POLLINATORS

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The two major pollinators of alfalfa seed crops in the West are the alkali bee and the alfalfa leafcutting bee. The alkali bee nests in the ground in natural or artificial sites. The leafcutting bee spends its life above ground in artificial nests and shelters. Both pollinators must be protected from predators and from harmful insecticides.

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ALKALI BEES

The alkali bee, *Nomia melanderi*, is native to the Northwest (Fig. 1). It occurs naturally in limited arid areas west of the Rocky Mountains. It is a soil-nesting, solitary bee, although it nests gregariously, often in large concentrations. Each female constructs and provisions her own nest with no contact between adults and larvae. In nature, nesting is confined to relatively bare alkali spots where the soil is sub-irrigated over a hard-pan layer.

Adults are about two-thirds the size of a worker honey bee. Females have stingers but, unlike honey bees, rarely use them. Adults are black with metallic-colored bluish, greenish, or yellowish bands circling the abdomen. Males have white-colored faces, long antennae, and tibial spurs. Females have darker-colored faces, shorter antennae, and lack tibial spurs.

Biology

Alkali bee adults emerge from the soil in late spring or early summer, depending on temperature and soil moisture. Seasonal activity varies in different areas: from late May to mid-August in Washington, from early June to early September in Idaho and Nevada, and from late May to early September in Oregon.

The average sex ratio is 1.4 males to 1.0 female. Males emerge somewhat earlier than females, apparently to insure sufficient mating numbers when females emerge. Males take some nectar from

Fig. 1—Alkali bee.

flowers, but no pollen. They often gather in sleeping aggregations on plants near the nest area. Male activity is largely confined to patrolling nesting areas or nearby plants in search of females.

Females begin constructing their nests soon after mating. They prefer to dig in existing holes in the ground. Physical structures around the site are used by females to find their own nest entrance hole. The nest consists of a vertical shaft with a lateral tunnel that has oval cells branching from it. Cells may be as deep as 12 inches below the surface, but most are 4–8 inches and are lined with a moisture-resistant secretion produced by the females. Soil removed from the nest is deposited around the entrance hole to form a mound with a harder central turret.

Females live four to six weeks, but apparently become senile with age. The number of progeny per female is highly variable. Under good conditions in large-scale commercial operations, females may average seven to nine progeny in natural sites and ten to twelve in artificial sites.

There is only one generation a year in the Pacific Northwest and Nevada, although about 1% emerge one month after the rest of the population. In southern Utah there is a small second generation. In California there are two generations per year.

Pollination

The native alkali bee has become a major pollinator of the introduced alfalfa plant. Alkali bee females trip at least 95% of the alfalfa flowers as they gather pollen for the nest. Females also forage blooms in the lower foliage and fly in cooler, windier weather than most other alfalfa pollinators. Under good conditions, each female will trip about 25,000 alfalfa flowers during her life and provide for production of ⅕–½ pound of clean seed. The exact number of foraging females required in the field is not known but should exceed 3,000 per acre throughout the peak three weeks of flight. At times, yields of 2,000+ pounds of clean seed per acre have been obtained with the alkali bee on commercial acreages.

Females tend to forage close to the nest site (within a 1-mile radius), although they have been found up to 7 miles away. Males often become so numerous on alfalfa near the nest that they drive females to fields further away. Females will rarely stop to forage on closer blooms once they have established a more distant flight pattern. In some cases it may be necessary to stimulate bloom on a section of a field near a nest site so that females will not pass over it.

For maximum seed production, peak bloom of alfalfa should coincide with peak activity of alkali bee females.

Large alkali bee populations are needed for alfalfa seed production. A good natural nesting site will average about 1 million nests per acre. An acre of bed with this number of nests should provide 1,000 pounds of clean seed per acre on 200 acres of alfalfa. The maximum population in artificial beds is about 5.5 million nests per acre.

Nesting Sites

Nesting sites for the alkali bee can be natural or artificial. Regardless of the site type, four basic conditions must be met and maintained in order to produce sufficient alkali bees for pollination.

1. The soil must be moist throughout the nesting area down to a depth of 12 inches. Alkalinity is purely a secondary character that indicates the soil has good subirrigation qualities. Alkali bee production will be limited if nesting sites get too dry, but too much moisture enhances mold and disease development. Soil moisture in good sites varies from 8–32% depending on soil type. Tensiometers may be used to determine soil moisture rapidly and accurately. A reading of 15–25 centibars indicates adequate moisture regardless of soil texture.

2. The soil must be firm and compact without either a crusty or fluffy layer at the surface. The surface must also have a salt seal to reduce evaporation. Sodium chloride (common salt) hardens and seals the surface and should be used at 1–2 pounds per square foot, depending on the condition of the bed. A light, fluffy surface layer is an indicator of high calcium content and a need for sodium salts. Soils with high natural sodium content will become too hard and crusty with sodium chloride applications. Calcium chloride at about ¼ pound per square foot or less is the best treatment for beds with a hard crust. CAUTION: Soils with natural high salinity are adversely affected by salts. Salts should be spread

evenly on the soil surface by raking during the early spring. Incorporating them into the surface layer will keep rains from washing them away. Discing to 3–4 inches is *not* recommended. It will dilute the surface-sealing effect.

3. The surface should be bare with sparse vegetation. Plants use soil moisture and bees prefer to nest in bare ground. Limited vegetation will help protect bees from summer rains when they occur. Strips of vegetation will also serve to reduce wind erosion.

Saltgrass (*Distichlis*), bermuda-grass (*Cynodon*), alkali weed (*Bassia*), kochia (*Kochia scoparia*), and other weeds can quickly become a serious problem on alkali bee sites if they are allowed to spread unchecked. Chemicals are the best way to control weeds. Heavy applications of soil residual herbicides do not harm any stage of the alkali bee. The following chemicals (listed in order of preference) have given excellent results for 5–10 years following application: Hyvar X (Bromacil) at 40 lbs. per acre; Monobor chlorate at 1,200 lbs. per acre; and Pramitol or Atratol at 800 lbs. per acre. Roundup plus diesel oil applied in the fall has given good results. Atrazine at 2 lbs. per acre plus Simazine at 2 lbs. per acre have given good results when applied during early winter for annual weed control.

4. A silt loam with 12–24% clay is the soil type preferred for nesting, but alkali bees successfully nest in other soils. In some cases sites may appear normal, but the ground is too hard for nesting. This condition is not obvious if a hard layer occurs at the 4- to 6-inch depth.

Site Construction

For semi-natural sites of an acre or more, large basins or reservoirs are dug along the upper edge of sloping sites so water will seep through the soil downhill. The basins are 18–36 inches deep and 10–100 feet long, depending on the natural contours of the site. Sometimes ditches are dug around the edge of a bed or at several contour levels along the slope. Basins or ditches should not cut through the underlying hardpan layer. They should be kept full of water throughout the spring.

In semi-artificial sites, deep soil can be used for beds if water is supplied through rows of underground pipes and perforated tiles or drain tubing laid across the bed at intervals. Tile rows must be about 8–10 feet apart to provide even distribution of water throughout the bed. A large amount of water is required, from 5,000–20,000 gallons per 1,000 square feet before the nesting season. Water must be added during the season to maintain a tensiometer reading of about 15 over the lines and about 25 between lines.

Artificial sites can be prepared by digging excavations 1–3 feet deep over a 30x60 foot or larger area. The bottom of the excavation is covered with an 8-mil polyethylene liner. This plastic sheet is protected with 2–3 inches of soil and then covered with 8–10 inches of ¼–1 inch diameter clean gravel (not crushed rock which can puncture the liner). The gravel should be covered with an inch or two of straw or with burlap to keep dirt from plugging the gravel. The excavation should then be filled with silt loam until the surface is gently crowned. Upright tiles are placed at intervals of 25 to 50 feet. They extend into the gravel or connect with a grid of drain tiles. Water is then added through the upright tiles. One watering in late May will usually last the entire season. The amount required varies from 70–300 gallons per 1,000 square feet, depending on existing soil moisture. (For more details, see the alkali bee section.)

Colonizing New Sites

Newly created alkali bee nesting sites are usually colonized slowly, making it necessary to introduce bees. Two techniques have been successful.

Soil cores from established beds may be used as starters in new sites. Small quantities can be cut with hinged metal sleeves driven into the ground. The cores are placed in sheet metal holders or on burlap sacks for transport. Large operations require mechanized cutting of cores. Cores are most efficiently cut with a cubic-foot hydraulic attachment on a backhoe. As individual blocks of soil are removed, they are shoved into cardboard boxes. Once the cores are transported to the new site, they should immediately be placed into the ground. This prevents the soil from drying out, causing a loss of bee prepupae. When the cores are placed into the ground, they should be positioned and moistened to ensure a connection between the core and the host soil. Without this connection, no water can move into the core and it will eventually dry out, killing up to 100% of the bee prepupae.

Transferring adult bees is an easier way to colonize new sites from established ones. To be successful, transfers must be made when the female bees are young and just beginning to nest. They are swept from the site with an insect net. After about 200 bees are accumulated in the net, carbon dioxide from a cylinder is used to quiet them. The bees are then emptied into paper sacks and placed into cold chests. Ice should be present in the chests, but care should be taken to prevent the bees from coming in direct contact with it. The bees should be kept cool until they are released at night on the new site. Holes several inches deep should be punched into the soil with a pitchfork or other device before releasing the bees. They will crawl into the holes and use them to start nests. The advantage of using this method of establishing bees is that natural enemies are left at the old locality.

Renovating Beds

Beds which have been heavily populated with bees over a number of years begin degenerating and losing their effectiveness. The soil becomes honeycombed with cells and tunnels and loses much of its original compact structure. Fungus growth in cells increases markedly. One method of renovating is to plow and/or disc the soil thoroughly. The best method is to remove old soil to a 12-inch depth and replace it with a soil of the type described earlier. Silt loam soil provides excellent replacement material.

Parasites and Predators

Bomber flies, *Heterostylum robustum*, are the major parasite of alkali bee larvae. The adult female flicks eggs near or down the alkali bee nest entrance. The parasite larvae crawl or are carried into the bee cells. Adult bomber flies are hairy, light brown and white, and about the same size as alkali bees. Mature larvae are brownish, leathery, C-shaped, and about the same size as alkali bee prepupae. The most effective control of the bee fly is by walking around on alkali bee beds and hitting emerging flies with a fly swatter between 9 a.m. and noon for a two-to three-week period beginning a little before alkali bee emergence. The bomber fly does not emerge in the afternoon. When there is good alkali bee activity over the bed, bomber fly activity is reduced. High populations of bomber flies are usually an indication that something else is wrong with the bed.

Obliquebanded conopid flies, *Zodion obliquefasciatum*, are also serious enemies of the alkali bee. They are internal parasites of adult female bees and reduce bee longevity and the number of progeny produced. Adults are reddish, about half the size of alkali bees, and have large heads and eyes and one pair of wings. The adult parasite darts out and grabs a female alkali bee and deposits an egg between the abdominal segments of the bee. The parasite larva eats away at the tissues and ovaries of the alkali bee although the bee continues to work and tries to build a nest. Eventually the alkali bee female gets too weak and dies. Usually this occurs within a cell she has constructed. Conopids are controlled by putting red stakes about 12 inches high about 10 feet apart throughout the bed. The stakes should be coated with Dylox. Upon emergence, the female conopid fly crawls up these stakes and becomes trapped.

Black oil beetle, *Meloe niger*, consumes the host food after destroying the egg and is also a predator of all larval stages of the bee. Adults are black, wingless, 1–1½ inches long, and have large abdomens. After mating, females lay a mass of about 3,000 eggs in the ground. Triungulins (active first larvae) emerge, crawl up plants to flowers, attach to visiting alkali bees, and are transported to the bee cell. There they change through four distinct forms, consuming the contents of at least two cells. An effective control is a ditch 6 inches wide and 12–18 inches deep dug around the bee bed and lined with plastic. Another effective control is 4-inch garden fencing placed around the bed. Adults leaving the bed can not fly or crawl over the fencing. Bury 5-gallon buckets containing ½ gallon of oil at several places on the alkali bee bed side of the fencing. Beetles crawl along the fencing, fall into the buckets and die. If fencing is not feasible, Guthion (azinphosmethyl) at 10 pounds actual per acre can be applied around, but not on, the bee bed at 4-5 day intervals during the time adult beetles are emerging.

Several other insects at times can become serious parasites and predators of the alkali bee: flesh flies, humpbacked flies, cuckoo bees, and ants. Vertebrate predators of alkali bees include skunks, mice, and birds. Any one of these may cause severe damage. Unfavorable weather conditions are often the main factor limiting population. Insecticides are another major killer of alkali bees. Alkali bees are highly susceptible to poisoning by most organophosphorus and carbamate insecticides used in crop pest control.

ALFALFA LEAFCUTTING BEES

Alfalfa seed growers have been aware of the value of the alfalfa leafcutting bee, *Megachile rotundata*, since the late 1950s (Fig. 2). Since it nests in many kinds of artificial structures, as well as holes in banks, beetle holes in wood, and other natural cavities, it is not limited by soil conditions and can be successfully propagated under a wide range of climatic conditions. Each female will trip enough flowers to produce up to ¼ pound of seed. Leafcutting bees are responsible for excellent yields in areas where alfalfa seed could not previously be grown economically.

Alfalfa leafcutting bees vary considerably in size, from ⅕ to ⅖ inch long and 1/12 to ⅙ inch wide. Females are black with short white hair on various parts of the body; they have a pollen brush of long white bristles on the underside of the abdomen. Males have buff-colored hair, two light spots on the rear end, and lack the pollen-collecting brush. Females are typically larger than males and have a more pointed abdomen. They have four or five stripes of white hair across the abdomen.

Biology

Depending on location and weather, males begin to emerge from early till mid-June and females a week later. The bees mate shortly after emergence. Within another two or three days, the female begins to nest, always in existing tunnels. A thimble-shaped cell is formed with pieces of leaves which she cuts, carries, and manipulates with her mandibles by chewing the edges of the leaf pieces and then pushing against the walls of the nesting tunnel.

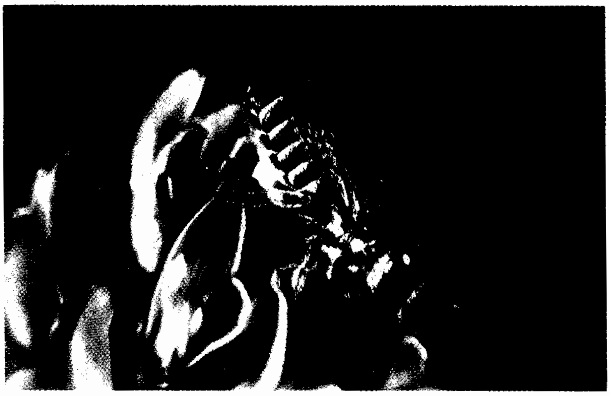

Fig. 2—Alfalfa leafcutting bee.

She provisions the cell with nectar and pollen, lays an egg, and closes the cell with round pieces of leaf. On the average, a female builds from four to seven cells in a nesting tunnel, plugs it with many leaf cuttings, and then repeats her labors in other tunnels. During warm and dry weather, a female can complete an average of one cell per day. Since she lives four to six weeks, she can produce 30–40 offspring, but a typical average under field conditions is 12 healthy larvae per female. A sex ratio of two males to each female is average, but a one-to-one or even higher ratio of females sometimes occurs.

In the Pacific Northwest and Nevada, the leafcutting bee has two emergence periods each year. Generally 10–20% of the larvae emerge the same season as second- or summer-generation adults.

Advantages of the Leafcutting Bee

The alfalfa leafcutting bee gained favor among growers very rapidly after its potential was realized. Several biological features of the bee have encouraged large populations to be built up and managed.

- It usually forages in the field where it nests. For this reason it benefits only the grower managing it and is not as likely to be killed by insecticide treatments on neighboring fields.
- It collects alfalfa pollen readily and efficiently trips the alfalfa flower.

- Its foraging period generally coincides with the blooming period of alfalfa.
- It emerges readily following sufficient cold treatment and within a predictable period based upon incubation temperatures.
- It has a long foraging life (four to six weeks) and produces a large number of offspring for a solitary bee.
- It is gregarious.
- It usually nests above ground in artificial nests.

Management Practices

Management is based primarily on providing nesting holes and shelters in or at the edge of seed fields. Various types of nest materials are provided. Each has its advantages and disadvantages. Materials most commonly used include: drilled wood boards with removable backs, drilled wood boards with solid backs, paper soda straws, laminated wood, and laminated plastic.

Management systems mostly are associated with the degree of care given to the bees at different life stages and seasons.

The most common level of management is to place the nesting materials in shelters of various kinds and position the shelters in and around fields during the growing season. Many growers also bring the nests into unheated buildings or basements for protection during the winter. However, better care is provided by placing the nesting materials in cold storage until late spring and then into incubation at 88°F. and 50% humidity until males begin to emerge.

The most efficient level of management is the loose-cell method: removing cells from nesting holes in the fall (using a laminated nesting material), cleaning by running them across mesh screens to eliminate excess leaf pieces and many insect predators, bulking the cells in large containers, and placing them in cold storage. The following spring the cells are placed in trays and incubated before placement in the field. Handling the bees in loose cells during the off season allows more efficient use of cold storage and incubation facilities, provides for better nest destroyer control in the fall and better parasite control in the spring, and furnishes clean empty units for use the following year. The loose cell method is not without problems. The cells are vulnerable to improper incubation temperatures and humidities and also to destruction by small parasitic wasps.

For greater detail, see the separate section on loose cell management.

Shelters

The use of proper shelters or domiciles for bee nesting is essential for good bee activity and propagation. Domiciles should be as large as possible and painted yellow, blue, or green. The bee orients best to large objects in a field and is able to work more efficiently in large shelters. Domiciles should be constructed so that the nesting materials are not exposed to direct sunlight at any time—a southeast exposure is favored with an awning that prevents sun from shining directly on the boards and on the floor of the domicile. Nesting material should not touch flimsy plywood siding or the ceiling. Lack of insulation allows daytime temperatures to go over 100°F. if bee boards touch the siding.

Airflow in the domicile must provide good ventilation and heat dissipation in the afternoon. A small opening between the walls and roof will allow rising hot air to escape from the domicile. Wire screens on the front of the domicile can be used to prevent bird predation. They must be at least 2-inch mesh to minimize injury to bees.

Small domiciles cannot be located next to large, trailer-size domiciles, since bees will drift to the larger shelters. Leafcutting bees must be allowed to fly freely within the domiciles. For each full board in the domiciles, 1-1½ empty boards must be provided initially. More nesting material is added later, if needed. There are 9,000-12,000 leafcutter cells per gallon. Since one-third of these will contain female larvae, three to five boards must be provided per gallon of bees, initially. The grower needs approximately 5,000 females per acre to get a good crop of seed, but the number will vary according to bee vigor and health. A good rule of thumb is that there should be roughly three vacant holes for every female leafcutting bee. Bee domiciles must be kept clean to help control parasites, predators, and diseases.

Population Limiting Factors

The alfalfa leafcutting bee, like the alkali bee, has the potential for a three- to fivefold increase, or more, each summer. Many of the same factors that prevent the alkali bee from increasing have also prevented leafcutting bees from multiplying. Good weather during the flight season is probably the most critical factor. Without it, bee activity is greatly reduced. There are over 20 species of insects which are parasites, predators, or nest destroyers of the leafcutting bee.

Parasites

The minute chalcid, *Tetrastichus megachilidis*, and the Canadian chalcid, *Pteromalus venustus*, are 1/12 inch long and metallic blue or metallic green. They can be serious pests during incubation of loose cells. Unless controlled, up to 50% of the bee larvae can be destroyed before adults emerge. The safest method of control currently is the use of ultraviolet lights over water trays to attract and trap adults during incubation. Fine sawdust may be placed over the cells to a depth of 1½–2 inches to prevent adults from actively going from cell to cell and parasitizing the contents.

Imported chalcids, *Monodontomerus obscurus*, are shiny metallic blue-green with red eyes, ⅒ to ⅐ inch long, and have a long slender ovipositor and enlarged hind legs. This chalcid is also damaging to loose cells during incubation and can be controlled as described for the other chalcids.

The red-marked sapygid wasp, *Sapyga pumila*, is ⅓ inch long and mainly black with yellow or white spots and a red marking about the middle of the abdomen, which is teardrop shaped. The parasites are elongated and cylindrical. The body is smooth and shiny, with few hairs. The sapygid female drills a hole through the cap of a leafcutting bee cell and deposits one or more eggs. The wasp larva hatches prior to its host and punctures the leafcutting bee egg. The parasite emerges the following spring about the same time as the leafcutting bee. This wasp has caused up to 78.5% parasitism in some areas. Currently, effective control of this pest can be accomplished through the use of phase-out and field shelter traps.

Predator

Adults of the checkered flower beetle, *Trichodes ornatus*, are ¼–⅖ inch long. They are shiny metallic blue with either bright red or yellow markings on the wing covers. Adult females insert eggs between the leaf pieces of the tunnel plug and in small cracks in wood structures where the bees are nesting. Red-colored larvae can be found in bee nests beginning in late June. One larva often consumes up to eight cells and can destroy more than 20.

A chemical lure trap has been useful in reducing this pest. Phase-out traps also help control checkered flower beetles.

Nest Destroyers

Carpet beetles, *Trogoderma* spp., are ⅑ to ⅐ inch long and oval shaped. They are generally dark but have a mottled appearance from light-colored bands of bristles on the wing covers. Mature larvae are brown-banded and covered with long brown hairs. Carpet beetles prefer to feed on pollen and old cells. Infestations are an indication that there are too many cells containing only pollen. Good management practices, cold storage, ultraviolet light traps, phase-out traps, and fishmeal-honey poison baits provide effective control of the carpet beetle.

Giant flour beetles, *Tribolium brevicornis*, are ⅕–¼ inch long and dark brown to almost black. Larvae are tan to white with dark bands across the body and ⅓–⅖ inch long. Several closely related, but smaller, flour beetles are simply nest destroyers. However, the giant flour beetle can easily penetrate bee cocoons and become a serious predator. Control consists of the methods described for carpet beetles. Severe infestations may require fumigation.

The distinctively marked California spider beetle, *Ptinus californicus*, is not common in all areas but has reached outbreak numbers with certain growers. The adult is ⅕ inch long, dark gray to black, and has four white markings on the wing covers. Larvae are white with a light brown head, ⅓ inch long, and C-shaped. Adults emerge during incubation of nest material. They mate and apparently return to the bee nests to lay their eggs in the stored pollen. No special types of control have been developed, but phasing out infested materials helps considerably.

Chalkbrood Disease

In 1974, chalkbrood fungus disease appeared in near epidemic proportions in a northern Nevada leafcutter population. Until 1973, the presence of chalkbrood in leafcutting bees was acknowledged, but its low incidence (less than 1%) did not cause much concern to either growers or researchers. In 1974, the disease caused a 20% loss in Nevada bees and, by 1976, losses averaged 50%.

Chalkbrood increased in Oregon and Idaho populations in 1975 and, by 1977, was becoming epidemic with some losses over 50%. By 1978, it had begun to build up in leafcutter stocks in both Washington and Canada, and surveys have shown it to be present in virtually all populations in the West and Midwest. Certain practices can help reduce the incidence of chalkbrood: Starting the season with as clean a brood as possible, maintaining temperatures less than 90°F. and greater than 60°F. during alfalfa leafcutting bee activity, providing good ventilation in the domiciles, and avoiding stress conditions for the bees. For greater detail on chalkbrood, disinfecting procedures, and heat treatment (kilning) of bee nesting materials, see the separate section on chalkbrood.

Domiciles should be faced southeast and provided with an awning so that direct sunlight does not overheat the bee boards. Bees handled in a loose cell system do not come in contact with infested larvae as often as bees emerging from solid boards. In addition, punch boards and laminated nesting materials are more easily cleaned and treated.

Weather

Probably the greatest mortality of all occurs in the egg and early instar stages of the bee. This mortality is due to heat stress and/or exposure to poor weather conditions. Egg and early larval mortality are reduced in well-ventilated domiciles that face in a southeast direction.

Insecticides

The alfalfa leafcutting bee is even more susceptible than the alkali bee to most of the insecticides sprayed on alfalfa fields, and losses often occur from improper use of chemicals.

Pollinators are not only essential for crosspollination and increased seed production but also help the plant ward off insect pests. The sooner an alfalfa flower is tripped, the sooner the plant begins to dry up and the seedpods begin to mature. As it dries, the plant is less susceptible to lygus bug and aphid feeding.

The goal of the alfalfa seed grower under an integrated system is to eliminate pest insects with a prebloom spray before the pollinators are flying. The next step is to introduce the pollinators into the field and quickly set the plants so they dry out and further plant damage becomes unimportant. Pollinators can then be removed and placed in another field with later blooming time. Reduction in the number of spray applications is dependent on good pollinator numbers, and large pollinator populations depend on good bee management.