Introducing the Alfalfa Leafcutting Bee, *Megachile rotundata* (F.)(Hymenoptera: Megachildae), into Australia – A Case Study

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Abstract

Introductions of foreign bees for agricultural pollination raises the concerns of accidentally introducing unwanted species (e.g. pests, diseases, parasites) and competition with native pollinators. The alfalfa seed industry in Australia suffers from yields one-third of those in North America with one of the

main factors being poor pollination. In 1995, Pioneer Hi-Bred International, Inc. and International Pollination Systems - U.S.A. applied to the Australian Quarantine and Inspection Service (AQIS) for permission to import the alfalfa leafcutting bee (*Megachile rotundata* (F.)) from Canada into Australia to improve pollination of alfalfa. A team composed of Australian seed producers, the Australian beekeeping industry, Environment Australia, and Commonwealth Scientific and Industrial Research Organization examined the issue and advised AQIS to allow limited importations in 1998 of Canadian alfalfa leafcutting bees. A rigorous protocol was required to ensure other organisms were not also released with the bees. This involved obtaining high quality Canadian stock, cold storage to eliminate mites, Vapona treatment to control parasitoids, and dipping adult bees in sodium hypochlorite or iodine to kill chalkbrood spores. In 1998, 200,000 Canadian leafcutting bees were released in Australia. In 1999, that number was increased to 650,000 leafcutting bees.

Key Words Alfalfa leafcutting Bee, *Megachile rotundata*, Australia, pollination

There may be many reasons for introducing a foreign bee species for agricultural pollination. In some cases, the existing native or non-native pollinators fail to fully pollinate a crop, causing losses in quantity or quality. Sometimes, an exotic crop is introduced without it's native pollinators (e.g. alfalfa in Australia) and suffers from poor pollination. Managing wild, native pollinators is often difficult or may take decades of development to direct sufficient quantities of bees to pollinate the crop. Introducing foreign bee species raises concerns of accidentally introducing unwanted species (e.g. pests, diseases, and parasites) and competition with native pollinators. In such cases, the benefits of improved pollination must be weighed against the possible negative outcomes.

Alfalfa, or lucerne, seed production in Australia currently yields about a third of that in North America (300 kg/ha in Australia versus 900 kg/ha in North America)(R.B., unpublished data). Pollination is thought to be one of the major limiting factors to higher, reliable yields and improved seed quality in Australia (Morthorpe et al. 1989). Pollination efficiency (i.e., proportion of flowers setting seed pods) when honeybees are used in commercial fields in Australia is 35%. Research in Australia showed that when alfalfa leafcutting bees (*Megachile rotundata* (F.)) were introduced, pollination efficiency was over 90% (Morthorpe and Jones 1988, Woodward 1994). Poor seed yields have been a major barrier to competitiveness of Australia's alfalfa seed industry in world markets.

Alfalfa hay is a key component of the Australian agricultural economy (over $225 million U.S. estimated). Alfalfa is also important in sustainable cropping systems and this perennial legume can counter environmental problems, such as soil salinity, low fertility, acidity and erosion (Hanson et al. 1988).

The development of a professional pollination services market in Australia has been slow in comparison with other agricultural economies there. The Australian pollination industry currently depends on one pollinator, the introduced European honeybee (*Apis mellifera* L.). Honey bees pollinate a wide range of plants and crops, but they are not the best pollinators of some crops (e.g. alfalfa) (Batra 1984, Free 1993). It is estimated from seed industry surveys that over 30% of Australia's alfalfa seed production has not had any honey bees placed in the fields (16% for Pioneer Hi-Bred Australia). This is the result of competition from seasonal honey flows from native plants like Eucalyptus. Thus, domestic and export seed growing contracts are threatened in Australia by the opportunistic nature of the honey production industry.

In addition, honeybees are under tremendous threats worldwide by a range of diseases, pests and parasites, and are considered undesirable competitors for floral resources in Australia (Sugden et al. 1996). Knowledge of the role of Australia's native bee populations is limited. A weakening supply of honeybees could be catastrophic for Australia's agricultural and horticultural industries. Domestication of some native bee species may be possible, but this represents a

long term (10-15 years) program, and to date has received little to no attention from industry or government (Bray 1973).

The apparent pollination crisis in Australia led Morthorpe and Jones (1988) to state that appropriate agricultural and environmental policies and coordinated research programs are urgently needed, to ensure adequate pollination of entomophilous crops and other cultivars in Australia. In 1995, Pioneer Hi-Bred Australia and the United States-based International Pollination Systems-U.S.A. P/L applied to the Australian Quarantine Inspection Service (AQIS) for permission to import alfalfa leafcutting bees from Canada to improve pollination of alfalfa seed crops in Australia. Since the application was made, a consultative committee comprising representatives of the alfalfa seed industry, Australian beekeeping industry, Environment Australia, and Commonwealth Scientific and Industrial Research Organization (CSIRO), have examined and advised AQIS on quarantine issues related to the proposal by Pioneer Hi-Bred Australia to import leafcutting bees to Australia from Canada to improve pollination of seed alfalfa. In January 1998, AQIS approved a trial importation of the bee through the high-security quarantine laboratory at Division of Entomology, Canberra.

There are a number of desirable characteristics, which make the alfalfa leafcutting bee a logical candidate for introduction into Australia:

1. Alfalfa leafcutting bees are highly efficient in pollination of alfalfa (Peterson et al. 1992). The females are all pollen gatherers and thus trip and pollinate most or all flowers visited (Batra 1984).
2. Alfalfa leafcutting bees can pollinate a crop rapidly, reducing the risk of pollination failure and weather damage from late harvests.
3. A shortened pollination period reduces water and pesticide usage, thereby providing environmental as well as economic advantages for the seed grower.
4. Alfalfa leafcutting bees have a preference for alfalfa flowers, so adequate pollination is assured, even when other crops or plants are in bloom nearby.
5. Leafcutting bees forage within the field in which they nest (Bohart 1972), and have a limited period of foraging (one month during summer when natural flora has limited flowering). Leafcutting bees also have poor survival rates where artificial nest sites are not available, which helps to keep them in shelters.
6. The use of leafcutting bees is compatible with the use of honeybees. Both honey bees and leafcutting bees can be kept in the same area, if alfalfa honey production is desired
7. The demonstrated value of alfalfa leafcutting bees in Australia may stimulate research on native *Megachile* species and other native pollinators.

Australian Megachilidae and Previous Alfalfa Leafcutting Bee Introductions

The alfalfa leafcutting bee is a member of the subgenus *Eutricharaea*, a large but poorly understood subgenus of the genus *Megachile*. The subgenus as presently defined is comprised of 150 species, living in most parts of the world. Their habit of nesting in hollow stems and twigs appears to have contributed to their widespread distribution, both naturally and through commerce. The alfalfa leafcutting bee is endemic to much of Eurasia, extending from western Europe and North Africa through northern Iran and southern Siberia to Mongolia (Stephen 1996). It is adventive or introduced in North and South America and New Zealand. Australia has about 1630 described bee species, most of which are solitary, including about 36 species of leafcutting bees in the *Eutricharaea* (Michener 1965, Houston 1993).

In North America, the alfalfa leafcutting bee is the key pollinator of alfalfa. First recorded in the eastern U.S. in the 1930's, the alfalfa leafcutting bee was discovered in the Treasure Valley of western Idaho and eastern Oregon in the late 1950's (Stephen 1961). Since its discovery in North America, sophisticated management systems have been developed to take full advantage of the bees' pollinating potential. Specially built leafcutting bee shelters are now commonly found in North American alfalfa seed fields and fields of some other crops.

The alfalfa leafcutting bee has already had at least three introductions into Australia from a New Zealand population (originally sourced from Idaho and Canadian stock in the early 1970's). An introduction of the alfalfa leafcutting bee

from Canada to Australia in 1970 resulted in the destruction of the bees in quarantine after discovery of a chalcid (*Pteromalus sp*.) and a larval pathogen (*Ascosphaera sp*.) (Fern 1974). Beginning in 1988, alfalfa leafcutting bees from New Zealand sources were introduced on alfalfa seed farms near Keith, South Australia. The introductions continued over a five year period, with an additional introduction near Adelaide in 1996 (Woodward 1994, Woodward 1996). These populations produced very few bees and there is little documentation regarding those populations.

Honey bee Industry/Environmental Concerns

Honeybees were first introduced into Australia in 1810, but failed to establish (Ziegler 1993). A second introduction in 1822 in mainland Australia was successful, and additional introductions of other races into other parts of the continent occurred over the next 50-60 years; apiaries were established in each state (Paton 1996). Today, managed honey bees are found in all Australian states and territories. There are currently around 673,000 registered hives in Australia. It is estimated that an average of at least 30,000 tons of honey are produced each year in Australia. The gross value of production over all sectors of the honey bee industry is estimated as being between $60 and $65 million (Australian dollars) per annum, of which $49 million comprises honey production (Gibbs and Muirhead, 1998).

In January of 1996, the Federal Council of Australian Apiarists' Association (FCAAA) voiced two concerns regarding the importation of alfalfa leafcutting bees from Canada. First, that leafcutting bees from Canada might provide a conduit for Varroa mite (*Varroa destructor*) into Australia. Secondly, that *Ascosphaera* spp. occurring in Canadian leafcutting bees might infect Australian honeybees or Australian native bees. They asked that CSIRO provide independent information that would alleviate concerns amongst Australian honey bee producers on these two key issues.

Environment Australia stated that their main concern in importing the alfalfa leafcutting bee into Australia was its potential impact on native species of bees. To address this issue, a monitoring and reporting program was agreed upon. Trap nest sample blocks for native bees would be used at all release sites in those states which agreed to the releases of alfalfa leafcutting bees from Canada (New South Wales, Victoria, and South Australia) and would be monitored during the flying period of the alfalfa leafcutting bee populations.

Evaluation of Quarantine Risks - A Report from CSIRO

In June and July of 1997, Denis Anderson of the CSIRO Division of Entomology, Canberra, conducted on-site inspections of ongoing leafcutting bee research in Canada and the U.S. This study was commissioned by the AQIS to identify possible quarantine risks and risk management options associated with introductions of alfalfa leafcutting bees to Australia from Canada (Anderson 1997).

Anderson (1997) identified the following quarantine concerns:

- The presence in Canada of Varroa mite, *Varroa destructor*, considered a serious parasite of honey bees, might enter leafcutting bee nest material, survive for extended periods in that material in storage at 5°C, and then enter Australia.
- The presence of the leafcutting bee chalkbrood disease in Canada caused by the fungus *Ascosphaera aggregata* (Stephen et al. 1981). It was considered that spores of this fungus could enter Australia on imported leafcutting bee material and infects native leafcutting bees or become a serious management problem to a fledgling leafcutting bee industry.
- The presence of other species of *Ascosphaera* fungi in Canada (Goerzen 1991). It was considered that the risks associated with introductions of some of these fungi were essentially the same as those for *A. aggregata.*

- The presence in Canada of several parasitoids of leafcutting bees (Richards 1972). It was considered that the risks associated with introduction of these parasitoids were also the same as those given for *A. aggregata*.
- The presence in Canada of several native megachilid bee species. It was considered that these bees may build their nests in leafcutting bee nesting blocks in alfalfa fields in Canada and, because they resemble the alfalfa leafcutting bee, could accidentally enter the Australian environment when those bees were introduced and subsequently released to the field.
- The presence in Canada of several insect pests in leafcutting bee nest material (Eves et al. 1980). It was considered that these pests could enter Australia with leafcutting bee nest material and pass through quarantine to become pests of native leafcutting bees, or to the fledgling leafcutting bee industry.

In experiments conducted at the University of Manitoba, Winnipeg for this commission, adult female *Varroa destructor* mites were shown to be unable to survive longer than 9 days in leafcutting bee nest material stored at 5°C (Anderson 1997). Hence, the mite was determined to present no quarantine risk with importation of leafcutting bees, provided that leafcutting bee cells intended for export are stored for a least 1 month at 5°C in Canada prior to shipment.

The findings of this commission indicated that leafcutting bees could be introduced to Australia from Canada without the risks of introducing unwanted

pests, parasites and diseases, provided the following recommendations were followed:

1. Leafcutting bee cells intended for export to Australia should contain only diapausing prepupae.
2. Individual consignments of leafcutting bee cells from Canada should (initially) not exceed 100,000 cells per consignment.
3. Leafcutting bee cells intended for export to Australia should be sourced from reputable beekeepers in Canada that use the loose-cell management system and can demonstrate long histories of low incidences of chalkbrood disease and parasitoids.
4. Leafcutting bee cells intended for export to Australia should be sourced (initially) from a univoltine (single generation) strain of leafcutting bee.
5. Leafcutting bee cells intended for export to Australia should have been stored for at least one month at 5°C prior to shipment from Canada.
6. Leafcutting bee cells intended for export to Australia should be surface sterilized by using paraformaldehyde fumigation prior to shipment from Canada (Goerzen 1992). Any damaged cells should be removed before fumigation.
7. A representative sub-sample of leafcutting bee cells intended for export to Australia from Canada should, prior to shipment, be tested for parasitoids and clinical evidence of chalkbrood disease at the Canadian Leafcutting Bee

Cocoon Testing Centre (LBCTC), Brooks, Alberta. Single consignments of cells should be accompanied by a health certificate issued by the LBCTC stating that the shipment contains 0.1% or less of cells with chalkbrood infected larval cadavers and 0.25% or less of cells affected by chalcid wasp parasitism.

8. A representative sub-sample of leafcutting bee cells arriving in Australia should be tested for parasitoids and clinical evidence of chalkbrood disease at the CSIRO Division of Entomology.
9. Leafcutting bee cells arriving in Australia should be transferred directly into an AQIS approved quarantine facility and checked for physical damage.
10. Damaged leafcutting bee cells detected in Australia in newly arrived consignments from Canada should be removed and destroyed and the remaining intact cells dipped for 30 seconds in a 2.0% sodium hypochlorite solution prior to incubation to control fungal disease.
11. Incubators used in the approved quarantine facility in Australia should be constructed from transparent Perspex®.
12. Leafcutting bee cells should be placed in incubators in the quarantine facility in Australia as loose cells in a single layer.
13. Incubators used in the quarantine facility in Australia should be fitted with a "bleed-off system". A bleed-off system is one that allows all bees to emerge

in the incubator where they are held chilled until they are released (Stephen 1981).

14. Vapona strips should be placed in incubators in the quarantine facility in Australia between days 7 to 14 of the 24-day leafcutting bee incubation period (Richards et al. 1987).
15. Acaricide strips (Apistan® or Bayvarol®) should be placed in incubators in the quarantine facility in Australia as adult leafcutting bees begin to emerge.
16. Newly emerged adult leafcutting bees in quarantine in Australia should be surface sterilized to control fungi by dipping in a 2.0% sodium hypochlorite solution for 15 seconds prior to release to the field (Stephen et al. 1982).

The current complete protocol can be found on the Internet at http://www.aqis.gov.au/docs/anpolicy/a98-016.htm.

Releases of New Zealand Leafcutting Bees, 1997

Two independent releases of a New Zealand population of alfalfa leafcutting bees were conducted in February 1997 in Australia. David Woodward imported a population of 10,000 cocoons, which he incubated at the Quarantine Facility at the Waite Institute in South Australia. These bees were released near Adelaide, South Australia. By comparison, in the western United States, up to 100,000 bees/ha are released in alfalfa seed fields (Baird and Bitner 1991).

The second release was a New Zealand population of alfalfa leafcutting bees obtained by Pioneer Hi-Bred, Australia. Bees were incubated at the CSIRO Quarantine Facility in Canberra, ACT. From February 8 to February 15, a total of 8,151 adult bees were taken from the Quarantine Facility and transported to a farm (site 1) near Malthoura, NSW. Approximately 1,000 of the bees died en route leaving a population of an estimated 2,000 females and 5,000 males at the release site. This mortality was attributed to the dipping procedure.

These adult bees were released into two wooden bee shelters (1.5 x 1.5 x 1.5 m) on a 50 hectare alfalfa seed field. The site was chosen because of its isolation from native vegetation, nearby buildings and forests, so that interactions and dispersal would be minimized. Commercially available nesting material was provided for the leafcutting bees; 800 viable cells were produced by the ~2000 females at the end of the 1997 growing season. During the winter, mice destroyed 600 of these 800 cells, leaving only 200 for release in the 1998 season. These 200 cells were incubated and placed into the same field in December 1997. High temperatures (44°C) in December probably killed all bees in the remaining 200 cells, as no adults emerged from them.

Trap nests which were placed in transects from 1 to 5 km from the initial release site yielded only 10 alfalfa leafcutting bee nests from the 2,000 trap nest holes and none were found 5 km away from the release site. No native bee nests

were found, though 53 holes were occupied by 3 species of *Pison*, (Sphecidae) spider-collecting wasps.

A nest of a native megachilid identified as *M. macularis* was discovered in the soil near the initial release site. Only 20 cells were recovered from this nest.

Releases of Canadian Leafcutting Bees, 1998

Because of the failure to establish bees from New Zealand, in February 1998, the first releases of the Canadian Stock of the alfalfa leafcutting bee began. A total of approximately 200,000 adult bees were released, following the protocol specified by AQIS, above. There were two release sites near Malthoura, NSW. The first (site 1) was the same as the previous Pioneer release site, and the second (site 2) was in an alfalfa field approximately 20 kilometers from the first. At site 1, the first release was made on 24 February 1998 in a 25 ha alfalfa field in full bloom. A week after the first release, 20,000 additional bees were released at the same site. At this time, 60,000 bees were also released at a second location, 1.5 km from the other releases at site 1. At site 2, 80,000 bees were released in a single shelter between 2 and 14 March 1998. Blooming native plants were scarce within 5 km of the two release sites.

Because of drought conditions, the primary flower source was the irrigated alfalfa fields. On 23 April 1998, the polystyrene nesting blocks containing the new nest cells that had been constructed by the released bees at both sites were collected from the shelters and transported to the CSIRO Division of Entomology

Canberra, where the number of recovered cells was estimated. Some cells were also examined for pests and pathogens. A total of 20 trap-nest blocks, each containing 50 holes, were placed at each release site. The trap-nest blocks were set out near the release sites and up to one kilometer from the sites. The blocks were retrieved in April, and sent to the CSIRO laboratory in Canberra. Only 9 of the 2,000 holes were occupied by alfalfa leafcutting bees nests, indicating a low disperal rate. No nests of other species of bees were found and there were 35 holes containing nests of *Pison.*

More nests of native *M. macularis* were found along the ditch banks in crevices in the soil at site 1. A total of 2,000 cocoons of this species were collected in 1998. These cells were taken to the CSIRO laboratory with plans to attempt to increase their numbers in 1999. Drawbacks for this pollinator include: (1) it is a ground nesting species, making it difficult to manage, and (2) it appears to be completing its nesting cycle before the end of January, when bees are needed in alfalfa.

In November 1998 a shipment of 50,000 New Zealand leafcutting bee cells arrived into quarantine at CSIRO. These cells were dipped in sodium hypochlorite and placed in incubators at 30°C. Simultaneously, 40,000 similar cells, part of the previous importation, were removed from storage at 8°C and placed in incubators. These 'carry-over' cells had been held at 8°C for a total of 14 months prior to incubation.

In order to minimize the negative effects of the sodim hypochlorite dip on the bees, AQIS allowed the dip solution to be changed to 0.1% iodine. AQIS agreed to this change because the bees originated from areas in Canada considered to be free of chalkbrood. The New Zealand bees were dipped in a 0.1% solution while the 'carry-over' bees were dipped in a 0.2% solution.

Recoveries of alfalfa leafcutting bees were far less than acceptable for commercial development.

Releases of Canadian Leafcutting Bees, 1999

In 1999, 650,000 Canadian alfalfa leafcutting bees were brought into Australia. After being dipped, bees were also dried in batches of 6-8,000 with a drier built for this purpose. Bees were once again released at sites 1 and 2. A new site was chosen at the CSIRO Experimental Station in Ginninderra, ACT (site 3). Emergence of the bees began in mid January and finished in the first week of March. Approximately 42,000 bees were released at site 3 in two shelters. Approximately 358,000 bees were released at sites 1 and 2, and 250,000 bees were held over for release in the summer of 1999/2000. As in previous trials, only a small percentage of females remained and nested successfully at the release sites. All releases since 1998 yielded less than 10% recovery (90% decline in population). In Canada, the bees usually increase by 125 to 200% each year. The treatment of adult bees with sodium hypochlorite or 0.1% iodine appeared to be detrimental to the bees.

Trap nests were placed in the vicinity of each release site and early observations found no alfalfa leafcutting bees nesting in them. However, these nests will remain in the field until the end of the growing season and will be examined at that time.

Future Directions

Future imports of leafcutting bees will come from cells produced at a single locality and at the same time in order to prevent extended emergence times and to allow increased accuracy in estimating release dates.

Experiments need to be carried out to determine the factors responsible for altering the behavior of both male and female bees after their release to the field. An obvious candidate for investigation is the dipping solution used to treat adult bees before their release. This work needs to be conducted in North America, as it is not possible to have positive experimental controls for the work to be conducted in Australia.

This ongoing case study has demonstrated a process where all stake-holders interests were considered to create a protocol for introducing a foreign bee species. The consultative committee carefully weighed benefits of improved alfalfa pollination against the possible negative outcomes of introducing foreign bee diseases, parasites and pests and competition with native bees for nest sites. The protocol that emerged allows for strategic control operations and appropriate management techniques. We recommend a decision making process that takes

into account all viewpoints, as was practiced in this case, for future foreign bee introductions.

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Footnotes

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