



Organic Crop Production



Management Techniques
for Organic Farming

Ted Goldammer



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Management Techniques for Organic
Farming

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First Edition

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By Ted Goldammer

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CHAPTER ONE

Introduction to Organic Farming

Organic farming is a system for crops that emphasizes environmental protection and the use of natural farming techniques. It is concerned not only with the end-product, but with the entire system used to produce and deliver the agricultural product. To this end, the entire farm cycle, from production and processing, to handling and delivery, excludes the use of artificial products such as genetically modified organisms (GMOs) and certain external agricultural inputs such as pesticides and synthetic fertilizers. Organic farmers rely instead on natural farming methods and modern scientific ecological knowledge in order to maximize the long-term health and productivity of the ecosystem, enhance the quality of the products, and protect the environment. Proponents of organic methods believe that it is a more sustainable and less damaging approach to the environment.

1.1 History of Organic Farming

Traditional farming (of many particular kinds in different eras and places) was the original type of agriculture, and has been practiced for thousands of years. All traditional farming is now considered to be “organic farming” although at the time there were no known inorganic methods. After the industrial revolution had introduced inorganic methods, most of which were not well developed and had serious side effects, an organic movement began in the 1930s as a reaction to agriculture’s growing reliance on synthetic fertilizers and pesticides. For example, the introduction of chemically synthesized farm inputs such as urea and DDT were criticized by scientists, philosophers, and practitioners who questioned whether the widespread adoption of such practices was sustainable. The history of this modern revival of organic farming dates back to the first half of the 20th century at a time when there was a growing reliance on these new synthetic, non-organic methods.

The Emergence of Organic Farming

Organic farming has its roots with the ideas of scientists such as Rudolph Steiner, J.I. Rodale, Lady Eve Balfour, Sir Albert Howard, and other scientists beginning from the 1930s. Contemporary American organic farming has its roots in the organic farming movements that spread across Great Britain and continental Europe from the 1920s through the 1950s. The pioneers of the early organic movement were motivated by a desire to reverse the perennial problems of agriculture—erosion, soil depletion, decline of crop varieties,

low quality food and animal feed, and rural poverty. The proponents of organic farming believed that the highest quality food and the sustainability of agriculture were achieved by “feeding the soil,” thereby building soil fertility. Their practices—drawn from mainly from European and Asian models—included managing crop residues, applying animal manures, composting, green manuring, planting perennial forages in rotation with other crops, and adding lime and other natural rock dusts to manage pH and ensure adequate minerals. This contrasts with the (then emerging) strategy of using soluble fertilizers, which bypass the soil food web to fertilize plants directly.

Post-World War II Organic Era Farming

Technological advances during World War II accelerated post-war innovation in all aspects of agriculture, resulting in big advances in mechanization (including large-scale irrigation), fertilization, and pesticides. In particular, two chemicals that had been produced in quantity for warfare were re-purposed to peace-time agricultural uses. Ammonium nitrate became an abundantly cheap source of nitrogen, and a range of new pesticides appeared—DDT launching the era of widespread pesticide use. These technical advances resulted in significant economic benefits; however, the rise in chemical treatments greatly worried organic farmers and consumers in the post-war era. In the 1940s, an international campaign called the Green Revolution was launched in Mexico leading to the development of new disease resistance high-yield varieties of wheat. By combining the wheat varieties with new mechanized agricultural technologies, Mexico was able to produce more wheat than was needed by its own citizens, leading to its becoming an exporter of wheat by the 1960s. Prior to the use of these varieties, the country was importing almost half of its wheat supply. The Green Revolution encouraged the development of hybrid plants, chemical controls, large-scale irrigation, and heavy mechanization in agriculture around the world. During the 1950s, sustainable agriculture was a topic of scientific interest, but research tended to concentrate on developing the new chemical approaches (See Figure 1.1).



Figure 1.1 Farmer spraying pesticides

Environmental Movement

A truly significant event in the history of organic agriculture took place in 1962, with the publication of Rachel Carson’s *Silent Spring*. *Silent Spring* highlighted the dangers—real and perceived—of pesticides, making organic agriculture especially attractive, as it eschewed the use of most synthetic pesticides. *Silent Spring* is widely considered as being a key factor in the banning of DDT in many countries. The book and its author are often

of generic materials and brand names of specific products that are found to be consistent with the USDA organic standards. Because product labels do not provide complete information about active and inert ingredients, the OMRI Products List is a reliable resource and contains a current and rather complete inventory of allowable products. These lists help interpret the NOP's National List and enable producers and processors to determine under what circumstances a material or product is allowed for use in organic production. OMRI lists are updated quarterly, and users should be sure they are using the most current version of the list. The most current product listings can be found on OMRI's website. OMRI also operates an organic seed information service to help growers find organic seeds.

Companies pay a fee and fully disclose their formulations and other necessary proprietary information to OMRI for a thorough review. Thus, OMRI provides a needed service for manufacturers who do not wish to disclose "trade secrets" to the general public but desire to sell their products to organic producers. However, because inclusion on the OMRI list is voluntary, omission from the OMRI List does not necessarily mean the substance is prohibited. The certifying agency, however, makes the final decision regarding what products can or cannot be used on the organic farm.

Organic Materials Review Institute List

Organic Materials Review Institute certificates are issued to suppliers of products that have successfully completed the OMRI product review process and have been assigned an OMRI status of either Allowed or Allowed with Restrictions in accordance with the specified organic standard(s). OMRI-approved products may be used on operations that are certified organic under the USDA National Organic Program. However, it is up to the certifying agency to determine when it is appropriate to use any of the OMRI listed products, regardless of OMRI's designation. So, even if a farmer can use a product on the OMRI list, they must check with their certifier before initial use. Prohibited products may not be used in organic production, processing, or handling. Products that are listed by OMRI as approved for use in organic production carry the label shown below (See Figure 3.1). Certificates are valid for one year and must be renewed annually. Some products may be listed one year and not the next. Reformulations can render a product non-compliant. Alternately, a reformulation can bring a previously non-compliant product into compliance. In some instances, a producer will be required to document the lot number of a product in order to verify its compliance. OMRI makes no claims to product effectiveness; they only confirm the product is approved for use under the NOP.



Figure 3.1 OMRI label

The Washington State Department of Agriculture Organic Food Program, a USDA-accredited certifier, maintains a list of products (known as the Brand Name Materials List, BNML) that have determined meet the requirements under the National Organic Standards. WSDA does not imply any guarantee or endorsement of any of the products listed on the BNML. In addition, manufacturers of these products are not required to list their products on the BNML. Therefore, this is not a comprehensive list of brand name materials that meet organic standards. Please refer to the National List of Allowed and



Figure 4.1 Soil organic matter is the very foundation for healthy and productive soils.

Benefits of Soil Organic Matter

In addition to supplying nutrients, soil organic matter improves soil fertility by imparting favorable chemical and physical attributes to soil. Soil organic matter can bind nutrients through the process of cation exchange. Ammonium, calcium, magnesium, and potassium are nutrient cations that are held on cation exchange sites on organic matter. The CEC of soil organic matter can contribute from 20 to 70 percent of the total cation exchange capacity of soil. Soil structure is influenced by the association of soil organic matter with minerals to form aggregates. Aggregate formation improves soil structure and water infiltration and increases water-holding water capacity. These changes improve root growth and provide habitat for a diversity of soil organisms. Soil organic matter enhances nutrient cycling, provides habitat for a diversity of soil organisms, and creates a favorable environment for plant growth.

Classification of Soil Organic Matter

Several types, or “pools,” of soil organic matter exist, each important for different soil functions. Think of these pools of soil organic matter on a continuum from fresh, active organic matter that is gradually transformed to well-decomposed humus (i.e., stable fraction).

Active Fraction

The active fraction of organic matter is composed of a range of material, including recent plant litter and highly decomposed unrecognizable plant and other organic residues that break down in a very short time, from a few weeks to a few years. This kind of organic matter is associated with biological activity in the soil. The active organic matter accounts for only a small fraction of the total organic matter in the soils but is much more sensitive to

Conventional Tillage

Conventional tillage entails turning under and thoroughly mixing crop residues or cover crops into the top 6 to 10 inches (15 to 25 cm) of soil. The goal of conventional tillage is to leave a residue and vegetation-free soil surface, with a uniformly mixed soil horizon to the plow depth. Conventional tillage systems typically involve a primary pass with a heavy tillage tool (e.g., moldboard plow) to loosen the soil and incorporate materials at the surface (e.g., fertilizers, amendments, weeds, etc.), followed by one or more secondary passes, often referred to as secondary tillage, to create a suitable seedbed. Secondary tillage operations are typically performed with a variety of tillage implements such as a disk harrow, field cultivator, or spring-tooth harrow. The operations and equipment used for tillage vary considerably for different crops and in different regions.

Primary Tillage

Primary tillage is the first soil tillage after the last harvest, which involve loosening the soil, inverting the soil, and uprooting weeds and crop stubble (See Figure 5.1). Primary tillage techniques are always aggressive and usually carried out at considerable depth, leaving an uneven soil surface. For weed species that are propagated by seeds, primary tillage can contribute to control by burying a portion of the seeds at depths from which they are unable to emerge. Primary tillage can also play a role in controlling perennial weeds by burying some of their propagules deep, thereby preventing or slowing down their emergence. Some of the propagules can be brought up to the soil surface, where they will be exposed directly to cold or warm temperatures or desiccation conditions. The implements used to perform primary tillage include moldboard plows, chisel plows, disk plows, rotary tillers, and spading machines.



Figure 5.1 Deep soil tillage

crop(s) is critical to maximize the benefits of including them in the crop rotation. The key to selecting the right cover crop is matching it to the next cash crop, watching the weather, and timing termination to minimize negative impacts on soil moisture and temperature. Selection of cover crops will depend on the goals of the organic farmer, which may include providing biological nitrogen, organic matter, insect habitat, weed management, erosion protection, or combinations of these. Species selection will also depend on when the cover is planted—cool season or warm season. How the cover crop will be terminated should be part of the planning process as well. A cover crop can be used for a short period of time in the spring before the cash crop or later in the fall after a main crop has been harvested. In cases where crop rotations are very tight, it is often easier to insert a fall cover crop after the harvest of a cash crop, provided there is enough time for it to establish before early fall frosts. Table 7.4 lists cover crops that are grown for specific purposes (Hoorman *et al.*, 2009).

Table 7.4
Cover Crops Grown for Specific Purposes

Purpose	Cover Crops
Organic matter (high C:N)	Sorghum-sudangrass, cereal rye, annual ryegrass, triticale, oats, wheat, spelt, barley
Nitrogen (low C:N):	Cowpea, winter pea, red clover, sweet clover, hairy vetch, alfalfa, soybeans, mung beans
Reduce soil compaction (deep rooted)	Sorghum-sudangrass, annual ryegrass, oilseed or tillage radish, sweet clover-deep taproot, cereal rye, oats
Forage or can be grazed	Oats, forage radishes, turnips, cereal rye, annual ryegrass, teff for dry fields, sorghum-sudangrass, barley
Prevent soil erosion	Grasses have fibrous root systems to bind soil, and the best grass cover crops include cereal rye, annual ryegrass, oats, wheat, and barley. Other cover crops include buckwheat with a shallow fibrous root system, cowpea, winter pea
Recapture excess nutrients (nitrogen, phosphorus)	Oilseed or tillage radish, turnips, annual ryegrass, cereal rye, oats, wheat, sorghum-sudangrass, and buckwheat, sweet clover, winter pea, cowpea, red clover, hairy vetch
Tolerate wet soils	Sweet clover, red clover, annual ryegrass, cereal rye, wheat, and oats
Tolerate heat and drought	Cowpea, hairy vetch, mung beans, sweet clover, sorghum-sudangrass, buckwheat, barley, teff
Attract beneficial insects	Buckwheat, sweet clover, red clover
Cold tolerant	Cereal rye, wheat, spelt, triticale, winter pea, and sweet clover
Natural herbicides or allelopathic effects for weed suppression	Cereal rye, oilseed or tillage radish, mustard, oats, barley, buckwheat, and sorghum-sudangrass. Annual ryegrass, cereal rye, sorghum-sudangrass may be used for controlling soybean cyst nematodes.

Tillage Practices

Various tillage practices can make an impact on crop rotations. For instance, farmers must consider how different types of tillage systems can influence a rotation. For example, if

forms or timing of development may make cultivation and use of inputs more difficult and less effective. Planting crops in alternate rows or strips greatly simplifies management and captures some of the benefits of intercropping. It may do little, however, to increase resource capture by the crops, unless alternating strips are close together.

8.2 Intercropping Technical Criteria

When two or more crops are cultivated in an intercropping system, each crop should have adequate space, to maximize cooperation and minimize competition between the crops. To accomplish this, attention should be paid to the specific local conditions (climate), the choice of crops, the arrangement of crops in space and time, the plant density, maturity dates of the different crops, plant architecture, and spatial arrangements.

Crop Choice

Almost any type of crop or combination of crops can be used for intercropping. Choose crops that are locally grown and well adapted to the climatic conditions. Seeds or other plant material can be obtained from other farmers, on local markets or from specialized seed producers. Consider including a pulse crop in the intercrop, as pulses fix nitrogen and help to improve soil fertility and soil structure.

Plant Densities

When two or more crops are grown together in a field, plant densities need to be adapted to maximize yields. If full rates of each crop were planted, neither would yield well because of intense over-crowding. By reducing the seeding rates of each, the crops have a chance to yield well within the mixture. The challenge comes in knowing how much to reduce the seeding rates. The best way to find out the best plant density is to experiment with different seeding rates.

Planting and Maturity Dates

In intercropping systems, it is better if the crops in the mixture have different maturity dates, with different times of peak demand for nutrients, water and sunlight, thereby reducing competition. For example, a common practice in the old southern U.S. cotton culture was to plant velvet beans or cowpeas into standing corn at last corn cultivation. The corn was close enough to maturity that the young legumes did not compete. When the corn was mature, the beans or peas had corn stalks to climb on. The end result was corn and beans that were hand harvested together in the fall. Following corn and pea harvest, cattle and hogs would be turned into the field to consume the crop fodder. Selecting crops or varieties with different maturity dates can also assist staggered harvesting and separation of grain commodities.

Plant Architecture

In designing an intercropping system, it is useful to pay attention to differences in plant architecture between the crops given that different crops may have a different architecture (i.e., height and width of the plant). Tall plants may shade shorter plants, thereby aiding

PTO (power take-off) operated, but some are driven from the ground wheels. Some are hydraulically powered for greater speed variation, especially for the apron drive, to vary the application rate. Rear-delivery technologies may include a spinner spreader, single or double horizontal beaters, and vertical beaters. Manure spreaders may be tractor-drawn models or they may be mounted on a truck.

Side-Discharge Box Spreaders

Side-discharge spreaders are open-top spreaders that use augers within the hopper to move wet manure toward a discharge gate (See Figure 9.3). Manure is then discharged from the spreader by either a rotating paddle or set of spinning hammers. Side-discharge spreaders provide a uniform application of manure for many types of manure with the exception of dry poultry litter. Side discharge units can handle materials with a wide range of moisture contents making them a great fit where manure is too solid for a tanker, but too loose for a box spreader, like sand-laden pit manure.



Figure 9.3 Side-discharge box spreader

Box Spreaders with Vertical Beaters

These spreaders provide an excellent spread pattern and exceptional breakup of materials. These characteristics, combined with a fast unloading time, make this type of spreader an ideal choice for producers seeking to take maximum advantage of the nutrient value of their manure, from pen pack to dry yard manure. These machines either use apron floor chains or piggy-backed hydraulic cylinders to push material out of the box and through the beaters.

Box Spreaders with Spinner Beaters

Box spreaders with spinner discharge can handle many dry, flowable, high-value materials such as compost and poultry litter. A heavy-duty metering end gate, effectively controls the movement of materials to the spinners. Some are equipped with a hydraulically adjustable apron, which allows the producer to accurately control spread rates down to 1 ton per acre. Some models have a horizontal beater and spinner combination, which breaks up any clumps or clods of material and will spread up to 60-feet wide in a very precise, even spread pattern.

Box Spreaders with Horizontal Beaters

A box spreader with horizontal beaters is a great choice for a basic manure spreader (See Figure 9.4). It has a relatively low power requirement and is simple to operate. In addition, the spread pattern of this type of machine is relatively narrow and covers just the width of the

- **Particle Size.** The water holding capacity of substrates can be increased by decreasing particle size, which increases the amount of inner particle pore space although this can increase the potential of water logging.

10.5 Composting Methods

On-farm composting of organic materials is commonly done using the following methods: (1) passive windrow composting method; (2) passively aerated windrow composting method; (3) aerated static windrow composting method; (4) turned windrow composting method; (5) in-vessel composting method; and (6) vermicomposting. The proper approach depends on the time to complete composting, the materials and volume to be decomposed, space available, the availability of resources (e.g., labor, finances), and the quality of finished product required.

Passive Windrow Composting Method

Passive windrow composting is a very low-cost approach requiring more land, but less labor and capital than other composting methods. Generally, material to be composted is collected and promptly piled into windrows, which remain untouched. Farmers who use this method may or may not use a compost recipe, and they usually make no attempt to adjust moisture content, or the carbon-to-nitrogen ratio (C:N). The piles are not aerated, and their temperatures, which are so critical to proper composting, are not monitored. Passive compost piles often turn anaerobic, when organisms that do not require oxygen take control of the decomposition process. This method is not approved for certified organic production. It has mixed or often poor results because organic materials are placed in a pile and left alone to decompose over an extended period of time. Passive aeration has been successfully used in composting manure from poultry, dairy cattle, and sheep.

A windrow is simply an elongated pile of material with a more or less triangular cross-section (See Figure 10.3). A windrow should measure about 10 feet (3 m) wide and 5 feet (1.5 m) high; its length will vary depending upon the amount of materials used. Large passive windrows can be as wide as 24 feet (7 m), and as high as 12 feet (4 m) and of any length. The windrow architecture enhances aeration by convection (hot air rising off the top draws cool, ambient air in through the sides) and also facilitates equipment access for building the windrow (often done in layers) and turning the completed pile.

Passively Aerated Windrow Composting Method

In the passively aerated windrow method, the pile is aerated with perforated pipes embedded in the bottom of the pile (See Figure 10.4). Aeration occurs as hot gases rise in the windrow—called the “chimney effect.” The pile should be 3 feet (1 m) high by 10 feet (3 m) long, with an insulating layer of finished compost on the bottom and top. Amendments such as straw and wood chips are sometimes used to improve structure, which permits satisfactory aeration without turning. An aerated static windrow compost pile is similar to passively aerated windrows but has fans that force air through the perforated pipes.

11.3 Developing Economic Thresholds

A decision to use a pesticide should be made only when a pest population has reached or exceeded an economic threshold (ET), a fundamental concept in integrated pest management. The economic threshold (sometimes called an action threshold) is the pest density (number of pests per unit area) at which control efforts are triggered so as to prevent pest populations from reaching the economic injury level. Thresholds should be quantitative (numerical) to be useful. For example, they could be based on the average number of pests per trap each week, the percentage of plants or leaves found to be damaged or infested during visual inspection, or the number or size of weeds for a given area. The economic injury level (EIL) is the pest population density that causes losses equal to the cost of control measures. To justify using a control method, it is necessary to set the ET below the EIL (See Figure 11.5). Otherwise, producers lose money—first from the damage caused by the pest, and then by the cost of the control method. Setting the ET below the EIL triggers the appropriate control method before pests reach the EIL. The principal components used derive economic threshold levels (ETLs) as the damage caused by a single or set number of pests; the cost of controlling the pest; and the value of the crop. Typically, a destructive insect feeding on a high valued crop results in a low economic threshold value. A low valued crop, combined with a less destructive insect results in a higher ETL.

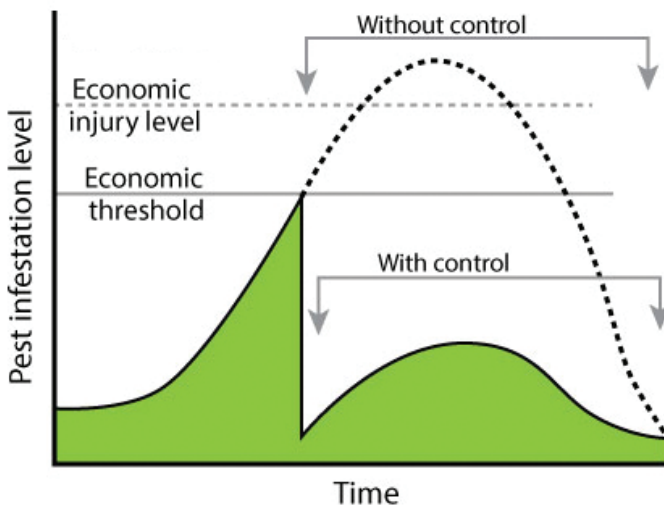


Figure 11.5 Change in pest population density over time.

Treatment Thresholds

Thresholds vary with crop, stage of plant development, cost of control methods, type of pest, and time until harvest and market. The amount of pest presence or damage that can be tolerated is determined by many factors, including the type of pest and damage, crop species and cultivar, stage of plant development, time until harvest or sale, and market conditions. Treatment thresholds may be higher for mature plants of certain crops since more mature plants are often better able to tolerate some level of certain types of pests or their damage.

Ideally, an ETL is a scientifically determined ratio based on results of replicated research trials over a range of environments. Even when published ETLs exist, they should be used

4. Mating disruption has been used worldwide to control oriental fruit moth in stone fruit, peaches and nectarines using both hand-applied and sprayable formulations.
5. Pheromones used in the mating disruption of omnivorous leafroller with hand-applied or sprayable formulations in California vineyards. Given that this pest is only important in the state's warmer grape-growing regions, the need for pheromones is geographically restricted.



Figure 12.5 Pheromone traps are an ideal for the monitoring of Lepidoptera pests in both indoor and outdoor growing areas that are commonly affected by this type of pest.

12.10 Insect Growth Regulators

Insect growth regulators (IGRs) have proven extremely effective as components in IPM programs for control of insects which have become resistant to standard insecticides. Typically, IGRs are less harmful to the environment and more compatible with pest management systems that include biological controls. They generally don't affect non-target species—such as humans, birds, fish, or other vertebrates. Insect growth regulators are compounds that mimic the action of hormones to disrupt the molting process and modify growth of insect or mite pests. They do not kill insects directly, but interfere with normal development so insects die before they mature. Some cause insects to stop feeding. Others affect egg, larval, nymphal, or pupal development. They inhibit metamorphosis and may negatively affect reproduction and egg viability. Insect growth regulators are primarily used to kill immature stages of plant-feeding insects, including caterpillars, fungus gnats, leafminers, mealybugs, scales, shoreflies, thrips, and whiteflies.

How Insect Growth Regulators Work

Insect growth regulators (IGRs) use a different and more selective mode of action; they disrupt the growth process of insects, preventing them from reaching reproductive

short time in which beneficial organisms have a competitive advantage over pathogenic and parasitic organisms, a population shift large enough to suppress these detrimental organisms may occur, limiting their recolonization.

Effect on Soilborne Pathogens

Soil solarization is effective against fungal pathogens such as *Verticillium* spp. (wilt), *Fusarium* spp. (several diseases), and *Phytophthora cinnamomi* (Phytophthora root rot), and bacterial pathogens such as *Streptomyces scabies* (potato scab), *Agrobacterium tumefaciens* (crown gall), and *Clavibacter michiganensis* (tomato canker). It also reduces soil populations of different plant parasitic nematodes, especially *Meloidogyne* spp. (root-knot), *Pratylenchus thornei* (root lesion), *Pratylenchus* (root lesion), and *Xiphinema* (dagger) nematodes which are the most important ones for Colorado crop growers.

13.4 Biorational Control of Crop Diseases

Organic growers have available a large array of biorationals that may be applied for the management of crop diseases. Biorationals typically used to control crop diseases include microbials, minerals, and spray oils. Microbials include live organisms (e.g., beneficial bacteria, fungi, nematodes, and viruses) and/or their fermentation products as the active ingredient. Minerals include sulfur, lime-sulfur, various forms of copper, and potassium bicarbonate. Spray oils include petroleum-derived oils (referred to as “narrow-range oils”); oils derived from plant and fish sources; and essential oils, such as wintergreen, clove and rosemary. Preventive, cultural, mechanical, and physical methods must be the first choice for pest control, and conditions for use of a botanical or synthetic material permitted on the National List must be documented in the organic system plan.

Minerals

Sulfur and copper are the disease control materials most applied on organic farms. Elemental sulfur may be used for a broad range of diseases in a wide variety of plants. Copper products must be applied in a way that minimizes copper accumulation in the soil. Among the copper products allowed are copper sulfate, copper hydroxide, copper octanoate, copper oxide, and copper oxylchloride. Bordeaux mix (copper sulfate combined with hydrated lime) and lime-sulfur are also permitted. Potassium bicarbonate, a relatively new product as a fungicide is also permitted. Each of these products and their uses are summarized in Table 13.1 and described in more detail in the following sections.

Application of Minerals

The frequency of application of any mineral-based pesticides is related to its residual time, or the time required for the product to degrade in the environment. Synthetic materials, approved for organic crop production, in general have a short residual time. On the other hand, this short residual time also limits most concerns about build-up in the soil that are associated with some commercial products. Effective control requires that the application of materials begin prior to conditions favorable for disease development or immediately following the first symptoms of disease. In foliar applications, these materials provide a protective barrier on plant surfaces that interfere with the pathogen. Repeated applications



Figure 14.16 Under-the-trellis retractable rotary mower. Photo courtesy of Butler Equipment, Inc.

14.5 Flame Weeding

Many organic farmers have included propane (LP) flame-burners as an additional tool in their weed management toolbox. Heat from the flamer kills the plant by rupturing cell walls, not burning the plant tissue. After flaming, weeds that have been killed change from a glossy to a matte finish. The length of time the flame is applied depends on the age, size, and tenderness of the weed. Flaming is used particularly during times of high field moisture when tillage with large machinery is not feasible. In drier weather, flaming is used in conjunction with cultivation. Flaming is most effective on annual broadleaf plants that have relatively thin (non-succulent) leaves and aboveground or unprotected growing points. In general, younger plants, especially newly emerged seedlings, are more susceptible to flaming than older plants. Flaming is least effective on weeds that can effectively avoid or tolerate high temperatures—for example, those with pubescent leaves (common purslane) or those that can initiate new growth after flaming, such as those with below-ground growing points (annual grasses). Weeds that have germinated, but are not yet emerged, will also not be affected by flame weeding. Because flaming does not control grasses or perennials well, rotary hoeing or harrowing may be a better option.

Advantages and Disadvantages of Flame Weeding

Flame weeding is an increasingly attractive weed control method because it provides multiple advantages over chemical and mechanical weed management methods used in both conventional and organic farming operations. Compared with the use of chemical herbicides with conventional crop systems, flame weeding does not leave chemical residues in or on plants, soil, air, or water. Flame weeding does not pose safety risks to people in the surrounding area because it avoids drift hazards associated with chemical treatments; and unlike herbicides, flame weeding offers a treatment option that weeds cannot become