. Other pests presented periodic problems in corn. In 1992, feeding by seedcorn maggot (*Delia platura*) resulted in damage to 25% of corn seedlings in the organic and low-input system. This pest is known to be problematic under conditions with high organic matter and moist surface residue, characteristics typical of cover-cropped agroecosystems after incorporation. Nevertheless, yield reductions in those systems, relative to the conv-4 systems, were not observed.

Soil-borne pathogens in tomato showed some significant differences between treatments but only a few were consistent over the 2 years of sampling (1995-96). Differences in corky root, and root rots caused by *Fusarium* spp. and *Pythium* spp. appeared to be influenced most by the length of the rotation. These diseases tended to be more common in the conv-2 system compared to the other systems, all of which had 4-year rotations. General reductions in soil-borne pathogens and root disease severity in organic and low input compared to conventional systems can be ascribed to longer rotations, regular applications of organic amendments, or abstinence from or reductions in pesticide use. While it is well known that diseases are more effectively managed with longer rotations, the economic returns from tomato production encourage growers to plant this crop more often. Increased disease severity in this analysis was not associated with detectable yield loss. Nevertheless, the risks of future yield loss to soil-borne pathogens are greater with the 2-year rotation compared to the 4-year rotations.

Tomato Pests Monitored

Arthropods	potato aphid tomato fruitworm beet armyworm	1989-1995
Weeds	total weed cover total weed biomass	1990-1996 1990-1992, 1993-1996
Diseases	Corky root Pythium rot Phytophthora Rhizoctonia Fusarium wilt Knobby root	1995-1996
Nematodes	root knot nematode root lesion nematode	1988, 1990-1995

In addition to the disease observations in tomato we noticed a build up of vetch stem and foiar pathogens (*Botrytis* sp. and *Ovularia* sp.) in the low-input and organic systems during the first 8 years of the project. This build up was presumably due to the high frequency of lana vetch (V*icia Dasycarpa*), the winter cover crop in this rotation. Late season decline from disease stems and foliage became very apparent in 1995 prior to cover crop incorporation. As a result, the cover crop rotation has been expanded by substituting common vetch (*Vicia sativa*) in the rotation preceding tomatoes, sorghum sudan (*sorghum* spp.)+*Lab Lab purpureus/*cowpea (*Vigna unguliculata)*preceding safflower and by including field pea (*Pisum sativum*) with purple vetch (*Vicia benghalensis*) and oats in the niche between corn and bean.

In general, plant-parastic nematode densities have been low and have not required management intervention to reduce their numbers. Root-knot nematode and root-lesion nematode tended to increase in all treatments and crops over the course of this study. However, neither of these pests reached what would be considered economically damaging levels; hence no chemical treatments were directed at them. The increasing densities in all systems suggest that the continued use of susceptible varieties, which are selected based on market deamand, may create future pest management problems and should be reconsidered in light of the potential economic and environmental costs of their continued use, including yield loss and/or the need for nematicide applications. This situation illustrates the conflicts which can arise between integrating pest

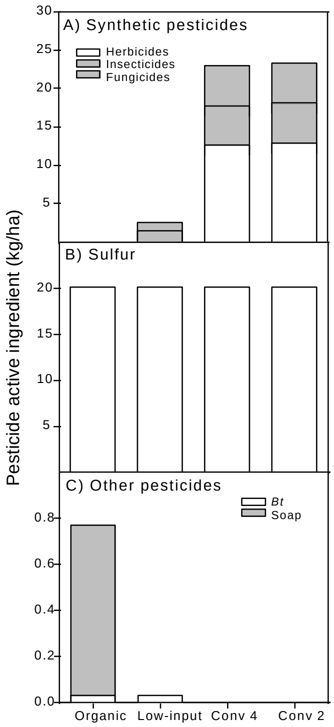


Figure 2. Cumulative amount of pesticide active ingredient applied as synthetic pesticides (A), sulfur (B), and other pesticides (C) in the tomato systems, for the period

management practices and full-filling the requirements of processors or buyers.

Pesticide Use

Sulfur and synthetic chemical herbicides accounted for most of the pesticide active ingredient applied to the tomato systems over the 8 years (Figure 2). Sulfur, used to control russet mites, was applied equally across all 4-year systems in the first 3 years of the study. By contrast, most synthetic herbicide was applied to the conventional systems. Herbicides were used in the conventional tomato systems in all 8 years of the study, but not used in the low-input or organic system. Total synthetic pesticide use in the low-input system was 10% of that used in the conventional systems. No synthetic pesticides were used in the organic system. Instead, insecticidal soap and *Bt* were each applied to the organic tomato system in 1 year of the study to control potato aphids and tomato fruitworm, respectively. Increased cultivation and hand weeding were substituted for the herbicides. Fungicide was applied preventatively only in the first year of the study in anticipation of a predicted early fall rain.

Total pesticide use in corn was substantially less than in tomato largely because of the absence of sulfur (Figure 3). Total herbicide use in the low-input system was about 30% of that in the conv-4 system. However, because no insecticides were used in the low-input system, total pesticide use in the low-input system was only about 25% of that in the conv-4 system. No pesticides were used in the organic corn system.

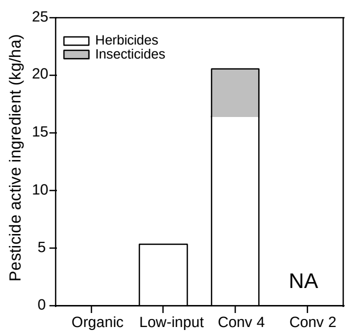


Figure 3 Cumulative amount of pesticide (active ingredient) applied in the corn systems over 8 years (1989-1996).

Pest Management Costs

Comparisons of total pest management costs in the alternative systems relative to the conv-4 system illustrate considerably different patterns between the tomato and corn crops. In tomato, pest management costs in the alternative systems averaged 51-57% more than conv-4 system costs over the 8 years (Figure 4). Weed management costs contributed the most to total pest management costs in all tomato systems and, as a proportion of total production costs, were nearly identical across treatments. However, in absolute costs, weed management was considerably more expensive in the alternative systems due to greater reliance on hand hoeing. In fact, hand hoeing was largely responsible for the large differences in costs between between the alternative and conventional tomato systems.

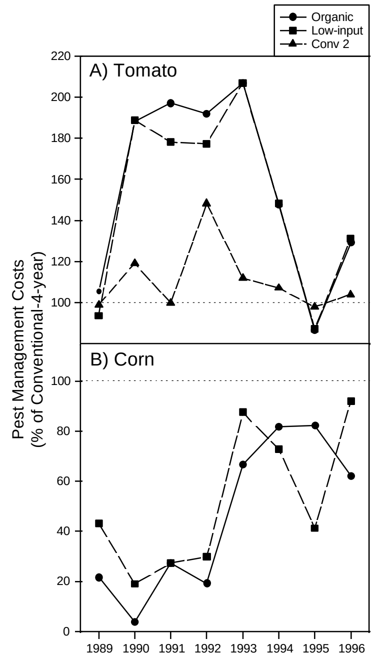


Figure 4 Relative pest management costs in the tomato (A) and corn (B) systems as a percentage of pest management costs in the conv-4 system, 1989-1996.

In contrast, pest management costs in the alternative corn systems were lower, averaging 48-54% less than costs in the conv-4 system throughout the study (Figure 4). However, in absolute costs, treatment differences were much smaller in corn than tomato because pest management comprised a relatively small portion of corn production expenses, and corn was only about one-third as costly to produce as tomato. Nevertheless, cultivation was more cost effective than herbicide use in managing corn weeds, and brought pest management costs down to approximately 5% of total production expenses in the alternative systems.

Summary

The findings of this study illustrate the differences in the potential to reduce pesticide use in processing tomato and corn systems in northern California. It suggests that pesticide reductions in processing tomato production, particularly for weed management, are economically costly using currently utilized non-chemical practices and available technologies. Although pesticide use could be reduced by 50%, resulting in less potential environmental impact, premium prices are needed to compensate growers for increased pest management costs which may average 50% more than conventional pest management costs. In a sense, consumers paying for organic premiums are internalizing some of the environmental costs of agriculture because farmers are compensated for reducing the environmental impact of pesticide use. But without premium prices, such increased costs may not be justifiable in a system in which weed management expenses account for over 20% of total operational costs.

In contrast, pesticide use in corn grown in a 4-year rotation could be reduced by 50-100% with little or no reduction in yield. Further, the substitution of cultivation for some or all herbicide applications may reduce pest management costs by 50% or more and result in less potential environmental impact. With-

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