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COVER PHOTOS are by Christopher Kious, Department of Entomology, Washington State University. The front cover shows color phases of the checkered flower beetle. The back cover shows various sizes of its larvae.

Parasites, Predators, and Nest Destroyers of the Alfalfa Leafcutting Bee, *Megachile rotundata*

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The alfalfa leafcutting bee *Megachile rotundata*, a native of southeastern Europe, was accidentally introduced into eastern North America in the 1930s. The first western record of the bee was in California in 1940. It spread to Oregon, Nevada, Idaho, and Utah by 1958 and was found in all Washington seed areas by 1961. This alfalfa crop pollinator was imported to Canada in 1962 from Idaho and Utah. The leafcutting bee now occupies the northern three-fourths of the contiguous United States and southeastern Canada.

This publication reviews the background, biology, and interactions between the alfalfa leafcutting bee and its natural enemies in North America. It is designed to aid alfalfa seed growers in identifying natural enemies and to provide useful information for successful bee management.

The gregarious, aerial nesting bee lives in a variety of nest structures. In commercial alfalfa seed fields, females construct nests in man-made tunnels of wood, paper, plastic, or polystyrene. The bees fill the tunnels with $\frac{3}{8}$ inch long cylindrical cells typically constructed from 15 leaf pieces and filled with 17 loads of pollen and nectar. An egg is laid on the pollen-nectar mass, the cell is capped with leaf pieces and another cell is started.

After the egg hatches, the larva feeds on the pollen-nectar mass and develops through five growth stages ending in a mature larva within a cocoon. From egg to mature larva takes 14-21 days. The bee overwinters as a mature larva or changes into an adult, and emerges the same year. It has at least a partial second generation in the northwestern United States and Canada.

A 3-inch long tunnel contains at least six cells; typically the bottom two cells are females and the upper four are males. A female will usually live 45 to 60 days and produce 12 cells although individual females have produced as many as 35. A female producing 25 cells in her life could potentially pollinate enough alfalfa flowers to produce 1.1 pounds of seed. However,

under field conditions females average less than 0.1 pound of seed.

The initial rapid growth of leafcutting bee populations was probably limited only by the availability of nesting sites. Alfalfa seed growers alleviated this problem by furnishing boxes of soda straws or boards with holes drilled in them to serve as nesting sites. Bee populations increased rapidly until the middle 1960s, then leveled off. Natural enemies had begun to adapt to this concentration of a readily available food source. In 1961 there were no reported natural enemies of the bee in the Northwest. By 1966 there were 35 species of native or introduced parasites, predators, and nest destroyers.

Some natural enemies such as the parasites *Monodontomerus obscurus* and *Pteromalus venustus* may have been introduced from Europe with the leafcutting bee. Others, such as the redmarked sapygid, *Sapyga pumila*, and cuckoo bees were native on other wild bees but slowly adapted to the leafcutting bee. The sapygid became a major problem, but it was not well adapted to the leafcutting bee, and up to 84% of its parasitism was unsuccessful. Both the bee and the parasite larvae died.

Some native parasites such as *Monodontomerus montivagus* were quite commonly found in bee samples in the early 1960s. However it was quickly displaced by the imported parasite, *Monodontomerus obscurus*, which was better adapted to the timing of the leafcutting bee's emergence.

Stored products pests quickly adapted to the protein-rich contents of the leafcutting bee cells. Carpet beetles, *Trogoderma* spp., were the earliest nest destroyers to cause extensive damage in leafcutting bee nest structures. Within a few years carpet beetles were displaced by the American black flour beetle, *Tribolium audax*. Currently the giant flour beetle, *Tribolium brevicornis*, has displaced the black flour beetle in most areas, but carpet beetles are again becoming more prevalent.

The checkered flower beetle, *Trichodes ornatus*, has been the only serious true predator of the leafcutting bee. The beetle larva must feed on

several bee larvae to complete its development. The beetle was originally a predator on several native wild bees but soon adapted to the high concentrations of leafcutting bees. It was restricted as a serious pest to an isolated seed area in southeastern Washington and adjacent Oregon until the early 1970s. However, by 1974 it had become the most serious pest in all Washington seed areas and had become a more serious problem in Oregon, southern Idaho, and Nevada.

Expansion and development of the alfalfa leafcutting bee pollination industry has led to an active commerce, and movement of bees being bought and sold is common among the states and Canadian provinces. This has resulted in spreading natural enemies to all areas in which bees are being used for pollination. Some natural enemies are more successful than others in certain areas because of favorable or unfavorable environmental conditions and differences in bee management practices. The severity of individual enemy species has changed as bee management practices have changed (usually in response to a particular enemy problem).

Parasites

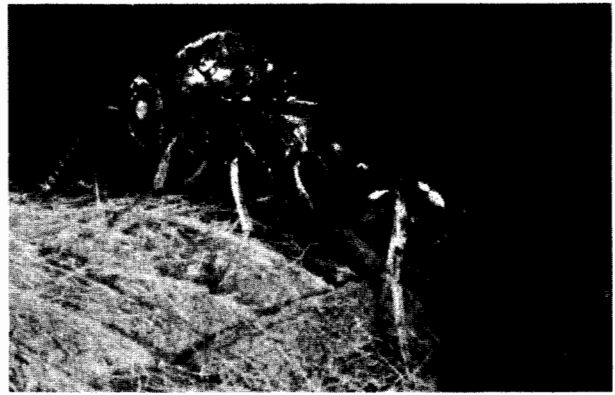
Offspring of parasites normally consume a single bee larva. There may be a single parasite larva on each host (*Sapyga*) or several parasite larvae (*Monodontomerus*), but development is confined to the single bee cell.

Imported Chalcid, *Monodontomerus obscurus*

The imported chalcid, a European species, is found in all seed-producing areas of North America.

Adults are shiny metallic blue-green with red eyes. Females are 1/7 inch long and males are 1/10 inch long. Females have a long slender ovipositor (egg laying organ) and enlarged hind legs. Adults emerge through a single hole in the leafcutting bee cell. Males emerge before females and group around the exit hole where they mate with the females as they emerge. A courtship pattern is followed before mating is consummated. An overabundance of males can cause a 50% reduction in eggs laid by disrupting the female with continuous mating attempts.

The female saws a hole through the cell of the bee with her ovipositor and injects the mature bee larva with a paralyzing fluid. She lays from



Imported chalcid adult

3-51 (averaging 10) slender eggs, 1/36 inch long on the surface of the bee larva. Newly hatched larvae attach to the bee larva with their mouth hooks and feed externally on the host body fluids. Larvae are white with many short bristles and 1/10 inch long when mature. At 88°F total life cycle from egg to emerging adult averages 20 days. The sex ratio averages 1:3 males to females. The number of parasites completing development per bee cell ranges from 3 to 27 and averages 10.

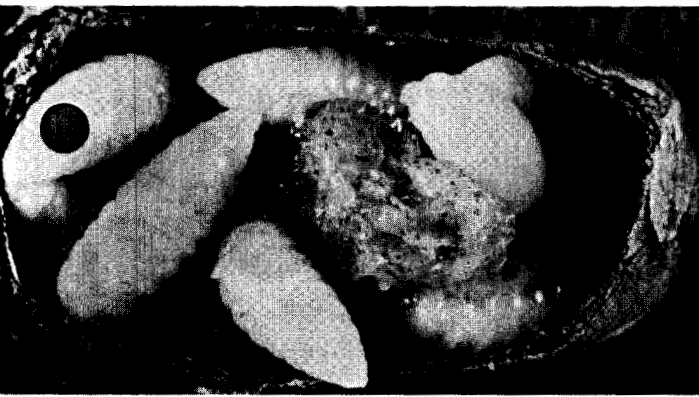
Parasites overwinter as mature larvae and adults emerge over a 7-day period beginning about 10 days after bees are placed in incubation rooms at 85°F. Adult parasites immediately parasitize developing bee larvae that are exposed, such as in loose cells or straws. Bees in drilled or groove boards are attacked through cracks that expose rows of bee cells. Parasite attacks on mature bee larvae or white pupae will result in a new generation of adults emerging in about 20 days. Attacks on black pupae or newly formed adults usually result in death of both the parasite larvae and the bee host. Under poor bee management conditions up to 50% parasitism has been observed in loose cells or straws in incubation rooms.

The move from use of straws to drilled boards by Pacific Northwest growers in recent years has reduced imported chalcid infestations. Although loose cells and straws are highly susceptible to parasitism, good bee management practices can minimize infestations.

Canadian Chalcid, *Pteromalus venustus*

The Canadian chalcid is a European species which was originally found only in western Canada. However, the parasite currently can be found in all northwestern states.

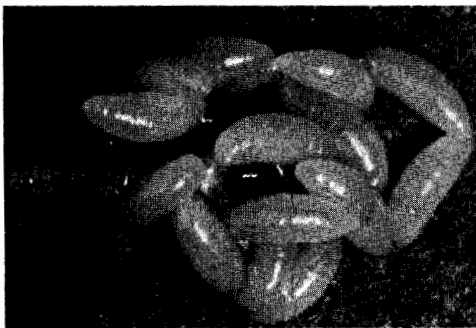
Adult females are 1/10 inch long, and males are 1/12 inch long. Both are black with a dark



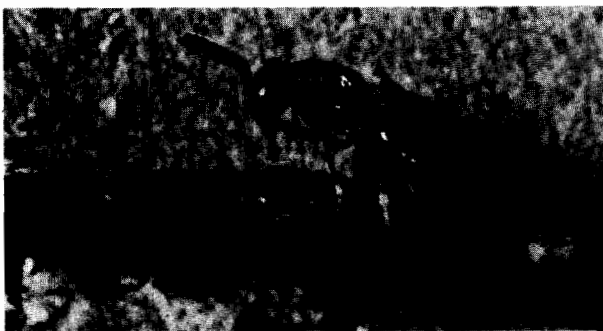
Imported chalcid larvae

brown to green coloration on the main segments of the legs. Males and females are similar in structure to the imported chalcid but are slightly smaller. Adult Canadian chalcids emerge through a single hole chewed through the leafcutting bee cell. Males emerge first and mate with females immediately after they leave the cell.

The female pierces the bee cell with her ovipositor and stings the bee larva, injecting it with a paralyzing fluid. She lays 50 to 60 eggs on the surface of the bee larva. The eggs hatch in a few days and the white hairless larvae attach to the paralyzed bee and begin feeding. The parasite larvae are about 1/10 inch long when mature. Egg to adult takes about 14 days at incubation room temperatures of 85°F. The sex ratio aver-



Canadian chalcid larvae



Canadian chalcid adult

ages 1:1 males to females. Parasites completing development per bee cell range from 19-49 (average 32).

The Canadian chalcid overwinters as a mature larva and adults emerge over a 4-day period beginning about 8 days after bees are placed in incubation rooms at 85°F. Exposed loose bee cells are quite susceptible to reparasitism and a second generation of parasite adults can emerge about the time bees are taken to the field. In southern Idaho in 1976 an initial 3% parasitism of 100 gallons of imported bees resulted in a loss of 40% of the bees before they reached the field when parasites were not properly controlled.

The Canadian chalcid has the potential to cause greater damage than the imported chalcid because of its higher reproduction potential and its shorter emergence time.

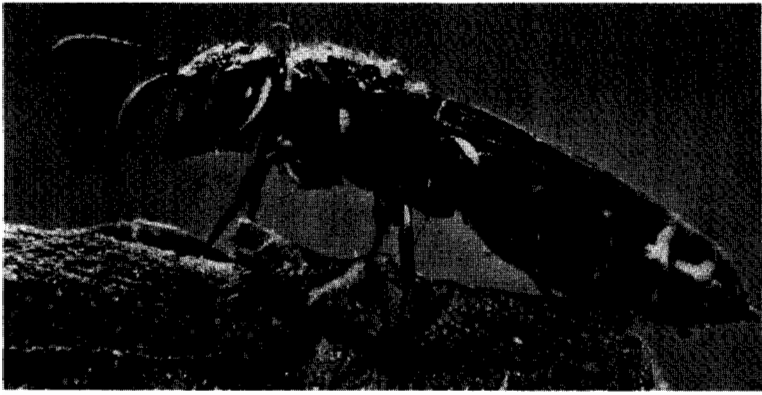
Redmarked Sapygid, *Sapyga pumila*

The redmarked sapygid is a native species which primarily attacked other wild bees before populations of leafcutting bees became abundant. It was first found in leafcutting bees from Idaho, Oregon, and Utah in 1958 and in Washington in 1964. It is now present in all western United States seed growing regions.

Sapygid females are about 1/3 inch long and black with yellow or white spots and a red or maroon band around the middle of the abdomen. Males are slightly smaller and solid black with no band. Adults are elongate and cylindrical with tear-drop shaped abdomens. The body is smooth and shiny with few hairs.

The female forages for pollen and nectar during the morning hours and visits leafcutting bee nests throughout the afternoon. She lands on the nest surface and searches for unplugged nests. When she finds an unplugged nest, she enters the hole and searches for the cell cap. She inserts her ovipositor through the cell cap and deposits one or more eggs near the bee egg. The wasp larva hatches in 1-2 days, punctures the bee egg, then begins feeding on the cell provisions. When more than one parasite egg is laid in a single cell, the resulting larvae attack each other and either one or none survive. In such cases of unsuccessful parasitism, the bee egg is normally killed.

A successful parasite larva consumes most of the pollen and nectar provisions in the bee cell, then spins a cocoon in which it overwinters. The parasite cocoon is the same size as the bee cocoon



Redmarked sapygid adult

but can be recognized by the curved nipple on the posterior end and the many large black fecal pellets attached to the outside. The parasite emerges the following spring about the same time as the leafcutting bee.

The sapygid reached epidemic proportions in southern Idaho by 1970 but populations have been quite sporadic in other seed growing areas. Infestations of 35% have been reported in Idaho and Oregon, 15% in Nevada, and 8% in Washington.

Woodboring Chalcid, *Leucospis affinis*

The woodboring chalcid is a native parasite which has been found in leafcutting bees from all western United States seed growing areas.

Adults are about 1/3 inch long and are black with bright yellow markings. The upper portion of the hind legs is enlarged and toothed on the lower side. The female has a long stout ovipositor which curves upward and forward over the abdomen.

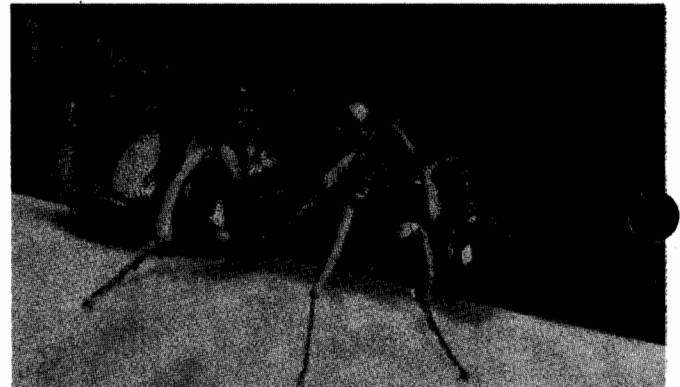
Females stand on the nest surface and force their ovipositor through the cell plug at the hole entrance or through the wood on the side of a nest structure. The ovipositor can penetrate more than 1/4 inch of wood. One to three crescent-shaped eggs are laid on each immature or mature bee larva. When more than one egg per cell is laid, the first parasite larva to hatch kills the other parasite eggs. The egg hatches into a smooth white, distinctly segmented larva. The parasite larva feeds externally, consuming the bee larva contents until only a flaccid skin remains. Small, round black fecal pellets are excreted during the entire larval period. The parasite pupates inside the bee cocoon and does not spin a cocoon of its own. Parasites emerge 14 days after the start of incubation and the sex ratio is 1:2 males to fe-



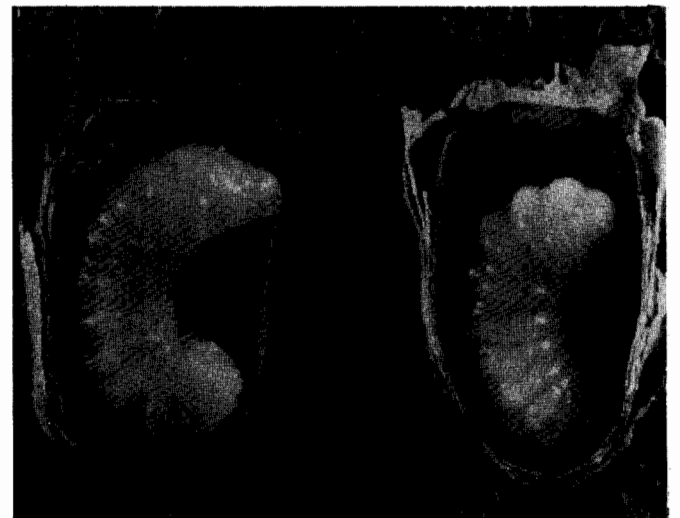
Redmarked sapygid cocoon

males. Egg to adult takes about 23 days and there is more than one generation per season.

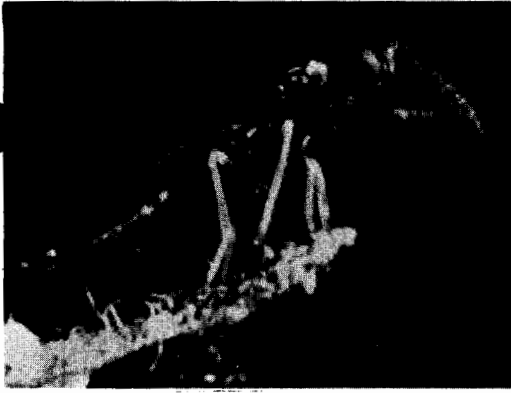
Parasitism up to 20% has occurred in Washington and up to 3% in Idaho, but the woodboring chalcid has not become a serious pest in any of the seed growing areas. It apparently has not become well adapted to its new host.



Woodboring chalcid adult



Woodboring chalcid larva (right) compared to bee larva



Minute chalcid adult



Minute chalcid larvae in bee pupa

Minute Chalcid, *Tetrastichus megachilidis*

The minute chalcid, a native, was first reported as quite destructive on the pale leafcutting bee, *Megachile concinna*, in the Southwest. The parasite has since adapted to *M. rotundata* and has spread with the bee into northwestern seed areas.

Adults are about 1/16 inch long and metallic blue. The body is elongate and slender and the lower hind legs are light yellow or white.

The female parasite inserts her ovipositor through the bee cell and deposits eggs within the body cavity of the bee larva. The parasite eggs hatch and larval development is completed inside the bee larva. Females can also successfully parasitize dark, nearly mature bee pupae. Egg to adult takes about 15 days and two generations can be completed before bees emerge as adults. The number of parasite larvae developing within a single bee larva ranges from 92-182, averaging 129. Parasites developing within single bee pupae range from 5-60, averaging 19.

The minute chalcid is potentially very destructive because its small size would enable it to enter cracks in drilled boards and groove boards and oviposit into the exposed bee cells. The ability to pass two complete generations in an incubation room and the tremendous rate of reproduction

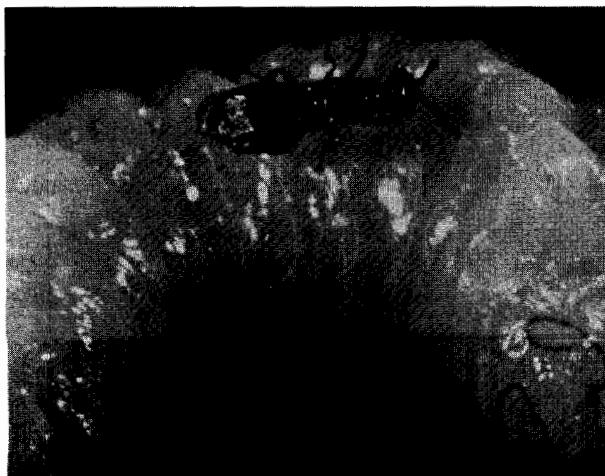
would allow it to reach epidemic populations in a short time. However, in Washington, parasitism has never exceeded 19% even when the parasite was confined on exposed bee cells. Nevada has reported infestation in the field of 3-4% and low infestations have been reported in other seed growing areas. Currently, infestations are increasing in some areas.

Omnivorous Chalcid, *Melittobia chalybii*

The omnivorous chalcid, a native, has been found parasitizing leafcutting bees in the seed growing areas of Alberta, Saskatchewan, Utah, Idaho, Oregon, Nevada, and California.

Adults are about 1/25 inch long and dark brown to black. Males lack wings and eyes while females are normal. Mating takes place within a bee cocoon and males never leave the cocoon. The female chews a hole in the bee cocoon and stings the bee, causing it to die. She feeds on the fluids from the wound and lays eggs on the surface of the bee. Eggs hatch in 2 days and the young parasites feed on the host fluids. Several generations may be passed on a single host and from 74-281 parasites (averaging 175) are produced. At room temperatures from egg to adult takes 17 days. The sex ratio is 1:23 males to females.

Omnivorous chalcid adult



Comparative larval sizes, left to right, Omnivorous Canadian, and Imported chalcids



The omnivorous chalcid is a common laboratory pest of leafcutting bees but has not become a serious pest in any of the commercial alfalfa seed growing areas of North America.

Other Chalcids, *Monodontomerus montivagus* and *Dibrachys confusus*

Monodontomerus montivagus and *Dibrachys confusus* were found in alfalfa leafcutting bees samples from many seed growing areas when the bee first became recognized as an effective alfalfa pollinator. However, they have not been reported in recent years and obviously are of little importance as natural enemies of the bee.

Cuckoo Bees, *Coelioxys* and *Stelis* spp.

There are six species of *Coelioxys* and one species of *Stelis* cuckoo bees that are parasitic on the alfalfa leafcutting bee. They belong to the leafcutting bee family Megachilidae and are very similar in appearance to the pollen-collecting leafcutting bees. Cuckoo bees are widely distributed in the western United States and Canada.

Cuckoo bee females lack pollen-collecting hairs on the underside of the abdomen and have a longer, more sharply pointed abdomen than the alfalfa leafcutting bee. Males are smaller than females and have a broader abdomen. Females can be recognized by their furtive flight in front of leafcutting bee nests as they attempt to enter tunnels to lay eggs.

In general, cuckoo bee females deposit an egg at the bottom of the host cell while it is being provisioned. The egg is colorless and has a swollen anterior end. Upon hatching, the first stage larva is small and delicate and remains in that stage about 11 hours. The second stage is elongate and cylindrical with a large head and large, hard sharp-pointed mandibles. The larva has a pair of horn-like dorsal spines which it uses to burrow to the surface of the provisions. The third stage looks the same as the second and usually kills the host or other cuckoo bee larvae. Fourth and fifth stages do not have large head capsules or long mandibles and appear similar to the leafcutting bee larva. After development is completed the mature larva spins a cocoon.

Cuckoo bees have been found as parasites of the alfalfa leafcutting bee in almost all seed growing areas, but until recently none have become a serious pest in the United States or Canada. In 1977 a report from the southern Idaho area in-



Adult cuckoo bee

dicated that 10% of the total bee emergence of a Canadian stock in an incubation room was cuckoo bees.

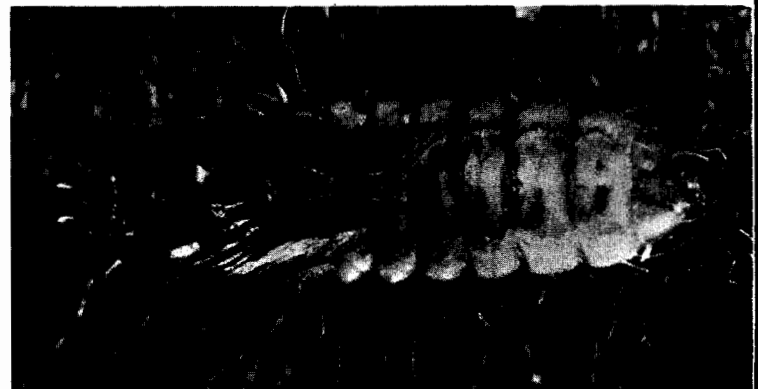
Dewy Bee Fly, *Anthrax irroratus*

The dewy bee fly is a native parasite that has been found in low numbers in all seed-producing areas of the United States.

Adults are dull black and lightly bristled with a scattering of dark markings on the wings. They are $\frac{1}{4}$ to $\frac{3}{8}$ inch long and bomber fly-like in body appearance. The female lays eggs by hovering in front of a bee tunnel and flipping its tail, throwing eggs into the entrance. Upon hatching, the active slender white larva crawls into a bee cell. It attacks a mature bee larva or pupa, feeds to maturity, and turns into a pupa within the bee cell. The pupa has a cream colored abdomen with black spots on the back and a black head. Two horny spines projecting from the head are used to break through the bee cell before the adult emerges.

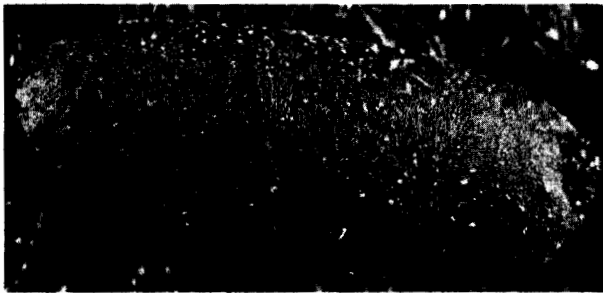


Dewy bee fly adult, above, pupa, below





Longtongued blister beetle adult, above, cocoon, below



A single sample from central Washington contained 3% dewy bee flies, but this parasite has been of little importance in other seed-growing areas.

Longtongued Blister Beetle (Sunflower Beetle), *Nemognatha lutea*

The blister beetle is a native species which occurs in all alfalfa seed-growing areas of North America. It is a parasite on larger wild bees, where it consumes only one host. However, it must consume two or three leafcutting bee larvae to complete development because of their smaller size.

Adults are usually yellowish tan. Size is variable and relates to the amount of food the larva eats. They range from 1/4 to 2/5 inch long and have a triangular shaped head. Adults are active flyers, having membranous hind wings and hardened forewings that entirely cover the abdomen. Mouthparts form a tube almost as long as the body. The tube is highly modified to take up nectar. Adults are commonly seen on sunflower, thistle, whitetop, and yarrow and may be found from March to October.

Eggs are laid in masses at the base of buds and flowers of host plants. They are about 1/40 inch long, yellow, and the egg mass is covered with an adhesive coating. The average number of eggs per mass is about 200 and each female usually lays only one egg mass. Eggs hatch into dark brown

triungulin (first stage) larvae which are about 1/25 inch long and have three claws on each leg. The triungulin has a small pad on the tip of the abdomen and is able to spin silk from the tip of the abdomen. Triungulins hatch and remain in the egg mass about 2-3 days before dispersing. They are quite active and search out and attach to any bee which visits the flower. After the bee returns to its nest, the triungulin detaches itself and begins feeding on the cell provisions. If the triungulin does not kill the bee egg, the next stage will.

The second through fourth stage parasite larvae are creamy white with a light brown head and will reach a length of 3/4 inch when mature. The larva appears grub-like and has two tube-like appendages on the top of the last segment. It consumes all the pollen in the first bee cell, then invades a second or third where it will consume pollen or bee larvae, whichever is present. Mature larvae form a hard dark brown cocoon-like coarctate, which is the overwintering stage. The coarctate is usually the only stage found in bee samples. From egg to overwintering coarctate takes about 30 days.

The sunflower beetle has destroyed up to 10% of the bee samples in central Washington seed areas and is often the major parasite found in wild trapped bees. In Alberta, Canada, it is more prevalent in areas adjacent to native prairie than in cultivated areas. The beetle has become more prevalent in all seed growing areas in recent years.

Predators and Nest Destroyers

Predator larvae actively search for their bee hosts and consume two or more bee larvae before reaching maturity (checkered flower beetle). Nest destroyers are attracted to the bees' pollen stores but often kill and consume bee larvae while tunnelling through cells in search of pollen (carpet beetles).

Checkered Flower Beetle, *Trichodes ornatus*

The checkered flower beetle is a native predator found in all seed growing areas of the western United States and Alberta, Canada. Adult beetles have two color strains, the yellow northern strain and the red southern strain. Early in the development of the leafcutting bee industry, the yellow strain was predominant in the Northwest.

However, recent large-scale importations of bees from south to north and back have mixed the color strains in most seed growing areas.

Adults are $\frac{1}{4}$ to $\frac{1}{2}$ inch long and shiny metallic blue with either bright red or yellow markings on the wing covers. They fly up to 0.4 mile to visit a large number of different flowers including yarrow, dog fennel, wild carrot, whitetop, and milkweed. They primarily feed on pollen but will also feed on flies or other small insects. Mating occurs on the flowers or on the leafcutting bee nests.

Beetles lay their eggs between leaf pieces in the tunnel plug, in narrow cracks in wood nest structures, or in cracks in the shelter walls. Eggs are pale pink, about $\frac{1}{16}$ inch long, and are laid singly in groups of up to 25 eggs. A single female can lay up to 87 eggs.

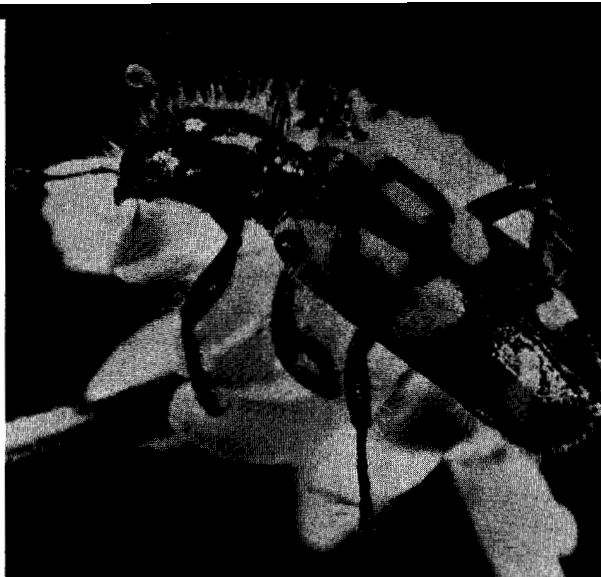
Newly hatched larvae are about $\frac{1}{16}$ inch long and are light red with a black head. They enter the nest tunnels, invade the bee cells, kill the bee eggs or larvae, and consume the pollen stores. The third stage leaves the original cell and burrows into adjacent cells where it feeds on all stages of bee larvae. Often up to seven beetle larvae can be found in a single nest tunnel, but one usually kills the rest.

Young checkered flower beetle larvae can be found in bee nests beginning in late June and extending into the winter months. Larvae hatching in June or July will develop into fourth stage or mature larvae by late summer or early fall.

The mature larva is pink to red with a black head capsule and has two hook-like structures on the tip of the abdomen. Mature larvae are about $\frac{2}{3}$ inch long and can chew through up to $\frac{1}{4}$ inch of wood. They usually leave the host cell and construct a reddish-brown papery pupal chamber, frequently sealed at the opening of the tunnel where they overwinter. There is a molt to the fifth stage in early spring which lasts about 2 weeks before the change to a pupa. The pupal stage lasts about 7 days and adults begin to emerge about 14 days after the start of incubation. Larvae can overwinter in all stages and will become active when temperatures exceed 38°F .

Usually beetle larvae will destroy all bee cells in a tunnel and move to a second tunnel to feed. One larva often consumes 8 cells and destroys more than 20. Larvae can be particularly damaging in loose cell operations during incubation. They penetrate numerous cells and kill bee larvae while searching for a suitable site to pupate.

Checkered flower beetles have destroyed up to



Checkered flour beetle adult, above, larva below



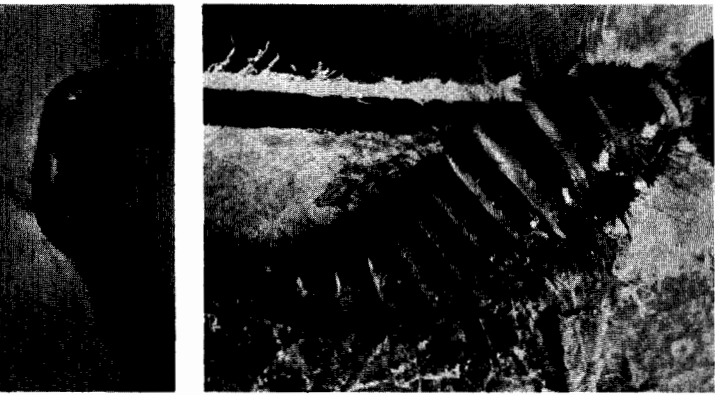
89% of the bees in samples from southeastern Washington. Average bee loss to beetles for all seed-growing areas in Washington was 27% in 1976, 35% in 1977, and 25% in 1978. Infestations of 33% have been reported in Oregon, 22% in Idaho, and 39% in Nevada. Losses in other seed growing areas have been much lower, but they have been increasing in recent years.

Smooth Carpet Beetle, *Trogoderma glabrum*

The smooth carpet beetle is a European nest destroyer that quickly adapted to the leafcutting bee in the mid-1960s. It was found in all alfalfa seed-growing areas and was recognized as the first major enemy of the bee. Although primarily attracted to pollen, it enters spun cocoons and kills both mature and immature bees as it moves through the tunnels.

Adults are oval and dull black with three lines of white bristles across the wing covers. Older beetles turn shiny black when the bristles are worn off. Males are $\frac{1}{9}$ inch and females $\frac{1}{7}$ inch long.

Females lay over 100 eggs in cracks or crevices usually in the back of the nest structures. An egg hatches in 6-7 days and the young larva is reddish brown and covered with long hairs. Its underside is white and there are long tufts of hair at the posterior end. The larva reaches a length of about $\frac{1}{4}$



Smooth carpet beetle adult (left), larva (right)

inch when mature. Life cycle takes 25-139 days depending on the temperature and food supply. The beetle overwinters in all stages and becomes active and larvae feed anytime the temperature exceeds 45°F. Adult beetles do not feed. They live 3 to 50 days depending on the temperature.

Adults are repelled by light and seek the darker areas of nest structures. They lay their eggs in cracks at the back of groove board nest structures or boxes of straws. Eggs hatch in 6-8 days and the larvae begin feeding from the back of the tunnel forward, consuming female bees first as they move through the tunnels. Samples with high beetle infestations have shown up to 10% reduction in female bees as compared to similar sample material with low infestations.

Bee samples from the Northwest in the late 1960s indicated up to 60% of the tunnels were infested with smooth carpet beetles. Better management practices and the adaptation of the American black flour beetle to the bee in the early to mid-1970s reduced carpet beetle populations severely (see black flour beetle).

Warehouse Beetle, *Trogoderma variabile*

The warehouse beetle is a European species first recorded on grain in California in 1954 and in Saskatchewan in 1958. It has since been found in leafcutting bee nests in all areas where they are raised. It is less destructive on bees than the smooth carpet beetle, but it will still penetrate spun cocoons and kill bee larvae when searching for pollen.

Adults are oval and dark brown with red-brown wing covers mottled by three rows of tan bristles. Males are 1/9 inch and females 1/7 inch long. Mature larvae are reddish brown, banded and



Warehouse beetle adult, left, larva, right

hairy, lighter in color than the smooth carpet beetle, and are about 1/5 inch long.

Warehouse beetles are found in all stages throughout the year. Females lay an average of 49 eggs, which hatch 7 days after laying. From egg to adult takes 45 days at 90°F.

The warehouse beetle is commonly found in leafcutter stocks but has been a problem only on rare occasions.

Carpet Beetles—*Trogoderma inclusum*, *T. simplex*, *T. sternale*, *Attagenus piceus*, *Anthrenus verbasci*, *A. occidens*, and *Megatoma variegata*

These carpet beetles have been found in alfalfa leafcutting bee nests on occasion in various seed growing areas. None have proved important as serious nest destroyers of the bee.

American Black Flour Beetle, *Tribolium audax*

The American black flour beetle is a native southwestern nest destroyer first found in leafcutting bee nests in Utah in 1964 and Washington in 1966. It since has spread with leafcutting bee commerce to all areas in which bees are raised.

Adults are dark brown to black and are 1/8 inch long. Females lay eggs in cracks of nest structures or in the pollen debris left by emerging adult bees. The larva is pale brown with a black head and dark brown bands across the body. It is about 3/8 inch long when mature and is quite active. At 86°F from egg to adult takes 41 days. The beetles feed on pollen masses in the nests and cannot penetrate spun cocoons. They could destroy bee eggs or young larvae if they invaded cells during the nesting season.

The American black flour beetle adapted quickly to the leafcutting bee in the late 1960s and growers were quite alarmed over the high numbers of beetles associated with bee nests. However the beetle turned out to be essentially harmless to the bees and, in some ways, beneficial. The beetle displaced and virtually eliminated carpet beetles by



American black flour beetle, left, larva, right

secreting a toxic substance (Quinone). Since the carpet beetle could penetrate cocoons and the black flour beetle could not, the displacement was beneficial to the bees. High populations of black flour beetles are directly related to the number of pollen masses in the nests which result from other mortality factors. They have not been shown to be a cause of bee mortality.

Giant Flour Beetle, *Tribolium brevicornis*

The giant flour beetle is a native southwestern nest destroyer first found in Washington in 1968 and in Nevada in 1970. It currently infests the commercial bee operations of all the western states.

Adults are 1/5 to 1/4 inch long and dark brown to black. Larvae are similar to black flour beetle larvae but are 1/3 to 1/2 inch long and more robust in appearance. From egg to adult takes 30 days at 85° F, and adults may live up to 2 years. The beetle larvae feed primarily on pollen but can penetrate bee cocoons.

Since 1972 the giant flour beetle has essentially displaced the American black flour beetle. It may have a competitive advantage since it can survive on bee larvae when pollen is absent whereas the black flour beetle cannot penetrate bee cocoons. Regardless, this displacement is not advantageous to the leafcutting bee. Not only does

the giant flour beetle feed on mature bee larvae but it evidently does not secrete toxic Quinones, for carpet beetles are again becoming more prevalent.

Giant flour beetle infestations of 50% have been reported in Nevada, 30% in Idaho and Oregon, and 11% in Washington. The giant flour beetle has become a major problem in all other seed-growing areas as well.

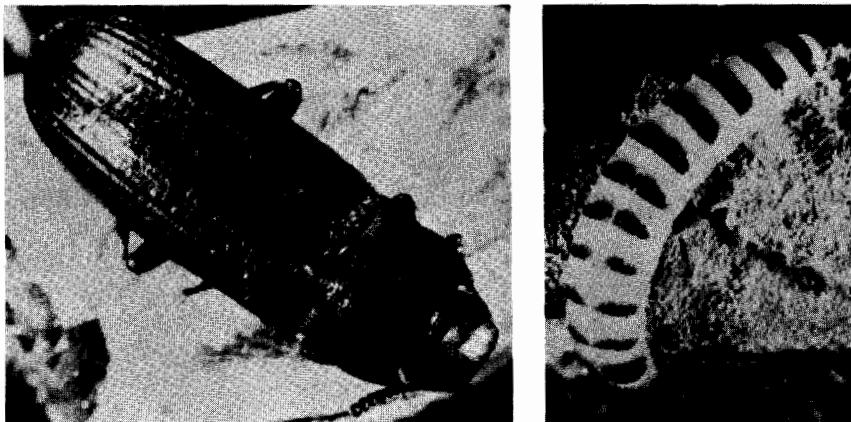
Red Flour Beetle, *Tribolium castaneum*; Sawtoothed Grain Beetle, *Oryzaephilus surinamensis*; and Rusty Grain Beetle, *Cryptolestes ferrugineus*

The red flour, sawtoothed, and rusty grain beetles are cosmopolitan in distribution and on occasion have been found in leafcutting bee nests in incubation. None have become significant pests under field conditions.

Cadelle, *Tenebriodes mauritanicus*

The cadelle is cosmopolitan in distribution and was first recorded in leafcutting bee shelters in Washington in 1964. It has since been found in all alfalfa seed growing areas.

Adult beetles are 1/3 to 1/2 inch long and shiny black to brown. Females insert white, slender, elongate eggs in cracks and crevices of bee nests. Eggs are laid in groups of 10-60 and a single female can lay over 1,300 eggs. Hatching takes place in 7-10 days and the white larvae feed on the pollen debris left by emerging adults. As the larvae develop they invade the bee tunnels and feed on the cell provisions and bee larvae. Mature larvae are about 3/4 inch long and grayish white with black head capsules. There are two black hooked structures at the tip of the abdomen. Lar-



Giant flour beetle adult, far left, larva, immediate left



Cadelle adult, far left, larva, immediate left

vae resemble the checkered flower beetle larvae except for coloration. Mature larvae tunnel into wood to pupate and the life cycle from egg to adult takes 70-90 days. Adult females commonly live for 1 year and some may live for 2 years. Both beetle adults and larvae will feed on bee larvae as well as pollen.

Cadelles are occasionally found in bee samples from most seed areas but have not exceeded 6% infestation in most areas except for northern California, where infestations up to 60% have been reported.

Indian Meal Moth, *Plodia interpunctella*

The Indian meal moth is native to Europe but has a worldwide distribution. It has been a common grain infesting and honeycomb infesting moth in the Pacific Northwest for many years. The moth is attracted to the pollen in leafcutting bee nests and is found in almost all seed growing areas.

Adults have a pale gray body and a wingspan of nearly $\frac{3}{4}$ inch. The outer $\frac{2}{3}$ of the forewings are dark red-brown or coppery while the inner portion of the wings are whitish gray. A female moth will lay 100-300 eggs singly or in groups on the surface of the bee nests. The eggs hatch in 1-2 days and the larvae enter the tunnels searching for pollen. Larvae are pinkish white and about $\frac{1}{2}$ inch long when mature. They tunnel through bee cells and feed on both the cell provisions and bee larvae. Considerable webbing is always found in cells and tunnels the larvae have invaded. Mature larvae spin a silken cocoon within the tunnels and change to light brown pupae. The life cycle takes about 6-8 weeks and breeding can be continuous when bees are not placed in cold storage.

Indian meal moth infestations have not exceeded 3% in most seed growing areas but on occasion have caused more serious damage to loose cells in incubation rooms.



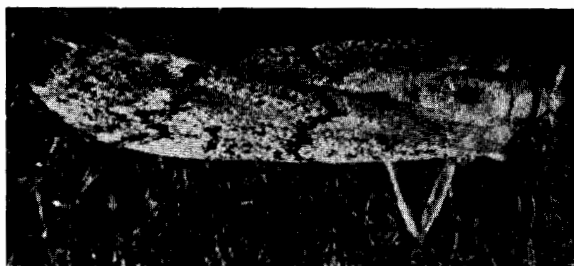
Indian meal moth adult, left, larva, right

Dried Fruit Moth, *Vitula edmandsae*

The dried fruit moth is a native species commonly found in nests of many different wild bees and honey bees. The moth has been found in leafcutting bees nests in most United States alfalfa seed growing areas, but has not been reported in Canada.

Adult moths are light gray with darker gray irregular markings on the wings. Wingspan is $\frac{3}{4}$ inch and the body is $\frac{1}{3}$ to $\frac{2}{5}$ inch long. Female moths live for about 17 days and lay from 100-325 eggs on the surface or in crevices of the bee nest. Larvae invade the bee tunnels and immediately begin building webbed shelters in the cells from which they protrude while feeding. When disturbed, the larvae withdraw into the webbed shelter. Larvae work through the bee tunnels consuming both pollen and bee larvae. Larvae are greenish white with pale brown heads when mature and are about $\frac{5}{8}$ inch long. Mature larvae spin silken cocoons within the tunnels and change to light brown pupae. The life cycle takes 38-47 days and breeding is continuous under incubation conditions.

The dried fruit moth has been found on occasion in leafcutting bees in almost all areas but has not been as common as the Indian meal moth. Infestations have been confined primarily to the



Dried fruit moth adult

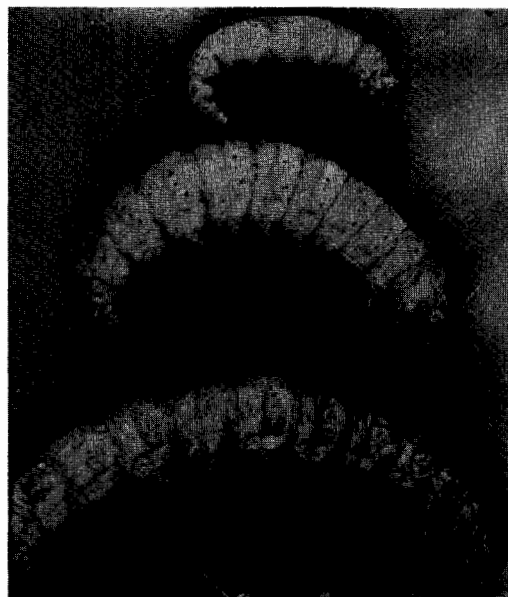
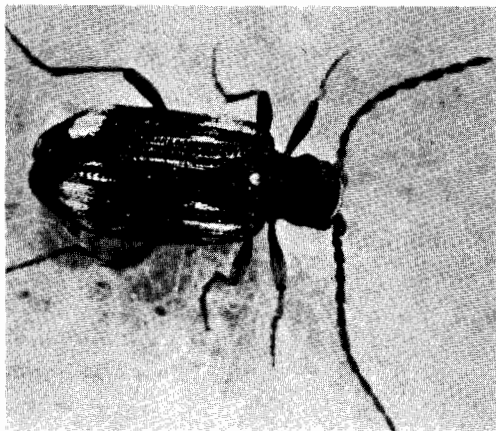
incubation room and have been rarely found in the field.

California Spider Beetle, *Ptinus californicus*

The California spider beetle is a native species from the Southwest that was apparently brought into the Pacific Northwest by leafcutting bee commerce. It was first collected in Washington in 1967 and had been reported from all Northwest seed growing areas by the mid-1970s.

The adult is dark gray to black with four white markings on the wing covers. It is 1/5 inch long and the antennae are longer than the length of the body. It has wings but does not fly.

Beetles overwinter as adults and emerge from leafcutting bee nests at the beginning of incubation. They mate and return to the bee nests to lay eggs on the pollen masses of bee larvae that have died before reaching maturity. Adults live about 6 weeks and females lay 40-50 eggs, usually in batches of 5-6 per bee cell. Eggs are laid in crevices of the pollen mass or between the pollen and the cell wall. Eggs hatch in 18-20 days and the young larvae grow quite rapidly, usually becoming covered with long, thread-like strands of fecal material. If a live immature bee larva is present, it can be surrounded by the fecal material and prevented from reaching the pollen stores, resulting in its starvation and death.



Dried fruit moth larvae

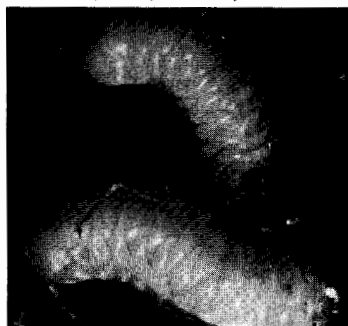
Larvae are white and grub-shaped and form leathery or brittle cocoons at maturity. Mature larvae pupate, change to adults, and overwinter as adults within the cocoon. Egg to adult takes about 110 days. In bee stocks not held in cold storage, adults emerge in February to late March.

The beetle reached high populations in a few areas of southern Idaho in 1970. It has been found in Washington in incubation rooms in exceedingly high numbers in association with bee boards imported from southern Idaho but has rarely been successful in the field. The beetle evidently has not adapted to the more arid regions of the seed growing industry.

Ants, *Formica*; European Earwig, *Forficula auricularia*; and Yellowjackets, *Vespula*

Ants and yellowjackets will occasionally visit leafcutting bees nests and feed on adult bees, larvae, or the nest provisions. Earwigs normally feed only on the nest provisions. All are sporadic problems restricted to a few seed areas.

California spider beetle
adult, left, larvae, below



Effectiveness of Different Control Measures* on Individual Species of Natural Enemies

Control Methods	Chalcid Parasites	Carpet, Flour, Spider, Cadelle Beetles	Sapygids	Flour Moth	Checkered Flower Beetles	Blister Beetles	Cuckoo Bees, Bee Flies	Yellow-jackets	Ants, Earwigs
Phasing out	2	3	1	3	1	1	1	0	0
Phase out traps	1	2	2	1	3, 1†	1	0	0	0
Cold storage 35-38°F	0	2	0	2	2	0	0	0	2
Black lights	3	2‡	2	3	0	0	0	0	0
Sprays	1	2	0	1	1	0	0	0	0
Baits	0	2	0	0	0	0	0	3	1
CFB & sapygid night traps	0	1	2	0	3	0	0	0	0
Fly Strips	2	1	0	2	0	0	0	0	0
Mating station traps	0	0	2	0	0	0	0	0	0
Sawdust coverings	3	0	0	0	0	0	0	0	0
Sorting, tumbling	0	3	0	2	2	2	0	0	0
Insecticide vapor strip§	3	1	0	2	0	0	0	0	0
Squashing	0	1	2	0	2	0	1	1	1
Insecticide paint, oil baths, grease	0	1	0	0	0	0	0	0	3
Sticky boards	2	2	1	2	0	0	0	0	0
Vacuuming	3	1	1	1	0	0	0	0	0

*0—no control, 1—poor control, 2—fair control, 3—good control, 4—excellent control.

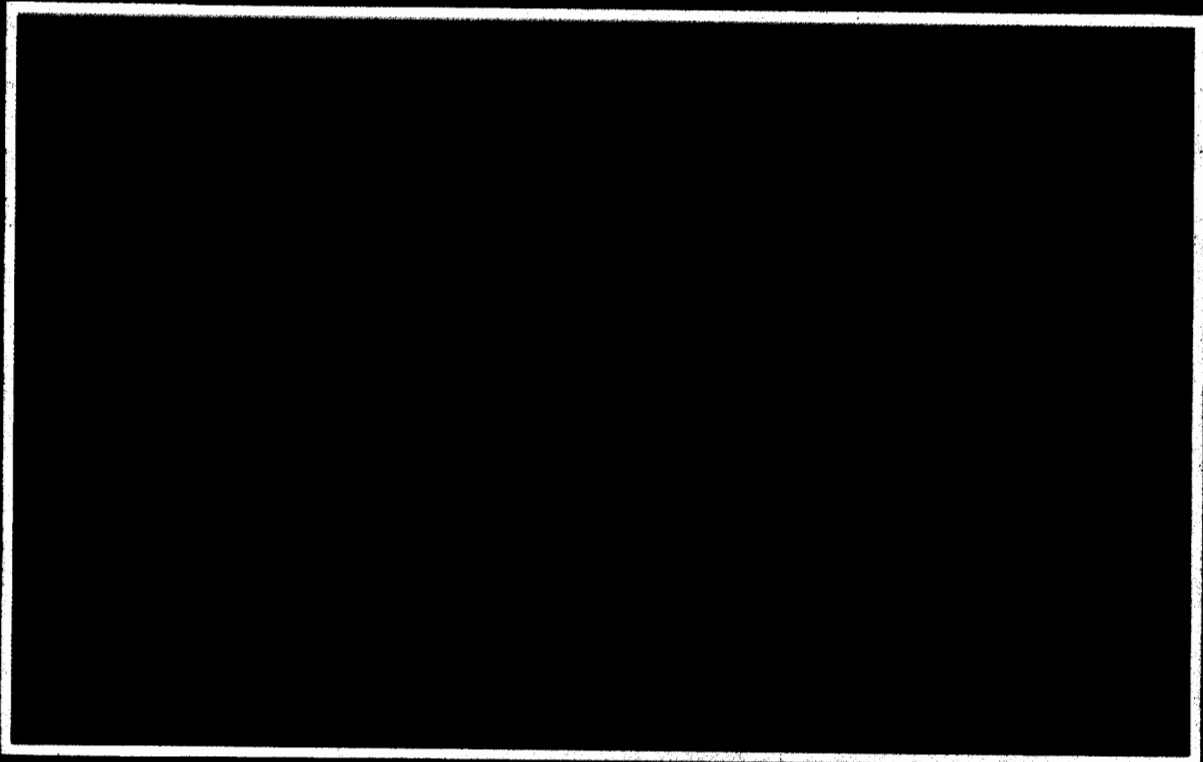
†3 for Larson type, 1 for others.

‡Except giant flour beetles.

§Use extreme caution. Use one-half normal rate of insecticide vapor strip beginning the 9th and ending the 13th day of incubation. After removing vapor strips, open incubation room and air with circulating fans for 24 hours before resuming incubation.

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PHOTO CREDITS: Canadian chalcid adult and larvae (p. 5) and comparative larval sizes (p. 7) from Research Station, Canadian Department of Agriculture, Lethbridge, Alberta. Checkered flower beetle larva (p. 10) from Roger D. Akre, Department of Entomology, Washington State University, Pullman. California spider beetle larvae (p. 14) from Bee Biology and Systematics Laboratory, USDA, Logan, Utah. Remainder from Jack D. Eves, AgReCon, Prosser, Washington.



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