Integrated Pest Management

The key to crop management in any farming system is the prevention of anything that will decrease the amount of crop harvested. Pest insects feeding on plants, for example, can reduce harvests or destroy crops. The key to prevention is healthy plants and the key to healthy plants is in the soil. Research has shown that healthy plants are not attacked as often by pest insects as less healthy plants. Removing infested plant material including crop residues from the field reduces carryover of pests from one planting to the next and thus prevents re-infestation.

Good soil management that results in healthy plants is the first and most important line of defense against insect and disease problems

Insects

A Brief Sketch of Insect Natural History

The number of insect species is greater than the number of all other species of organisms combined (excluding prokaryotic organisms-*bacteria*). The number of taxonomically described beetles (only one of 31 orders of insects) is more than 250,000 species—more than all the species of flowering plants. Estimates on the number of species of insects not yet discovered range from between 2 and 100 million species

Insects have been around for more than 350 million years. Except for marine habitats, insects have adapted to almost every environment possible. The reasons for their success include the following factors:

- **Short generation times and high numbers of offspring** result in populations that are highly adaptable under the stress of environmental changes.
- **A highly efficient body plan and construction:** The insect "exoskeleton" is a light-weight, but incredibly strong "suit of armor" whose external waxy coating protects against moisture loss. Outwardly directed ridges and spines serve to protect or hide the insect from enemies, or are colored and modified to attract mates, while inward protruding ridges and spines serve as points of attachment for muscles.

- **The ability to fly**: Active flight was first to evolve in the insects, aiding dispersal to new and potentially favorable environments
- **The development of "complete metamorphosis"** in some orders, allowing the juvenile stages to no longer compete with the adults for space or resources. Body forms could be solely adapted to a specific and independent role or function.

Beneficial Insects:

Not all insects are harmful. ***Identification*** is essential to distinguish the harmful from the beneficial insects.

- **Pollination**: Many species of native bees and flies pollinate crops
- **Organic matter decomposition**: Mold mites, springtails, wolf spiders, centipedes, sow bugs, ground beetles exist at different trophic levels and serve to break down organic matter into its constituent parts. They feed directly on organic matter or prey on those that do.
- **Natural or intrinsic levels of pest suppression**: Some insects feed on other harmful insects. The great diversity of insects includes predaceous, parasitic and parasitoid adaptive strategies and are "natural enemies" of agricultural pests. These "beneficial insects" may serve to effectively suppress the development of pest populations if the habitat for these species is effectively managed.

Crop losses attributed to insects:

Arthropod Monitoring and Management Procedures

The first step in any pest control system is **monitoring**. Monitoring is the systematic scouting of crops for pests and natural enemies, either regularly or at susceptible times to understand if the self-regulatory regulation of pests is still intact or if additional measures need to be taken. The methods for monitoring differ from pest to pest. It is important to know for each pest when to monitor, the proper method and possibly what tools to use. Typical aids for monitoring are sweep nets, sticky traps, and pheromone traps. Observations need to be made on a daily basis to monitor pest types and numbers to determine when to intervene. This is important because any type of intervention costs time and money.

Monitoring methods commonly used

- Visual inspection/observation: Regular visual inspection and observation of plant parts in field and lab is the most effective
    - Monitoring protocol for in-field visual inspections
        - Survey crops systematically and on regular basis
        - Frequency: 1x/week; 2x/week during peak growing season
    - Vegetable crops:

        - Walk furrows and check both sides of leaves on every few plants
        - Remove wilted plants and examine root system for indications of soil borne insects, pathogens
    - Root crops:
        - Check the soil before you plant from the soil level to 4 inches down by running your fingers through the soil looking for small insects. Collect and identify samples.

Arthropod sampling techniques for the garden and small farm

- **Traps**: Less effective as they tell what is on the farm and not necessarily what is affecting the crops. Traps may also catch arthropods that come from outside the farm or garden.
    - **Pheromone traps**: Attract insects by chemical lure
    - **Sticky traps**: Capture flying adult insects
    - **Light traps:** Select for nocturnal insects
    - **Pit fall traps**: Capture ground-dwellings arthropods and spiders
- **Catching:** Most effective in determining abundance and corollating arthropods with damage
- **Sweep nets:** Use to capture insects on vegetation
- **Aspirators**: Use to capture very small insects on vegetation
- **Shaking plants:** Shaking or beating plants or branches onto paper for later sampling is a useful way to gather insects for identification that might normally go unseen
- **Degree-day monitoring:** For some pests and beneficial insects researchers have developed temperature development thresholds at which time management actions may best be taken

Identification and Understanding Life Cycles.

Another important tool in pest and disease control is identification and understanding of the life cycles. The accurate identification of the species, life cycle, habitat requirements, time and location of occurrence, damage pattern, susceptible time for control form an important part of the knowledge of pests and natural enemies and are indispensable for a successful long-term pest management strategy.

Identification can be done using field manuals or by collecting a specimen or diseased tissue and pest is identified, a study of its life cycle will reveal when it is the most vulnerable to existing controls.

Climate and weather conditions also influence the pest activity and rate of reproduction. Knowledge of these can help to predict the likelihood of disease infections and thus aid in the designing of appropriate preventive measures.

Sustainable Agricultural and Preventive Pest Management:

Preventing the Growth of Pest Populations Beyond Economic Thresholds

- **Management procedures**
    - Determine if control action threshold has been exceeded
    - Implement control actions
    - Document control actions taken and responses to treatment

Crop rotation: Changing on an annual basis the place in the garden or field where crops are grown interrupts the host/pest cycle and thereby reduces or limits the development of populations of both arthropod pest and pathogens

Cover cropping: A form of crop rotation, cover cropping interrupts the host/pest cycle, and with certain cover crop species serves as habitat for natural enemies of insect pests, which often suppress pests. Be aware that inappropriate choices of cover crop species can increase pest populations

Polyculture cropping patterns: An agricultural landscape that is populated with a diversity of crops reduces the carrying capacity of the land for a given pest population and increases the possibility of supporting natural enemies of insect pests

Sound soil fertility management

- Soil organic matter management: Regular additions of organic matter (e.g., compost, cover crops, and/or manure) stimulates soil biological activity and diversity, which may prevent certain pest populations from increasing beyond economic thresholds.
- Nutrient budgeting, soil amending, and supplemental fertilizing: Designing efficient amendment and fertilization plans around crop nutrient requirements and avoiding unnecessary nutrient inputs may prevent pest problems associated with both nutrient deficiencies and excesses.
- Sound irrigation and tillage practices: Maintaining desirable soil physical and chemical properties through properly applied irrigation and tillage will help prevent the pest problems associated with poor soil quality.

Farmscaping

- the use of non- crop vegetation for increasing and managing on-farm biodiversity to favor beneficial insects.
- Native plant associations, farmscaping, and the use of non-crop vegetation. A

greater diversity of non-crop vegetation (native and planted) in and around the farm may increase the carrying capacity for natural enemies of arthropod pests that often suppress pests before they become a problem. Insectary plantings: Plants known to produce abundant nectar used by natural enemies as a secondary food source. Help provide habitat for beneficial insects.

- "**Trap crops":** Intentionally planted alternative food sources for pest organisms. Trap crops reduce or prevent large numbers of pest arthropods from feeding on cash crops.
    - A trap crop is one the bugs prefer to the main crop. It is planted to "trap" the pests and keep them away from the main crop.
    - Trap crops are used to protect the main crop from a pest or a variety of pests.
    - The trap crop can be a different plant species, variety, or just a different growth stage of the same species as the main crop, as long as it is more attractive to the pests when they are present. If given a choice, cucurbit pests such as squash bugs and striped and spotted cucumber beetles prefer squash and pumpkins to watermelons, cantaloupes, cucumbers, and gourds—in that order.
    - The required trap crop planting size depends upon the intensity and direction of the pest attack expected, as well as the mobility of the target pest insect.
    - Usually, planting a trap crop around the perimeter of a crop area will be effective against insects of intermediate mobility.
    - Trap cropping tends to work best for insects of intermediate mobility rather than those, like aphids, that are passively dispersed by air currents, or insects that are strong fliers.
    - Trap crops are more economical to use if the system is easily planted and maintained and if they have some other use, such as supporting beneficial insects or if they can also be marketed. If they require a small amount of space relative to the main crop, they will be more economical.
    - The type of plants to use as trap crops varies according to the intended primary crop and expected types of pest insects. These will also vary due to the differences in climate within the state. One plant that is commonly used as a perimeter trap is collard greens to protect cabbage.
- **Companion planting**: Plants intentionally planted adjacent to cash crops that repel pests. The use of resistant crop varieties: Certain crop species have undergone extensive selective breeding in order to develop greater resistance and resilience to common agricultural pests. Such varieties should be used

where appropriate.

Biological control methods

Classical biocontrol: The importation and release of exotic biocontrol agents, with the expectation that the agents will become permanently established and no further releases will be necessary

- **Inoculative biocontrol**: Natural enemy releases are made when pest populations are low, giving the population of natural enemies enough time to develop with the pest population. Inoculative biocontrol relies on subsequent generations to manage the target pest. As the released natural enemies are not necessarily adapted to the release environment populations, releases (inoculations) are made at the start of each growing season.
- **Inundative biocontrol**: Similar to the use of chemical pesticides, this method relies on mass releases of natural enemies to control a large population of target pests that are causing damage close to the economic threshold. Relies on sheer numbers and periodic and seasonal releases to suppress a given pest population.
- **Microbial biocontrol**:
    - Bacillus thuringiensis—Bt. This is a soil bacterium that contains a chemical toxic to larval insects. The Bt that is available contains weakened or dead bacteria. The Bt powder is dusted onto plant surfaces being eaten by larva, the bacteria are ingested and the toxin is released. Bt acts by blocking the larvae from absorbing nutrients in their digestive systems.
    - Naturalis
    - Predatory nematodes

Chemical control methods

- Powders, soaps, and oils
    - Diatomaceous earth
    - Oils and neem oil
- Botanicals – (Garlic barrier, Hot pepper wax, Neem extracts, Pyrethrins,
    - Rotenones)

Cultural control methods

- Changes in frequency or timing of irrigation
- Pruning to increase air circulation or prevent contact with soil
- Field sanitation between cropping

Examples of physical control methods

- Row covers
- Solarization

- Vacuums
- Traps
- Flooding
- Tillage
- Field sanitation
- Netting
- Hand picking
- Reflective mulches
- Petroleum oil barriers

Pheromones

- Pheromones defined: The chemical sex attractant used by many insect species to draw mates
- Trapping out: The use of pheromone traps to trap and kill
- Mating disruption: The timed mass release of synthetic pheromones with the mating times of agricultural pests resulting in the inability of mating pairs to form.

Repellants

A way to prevent pest insect damage is to repel them with a substance that can be sprayed on the plants. This is usually done with garlic oil that is commercially available in large quantities. It has a small quantity of soap that doesn't harm plants mixed in to make it soluble in water. This mix of garlic oil and soap is diluted in water and applied directly to the plants.

Another substance used to repel pests is an herb commonly called **tansy**. Cuttings from the plant can be boiled in water to make a tea. This can be diluted and applied.

These and other mixtures have the effect of making the plants unpalatable to the pests, resulting in little or no damage to the crops. These repellants should be reapplied on a regular basis or after a rain. Application should be stopped enough ahead of harvest for the repellents to be washed off.

Barriers

Barriers are used to keep pest insects from being able to reach the crops. The most common and inexpensive type of barrier is floating row cover. This is a non-woven, synthetic cloth that is lightweight enough to be placed directly on plants without any support structure. It comes in various widths and can be used on beds or rows.

Floating row cover can be left on the beds or rows since 100 percent of the water that lands on it will pass through to the soil and 80 to 90 percent of the sunlight will be transmitted. An added benefit to growing under row covers is that it will act somewhat as an insulator, slightly raising the soil temperature underneath. This will result in more soil life activity in the spring and faster plant growth. A drawback is that must be

removed when cultivating for weeds and replaced. It also will degrade in sunlight, lasting for only one or two crops before it becomes brittle and tears.

These covers are excellent for crops that are harvested before they bloom, like cabbage and broccoli, because they don't have to be removed to allow pollinators in. They can be left under row cover until harvest. This will prevent pests like cabbage moths from laying eggs on the plants. For those crops that require pollination, like squash, the row covers should be removed as soon as the first flowers bloom.

Another type of a barrier is a collar that is placed around new transplants. These are usually made of heavy paper or cardstock and protect tender plants from attack by cutworms. The collars are wrapped around the top of the root ball before they are transplanted so that there is about half inch of soil holding them in place. These are effective against both types of cutworms- those that chew through the stem at the soil level and those that climb the plant and eat the tops. Collars are used on transplants of tomatoes, tobacco and other crops attacked by cutworms.

Floating row cover.

- Allows water and most sunlight through.
- Must be securely anchored to do its job.
- Weeds will grow under cover - must check regularly to control weeds.
- Will warm the soil slightly

Killing (Method of last resort)

Due to the highly adaptable nature of insect populations, repeated exposure to insecticides often leads to insecticide resistance—an inherited increase in the physiological range of tolerance to synthetic chemical controls. This often leads to the need for increased application rates of insecticides to achieve similar degrees of control, leading to further resistance and eventual loss of effectiveness of insecticide

Insecticide-induced resurgence: The rapid expansion of pest populations following a pesticide application resulting from pest populations being "released" from the population-control mechanism of predation by beneficial insects and spiders killed by pesticide exposure

When pest insect populations reach the ***critical point*** where crop damage is unacceptable, some type of intervention is needed. The most time and cost effective intervention at this point is to kill off the pest population. This can be done using insecticides that target only the pests. If there is no target insecticide available, a broad- spectrum insecticide that is acceptable under the organic rule can be used. In small- scale operations or small numbers of specialty crops, techniques like hand picking are effective.

An insecticide that targets the pest insects and does not kill the beneficials can be effectively used. However, some understanding of the life cycles of the pests and the insecticides used is necessary. One product that targets soft-bodied insects is insecticidal soap. This is effective in controlling aphids by dissolving the waxy coating on the outside of their bodies and causing them to dehydrate. Because of the way it works, the pests must be drenched in the soap solution. This requires direct contact with the solution so that it covers the pests.

Another insecticide that targets specific pests is ultra-refined vegetable oil. This is prepared so it is soluble in water and can be diluted. A solution of this oil can be sprayed on larval forms of insects to kill them. When the solution dries, the oil turns into a paraffin-like coating that smothers the larvae. Again, the pests must be drenched with the solution for it to be effective, unlike the broad-spectrum insecticides.

All of these insecticides take some time to kill the pests- from hours for soap and oil, to days for the Bt. But they do not need to be reapplied unless rain or overhead irrigation washes the insecticide off the pests' bodies or the plant surfaces being eaten.

The **broad-spectrum insecticides** (sometimes called botanicals) allowed by organic standards are all derived from plant material. These include rotenone, pyrethrum, sabadilla and others. They are called broad-spectrum because they kill almost all of the insects that come in contact with them- pests **and** beneficials. These are the only substances known to be effective on the adult stage of most insects.

Since they kill most of the insects they should be used only as a last resort and to save a crop that would otherwise be destroyed. There are two cautions about using these insecticides. The first is the misconception that, since these are organic, they are safe. Most of these insecticides are nerve agents and affect people as well. They should be handled and applied in the same way as chemical pesticides: Wear protective clothing and a respirator, avoid skin contact or inhalation of the powders, and wash immediately if contact happens. The safest way to apply these is as a solution, so dissolvable forms should be purchased.

Another caution is in making sure that a botanical insecticide does not contain any chemical insecticides that may void your organic certification. Some companies add these to insure their effectiveness. Be sure to contact your certifying agent before purchasing any such product to ensure that it is approved for use.

Botanicals have a much shorter shelf life than chemically produced insecticides. They should be stored carefully to maintain potency, avoiding moisture, and they

should be used in the year they are purchased. In addition, they are considered toxic waste and should be disposed of through a toxic-waste collection program.

Ineffectiveness of attempts to control pests with agricultural chemicals

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While there is no doubt that insects can and do cause significant losses to farms and gardens, it is also increasingly clear that much more attention is given to insects as "pests" than is often warranted by the evidence. This is in large measure due to the fact that multi-national chemical companies have enjoyed decades of profits from chemical insecticides on the order of $35 billion per year, and in order to justify their continued profit taking—at the expense of the health of ecosystems and millions of people—insect pests need to be sold as "serious threats," even when they might not be so.

Disease Control

Diseases in plants are caused by bacteria, viruses, and fungi, with fungi causing the most disease. **Prevention** is the only way to treat diseases of bacteria and viruses, but there are some control methods for fungal diseases. Identification, knowledge of the life cycle and determining the best course of action are necessary for disease control.

Like insect pests, disease control starts with identification. Tissue samples or photos of the diseased plants can be sent to the extension office where a specialist can diagnose the disease. Once this is known, organic disease controls can be administered.

In the case of a **bacterial or viral disease**, there is nothing that will slow down or stop the disease. In these cases, **prevention** is the only form of control. With the example of tobacco mosaic virus, this means preventing contact with anything that may carry the virus. The most common vector is tobacco products. These should be kept away from plants and growing areas. In addition, anyone using tobacco

products should wash their hands thoroughly before working with plants.

The most common ***vector*** for bacterial wilt is the **striped and spotted cucumber beetle**. The bacteria that cause this disease cannot survive in dry plant material for more than a few weeks so affected plants are not a problem. The bacteria live through the winter in the gut of the adult beetles and plants are infected when these feed on the plants. Preventing beetles from feeding on crops is the only known prevention.

Fungal disease is the most common and, fortunately, the most treatable. There are many different fungal diseases and they attack plants in different ways. The most obvious one is commonly called **powdery mildew**. This appears as a white to gray-looking powder on the leaves of plants. Powdery mildew can grow on a large variety of plants, from squash to trees, and can over-winter on these and other weeds.

Some fungi that attack plants live in the soil and grow into the roots of weak plants. An example of this is ***fusarium***. *Fusarium* will flourish in a soil where the biodiversity has been lessened through poor management or fumigation. *Fusarium* is controlled through biodiversity in the soil. An important part of control is reduction of tillage to promote the growth of beneficial fungi that control this and other disease-causing fungi.

Weed Control

"A Weed is… Any plant that interferes with human welfare or activity, or is otherwise objectionable. Plants Out Of Place (P.O.O.P Rule)" - *Ted Radovich*

Farmers have developed many different approaches to managing weeds, using everything from chemical herbicides to hand picking weeds to cultivating with tractors. Each approach has its tradeoffs in terms of effectiveness and associated economic, environmental and human health related costs. Increasingly, the public is seeking food that is grown without synthetic pesticides, including herbicides used to control weeds, out of concerns about personal health and the effects of pesticides on the environment and farm workers.

To lessen the negative impacts of weeds and weed management practices, farmers need to know the effectiveness and consequences of different weed control approaches in different situations. This requires understanding the biology of weeds in relation to crops and farming systems.

Classification of Weeds

- **Broadleaf**
    - Many of Hawaii's annual weeds that have growing points high above the ground. Their succulent growth leaves them more tender and vulnerable than grasses.
- **Legumes**
    - Annual or perennial broadleaf plants that fix N gas from the air, and are more tolerant to poor soil conditions.
- **Grasses/Sedges**
    - Often strong perennials with growing points close to or below the ground. They are notorious for having tough foliage with high silica content.

Negative aspects of weeds:

- Direct competition with crop
- Hosts to crop pathogens, nematodes
- Clog irrigation water
- Contaminate crop with seeds/parts
- Reduce access to field or pasture
- Poison livestock
- Competition for light
- Rapid expansion of tall foliar canopy
- Climbing habit
- Superior reproductive ability
- Germinates under wide range of conditions
- Rapidly reaches reproductive stage
- Seed production is high
- **Allelopathy**
    - Harmful effects of one plant on another plant by the release of chemicals from plant parts by leaching, root exudation, volatilization, residue decomposition and other processes.

Positive benefits of weeds:

- Protect topsoil
- Conserve moisture
- Extensive root systems penetrate deep into the subsoil.
- Improve crop root growth
- Drainage

- Accumulate nutrients from the subsoil, particularly trace elements, and transport them to the soil surface.
- Nurse crop
- Food and Shelter for beneficial organisms
- Food and Medicine for people

Weed Management in no-tillage fields

No-tillage systems generally use herbicide applications instead of cultivation for weed control. A greater reliance on herbicides requires attention to detail - types of weeds, weather trends, cropping patterns, soil type - in order to control weed populations without adversely affecting the environment. The first few years of no-tillage may require higher herbicide inputs. However, many long-term growers claim once no-till is established, herbicide costs decrease substantially and become competitive with conventional systems.

Without deep tillage, weed seeds stay near the soil surface instead of being buried too deep for germination. Small-seeded broadleaf weeds and annual grasses can germinate under crop residue. Large-seeded weeds need deeper soil placement to germinate. With continued no-tillage, large-seeded weed populations tend to decline.

Early pre-plant

For the best results apply early pre-plant herbicide treatments before germination of summer annual weeds. The timing of these treatments range from ten to 45 days prior to planting of the crop Applying herbicides early in the season, when rains are more frequent, insures activation of the herbicides. Early application also helps spread out the spring work load. With timely herbicide applications, the fields will be free of weed at planting Early killing of weeds also discourages insects attracted to weedy fields, such as black cutworm moths. Two types of pre-emergence herbicide programs are common in no-tillage:

- full season program - where herbicides control weeds throughout most of the growing season,
- short residual program - where the crop shades out later germinating weeds. Post-emergence treatments may be necessary for weed escapes.

Integrated weed management

- Prevention: **<u>Don't allow weeds to go to seed.</u>**
  - Average number of seeds in soil is 30,000-350,000 weed seeds/square meter; (120 million-1.4 billion per acre)
    - *Amaranth* 235,000

"One year of seeding, Seven years of weeding"

Critical period

- Generally vegetable crops should be kept weed free during a critical weed-free period early in development.
- Critical periods:
    - ~3-5 weeks for transplants and grains.
    - 5 weeks for direct seed veggies and veggies with small canopies or wide spacing.
    - Onions are kept weed free throughout growth.

Weed Prevention Strategies

- Don't allow weeds to go to seed.
- Clean equipment before moving from infested field.
- Buy uncontaminated crop seed from a reputable source.
- Thoroughly compost (131 F for 3 days) manure and other residues that might contain seeds. Almost no seeds survive in chicken manure.
- Filter surface water if possible.
- Apply fertilizer and irrigation directly to the crop row if possible.
- Work with your neighbors.
- Rotate weed-susceptible crops (carrots, onions, widely spaced crops) with suppressive crops such as sweet corn, pumpkin, sweet potatoes. Weed suppressive cover crops should be used in problem areas.
- Sudex, Buckwheat, Crotolaria, Cereal rye, Rape.
- Ground cover critical for weed suppression. Pay attention to cover crop pest problems and requirements. See CTAHR cover crop database:
    - http://www2.ctahr.hawaii.edu/sustainag/Database.asp
- Variety selection and spacing
    - Choose crop varieties that are well adapted to your area.
    - Plant at the best time of year for vegetative growth.
    - Choose crop varieties with vigorous canopy development.
    - Purchase high quality seed.
    - Use transplants where possible.
    - Space plants at the higher end of recommended density ranges.

- Cover Crop Allelopathy
    - Allelopathy is controversial as an effective weed suppressive strategy.
    - Most consistently demonstrated with rye and correlated with DIBOA

(2,4-dihydroxy-1,4-benzoxazin-3-one)

- Suggested strategy: seed at high density, irrigate until good cover established, drought-stress plants to increase DIBOA, kill early in development when DIBOA highest, do not incorporate residue.

Mechanical

The main thing with mechanical weed control is to kill the weeds when they are young and small, before they have a chance to get established or compete with crops. Killing the weeds while they are young also prevents them from making more seed. Setting the cultivating equipment deep enough to disturb the roots of the young weeds will kill them. However, care should be taken not to go too deep and disrupt the beneficial soil life, like the mycorrhizal fungi.

If weeds have been allowed to get larger, they can still be killed with mechanical cultivation. Tines can be set deep enough to cut the growing crown of the weeds from the roots, leaving the roots undisturbed. This will kill most common weeds.

On a smaller scale, there are hand tools that are helpful in making weeding more efficient. A wheel hoe can greatly speed up the weeding process, especially when the weeds are small. Stirrup hoes which cut off the weed at the ground level are very effective. Weeding on a hot, dry day will ensure that the weeds pulled up will die. If weeds are left in the field, and it rains, some will re-root. Sharp edged diamond hoes are effective at reaching weeds growing between plants The key to all effective methods of weed control is to destroy the weeds early before they develop extensive root systems.

- Plant very straight, uniformly spaced rows to allow for close cultivation to the plants.
- Keep cultivation shallow to minimize weed seed germination.
- Cultivate weeds early (< 1 inch ideally) at ~50% field capacity.
    - Push dirt into rows of long-stemmed plants to cover small weeds.

Flaming

Flame weeding is another method used to control weeds. The idea behind flame weeding is to kill weeds with a wave of heat, without disturbing the soil or harming the crop root system. A thin line of heat directed at the stalk will boil the water within the weed's cells. The pressure generated by this expanding water will rupture the cells, destroying a cross section of the stalk. When this happens, plant food and water cannot move from roots to leaves and the plant withers and dies. The point of flaming is not to charbroil the weeds, but heat them just enough so that they wilt.

The most effective method is to catch weeds early, from 1-4 inches. At this small

stage, flaming is nearly 100 percent effective, whereas weeds over 4 inches are more difficult to kill without an extended dose of heat. By destroying cell structure in the plant leaf, the weed will no longer put energy toward growth. So even on big weeds, there will be a stunting effect or even a kill, depending on how established the root system is and how long the plant was exposed to heat.

Flaming can be done with a small propane torch in small areas. However, for larger areas one of the weed flaming torches is an excellent tool. Flame weeders with multiple torches, or heads, are available to cover large areas.

- High temperatures burst cells (don't burn plants).
- Weeds should be small (< 3").
- Weeds should be well-watered, but with dry leaf surface.
- Flaming at night increases efficacy
- Most effective on broadleaf weeds.
- Grasses more resistant.
- Can be done before (1-2 days) and after crop emergence.
- Tolerance of crops to flaming varies with species and size
- Recommended rate = 18-27 pounds propane per acre.
    - 1 gallon liquid propane = 4 pounds.
    - 5-7 gallons of liquid propane per acre.

Chemical Strategies

- Organic herbicides
    - Active ingredients are usually essential oils and/or acids. The most common:
        - Clove oil
        - Acetic acid
        - Citric acid
    - These are contact herbicides, effective only on small weeds, and more effective on broadleaves than grasses.
    - Corn gluten meal is also used

Stale seed bed technique –

One other method of controlling weeds is to use a stale bed. To create a stale bed an area is tilled and allowed to sit undisturbed until the weeds have germinated. It is then lightly cultivated to kill the weeds with as little disturbance of the soil as possible. Depending on the weed seed load in the soil, the plot can be either planted immediately or allowed to go through another cycle of germination and cultivation before planting. This technique is used to exhaust the active seed bank in the first several inches of soil.

- The area is tilled, fertilized and irrigated to promote weed germination.
- Young weeds are killed mechanically.
- Weeds are allowed to flush again and killed.
- Seeds or transplants are placed in the field with minimal or no tillage.

Mulch

- Plastic and organic mulches may be used.
- With organic mulches, light exclusion and persistence is most important.
- In general, grasses persist the longest, legumes the shortest.
- Living mulches, if controlled properly, can increase soil moisture and bioactivity, reduce pest pressure and weed competition.
- Black plastic mulch extremely effective, and warms soil.
- **Solarization** to kill weed propagules with clear mulch is tricky:
    - Smooth bed
    - Film must be against soil
    - Air temperatures > 90 F
    - Plastic left for 4-6 weeks
    - Do not till more than 3 inches afterward
    - Solarization is most effective when combined with other strategies.
- Other mulch colors may improve crop photosynthesis (Red) or disorient pests (Silver)
- Weed control in an organic system is mostly limited to mechanical means. This can be done using implements such as cultivating tines or harrows with a tractor. Alternatively, a hoe can be used for handwork.

Companion Planting

Growing different plants together is called companion planting. It can be done to increase food production from a given area of land. This practice seems to protect the plants from some soil-borne diseases and pests. Antagonism and competition between the plants must be considered when deciding on companion planting.

Companion planting is the method of growing two or more crops in the same row or bed. This area has not been the subject of very much scientific research. Most of our knowledge about companion planting comes from trial and error over many years and from different parts of the world. Lists of crops that can be grown together can be found in a number of sources. Some of these lists also contain information about antagonists, allelopathic properties of some plants, or crops which do poorly when planted together.

Cite:

UC IPM Online
http://www.ipm.ucdavis.edu/NATURAL/index.html

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The Market Gardener

Market Farming Success

Gardening at Dragon's Gate

Jari Sugano's WES Top Ten Pests

Visit: http://www.ctahr.hawaii.edu/UHMG/pests-disease.asp AND
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Reading: 134-140, 148-154 from Sustainable Market Farming AND
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Web Resources:

Insects of Hawai'i
http://www.starrenvironmental.com/images/?o=insects

USDA Forest Service and the Bugwood Network
www.insectimages.org
More than 5,400 high-quality insect and insect damage photographs available in digital format.
Entries are classified by subject, common name, scientific name, life stage, and host. From the easily navigated web site one can quickly click to the desired target. Available for downloading and use for educational applications with no royalties or fees required, as long as appropriate credit is given to the source

CTAHR COVER CROP DATABASE
http://www2.ctahr.hawaii.edu/sustainag/Database.asp

MANAGING COVER CROPS PROFITABLY (book)
www.sare.org/publications/covercrops/covercrops.pdf

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http://www2.hawaii.edu/~leary/a.htm

WEED BIOCONTROL IN HAWAII & WEEDS AS RESOURCES
http://www2.hawaii.edu/~theodore/Links.htm
Weed Control in No-Tillage Systems
https://www.extension.purdue.edu/extmedia/CT/CT-2.pdf
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Managing Cover Crops Profitably
www.sare.org/publications/covercrops/covercrops.pdf

Principles of non-chemical pest management
http://www.oisat.org/principles.html

Suppliers

Koolau Seed and Supply, Inc., 48-373G Kamehameha. Hwy, Kaneohe, HI 96744, 808-239-1280. *Cover crop seeds.*

United Agri Products (UAP) 96-1345 Waihona St. 808-454-0041
Various products

BEI 311 Pacific Street, Honolulu, HI 96817, 808.532.7400. *Various*.
Airgas/Gaspro Airgas Gaspro 2305 Kamehameha Hwy., Honolulu, HI

96819, (808) 842-2222.

Peaceful Valley Farm Supply, P.O. Box 2209, 125 Clydesdale Court, Grass Valley, CA 95945, (530) 272-4769. http://www.groworganic.com

Flame Engineering, Inc., P.O. Box 577, LaCrosse, Kansas 67548, 1-888-388-6724, http://www.flameengineering.com