MANAGEMENT OF THE ALFALFA LEAFCUTTING BEE:

IN NORTHWESTERN CANADA

Contribution No. NRG 84-21, Agriculture Canada,

Beaverlodge

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1. ALFALFA POLLINATION AND SEED PRODUCTION IN NORTHWESTERN CANADA

Alfalfa has been grown for seed in northwestern Canada for a number of years. Records of alfalfa seed production in the Peace River region of northern Alberta indicate that the average annual production for the period 1935-1955 was 1,500 tonnes. To produce seed, alfalfa like other forage legumes requires an insect for pollination. Alfalfa seed fields in the Peace were traditionally surrounded by uncleared land -- the natural habitat of bumble bees, native leafcutting bees and other insect pollinators. Large acreages of bush were cleared for cultivation in the mid 1950's thus resulting in a depletion of the natural habitat for insect pollinators. This coincided with a decrease in alfalfa seed production. Annual production between 1955-1958 was 50 tonnes. The introduction of the leafcutting bee, *Megachile rotundata* Fab. into the region in the early 1970's and the development of a successful management system for the bee in the north by scientists at Agriculture Canada's Beaverlodge Research Station and Fort Vermilion Sub-Station resulted in the successful re-establishment of the alfalfa seed industry in northwestern Canada in the late 1970's.

region. Leafcutting bee cells from northwestern Canada are used extensively in the region and have found their way to international markets - a far cry from the 400-500 cells that were first introduced into the Peace River region in 1966.

3. LIFE CYCLE OF Megachile Rotundata Fab. -- THE LEAFCUTTING BEE

Megachile rotundata is a reliable insect pollinator because it is gregarious - i.e., large numbers of this species can be made to nest in a given area with the provision of man-made nesting material. During the growing season, female bees construct cells in nesting tunnels with oblong-shaped leaf cuttings. These cells are then provisioned with nectar and pollen that the bee collects from the alfalfa florets. It is during this process of nectar and pollen collection that the bee transfers pollen from the florets of one plant to the florets of another plant (cross pollination) - a pre-requisite for good seed set. The female bee then lays an egg in each cell and uses more leafcuttings to cap the cell. The egg hatches in its cell, and the larva feeds on the nectar and pollen. During this developmental phase, the larva has a blind gut and cannot defecate and contaminate the cell. After eating all the nectar and pollen, the larva deposits its fecal pellets at the end of the cell and separates itself from this fecal matter by spinning a tough silken cocoon. The full grown larva spends the winter in this cocoon.

The female bee constructs the first cell at the back end of the tunnel. A total of 7 to 9 cells are constructed in each tunnel. Commercially manufactured wood and polystyrene nesting tunnels, that are used predominately in northwestern Canada, vary from 8 to 10 cm in length. After all the cells in a tunnel have been constructed, tunnels are capped with a number of leaf cuttings. One to three tunnels are usually filled by a bee during an average growing season in northwestern Canada.

Adult bees die at the end of the growing season. Nesting tunnels are brought indoors in the fall and are stripped after 4 to 6 weeks of storage at 18°C to 20°C. This initial storage is essential to ensure that most of the larvae complete development and spin cocoons prior to removal of cells from the nesting material. These cells are then stored at 5°C during the winter months. In the following spring, cells are incubated at 30°C. Incubation is timed to enable the emergence of adult bees to coincide with bloom on the alfalfa crop.

4. MANAGEMENT OF THE LEAFCUTTING BEE: THE ANNUAL ROUTINE

(i) Obtaining leafcutting bee cells

It is important to purchase good quality cells - i.e., a large percentage should be viable and not contaminated by diseases or infected by parasites. It is recommended that a quality test be done, by an unbiased third party, on the bees you wish to purchase prior to finalization of a sale. The Cocoon Testing Centre at Brooks, Alberta provides such a service.

Cells can be purchased from producers in western Canada. In most years, cells that have been produced in northwestern Canada are available for sale. Studies have shown that bees brought into the area from lower latitudes gradually adapt to foraging under the environmental conditions of northwestern Canada and until this occurs, they are not as productive as the bees produced locally in the first few generations of use. If you wish to obtain bees from outside Canada, a permit from Agriculture Canada, Plant Quarantine Division, is required.

(ii) Incubation

A controlled-temperature room in which temperatures between 5°C and 30°C and a relative humidity (RH) range of 50 to 70 percent can be maintained is ideal. This will allow for:

- the incubation of bees at 30°C and a RH of about 70 percent from June to early July;
- cool storage for bees in nesting boxes at 15 to 16°C with a RH of about 50 percent from early August to mid-November when larvae are spinning cocoons;

- cold storage at 5°C at a RH of about 50 percent for cells (stored in honey pails or other mouse-proof containers) that have been stripped from nesting material from November to June.

Depending on the size of the pollinating operation and the crops to be pollinated - e.g., bloom is likely to be delayed in some crops and/or areas as compared to others hence bees are required 5 to 7 days later -- it may be advisable to have two smaller rooms instead of one large room. The former would facilitate commencement of incubation at different times. Some factors - e.g., control measures for emerging chalcid parasites between days 8 to 12 - warrant that two batches of cells, each with a different requirement for date of emergence of bees, not be incubated in the same room.

It is recommended that this controlled-temperature room have an insulated door and that the walls and ceiling be adequately insulated. Minimum R-values of 10 and 30 for the walls and ceiling, respectively, are desirable. Other requirements are a compressor for cooling, baseboard heaters, two thermostats with a control sensitivity of $\pm$ 0.5°C - one for refrigeration and one for heating, and a humidifier with a capacity of 10 to 20 litres a day. In addition to the above, the electric wiring should be adequate to operate lights, fans, a time clock and other electrical equipment as required, e.g., uv and black lights for attracting parasites, a vacuum cleaner etc. The fan and lights must be on a different circuit from the heating equipment so that they can be left on when the thermostatically controlled heat circulating unit is off. Maximum-minimum thermometers could be placed in the room to check temperatures. The installation of an alarm system to inform the operator when temperatures exceed the critical high and low levels of safe operation is recommended.

The size of the controlled environment room will depend on the size of the operation. As a guideline, a 3.6 x 3.6 m (12 x 12') room is adequate for 2 million bees. There are other alternatives such as the use of chick incubators for incubation of cells and freezers for storage of cells at 5°C.

Cells are usually incubated in trays. Trays vary in size and can be made or purchased. Trays are usually constructed to hold 20,000 cells to correspond to the recommended stocking rate in the area -- 20,000 per acre equivalent to 50,000 per hectar. Cells should not be spread more than 5 cm (2") deep in trays. A 56 cm (22") x 61 cm (24") x 7.6 cm (3") deep plywood tray is sufficient for 20,000 cells. A 56 x 51 cm (22 x 20") wire screen attached to a 56 x 10 cm (22 x 4") plywood strip is used to cover the tray. Trays are usually stacked on a rack for convenient placement and transfer into and out of the controlled-temperature room. A minimum free space of 30 cm (12") at the top and bottom of the rack and 5 cm (2") between trays is required for air circulation to remove heat released by the bees (during hatch) and vapours from introduced pest strips during incubation. Consequently, if trays are stacked one on top of the other, a build-up of lethal temperatures and/or toxic fumes will result in high levels of bee mortality. Interspersing 2 x 4" lumber strips between incubation trays will facilitate adequate air circulation in cases where a rack for stacking trays is not available.

Incubation is usually started 16 to 18 days before 10 percent crop bloom. Males start emerging on day 19 and females usually emerge after day 20. Emergence is usually complete by day 29 to 30.

If the weather is inclement, bee emergence may be delayed for 7 to 10 days by lowering the temperature of the incubator to 10-15^{o}C prior to or during emergence. It is important to monitor temperatures in the incubation trays as changes in ambient air temperature do not always alter temperatures in the trays. As an alternative, emerged adult bees can be held at 6^{o}C for 2 days or at temperatures ranging from 11 to 16^{o}C for up to 10 days without any appreciable adverse effect.

Beekeepers who operate within a range of 15 to 20 miles could use the system of incubation originated by the Agriculture Canada Research Station at Melfort (See Appendix 1). The basic principle is building special incubators that are housed in a room at 30^{o}C with a RH of approximately 70 percent with forced air for ventilation. The emerging bees are collected in trays and taken daily to field shelters. This system insures maximum emergence of adults, provides an excellent way to control the introduction of chalcid parasites and predators into the field and insures that cells are not left in the field with the accompanying danger of spread of disease.

(iii) <u>Field Shelters</u>

Ultraviolet resistant polyethylene of 4 to 6 ml thickness or fibreglass shelters are used almost exclusively in the northern seed growing areas of British Columbia, Alberta, Saskatchewan and Manitoba. Temperatures are usually higher inside as compared with that on the outside of these shelters and this is important to activate the bees into flight and foraging. Furthermore, it is mandatory that the entrance to the shelter face south. The latter permits the face of the hives to be exposed to sunlight for extended periods thereby permitting a more even distribution of bees in all the hives in the shelter.

Shelters are either square, rectangular or triangular (A-frame). They are usually made of appropriately sized panels that are stored flat in the off-season and during the growing season, are put together in the field with double-headed nails. In a majority of cases, shelters are usually small and contain nesting material for 20,000 (in a 4' x 4' shelter) or 40,000 (in a 4 x 8' shelter) bees -- the recommended stocking rate for 1 and 2 acres, respectively. Studies are being conducted in the Peace River region of northern Alberta on the use of larger shelters to facilitate pollination of up to 8 acres from one shelter. Prior to the installation of shelters in the field, 3 m (10 ft) pathways from the edge of the crop to each shelter are mowed to permit vehicle access to the shelter with minimal damage to the crop. Shelters are usually set up in the field in June and are removed after the nesting material is taken indoors sometime in late August or early September. The shelters are relatively light and should be firmly anchored into the ground.

Drift or loss of bees from the vicinity of the shelters could be a problem with small shelters. Bees normally drift to the south or west and to end shelters in a row. They also drift to higher elevations and from open fields to sheltered areas. They have been observed to overfly alfalfa for such crops as alsike clover and birdsfoot trefoil. Drift can be minimised by ensuring that there is enough crop bloom before bees are introduced into the field.

(iv) Nesting material

Commercially produced grooved wood and polystyrene nesting boards are the predominantly used nesting materials. These grooved boards are firmly held together in a 30.5 x 56 cm (12 x 22") plywood box or hive to form nesting tunnels for the bees (in some commercial operations 30.5 x 112 cm hives are used for polystyrene nesting boards). The recommended stocking rate is 20,000 cells per acre and a total of about 9,000 tunnels are usually sufficient for 20,000 emerging cells with a 2:1 male to female ratio - i.e., about 1.4 tunnels for each female bee.

Kiln dried white pine and ponderosa pine are generally used in the manufacture of wood nesting boards. They are available in 2 ft. (∿ 61 cm) or 4 ft. (∿ 122 cm) lengths, 5 1/4" (∿ 13 cm) width and 3/8" (∿ 0.95 cm) thickness. Thirteen tunnels are present across the width of the board each about 1/4" (∿ 0.64 cm) in diameter. These 2 ft. or 4 ft. lengths are cut into six or twelve 4" sections, respectively. Thus, these wood tunnels are 4" long and 1/4" in diameter. A wood hive has 1378 tunnels (106 boards x 13 holes) and weighs about 45 lbs. (18 kg). Six hives i.e., 8,268 nesting tunnels are made available for each acre of crop to be pollinated.

Most of the polystyrene boards used are available in one length - 3 3/4" (∿ 9.5 cm). They are 11 3/4" (∿ 30 cm) wide and 3/8" (∿ 9.5 cm) thick. Thirty tunnels are contained across the width of the board, each 3 3/4" long. Fifteen of these tunnels are 8/32" (0.64 cm) in diameter and the other fifteen are 9/32" (∿ 0.71 cm) in diameter. A 30.5 x 56 cm polystyrene hive has 1500 tunnels (50 boards x 30 holes) and weighs about

15 lbs. (7 kg). Six hives, i.e., 9,000 nesting tunnels are made available for each acre of crop to be pollinated.

The face of the nesting boards should be sprayed with a black or dark stain with a linseed oil base. After the dark stain is dry, fine line patterns in a contrasting stain (e.g., blue, beige or green) should be sprayed or painted on about one-third of the area. These patterns (usually letters of the alphabet) assist bees in orientation.

Disposable nesting material made of fluted craft paper with tunnels 3" (~ 8 cm) long and 7/32" (~0.56 cm) in diameter are now being marketed in the U.S. under the Rol-A-Board trademark. Rol-A-Board is sold as a pollinating unit. Each unit consists of four rolls (each with 1,500 holes) attached to a backing made of cardboard. To date, this nesting material has not been used extensively in northwestern Canada.

(vi) Introduction of bees into alfalfa seed fields

Incubation trays are taken out into the field when about 40 percent of the male bees and about 5 to 10 percent of the female bees have emerged. Ideally, this should coincide with about 10 percent bloom of the crop.

The length of time for completion of emergence is dependent on temperature. Thus, if bees are placed in the field when about 40 percent of the males have emerged and the daytime temperatures are in the 25 to 30°C range, most of the pupae will usually complete development and chew their way out of their cells in 7 to 10 days. However, if temperatures stay below 19°C for up to 5 days, emergence will be considerably delayed. To prevent this from happening, trays should be brought indoors and reincubated for 1 to 2 days at 30°C. Also if incubation facilities are in close proximity to the field, trays could be brought indoors and incubated overnight on a daily basis. Bee emergence is then completed within a week. However, in most instances this is not practically feasible, and trays are kept in the shelters for up to 3 weeks to facilitate maximum emergence. Extremes in temperature at this stage is detrimental to developing pupa. It has been shown that significant mortality occurs after 9 days continuous exposure to low temperatures between 4 to 5°C. At the other extreme, developing pupae can withstand temperatures up to 45°C for up to one hour with no significant reduction in emergence. However, emergence is significantly reduced if this exposure time at 45°C is increased to 2 or 3 hours. An increase in temperature to 50°C for any length of time results in total mortality. It is therefore advisable to ensure that incubation trays are kept away from such temperature extremes. For example, if air temperatures inside the shelter are above 38°C incubation trays could be placed outside the shelter, preferably in the shade. Air temperatures inside polyethylene and fibreglass shelters are higher than those outside the shelter. Emerging bees are able to cope with extremes of temperature more so than pupae that have not completed development. It should be noted that in literature to date, the effects of extremes of temperature on bee emergence have been recorded but these temperature effects on subsequent bee vigor, life span or reproductive behaviour have not been documented. It is therefore advisable to keep developing pupae away from extremes of temperature whenever practically feasible.

Before trays are taken out to the field, dampen cells in trays to increase humidity. Many unemerged adults die if cells in trays are too dry and tough for the bees to chew their way out. For any distance travelling, a darkened van or truck with provision for ventillation is preferred. If temperatures are too high, ice may be required for cooling. Temperatures between 15 to 20°C during transportation are recommended.

The metal wire screen on top of the tray is usually covered with a layer of coroplast or wax paper to discourage other insects from getting into the tray. Trays are usually left in the shelters for up to 2 weeks to facilitate maximum emergence. During this period, female bees often use old cells in the trays for nesting. After emergence is deemed complete, the cells from each tray should be transferred to a large bag or other container to allow the female bees to fly off before removing the cells from the field. This is best done under warm sunny conditions conducive to flight. Empty cells should be incinerated and disposed of away from field shelters. This is an essential hygiene measure for the prevention of the spread of diseases, parasites and predators of the bee.

In cases where the 'bleed off' system of incubation is used, newly emerged bees are taken out, daily or twice daily as required, in trays to be released into the field. This is done regularly for about two weeks.

(vii) Moving bees during the growing season

Moving bees from one field to another is not recommended. In most instances, pollination is seldom completed in one field to warrant moving bees to another field in the short growing season in northwest Canada. However, if for some reason bees have to be moved, it is best to do so in the early hours of the morning between 0300 and 0500 hours. Temperatures at this time are usually below 15°C and the bees are immobilized in their nesting tunnels. If handled carefully, nesting material can be moved with minimum damage to the bees. However, large bee losses can be anticipated if domiciles are moved at any time during the growing season because bees in northwestern Canada do not consistently return to their nesting tunnels at night. It has been speculated that the long days at higher latitudes encourage the bees to forage late into the day and sudden drops in temperature at this time paralyses the insect on the crop, away from its nesting tunnels. Attempts to recover a large number of bees from one field for transfer to another can be facilitated by the provision of unused nesting material for 1 to 2 weeks after the initial transfer of nesting material has been made to help collect the 'stragglers.'

(viii) Fall and winter management

The adult leafcutting bee population in field shelters gradually decreases by early to mid-August. By then, most of the nesting tunnels have been filled and capped with leaf cuttings. Nesting boxes are then ready to be brought indoors for the winter. The following schedule is recommended for the successful fall and winter management of leafcutting bees.

1. Nesting boxes should be stored at 18 to 20°C for six to eight weeks to allow the larva in each cell to complete its development, i.e., spin a cocoon or reach the diapause stage.
2. After about six weeks, select a few cells at random from each nesting box. Gently scrape the flat end of each cell and examine the exposed tissue. If the tissue is brown then development has been completed

the larvae has spun its cocoon. If this has occurred in a large percentage of cells, then the cells are ready to be removed or stripped from the nesting material.

3. A small percentage of cells, probably containing the earliest laid eggs may not go into diapause. Development will continue and a second generation of bees will be produced in late August. This second generation hatch can be kept to a minimum by bringing nesting boxes indoors when most of the nesting tunnels are filled. Second generation bees will stop developing and will die when the storage temperature is lowered.
4. Strip cells from nesting boards. Ensure that cells are not crushed or damaged with mechanical strippers.
5. Tumble cells thoroughly and remove excess leaf debris. Often, insects like the checkered flower beetle are present in the leaf material and can be removed during tumbling. Ensure that most of the cells are broken up individually. Empty cells are light and a large percentage can be removed during tumbling.
6. Cells should be tumbled outdoors or in a building with adequate ventilation. It is recommended that the operator(s) use face masks as an added protection against dust and mold spores that are released into the air during the process of tumbling cells.
7. Cells should be placed in containers and stored at 5^{o}C. Seal containers adequately to ensure that cells do not absorb moisture. Check cells periodically during storage period.
8. Cells can be sampled for quality after 10 to 12 weeks of storage at

$5^{o}C$.

9. In the spring, cells are incubated at $30^{o}C$ and the emergence of leaf cutting bees is timed to coincide with bloom of the alfalfa crop.

An annual routine for managing leafcutting bees

The following is a suggested annual routine for managing leafcutting bees in a majority of the forage legume seed growing areas of northwest Canada. The suggested time frame represents an average value for most areas.

No.	Job to be accomplished	Approximate time schedule
1.	Obtaining leafcutting bee cells	November of previous year to March of the year that cells will be used.
2.	Disinfecting nesting hives and assemblying nesting material	April-May
3.	(See Section 5(8) for methods of disinfection). Selecting suitable fields for pollination	April-June
4.	Mowing pathways to shelters	Mid to late June
5.	Spraying crop for harmful insects	June
6.	Preparing cells for incubation	May - early June

No.	Job to be accomplished	Approximate time schedule
7.	Setting up shelters	June - after crop spraying completed
8.	Incubating cells	June
9.	Take bees out to field	July
10.	Remove incubation trays from field	By last week in July
11.	Remove nesting material from field	Nesting boxes should be brought indoors after 75 percent of the tunnels in each box have been filled All nesting material should be brought indoor by late August - early September
12.	Remove shelters from field	Mid to late September

No.	Job to be accomplished	Approximate time schedule
13.	Store nesting material indoors until cells are ready to be removed from nesting tunnels	August to early October
14.	Removal of cells or stripping from nesting material	October - November
15.	Tumbling cells	November prior to storage
16.	Overwinter storage at 5^{O}C	November - June
17.	Cell quality test	December - March
18.	Repair/disinfection of shelters and hives	October - December
19.	(See Section 5(8) for methods of disinfection).	
	Storage of shelters and hives	After 18 above is complete December - May

5. DISEASES AND PARASITES AND PREDATORS OF THE LEAFCUTTING BEE

A number of investigations have dealt with chalkbrood - perhaps the predominantly studied disease of the bee at this point in time. Chalkbrood can result in heavy bee losses in a relatively short period of time. This disease is prevalent in some of the alfalfa seed producing regions in the western U.S. and, more recently, has been recorded in some provinces inwestern Canada. The cause and symptoms of chalkbrood and measures for controlling or possibly eradicating this disease are detailed below.

(1) Chalkbrood - the disease and causative agent

Chalkbrood is a fungal disease of the larva of the leafcutting bee. The fungus *Ascosphaera aggregata* has been identified as the causative agent. The chalkbrood disease of honey bee larvae is caused by a different species of fungus which does not cause disease in the leafcutting bee. Other species of *Ascophaera* are commonly found in leafcutting bee cells, usually growing on pollen stores. These other species do not appear to be pathogenic to the bee.

(2) The spread of chalkbrood

Chalkbrood is spread through the spores of the fungus. These spores can survive and remain infective for many years. They can be introduced into an area with contaminated equipment or nesting material or by infected leafcutting bee cells and leaf material.

(3) The symptoms of a chalkbrood-infected larva

Infected larvae shrink and harden. The interior of the larvae turns chalk-white from the growth of the fungus and the outer surface becomes glossy or cellophene-like. Some of the dead larvae remain white, but others usually become dark grey to black. Cells containing such larvae are fragile and collapse easily.

(4) Methods of larval infection

Only larvae are infected by chalkbrood. A healthy larva is infected when it eats pollen that is contaminated with chalkbrood spores. These spores germinate and the fungus grows inside the gut of the larva, and in later stages moves through the wall of the gut and into the body cavity. The fungus eventually forms black spore cysts under the skin of the larva. At maturity the cysts shatter and disperse a large number of spores. The continued growth of the fungus results in the death of the larva.

(5) Contamination of pollen provisions with chalkbrood spores

If emerging leafcutting bees crawl through infected leaf material or chew through infected larva to emerge, they become covered with massive numbers of spores that adhereto their body hairs. These adults then contaminate their mates, eggs and pollen provisions. Adult bees are carriers of chalkbrood spores.

(6) Possible prevention of entry of chalkbrood infected material into an area

a) Ensure that each consignment of cells purchased has been screened for the presence of chalkbrood.

b) If cells are brought into an area from an outside location, run the consignment separately and isolate the offspring until they are screened for chalkbrood.

(c) Disinfect all nesting material, equipment and storage facilities annually. See No. (8).

(d) Use the loose cell management system. Tumble cells to break into individual cells. Chalkbrood cadavers are light and a large percentage can be removed during tumbling. Breaking up the cells will ensure that the emerging bees do not have to chew through chalkbrood cadavers to emerge. An emerging bee can be dusted with up to 300 million spores when it chews through an infected cadaver.

(e) If equipment has to be shared, ensure that it is properly disinfected before and after use. See No. (8). The sharing of equipment should be avoided where possible.

(f) After bee emergence is complete, incinerate all leaf debris from incubation trays.

(g) Relocate shelters in fields each year to prevent buildup of fungal spores around shelters. Spray shelters and surrounding ground with a 5% sodium hypochlorite solution (household bleach) after nesting boxes are taken indoors.

(7) <u>For control and possible eradication of chalkbrood use the following in conjunction with prevention methods</u>

a) Remove infected cells, nesting material and incubation trays from area.

b) Disinfect storage facilities and all equipment that cannot be moved from area. See No. (8).

c) In the early spring burn top growth in all fields where infected bees were used for pollination in the previous growing season.

d) If possible, do not use leafcutting bees or other pollinators in the above fields forthe following growing season.

e) If (d) above is implemented, then lcoate trap nests in the field to ascertain whether bees are still present in the area and screen samples of their offspring, if present in these trap nests, for chalkbrood.

f) If 'clean' leafcutting bees have to be introduced into a field where chalkbrood-infected cells were found in the previous growing season, follow procedures recommended for prevention of chalkbrood. See No. (6).

g) If the offspring of the above are disease free, sterilize cells before use as an added precaution. See No. (8). If offsprings are infected, then remove from area.

(8) Disinfection of leafcutting bee cells and equipment for the prevention and control of chalkbrood

Chalkbrood is caused by a fungus or mold and any practice used to control mold will also help to control chalkbrood.

a) Disinfection of leafcutting bee cells

Leafcutting bee cells can be surface sterilized by immersing them in a 3% sodium hypochlorite (household bleach) solution for 1 to 2 minutes. The cells should then be dried away from direct sunlight or excessive heat. This should be done prior to incubation.

b) Disinfection of nesting material

It is preferable to incinerate all nesting material that is known to have contained chalkbrood-infected cells. If this is not possible then disinfect nesting material.

Wood nesting material can be disinfected by placing in an oven at 110°C for 24 hours. Both wood and polystyrene nesting materials can be disinfected by dipping nesting boards in a 5% sodium hypochlorite solution, or a 3 to 5% solution of stabilized dry chlorine (sodium dichloro-s-triazinetrione dihydrate) to which a wetting agent like Tween is added. The nesting boards should be disinfected in the spring and dried completely before use. Some loss of nesting material due to cracking or warping is inevitable.

c) Disinfection of shelters, equipment (e.g., strippers and tumblers) and storage facilities

A mist spraying of a 5% sodium hypochlorite solution is recommended.

To date, there is no cure for chalkbrood. The above information is based on the presently available data on the control or possible eradication of this disease.

The chalcids are the most common parasites of the leafcutting bee. Surveys of parasites in bee populations in northern Alberta show that *Dibrachys confusus* was the species most commonly found until the mid 1970's when it appeared to be gradually but not completely displaced by *Pteromalus venustrus*. Both species are similar in size and shape. Adult females are (2.5 mm) 1/10" long and males (2.0 mm) 1/2" long. Both males and females are black in color. On the main segments of the legs, Pteromalus has a dark brown to green coloration, while Dibrachys has a reddish yellow coloration.

Both species overwinter as mature larvae in leafcutting bee cells. Nine to seven days after the cells are placed in incubation rooms at 30°C, these chalcids are fully developed and start chewing their way out of infected cells through a single hole. The males emerge first. Mating occurs soon after the females emerge. These mated females immediately proceed to parasitise the surrounding healthy cells. The females pierce bee cells with their ovi-positors and sting the bee larva with a paralyzing fluid. The eggs hatch and feed off the bee larva and complete their development within 15 days. Hence, one batch of leafcutting bee cells can be parasitised by two generations of these chalcids.

Pteromalus has the potential to cause greater damage than Dibrachys. The average number of eggs laid by the latter species is 25; of these 10 to 12 develop into adults with a 2:1 male to female ratio. On the other hand, an average of 60 eggs are laid by Pteromalus in a bee cell; of these 20-25 develop into adults with a 1:3 male to female ratio. Thus, a 3 percent infestation with Pteromalus implies that 3 cells in every 100 or up to 60 adult parasites could be present (3 x 20, the latter being the average adult parasite per cell). Thus, in one reported case in the Literature, an initial 3 percent parasitism in 100 gallons of bees resulted in a loss of 40 percent of the bees before they reached the field when proper control measures were not taken.

The following control measures have been adopted resulting in different degrees of success. Black lights in combination with drown baths are used to attract and drown adults after emergence. This in combination with vacuuming helps to eliminate the adult population. However, since mating occurs soon after emergence, the mated females have already done considerable damage by reparasitising other non-infected cells before they leave the incubation trays, thereby fostering a second generation of chalcids. The use of insecticide vapour strips (Vapona No-Pest Strip, 19.2% dichlorvos) at one strip per (28.3 m^3) 1000 ft^3 during days 8 to 10 of incubation is most effective. Vapona should be used with extreme caution. After the vapour strips are removed, the incubation room should be aired thoroughly with circulating fans for at least 24 hours before resuming incubation. These fumes are very toxic to adult leafcutting bees.

The cuckoo bee, Coelioxys is not a serious pest in most seed growing areas in northwest Canada. They occasionally appear in some populations and are usually rapidly phased out. Except for physically removing this parasite, there is no known control measure. Cuckoo bees and leafcutting bees belong to the same family and are very similar in appearance. Female cuckoo bees lack pollen-collecting hairs on the underside of the abdomen and have a longer, more sharply pointed abdomen than the leafcutting bee. Males are smaller than females and have a broader abdomen. The female cuckoo bee lays its egg in the pollen and nectar provisions of a leafcutting bee cell. This egg gradually develops into a larva and in its advanced stages of development it usually kills the leafcutting bee larva in the same cell. After development is completed, the mature larva spins a cocoon in which it overwinters. In the following spring during incubation, adults usually emerge a few days before leafcutting bees.

The checkered flower beetle, Trichodes ornatus is a predator that actively searches for leafcutting bee cells to consume two or more bee larvae before reaching maturity. It occurs sporadically and is not usually a serious problem in the region. Adult beetles are (6 to 12 mm) (1/4 to 1/2") long and shiny metallic blue with either bright red or yellow markings on the wing covers. They lay their eggs between leaf pieces in the tunnel plug or between cracks in the nesting material. The newly hatched larva is bright red with a black head. They enter the bee cells, and feed on the pollen stores and bee larva. At maturity the larva is about 18 mm (2/3") long. They usually leave the bee cell and construct a reddish-brown pupal chamber at the opening of the leafcutting bee nesting tunnel where they overwinter. A large proportion of these larvae can be removed during tumbling of bee cells.

There are a number of other parasites, predators and nest destroyers of the leafcutting bees in the southern latitudes of the western Canadian provinces and in the United States. The effectiveness of different control measures on some of these species is summarized in Table 1.

6. CONTRACT POLLINATION

Some alfalfa seed producers prefer to contract out the pollination of their seed fields. A leafcutting beekeeper is then responsible for the introduction and maintenance of the bees and all the related equipment necessary to ensure optimum conditions for pollination. A suitable fee for this service is negotiated between the seed producer and beekeeper. Pollination costs are determined on a fee per acre basis or a previously agreed to percentage of the crop seed yield or a combination of both of the above. Information on beekeepers interested in contract pollination can be obtained from the Alfalfa Seed Producers' Associations in the prairie provinces or local District Agriculturists.

7. POLLINATION OF OTHER FORAGE LEGUMES BY THE LEAFCUTTING BEE

The leafcutting bee has been used to pollinate experimental plots of a number of other legumes -- the clovers (alsike, red and sweet), birdsfoot trefoil and sainfoin. Studies on the use of this bee to pollinate large acreages of other legume crops are currently underway.

Table 1. Effectiveness of Different Control Measures* on Individual Species of Natural Enemies.

Control Methods	Chalcid Parasites	Carpet, Flour, Spider, Cadelle Beetles	Flour Moth	Checkered Flower Beetles	Blister Beetles	Cuckoo Bees, Bee Flies	Yellow-jackets	Ants, Earwigs
Phasing out	2	3	3	1	1	1	0	0
Cold storage 35-38°F	0	2	2	2	0	0	0	2
Black lights	3	2**	3	0	0	0	0	0
Sprays	1	2	1	1	0	0	0	0
Fly strips	2	1	2	0	0	0	0	0
Sawdust coverings	3	0	0	0	0	0	0	0
Sorting, tumbling	0	3	2	2	2	0	0	0
Vapona strips	3	1	2	0	0	0	0	0
Squashing	0	1	0	2	0	1	1	1
Insecticide paint, oil baths, grease	0	1	0	0	0	0	0	3
Sticky boards	2	2	2	0	0	0	0	0
Vacuuming	3	1	1	0	0	0	0	0

*0 - no control, 1 - poor control, 2 - fair control, 3 - good control
** Except giant flour beetles

(Adapted from Parasites, Predators and Nest Destroyers of the Alfalfa Leafcutting Bee, Megachile rotundata by J.D. Eves, D.F. Mayer and C.A. Johansen, wrep 32, 1980.).