Ruz L. 2002 Bee Pollinators Introduced to Chile: a Review . IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment / Brasília. p.155-167.

BEE POLLINATORS INTRODUCED TO CHILE: A REVIEW

Luisa Ruz

ABSTRACT

This paper describes and analyzes the various bee species that over the years have been introduced into Chile for pollination purposes, and have colonized different geographical areas of the country. It calls attention to the need for evaluation of the impact of each species in its new Chilean envinronment, and also emphasizes that studies of ecological consequences should be conducted prior to planned bee introductions anywhere.

INTRODUCTION

Numerous countries have improved their orchard and crop yields by using and managing colonies of *Apis mellifera* L., but, in some cases, better results have been obtained working with more specialized bees to pollinate alfalfa, clover, and tomatoes. Information about the subject has been documented by an extensive literature by numerous authors, which will be analyzed here only to the extent necessary for explaining particular situations relevant to those in Chile.

In Chile, several bee species have been introduced for commercial purposes to increase the yield of seeds, as well as to improve production or increase the quality of fruits in tree orchards and cultivated crops. The history of these pollinators is described and analyzed in this paper. Especially important is the need to find out the current status of these pollinators since they were introduced.

This review concentrates on specialized literature that covers the *Apis* and non-*Apis* pollinators introduced into Chile mainly over the last 35 years. *Apis mellifera,* which will also be discussed, became established in the early 19th century. The analysis of the bee pollinators focus on: 1) their distributional spread after their establishment; 2) the probable environmental impact they may have achived over the years; 3) their pollination success on target or non – target plants; 4) prospective needs for a modified legislation concerning the introduction of foreign bees; 5) an educational approach about the problem at various levels; 6) the need for more studies to evaluate risks of foreign introductions.

An important goal for this presentation is also to promote a discusion about the potential impact of the introduced bee pollinators , which should be studied previous to the introductions being planned.

Bee Introductions: An Historical Overview

Ruz L. 2002 Bee Pollinators Introduced to Chile: a Review . IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment / Brasília. p.155-167.

Apis Mellifera - Concern over bee introduction for pollination purposes began in Chile more than one hundred years ago with *Apis mellifera* , the bee species most easily managed and widely distributed over the world. It was established in Chile in 1848, and since then, has been commonly used to improve pollination and as a valuable honey producer.

Fruit trees such as apple , apricot, peach, plum, pear, and avocado, have shown increased fruit set by placing honey bee hives near the flowering plants. Honey bees can also be directed to target crops. By using chemical attractants, as proposed by Jay (1986), the bees are attracted to some crops and this promotes cross-pollination to set seeds.

In Southern Chile, spraying with Beeline and lavander on *Rubus idaeus* (raspberries) had no positive effects on the fruit characteristics (Neira *et al.* 1994), but BeeScent increased the number of visits and time spent on raspberry flowers by honey bees (Neira *et al.* 1997).In other studies, the use of Beeline and Beescent in pear orchards increased the number of visiting bees, but no differences in fruit set resulted (Neira *et al.* 1996) . In central Chile, however, better results have been obtained using a product (C 598) on Fuerte avocado cultivars. Applications of this product increased the fruit set by 40 % (Apablaza 1981).

The number of hives used to increase pollination by bees in crops has been based mainly on the experience of other countries, and varies according to: flowering time, number of flowers, floral color and structure, nearby orchards, floral rewards and other factors. Avocado flowers, among the trees mentioned above, are on of the least attractive to the honey bee according to Vithanage (1990), even though he states, studies in Australia, the honey bee plays a leading role in avocado pollination, and that providing three hives per hectare at flowering time significantly improved fruit set.

Flowers of the raspberry in southern Chile were visited by the following insect taxa in addition to *A. mellifera* as reported by Neira *et al.* (1997): 4 species of Coleoptera, 7 species of Diptera and 11 species of Hymenoptera, most of them bees (Apoidea). Two species of bumble bee were reported; the native *Bombus dahlbomii* and the introduced *B. ruderatus.* In addition, 7 species of solitary bee; *Manuelia gayi* and *M. postica* (Anthophoridae), *Cadeguala albopilosa* and *C. occidentalis* (Colletidae), *Corynura chloris*, *Ruizantheda proxima* and *Dialictus* sp. (Halictidae) were reported.

In the desert region of northern Chile, Pampa del Tamarugal, *A . mellifera* is one of the few species that might play an important role in the pollination of mesquite (*Prosopis)* (Toro *et al.* 1993). Studies looking at feral and managed colonies indicated that they transport the pollen mostly from *P. tamarugo.* The presence of pollen on the head and sternal area of the individuals makes them potentially good pollinators of this plant species (Toro *et al.* 1992). Honey bees, however, because of their careful and slow movement amoung flowers of the same inflorescence, are less efficient than the native bee, *Centris mixta* (Anthophoridae), which rapidly explores a greater number of flowers (Toro *et al.* 1993). The introduction of honey bees for commercial apiculture into this particular geographic region does not seem to be advantageous. A low percentage of individuals from either feral or managed colonies carry complete loads of pollen on their

corbicula (Toro *et al.* 1992). In addition, honey bees in this area of the country may be detrimental to native bees that pollinate *Prosopis,* by competing for the limited food resource (Toro 1986a).

Colonies of *A. mellifera* have also been introduced to Quillagua in northern Chile. More than ten years ago, before their introduction into this region, the insect fauna collected in alfalfa fields showed a high species diversity in relation to the size of the area . Some of the species were native bee pollinators responsible for seed production. More recent field observations in this area at the same time of the year indicated that plots of alfalfa where no production of seeds was observed, were visited almost exclusively by honey bees (Ruz, personal observations). As a result of this new situation, several questions can be raised: Does this mean that there is competition between honey bees and native bees? If not, why are native bees not visiting, nor pollinating the alfalfa now? Do the local farmers who encouraged the honey bee introduction to that area have the required undertanding of bee behaviour and its relation with the flowering plants? And, how do environmental conditions affect this behaviour? These are all are questions that need to be answered.

Differences in bee diversity have also been observed in other geographic areas of north central Chile, depending on the presence or absence of honey bees. In Incahuasi, a small isolated area close to La Serena where honey bees are not present, *Geoffreae decorticans* (Papilionaceae) is pollinated by several species of native bees (Anthophoridae,Colletidae and Halictidae). In locations near larger towns, however, the same plant species is visited only by the European honey bee.

Most of the Chilean desert areas already mentioned, are isolated and small, maintain a very few insect fauna and are not invaded by species from other regions. This is an important fact, because it is possible easy to detect changes in the ecosystem when they occur, and evaluate the impact that any foreign species may have when introduced into a new environment .

Some authors have reported that honey bees are poor pollinators when foraging in alfalfa and red clover crops (Bohart 1952; Westerkamp 1991).

Westerkamp (1991) explains that honey bees are poor pollinators because colonies are long-lived and are not adapted to any species of flower. Innate behaviour does not exist , so foragers have to learn how to handle the flowers through trial and error. After learning they prefer to reach the nectar in the shortest way possible, without contacting the plants reproductive elements so becoming inefficient pollinators**.** On the other hand, the nectar collecting-bees “learn” to avoid tripping flowers, but trip 7 to 85 % during the learning process (Tucker 1956). Trial and error, at least during this period apparently would favour pollination, and as Roubik (1989) notes “a good pollinator is often one that makes mistakes”. Considering this fact, it would be important to use a significant number of new colonies for alfalfa pollination (McGregor 1976) . This is one of the most effective strategies used to pollinate crops with honey bees.

Observations made by Bohart (1952) in Utah indicate that in alfalfa, most honey bee nectar gatherers “steal” the nectar from deep nectaries by perforating the corolla without tripping the pollination mechanism. They are poorly equipped to be efficient pollinators**.**

Alfalfa pollen is not its preferred food source of honey bees so pollination may occur, but only if they are present in great numbers. Similar situation have been described by Macfarlane and Griffin (1985) for honey bees visiting red clover in New Zealand.

Native bees, on the other hand, trip most of the flowers when visiting the plant for pollen so they are more effective pollinators. But if they have to work large fields, there would be insufficient numbers to provide adequate pollination. Only a few species of bees are known to increase their populations rapidly (Bohart 1952).

As stated by Cane (1997), honey bees are the most versatile pollinators available to agriculture. However, they still have several morphological, behavioural, phenological and nutritional limitations, which are not shared with native bees (reviewed in Parker *et al.* 1987; Free 1993). On the other hand, despite the fact that non-*Apis* bee species may be superior pollinators to honey bees for some crops, only a few of them are managed for agricultural pollination. A greater understanding of the factors controlling gregarious nesting in ground-nesting bees would facilitate the management of such bees as promising agricultrural pollinators (Cane 1997). The problem, however, is that wild bees are not numerically abundant to be reliable working in crops with many flowers (Torchio 1990). Several factors, such as pesticides, climatic conditions, loss of nesting sites, and others, may affect unmanaged populations of native bees, as well as honey bees in agricultural settings.

Management strategies for non-*Apis* bees are urgently needed .

Non-*Apis* Pollinators

According to Torchio (1995), some apiculturists (Levin 1986; Robinson *et al.* 1989) and others, have overestimated the value of honey bee pollination, treating estimated figures as factual data, and stating that honey bees account for at least 80% of all insect pollination. These studies have not been based on quantitative comparisons of pollination efficacy among bee species. Robinson *et al.* (1989), on the other hand, although recognizing the potential value of native bees as pollinators, states that they are not dependable because their population densities vary greatly from year to year . This assertion is strongly criticized by Torchio (1995), who states that there is no equity making comparisons between the intensively managed honey bees and the complexity of unmanaged native bees, and that only after this equity is established, comparisons based on scientific evidence could be made.

Wild bees are indeed an alternative for crop pollination. Some species have been successfully managed for commercial pollination; Megachile rotundata *(Megachilidae) is a bee of European origin, accidentally introduced to the United States, and Nomia melanderi (native species in the United States) and some species of Bombus (Bohart 1970) are examples.*

***Megachile rotundata* -** Historically in Chile, there was no production of alfalfa for seeds, except in small cultivated plots in the northern part of the country, where *A. mellifera* was poorly pollinating the flowers. Alfalfa fields found from low altitude to over 3000 m are

mainly cultivated for hay to feed cattle, however, they do produce seeds as the result of being pollinated by bees other than honey bees (Ruz, personal observations). Seed production in this plant is highly dependent on efficient pollinators (Bohart 1957) .

The introduction of *M. rotundata* in 1963, and then massively in 1971 from the United States, has increased the efficiency of pollination in alfalfa (Arretz and Aracena 1975). Stephen (1972) has stated that alfalfa fields in the United States pollinated only by honey bees produced a seed set of 760 kg/ha, while those pollinated by *M. rotundata* produced 1.398 kg/ha.

This bee species, in spite of its potential as an efficient pollinator, was not very successful at the beginning of its introduction to Chile. The populations were seriously affected by parasites, such as *Monodontomerus* and *Tetrasticus* (Hymenoptera) families, dermestids as *Trogoderma*, and several others, all introduced with the bee nests from the United States (Arretz 1973) . Another important parasite was detected 13 years after the first introduction. It was probably already present in Chile parasitizing some Cecidomidae and native Tephritidae (Arretz *et al.* 1989). Parasites were one of the main mortality factors, affecting the colonization of *M. rotundata,* especially at immature stages. In addition, climatic conditions and pesticides sprayed on alfalfa have increased mortality. After a few years, nevertheless, *M. rotundata* definitely became established near Santiago, but population densities have remained low. At present, seed -growers that have re-established new stocks of bees apparently make good profits growing alfalfa for seed but information about productivity or rearing bees is not available in the country.

The impact and spread of *M. rotundata* in Chile, since its introduction has not been evaluated. Its colonization seems to have been slow, however, a new record for the range of distribution has been found by us (Ruz and Monzón, in preparation) in Chincolco (lat. 32º 33'S and 71º 70'W), a valley located at 150 km north of Santiago, and in the nearby area, El Sobrante where large populations were established. Recently, the area was sampled again (H. Monzón, personal communication), but only a few individuals were found, probably as a a result of a dramatic drought throughout most areas of Chile.

***Bombus ruderatus* -** A similar situation related to alfalfa has been observed for red clover *Trifolium pratense*, the main small-legume seed crop in Chile. This plant is also poorly pollinated by honey bees, but is preferred as a food resource by the long-tongued bumblebee, *Bombus ruderatus.*

The florets of red clover have a deep corolla and the sparsely produced nectar is hidden. Sufficient pollination occurs with strong pollen-collecting bee populations during the flowering time of the legume. However, pollen-collecting by bumble bees declines over the season, which is a negative factor for later flowering varieties (Arretz and Macfarlane 1986).

Bombus ruderatus, a reliable pollinator of red clover (Gurr 1974), was introduced to Southern Chile in 1982 from a New Zealand stock (Arrets and Macfarlane 1986) with the purpose of obtaining higher yield of seeds. This bumble bee is polylectic, since does not only visit red clover, but also crops like cranberries, raspberries, and a variety of

weeds, among which one of the most important is *Echium vulgare*, an introduced plant where *B. ruderatus* have been observed in great numbers, especially at high altitude (in Icalma, X Region, approximately at 1.500 m (H.Toro, personal communication). Also, *B. ruderatus*, since its introduction near Malleco, has spread toward the north to Chillán (H.Toro, personal communication) and to the south to Puerto Montt.

Echium vulgare is very attractive to honey bees and distributed from Santiago to Malleco (Hoffmann 1995) often being present near red clover fields (R.Rebolledo, personal communication). According to Herrera (1996), introduced crop plant and weed species are often opportunistic, they obtain benefits from local pollinators, achieving pollination and setting seeds, even after being separated geographically from their habitual pollinators. This explanation applies exactly to *E. vulgare* in Chile.

The fact that *B. ruderatus* does not particularly prefer red clover may imply that it is favouring the reproduction and spread of the weed instead of increasing seed production of the legume, which was the objective of its introduction. This hypothesis, however, needs to be proved and data must be gathered to be quantified. Populations of *B. ruderatus* have apparently decreased over the last two years, perhaps affected by altered climatic conditions (G.Pérez, personal communication). However, their range has expanded. Likewise, populations of our native bumblebee *B. dahlbomii* have notably decreased (Ruz, personal observation), but this fact may or may not be the result of the presence of *B. ruderatus*. So studies to evaluate this situation are much needed.

Bees reported pollinating red clover in Chile are: *A. mellifera*, *B. dahlbomii,* and the few species of solitary colletid bees: *Diphaglossa gayi*, *Cadeguala occidentalis* and *Colletes cognatus*, the first two species being typical generalists from central Chile. These solitary bees, however, because they are ground nesting, may not be ideal for large-scale pollination management (Arretz and Macfarlane 1986). Macfarlane (1985) also mentioned that other visitors of red clover in Chile are *Anthophora paranensis*, *A. incerta* and *Centris chilensis* (Anthophoridae). Anthophoridae are more likely to be efficient pollinators because of their preference for red clover flowers. However, their distribution may be restricted and have been found to visit red clover only in central north Chile, not in the southern regions (Macfarlane 1985).

Bombus terrestrus - ***A more recent bee introduction to Chile is* B. terrestris, *whose colonies were commercially imported from Israel (E. López, personal communication) and Belgium (M.Beeche, personal communication). Several countries have already introduced this species, which has proved to be an efficient pollinator, thus increasing the yields of tomatoes grown in green houses.***

Colonies of *B. terrestris* have been reared commercially since 1988 in the Netherlands (Hughes 1996) for greenhouse tomato pollination after first trying honeybees for the same purpose (de Ruijter *et al.* 1988). Although Ruijter (1996) recognizes that introducing organisms into new areas is a risk, he also states that based on earlier studies, so far, no drastic changes in the abundance of the different bumblebee species

have been observed. The importation of *B. terrestris* to Chile was authorized in 1998, by the Servicio Agrícola y Ganadero (SAG) in Chile, according to the International Rules established in the "Behaviour Code for the importation and liberation of exotic agents for biological control", and as part of the international policies practiced by the Food and Agriculture United Nations Organization and accepted by FAO. The same regulations have been applied to all the species introduced previously (M.Beeche, personal communication), which must be fulfilled by the importers before a species introduction can be authorized.

Colonies of *B. terrestris* were distributed to different localities from north to central Chile. Some preliminary evaluations of its effect as a pollinator of different varieties of tomatoes have been conducted in greenhouses in Quillota, in central Chile. Positive results were obtained under some conditions, with higher yields using bumble bees compared to tomatoes treated with hormones (López and Garay 1998a, 1998b).

Some of the imported colonies are now freely working in the field (E.López, personal communication), so in the future their behaviour, as well as their spread and the potential populations of honey bees effects on populations of other species should be investigated. In Israel, *B. terrestris* has proven to be very invasive, causing reduction in honey bees, and various solitary bees. The bumble bees seem to have favorable adaptations, such as tongues of variable length amoung indiviuals in a colony and ability to work in unfavorable weather (Dafni and Shmida 1996). Dafni and Schmida (1996) also observed that this species may have displaced other bees by depletion of nectar in the early morning. In addition, solitary bees were almost entirely excluded from some plants, being physically chased away by *B.terrestris*.

In New Zealand, according to Wratt (1968 *B. terrestris*. *B. ruderatus* and *A. mellifera* compete when foraging in large numbers, and when their activities coincided in two crops adjacent to each other (one of red clover and the other of alfalfa). In red clover, the number of *B. ruderatus* decreased with increasing temperature because of increased competition from honey bees. The latter were collecting pollen and probably pollinating this crop, but were totally ineffective as pollinators on alfalfa, on which they were robbing nectar by side entry. On the other hand, *B. terrestris* foraged on alfalfa by top entry only, and it was the only species among the 3 that gathered pollen from the crop. Because *B. terrestris* can also gather and rob nectar from red clover, it proves to be a versatile pollinator, and it may work better on either crop if they are grown separately, in different localities. Red clover can be an alternative source of nectar when adjacent to alfalfa so jeopardizing alfalfa pollination.

Bombus Impatiens - *B. impatiens* is a species of bee from eastern North America used for greenhouse tomato pollination. Although information exists about the importation of *B. impatiens* by some seed growers (M.Beeche, personal communication), the details on the reasons of this introduction were not available. The present state of this bumble bee in Chile is unknown. More data needs to be gathered.

DISCUSSION

Ruz L. 2002 Bee Pollinators Introduced to Chile: a Review . IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment / Brasília. p.155-167.

Introduction of any foreign species into new environments is evidently a risk; it may affect the interactions of the pre-existing animal species, or the reproductive systems of plants. In Chile, there is an increasing interest in importing bees of commercial value, as in the case with bumble bees. There is also a constant desire to introduce honey bee colonies into areas with native insects already well adapted to native vegetation, without the proponents having any real knowledge of the effects of such introductions.

Studies considering native bees related to the polination of cultivated crops have not been done, except those of Toro *et al.* (1993) and these proceedings, where *Centris mixta* was noted as the main pollinator of *Prosopis tamarugo* in Northern Chile.

A discussion about the introduction and development of apiculture in arid and semiarid regions of Chile has been given by Toro (1986a). Even though his argument is mainly theoretical, the problems indicated are likely to occur. They are based on biological principles that need to be kept in mind. Honey bees may compete with the native *C. mixta,* which would mean alteration to the native vegetation in terms of pollination, as well as to non-*Apis* bee behaviour.

It seems that, among bee pollinators, it would be difficult to asses the degree of competition. However, according to Toro (personal communication) it is possible to distinguish two different levels at which competition may exist: 1) adult bees, that feed primarily on nectar, would be more competitive if they are social versus solitary because the former store this provision. Nectar is renewed through the day, but may be depleted by social bees, preventing the solitary natives from using this food resource. 2) larvae feeding on pollen gathered by the adults should be those competing for this resource. This situation would be more stressful for some native solitary bees, especially oligolectic species, which feed on pollen from only a few plants, particularly under severe environmental conditions.

Some explanations of the possible consequences for specializing on plants after the displacement of oligolectic bees by generalists are given by Toro (1986a) and these proceedings. His reflexions, in general , agree with those of Corbet (1997) who discussed the problem extensively through several questions to point out to the importance of pollinators in species preservation, conservation and ecosystem stability. More research on pollination of native plants and a better knowledge of honey bee interactions with native bees should be conducted in Chile and elsewhere. Most contributions on the subject of crop pollination in Chile refer only to honey bees increasing yield not the possible ecological consequences that their introduction into new areas may have produced.

In Chile, crops like red clover are associated with solitary bees, as previously mentioned. The effect of *B. ruderatus* on these native bees after its introduction on the target plant, however, has never been evaluated. Social bees, in contrast to solitary ones, are born "knowing" much less about their resource environment, because it is generally not predictable in terms of whole colony requirements (Heinrich 1976) .Thus, they exploite a variety of plants through the season. This social and generalist behaviour may negatively affect the foraging of the more specialized solitary bees and a displacement of at least some of them may occur. In the long-term , if this situation happens, a decrease or a loss of bee diversity would result. The presence of *B. terrestris* in Israel,

as noted above, has already caused a decrease on native bee populations as a clear example of what might happen in Chile, too. More attention and care to these important issues should be considered in the future before new introductions are approved. Authorization for importing biological material, such as bee pollinators, should not only be determined by the presence or absence of parasites or other noxious agents, but also based on biological studies and consultation by specialists. Regulations should include these aspects as well.

In Canada and the United States, the introduction of foreign bumble bees is prohibited and only local species are reared (Ruijter 1997). Even trans-continental movements are strongly discouraged. *B. terrestris* was imported to Japan from Belgium in 1991 for tomato pollination There it was succsessful in producing high-quality fruits (Iwasaki 1995) but it's escape has caused problems of hybridization with native species. More recent laboratory studies conducted on reared colonies of native Japanese bumble bees indicate, however, that there is no significant differences in the pollination efficiency of *B. terrestris* and the natives *B. hipocrita* and *B. ignitus* (Asada and Ono 1997). This fact suggests that with no ecological risk, the Japanese bumble bee should have been used instead of the imported *B. terrestris* (Asada and Ono 1997).

In Chile, the native *B. dahlbomii* has not been well studied to be managed in crop pollination. Nevertheless , recent preliminary research has been conducted to evaluate the effect of this bumble bee species as pollinator of cultivated tomatoes. The result of this study indicated a high number of flowers visited by this native bumble bee, and a significant increase of the tomato seed production (Wagner and Estay 1998). *B. dahlbomii* may prove to be a good alternative to be used in crop pollination, without environmental risk.

B. dahlbomii also needs to be evaluated from the view point of its abundance, which apparently has decreased over time. This bumble bee species was common but today, at least in central Chile, it is rarely seen. Its abundance has also decreased in the South. The factors affecting the populations of this species need elucidation.

In regard to *B. terrestris***,** which has been recently introduced into Chile, we do not know how it is going to behave in cases where it is not confined to greenhouses. If feral individuals start new colonies they may increase their distributional range to southern areas where two other species of *Bombus* are already present, one of them the native *B. dahlbomii*. Because all three bee species are polylectic, several questions arise. What flowering plants would be preferred by each one and which would be more or less efficiently pollinated? Will they compete with for food resources? Will they partition the available resources? Will the introduced species really visit the target plants they are suppossed to pollinate ? Where do the native solitary bees fit in this scheme? Considering that *B. terrestris* is a versatile pollinator, what will happen to *M. rotundata* when interacting with it on alfalfa crops in central Chile?

These are not easy questions, but they need to be answered. Research programs should be conducted in this respect. Educational programs should also be available at the primary and high school level, as well as to the general public. Young people should get the appropriate knowledge to protect and conserve our natural and sometimes unique flora and fauna. Introductions of foreign organisms should be avoided, and if

introduced, the possible implications should be known. Farmers should also be educated on this subject. The Department of Agriculture should readily provide active support for such programs and scientific institutions, such as entomological societies, should also be greatly involved .

The diversity of native bees in Chile is poorly known, judging from the large number of new species recently described (Toro, 1986b), and actions should be taken to conserve and preserve these species. We should be alert to any possible change that may threaten our environment . Through bee surveys conducted over the last 30 years, it has been possible to detect how bee abundance and diversity has systematically decreased, especially near coastal areas in central Chile. Several factors may be involved in this process, and human activity is apparently one of the most important. Wild areas have been used for human needs, nesting sites of bees have been destroyed and, native vegetation eliminated. What were refuges for native insects have been replaced by roads and buildings. Such environmental changes have negatively influenced the bee diversity and abundance.

Habitat fragmentation in Chile has become one of the major threats to plant and animal communities in both natural and agricultural landscapes. Plant-pollinator interactions can be expected to be disrupted (see Steffan *et al.* 1997).

Pesticide applications in Chile is another possible cause of the decrease in the wild insect pollinators. Pesticides seriously affect bees when foraging on flowering plants, and produce important effects on their populations as illustrated by Kevan and Plowright (1995), Kevan *et al.* (1998) and Kevan (1999). The effect of pesticides on native bees in Chile should also be evaluated .

In short, more ecological studies and control measures for conservation and preservation of the species diversity in ecosystems of Chile are urgently needed to protect our native vegetation and the apidological fauna for pollination purposes.

CONCLUSIONS

The introduction of foreign pollinators has been documented as hazardous by researchers from other countries, the decline in diversity of native pollinators as one of the major consequences. Another in the possibility of introduced bumble bees pollinating non-target plants, such as weeds, so favoring the reproduction of undesirable vegetation. This experience should be taken into consideration in Chile, because several wild bee species which seem to be efficient pollinators may be seriously affected. In spite of knowing about these negative effects, there is a strong pressure from farmers to introduce several species of *Bombus* into Chile to pollinate cultivated plants in greenhouses.

In Chile, there is an urgent need to focus research studying the native bees at the specific level, and their role as pollinators both in native vegetation and cultivated crops. This would help better understand the impact of the already introduced bees and their interactions with native species.

Further studies and evaluation of the effects of introduced bees must be made in chile in order to preserve the diversity in the environment.

Governmental agencies, such as agriculture services (sag in chile), should add complementary rules to implementation of the present regulations in order to avoid authorizations for introduction of foreign pollinators without previous biological studies of potential environmental impact.

Educational Programs, at every level, are necessary to keep people aware of the real needs we have for the conservation and preservation of our natural ecosystem.

ACKNOWLEDGEMENTS

I am very grateful to Haroldo Toro (Universidad Católica de Valparaíso, Chile) for reviewing this manuscript. His valuable comments, suggestions and interesting ideas undoubtely benefited this paper. My appreciation also goes to Simone A. O'Donoghue-Vannoy (Southwest Texas State University, Texas), for her great help in making the adequate language corrections.

REFERENCES

Apablaza C. Efecto del C 598 como atrayente de abejas (*Apis mellifera* L.) en la polinización de paltos (*Persea americana* Mill.) cultivar Fuerte [tésis de título de ingeniero agrónomo]. Valparaíso: Universidad Católica de Valparaíso; 1981.

Arretz VP. Factores de mortalidad de *Megachile rotundata* (Fabricius) en Chile. Revista Chilena de Entomología 1973; 7: 59-78.

Arretz VP, Aracena D. Utilización de *Megachile rotundata* (Fab.) en la polinización de la alfalfa. Boletín Tecnio. Facultad de Agronomía/Universidad de Chile 1975; 40: 15-37.

Arretz VP, De Santis L, Guerrero MA, Lamborot L. Presencia en Chile de *Aprostocetus daira* (Walker) (Hymenoptera: Eulophidae). Acta Entomológica Chilena 1989; 15: 275-6.

Arretz VP, Macfarlane RP. The introduction of *Bombus ruderatus* to Chile for red clover pollination. Bee World 1986; 67: 15-22.

Asada S, Ono M. Tomato pollination by japanese native Bumblebees (*Bombus* spp.). In: Richards KW, editor. Proceedings of the 7th International Symposium on Pollination. Pollination: from theory to practise. Acta Horticulturae 1997; 437: 289-92.

Bohart EG. Pollination on native insects. USDA Year Book of Agriculture 1952; 2302: 107-21.

Bohart EG. Pollination of alfalfa and red clover. Annual Review of Entomology 1957; 2: 355-80.

Bohart EG. Commercial production and management of wildbees: a new entomological industry. Entomological Society of American Bulletin 1970; 16: 8-9.

Cane J. Ground-nesting bees: the neglected pollinator resource for agriculture. In: Richards KW, editor. Proceedings of the 7th International Symposium on Pollination. Pollination: from theory to practise. Acta Horticulturae 1997; 437: 309-23.

Corbet SA. Role of pollinators in species preservation, conservation, ecosystem stability and genetic diversity. In: Richards KW, editor. Proceedings of the 7th International Symposium on Pollination. Pollination: from theory to practise. Acta Horticulturae 1997; 437: 219-28.

Dafni A, Shmida A. The possible ecological implications of the invasion of *Bombus terrestris* (L) (Apidae) at Mt Carmel, Israel. In: Matheson A, Buchmann SL, O'Toole C, Westrich P, Williams IH, editors. The conservation of bees [Based on Symposium organized jointly by the International Bee Research Association and the Linnean Society of London, held in April, 1995]. London: Academic Press; 1996. (Linnean Society Symposium Series, 18)

Free JB. Insect pollination of crops. 2nd ed. New York: Academic Press; 1993.

Gurr L. The role of bumble bees as pollinators of red clover and lucerne in New Zealand - a review and prospect. Proceedings of the New Zealand Grasslands Association 1974; 36: 111-2.

Heinrich B. Bumblebee foraging and the economics of sociality. American Scientist 1976; 64: 384-95.

Herrera CM. Floral traits and plant adaptation to insect pollinators: a devil's advocate approach. In: Lloyd DG, Barret SCH, editors. Floral biology. Studies on floral evolution in animal-pollinated plants. New York: Chapman and Hall; 1996. p.65-87.

Hoffmann A. Flora silvestre de Chile (Zona Central). Santiago: Ediciones Fundación Claudio Gay; 1995.

Hughes MJ. Commercial rearing of bumblebees. In: Matheson A. Bumblebees for pleasure and profit. Cardiff (UK): International Bee Research Association; 1996. p.40-7.

Iwasaki M. Introduction of commercial bumblebees into Japan. Honeybee Science 1995; 16: 17-23.

Jay S. Spacial management of honey bees on crops. Annual Review of Entomology 1986; 31: 49-65.

Levin MD. Using honeybees to pollinate crops. Washington (DC): USDA-ARS; 1986.

López and Garay. Evaluación de tomate de otoño en invernadero mediante el uso de *Bombus terrestris*. In: IX Congreso Latinoamericano de Horticultura; XLIX Congreso Agronómico de Chile; 1998a; Santiago; Chile.

López and Garay. Evaluación de *Bombus terrestris* como polinizante de tomate primor tardío en invernadero. In: IX Congreso Latinoamericano de Horticultura; XLIX Congreso Agronómico de Chile; 1998b; Santiago; Chile.

Macfarlane RP. A kiwi on tour to Chile, England and France. Wata 1985; 8(2): 18-22.

Macfarlane RP, Griffin RP. An assesment of bumble bees and honey bees as pollinators of red clover. Australasian Grasslands Invertebrate Ecology Conference Proceedings 1985; 4: 114-20.

McGregor SE. Insect pollination of cultivated crop plants. Washington (DC): Department of Agriculture of the United States; 1976.

Neira M, Barriga JA, Mundaca N. Características de los frutos de *Rubus idaeus* L., asociadas al uso de dos atrayentes y un repelente. Agro Sur 1994; 22(1): 77-82.

Neira M, Lobos N, Riveros M, Carrillo R, Pessot R, Mundaca N. Entomofauna asociada a flores de frambueso (*Rubus idaeus* L., CV Meeker) y evaluación de la actividad polinizadora de *Apis mellifera* L. bajo la influencia de un atrayente feromonal. Revista Chilena de Entomología 1997; 24: 37-44.

Neira M, Nallar J, Pessot R, Carrillo R. Actividad polinizadora de *Apis mellifera* L. en peral, bajo la influencia de dos atrayentes. Agro Sur 1996; 24(2): 167-76.

Parker FD, Batra SWT, Tepedino VJ. New pollinators for our crops. Agricultural Entomology Review 1987; 2: 279-307.

Robinson WS, Nowogrodski B, Morse BA. The value of honey bees as pollinators of U.S. crops. American Bee Journal 1989; 129: 411-23/477-87.

Roubik DW. Ecology and natural history of tropical bees. Cambridge: Cambridge University Press; 1989.

Ruijter A. Commercial bumblebee rearing and its implications. In: Richards KW, editor. Proceedings of the 7th International Symposium on Pollination. Pollination: from theory to practise. Acta Horticulturae 1997; 437: 261-9.

Ruijter A, Eijnde J, Steen, J. Bestuiving van tomaten door honingbijen. Maandschrift voor Bijenteelt 1988; 90(4): 124-5.

Steffan–Dewenter I, Tscharntke, T. Bee diversity and seed set in fragmented habitats. In: Richards KW, editor. Proceedings of the 7th International Symposium on Pollination. Pollination: from theory to practise. Acta Horticulturae 1997; 437: 231-4.

Stephen WP. Studies in crop pollination Nº1. Washington (DC): Organization at the American States; 1972.

Torchio PF. Diversification of pollination strategies for U.S. crops. Environmental Entomology 1990; 19: 1649-56.

Torchio PF. Prospects for the future. Pollination of cultivated plants in the tropics. FAO Agricultural Services Bulletin 1995; 118: 85-92.

Toro H. Problemas en la introducción y desarrollo de la apicultura en zonas áridas o semiáridas de Chile. Boletín de la Sociedad de Biología 1986a; 57: 81-8.

Toro H. Lista preliminar de los apidos chilenos (Hymenoptera: Apoidea). Acta Entomologica Chilena 1986b; 13: 121-32.

Toro H, Chiappa E, Covarrubias R, Villaseñor R. Transporte de polen por *Apis mellifera* en la Pampa del Tamarugal. Acta Entomológica Chilena 1993; 17: 95-9.

Tucker KW. Honey bee pollinators of alfalfa in Minnesota. In: Report of the 15th Alfalfa Improvement Conference; 1956; St. Paul (MI), USA. p.32-3.

Vithanage V. The role of the European honeybee (*Apis mellifera* L) in avocado pollination. Journal of Horticulture Science 1990; 65(1): 81-6.

Wagner A, Estay P. Evaluación de *Bombus dahlbomii* (Guer.) (Hym., Apidae) como agente polinizador de flores de tomate cultivado *Lycopersicon esculentum* (Mill.). In: XX Congreso Nacional de Entomología; 1998; Concepción, Chile.

Westerkamp C. Honey bees are poor pollinators – why? Plant Systematics and Evolution 1991; 177: 71-5.

Wratt EC. The pollinating activities of bumblebees and honeybees in relation to temperature, competing forage plants and competition from other foragers. Journal of Apiculture Research 1968; 7(2): 61-6.