Organic Weed Management

(Version July 18, 2017)

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Introduction

Weed management in organic crops is in most ways the same as in conventional crops. Successful conventional and organic weed manager's practice integrated pest management (IPM) by preventing weed competition from damaging the crop as well as weed seed reproduction or introduction of material contaminated with weed seed. There is one important difference between conventional and organic systems, organic producers do not have access to synthetic herbicides like conventional producers and hence in many cropping situations the only form of "rescue treatment" is hand weeding–an expensive proposition. It cannot be overemphasized that no one tool is responsible for the success of an organic weed management program, but the key to success is an integrated program utilizing cultural and mechanical weed control tools in a coordinated effort to manage weeds. The best case scenario for an organic weed manager is to farm a field with a low weed population. How do we arrive at this ideal situation? The story starts with a discussion of IPM.

IPM Definition

Weeds are pests, and therefore the principals of integrated pest management can be applied to weeds. IPM is a decision support system for the selection and use of pest control tactics singly or harmoniously coordinated into a management strategy, based on cost-benefit analyses that take into account the interests and impacts on producers, society and the environment (Norris et al. 2003). Integrated weed management takes a cropping systems approach that relies on essential knowledge for its implementation and focuses on crop health. It can be viewed as a series of interactions among several weed control components. It is about putting the components together and not taking them apart. It is about integration of components rather than reliance on a single technology (Swanton et al. 2008).

Strategies and tactics for IPM

Prevention

If a pest is not present in a field or geographic region, then preventing introduction of the pest is highly desirable. The scale of prevention effort can range from the field level to the country level. Here we discuss prevention at the field level where control is in the hands of the farmer (Norris et al. 2003).

The priority of prevention is to limit the entry of new exotic weed species into the field. However, prevention must whenever possible limit the entry of any weed seed into the seedbank whether it is already in the field or not.

Many of the concepts pertaining to the damage caused by replenishing the seed bank are discussed in the seed biology section of this course. Every method of weed control in both conventional and

organic systems can be used to prevent weeds from going to seed. Tillage of a harvested field soon after harvest to kill uncontrolled weeds is an example of preventing weed seed production.

Sanitation
This is a preventative weed management practice. Control of weeds in the peripheral areas surrounding a field such as drainage ditches, roads and other non-crop areas is important to prevent invasion from areas surrounding the field. This is especially important for management of wind-blown weed seed from species like hairy fleabane and horseweed (Daugovish and Fennimore 2008). Cleaning soil from tillage equipment while moving from one field to another is another method of sanitation to prevent movement of weed seed between fields.

Field selection
This is a form of avoidance. For some crops such as strawberry or lettuce, there are no tools available to control perennial weeds such as field bindweed or yellow nutsedge. Therefore fields used to grow many horticultural crops must be carefully selected to avoid these difficult weeds.

Putting IPM into practice on weeds

Level I—Weed control
Weed control describes the suppression of one or more weeds with a single tool or technology. The tool can be chemical, mechanical or biological, but the objective is the same – to reduce the impact of the target weed usually by killing it before it causes damage through competition with the crop or reseeding the seedbank (Cardina et al 1999). Weed control is justified by numerous studies that show uncontrolled weeds can cause complete crop loss. Here we will discuss individual physical and cultural weed control techniques that are used in organic cropping systems.

Organic-compliant techniques are classified as: **cultural techniques**, **barriers**, **burning or uprooting**.

Cultural techniques
Examples of cultural techniques are the use of transplants instead of direct-seeded crops. Transplants are larger and less susceptible to weed competition than seeded crops. Other examples of cultural techniques include crop rotations. For example vegetable crops grown in rotation with crops that have more effective weed control programs will help to keep the field clean of weeds. The constantly changing conditions that occur as the field is rotated from crop to crop allow no one weed species to become predominant.

Field selection, discussed above would be another example of a cultural technique.

Barriers
These techniques use a mulch layer of soil, plastic, fabric or organic materials that suppress weed emergence. Soil used as a barrier is established by various methods including soil solarization, and water management.

Mulches
These are barriers to weed growth that consist of plastic or paper tarps, fiber mats, straw or other organic material. Mulches serve multiple functions, such as warming the soil, protecting the crop

foliage and fruit from the soil, enhancing moisture retention and weed control. Clear tarps are most useful for warming the soil, but can enhance weed growth in non-fumigated soils and are not recommended in organic systems. Synthetic mulches are available in black, blue, brown, green, red, white, and yellow colors. Many of the colors (white and yellow) are available on a black background that greatly improves weed control. Blue and clear plastic mulches result in the poorest weed control because they permit the greatest amount of light to penetrate the plastic that allows weed germination and growth under the plastic (Johnson and Fennimore 2005). Black, and brown block light effectively and are recommended for use in organic systems. Growers should proceed with caution when using green mulches because there is considerable variation in light interception by green mulches that results in variable levels of weed control. Organic mulches such as wood chips, chopped straw and rice hulls are sometimes used to control weeds in home gardens and landscapes. To control weeds effectively the organic mulch must be at least 2 inches deep and needs to block light from reaching the soil surface.

Soil solarization

One of the most difficult tasks of weed control is to kill dormant weed seeds in the soil before they emerge. Soil fumigants such as methyl bromide have been used to kill dormant weed seeds in the soil for many years. However, soil solarization is a non-chemical method of soil disinfestation that kills both soil borne diseases and weeds (Elmore et al. 1997).

Soil solarization involves placing a clear polyethylene plastic sheet over the soil that is moist and well tilled (fig. 1). The plastic sheet needs to be kept in place 4 to 8 weeks. During summer when solar radiation is highest soil solarization is most effective. Solarization works by trapping Incoming solar energy under the clear plastic where it heats the soil to critical temperatures needed to kill pests. The moisture in the soil helps to distribute the heat so that it is more uniformly distributed. Soil solarization is less effective in cooler climates such as coastal areas that are foggy in summer months.

Solarization kills weed seed by exposure to heat for a critical period of time, which is why treatment is required for 4 to 8 weeks – to ensure that the soil temperature reaches critical soil temperatures and durations needed to kill weed seed, especially several inches below the soil surface. Moisture helps by holding heat in the soil and by germinating seed so that they are easier to kill with solarization. Dormant seed are also killed, but they

Figure 1.
Soil solarization with clear polyethylene tarp prior to planting strawberry.

are more susceptible when moist and swollen than when dry. Time also increases the chance that heat will penetrate deeper into the soil and kill more weed seed.

It is best to keep the soil moist during the 4 to 8 week solarization period. One effective method is to install drip irrigation in the soil prior to clear tarp installation. The irrigation tape must be buried at least 2-inches deep in the soil to prevent damage to the drip tape. Drip tape left on the soil surface under clear plastic often melts under the intense heat and lensing effect immediately below the clear plastic, and must be avoided.

Water management

There are a number of ways that water management can help reduce weed pressure such as buried drip irrigation, use of dust mulches and preplant irrigation.

Buried drip irrigation

Drip tape buried below the soil surface can provide moisture to the desirable plants and minimize the amount of moisture that is available to weeds on the surface (Grattan et al., 1988; Biasi et al 2000; Sutton et al. 2006). Drip irrigation tape buried 6-8 inches below the surface of the bed can irrigate the crop and keep the soil surface dry so that weed germination is minimal. If properly managed, this technique can provide significant weed control during the dry months of the year. Possible disadvantages to buried drip includes the difficulty of prompt detection of any leaks or emitter blockage, damage from roots and animals.

Dust mulches

The Mediterranean climate of California with dry summer weather allows growers to utilize a dust mulch to avoid weeds (Bell, 1989). Weeds are germinated by an irrigation, killed by cultivation or flaming and the top few inches of soil are allowed to dry and form a dust mulch. Large seeded crops (i.e. corn, cotton, melons, squash, or beans) or transplants are planted through the dry soil into the zone of soil moisture. These crops can germinate and/or grow and provide partial shading of the soil surface without supplemental irrigations that would otherwise provide for an early flush of weeds.

Preplant irrigation and shallow tillage

Preplant irrigation, that is the watering of the field in the days or weeks before planting, can be used to manage weeds. After listing of raised beds, pre-plant irrigation of dry soil, followed by an interval of one to three weeks to dry the field, then followed by shallow tillage to create a smooth planting bed, is essential during field preparation for small seeded crops. This practice kills many weeds that emerge during the interval between irrigation and shallow tillage. The weed control objective of preplant irrigation is to get weeds to germinate before crop planting, when it is easier and more economical to control them, than during the crop production season when weed removal is more difficult and costly due to the need to protect the crop.

Annual weed seeds typically germinate and emerge from the top 1 to 2 inches of soil. Preplant irrigation can be used to deplete the upper soil layers of “germinable” weed seeds (nondormant seeds that germinate after watering). By depleting weed seeds in the upper soil layers, we are using field soil as a mulch to inhibit emergence of germinable weed seeds from deeper soil layers. This is why it is important to not till the preirrigated beds too deeply, to avoid the risk of movement of germinable weed seed from deeper soil layers to the soil surface where they can germinate.

Preplant irrigation and shallow tillage works by establishing a clean soil layer depleted of weed seed close to the soil surface (fig. 2). Studies conducted at Salinas, CA found that preplant irrigation can provide up to 50% weed control (Shem-Tov 2006).

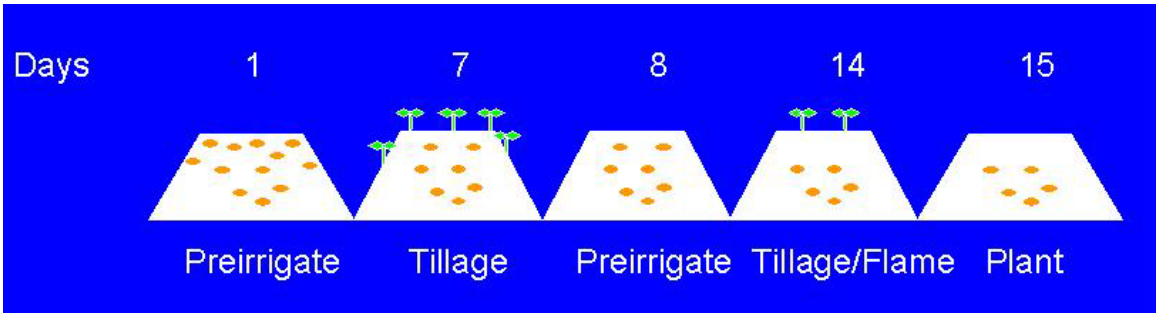

Figure 2. Weed removal using preirrigation followed by tillage or flaming. The schedule of events is preirrigation on days 1 and 8 followed by shallow tillage or flaming on days 7 and 14.

Burning or uprooting

These methods involve damaging the weed foliage with organic-compliant herbicides or propane flaming. Uprooting involves traditional cultivation and hand weeding.

Herbicides

There are a limited number of organic-compliant herbicides available. To date all are contact herbicides with no soil activity. These products are primarily used by home owners, and there is limited use in commercial agriculture due to high cost and weak activity. This may well change in the future as this is an active area of research. Potential organic-compliant herbicides might include acetic acid (vinegar), fatty acids, soaps and natural oils such as clove oils (Boyd and Brennan, 2006a). Research reports indicate that acetic acid based products can control weeds under some circumstances. However, the performance of acetic acid products is inconsistent (R. Smith and T. Miller, personal communication, Boyd et al. 2006b). More research and development in the area of organic-compliant herbicides is needed.

Selective flaming

A directed flame or a hooded burner can be used to kill weeds while protecting the crop from injury. Flaming is intended to kill weeds by over-heating them rather than actually burning them. Crops which use this technique include cotton, corn, soybean, grain sorghum, castor beans, sesame and tree and vine crops. Flaming has been used in organic vegetable crops to remove weeds from stale seedbeds prior to seeding or after seeding but prior to emergence such as in onion. Flaming has also been effective in landscapes to control weeds on bare soil and along fencerows and pavement cracks, but care must be taken to avoid fires.

Proper timing is essential for greatest weed control and minimal injury to the crop. Generally the best weed control is obtained when the weeds are 1 to 2 inches tall. In cotton, flaming can begin when cotton stems are 3/16 inch in diameter at ground level. By this time, the cotton plant is about 8 inches tall and the stems are strong enough to survive treatment.

Timing is also critical for selective burning in corn, which should not be flamed when the crop is 2 to 12 inches tall. Corn less than 2 inches tall can be flamed because the growing point is still below the

soil surface. Corn taller than 12 inches will not be injured by flaming small weeds at the base of the plant.

Cultivators
Sled-mounted cultivators can give very accurate control in row plantings. Sleds require more tractor power to pull than gauge-wheel cultivators but provide greater precision for vegetable row-crop production. Guide wheels (cone wheels, rubber guide wheels, etc.) also can improve the precision of cultivations if set up properly (fig. 3). Sled cultivators are generally rear-mounted on the tractor. Cultivators can also be set up on tool bars mounted between front and rear wheels of a row crop tractor with an off-center driver seat and steering column to allow for easy viewing by the operator.

Figure 3. Row-crop cultivators may include combinations of bed knives, rolling baskets and duckfoot sweeps.

Hand-weeding
Precision cultivation and cultural methods use will not eliminate all weeds. Therefore, hand weeding is a necessity in row-crop production and in some orchard and vineyard situations. Hand weeding removes those last few weeds missed by other methods, which if allowed to go to seed, will replenish the seedbank and reinfest the field. Prevention of weed seed production is desired, especially of those, which are aggressive competitors (or prolific seed producers).

In orchards and vineyards, hoeing is often needed during the first year of establishment. Excessive competition from weeds may kill some crop plantings by depriving the crop of light or water. As a result, a two-year-old crop could require first-year management techniques. Trees or vines should not be planted in a sod turf or weed cover, as growth is severely reduced in such situations. Supervision, monitoring, and incentives all are needed to get optimum results from hoe crews. For organic crops hand hoeing is extremely important as there are no herbicides for use in these systems. After plastic installation in crops like strawberry, hand weeding with hoes or weed hooks

to reach weeds under the plastic are the only means of weed control remaining other than in the furrow bottom where cultivation and directed sprays are still possible.

Level II—Weed management
The next level of integration is the coordinated use of two or more weed control methods with the objective of reducing weed infestations to acceptable levels (Cardina et al. 1999). Organic and horticultural crops are highly dependent on integrated weed management systems because these producers have no one tool which alone provides acceptable weed control. California lettuce producers use integrated weed management systems that include the use of cultural tools such as crop rotation, stale seedbed preparation, herbicides, mechanical cultivation and hand weeding (Haar and Fennimore 2003, Shem-Tov et al, 2006).

An example of level II management in lettuce. Preplant germination of weeds involves the use of irrigation or rain to stimulate weed seed germination before planting lettuce. The emerged seedlings are then killed by shallow cultivation, or flaming, or a combination of these treatments. Germinate and remove weeds as close as possible to the date of planting to assure that the seasonal weed spectrum does not change before planting the vegetable crop. Waiting 14 days after the time of preplant irrigation allows weeds to emerge and for the field to dry enough to permit use of shallow tillage to control emerged weeds. Done properly, this method removes up to 50% of the weeds that would have otherwise emerged in the subsequent crop. If time permits, repeat the preplant process to further reduce weed populations (Fennimore et al. 2009). After planting lettuce, at least two inter-row cultivations are made and at least two hand weeding passes are made (Haar and Fennimore 2003).

Level III
This involves cropping systems management and is beyond the scope of this class. Area-wide pest management is the management of weeds on a regional scale by governmental entities. For example use of prevention to limit the spread of herbicide resistant weeds across a region or quarantine of noxious weeds in contaminated hay (Cardina et al 1999).

Essential knowledge base for IWM

Tillage system
The weed seedbank in conventional tillage is more evenly distributed in the soil profile, whereas in reduced tillage systems weed seed tends to be in the upper layers of the soil profile. Potential management methods for use in reduced tillage would be to promote winter kill to reduce the longevity of the seedbank, to allow for increased predation and to take advantage of a more uniform germination which makes control methods more effective (Swanton et al. 2008). Because tillage introduces selection pressure on weeds, tillage rotation would help balance out the selection pressure between conventional and reduced tillage.

Critical period of weed control
This defines the critical time when the crop must be protected from weed competition. The choice of weed control tool such as mechanical cultivator or herbicide must be applied or used in such a way that weed populations are held below damaging levels during this time (Swanton et al. 2008).

Harvest window

This is the period from the end of the critical period until harvest. Weeds that emerge during this period do not influence yield, but may influence quality and ability to harvest the crop. The decision to control weeds during this time must be made more carefully as weed control operations during this time may be a waste of money and time (Swanton et al. 2008). Weed management decisions should not be made on how the crop looks at harvest, but on how well the weeds are controlled during the critical period of weed control. Basing the decision solely on potential for competition to the crop is controversial. Late emerging weeds may not compete with a crop but they can set seed and reinfest the seedbank. A good argument can be made that there should be no tolerance for any weed seed set.

Summary

Any single intervention to control weeds will place selection pressure on the weed population in any given field. Use of multiple interventions in an integrated manner is the most effective means by which to manage weeds in a sustainable and long term basis. The problem is that short-term economic constraints faced by growers make it harder to convince them to take a more long-term view.

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