Sustainable Agriculture Farming Systems Project
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Weed Management in Organic and Low-Input Farming

The use of herbicides usually provides a cost-effective and convenient means of suppressing weeds. However, there can be environmental, economic, and social consequences that are overlooked until they become serious problems. The recent U.S. Geological Survey's National Water Quality Assessment reported that herbicides are widespread in surface and ground water, particularly in agricultural areas and often above drinking water standards. An objective of organic and low-input farming is to eliminate or reduce dependence on synthetic pesticides, including herbicides. Research at the Sustainable Agriculture Farming Systems (SAFS) project has focused considerable effort on evaluating the feasibility of non-chemical weed management and assessing the agronomic and economic trade-offs of weed management practices in organic and low-input farming systems.

The SAFS Project

The SAFS project was established in 1988 to study agronomic, biological, and economic aspects of conventional and alternative farming systems in California's Sacramento Valley. Four farming system treatments are represented at the site including four-year rotations under conventional, low-input, and organic management and a conventionally-managed, two-year rotation. The crops include processing tomato, safflower, bean, corn, winter wheat, and a multipurpose oats/vetch crop. The conventional systems are managed with practices typical of the surrounding area, which include the use of synthetic fertilizers and pesticides, including herbicides (Table 1). In the low-input system, synthetic fertilizer and pesticide inputs are reduced to about 50% of that used in the conventional systems. The organic treatment is managed according to the regulations of California Certified Organic Farmers (CCOF); therefore, no synthetic chemical pesticides or fertilizers are used.

Weed Management At the SAFS Project

Weeds can reduce crop yields by competing for nutrients, water, or light and interfere with field operations, such as harvest. However, the presence of some weeds in a field is not necessarily a problem. In fact, weeds can provide some benefits, including habitat for predaceous and parasitic arthropods which help keep pests in check and protect soil from wind and water erosion when there is little or no crop cover. Finding the right balance should be the goal of sustainable weed management.

The principal goal of weed management does not differ fundamentally among the conventional, low-input, and organic systems of the SAFS project. In all systems, the objective is to prevent weeds from directly or indirectly reducing harvestable crop yield. However, the specific combination of tactics used in each of the systems, as well as their effectiveness, cost, and potential environmental and health effects, do differ considerably.

A comparison of the conventional and organic tomato systems in 1997 provides an interesting contrast of weed management strategies (Figure 1). Although the organic and conventional tomato yields were similar, weed management differed substantially. In conventional production, herbicide applications were the primary means of controlling weeds (Table 1). In 1997, a total of four herbicide applications were used in the conventional system; three before and one following tomato planting. The first two herbicide applications were used to kill winter weeds, the third was used just before tomato planting and intended to prevent weed growth in the tomato row, and the fourth was applied using a power incorporator just before the tomato plants reached first bloom. Two cultivations and 7 hours of hand hoeing were also used in the conventional system.

In contrast, the organic system utilized two non-chemcal tactics to reduce early season weed pressure:

Table 1: Cumulative herbicide use (lbs/acre active ingredient) in the SAFS cropping

Crop	Farming System			
	Organic	Low-Input	Conv 4-yr.	Conv 2-yr.
Tomato	0	1.0	17.4	16.7
Corn	0	5.9	17.6	NA
Safflower	0	0.7	7.7	NA
Bean	0	0	5.1	NA
Wheat	NA	NA	13.7	14.5
Oats/ Vetch	0	0	NA	NA

transplanting and pre-irrigation followed by cultivation. Beds were formed in the spring

Table 2: Weed Management Costs in SAFS Cropping Systems,

Crop	System	Weed Management Costs			
		Labor	Fuel	Materials	Total
Tomato	Conv 4-yr	102	19	48	169
	Conv 2-yr	102	21	53	176
	Low-Input	39	8	9	55
	Organic	156	20	0	176
Beans	Conv 4-yr	10	12	13	35
	Low-Input	10	8	0	18
	Organic	35	10	0	44
Corn	Conv 4-yr	16	17	34	67
	Low-Input	10	10	4	23
	Organic	9	11	0	20
Safflower	Conv 4-yr	10	13	30	54
	Low-Input	8	9	0	17
	Organic	8	10	0	18
Wheat	Conv 4-yr	2	2	37	41
	Conv 2-yr	2	3	37	42
Oats/Vetch	Low-Input	0	0	0	0
	Organic	0	0	0	0

following the incorporation of the cover crop and composted manure. The ground was then irrigated with sprinklers to promote the germination of weed seeds near the soil surface. These weeds were eliminated with shallow cultivation so that deeper seeds were not brought to the surface. The beds were then ready for transplanting. The use of transplants provides some advantage over early-season weeds and eliminates the need for thinning several weeks after crop emergence. A combination of cultivation and hand hoeing were used throughout the rest of the season. Early season cultivation was accomplished with a "close cultivator" which included flat knives, disks, and shields to protect the tomato seedlings. This eliminated weeds within an inch or so of the tomato plants. Later in season, a belly-mounted cultivator was used which included knives near the crop and on the shoulders of the bed, shovels in the furrows, and basket rollers on the top of the bed. A total 16.8 hours of hand hoeing was required in the organic system (Figure 1).

In 1997, an herbicide application was used in the low-input tomato system for the first time in the history of the SAFS project. Trifluralin was applied prior to transplanting. The goal was to reduce hand hoeing costs in that system in order to improve its economic performance (see below). This approach proved to be very effective - only one cultivation and 4.2 hours of hand hoeing were required after transplanting. This practice, however, is incompatible with the organic system, which does not use herbicides, and the conventional system since trifluralin cannot be used before direct seeding of tomato.

In other crops grown at the SAFS site, including corn, beans, and safflower, hand hoeing is generally not an option because it is too costly relative to the value of the crop. Therefore, cultivation, used in conjunction with good irrigation timing, is the only substitute for herbicides. Cultivation can be an effective means of weed management but requires diligence to prevent weeds from escaping control. Special attention to field edges is necessary to prevent potentially troublesome weed problems later. Factors beyond a farmer's control, such as an untimely rain, can work against weed management efforts, and may make dependence solely on cultivation somewhat more risky than a combination cultivation and herbicide applications.

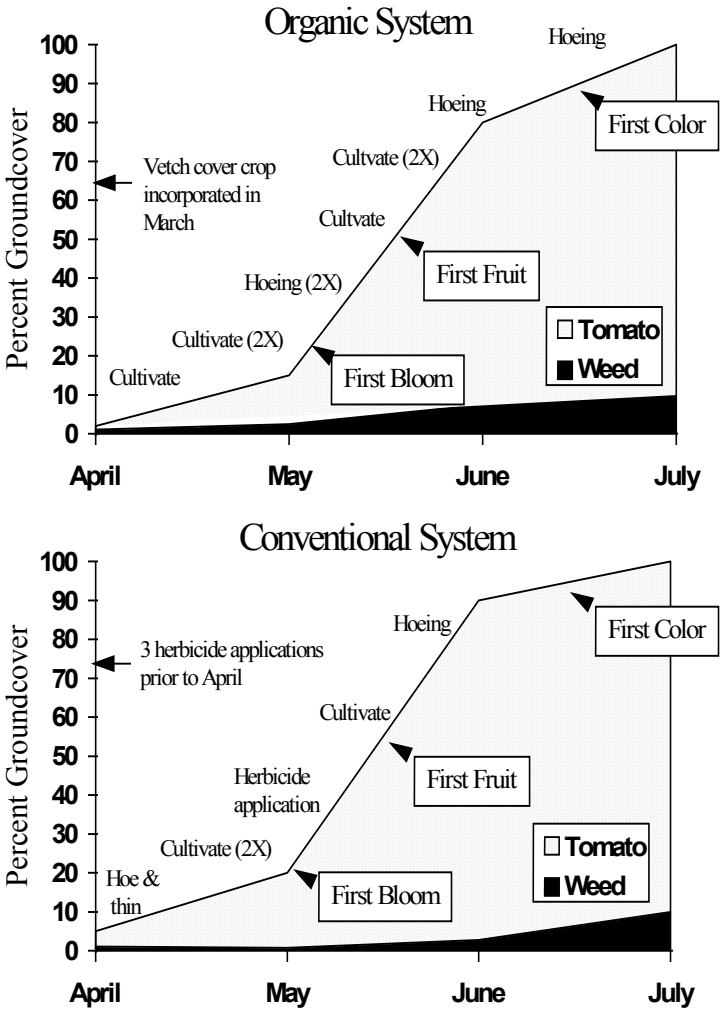
Weeds in the organic corn system, for example, are often managed adequately with a rolling (rotary) cultivator. This implement has gangs of spiders with curved teeth that spin, throwing soil toward or away from the row. Weeds outside of the crop row are uprooted or cut and small weeds within the row can be buried. In 1997, however, crow feeding on seedlings resulted in relatively poor corn stands in all farming systems. This provided space within the corn rows for broadleaf weeds like common lambsquarters and pigweed. An application of 2,4-D was used in the conventional and low-input systems to suppress these weeds but there were no control options for the organic system, and corn yields suffered.

Economics of Weed Management Practices

Among the crops grown at the SAFS project, weed management is considerably more costly in tomatoes compared to all others in 1997 (Table 2). This is largely due to the labor costs associated with hand hoeing. Although all tomato systems depend on hand hoeing, the organic system had the highest cost. In 1997, total weed management costs in the organic

tomato system were comparable to the conventional system, though in some years the costs in the organic and low-input systems have been much higher than the conventional systems - almost twice as high in some years. The herbicide application used in the low-input system prior to transplanting lowered total weed management costs in that system considerably by dramatically reducing hand hoeing costs. For the first time the low-input system had lower weed management costs than the conventional systems. This practice will be continued in future years in an effort to improve the profitability of the low-input system.

Hand hoeing was used in the organic beans for the first time in the 9 years of the SAFS project. Problems with bean harvest in previous years due to weeds clogging the machinery prompted a more aggressive effort to keep weed levels low. Hand hoeing is generally not an economically feasible option in beans but was justifiable in the organic beans due to the price premiums received. Weed management in corn and safflower is generally cheaper under organic and low-input management because herbicides are not used. In 1997, weed management costs in these systems were about one-third of those in the conventional corn and safflower crops (Table 2).



Future Possibilities

Weed management currently accounts for nearly one-third of tomato production operating costs in all SAFS farming systems. However, in absolute costs, weed management has usually been more expensive in the low-input and organic systems due to greater reliance on hand hoeing. The use of a single herbicide application in the low-input system greatly improved the economic performance of that system in 1997. But, non-chemical alternatives are needed as well. Two possibilities have been evaluated at the SAFS project: flaming and weeder geese. Flaming may be compatible with conventional, low-input, as well as organic systems but is no less dependent on fossil fuel that herbicides. By contrast, the use of weeder geese is a biological weed management approach which may be appropriate for organic operations and reduce hand hoeing costs. Geese may be especially effective at reducing grass growth in the tomato rows. Preliminary studies indicate that both of these methods may have some potential and future research will be aimed at refining these management methods and assessing their costs.

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