SASKATCHEWAN ALFALFA SEED PRODUCERS ASSOCIATION

ALFALFA SEED AND LEAFCUTTING BEE PRODUCTION IN SASKATCHEWAN

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Introduction

Alfalfa seed production is a well-established industry in Saskatchewan. In 1996 some 26,000 acres were devoted to pedigreed alfalfa seed production in Saskatchewan, with a similar amount estimated to be in common seed production. In addition to seed, most growers market surplus leafcutting bee cells.

Alfalfa is a unique crop. Successful seed production requires a blend of farming, beekeeping, and marketing skills. This bulletin is intended as a summary "checklist" of topics a new or prospective grower should investigate. Because of the complex nature of the crop and the unpredictability of the forage seed market, new growers should contact experienced growers, extension personnel and seed dealers for current information.

Important Organizations

There are a number of organizations with which the new grower should be familiar.

The **Saskatchewan Alfalfa Seed Producers Association (SASPA)** represents alfalfa seed and leafcutting bee producers, and acts as a liaison between Saskatchewan producers and the seed trade, the Provincial Government and Federal Government on matters of industry concern. SASPA disseminates technical information to its members through newsletters, field days and meetings. SASPA also provides technical advice on leafcutting bee management, and sponsors extensive research and development programs in leafcutting bee management.

The **Canadian Alfalfa Seed Council (CASC)** is an umbrella organization representing the three prairie alfalfa seed producer organizations. It oversees the operation of the Canadian Cocoon Testing Centre at Brooks, Alberta.

The **Canadian Cocoon Testing Centre (CCTC)** is a user pay leafcutting bee cocoon testing service operating out of the facilities of the Alberta Special Crops and Horticultural Research Centre at Brooks, Alberta. Leafcutting beekeepers can have cocoon samples analyzed for quality, disease and parasite levels and male:female ratio.

SeCan is a nationwide organization that promotes and markets Canadian pedigreed seed varieties. Growers can obtain general SeCan varieties directly, or contract with other SeCan growers who hold exclusive or restricted varieties. To obtain a general release variety, the grower must become a SeCan member before December 31 of the year prior to the year the grower plans to plant the variety.

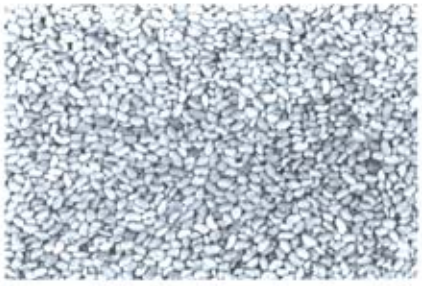

Figure 1. *The goal: clean, healthy alfalfa seed.*

The **Canadian Forage Seed Project** is a joint seed trade/federal/ provincial organization that sells foundation seed of public varieties. No membership, other than membership in the Canadian Seed Growers Association, is required. Seed is presently available through the Saskatchewan Agriculture & Food forage specialist or through members of the Canadian Seed Trade Association.

Other organizations of interest to the grower are the **Canadian Seed Trade Association,** representing the commercial seed trade, and the **Saskatchewan Forage Council,** an umbrella body that represents forage growers in Saskatchewan. Addresses for these organizations are listed at the end of this publication.

Pedigreed Seed Production

Growers wishing to produce certified seed must conform to **Agriculture and Agri-Food Canada** Seeds Act regulations. **The Canadian Seed Growers Association (CSGA)** is responsible for matters relating to the maintenance of crop pedigree, such as field isolation and sanitation.

When a grower completes an "Application for Field Inspection", the grower automatically becomes a member of CSGA. Note that the deadline for applying for inspection of forage seed fields is June 10 of the first year of seed production.

Choosing a Variety

The first time grower has several options in choosing an alfalfa variety to grow. Firstly, the grower must decide whether to sow foundation seed to produce certified seed, or to sow certified seed to produce common seed. With either grade, all costs of production are equal with the exception of seed cost and the cost of certifying the seed. Certified seed is generally priced at a premium over common seed.

If the grower chooses to sow foundation seed, the following sources are available:

- foundation seed of public varieties (Beaver, Algonquin, Rambler)

- foundation seed of SeCan general release varieties (Rangelander)
- foundation seed of proprietary varieties, the marketing and distribution rights of which are owned by seed companies

The first two options allow the grower to produce seed without a production contract, while the last option is governed by a contract between the grower and a seed company. Generally, proprietary varieties are priced at a premium over public or SeCan general release varieties.

Choosing the Right Field

Alfalfa tolerates a wide range of soil types. Many growers report that sandy land with a high water table, while not ideal for other crops, is quite acceptable for alfalfa. Land that floods for more than a few days at a time should be avoided. In general, the best land will produce the best seed crop. Leafcutting bees are less active under windy conditions, so fields that are sheltered by trees are a good choice. In addition, swaths are less likely to blow if the field is sheltered. Fields of pedigreed varieties must be isolated from non-pedigreed fields. Consult the CSGA Bulletin **Regulations and Procedures for Pedigreed Crop Production** for further details. If you plan to manage your own bees, remember that it is a labour intensive activity, and a convenient field location is an asset.

Weed control in alfalfa is expensive and may not be completely successful, so starting with a clean field is essential. The most recent **Canada Seeds Act Regulations** prohibit **any** level of contamination of certified alfalfa seed by the weeds listed in Table 1. Growers should familiarize themselves with these weeds and avoid them at all costs.

Table 1. Prohibited and Primary Noxious Weeds Seeds for Certified Alfalfa Grade as of May 2, 1989.

Weeds important in Saskatchewan are marked with an asterisk (*).

Dodder
Greasewood
Field bindweed*
Golden-bean
Halogeton
Low larkspur
Hoary cress
Tall larkspur
Horse nettle
Seaside arrow grass
Leafy spurge*
Jimson weed
Russian knapweed
Common crupina
Tansy ragwort
Yellow starthistle
Red bartsia
Couchgrass*
Diffuse knapweed
Great ragweed
Spotted knapweed
Ox-eye daisy
Nodding thistle
Perennial sowthistle*
Poison hemlock
Wild mustard*
Death camus
Wild radish
White camus
Yellow rocket
Western water hemlock
Bladder campion*
Narrow-leaved milk vetch
Toadflax*
Two-grooved milk vetch
White cockle*
Timber milk vetch
Canada thistle*
Early yellow locoweed
Bedstraw (Cleavers*)
Silvery lupine
Johnson grass
Velvet leaf

Source: Canada Seeds Act

In addition, seeds of certain other weeds such as sweet clover, black medic and night-flowering catchfly, while not "Prohibited" or "Primary Noxious", are difficult to separate from alfalfa seed. Fields contaminated with any of these weeds should be avoided.

Seedbed Preparation

A firm, clean seedbed is essential for a good seed stand. Packing before seeding is useful, to provide a firm bed to seed into. Most fields are seeded on summerfallow, but stubble can be seeded if the land is free of weeds.

Spring seeding is the most common, from May to early June. A few growers have tried late fall seeding just before freezeup. This is not recommended if the field is prone to wind erosion over the winter.

Seeding Rates and Row Spacing

There is a wide variation in seeding rates used in Saskatchewan, from 0.5 pound per acre up to 2.5 pounds per acre. Research suggests that the optimal rate is between 0.5 and 1 pound per acre. Row spacings also vary widely: growers in the Parkland area use 6, 12, or 18-inch row spacings, while growers in the south go to 3-foot spacings. In general, as moisture and weeds increase, row spacings should decrease. Wider row spacings provide some opportunity for inter-row cultivation after the crop is well established.

Manitoba research has shown that highest seed yields are obtained with established plant populations of about 22,000 plants per acre (using 24 inch row spacing), or roughly 2 square feet for each plant. Even at the low seeding rates suggested above, thinning may be useful to maintain optimum plant populations on older stands.

Broadcasting is used by some growers, particularly in wet fields, but it has disadvantages. Germination rate is usually lower than in drilled seedings, and inoculation is not as successful. If broadcasting is used, both seeding and inoculation rate should be increased.

Seeding depth is critical; it should not be more than one half inch in most soils. On sandy soils placement can be slightly deeper. Disc press drills are commonly used for seeding alfalfa, but many types of seeders are successfully used, as long as they can handle low seeding rates and have good depth control. A firm seedbed is essential for proper seed placement and depth.

Fertilization

Little is known about optimum soil fertility for alfalfa seed production. Pending further research, the grower is well advised to sample fields prior to seeding, and follow soil test recommendations. Some nitrogen may be added before seeding, but properly inoculated alfalfa plants will look after their own nitrogen needs. Phosphorus levels should be maintained, since alfalfa is a heavy user of this element. Sulfur may become limiting in the course and medium-textured soils of the Parkland region. Adequate boron is necessary for optimum flowering, nectar secretion and seed set; however, excess boron may be detrimental.

Inoculation

Seed should be inoculated every time you sow a field. Make sure you buy alfalfa-type inoculant (double-check the container when you purchase it) and keep the inoculant cool at all times.

Use a sticking agent to "glue" the inoculant to the seed. Syrup or molasses works well, but powdered milk has been found to be the best sticking agent. Mix the milk to about the consistency of light cream and pour just enough on to totally wet all the seed. If seeding a small amount, use a clean floor or a plastic sheet as a mixing surface. Simply pour the sticker on, thoroughly mix the seed, and allow the excess to drain off. Then pour on the inoculant, and mix again thoroughly. The seed will now flow easily and can be seeded immediately.

For large amounts of seed, augers do a good job of mixing seed, inoculant and sticker together.

Never skimp on inoculant. If seeding conditions are not ideal, do not hesitate to double or even triple the recommended rate. Good nodulation is essential to a healthy, productive alfalfa stand. To check a field for nodulation, examine the roots in June, before flowering begins. Swollen, pinkish-colored nodules should be evident.

Figure 2. *Legume inoculation is essential. Make sure you get the correct alfalfa variety and use a sticking agent*

Companion Crops

Companion crops have advantages and disadvantages. In general, conditions of a) good soil moisture b) high weed populations and/or c) wind erosion potential all point to the use of a companion crop. When these conditions are not present, companion crops are not recommended.

A companion crop should be seeded at half (or less) the normal seeding rate, either at right angles to the alfalfa or in alternate rows. A separate seeding operation, at right angles, is ideal, since it minimizes competition and allows each crop to be seeded to its optimum depth.

Flax is the least competitive and therefore the first choice for companion crop, but it will limit the producer's herbicide options. If wheat or barley are used, they should be taken off early as greenfeed, to allow the alfalfa to develop in late summer. Canola crops should be harvested early, and volunteer canola plants must be removed from the field in subsequent years. Note that the Canada Seeds Act has a zero tolerance for canola seed in pedigreed alfalfa seed and that canola cannot be separated from alfalfa seed in the cleaning plant.

One Manitoba study compared alfalfa seed production with and without a rapeseed companion crop. In the spring of 1979, Algonquin alfalfa was seeded alone at 1/2 pound per acre in one plot, and together with rapeseed at five pounds per acre in another. Rapeseed was combined at maturity and the straight alfalfa plot was cut for hay in mid-August. The subsequent-year seed yields are set out in Table 2.

More recent trials by Waddington and Malik in Melfort produced results that differed from the Manitoba study. Using Beaver Alfalfa and Candle Polish rape together in a number of different seeding arrangements, the researchers found no consistent differences in alfalfa seed yield when compared to straight alfalfa control plots. They suggest that Polish rapeseed can be used successfully as a companion crop in northeastern Saskatchewan, but further study is required to determine optimum seeding rates.

Growers should also be aware that the Canada Seeds Act sets very low tolerance standards for seeds of the Brassicas (mustard, rape, Canola, etc.) in alfalfa seed. For example, for Certified #1 alfalfa, only four Brassica seeds are allowed per 25 grams of alfalfa seed.

If a straight alfalfa stand is strong and vigorous it may be cut for hay during the seeding year, but only after growth has stopped in the fall.

Table 2. Performance of Alfalfa Seed Plots Seeded With and Without a Rapeseed Companion Crop.

Companion Crop	Established Year Yield (Seed or Forage)	Alfalfa Seed Yield (lb./acre) 1st Yr.	2nd Yr.
Rapeseed	25 bus./acre	210	428
None	0.9 tons/acre*	308	472

*Hay crop cut in mid-August

Source: Alfalfa Seed Production Management in Manitoba Manitoba Alfalfa Seed Producers Association, 1984.

Weed Control

There are few chemicals registered for use in alfalfa fields. Herbicide recommendations change frequently; the current **Crop Protection Guide - Weed Control Section** (Saskatchewan

Agriculture & Food) should be consulted for specific information.

A number of unregistered herbicides are used in alfalfa, but the practice is risky and the manufacturers are not responsible for losses occurring from unregistered use. Growers wishing to try an unregistered chemical should contact the manufacturer's representative for technical advice.

Depending on row spacings and available equipment, established alfalfa fields may be cultivated to control weeds. This should be done carefully to avoid damage to the alfalfa roots or crowns.

Insect Pests in Alfalfa

The major insect pests of alfalfa grown for seed production in Saskatchewan are lygus bugs and alfalfa plant bugs. Pea aphids and grasshoppers may occasionally reach economically damaging levels. Insect pest management programs have been developed for seed alfalfa which emphasize weekly monitoring of fields and insecticide treatment only when warranted.

Alfalfa plant bugs overwinter as eggs in stems and stubble, while lygus bugs winter as adults in surrounding bush, headlands and shelter belts. Burning fields in the spring is a very effective means of controlling alfalfa plant bug, but care must be taken that the alfalfa crowns are still dormant when burning is done or growth will be set back. Lygus adults migrate into fields during May; the females lay their eggs in alfalfa stems and the young nymphs first appear from early to mid-June. Alfalfa plant bug nymphs appear somewhat earlier. Both insects feed by piercing the plant tissue and sucking plant juices, and both prefer rapidly growing tissue such as buds and new pods. Each progresses through five nymphal stages; new adults appear in July. The late nymphal and adult stages are the most damaging to the crop. If large numbers go unchecked, alfalfa plant bug can destroy most of the flower buds in a field, while lygus bug can cause damage to developing buds, seeds and pods. Monitoring by means of a sweep net will indicate the numbers and progression of each population. If numbers warrant treatment, timing is aimed at the third nymphal stage in order to achieve control before the more damaging fourth and fifth nymphal stages appear in any number.

Aphids are also plant juice feeders, congregating on stems and causing general plant damage, including loss of vigour and premature drying. Grasshoppers feed on all plant parts. Both insects should be monitored throughout the summer in order to determine if numbers warrant chemical treatment.

Further information on monitoring and control of these insects is available in the current **Crop Protection Guide - Insect Control Section** (Saskatchewan Agriculture & Food).

Diseases in Alfalfa Seed

Diseases of alfalfa seed include grey mold ***(Botrytis cinerea / Sclerotinia sclerotiorum)***, black stem ***(Aschochyta sp.)***, and verticillium wilt ***(Verticillium albo-atrum)***.

Grey mold can be devastating to alfalfa seed crops. During cool, wet summers this fungus can grow over the floral racemes and cause floral death and premature floral drop. It can also cause death of young seed pods. It can be controlled using a properly timed fungicide application. Consult the current **Crop Protection Guide - Disease Control Section** (Saskatchewan Agriculture & Food) for more information on this disease.

Black stem is not considered to be a problem in alfalfa seed; however, in some years and in some fields it is quite prevalent and may be causing premature drying of the crop.

Verticillium wilt is a fungal disease of alfalfa which causes shortening of the life of the stand. It is prevalent throughout many alfalfa growing regions. Saskatchewan is currently virtually free of this disease except in an isolated occurrence in an irrigation district in southwestern Saskatchewan. It is spread by such means as movement of infected foliage from field to field and long distance movement of hay. Most new varieties are resistant to this disease.

Harvesting, Cleaning and Storage

After pollination, alfalfa seeds take about five to six weeks to mature. If the crop is to be swathed, this operation may begin when most of the seed pods have matured and are brown or black in color. Some additional ripening will occur in the swaths, which require 7-10 days minimum drying time.

Alfalfa swaths are light and fluffy, and are prone to blowing. Swath rollers are recommended to minimize damage, as is orienting the swaths parallel to prevailing winds.

Straight combining is a popular option that reduces seed losses. A variable-speed pickup reel is useful for straight combining. By adjusting reel speed, the producer can minimize the amount of seed stripped off as the crop is taken into the combine.

Straight combining is usually done in conjunction with chemical desiccation of the crop, which speeds drying. Very little seed ripening occurs after desiccation so most of the pods should be mature already before spraying. Combining usually takes place 10-14 days after treatment.

A hard frost will effectively desiccate an alfalfa seed crop. Some farmers will wait for a killing frost up to a certain date, and then switch to desiccation or swathing if frost has not arrived.

The extent of combine modification will depend on whether the machine will be used strictly for alfalfa or for grain crops as well. Check with a dealer for specific recommendations on your particular combine make and model. Leakage from the combine can be a problem given the small size of alfalfa seed; it is a good idea to plug all leaks (flexible caulk and a caulking gun works well) to avoid losses.

Slow ground speed is advisable when

combining, as is frequent monitoring of the chaff for seed loss.

The crop aftermath may be chopped and spread on the field, baled up, or burned. Most producers feel the best practice is chopping and spreading, in order to maintain soil nutrients and organic matter. Spring burning provides some protection against insect and pathogen buildups. Burning must be done before greenup to avoid stand damage.

Seed moisture levels in excess of 13-14% will require drying before storage. In general, if seed separates from the pod readily during combining then heating will not be a problem during storage.

New growers should be aware that alfalfa is a difficult crop to harvest. Conventional grain crops present few harvesting problems when compared to alfalfa.

Alfalfa Leafcutting Bees

Introduction

Alfalfa leafcutting bees ***(Megachile rotundata)*** are necessary for optimum seed set of alfalfa. The bees collect alfalfa pollen as a food source, and in doing they transfer some pollen from the flowers of one plant to the flowers of another. This process, called cross-pollination, is necessary for seed set in alfalfa. Honey bees tend to harvest only nectar from alfalfa, because the tripping mechanism of the alfalfa floret which releases the staminal column deters them from probing into the flower for nectar. Instead, they probe the flower from its side, thus not tripping the flower. If pollen is required the honey bees will gather it from other floral sources such as canola. Leafcutting bees, on the other hand, must collect pollen in order to provision their nests, and therefore actively trip the alfalfa flowers they visit, exposing the pollen for collection and the sticky stigmatic surface for cross-pollination.

The alfalfa leafcutting bee was first introduced into Saskatchewan in the early 1960's. Before that, alfalfa seed was produced mainly in the northeastern agricultural areas, and pollination of the crop was carried out mainly by native leafcutting bees and bumble bees. Crops fluctuated widely from year to year. The introduced leafcutting bee has supplemented and to some extent replaced native pollination. It has extended the boundaries of the alfalfa seed producing region and has allowed a more constant production. Experimentation by research and extension personnel and growers has resulted in the development of current management techniques.

The seed grower must decide whether to purchase leafcutting bees and become involved with bee management or to contract out the pollination to a leafcutting beekeeper. Management of bees is very labour-intensive throughout the growing season and especially in May and June, and a substantial capital expenditure is initially necessary. Leafcutting bee populations do tend to increase each year, and while the sale of extra leafcutting bees will offset start-up and operating costs, markets are time-consuming to establish. Contracting with a leafcutting beekeeper is on a crop-share basis. If the contracting route is chosen, the grower and beekeeper need to establish the management responsibilities of each and the cost share arrangements.

Figure 3. *Female leafcutting bee.*

Bee Biology

The leafcutting bee goes through the four life stages common to many insects; egg, larva, pupa and adult. Once the egg hatches, the young larva begins to feed on pollen and nectar provisions collected by the adult female. It grows and moults until it reaches its full size, and then spins a cocoon of fine silk-like threads, which harden to become a protective water-resistant covering. The full-sized larva within its cocoon then enters the prepupal resting stage, called diapause. Once winter passes, the prepupa resumes its development, moults again to the pupal (immature adult) stage, and then develops into an adult bee. The new adult chews through its cocoon and leaf cappings and emerges from its cell. Adult males begin emergence several days before females, and the ratio of male to female is generally about 2:1. Mating occurs soon after the females emerge, and both males and females forage for nectar from nearby blossoms. The female begins nesting almost immediately, in sites such as tunnels in logs, holes and crawl spaces in buildings, or appropriate nesting material supplied by the grower. The female begins constructing and provisioning the cell; she cuts oval leaf pieces from such plants as alfalfa, buckwheat and rose and uses them to line the tunnel, cementing them together with saliva. She then collects pollen and nectar to form a moist pollen ball in the cell.

The bee lays a single egg on the pollen ball, cuts more round leaf pieces to cap the cell over, and begins the whole process again on top of the first cell. Once a tunnel is full of capped cells, generally from 8-11 in standard nesting material, the female cuts more leaf pieces and cements them in place to form a plug. The first eggs in each tunnel are female; subsequent eggs are male.

Obtaining Leafcutting Bees

Leafcutting bees are generally purchased during the fall, winter or early spring as prepupae in diapause. Bee populations vary in quality. Some of the criteria of quality are: live count per pound or kilogram, male:female ratio, presence of parasites and diseases, and presence of mold in or on cocoons. These criteria can be determined in a number of ways. The Canadian Cocoon Testing Centre offers sample analysis on a fee-for-service basis which gives a breakdown of the sample quality.

Many beekeepers use this service. In addition, many beekeepers routinely sample their bee populations in the autumn and cut open cocoons in several pre-weighed subsamples, separating the cocoons into appropriate categories and calculating a live count from the results. A small incubator is needed to determine the sex ratio, since the prepupae must develop into adults before their sex can easily be determined. The leafcutting bee buyer can ask to see the results of the Brooks test on the bees he/she considers purchasing. The buyer is also well advised to sample the bees on the spot and to cut open 4-15 gram subsamples to determine the live count and the presence of parasites, disease and mold. Parasites and chalkbrood disease are potentially devastating problems which can be avoided through judicious acquisition of leafcutting bees. Local purchase from a known beekeeper may be more sensible than long distance or out-of-province purchase. **It is illegal to import leafcutting bees and/or used nesting material from other countries.**

Parasites, Diseases and Predators of Leafcutting Bees

The most common parasite in Canadian leafcutting bee populations is ***Pteromalus venustus,*** a small wasp which lays eggs through the leaf covering of the cell onto the developing immature bee. The parasite larvae consume the immature leafcutting bee larva, then either go into diapause or develop and hatch out as adults.

Figure 4. *Female Pteromalus parasitizing leafcutting bee cell.*

Prevention and control methods begin with the purchase of parasite-free bees, a condition which can be determined through sampling. Parasites are most easily controlled during incubation. Black lights (CGE F20T12/BLB) are used during incubation to attract adult parasites out of the incubation trays; a container of water with surfactant added is placed under each black light to trap and drown the parasites. Regular vacuuming of the edges of trays, supports, and other surfaces where parasites are seen will also help to reduce the problem.

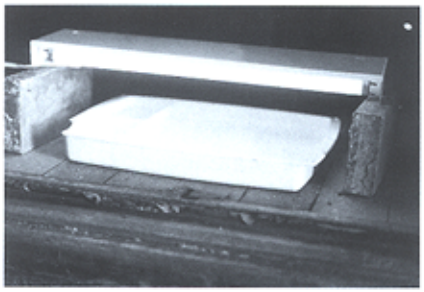

Figure 5. *Parasite control: ultraviolet light over water bath.*

Insecticide vapour strips are effective in parasite control. Strips are hung in the incubator before the first parasites are seen, about day 8, and are removed by day 13 of incubation. The incubator is then thoroughly aired for at least 24 hours before incubation is begun again. The recommended rate is 3/4 strip per 1000 ft^3. Caution is advised when using these strips, as lingering vapours may cause bee mortality. Other species of parasitic wasp which may occasionally be found in leafcutting bee populations are ***Melittobia chalybii*** and ***Monodontomerus obscurus***. Both are controlled by the methods described above. New control measures for parasites are being developed through SASPA. Consult SASPA for updated control information.

Chalkbrood disease ***(Ascosphaera aggregata)*** is a fungal disease present in leafcutting bee populations in parts of the prairie provinces and the Northwestern United States. Young larvae consume chalkbrood spores which germinate and grow in the gut, causing eventual death. Cadavers appear a brassy, light-brown color (non-sporulating) or a very shiny, cellophane-covered black color (sporulating). Adults are not affected, but females can contaminate the pollen balls they provide for their young. The disease is easily spread throughout an area by spore dispersal and adult bee drift, and among areas through purchase of infected leafcutting bees and used nesting material. **If left unchecked, this disease can decimate leafcutting bee populations.**

Figure 6A. *Healthy leafcutting bee prepupa*

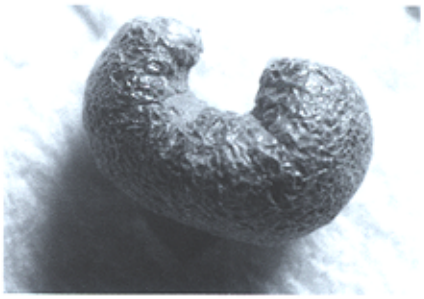

Figure 6B. *Sporulating chalkbrood cadaver*

Figure 6C. *Non-sporulating chalkbrood cadaver*

The best known prevention is to avoid purchasing contaminated bees and equipment. In order to control chalkbrood and other molds, yeasts and bacteria, a fumigation treatment of nests with paraformaldehyde is effective. Nests are cross-stacked in a building kept for this purpose. Paraformaldehyde prills are placed in an electric frying pan with controls available to the outside of

the building, at the rate of 20 grams/m^3 of inside space. Humidity within the building is brought to 60-70% or higher, and temperature is held at about 18°C. The building is sealed, locked and posted with "no entry" signs, and the electric frying pan is turned on. The paraformaldehyde prills are vapourized by the heat, and the resulting formaldehyde gas sterilizes all surfaces within the building. Once the prills are vapourized the building is left sealed for 24 hours, then vented for 48 hours prior to entry. Nests are then removed and taken to the field shelters for final airing. Under no circumstances should the fumigation chamber be entered prior to extensive airing.

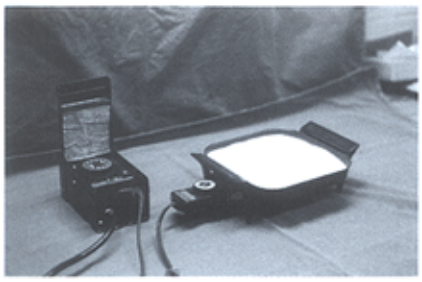

Figure 7. *Paraformaldehyde in an electric frying pan with an electric timer, ready for fumigation.*

Leafcutting bee cocoons in their trays may be fumigated in the same manner, then aerated thoroughly before moving the trays to the incubation building. Formaldehyde vapour may be noted during the first few days of incubation, and an air-to-air heat exchanger may be necessary in order to remove the formaldehyde vapour while maintaining incubation temperature.

Bleach treatment of cocoons, nesting material and other equipment is also effective in controlling chalkbrood. The recommended practice is to dip each nesting box, tunnel openings up, in a 5% bleach (sodium hypochlorite) solution plus 0.1% surfactant for 3-5 minutes. The box is then drained and allowed to air dry in the shelters prior to bee release. The concentration of bleach should be monitored periodically with a bleach test kit. Some beekeepers also dip the leafcutting bee cocoons in a 3% solution on order to surface-sterilize them. Cocoons must be completely dried before incubation begins. Drying is done on the shop floor, using air circulation and turning the cocoons until they feel dry. Direct sunlight should not be used for drying as it may overheat and kill the prepupae.

Nesting Material

The first decision to make is whether to purchase wood or polystyrene nesting material. Wood is more expensive and heavy, making handling less easy than polystyrene, which is less expensive and lighter in weight. However, wood is more durable than polystyrene and is less prone to surface mold buildup. Polystyrene can be treated each year with bleach solution to control chalkbrood and mold problems, while wood may tend to warp and crack when dipped, unless it is tightly clamped. Fumigation with paraformaldehyde does not adversely affect either wood or polystyrene.

The grower must also decide whether to use nesting laminates or drilled blocks. Both are available in wood and polystyrene. While blocks are easier to handle, the beekeeper must remember that **cell removal from nesting material each fall is of paramount importance for proper disease, mold and parasite control**. Cell removers are available to harvest drilled blocks, but unless the blocks have been thoroughly dried, some damage to the cells will result. **Blocks with blind holes are not recommended**.

Polystyrene blocks are widely used and are available from several commercial sources. Their advantages are in cutting down handling and reconstruction time during cell removal. Their disadvantage is also in the cell removal process. Blocks must be actively dried in order to ensure that the leafcutting bee cocoons can be removed without damage.

Nests are also available in various tunnel depths, the most common being 3 and 3.75 inches. Research has shown that tunnels under 2 inches and over 6 inches in depth will negatively affect the male:female ratio. There is no measurable difference between 3 and 3.75 inch tunnel depth in this regard. The advantages of a shallower tunnel depth include faster filling of nests in the field and quicker drying for cell removal. The advantage of the deeper tunnel is more nesting tunnel availability per nest in the field.

Used nesting material is often available for purchase. The beekeeper must weigh quality and price of new against used nesting material, remembering that with used material comes the possibility of disease. Used nesting material should always be thoroughly cleaned and fumigated or dipped in a bleach solution before using.

A market exists for filled wood and polystyrene nesting blocks, as many American alfalfa seed producers are not set up to incubate loose cells and prefer to incubate in blocks. Wood is probably preferred for its longevity. It is economically feasible to market only full blocks. For those which are partially full and which must be run for another season in Canada before selling into the US market, leafcutting beekeepers should note that while it is a great temptation to incubate these partially full blocks rather than strip them of cocoons, parasite and chalkbrood problems will quickly build up from low to economically damaging levels if this is done.

Nesting boxes are constructed to accommodate the width and depth of the laminate or block, with the length adjusted for the number of laminates or length of block desired. Box length must also accommodate the rack design in the field shelter. Boxes must be of tight and durable construction so that predaceous and parasitic insects cannot get in. The backs of the nesting boxes are generally made of water absorbent material; a combination of hardboard and a layer of foam may be used, or the backs may be made of tentest with a layer of foam to seal the back of each tunnel and prevent entry by parasites. Laminated nesting material is held tightly together and against the backs of the boxes by nailing wood strips along each side and using some type of spring at the top, to

compress and hold together the nesting laminates. Molded plastic nesting boxes are commercially available. Nesting blocks may be strapped to backs of tentest with a lining of foam. Commercial strapping machines are available for this purpose.

Shelters

Shelters protect the adult leafcutting bees and developing immature bee larvae from wind, rain and direct sun. Depending on latitude, shelters can be designed to be cooler or warmer than ambient air temperature. Many shelter designs are used, from simple 4'x8'x8' plywood shelters to molded plastic domes. Shelters are generally constructed to hold 100,000 adult leafcutting bees and about 20 nests, for pollination of five acres. Because of the proliferation of new shelter designs, new beekeepers are advised to visit several experienced beekeepers and look at shelters, then weigh the pros and cons before designing and building. The key features to look for in a design are light within the shelter (but not direct sunlight), stillness within the shelter (wind protection), and maintenance of beneficial temperature; parkland areas generally require a shelter design that maintains the temperature at slightly above ambient, while southern regions require a design that may be cooler than ambient. In parkland regions, an enclosed shelter which allows good light within is ideal. Care must be taken that the shelter is not dark inside, as leafcutting bees require some light in order to orientate to their nests. The shelter must also be durable, be resistant to breakdown by ultraviolet light, and require minimum maintenance once constructed.

Figure 8. *A common shelter design in Parkland regions.*

Molded plastic dome-like shelters are commercially available and are generally quite acceptable, providing good shelter from wind, sun and rain, maintaining even temperatures and allowing good bee multiplication.

Racks are constructed in the shelter to hold the nests. These may consist of slats, with cleats fitted to attach to tops and bottoms of nesting boxes, or friction-fit racks of wood or metal. Care must be taken to ensure that there is an air space between box and shelter so that excessive heating does not occur within the nest.

Incubators, Cell Removers and Tumblers

In addition to field equipment, the leafcutting beekeeper requires an incubator large enough to accommodate the leafcutting bee population. The incubator is a room or building equipped with thermostatically-controlled heating, cooling and air circulation systems. Within the incubator are racks to hold screened trays, in which leafcutting bee cocoons are incubated.

The incubator may also be designed to allow bleed-off of adult bees, either into smaller trays or into a separate room where they may be kept cool pending field release.

A cell remover and a tumbler are also needed for removal of cocoons from nesting material in the autumn. Cell removers are designed around two sets of teeth between which the individual nesting laminates are pushed. The cells or cocoons are scooped out of their grooves by these teeth, and then fall down a chute into a storage container.

Cell removers with a set of plungers are also available for pushing cocoons out of solid nesting blocks. A tumbler, comprised of a cylinder of mesh or expanded metal (4.75 mm openings) and a hand crank or motor, allows removal of excess leaf material and debris, to lessen the volume of the cocoons to be stored.

Winter storage containers for leafcutting bee cocoons include large black plastic bags, cardboard drums, boxes and 45 gallon steel drums. Cardboard drums with removable lids are commonly used.

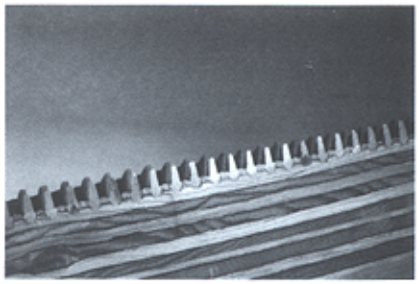

Figure 9. *The teeth of a cell remover, used to dislodge leafcutting bee cells from nesting laminates.*

Management of Leafcutting Bees

Leafcutting bee cocoons should be stored during the fall, winter and early spring at 5-8^{o}C in dry containers, in a temperature-controlled facility free of rodents and excess moisture. These storage conditions must be maintained until it is time to begin incubation.

The incubation period is about 24 days, and should begin approximately three weeks prior to the anticipated date of 10% alfalfa bloom. While this date varies from year to year, many beekeepers usually aim for a release date around July 1, and commence incubation at the end of the first week of June. Cocoons are placed in incubation trays, with screens removed, in the incubator a day or two early and allowed to warm up slowly before temperatures are increased. The optimum incubation temperature is about 29-30^{o}C at a relative humidity of about 50%. Parasitic wasps must be controlled during incubation, especially between days 8 and 13. If insecticide vapour strips are used, the incubator must be thoroughly aired upon removal of the strips for at least 24 hours before incubation is resumed, at which time the screened tops are placed on each tray. Temperature must be carefully monitored during the whole period, because developing pupae and newly hatched adults are easily killed by high temperatures. Some producers have back-up power for their air-conditioning

systems, as well as alarms which are triggered when temperatures rise. High relative humidity is essential during the hatch period for successful emergence and wing development. Adult males begin emergence around day 18 and peak around days 21-22, while adult females begin emergence around day 20 and peak around days 23-24.

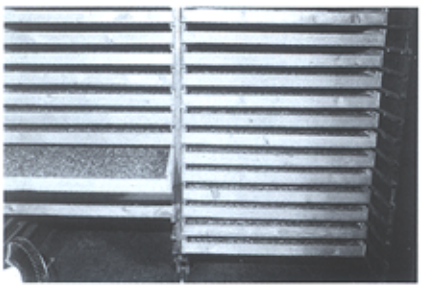

Figure 10. Racks of incubation trays holding leafcutting bee cells.

In order to monitor bee emergence the beekeeper can place several 100 cocoon samples in small compartmented trays made of fluorescent light diffuser and plexiglass. These samples are examined each day, and the extent of hatch of each sex noted. Release date can thus be timed to when 60-70% of the hatch is complete.

The producer may see adult bees present around day 14 or 15. These will be native leafcutting bees, mainly ***Megachile relativa***, which have nested along with the domesticated bees and which have a shorter incubation period.

If inclement weather or slow field development necessitates a delayed emergence, the incubation period may be lengthened by cooling the developing pupae to 10-15^{O}C before emergence is begun. Pupae develop very slowly below 20^{O}C and can be held at these temperatures for up to ten days without harm. Cooling may begin at any time after the insecticide vapour strips are removed from the incubator and the incubator is thoroughly aired. Bees may even be cooled after the emergence is begun. Adult bees live only a few days at 30^{O}C in the incubator, and it is better to begin cooling between days 18 and 21 of incubation, when the bees (especially the females) have just begun to emerge, rather than after day 21-22, when the bees have already burned up a portion of their food reserves; this will ensure that the survival of the bees is maximized.

While incubation is in progress, shelters and nesting boxes are placed in the fields. Shelters are orientated to the east or southeast for morning warmth and light, and are pegged and roped so that they cannot blow over. One shelter is generally allowed for every five acres, and one to two tunnels are allowed per female. Thus, at a stocking rate of 20,000 bees per acre and a male:female ratio of 2:1, there will be 6700 females, requiring from 6700 to 13,400 tunnels per acre. This is equal to about 22 nests each comprised of 3,000 tunnels. For five acres, each shelter will therefore need to hold enough nesting boxes to allow five times this number of tunnels. Rodent poison may be placed in each shelter to control field rodents, which can damage nests and new cocoons.

Once the female hatch is well underway the adult bees are released. Trays are taken to each shelter, preferably in the late evening or early morning, placed out of the direct sun and screens removed. If release is done during the day, and the bees have clumped together in the trays they should be gently shaken and prodded until they take flight. Trays may be left in each shelter, or after all the adults have left they may be brought in for re-incubation, to ensure that all of the late-emerging females are hatched and released. In warm years enough heat units may accumulate in the field to allow final development and hatch of these females. However, re-incubation ensures a complete hatch. To monitor field hatch, the 100 cocoon incubation trays may be taken out with the large trays and left in each shelter. The beekeeper will then get an indication of when field hatch is complete. Cocoon material should be removed from the field and disposed of once the hatch is finished.

If a bleed-off incubator is used, bees are released on a daily basis as weather permits. Adult bees may be held at 10^{O}C for up to five days.

After adult bees are released, regular field checks allow assessment of nesting activity. Some drift of adult bees may occur, especially in fields that are not well sheltered. Extra nesting boxes may be required in downwind shelters if substantial drift occurs. Nesting boxes may be exchanged at night if equalization among shelters is desired. Nesting boxes which are 70% capped before the first week of August should be replaced with new boxes. Bee activity generally decreases by mid-August; thus, any new boxes will be only partially filled after that time. Nesting boxes are removed from the field during the heat of the day in order to ensure that the adults are absent from the tunnels.

Once nesting boxes are removed from the field they are cross- stacked and stored at 20^{O}C for about three weeks. This period allows egg hatch, larval feeding and cocoon-spinning to be completed before the cells are removed and placed in storage.

If laminates or cells feel damp to the touch the nesting material may be stood on its side, exposing the back of the nest to allow better drying. Excess moisture may enhance fungal growth, which is detrimental to the health of both leafcutting bees and beekeepers. Parasite control is essential, as fall emergence of ***Pteromalus*** can occur. Insecticide vapour strips may be utilized during the post-field period if an abundance of ***Pteromalus*** is noted.

Once the three week period is finished, nests may be cooled to 5-8^{O}C and the nest backs removed to enhance drying of the leaf material. If polystyrene blocks are used, they must be actively dried prior to cell removal. The drying process involves cross-stacking the filled blocks and running air through the stacks with overhead fans, while exhausting the moisture-laden air using a wall-mounted exhaust fan. Humidity may be monitored during the process, and when room humidity stabilizes at 25-30% the blocks may be dry. Temperature must not exceed 15^{O}C for any length of time or leafcutting bee diapause may be compromised. Generally blocks are dried for 1-2 weeks prior to the cell

removal process, and those which are not completely full are stripped first. Cocoon quality must be constantly monitored to ensure that crushing is not occurring.

Most beekeepers wait until field work is done before extracting the leafcutting bee cells. Once nests are dry, cell removal and tumbling can occur at any time.

Beekeepers should wear dust masks and maintain good air circulation during the cell removal and tumbling process. Many beekeepers become sensitized or allergic to the dust which is associated with the cells. Cell removers and tumblers should be hooded or covered, and vented to the outdoors.

It is important to store leafcutting bee cocoons, whether in nests or as loose cells, at temperatures over $0^{o}C$. At no time should they be subject to subzero temperatures. The 5-$8^{o}C$ range is ideal for maintaining diapause and control of storage pest insects such as dried fruit moths and carpet beetles.

Once cells are ready for winter storage they may be sampled for quality and quantity determination. About one cup is taken from every five gallons of cells, and this initial sample is mixed well and then stored with the other cells pending subsampling and evaluation of cell contents.

Marketing of Leafcutting Bees

Leafcutting bee cocoons can be marketed to new beekeepers in Canada and to beekeepers in the United States, primarily Washington, Idaho, Oregon, Montana and Nevada. Leafcutting bee populations in these regions are difficult to maintain due to disease, predation, and second generation problems; thus growers require a steady input of new bees. There is also an occasional overseas sale of leafcutting bee cocoons.

The first-time leafcutting bee marketer must make contact with potential buyers once the level of cocoon quality has been established. One method of contact is to attend provincial and state association meetings. Another method is to advertise in farm newspapers in Canada and the United States.

The beekeeper not wishing to be directly involved in marketing may sell cocoons through a leafcutting bee broker. Several such brokers exist in Canada and the United States.

Some producer/marketers use a combination of laminates and blocks for nesting material. Cocoons for their own use are removed from laminates and stored. The surplus cocoons are then marketed into the United States in solid blocks, which are popular there.

Ten Points to Remember:

1. Contact seed dealers, experienced growers and extension personnel for information **before** you make any cropping decisions.
2. Inoculate the seed properly, using a sticking agent.
3. Start with clean land, prepare a firm seedbed, and place the seed close to the soil surface.
4. Buy high quality leafcutting bees which are disease-free and parasite-free.
5. Store cocoons above $0^{o}C$, preferably in the $5\text{-}8^{o}C$ range.
6. Carefully monitor incubation temperatures.
7. Control parasites and mold problems.
8. Check regularly on leafcutting bee activity in the field.
9. Store nesting boxes at $20^{o}C$ for three weeks before cell removal and cool storage.
10. Ensure that cocoons are removed from nesting boxes.

Addresses:

Agriculture and Agri-Food Canada
Saskatoon Research Centre
107 Science Place
SASKATOON, SK
S7N 0X2

Agriculture and Agri-Food Canada
Box 1240
MELFORT, SK
S0E 1A0

Saskatchewan Alfalfa Seed
Producers Association
107 Science Place
SASKATOON, SK
S7N OX2

Forage Specialist
Saskatchewan Agriculture & Food
3085 Albert Street
REGINA, SK
S4S OB1

Canadian Seed Trade Association
39 Robertson Road
Suite 302
NEPEAN, ON
K2H 8R2

Canadian Seed Growers Association
Box 8455
OTTAWA, ON
K1G 3T1

Prepared by Dorothy Murrell
Edited by D.W. Goerzen
Saskatchewan Alfalfa Seed
Producers Association
107 Science Place
Saskatoon, SK S7N 0X2
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