Chapter 7

Insect Pest Management

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This chapter is divided into three main sections. The first section is an overview of insect pest management and discusses a systems approach to it. What can be done on a farm-wide or long term scale to reduce insect pest problems on the farm. The second part examines more immediate pest control remedies that have been used over the years to reduce pests. These include physical, cultural, biological and chemical controls, how they work and are implemented as well as examples of each. The third section is a series of tables which act as a summary of the first two sections examining how to reduce certain pests in a particular crop. These management tools have either been tested by the author, reviewers or are in the literature as having a good possibly of reducing the pest in question. Controls that are not included are home remedies or home mixtures, i.e., two parts salad oil, 3 tablespoons of liquid soap, 6- ground up cayenne peppers, etc. The author as well as other biocontrol workers has tried many of these remedies and none have reduced pests compared with the control. There are, however, some remedies that growers have developed on their own farms that seem to work for them in their particular farming system. Unfortunately, when trialed on other farms the management tactic does not always work because the conditions are not similar enough or for unknown reasons. It is difficult therefore, to recommend these grower options, not because they don't work but because we do not understand how they do work. However, a few of the more reliable grower developed alternatives **(GDA)** are included.

Table 1 is set up so that within each management category the best possible method(s) are presented with the understanding that in some cases the management tactic listed will not always give good, consistent results (the level of "control" is given for each management tactic for each pest). As an example under Colorado potato beetle: Physical control: kaolin clay. Kaolin clay has been shown to work under certain circumstances but is not reliable or consistent, nevertheless, it is listed because it has been shown to be the best physical control available and that it may work in your farm management program to reduce CPB as it has in a few other situations. Another example is: flea beetle: biological control: none. This does not mean there are no predators or parasitoids of the flea beetle, but that biocontrol has little chance of reducing a pest population by itself once the population reaches pest status. Some management tactics listed may involve a great deal of work and or management on the part of the grower and give anywhere from poor to good results. It is listed to give the grower as many legitimate options as possible, even though it may mean a great deal of time and management, only the grower can decide if it is worth their time to implement the management practice. In the table the general management tool is stated, i.e., "crop rotation".

A Systems Approach to Pest Management

One of the main strategies for pest control in organic production systems is the ecological pest management approach that treats the whole farm as a complex system. Ecological pest management's strategy is to manage the whole farm to keep pests at acceptable populations using many integrated approaches. Integrating natural strategies into farming systems, manages pests in a way that is healthier for the environment and eliminates many of the problems associated with agrichemical use. Part of this technique includes understanding the life cycle of pests and their natural enemies, which allows the grower to better manipulate the system to enhance the built-in defenses available through nature.

Biological control is the use of natural enemies or beneficial insects, to reduce or delay pest outbreaks. The goal of ecological pest management is to increase biological control and hold a target pest below economically damaging levels – not to eliminate it completely – since decimating the population also removes a critical food resource for the natural enemies that depend on it. Increasing plant and animal diversity supports the abundance and effectiveness of natural enemies.

Increasing Natural enemies

Beneficial organisms such as predators and parasites are found more frequently on diverse farms where no pesticides are used, than in monocultures or in fields routinely treated with pesticides. Farm systems that typically include more beneficial organisms have: fields that are small and surrounded by natural vegetation, cropping systems that are diverse with plant populations in and around fields with many perennials and flowering plants, crops that are managed organically or with minimal agrichemicals, soils that are high in organic matter and biological activity and – during the off-season – fields covered with mulch or vegetation. Just the use of straw mulch provides humid, sheltered sites for nocturnal predators like spiders and ground beetles. A diversity of plants provides many adult predators and parasites with pollen and nectar which they need to have energy to search for hosts (pests). Predaceous ground beetles do not disperse far from their overwintering sites; access to permanent habitat near or within the field means they will be present to feed on early-season pest populations. You can enhance these populations of natural enemies by providing resources to attract and keep them on your farm.

Flowering plants such as buckwheat can be grown in field margins to increase populations of syrphid flies and reduce aphid populations in adjacent vegetable crops. This method is most effective for pests of intermediate mobility. You can provide natural enemies with habitats by sowing diverse flowering plants into strips every 200 to 400 feet across the field. Beneficials can use these corridors to circulate and disperse into field centers. This practice increases the diversity and abundance of natural enemies. Strips of buckwheat and tansy leaf in cabbage increases populations of small parasitic wasps that attack the cabbage aphid.

The size and shape of the blossoms on plants have a bearing on which insects will have access to the flowers' pollen and nectar. For most beneficials, including parasitic wasps, the most helpful blossoms are small and relatively open. Plants from the aster, carrot and buckwheat families are especially useful (Table 1). Timing of flowers is important to natural enemies, as they need pollen and nectar during active times, especially in the early season when prey is scarce. One of the easiest ways to supply nectar and pollen sources is to provide mixtures of plants with relatively long, overlapping bloom times. Examples of flowering plant mixes might include species from the daisy or sunflower family (Compositae) and from the carrot family (Umbelliferae).

Table 1. Flowering Plants That Attract Natural Enemies

COMMON NAME	COMMON NAME
*Umbelliferae (*Carrot family)	Legumes
Caraway	Alfalfa
Coriander (cilantro)	Big Flower vetch
Dill	Fava bean
Fennel	Hairy vetch
Queen Anne's lace (wild carrot)	Sweet clover
Wild parsnip	Crimson clover
*Compositae (*Aster family)	
Blanketflower	Brassicaceae (Mustard Family)
Coneflower	Hoary alyssum
Coreopsis	Sweet alyssum
Cosmos	Yellow rocket
Goldenrod	Wild mustard
Sunflower	
Yarrow	Other species
	Buckwheat
	Cinquefoil

General Pest Management Tactics

CULTURAL CONTROLS involve the adjustment of standard farm practices to avoid pests or to make the environment less favorable for them. There are several types of cultural controls; the following are a few examples of commonly used methods. **Crop rotation** replaces a crop that is susceptible to a particular pest with another crop that is not susceptible, on a rotating basis. For example, Colorado potato beetle can be starved out by following potato or tomato with a legume crop such as soybeans or clover, or by using corn. **Sanitation** refers to keeping the area clean of plants or materials that may harbor pests. Examples include removal of weeds that may harbor mites, aphids, or whiteflies; destruction of crop residues such as squash vines that allow late season pests such as squash vine borer or squash bugs to mature and overwinter;

cleaning of farm equipment that can spread pests (nematodes) from field to field. Fall tillage exposes overwintering pests such as squash vine borers to predation and winter weather. Be sure to use only clean seed or transplants in your field. Sometimes pests can be introduced by infested or infected transplants from southern production areas. **Companion planting** is planting an additional crop to attract natural enemies or makes it difficult for pests to find their more favored host crop. An example of this would be planting buckwheat in between rows of vegetables to increase natural enemies such as parasitoids, Orius, lacewings, or lady bugs**.**

Trap cropping is the planting of the pest's preferred vegetable variety before or during the presence of the main crop; the insects are attracted to the trap crop which is then destroyed. For example, potato can be planted before tomato to attract Colorado potato beetle to the potato trap crop. Another version of this is the **Perimeter Trap Crop,** which concentrates pests in the border area of the field. This technique involves planting usually one but sometimes more rows of an attractive plant species so that it encircles the less attractive main crop, and intercepts a migrating insect population. Examples of this are: reducing diamondback moth larvae on cabbage, using collards as the trap crop; pepper maggots on bell peppers or eggplant, using hot cherry peppers as the trap crop; and cucumber beetles on summer squash, winter squash, cucumbers, melons, and sometimes pumpkins, using Blue Hubbard or Buttercup squash as the trap crop. While this technique has shown some success, it does require extra land and another crop must be grown, planted and cared for so that it is attractive to the pest (if the perimeter trap crop is in poor condition it will not attract the pest). Another consideration is that once the pest builds on the trap crop it has to be eliminated in some way so that it does not simply migrate to the main crop. In organic systems this usually means the rapid destruction of the trap crop. It is difficult to destroy the trap crop without causing the pest to move into the main crop. For certain highly mobile pests such as cucumber beetles or squash bugs trap cropping has had limited success, but works better for less mobile pests such as aphids or Colorado potato beetle. For Mexican bean beetle (MBB) control one **grower developed alternative (GDA)** uses the parasitic wasp *Pediobius foveolatus* and a trap crop. Plant the trap crop of beans as early as possible (weeks before and in a different area than the regular planting of beans). Once MBBs start to increase on the trap crop of beans *Pediobius sp* should be released. The wasp parasitizes the larvae. Two problems with this method is that the wasp needs to be released each year and it is expensive (~$1.30/wasp and $\geq$100 are needed to make it work). The timing of release is critical—too few MBB and the wasp dies out or leaves the area, too many MBB and the trap crop is destroyed.

Timing of plantings can reduce certain pests by making the crop unavailable to the pest. Seedcorn maggots can be avoided in vulnerable crops by planting the crop only after the soil temperature reaches 65^{o} F at a 4-inch soil depth. Heating of the soil can be sped up by using black plastic mulch or sped up even further using clear plastic mulch (weeds will be a problem though under the clear mulch). For cabbage maggots the adults emerge and become active about the same time as Forsythia and yellow rocket bloom and the transplanting of brassicas should not be done at this time. However, fall root crops such as turnip and rutabaga can be damaged by later generations of the

cabbage maggot, which are active in late August and early September when soils are cooling down, so planting when soils are warmer will decrease maggot damage. **Choice of cultivar** used can be important at times and if marketing considerations are not important (and usually they are) certain varieties can be used that are less susceptible to a pest. An example is using different cucurbit or squash types that are less attractive to cucumber beetles. These varieties are in the order of most attractive to least for cucurbits: bitter gourd> Blue Hubbard squash> winter squash> cucumbers> summer squash> cantaloupe> pumpkin> honeydew> Butternut squash> watermelon; for different squash cultivars: Slender Gold> Seneca Prolific> Sunbar> Yellow Crookneck> Scallop> Table Ace> Carnival> Table King. For squash bug the most susceptible cucurbit types are: Summer squash (zucchini and crookneck) = Hubbard squash= pumpkin> marrow squash.

Cover crops can be used to attract natural enemies, such as predators like lady bugs, lacewings, big eyed bugs, etc. as well as parasitoids (see biocontrol section) but usually are selected based on agronomic reasons. It may be better to avoid certain cover crops such as wheat in areas where onion thrips are a problem, because thrips overwinter well in wheat. Oats would be a better cover crop in this case. Crimson clover can harbor large populations of Lygus bugs and would not be a good cover crop for strawberry.

Mulch can come in different forms or colors. **Reflective mulch** can be used to reduce aphid and possibly leaf hopper populations which reduces virus transmission in squash, cantaloupe and leaf crops to gain an additional 2-4 weeks of a virus free period. Different colors of plastic mulch have not been consistently shown to reduce pest problems, and therefore cannot be the sole reason to use it, i.e., there are horticultural reasons. **Straw mulch** laid between rows of plastic or used around plants to reduce weed growth can attract natural enemies. In potato, straw mulch attracts greater populations of ground beetles that climb potato plants during the night and consume Colorado potato beetle eggs and larvae. However, in cucurbits straw mulch around plants can at times increase squash bug problems.

PHYSICAL CONTROLS are methods that physically keep insect pests from reaching their hosts. Barriers include floating **row covers** such as Reemay® and Agriforce® for many vegetable crops, and plant collars to keep cutworms from attacking plants such as tomatoes. Row covers are good for early season pests as it is difficult to effectively cover a large plant later in the season. Using row covers to protect cucurbits early in the year from cucumber beetles is an effective method of control. As well as using row covers on eggplant to protect this crop from early season flea beetle populations. Row covers can be used to cover bulb crops like onions and protect them from onion and seedcorn maggot infestations. Once these covered crops are larger, the row cover can come off as the plants are much less susceptible to the pests (plus the cucurbits need to be pollinated). Another physical control is **Kaolin clay** (Surround WP®), which is naturally occurring clay. Kaolin clay is ground and processed to reach a uniform particle size for application as a plant protectant. Applied as a suspension in water, Surround

produces a dry white film layer on the surface of leaves, stems and fruit after evaporation of the water. It acts as a physical barrier preventing insects from reaching the plant. It also acts as a repellent by creating an unsuitable surface for feeding or egg-laying. The dried clay particles can act as an irritant to the insect and can trigger an excessive grooming response. These responses take place for both pest and natural enemy. While there are other physical methods of removing pests such as vacuuming, squashing them, trapping them, none are very effective and are usually too time consuming or expensive on a large scale to be recommended. **Rain** or over-head irrigation can reduce thrips, aphid, Diamondback moth, mite, etc. populations in vegetables. Frequent watering needs to occur (3-4 times/week) and the watering needs to be heavy enough to soak the ground around vegetable plants to be effective.

Insect Identification

Growers should become familiar with the biology and life-cycle of the major insect pests that attack their crops. Understanding some basic insect biology often reveals when the pest is most vulnerable to control measures and helps lead to successful management. Growers should recognize not just the destructive life-stages of major insect pests, but also the crop injury or damage they produce and the other life stages of the pest as well to help determine when control efforts are needed. Beneficial insects and their immature stages should also be recognized to avoid accidentally targeting natural enemies for control. An accurate diagnosis of a problem can often avoid years of frustration and needless expense. See the photo supplement section for help with identification of pests and natural enemies.

Scouting and Monitoring

Crops should be scouted for insects or damage on a regular basis throughout the growing season. For many crops and pests, this may mean walking fields weekly, or even more frequently, especially during critical or vulnerable plant developmental stages. Scouting crops always saves money in the long run by allowing for early pest detection, reducing crop damage and helping to maintain consistent quality. Monitoring insect populations with various types of traps (black light, pheromone, sticky, baited) can sometimes substitute for information gathered during crop scouting. Insect traps can help quantify pest pressure that is difficult to see, such as the number of night flying (i.e., corn earworm) moths present. The number of insects captured in traps is often used to time scouting activities, predict future pest levels, or is used in conjunction with action thresholds to time controls and help avoid crop damage.

Plant resistance has been used for decades to reduce pest problems. Some plants have physical and chemical variations that allow them to repel or tolerate pests. An example of this would be sweet corn varieties that have long, tight silk tubes which make it more difficult for worms or sap beetles to reach the ear. Another example is squash or pumpkin varieties that have resistance to certain viruses.

Natural Enemies

Predators

Lady beetles (Coccinelids)
A shiny, convex, half-dome shape and short, clubbed antennae. Most lady beetles are predaceous as both larvae and adults. Young lady beetle larvae usually pierce and suck the contents from their prey. Older larvae and adults chew and consume their prey. Larvae are active, elongate, have long legs, and resemble alligators. Eggs are oblong, yellow/orange, are about 1/25 inch in length and are laid on end in groups on leaves and stems near aphids. Pupation occurs on stems or other substrates-sometimes at the tip of a plant. There are 2-4 generations a year. Both adults and larvae feed primarily on aphids and occasionally on whiteflies and other soft-bodied insects and their eggs. It is NOT RECOMMENDED that lady beetles be purchased for release. Their tendency to rapidly disperse makes it difficult for them to be used in biological control programs in fields.

Green lacewings (*Chrysoperla carnea*-common green lacewing)
Generalist predators and are commonly found. Adult green lacewings are soft-bodied insects with four membranous wings, golden eyes, and green bodies. Adults often fly at night and are seen near lights. Most adult green lacewings are not predaceous, instead feeding on honeydew, nectar, and pollen. Females lay their tiny, oblong eggs on silken stalks attached to plant tissues. Depending on the species, eggs are laid singly or in clusters, each on an individual stalk. Eggs are green when laid, then darken before hatching. Larvae are white-cream colored with dark markings. Larvae are flattened, tapered at the tail, and are 5/8 to 4/5 of an inch when full grown larva. All larvae are predacious and have prominent mandibles which they attack their prey. Larvae prey upon a wide variety of small insects including thrips, mites, whiteflies, aphids, small caterpillars, leafhoppers, and insect eggs. Pupation occurs in loosely woven, spherical, silken cocoons attached to plants or under loose bark. All stages of lacewings can survive mild winters. Adult **brown lacewings** are not as common as green, but do look similar and are about half their size. Females lay eggs singly on their side onto plant tissues—not on hair-like stalks. Brown lacewing eggs look similar to syrphid fly eggs but are smoother and have a small protrusion on one end. Brown lacewing larvae look similar to green, but appear thinner. They feed on similar prey.

***Orius* spp** or minute pirate bugs
Small, 1/12 to 1/5 inch long, oval, black with white markings, and have a triangular head. Adults can be confused with plant bugs in the family Miridae, which are generally larger, have longer antennae, and only have one or two closed cells in the tip of their forewings. *Orius* spp undergo incomplete metamorphosis, and nymphs are usually pear-shaped and yellowish/orange with red eyes. Eggs are inserted into plant tissues. It takes three weeks from egg to adult. They are generalist predators and both adults and nymphs feed on insect eggs and small insects such as thrips, mites, aphids, whiteflies, and small caterpillars.

***Phytoseiulus* spp**.
Mites and do not have antennae, segmented bodies, or wings. They have an egg and immature nymphal stages before becoming adults. They are about the size of two spotted spider mites, but lack spots, are orange in color, and are shinier and more pear-shaped than their prey. A good rule-of-thumb is that any small, orange-red mite-like figure on a leaf that moves rapidly is probably a predatory mite. This predatory mite feeds exclusively on spider mites and consumes two or three adult females or several dozen eggs/day. It tolerates hot climates as long as the relative humidity is between 60 and 90 percent.

Ground beetles (Carabidae)
Medium to large soil-dwelling beetles, often about 1/3 to 2/3 inch long. Their shape and color varies greatly. Adults are often black or dark reddish, although some species are iridescent. Most species have a prominent thorax that is narrower than their abdomen. They have long legs, are fast runners, and rarely fly. Carabid adults and larvae feed on soil dwelling insect larvae and pupae, other invertebrates such as snails and slugs, and sometimes on seeds and organic litter. Larvae live in litter or in soil. Larvae are elongate and their heads are relatively large with distinct mandibles. Life cycle from egg to adult is in one year.

Syrphid flies (Syrphidea)
Regularly found where aphids are present. Adults hover around flowers, have black and yellow bands on their abdomen and resemble bees. Females lay oblong eggs, singly on their sides usually near aphids or within aphid colonies. Larvae are legless and maggot-shaped and vary in color and patterning, but most have a yellow/green longitudinal stripe on their back. Larvae are 1/32 to 1/2 inch long depending on species. Adult syrphid flies feed on pollen and nectar while the larval stage feeds on aphids and other soft-bodied insects and play an important role in suppressing populations of phytophagous insects. Larvae move along plant surfaces, lifting their heads to grope for prey, seizing them and sucking them dry and discarding the skins. A single syrphid larva can consume hundreds of aphids in a month. Not all syrphid fly larvae are predaceous, some species feed on fungi.

The **Aphid midge,** *Aphidoletes aphidimyza*
A delicate fly (resembling fungus gnats) with long, slender legs. They often stand with their antennae curled back over their heads. Larvae have two projecting anal spiracles (small tubes) relatively close together at their rear ends. Larvae develop through three instars, are pale yellow-reddish brown, and are about 1/10 inch long. The immatures feed like syrphid fly larvae on aphids, mites and other soft-bodies insects. Aphid midge adults are very good at finding low infestations of aphids in enclosed structures such as greenhouses or high tunnels, but are less effective in the field.

Soldier beetles, Cantharidae family
Long and narrow and are often about 1/2 inch long with a red, orange or yellow head and abdomen and black, gray or brown soft wing covers. Adults are often observed feeding on aphids or on pollen or nectar on flowering shrubs and trees. Larvae are dark,

elongate, and flattened. They feed under bark or in soil or litter, primarily on insect eggs, caterpillars and other insects. They are often mistaken for lightening bug adults, but lack the large pronotum found on lightening bugs.

Bigeyed bug *Geocoris spp*
Adults and nymphs are oval, 1/6 of an inch long, usually yellow/brown, and have a wide head with bulging eyes. Bigeyed bugs can be confused with other Hemipterans in the same family (Lygaeidae) as well as insects in the Miridae family. Other Lygaeids are more slender and have smaller eyes when compared to *Geocoris* spp. Bugs in the Miridae family do not have their eyes spaced widely apart and generally have longer antennae. Females lay oblong, white eggs singly on leaf surfaces which develop reddish eyespots shortly after being laid. Bigeyed bugs are common on low-growing plants including many field and row crops in which they stalk their prey. Their widely separated eyes give them an extensive field of vision for spotting their prey which includes insect eggs, other bugs, small caterpillars, flea beetles, and mites.

Grower developed alternative Predators: In asparagus to control asparagus beetle on ferns, chickens or turkeys are used in the field. Not only do they reduce beetle numbers and damage, but also supply some weed control and manure for the ferns.

Parasitoids

Most parasitoids, with the exception of Tachinids, are very tiny and almost impossible to identify for the average grower. Instead what should be looked for are the results of the host pest being parasitized. Aphids become brown and bloated, most other hosts become blackened or dark in color when parasitized.

Aphidius spp (aphid parasites)
Adults are small wasps, typically less than 1/8 inch long. During their larval stage, most feed within the body of an aphid, completing metamorphosis within the host. The female wasp lays an egg inside an aphid, the egg hatches and the larva eats the aphid from the inside. As the larva matures the aphid is killed and becomes slightly puffy or mummified, usually turning tan. The adult parasite chews its way out of the mummy leaving a hole. The genus *Aphidius* contains many species that provide biological control of aphids in vegetable crops.

The family **Tachinidae** is the most important family of parasitic flies in vegetable cropping systems. Tachinid larvae are internal parasites of caterpillars, stink bugs and other true bugs. Adults resemble stout houseflies (except squash bug Tachinids-see below), but with very heavy bristles at the tips of their abdomens. Egg laying habits vary. In some species, eggs are deposited on foliage near the host insect, and the maggots are ingested during feeding by the host after they hatch. Most commonly the adult fly glues eggs to the body of the host, and the maggots penetrate into the host's body after the eggs hatch-while the attached egg stays intact on the host’s cuticle. Tachinid maggots feed internally in their hosts and exit the host body to pupate. Pupae are commonly oblong and yellow to brown. Tachinid flies complete one to several

generations per year. One common Tachinid in Maryland cucurbit fields is ***Trichopoda pennipes***, a parasite of squash bugs. The female lays its oval white eggs singly or in groups on the sides or undersides of large nymphs or adults (an egg looks like a grain of rice stuck to the insect) of the southern green stinkbug and the squash bug. The larvae burrow into the bug's body where one larva will survive. The host dies after the maggot leaves the body. If larger nymphs are attacked they will not be able to reproduce when and if they become adults.

Voria rurali*s*
Attacks various species of cutworms and armyworms. Adult females lay one or several eggs into the host larva which quickly hatch and the maggot consumes the caterpillar internally.

Cotesia medicaginis
Adult wasps are black and shiny with long antennae roughly 0.12 inch long. The female lays an egg in very small caterpillars. The shiny white wasp larva feeds within the caterpillar, killing it, and emerging to pupate in a cottony white cocoon. A caterpillar parasitized by *C. medicaginis* may be recognized by being lighter than normal in color, somewhat shiny rather than velvety on the surface, and swollen toward the rear. Conspicuous evidence of *Cotesia* species is the white or yellowish cocoon.

Encarsia formosa
An important parasite of whiteflies. Females are tiny wasps (<1 mm in length) with a dark brown to black head and thorax and a bright yellow abdomen. Males are rare. Adult females “host feed” on all immature pest stages by puncturing the body with their ovipositors and consuming the exuding blood. Eggs are laid into third and fourth-instar whiteflies and hatch into larvae that feed within the whitefly nymph and grow through three larval instars before killing the host. Greenhouse whitefly nymphs turn dark brown or black (silverleaf white flies stay white) one week after being parasitized.

***Trichogramma* spp**.
Adult wasps lay their eggs within a recently laid host egg, and as the wasp larva develops, it eats the host embryo, causing the egg to turn black. Because their life cycle from egg to adult is about 7 to 10 days, these parasites have many more generations than their hosts, and their populations can increase rapidly. Because *Trichogramma* turns the eggs of caterpillar species black it is the best way to detect parasitization by this parasitoid. This wasp parasitizes tomato fruitworm eggs as well as many other caterpillar pest species.

Important Insect Pests of Vegetables

Cabbage looper *Trichoplusia ni*

This pest feeds on the underside of leaves of cabbage, lettuce, spinach, beets, peas, and tomatoes. It chews irregular holes through leaves. Moths lay greenish-white eggs on the upper surface of leaves. Larvae are pale green with four thin, white lines along

the back and a wide, pale line on each side of the body. Larvae move in a looping motion. When disturbed, loopers rear upwards. Larvae go into a resting or pupal stage in a flimsy, lace-like cocoon on the plant. Adults are brown moths with silver markings on the wings. Cabbage loopers do not overwinter in Maryland, but fly up from the south each year.

Imported cabbage worm *Pieris rapae*

The velvety-green caterpillar has a faint yellow stripe down its back and a row of faint yellow spots on each side. It feeds on the leaves of cabbage, cauliflower, broccoli, Brussels sprouts, turnips, radishes, kale, lettuce and weeds of the mustard family. Caterpillars chew irregular holes in the leaves and usually eat their way into cabbage heads from the bottom. Their fecal pellets often stain cauliflower heads. The adults are “cabbage white” butterflies and have black-tipped front wings with one black dot on each hind wing. The females fly during daylight hours and lay yellowish, elongated eggs, singly, on their tips on the underside of leaves.

Diamondback Moth *Plutella xylostella*

Larvae remain quite small throughout their lives. When disturbed, they often wriggle violently, move backward, and spin down from the plant on a strand of silk. They are colorless in the first instar, but later are green. Larvae feed only on cruciferous plants, i.e., broccoli, Brussels sprouts, cabbage, Chinese cabbage, cauliflower, collard, kale, kohlrabi, mustard, radish, turnip, and watercress. Collards are usually preferred by moths compared with cabbage. First instars act as leaf miners, then emerge from their mines after the first instar and thereafter feed on the lower surface of the leaf. Eggs are yellow or pale green and are oval and flattened and hatch in 4-7 days. The adult can overwinter in Maryland, but also move up from the southern states in the spring.

European corn borer *Ostrinia nubilalis*

Feed on leaves until about half-grown, when they bore into a plant's stem or fruit. On beans, small larvae feed on leaves, flowers and buds for 4-6 days at 70^{o}F before boring into bean pods. Larvae attack many species of plants, but corn, peppers, and potatoes are severely damaged. The caterpillar is cream colored, has a brown head, and is marked with small, round, brown spots. It overwinters as a nearly full-grown larva in cornstalks. Eggs are laid in groups of up to 50 on the underside of leaves and overlap to resemble small fish scales. There are 2-3 generations a year.

Beet Armyworm *Spodoptera exigua*

A general feeder and attacks foliage, stems of a wide variety of vegetables, i.e., beets, asparagus, corn, lettuce, cabbage, tomatoes, peppers, potatoes, onions, and peas. Larvae have a dark spot on each side of the thorax. The beet armyworm overwinters as a pupa, emerging in the spring as an adult. Females can lay 500-600 eggs over a seven-day period. Egg masses are covered with scales. There are several generations a year.

Tomato fruitworm *Helicoverpa zea* or corn earworm
Can attack almost any vegetable such as peppers, eggplant, beans, okra, lettuce, and cabbage, but does the most damage to corn and tomatoes. Fresh corn silk is preferred but if unavailable their next preference is tomato foliage, especially when plants are flowering. Eggs may hatch in two or three days and larvae feed on fruit, leaves or silks. Larvae can attack tomatoes from the time the fruit forms until it ripens, and attack corn as long as fresh silks are present. Larvae can be many different colors, i.e., brown, green, or pink. The head is yellow, and the underside of the body is always lighter than the back.

Cutworms (various species)
Attack asparagus, cabbage, squash, and tomatoes. Most cutworms cut off plants at or near the soil. Cutworms usually feed at night when temperatures are at least 65^{o} F. During the day these insects hide just beneath the soil close to the site of the previous night's damage. Cutworms curl up into a tight C shape when disturbed. Most cutworm larvae are dull in color as are the adult moths. Cutworms generally overwinter in the soil in the larval or pupal stage.

Fall Armyworm *Spodoptera frugiperda*
Larvae damage corn as well as beans, potatoes, peppers, tomatoes, spinach, cabbage, and cucumbers. Larvae are very small at hatch, but are 1-1/4 inches when grown. Larvae vary in color from light tan to green or nearly black with thin, yellow stripes along their sides, and have a prominent inverted Y on the front of the head. Moths do not overwinter and must move northward each summer from the Gulf Coast. There are many generations in Maryland.

Squash vine borer *Melittia cucurbitae*
Can be very destructive to squash and pumpkin. Eggs are oviposited at the base of a plant where larvae hatch and quickly bore into the stem causing the entire plant to wilt. Larvae overwinter in the soil in the same field they developed in and molt into a pupa the next spring. Within two or three weeks after molting, it emerges as an adult. The adult squash vine borers are black and red and look like wasps, which are active during the day when they lay eggs. There are 1-2 generations of this pest each year. Wilting plants are first seen in late June or July.

Hornworms *Manduca spp*
Large (3-4 inches) green worms with eight L-shaped, white markings along each side of the body and a black or red horn at the end of the insect. They can defoliate young plants such as tomatoes, peppers, potatoes. Adult moths are in the family Sphingidea and have a wingspread of four to five inches and fly mainly at dusk. Females lay green spherical eggs individually on plants. Hornworms overwinter in Maryland and have two generations a year.

Yellow striped armyworm *Spodoptera ornithogalli*
Larvae are dark green with a yellow-orange stripe along each side and black spots on their abdominal segments. It feeds on tomato and pepper fruit. Adults are brown, black, and white moths with a 1-1/2 inch wingspread. Eggs are covered with scales and are laid in clusters on foliage.

Both the **Common asparagus beetle** (CAB) *Crioceris asparagi* adult and larvae damage asparagus plants. CAB adults overwinter in sheltered locations such as under loose tree bark or in the hollow stems of old asparagus plants. They chew holes in the plant and cause a brownish discoloration of the tissue. The beetles lay numerous dark brown, oval-shaped eggs on end in rows on the spears, ferns, or flower buds. The grubs will feed on the tender young tips and on foliage. They feed for about two weeks and then fall to the ground to pupate in the soil. About a week later, adults emerge to start another generation. The spotted asparagus beetles also feed on foliage, eating out irregular areas, but the larvae cause little damage because they feed inside the berries.

Bean leaf beetle *Cerotoma trifurcata*
Adults are red to yellow and have a dark triangular mark on the front of the wing covers, six black spots in the center of the back and a black edge around the outside of the wing covers. They feed on beans, peas, cowpeas, soybeans and corn, some clovers, and many weeds. They spend the winter as adults in trash near bean fields. Adults drop from foliage when disturbed. Bean leaf beetles feed on foliage, making round holes. Eggs are laid in the soil near the base of plants. Larvae are white and feed on the roots of bean plants. There is one generation per year.

Colorado Potato beetles *Leptinotarsa decemlineata*
The common black and yellow-striped insects that feed on potato, tomato, eggplant, and pepper. Both the adult and the black-spotted, red or orange larvae feed on foliage. Their damage can greatly reduce yield and even kill plants. Colorado potato beetles overwinter in the soil as adults. They become active in the spring and begin to feed on any Solanaceous plants. Female beetles lay 10-20 orange-yellow eggs in batches on the underside of the leaves. Eggs hatch in four to nine days and the larvae begin to feed on potato foliage. The larvae are humpbacked with two rows of black spots on each side. They usually feed in groups and damage can be severe. The larval stage lasts two to three weeks. Full grown larvae burrow in the ground to pupate. In five to ten days, the adult beetle emerges. CPB can go from egg to adult in 21 days. There are two full generation a year.

Flea beetles *Phyllotreta and Epitrix spp*
Consist of many different species that attack a variety of vegetables that include potatoes, tomatoes, eggplant and corn. Flea beetles have enlarged hind legs and jump quickly. They overwinter as adults in trash around field borders and in ditch banks. Adults are small about 1/16 to 1/18 inch long and usually black. Most species lay eggs in the soil at the base of plants. Larvae are cylindrical, white with a brown head and feed on the roots. There are three or more generations per year. Adults cause numerous small round holes "buckshot" in foliage, which can result in plant death.

Mexican bean beetle *Epilachna varivestis*
Adults are orange-brown and the shape and size of lady beetles. They emerge from under brush or leaves, as soon as warm weather arrives. They have eight black spots arranged in three longitudinal rows on each wing cover. Larvae are light yellow and covered with stout branched spines, arranged in six longitudinal rows**.** Bean (snapbean, lima beans, and soybeans) is the preferred host, as well as beggarweed. The MBB can survive on cowpea, black-eyed pea, velvet bean, alfalfa, and clover. Adult and larval stages will feed on the foliage, flowers and pods of beans. Eggs are yellow-orange and are typically found in clusters of 40 to 75 on the undersides of bean leaves. There is one generation per season.

Striped cucumber beetles *Acalymma vittatum*
Yellow with three wide black stripes. Adults feed on leaves, stems, and fruit of cucurbits, while larvae feed on the plant's roots. Adults vector the causal agent of bacterial wilt of cucurbits and sometimes cucumber mosaic virus. Adults lay eggs at the base of plants. There are two generations per year. In addition to cucurbits, striped cucumber beetles feed on beans, peas, and corn.

Harlequin bugs *Murgantia histrionic*
Black, shield-shaped bugs with orange, red, and yellow markings. Immatures are nymphs that are similar in color to adults. Eggs are off-white barrel-shaped with two black bands; one at the top, the other near the bottom and a black spot just above the lower band. These bugs attack nearly all crucifers, as well as weeds such as wild mustard, shepherdspurse, peppergrass, bittercress, and watercress. They also can feed on squash, corn, bean, asparagus, and tomato. The harlequin bug overwinters as an adult and emerges early in spring. Adults and nymphs pierce stalks, leaves, and veins and extract plant juices. This feeding injury appears as irregular cloudy spots around the puncture wound. Young plants are likely to wilt, turn brown, and eventually die; while older plants are only stunted.

Squash bugs *Anasa tristis*
Feed almost exclusively on squash and pumpkins. Both adults and nymphs feed by sucking sap from plants. Damage usually can be detected by the occasional drooping of a leaf and a marginal yellowing of leaves that turns brown over time. Adults are about 5/8 inch long, brownish-gray, and flat across the back. This insect overwinters as an adult and mates in the spring. Reddish-brown eggs are laid on the underside of leaves oftentimes in the angle where two veins meet. Each cluster contains 15 or more eggs, which produce tiny, light gray nymphs. There is one generation each year.

Tarnished plant bugs (TPB) *Lygus lineolaris*
Feed on asparagus, potatoes, strawberries and beans. A small spot surrounded by a yellow area is typical of tarnished plant bug feeding. Blossoms also may drop from a plant as a result its feeding. Adults are flat, 1/4 inch long that are mottled brown with irregular splotches of white, yellow, and black. Eggs are usually inserted into plant

tissues. The nymphs resemble adults but are smaller and wingless. TPB overwinters as an adult and there are three to four generations per year in Maryland..

Aphids (many different species, most common species for Maryland include: green peach-*Myzus persicae*; melon-*Aphis gossypii*; and potato- *Macrosiphum euphorbia*) Feed by sucking juices from plants and feed on most vegetables. Some aphid species transmit viruses that cause diseases (watermelon mosaic virus, zucchini yellow mosaic virus, etc). However, out of a possible 50 species of aphids that can be found in pumpkin fields, only four have been shown to carry and effectively transmit the mosaic viruses. The melon and green peach aphids are strong vectors while the potato and bean (*Aphis fabae*) aphids were fairly poor vectors. Adults are soft-bodied, tear-shaped, and usually do not have wings. Two cornicles, or "exhaust pipes," extend from the hind end of most aphids. Aphids may be green, pink, yellow, or black. Immatures or nymphs resemble adults but are smaller. In the summer aphid females give live birth to clones of themselves (there are no male aphids in the summer). Within 10-14 days these female clones are giving live birth to clones. This is why aphid populations can increase very quickly. As aphids feed they defecate much of the sugary sap taken from the plant onto the leaf. This material “honey-dew” is difficult to remove if it gets onto fruit. A black sooty-mold also grows on the honey dew making any fruit that it is on unmarketable. Aphids overwinter as eggs and there are many, many generations a year.

Leafhoppers *Empoasca fabae*
Potato leaf hopper and other species feed on many leguminous plants as well as potatoes. Leafhoppers can inject toxins into plants causing a marginal necrosis on leaves known as hopperburn. Their feeding on beans causes leaves to be stunted and curled downward. Adults are pale green, wedge-shaped, and about 1/8 inch long. Eggs inserted into plant tissues produce green nymphs that resemble adults but are smaller. There are 3-4 generations per year.

Seedcorn maggot (SCM) *Delia platura* **and Cabbage maggot** *D. radicum* SCM Attacks sprouting seeds and stems of beans, peas, and cucumbers and other vegetables, while cabbage maggots prefer cabbage, cauliflower, broccoli, and related crops. Both can attack beets, radishes, and other vegetables. The most serious infestations occur in the spring during cool, wet weather and in soils high in organic matter. Adults are grayish-brown flies about 1/5 inch long. Eggs are laid in the soil close to plants. Maggots are 1/4 inch long when full grown, legless, and have chewing mouthparts at the narrow end of the body. It is as a maggot that this insect is destructive. Maggots feed on roots, either on the surface or by tunneling through them. Fleshy parts of radishes or turnips will show brown streaks where tunneling has occurred. Both maggots overwinter in soil in the pupal stage. There are three generations per year of these pests.

The **thrips pest complex** consists of several different species (*Frankliniella* spp and *Thrips* spp). The western flower thrips is usually the most destructive thrips species we have in Maryland. It is a good vector of tomato spotted wilt virus and when it feeds on vegetables causes more damage as compared with the much more common Eastern

flower thrips species. The most severe damage usually occurs in hot, dry years. Damage appears as white flecks or streaks on leaves. Adults are small slender insects about 1/20 inch long. They vary in color from yellow-orange to dark brown (you cannot distinguish thrips species based only on color). Eggs are laid into plant tissue. Nymphs look like adults but are smaller and usually lighter in color. Thrips mouthparts rasp plant tissues in order to suck the juices. Western flower thrips were thought to not overwinter in Maryland, but research by the author has shown they do overwinter in Maryland and even up into Pennsylvania. The common Eastern flower thrips overwinter as adults. There are as many as five generations a year in our area.

Two spotted spider mites *Tetranychus urticae*
Attack a very wide host range of vegetables (beans, peas, tomatoes, cucumber, eggplant, strawberries watermelon, cantaloupe, etc). As with thrips damage is worse during hot, dry periods. Adults are very small, oval and usually yellowish-white with two dark spots on either side of their body (overwintering females are usually reddish for the first few weeks). Adults lay large round eggs on the underside of foliage. The eggs hatch into young mites that resemble adults but are smaller. Adults and nymphs suck plant juices. As thrips do, mites scrape leaf material off the underside of leaves causing very small brown streaks that eventually come together turning the leaf yellow except for veins, which remain green. When an infestation is severe, fine silk webs may entangle an entire plant, and moving spider mites can easily be seen in the webbing. At this time it is almost impossible to control the mite infestation on that plant. Mites overwinter as adults and there are many generations a year.

Biopesticides

Bt products are proteins produced by *Bacillus thuringiensis* bacteria. The species *B. thuringiensis* is common in most soils. Bt has many subspecies that possess a variety of crystalline proteins with distinct insecticidal properties. Some subspecies work only on caterpillars, while others work only on beetles. It is important to match the subspecies of *Bt* with the insect type. Bt: *Bt kustaki*: caterpillars; *Bt aizawa*i: caterpillars (works better on certain hard to control species such as beet armyworm, diamondback moth and Imported cabbage worm); *Bt tenebrionis*: most effective on CPB larvae (does poorly on large larvae and adults though); *Bt israelensis:* fly larvae (including fungus gnats, blackflies, and mosquitoes). *Bt* must be ingested by a susceptible insect to be effective. Other insects that come into contact but do not ingest Bt, such as natural enemies, are not killed. When eaten by the insect, the protein becomes activated and binds to the insect gut creating a hole, which allows gut contents to enter the insect's body cavity. The insect ceases to feed and dies within a few days. Because *Bt* must be eaten by the insect to be effective thorough coverage is necessary. Early detection and application are crucial for good control because young larvae are more susceptible than older larvae to Bt. The spray may only last a few days before it is broken down by sunlight and weather. Additional ingredients such as stickers that promote adherence to leaf surfaces and UV light inhibitors that protect *Bt* from photo degradation may enhance efficacy.

Beauveria bassiana
A naturally occurring fungus that kills a pest by infection as a result of the insect coming into contact with its fungal spores. Insects vary in susceptibility to different strains. Over the years strains have been collected from different infected insects and cultured to create products for commercial use, i.e., *B. bassiana GHA* and *B. bassiana ATCC*. These products are produced through fermentation. Once the fungal spores attach to the insect's cuticle, they germinate sending out hyphae that penetrate the insect's body and grow. It takes 3-5 days for insects to die. High humidity and free water enhance activity of the fungus. Fungal spores infect and proliferate best in cool to moderate temperatures, where infected cadavers can serve as a source of spores for secondary spread of the fungus. Because spores have a short viability, good coverage (spray material must reach the undersides of leaves) is essential. Three applications of *B. bassiana* 7-10 days apart work best in increasing the chance of fungal spores being present to contact the pest. *B. bassiana* is sensitive to high temperatures and best results are achieved at application temperatures between 70 and 80°F. *B. bassiana* can help control thrips, whiteflies, aphids, small caterpillars and Colorado potato beetle larvae.

Neem products
Derived from the neem tree, *Azadiracta indica* and have been used for centuries for medical, cosmetic and pesticidal purposes. Neem pesticide products are usually made by crushing neem tree seeds and using water or a solvent to extract the pesticidal components. Other neem products are made from cold-pressed neem seed oil or from further processed neem oil. Neem products produced with different extraction techniques may result in different biologically active chemicals in the product. Neem cake, used as a fertilizer, is the residual seed meal remaining after extraction of oil from neem seeds. **Azadirachtin** acts as an insect growth regulator by preventing insects from molting by inhibiting production of ecdysone, the insect molting hormone. It also acts as an anti-feedant and an oviposition deterrent due to volatile compounds that repel some insects from depositing eggs. Most commercially available neem products (AZA-Direct®, Azatrol®, Ecosense® and Neemix®) list azadirachtin as the primary active ingredient. **Neem oil** is found in Trilogy® (neem oil that has had the azadirachtin separated from it). **Neem oil/soap** is found in Organica® K+ Neem, which is derived from neem oil to create potassium salts of fatty acids. Products containing both azadirachtin and neem oil seem to have greater efficacy in controlling some insects than either ingredient alone. In addition to foliar applications, neem can be absorbed through plant roots and systemically move upward through the plant through water conducting tissues, but sufficient quantities need to be applied to the root zone. There are few foliar systemic effects.

Entrust
Composed of substances (spinosyns A and D) produced by aerobic fermentation of the soil actinomycete *Saccharopolysora spinosa*. This species was found in soil samples from an old rum production facility in the Caribbean in 1982. Actinomycetes are the

bacteria that give soil that sweet ‘healthy’ smell when tilled. Spinosad is a fast-acting, somewhat broad-spectrum material that acts on the insect primarily through ingestion, or direct contact. It activates the nervous system of the insect, causing loss of muscle control. Continuous activation of motor neurons causes insects to die of exhaustion within 1-2 days. Foliar applications of spinosad are not highly systemic in plants although some movement into leaf tissue has been demonstrated. The addition of a penetrating surfactant increases absorption by tissues and activity on pests that mine leaves. Entrust can last effectively for 3-6 days on plant foliage.

Pyrethrum
A plant based insecticide derived from the dried flower heads of the pyrethrum daisy, *Chrysanthemum cinerariaefolium* and other species. Pyrethrum is a fairly fast acting contact insecticide with a quick knock-down in some insects, which leaves them paralyzed. Non-susceptible insects may be knocked-down but usually recover if the dose is low. In some pyrethrum products various oils (nutmeg, parsley, sassafras, etc.) have been added (but no PBO). The addition of these oils has increased the efficacy of pyrethrum for some pests. Pyrethrum has activity on many pest species, but control is not always possible.

Chemicals

Soaps are potassium or ammonium salts of fatty acids. They work by smothering soft bodied pests and disrupting their cuticle layer. In order to be effective, the fatty acids must come into contact with the pest insect. Once the soap dries on the plant surface, insects and mites will not pick up a lethal dose. Soaps have little efficacy against insect adults (unless soft bodied such as aphids) eggs and larger nymphs and caterpillars. Soaps function as wetting agents, which reduce the surface tension of water. Using them can allow spray materials to penetrate into small crevices and cover plant surfaces better with less “beading up”. Soaps are effective against some soft-bodied insects such as aphids, whiteflies, mites, and thrips.

Insecticide **Oils**, which can be used during plant growth, are highly refined, light weight; low impurity oils with sunscreens to reduce phytotoxicity. These are often referred to as ‘horticultural oils’. Petroleum oils are derived from crude oil, which is separated into fractions, which determine their insecticidal and plant phytotoxic values. Plant and fish oils are chemically classified as lipids containing long-chain hydrocarbons. Although there is interest in using botanical and fish oils as pesticides, the limiting factor is the variability in oil composition and no well-defined standards for pesticide use. Other oil products include mixtures of essential plant oils, such as clove and rosemary. These are generally pressed from leaves, stems, or flowers rather than seeds. Little information is available for the efficacy of these products. Oils are widely used to control insects and mites by blocking the respiratory system causing suffocation or breaking down the outer cuticle. Oils do an excellent job of controlling the egg stage of various mites and insects

by suffocating the developing embryo or interfering with the egg structure. Secondary toxicity mechanisms include penetrating arthropod tissues and degrading them, and fumigant effects of volatile oil components. Oils work best on sedentary or less mobile insects (aphids, thrips) and mites. Thorough coverage, especially of the underside of foliage is essential if oils are going to work. They tend to work best on smaller plants such as strawberry or the early growth stages of cucurbits, tomatoes, beans etc. because complete coverage is now possible.

One new organic product on the market is **Azera**®. It is a mixture of neem-azadirachtin and pyrethrum. In efficacy trials in Maryland (Dively 2009) this product has shown good to fair control of pests such as worms, thrips, mites, beetles.

Table 2. Different management tactics for control of pests on vegetables

Tables are set up so that within each management category the best possible method(s) are presented with the understanding that, in some cases, the management tactic listed will not always give good, consistent results. The level of “control” is given for each management tactic for each pest, rated 1-4, with level 1 "works well" and level 4 "works in some situations". As an example under Colorado potato beetle (CPB): Physical control: kaolin clay. Kaolin clay has been shown to work under certain circumstances, but is not reliable or consistent; nevertheless, it is listed because it has been shown to be the best physical control available and that it may work in a farm management program to reduce CPB, as it has in a few other situations. Another example: flea beetle: Biological control: none. This does not mean there are no predators or parasitoids of the flea beetle, but that biocontrol has little chance of reducing a pest population by itself after the population reaches pest status.

Some management tactics listed may involve a great deal of work and or management on the part of the grower and give anywhere from poor to good results. These are listed to give the grower as many legitimate options as possible, even though it may require a great deal of time and management. Only the grower can decide if it is worth the time to implement the management practice. In the tables, the general management tool is stated, i.e., “crop rotation”. A further explanation of crop rotation is given in the second section and the reader is referred back to this section if they are unsure how crop rotation works.

Key to control efficacy

[1]/ Overall works well, better than any other organic control when done properly.
[2]/ May work to some degree, but not consistently.
[3]/ Works only as part of an over-all plan of management to increase natural enemies and decrease pests, will not control all pests all of the time.
[4]/ Reported to work in some situations, but is not consistent or reliable.

Legumes: Pea, Green Bean, Lima Bean, Dry Bean

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
European corn borer (ECB)	None	Companion plants [2/] to increase natural enemies	Several predators [2/] and parasitoids [2/]	Bt[2/] must be applied often when larvae are small and feeding on leaves. Entrust [1/]	Azera[2/]
Fruit worm	None	Small larvae feed on foliage, flowers and the outside of pods. Larvae are more exposed than ECB larvae	Several parasitoids [2/]	Entrust [1/] -- Apply when larvae small	Pyrethrum [2/]
Aphids – Mostly pea aphids	None	Companion plantings to increase natural enemies [3/]	Many predators and parasitoids[2/]	Neem and *Beauveria bassiana* [2/] -- especially in cool weather	Soaps/oils [2/]
Potato leaf hopper	Row cover	Variety selection [2/] -- Blue Lake cultivars at greater risk than Tendercrop cultivars	None	Neem [2/]	Azera [2/]
Bean leaf beetle (BLB) and Mexican bean beetle (MBB)	None	Sanitation[3]/ – destruction of crop after harvest also provides good weed control Later planting[2]/ – plant in early June for BLB	MBB (GDA)-Parasitic wasp *Pediobius foveolatus* and a trap crop[1]/ of beans; also see trap crop section	Neem [2/]	Pyrethrum [2/]
Other Worms -- Cabbage looper Alfalfa caterpillar	None	Alfalfa caterpillar more of a problem in late June and July; Green clover worm not a consistent problem	Several predators and parasitoids [3/]	Entrust [2/] Bt [2/] Neem [2/]	Pyrethrum[2/] Azera[2/]
Seed corn maggot	Row cover [1/]	Reduce organic matter added to field [3/] Planting time can be delayed if cool and wet [2/]	None	None	None

[1/] Overall works well, works better than any other organic control when done properly.
[2/] Can work to some degree, but is not consistent.
[3/] Works only as an over-all plan of management to increase natural enemies and decrease pests, will not control all pests all of the time.
[4]/ Has been reported to work in some situations, but is not consistent or reliable.

Cucurbits: Watermelon, Pumpkin, Cucumber, Squash

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
Squash bug	Row cover [1-2/] -- works well early season, but once removed, pest will quickly infest	Varietal selection [2/] Crop rotation [2/] Sanitation [3/] Companion plantings [3/]	*Trichopoda pennipes*[2/] Tachinid will increase in population with good companion planting	Neem [2/]	Pyganic [2/]
Cucumber beetles (Striped, spotted) (striped cucumber beetles vector *Erwinia tracheiphila* causal agent of bacterial wilt-disease worse on cucumber > cantaloupe > squash > pumpkin)	Row covers[1/] – works well early season, but once removed, pest will quickly infest Kaolin clay [2/]	Varietal selection [2/] -- Some varieties less susceptible than others to feeding and bacterial wilt Perimeter trap cropping [2/]	None	Neem [2/]	Pyrethrum [2/] Pyganic [2/] Kaolin Clay + Pyrethrum [2/]
Squash vine borer	Row cover [1-2/] – works well early season, but once removed, pest will quickly infest	Varietal selection [2/] -- winter squash, pumpkin, zucchini are most susceptible; Butternut squash is not very susceptible	None	Entrust[1/] – apply weekly to base of plant for 3-4 weeks after vines start to run	None
Aphids -- Green Peach (GPA) Melon Aphid Potato aphid Foxglove aphid	Row cover [1-2/] --only used early season	Reflective mulch [2/] Companion plantings [2/] -- such as buckwheat to increase natural enemies	Natural enemies [3/]	Neem [2/]	Soaps, oils for use on small plants[2] Neem for larger plants [4/]

[1/] Overall works well, works better than almost any other organic control when done properly; [2/] Can work to some degree, but is not consistent; [3/] Works only as an over-all plan of management to increase natural enemies and decrease pests, will not reduce all pests all of the time; [4/] Has been reported to work in some situations, but is not consistent or reliable.

Solanaceous: Tomato, Potato, Eggplant, Pepper

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
Colorado potato beetle	Kaolin Clay [4]/	Rotational trap cropping [2]/ Cover crops [3]/ Straw mulching [2]/	Predators [3]/ Predators can be incased by using straw mulch [2]/	Neem Oil [2]/ Entrust [1]/	Azera [2]/ Pyrethrum[2]/
Flea beetle -- Eggplant, potato, tobacco, and palestriped flea beetles	Row Cover [1]/ Kaolin Clay [2]/ -- use before fruit half grown	Rotation [2]/ Sanitation[2]/ Trap cropping[2]/ using Chinese southern giant mustard (*Brassica juncea* var. *crispifolia*	None	Entrust [2]/ reduces population, but not a control. Neem [2]/	Pyganic [2]/
Hornworm -- Tomato and tobacco	None	Very few Hornworms rarely effect yield in larger (>1 acre) fields	Natural enemies [3]/ -- Larvae kept below threshold most of the time by natural enemies	Bt [1]/ -- must apply when larvae very small	Pyrethrum [2]/
Fruit worm	None	Cover Crops [3]/	Natural enemies [3]/	Entrust [1]/ or Bt [1]/	Pyrethrum [2]/
Other Worms— Beet AW, European corn borer (potatoes), Fall AW	None	Rotation can help [3]/ Cover crops[3]/	Predators[3]/ Parasitoids [2]/	Entrust [1]/ or Bt [2]/	Azera [2]/ Pyrethrum [2]/
Stinkbugs	None	Rotation [3]/ Cover crops and companion crops that increase Tachinids and other parasitoids[3]/	Tachinids [2]/ are an important group that will reduce stinkbug population	None	None
Thrips	Frequent and hard rains or irrigations will reduce population[3]/	Inter-cropping [2]/ Add flowering plants such as sunflower and buckwheat between vegetable rows	*Orius* [2]/ -- Add flowering plants such as sunflower to field	Entrust [1]/ *Beauveria bassiana* [2]/	Azera [4]/
Aphids (many species)	Early season use row cover [2]/; Later use Kaolin clay [2]/	Cover crops [2]/ Virus-resistant cultivars [2]/ Clean transplants [1]/	Parasitoids [2]/ Lady bugs, lacewings *Orius* [2]/	*Beauveria bassiana* [2]/	Soaps, oils [2]/

Mites TSSM	Kaolin Clay [2/]	Cover Crops [3/] Inter-planting buckwheat between rows [2/]	Predatory mites [2/] *Orius* [2/]	*Beauveria bassiana* [2/] Neem Oil [2/]	Soaps, oils [2/]
White fly -- Tomato, eggplant, pepper	None	Usually not a problem until later into the season – destroy crop immediately after harvest [2]	*Orius*, lacewings [2/] Parasitoids [2/]	*Beauveria bassiana* [2/] Neem Oil [2/]	Soaps, oils [2/]
Leaf hoppers (mostly potato)	None	Trap cropping [4/] Varietal selection [2/] -- Some potatoes more tolerant	None	Neem oil [4/]	Pyrethrum [2/] Pyganic [2/]

Sweet Corn

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
Corn earworm	None	Varietal – varieties with long, tight silks help keep out worms. Plant early as worm problems worse in August and September[3/]	Predators help, but not enough to be economical[3/]	Bt [2/] works well in MD for early planted corn, works poorly later into the season- even if delivered into silks Entrust [2/] - can work as a silk treatment (spray)	None
European corn borer	None	Planting date [2/] -- plant either early or later in season to miss first generation Sanitation [3/] -- shred stalks as soon as possible	Entrust [1/] – good results Bt [2/] – need to spray often Usually not economical	None	None
Fall armyworm	None	Area-wide planting to increase predators [3/]	None	Entrust [1/] - target silks or whorl Bt [2/] - not that effective	None
Rootworm beetles	None	Rotation [1/]	A few [3/]	None	None
Corn flea beetle	None	Crop rotation [2/] -- works fairly well but not 100%	Very few [3/]	None	None
Seed corn maggot	Row covers for earliest sweet corn varieties[3/]	Warmed soil best – cool, damp soils that delay germination are worse[3/]	None	None	None

[1/] Overall works well, works better than almost any other organic control when done properly; [2/] Can work to some degree, but is not consistent; [3/] Works only as an over-all plan of management to increase natural enemies and decrease pests, will not reduce all pests all of the time; [4/] Has been reported to work in some situations, but is not consistent or reliable

Root Crops: Carrot, Onion, Beet, Radish, Turnip, Rutabaga

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
Root maggots -- Seed corn Onion	Row covers [1/] --work best early on, but after plants are growing they can be remove	Planting Time [2/] - Avoid cool damp soils or wait until 680dd (42°F base), which is the end of last generation Rotation – move away from previous field if feasibl[1/] Tillage/ cultivation of old crop Sanitation – destroy cull piles[1/]	Few predators [3/] Ground beetles[3/] Rove beetles[3/] Fungal pathogens [3/]	None	None
Thrips	Heavy rains (or over-head irrigations) can reduce thrips population[2/]	Some onion cultivars more susceptible than others[2/] -- Red onions in general more sensitive to thrips. Green bunching onions greater chance for damage than bulb onions. Infestation prior to bulbing is worse than after bulbing	*Orius*[2/] most important, but not important for early season control, better for mid and late season control	Entrust [1/] – do not over apply – resistance possible *Beauveria bassiana* [2/]	Azera [2/]
Flea beetles	Usually not a problem unless very high numbers present	Eliminate weeds around field to reduce flea beetle population [3/] Rotation [2/]	None	Entrust [2/] - may only reduce population Neem [2/] - reduces population, but not consistent	Azera [2/]
Leaf miners -- Several species	Row cover [1/]	Worse damage in mixed cropping systems. Worse in green onions, little damage to bulb onions	Several parasitoids [1/] --Usually keep pests under control	None	Pyrethroid [2/] Azera [2/]
Worms -- Army worms, cutworms, Horn worms, Diamondback moth	Rain (or overhead irrigation) that is frequent and heavy reduces DBM, AW and other worms[3/]	Dry conditions favor DBM buildup	Ground beetles are important in reducing all worms except horn worm[2/] Parasitoids attack horn worms[2/]	Entrust [2/] Neem [2/] Bt [4/]	Azera [2/]

Aphids – Green peach aphid (GPA) Potato aphid	Kaolin Clay [4/]	Companion plants [2/] that build natural enemy populations in and around the field important	Predators and parasitoids [1/] are plentiful and usually keep aphid populations low	*Beauveria bassiana* [2/]	Soaps/oils [2/]

[1/] Overall works well, works better than almost any other organic control when done properly; [2/] Can work to some degree, but is not consistent; [3/] Works only as an over-all plan of management to increase natural enemies and decrease pests, will not reduce all pests all of the time; [4/] Has been reported to work in some situations, but is not consistent or reliable.

Brassicas: Cabbage, Broccoli, Cauliflower
Other Crops: Asparagus

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
Cabbage looper (CL) Imported cabbage worm (ICW) Diamondback moth (DBM)	Possibly row covers But not practical all season[2/]	Clean transplants [3/] Weed control [3/] Sanitation [2/] -- destroy crop right after harvest Trap crops [2/] -- Use collards	Several parasitoids [2/] ICW is an endemic pest, CL and DBM do not over winter well	Entrust[1/] Bt[1/] -best on ICW Neem[2/] Need several applications to see results	Pyrethrum[2/] Azera[2/]
Aphids -- Green peach (GPA) Cabbage aphid (CA) Asparagus aphid (AA)	Kaolin clay [4/] Row covers [1/] -- works well for early season protection Grower	Companion planting, whole farm management to increase natural enemies[2/] Destroy any volunteer spears[2/]	Parasitoids[2/] *Diaeretiella rapae* Aphid midge [2/] *Aphidoletes aphidimyza* A few predators[3/] but	Neem[2/] *Beauveria bassiana*	Soaps[2/] NOT effective against GPA Oils[2/] None
Cabbage maggot	developed alternative- use sticky roll tape over rows + B. bassiana[2/]	Planting time [2/] - adults first become active when forsythia or yellow rocket are in bloom 1st generation worse	none are very effective	+ sticky tape[2/]	
Flea beetles -- Crucifer and striped	Row covers [1/]	Weed control [3/] -- no brassica weeds in area Straw mulch [2/] Perimeter trap cropping [2/] -- use collards to attract flea beetles Rotation [3/]	Very few	Entrust[2/] has shown some control Grower developed alternative: Mijers Hot sauce[4/]	Pyrethrum[2/] Azera[2/]
Onion thrips	Row covers [2/]	Rotate away from wheat fields Planting – do not locate brassicas near wheat or oats	Orius [3/], but few predators migrate to brassicas	Entrust[1/]	Azera[2/]

Asparagus beetles -- Usually only the Common asparagus beetle (CAB) needs control The spotted asparagus beetle is usually not a major problem	None	Destroy any volunteer plants[2/] Check for beetles from 10 am -5 pm[2/]	Parasitoids[2/] -- *Tetrastichus asparagi* attack CAB eggs and larvae. They can sometimes parasitize up to 70% of the eggs. Predators[3/] -- Lady beetles	Entrust[2/]	None

[1/] Overall works well, works better than almost any other organic control when done properly; [2/] Can work to some degree, but is not consistent; [3/] Works only as an over-all plan of management to increase natural enemies and decrease pests, will not reduce all pests all of the time; [4/] Has been reported to work in some situations, but is not reliable.

Leaf Crops: Head Lettuce, Green and Red Leaf Lettuce, Endive, Parsley, Collards, Kale, Spinach, Turnip Greens

PEST	PHYSICAL	CULTURAL	BIOLOGICAL	BIOPESTICIDE	CHEMICAL
Lygus bug	None	Some cover crops, such as crimson clover, can increase their numbers, but others like pre-bloom hairy vetch can keep them away from leaf field[2/]	Many parasitoids[2/] , but they do not reduce populations consistently	Neem [2/]	Azera [2/]
Aster leaf hopper -- Vectors the casual agent of asters yellows	Row cover [1- 2/] -- if crop grown early enough in the season before it is too hot	Plow lettuce fields immediately after harvest to reduce aster yellow inoculums[2/]. The weeds: Queen Ann's Lace, dandelion, plantain, ragweed, horseweed are reservoirs for asters yellows.	None	None	Azera [2/]
Slugs	Kaolin clay [4/] Surround WP[2/] has shown some ability to kill and repel slugs	Tillage reduces slug populations[2/]	None	None	None
Aphids -- Cotton/melon aphid Green peach (GPA) Lettuce aphid Potato aphid	Row cover [1- 2/] -- if crop is grown in early season before it gets too hot	Reflective mulch [2/] reduces the number of aphids landing on plants. Plow field down [3/] as soon as harvested. Keep nitrogen levels as low as possible[2/] but high enough to produce good yields.	Many natural enemies [3/] Several parasitoids are very good[2/] as are lady bugs[2/], etc.	Neem [2/] *Beauveria bassiana* [2/]	Soaps [2/] Horticultural oils [2/]
Worms -- Cabbage looper Imported cabbage worm Diamondback moth	Row cover [1- 2/ --] if crop is grown early season	Overhead irrigation [2/] reduces moth flights and egg laying Quickly destroy crop once harvested[2/]	Many parasites [3/] attack stages of worm pests	Bt[1/] works well in controlling worms Entrust [1/]	Pyrethroids [2/]
Thrips	Row cover [1- 2/] early season	Avoid planting near grain crops or onions[2/]	*Orius* is a good thrips predator[2/]– sunflowers attract Orius adults	Neem [2/] *Beauveria bassiana* [2/]	Soaps/oils [2]

Flea beetles	Row cover [1-2] early season	Trap crop[2] – use collards, the glossy smooth leaves attract these beetles	None	Entrust [1] can reduce the population, but not control it	Azera [2]
Harlequin bug	Mild winters favor greater survival of bugs and increases chances of damage[2]	Trap crops[2] -- early planted kale, turnip or mustard; after population builds cover with straw mulch and burn trap crop. Destroy crop residue after harvest[2]	Natural enemies can help keep populations down, but at times not enough[2].	None	None