THE FEASIBILITY OF PRODUCING SPRING PACKAGES AND NUCLEI OF HONEY BEES (*APIS MELLIFERA* L.) IN THE FRASER VALLEY AREA OF SOUTHWESTERN BRITISH COLUMBIA

by

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ABSTRACT

The purpose of this research was to investigate the feasibility of producing honey bee (*Apis mellifera ligustica* L.) packages and nuclei in the Lower Fraser Valley area of southwestern British Columbia. Present management systems leave Canadian beekeepers dependent on package bee and queen importations from the southern United States each spring. Restrictions on the importation of bees from the U.S. are already in place due to the discovery of the mite, *Acarapis woodi*, in the U.S. in 1984. Further limitations or a ban on importations are possible due to this pest plus another mite, *Varroa jacobsoni*, and the Africanized race of honey bee, both of which are rapidly expanding their ranges northward from South and Central America. Thus, a local bee production industry would not only be a new and lucrative source of income to local beekeepers, but may be essential to the survival of Canadian beekeeping.

In a preliminary experiment, three different colony sizes (4, 10, and 20 frames) were wintered indoors and outdoors, in order to determine the best method of establishing colonies in the fall for package production the following spring. Twenty-frame (two-super) colonies wintered outdoors were significantly better than any of the other treatments for package production in the spring. Based on these findings, two-super colonies wintered outdoors were used for all subsequent research on package and nucleus production.

Various combinations of packages and/or nuclei were removed from two-super colonies in April to determine the biological and economic impact of package and/or nucleus production on these colonies. All colonies used for package and/or nucleus production yielded greater economic returns than the control colonies from which no packages or nuclei were removed. In addition, in almost every case the colonies used for package and/or nucleus production did not differ significantly from the control colonies by the end of the season in any of the biological characteristics monitored. The results indicate that spring package and nucleus production is feasible in the Lower Fraser Valley area of B.C. and would provide local beekeepers with an additional source of income.

A comparison of the biological performance and economic returns from colonies established in April from either 0.9 kg packages or four-frame nuclei was made in both the Lower Fraser Valley and Peace River areas of B.C. In the Lower Fraser Valley, nuclei were superior to packages both biologically and economically, while in the Peace River, no biological differences were found between the two, and packages provided higher economic returns. Either packages or nuclei would be viable in commercial beekeeping operations, depending on individual circumstances.

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DEDICATION

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CHAPTER 1

INTRODUCTION

The purpose of this research was to investigate the feasibility of producing honey bee (*Apis mellifera ligustica* L.) packages and nuclei in the Lower Fraser Valley area of southwestern British Columbia. Present management systems leave Canadian beekeepers dependent on package bee and queen importations from the southern United States each spring. A local bee production industry would not only be a new and lucrative source of income for local beekeepers but may also be essential for the survival of Canadian beekeeping. The parasitic mites, *Acarapis woodi* and *Varroa jacobsoni*, as well as the Africanized bee bee are threatening to cause severe restrictions or a total ban on the importation of packages and queens from the United States into Canada.

1.1 The Problem: Two Parasitic Mites and the Africanized Bee

1.1.1 Acarapis woodi

The mite, *Acarapis woodi*, poses the most immediate threat to package and queen importations from the United States. This mite is parasitic on adult honey bees and completes its life cycle inside the prothoracic trachea, feeding on haemolymph. The mite causes reduced longevity of host bees and this in turn causes the death of severely infested colonies in the winter. However, colonies with low levels of infestation do not show any obvious signs of the disease, making early detection difficult and facilitating the undetected spread of the mites (Bailey 1958, 1961, 1985). At present there is no effective means of control of *A. woodi* registered for use in North America (DeJong *et al*. 1982b).

Acarapis woodi originated in Europe and was first identified in England in 1921. Its distribution included most of Europe, Africa, South America, parts of Asia, and Mexico by 1981 (Nixon 1982). Since the initial identification of *A. woodi* in Mexico in 1980, the mite has been found to occur throughout almost all Mexican states (Wilson and Nunamaker 1982, 1985), resulting in a ban on all importations of packages and queens from Mexico into Canada. The arrival of this mite in the U.S. after its establishment in Mexican border states appeared inevitable, and in 1984 *A. woodi* was identified from bee colonies in Texas (Delfinado-Baker 1984). Since then, *A. woodi* has been discovered in 17 states (Anonymous 1985a), making eradication of this pest from the U.S. unlikely. Canada has taken steps to prevent the importation of *A. woodi* with package bees from the U.S. by imposing restrictions on the entry of package bees into Canada (B.C. Apiculture Newsletter 1985). During the 1985 shipping season packages and queens were allowed into Canada only if they were accompanied by a certificate which stated the bees originated from an apiary which had been sampled by government officials and found free of the tracheal mite. This agreement between Canada and the U.S. expired on October 15, 1985. For the 1986 season, the Canadian Honey Council (C.H.C.) has recommended to Agriculture Canada that bees should only be imported into provinces west of Ontario and that these bees must be certified based on the following criteria:

1. Any State wishing to export bees to Canada must have carried out a survey, sampling not less than 10% of the hives in that state.

   a) An apiary will consist of 100 hives or less. Larger apiaries will be divided into units of 100 or less hives for sampling purposes.

   b) A minimum of 5 hives per apiary will be sampled with a total minimum of 100 bees being collected.

   c) Fifty bees from the sample will be randomly chosen for examination.

2. If the state survey reveals a tracheal mite infestation, bees will be accepted

from that state by Canada only if that state has in place an acceptable action plan for containment and control of the tracheal mite.

3. Any potential shipper from states satisfying these criteria will then have to meet the following:

   a) 100% of the shipper's apiaries will be sampled;

   b) an apiary will consist of 50 hives or less with bees being taken from no less than 10 hives in each 50 hive apiary;

   c) a sample will consist of 500 bees;

   d) from the sample of 500 bees, 100 bees will be examined for tracheal mites (B.C. Apiculture Newsletter 1985).

A. woodi will likely increase its range in the U.S. for the following reasons: 1) practice of migratory beekeeping; 2) sale of packages and queens; 3) swarms and drifting bees from neighbouring infested colonies and; 4) lack of control measures (Delfinado-Baker 1985). Therefore, further and more severe disruptions of package and queen importations into Canada can be expected, emphasizing the need for immediate movement towards self-sufficiency among Canadian beekeepers. A nation-wide survey for the presence of *A. woodi* in Canada in 1984-1985 found Canada to be free of this pest. However, should the mite become established in Canada it would cause decreased honey yields, increased winter losses, and have a negative impact on the beekeeping industry (Clark 1985). The Saskatchewan Beekeepers Association has recently begun a research project at an isolated apiary site in La Ronge, Saskatchewan to determine the effect of the mite, *A. woodi*, on the honey bee colony's ability to produce honey and survive the winter conditions experienced in the northern prairies. This research will help to determine how serious a pest *A. woodi* would be if it became established in Canada (B.C. Apiculture Newsletter 1985).

1.1.2 Varroa jacobsoni

The second mite of concern to North American beekeepers is the external parasite *Varroa jacobsoni*. Adult female mites live on adult worker and drone honey bees, and feed on their haemolymph. The adult bee, however, is usually only an intermediate host and means of transport for the mite. The most serious parasitization occurs on larvae and pupae, with drones being preferred to workers. The female mite enters the cell of a late larval honey bee instar before it is capped. Eggs are laid inside the cell where the nymphal stages of the mite feed on the haemolymph of the larval and pupal bees. Mated female mites leave the cell with the emerging bee, remaining with the bee until they find a new brood cell to enter. During the winter, when brood is unavailable to parasitize, the mites remain on the adult bees and feed on their haemolymph. This mite causes emerging bees to have reduced weight, misshapen legs and wings, and shortened abdomens, with the severity of these abnormalities increasing as the mite population increases within the colony. This eventually results in a high proportion of non-viable bees, causing severe weakening and finally colony death. Symptoms within a bee colony with a low level of infestation are very difficult to detect, thus allowing for widespread establishment of the pest before its detection. There is no satisfactory method of control for *V. jacobsoni*, and evidence from Europe and the Soviet Union suggests that the mite does well in colder temperate climates such as would be found in Canada (Akratanakul and Burgett 1975; Ritter 1981; DeJong *et al*. 1982a).

Varroa jacobsoni was originally a parasite of *Apis cerana*, the Asian bee. It was not until the early 1960's that it was first described as a parasite of *Apis mellifera*. The spread of *V. jacobsoni* throughout most of the world has been quite rapid, aided by migratory beekeeping, the shipment of bees and queens, swarm movement, as well as the difficulty in detecting initial low-level infestations of the mite (DeJong *et al.* 1982b). By 1981 the world distribution of *V. jacobsoni* included Asia, eastern Europe, Africa, and South America (Griffith and Bowman 1981; Nixon 1982). *Varroa jacobsoni* has now spread throughout most of South America originating from bees imported from Japan to Paraguay in 1971 (Griffith and Bowman 1981). Its dispersal has been rapid due to the long-distance swarm movement of Africanized bees which can carry the mites with them. The mite will probably be carried into Central and North America on the Africanized bee as the Africanized bee spreads northward from South America. However, the most immediate danger of introduction of *V. jacobsoni* into North America is by transportation of the mite in feral swarms of Africanized bees on ships travelling to North American ports from South America. A recent incident emphasizes this danger. In 1984, a starved swarm of Africanized bees infested with *V. jacobsoni* was found in Chicago on a freighter from Brazil. The ship had come through the St. Lawrence seaway, passing by beekeeping areas in Ontario, Quebec, and the U.S. An extensive survey of bees along the route of the ship found no indication of *V. jacobsoni* (Clark 1985). However, should *V. jacobsoni* be discovered in the U.S., severe restrictions and possibly a total ban on the importation of bees from the U.S. into Canada would be imposed, leaving Canadian beekeepers reliant on alternate sources of bees.

1.1.3 Africanized honey bee

The third approaching problem involves the Africanized honey bee. In 1956, approximately 26 swarms of African honey bees (*Apis mellifera scutellata* L.) escaped from experimental colonies near Rio Clara, Brazil and hybridized with the local European bees to produce "Africanized" bees. Since then the Africanized bee has spread throughout South America and parts of Central America, and there appear to be no physical, climatological or known biological barriers to impede its northward movement into parts of North America. At present the Africanized bee has migrated as far north as Honduras and El Salvador and is expected to reach the state of Chiapas in Mexico by late 1985 or early 1986 (Taylor 1985). At present rates of spread of 300-500 km per year, the Africanized bee will reach Texas by 1990 and is anticipated to colonize most of the southern states (Taylor and Spivak 1984). However, not only is the natural northward spread of Africanized bees a threat, but Africanized bees could be carried on ships travelling from South America to the United States. There have been six interceptions of Africanized bees on ships' cargo at U.S. ports since 1979, according to the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (A.P.H.I.S.) (Anonymous 1985b). It has been speculated that the recent discovery of a feral colony of Africanized bees in the Lost Hills area of California on June 14, 1985 originated on an oil tanker from Venezuela (Cobey and Lawrence 1985a, 1985b). An extensive survey of a 462-square mile quarantine area by the California State Department of Agriculture has to date detected a total of seven Africanized colonies (Anonymous 1985c). This isolated incident does not pose any real threat to beekeepers in the U.S. since no mites appear to have been carried into the U.S. with the Africanized bees and all evidence indicates that extensive hybridization has already occurred between the imported Africanized bees and the domestic European bees in the area. This genetic dilution will eventually lead to the elimination of Africanized traits (Cobey and Lawrence 1985a, 1985b).

Such isolated introductions of Africanized bees involve only temporary disruptions of local beekeeping. It is the northward spread of the Africanized bee which poses the most serious threat. It is predicted that the establishment of Africanized bees in the U.S. will have an economic impact of from $26 million to $58 million in annual losses (U.S. dollars). These losses would be due to decreases in package and queen sales and pollination services, a decline in honey and beeswax production, a disruption of migratory beekeeping, and an increase in operating expenses (McDowell 1984). This study did not include the effects on public health, pollination (except almonds), beekeeping supply and equipment firms, beekeeping in other countries that depend on the southern U.S. for queens and packages, labor problems working with the Africanized honey bee, or bee disease problems associated with large feral populations. Therefore, annual losses could be even greater than estimated.

The Africanized bee will not naturally migrate as far north as Canada and will not become established in Canada due to climatic restrictions (Taylor and Spivak 1984). However, it could be brought into Canada with package and queen importations and cause disruptions in beekeeping with attendant economic losses. The establishment of Africanized bees in the southern U.S., which is the major package and queen production area, would cause severe hardship to Canadian beekeepers because their major source of spring bees would be lost. However, if Canadian beekeepers work towards self-sufficiency in the next few years, the establishment of Africanized bees in the U.S. would not have the same consequences.

1.2 A Solution: Self-Sufficiency

Two management systems are employed by Canadian beekeepers. The first management system involves destroying colonies each year after honey removal and establishing hives the following spring with imported packages for honey production the same season. The alternate management system involves wintering colonies and importing packages and queens in the spring to make up for winter losses. Both systems leave Canadian beekeepers heavily dependent on foreign sources to supply spring packages and queens. In 1984, 323,000 packages worth $7.4 million were imported into Canada (Statistics Canada 1984a). Ninety-nine percent of all imports come from the U.S., with New Zealand supplying the remainder (Clark 1985).

Canadian agriculture can not afford to jeopardize an industry whose honey and wax crop is valued at $50-60 million and which pollinates $1.2 billion worth of crops annually (Winston and Scott 1984). This industry is in jeopardy due to to its dependence on the United States for packages and queens, since importations from the U.S. could be severely restricted or banned within the next few years. A move towards a self-sufficient Canadian industry is essential and requires the following adaptations:

1. an increase in the number of hives wintered;
2. production of queens for use with spring-produced packages and nuclei as well as for summer requeening; and
3. production of spring packages and nuclei.

1.2.1 Wintering

There are two methods of wintering, indoors and outdoors. Outdoor wintering usually involves wrapping colonies in groups of four with some type of insulating material, such as roofing paper or black polyethylene and fiberglass. Each colony is given an upper entrance and colonies are kept in sunny locations protected from wind and dampness (Winston 1983b). Colonies wintered indoors are placed inside a well-insulated building in which environmental conditions are controlled. McCutcheon (1984b) recommended a dark chamber with a temperature of 2^{o}-9^{o}C, relative humidity of 50-75%, and a recirculated air flow of 0.10 liters per second per kg of bees. There are numerous variations in the techniques employed for both indoor and outdoor wintering depending on the specific environmental conditions of an area.

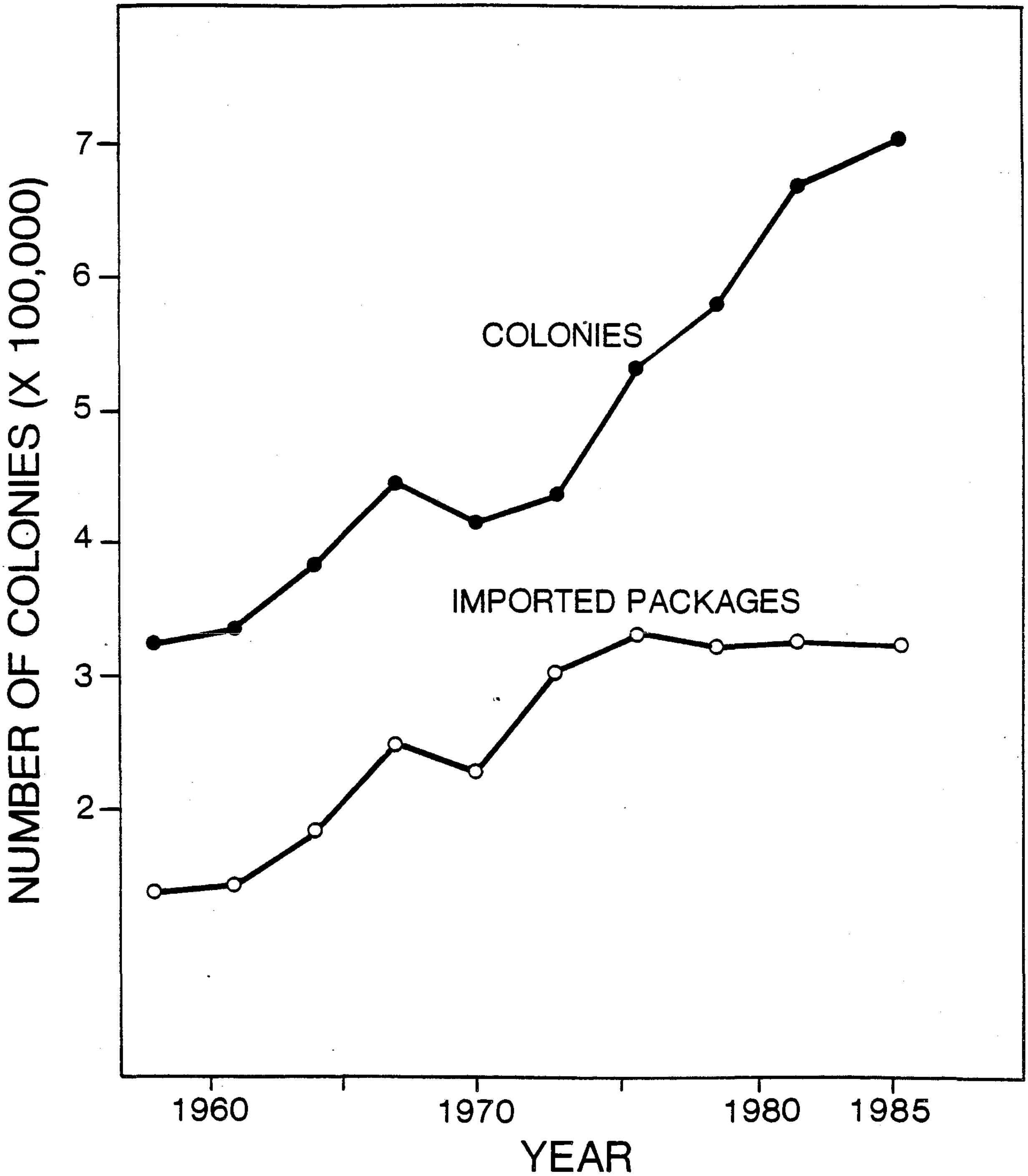
Over the past ten years there has been a dramatic increase in the number of colonies wintered in Canada; 31% in 1973 (Winston 1983b) compared to 65% in 1983 (C.A.P.A. 1984). New Brunswick, Ontario and Quebec led all provinces in percentage of colonies wintered at 80%, 95% and 98% respectively for 1983, while the remaining provinces wintered from 33% to 66% of all colonies in 1983 (C.A.P.A. 1984). In British Columbia 66% of all colonies were wintered in 1982 and 1983 and 80% in 1984, indicating a trend towards increased wintering (C.A.P.A. 1984).

The increase in the number of colonies wintered can be attributed to two factors: changed economic conditions and new technology which has improved both indoor and outdoor wintering success rates. Shipping costs for packages have almost doubled over the past ten years (Winston 1983b), resulting in the per-colony return for management systems using wintering techniques exceeding those for package-based operations. A study done in 1982 which compared the costs and returns of wintering bees versus the purchase of package bees for a 2,000 hive beekeeping operation in the Peace River region of Alberta found the wintering operation provided a return over cash of $29.62 per hive versus $16.48 per hive for packages (MacDonald and Monner 1982). Beekeepers in the Peace River area of both B.C. and Alberta have traditionally been oriented towards package management but are beginning to experiment with wintering colonies, both indoors in the Peace River and outdoors in southern B.C. The second option involves transporting hives in the fall from the Peace River area to areas in southern B.C. where the climate is conducive to outdoor wintering and spring build-up (such as Vancouver Island, and the Fraser, Okanagan and Kootenay Valleys). These hives are transported back to the Peace River area in the spring (April-May) for honey production. This technique could also be combined with package production. Beekeepers in southern B.C. could remove and sell any excess bees from these colonies in return for maintaining the hives through the winter. Both parties would benefit from this arrangement. Transporting hives from northern beekeeping areas to southern B.C. for wintering is a relatively new idea but will undoubtedly gain acceptance and popularity in the coming years (S. Mitchell, personal communication).

New technology is the second factor which has led to an increase in the number of hives wintered. Rather than become more complicated, the systems have become simpler and success rates have improved. Experimentation with new technology and techniques by both researchers and beekeepers has resulted in profitable and suitable methods of wintering hives both indoors and outdoors. Better insulating materials have improved outdoor winter success, and equipment for environmental control of indoor wintering facilities has improved indoor wintering success (Winston 1983b). However, losses of 10% can be expected with both indoor and outdoor wintering (MacDonald and Monner 1982; McCutcheon 1984b). At present winter losses are recovered by importing packages from the U.S., but recent research has investigated the possibility of making up losses from within the bee operation itself, utilizing queens reared in Canada (Gruszka 1983; Taylor and Clifford 1983; MacDonald 1984).

Wintering has become a viable alternative to package bees and has been gaining acceptance among Canadian beekeepers over the past ten years. However, although the number of colonies wintered has been increasing, this has not led to a decrease in the number of packages imported, which has remained constant over the past ten years (Fig. 1) (Statistics Canada 1984b). The increase in wintering has instead resulted in an increase in the total number of colonies (Winston 1983b). In

Figure 1: The total number of colonies and imported packages in Canada from 1958 to 1985. Data are from Statistics Canada and the Research Reports of the Canadian Association of Professional Apiculturists. (Revised from Winston 1983b).


NUMBER OF COLONIES (X 100,000)
7
6
5
4
3
2
COLONIES
IMPORTED PACKAGES
1960
1970
1980
1985
YEAR

order to attain self-sufficiency, wintering must continue to increase and cause a corresponding decrease in the number imported packages required each spring.

1.2.2 Queen production

To become self-sufficient, Canadian beekeepers must be able to supply queens: 1) for spring-produced packages and nuclei, 2) to replace queens lost from wintered colonies 3) for summer requeening of wintered hives. Queens for spring-produced packages and nuclei must either be produced in the spring or produced in the summer and wintered for use the following spring. Producing queens in the spring is very difficult due to the unsuitability of Canada's climate for queen rearing. Research by the B.C. Ministry of Agriculture and Food at Vernon has succeeded in producing both artificially inseminated and open-mated queens by mid-April (J. Gates, personal communication). However, these methods would be difficult to employ on a large scale. Therefore, producing queens in the summer, when the climate is conducive to such activities, and wintering these queens for use the following spring is desirable. There have been a number of different techniques tried for wintering large numbers of queens, including using nuclei consisting of from one to ten frames wintered indoors or outdoors and group wintering (Harp wintering system). Queens wintered outdoors in one or two-frame nuclei had a low rate of survival and the small nuclei were difficult to establish and manage (McCutcheon 1984a; Mitchell *et al.* 1985). Two-frame nuclei wintered indoors (Mitchell *et al.* 1985), three-frame nuclei wintered outdoors in groups of three per super on top of a two-super colony (McCutcheon 1984a), and four, five and ten-frame nuclei wintered outdoors on top of two-super colonies (MacDonald 1984) have given acceptable results. However, these methods are only practical for wintering a few hundred queens and are not feasible for wintering the thousands needed to become self-sufficient. The alternate method, wintering queens in groups

(Harp method), could be employed economically on a large scale providing winter mortality was low (<5%), as reported by Harp (1969). This method involves wintering queens in small compartments (3.75 x 3.75 cm and 2.25 cm deep) on pieces of comb. Queen excluders are placed over each compartment allowing hive bees to enter while preventing queens from escaping. All subsequent attempts to employ this method have resulted in unacceptably high mortality rates, 77–98% (Szabo 1977) and 28–79% (Mitchell *et al.* 1985). In addition, Mitchell *et al.* (1985) found poor acceptance and a high rate of supercedure for "Harp" queens monitored throughout the summer.

Queens reared under favorable climatic conditions during the summer could also be used to requeen wintered colonies and replace winter losses. Colonies which are wintered should be requeened every two years. This could be done after the summer honey flow, with queens reared in Canada during the summer. Requeening in the summer would involve a change in management practices, the common practice being to requeen wintered colonies in the spring with queens imported from the U.S. The use of queens reared in Canada to replace winter losses would also require modifications of traditional management techniques. Traditionally, winter losses are recovered by importing packages in the spring. Instead, nuclei could be established in June and July from stronger colonies and requeened with Canadian-produced queens. The nuclei would build up to wintering strength by September. These "extra" colonies would replace any colonies lost during the subsequent winter (Taylor and Clifford 1983; MacDonald 1984). Replacement colonies produced by this method would compete favorably on a cost basis with the alternative of buying package bees from the U.S.: $23 versus $26 profit respectively (Taylor and Clifford 1983).

A combination of spring and summer queen rearing, queen storage during winter, and summer requeening could significantly reduce Canadian dependence on imported queens from the U.S. Also, New Zealand could supply Canada with a limited number of queens. In 1968, importations of queens from New Zealand into Canada began on a restricted permit basis, with the cooperation of the New Zealand Department of Agriculture and the Canadian Department of Agriculture (Pankiw 1974). Increasing numbers of queens are imported from New Zealand yearly; 10,000 queens were imported in 1985 (Kemp 1985).

In conjunction with research on raising and utilizing queens produced in Canada, breeding projects aimed at producing queens which are suited to Canadian conditions have been implemented. The major efforts for queen selection have taken place at the Agriculture Canada research Station in Beaverlodge, Alberta and at the B.C. Ministry of Agriculture and Food facilities in Vernon and Powell River, B.C. Stock from both of these projects is now available to beekeepers. In B.C., 3,500 queens were produced and 600 were sold to beekeepers in 1983 (McCutcheon 1984a) and in 1984 5,300 queens were produced of which 1,700 were sold (C.A.P.A. 1984). In Alberta, 4,000 queens were produced and distributed to beekeepers in 1984 (C.A.P.A. 1984). The "Alberta Bee" stock is now being maintained at the Agriculture Canada Research Station in Beaverlodge, Alberta and produced for commercial use at Fairview College in Alberta. These projects have been instrumental in initiating fledgling queen rearing industries in both provinces, and all indications suggest that queen rearing will continue to grow. Other provinces across Canada are also experimenting with producing queens and altering traditional management techniques to accomodate these queens. These projects illustrate the interest in queen rearing in Canada and will result in increased self-sufficiency for the beekeeping industry.

1.2.3 Package and Nucleus Production

Canadian beekeepers import approximately 350,000 packages annually. In 1984, 323,000 packages valued at $7.4 million were imported (Statistics Canada 1984a). Each package consisted of 0.9 kg, 1.35 kg, or 1.8 kg of worker bees and a queen. The 0.9 kg size comprised approximately 69% of the imports with larger package sizes and queens comprising smaller portions of the import market (Clark 1985). These packages and queens are imported from the beginning of April through mid-May, with over 75% of all imports entering Canada through B.C. The provinces west of Ontario rely more heavily on package importations than do the provinces east of and including Ontario, reflecting a difference in management systems.

Nuclei could provide an alternative to packages for establishing colonies in the spring. A nucleus consists of from three to five frames of brood, honey and pollen as well as the attached bees and a queen. Regulations for the prevention of disease transmission prohibit the movement of beekeeping equipment between Canada and the U.S. Therefore, nuclei cannot be imported into Canada but are a management alternative worth investigating as long as production and distribution is within Canada.

To supply the needs of Canadian beekeepers, packages and/or nuclei must be produced in April and early May. However, the climate in most of Canada is not as conducive to early package and nucleus production as it is in the southern United States where rapid development of colonies during February, March and April is facilitated by favorable climatic conditions and the availability of forage (pollen and nectar). British Columbia, specifically Vancouver Island and the Lower Fraser, Okanagan and Kootenay Valleys, is the only region in Canada with climatic conditions suitable for spring package and nucleus production. Colonies can be easily wintered and bee forage is available during spring in these regions of southern B.C. Not only are the climatic conditions in southern B.C. suitable for spring bee production, but the package-based management systems of western Canadian honey producers provides a close potential market for packages and nuclei produced in B.C. In 1984, 90% of packages imported went to the four western provinces. Clearly, over $6 million of the Canadian package bee market lies close to B.C. (Statistics Canada 1984b). Furthermore, preliminary research done in the late 1960's found that it is possible to produce packages from colonies wintered in the Lower Fraser Valley of B.C. (Pankiw and Corner 1970).

In 1982, a three year research project was begun at Simon Fraser University to investigate the feasibility of and management techniques for developing a package and nucleus production industry in B.C., of which this thesis forms a part. In conjunction with this research, the B.C. Ministry of Agriculture and Food conducted a pilot project in package bee production in B.C. to determine: how and where to secure supplies for package production; how to produce, shake, package, and market packages of bees; and the cost of production of package bees. This information has been compiled by the B.C. Ministry of Agriculture and Food in; "Guidelines for Package Bee Production in B.C." (Anonymous 1985d). This research has already had an impact on the beekeeping industry in B.C. In 1982, virtually no packages or nuclei were produced for sale in B.C.; in 1983 approximately 120 packages and 600 nuclei were produced and sold in B.C.; and in 1984, 983 packages and 1,183 nuclei were produced and sold in B.C. (McCutcheon 1984a). Bee production in B.C. by all indications will continue to increase, and could eventually supply a significant number of packages and nuclei to Canadian beekeepers. A concentrated effort by all Canadian beekeepers to adopt wintering management practices in conjunction with the production of packages, nuclei and queens in

Canada could produce a largely self-sufficient Canadian beekeeping industry.

1.3 Objectives

The objectives of this research were to:

1. investigate methods of establishing colonies in the fall for bee production the following spring;
2. investigate the biological and economic impact of package and/or nucleus production on colonies; and
3. evaluate the biological and economic performance of packages and nuclei in the Lower Fraser Valley and Peace River regions of B.C.

CHAPTER 2

A COMPARISON OF FALL COLONY MANAGEMENT METHODS FOR PACKAGE PRODUCTION THE FOLLOWING SPRING

2.1 Introduction

Package producers in the southern U.S. have traditionally operated all colonies in two, 10-frame standard 9.5 inch deep Langstroth supers wintered outdoors (Roberts and Stanger 1969). Preliminary research in British Columbia used colonies in two and three standard supers wintered outdoors for package production (Pankiw and Corner 1970). Alternate colony sizes and wintering techniques have not been investigated for package production under B.C. conditions. Climatic conditions in the Lower Fraser Valley are very different from the package producing areas of the southern United States. Therefore, alternate colony sizes and wintering techniques may be better-suited to package production in B.C. Indoor wintering may result in biologically superior colonies for package production in April, and two or three small colonies may provide greater economic returns than one large colony.

In this preliminary experiment, three different colony sizes (4, 10 and 20 frames) were wintered, indoors and outdoors, to determine the best method of establishing colonies in the fall for package production the following spring.

2.2 Materials and Methods

This study was conducted from September 1982 to August 1983 in the Lower Fraser Valley area of southwestern British Columbia, using four apiary sites in

Langley (Fig. 2 Sites A, B, C, D) and an indoor wintering facility in Clearbrook (Fig. 2 Site E). In September, a total of 30 colonies were divided into five management treatments (six colonies per treatment), with one-half of the colonies of each treatment at each of two apiary sites (Fig. 2 Sites A and B). All colonies were headed by Italian (*Apis mellifera ligustica* L.) queens from B.C. Ministry of Agriculture and Food stock. During September and early October all colonies were fed sugar syrup with oxytetracycline hydrochloride and fumagillin antibiotics to provide sufficient winter stores as well as to prevent disease. The five management treatments were:

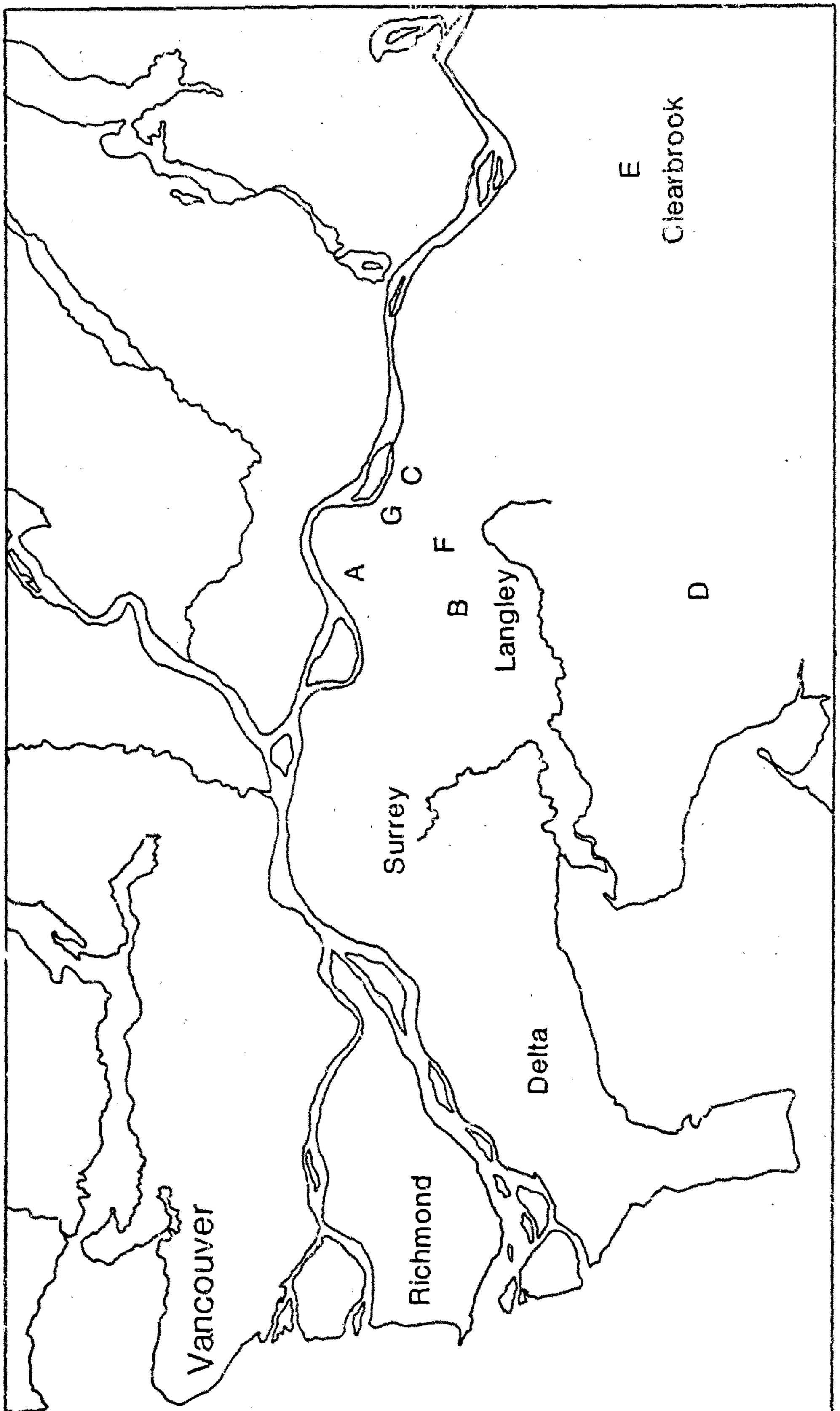
1. 20 frame x outdoors (two packages removed)

   Colonies were wintered outdoors in two supers (20 frames) of standard Langstroth equipment at apiary sites A and B (Fig. 2). The dimensions of each standard Langstroth super were 497 mm x 420 mm x 241 mm deep. From 18 February to 31 March, 1350 g of brewers yeast-based pollen supplement and 4.5 liters of sugar syrup with antibiotics (oxytetracycline hydrochloride and fumagillin) were fed to stimulate brood rearing. One 0.9 kg package was removed on each of two dates, 14 April and 28 April.

2. 10 frame x outdoors (one package removed)

   Colonies were wintered in one super (10 frames) of standard Langstroth equipment. On 3 November the colonies were transported to apiary site C (Fig. 2) and placed on top of two-super colonies (not otherwise associated with this experiment). The colonies remained at this location until 12 March when they were moved back to apiary site B (Fig. 2) where they remained for the duration of the experiment. Between 18 February and 31 March, 1350 g of brewers yeast-based pollen supplement and 4.5 liters of sugar syrup with antibiotics (oxytetracycline hydrochloride and fumagillin) were fed to stimulate

Figure 2: Apiary site locations, Lower Fraser Valley, British Columbia. Sites A, B, C, D, F and G are in Langley, site E is in Clearbrook.


Vancouver
Richmond
Delta
Surrey
Langley
A
B
C
D
E
F
G
Clearbrook

brood rearing. One 0.9 kg package was removed on 14 April. An additional 250 g of brewers yeast-based pollen supplement and 4.5 liters of sugar syrup were fed on 17 May to prevent starvation during a dearth in floral nectar.

3. 10 frame x indoors (one package removed)

Colonies were wintered in one super (10 frames) of standard Langstroth equipment. On 3 November, the colonies were transported to an indoor wintering facility at apiary site E (Fig. 2). The wintering chamber was completely dark with a temperature of 4^{0}–6^{0}C, 70% R.H. and a recirculation airflow of at least 2 liters per second per kg of bees. The colonies were moved from the indoor wintering facility to apiary site A (Fig. 2) on 12 March. Sugar syrup and pollen supplement feedings and package removal were the same as described for treatment two.

4. 4 frame x outdoors (one package removed)

Standard Langstroth supers were divided down the middle and a four-frame colony established in each half with entrances on opposite ends of the super (front and back). On 3 November, the colonies were transported to apiary site C (Fig. 2) and placed on top of two-super colonies (not otherwise associated with this experiment). The colonies remained at this site until 17 March at which time they were moved to apiary site D (Fig. 2) and each four-frame colony was established in a single super of standard Langstroth equipment (drawn comb). Between 18 February and 31 March, 600 g of brewers yeast-based pollen supplement and 2.2 liters of sugar syrup with antibiotics (oxytetracycline hydrochloride and fumagillin) were fed to stimulate brood rearing. One 0.9 kg package was removed on 14 April.

5. 4 frame x indoors (one package removed)

Standard Langstroth supers were divided down the middle and a four-frame colony established in each half with entrances on opposite ends of the super (front and back). On 3 November, the colonies were transported to the indoor wintering facility at apiary site E (Fig. 2). Conditions in the wintering chamber were as described for treatment three. On 17 March the colonies were moved from the indoor wintering facility to apiary site D (Fig. 2), and each four-frame colony was established in a single super of standard Langstroth equipment (drawn comb). Sugar syrup and pollen supplement feedings and package removal were the same as described for treatment four.

During the wintering period the following conditions applied to all treatments: insulating material was not used, the bottom entrance was reduced, and the inner cover was raised slightly to allow for ventilation.

To shake packages, frames containing workers were shaken into a funnel which rested on a screened package cage, which in turn rested on a scale used to determine when the proper weight of workers had been removed from each colony. A queen was added when 0.9 kg of workers were in the package. All colonies were managed for honey production after package removal, using standard techniques. A second brood super (standard Langstroth equipment) was added to colonies in treatments two and three on 31 May, and one or two honey supers (standard Langstroth equipment) were added to all colonies as required for honey storage. All colonies were fed oxytetracycline hydrochloride mixed in icing sugar from 31 March to 19 July for brood disease prevention.

Four colony characteristics were measured approximately every 14 days from early April to August: sealed brood, honey and pollen areas, and colony weight. Colony characteristics were also measured in October to ensure that no significant differences existed between colonies in treatments two and three or four and five before wintering. Five dates were chosen to describe the colony characteristics: prior to package removal (8 April); after package removal (11 May); mid-season (10

June and 6 July); and at the end of the season (3 August). Sealed brood, honey and pollen areas were measured using a plexiglass grid to estimate the area on each frame. All colonies were weighed with a tripod scale. Colony weight was determined by subtracting the weight of empty equipment from the tripod scale reading. Extracted honey was determined by weighing frames before and after extraction. All colonies were left with the equivalent of six full frames of honey after honey removal in August.

For economic analyses honey was valued at $1.39 per kg for bulk sales (McCutcheon 1983). Package profit was taken as $6.47 from B.C. Ministry of Agriculture and Food preliminary economic analysis of package production (Anonymous 1983). Both figures represent average B.C. prices in 1983.

Student's t-test was used to test for significant differences between experimental treatments ($P \leq 0.05$).

2.3 Results

None of the biological characteristics differed significantly between treatments four (four-frame nuclei wintered outdoors) and five (four-frame nuclei wintered indoors) in October or early April ($P > 0.05$ in all cases). Colonies in treatments four and five did not have large enough worker populations to have one 0.9 kg package removed on 14 April and were not monitored further.

None of the biological characteristics differed significantly between treatments two (one-super colonies wintered outdoors) and three (one-super colonies wintered indoors) in October or early April ($P > 0.05$ in all cases). One colony in treatment two became queenless during the winter and one colony was not strong enough to have one 0.9 kg package removed on 14 April, and these two colonies were eliminated from the experiment. None of the biological characteristics or extracted honey differed significantly between treatments two and three on any of the measurement dates from April through August ($P>0.05$ in all cases). Therefore, treatments two and three were grouped together (treatment two plus three) for comparison with treatment one.

All biological characteristics differed significantly on all measurement dates between treatments one (two-super colonies, two packages removed) and two plus three (one-super colonies, one package removed) ($P\leq0.05$), except for sealed brood which did not differ significantly on 11 May ($P=0.37$), 10 June ($P=0.29$) or 6 July ($P=0.24$) (Fig. 3). Extracted honey also differed significantly between the one and two-super treatments; 2.2 kg versus 13.8 kg respectively ($P=0.0025$) (Fig. 3). Economically, the two-super treatment yielded higher profits than the one-super treatments (Table I).

2.4 Discussion

The results indicate that indoor wintering is not justified in the Lower Fraser Valley area and that four-frame nuclei are not suitable for package production. Packages could be produced from both one and two-super colonies, but two-super colonies (two packages removed) were superior to one-super colonies (one package removed) as measured by both biological and economic criteria.

Four-frame nuclei (treatments four and five) were unsuitable for package production. Although the nuclei were fed pollen supplement and sugar syrup early in the spring to stimulate brood rearing and colony growth, the nuclei were not able to withstand the removal of 0.9 kg of worker bees by 14 April. This indicates

Figure 3: Biological (sealed brood, honey and pollen areas, and colony weight) and economic (extracted honey) characteristics on five measurement dates for one-super (one package removed) and two-super colonies (two packages removed). Standard errors are represented by bars above each histogram. (* $=P \leq 0.05$, ** $=P \leq 0.01$, *** $=P \leq 0.005$)

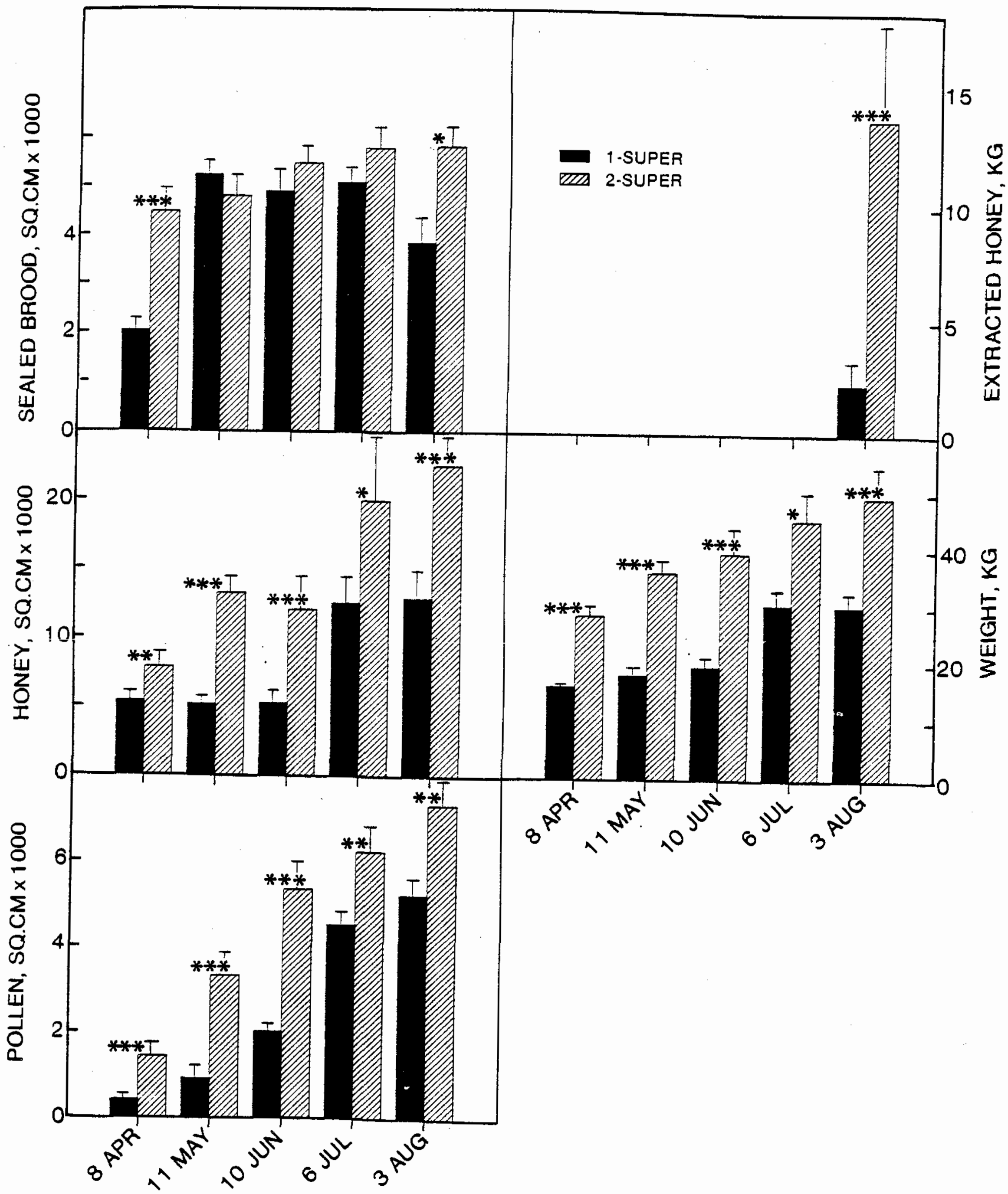

1-SUPER
2-SUPER
SEALED BROOD, SQ.CM x 1000
EXTRACTED HONEY, KG
HONEY, SQ.CM x 1000
WEIGHT, KG
POLLEN, SQ.CM x 1000
8 APR
11 MAY
10 JUN
6 JUL
3 AUG

Table I: Incomes from package bee production systems.

Treatment	Package Income ($)	Honey Income ($)	Total Income ($)
one super (one package removed)	6.37	3.06	9.43
two super (two packages removed)	12.74	19.18	31.92

a lower limit to the colony size which can be used for package production. However, nuclei produced the previous summer and wintered could provide an alternative to packages for establishing colonies in the spring. Nuclei could be established during August from the surplus of bees and brood available in most colonies at this time of year and headed by queens reared during the summer by Canadian beekeepers. These "extra" nuclei could be used in the spring in place of packages for establishing colonies, decreasing the dependence on spring produced packages and nuclei. However, research is needed to compare the biological performance and economic returns of wintered nuclei to spring produced packages and nuclei before this system can gain acceptance on a commercial basis.

Treatments two (one-super colonies wintered outdoors) and three (one-super colonies wintered indoors) did not differ significantly in any of the biological characteristics on any of the measurement dates or in extracted honey, indicating equivalent biological performance of one-super colonies (one package removed) wintered indoors and outdoors. The findings for treatments four (four-frame nuclei wintered outdoors) and five (four-frame nuclei wintered indoors) are consistent with those for treatments two and three: none of the biological characteristics differed significantly on 8 April. Thus, the results from both four and ten-frame colonies indicate there is no difference in the biological performance of colonies wintered indoors and outdoors. However, the economic returns from both systems are different. Indoor wintering is more expensive due to the cost involved in building and maintaining an indoor wintering facility. In regions of Canada which experience severe winter conditions the expense of indoor wintering may be justified, but it is not recommended in the Lower Fraser Valley area.

Two-super colonies (treatment one) were superior to one-super colonies (treatment two plus three) for package production both biologically and economically. Nearly all biological characteristics on all measurement dates were significantly lower for one-super colonies (treatment two plus three) than for two-super colonies (treatment one) ($P \leq 0.05$) (Fig. 3). The only exception was sealed brood, which did not differ significantly between the two treatments on three dates in May, June, or July. The reason for the lack of difference in sealed brood likely was due to different energy allocation in colonies of the two sizes. The smaller, one-super colonies alloted proportionately more energy and resources to brood rearing than did the two-super colonies, resulting in equivalent sealed brood areas between the two treatments. However, as a result of this intensive brood rearing the one-super colonies had proportionately fewer resources available for honey and pollen collection, as was reflected in significantly lower honey and pollen areas, colony weight, and extracted honey. This concept is supported by Farrar (1968) who demonstrated that smaller colonies have a higher relative brood production than larger colonies but lower relative honey yields. A full strength colony with 60,000 bees will normally produce 50 percent more honey than the total produced from four small colonies each with 15,000 bees. In this experiment, the smaller, one-super colonies (treatment two plus three) each produced only 2.2 kg of extracted honey whereas the larger two-super colonies (treatment one) each produced 13.8 kg of extracted honey.

Two-super colonies (treatment one) also provided higher incomes than one-super colonies (treatment two plus three). Two-super colonies provided an income of $31.92 (Table I) compared to $9.43 for one-super colonies (Table I). The higher income from the two-super colonies was due to the larger honey crop and the second package produced.

In late summer, a two-super colony could either be wintered as is or divided into two single-super colonies for the price of a queen ($8.00). The income from two single-super colonies would be ($9.43 x 2) - $8.00 = $10.86, still far less than the income of $31.92 obtained from a two-super colony. Therefore, it is recommended that two-super colonies not be divided into two single-super colonies in late summer.

In conclusion, two-super colonies (two packages removed) wintered outdoors were superior both biologically and economically to either one-super (one package removed) or four-frame nuclei, wintered indoors or outdoors, for package production. Based on these findings, all subsequent research used two-super colonies wintered outdoors for package and/or nucleus production. This is consistent with the colony size used by package producers in the southern U.S.

CHAPTER 3

THE BIOLOGICAL AND ECONOMIC IMPACT OF PACKAGE AND/OR NUCLEUS PRODUCTION

3.1 Introduction

Canadian beekeepers rely heavily on the importation of packages from the United States each spring to establish colonies. In order to become self-sufficient, packages or an alternative, nuclei, must be produced in Canada. To produce packages, a portion of the worker population is removed from the colony, whereas nucleus production involves removal of combs containing brood, honey and pollen in addition to a portion of the worker population. The comparative biological and economic impact of package versus nuclei removal has not been investigated. Nucleus removal may lower the biological performance of a colony, yet be economically feasible due to the higher sale price.

For this research, various combinations of packages and nuclei were removed from two-super colonies in April and the colonies were monitored through the season to determine the biological and economic impact of package and/or nucleus production.

3.2 Materials and Methods

This study was conducted from September 1983 to August 1984 in the Lower Fraser Valley area of southwestern British Columbia, using three apiary sites located in Langley (Figure 2 Sites A, B, F). A total of 56 colonies, each in two supers of standard Langstroth equipment, were divided evenly among the three apiary sites and requeened in September with Italian (*Apis mellifera ligustica* L.) queens reared from B.C. Ministry of Agriculture and Food stock. The dimensions of all standard Langstroth supers used were 497 mm x 420 mm x 241 mm deep. During September and early October all colonies were fed sugar syrup with oxytetracycline hydrochloride and fumagillin antibiotics to provide sufficient winter stores as well as for disease prevention. Frames of brood, honey and pollen were transferred between colonies so that by mid-October all colonies were of approximately equal size. Between 13 February and 16 April all colonies were fed a total of 1,550 g of brewers yeast-based pollen supplement to stimulate brood rearing as well as 13.5 liters of sugar syrup containing oxytetracycline hydrochloride and fumagillin antibiotics. Frames of brood, honey and pollen were again transferred between colonies in early April (before package and nucleus removal) to equalize colonies. Between 21 May and 8 June, when floral nectar was not available, 9.0 liters of sugar syrup was fed to all colonies to prevent starvation. Oxytetracycline hydrochloride mixed in icing sugar was fed from 5 April to 30 June for brood disease prevention. All colonies were managed for honey production throughout the season using standard techniques. One or two standard Langstroth supers were added to colonies as required for honey storage.

The 56 colonies were randomly divided among seven treatments with eight colonies per treatment being divided as evenly as possible among the three sites. The seven treatments were:

1. Control; no packages or nuclei removed.
2. 2-Packages; two packages removed on 16 April.
3. 3-Packages; two packages removed on 16 April and one package removed on 1 May.
4. 2-Nuclei; two nuclei removed on 16 April.
5. 3-Nuclei; two nuclei removed on 16 April and one nucleus removed on 1 May.

6. 1-Package/1-Nucleus; one package and one nucleus removed on 16 April.
7. 2-Packages/1-Nucleus; one package and one nucleus removed on 16 April, and one package removed on 1 May.

Packages were shaken as described in Chapter Two, all packages containing 0.9 kg of workers. The nuclei were established by placing three frames of brood (mainly sealed brood), one frame of honey and pollen, and the equivalent of four full frames of workers into a cardboard nucleus box to which a queen was added. Twenty of the packages and twenty of the nuclei were used in experiments described in Chapter Four of this thesis; the remainder were not used further.

Colony characteristics were monitored at approximately 21-day intervals from April until the honey was harvested in August. Five dates were chosen to describe the colony characteristics: before packages and/or nuclei were removed (8 April); after the first set of packages and/or nuclei were removed (25 April); after the second set of packages and/or nuclei were removed (18 May); mid-season (1 July); and at the end of the season (11 August). The colony characteristics monitored were sealed brood, honey, and pollen areas, colony weight, and frames of bees. Sealed brood, honey and pollen areas were measured using a plexiglass grid to estimate the area on each frame. All colonies were weighed with a tripod scale. Colony weight was determined by subtracting the weight of empty equipment from the tripod scale reading. The number of frames of adult workers was estimated by looking through the supers from above and below to determine how many frames were covered by workers. Extracted honey was determined by weighing supers before and after frames of honey were extracted. All colonies were left with the equivalent of six full frames of honey after honey removal in August.

Cost breakdowns used in determining income per colony were as follows:

1. Honey Income:

   Mean honey yield x price/kg = honey income

   Honey was valued at $1.12 per kg for bulk sales, the average B.C. price in 1984. Production costs have not been included in the calculation of honey income.

2. Package Income:

   $29.70/package - (production costs of $22.45) = $7.25

3. Nucleus Income:

   $35.00/4-frame nucleus - (production costs of $20.10) = $14.90

   It was assumed that the purchaser of the nucleus would provide the nucleus box as well as four replacement frames to the producer.

All figures used for economic analyses were obtained from the British Columbia Ministry of Agriculture and Food annual report (McCutcheon 1984c) and preliminary economic analysis of package production (Anonymous 1983).

Data were analyzed using ANOVA, followed by Duncan's multiple range test to compare means when F values were significant ($P \leq 0.05$).

3.3 Results

None of the biological characteristics differed significantly on the first and last measurement dates, 8 April (before package and/or nucleus removal) and 11 August (end of the season) (Fig. 4) ($P > 0.05$), except for frames of bees, where treatment five (three nuclei removed) was significantly lower than all other treatments except treatment three (three packages removed) on 11 August ($P = 0.03$) (Fig. 4). Biological characteristics differed significantly between various treatments on the three other measurement dates (Fig. 4) ($P \leq 0.05$). Generally, the treatments from which nuclei were removed (treatments four through seven) were significantly lower than the control and package treatments (treatments one, two and three), with treatments four (two nuclei removed) and particularly five (three nuclei removed) being the lowest of all. Extracted honey was not significantly different between any of the treatments ($P = 0.09$) (Table II). However, treatment five (three nuclei removed) produced only 10.4 kg extracted honey compared to 24.1 to 28.2 kg for the remaining treatments.

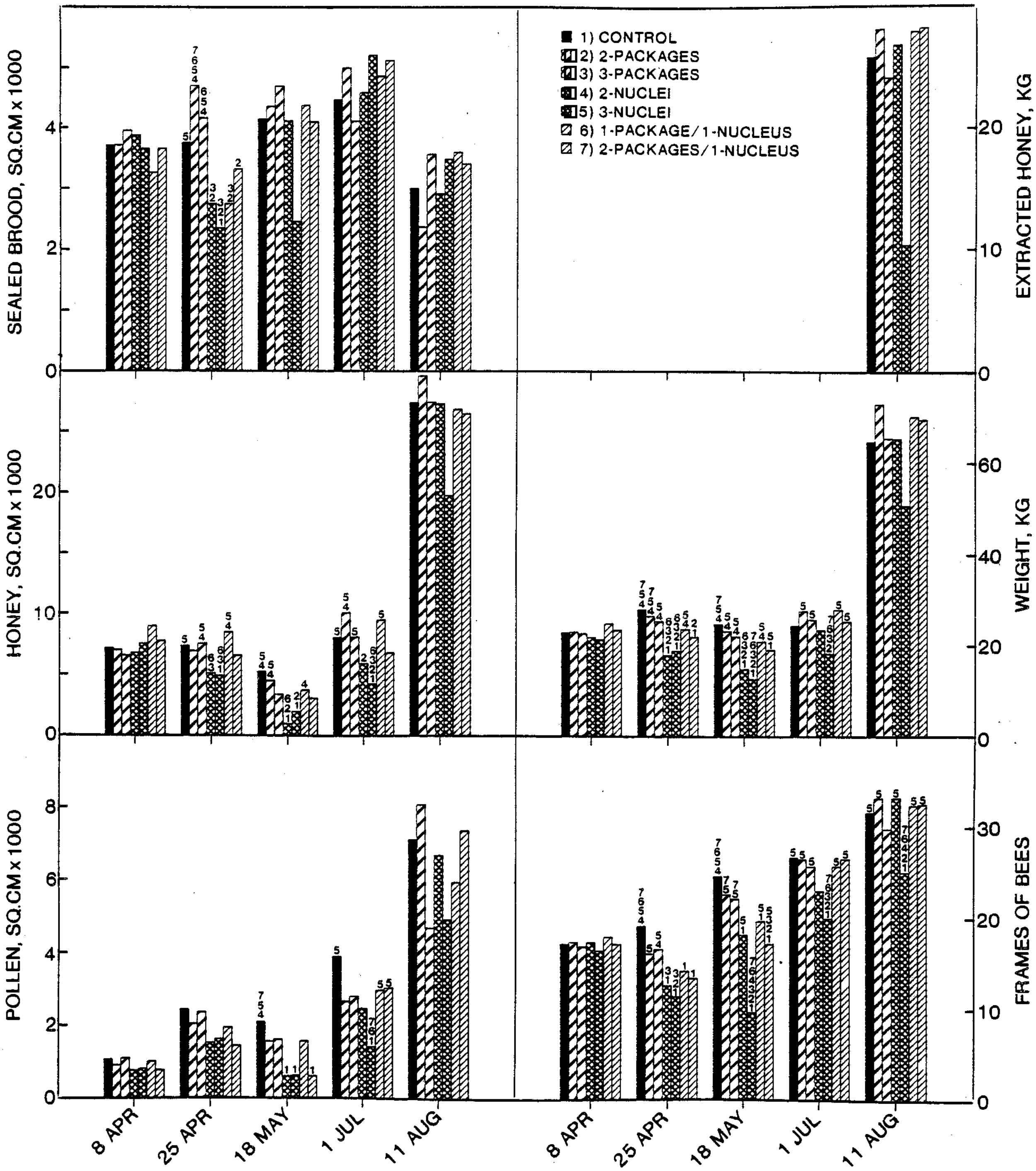
All treatments from which packages and/or nuclei were removed provided greater economic returns ($45.97–$60.98) than the control colonies used solely for honey production ($28.90) (Table II). The four treatments which involved nuclei production (treatments four through seven) provided the highest profits ($53.40–$60.98), followed by the two and three-package treatments ($45.97 and $48.74 respectively) (Table II).

3.4 Discussion

These results demonstrate that spring package and nucleus production in the Lower Fraser Valley area of British Columbia is both biologically feasible and yields a higher income than honey production alone.

On 25 April (11 days after the first package and/or nucleus removal) and 18 May (20 days after the second package and/or nucleus removal) various significant differences in biological characteristics were recorded between the treatments (Fig. 4). Generally, the treatments from which nuclei were removed (treatments four through seven) were significantly lower than the control and package-only treatments (treatments one, two and three) the two and three nucleus production

Figure 4: Biological (sealed brood, honey and pollen areas, frames of bees and colony weight) and economic (extracted honey) characteristics on five measerement dates for the seven treatments. Numbers above each treatment indicate significant differences between that treatment and the treatment indicated by the number ($P \leq 0.05$); no number above the histogram for a measurement date indicate that there were no significant differences between treatments ($P > 0.05$).



1) CONTROL
2) 2-PACKAGES
3) 3-PACKAGES
4) 2-NUCLEI
5) 3-NUCLEI
6) 1-PACKAGE/1-NUCLEUS
7) 2-PACKAGES/1-NUCLEUS
SEALED BROOD, SQ.CM x 1000
EXTRACTED HONEY, KG
HONEY, SQ.CM x 1000
WEIGHT, KG
POLLEN, SQ.CM x 1000
FRAMES OF BEES
8 APR
25 APR
18 MAY
1 JUL
11 AUG

Table II: Incomes from package and/or nucleus production systems.

Treatment	Package Income ($)	Nucleus Income ($)	Extracted Honey (kg)	Honey Income ($)	Total Income ($)	Economic Ranking
Control	-	-	25.8	28.90	28.90	7
2P	14.50	-	28.1	31.47	45.97	6
3P	21.75	-	24.1	26.99	48.74	5
2N	-	29.80	26.8	30.02	59.82	2
3N	-	44.70	10.4	11.65	56.35	3
1P/1N	7.25	14.90	27.9	31.25	53.40	4
2P/1N	14.50	14.90	28.2	31.58	60.98	1

colonies (treatments four and five) being the lowest of all. This trend can be attributed to the fact that these colonies had brood, honey, pollen and a larger portion of the worker population removed compared to the package-only treatments. By 1 July (two months after nucleus removal), all treatments were equivalent except for the treatment five (three nuclei removed) which was still significantly lower than almost all other treatments for all biological characteristics except sealed brood (Fig. 4). This indicates that colonies given the three-nuclei treatment were alloting a high proportion of their available resources to brood rearing, leaving a small proportion of the population available for foraging. This resulted in significantly lower honey and pollen areas and lower extracted honey yields than any other treatment (Fig. 4). This explanation is supported by Farrar (1968), who reported that smaller colonies put a higher proportion of available resources into brood rearing as compared to larger colonies, leaving a smaller foraging force which in turn produces lower honey yields.

By 11 August, the colonies from which packages and/or nuclei were removed (treatments two through seven) did not differ significantly from the control colonies (treatment one) in almost all of the biological characteristics. This is a remarkable result considering the amount of brood and workers removed in April. Changes in age-specific division of labor following package shaking or nucleus removal may be one mechanism responsible for this "rebound effect" (Winston *et al.* 1985). Winston and Fergusson (1985) found that workers emerging in colonies after two or three packages were shaken in April began foraging at earlier ages and had shorter life spans than in control colonies, suggesting that shifts in temporal caste structure can compensate for worker loss. This concept is based on observations from numerous studies (reviewed by Winston and Fergusson 1985) showing that under nonstressed conditions honey bee workers are lethargic and spend much of their time standing in the hive. Colonies, therefore, have a reserve force that can respond to both natural (swarming, predation, disease or sudden weather changes) and management (package and nucleus removal) population loss by accelerating their division of labor schedule so that tasks such as foraging are initiated at earlier stages. More research is needed on age-specific division of labor in stressed colonies to fully understand this "rebound effect".

Treatment five (three nuclei removed) did not rebound as quickly as the other treatments, perhaps due to the severity of the removal of bees and brood. Treatment four (two nuclei removed) produced as much honey as the control, whereas treatment five (three nuclei removed) had lower honey production, indicating an upper limit to the number of nuclei which can be removed without causing reduction in colony performance.

Colonies from which packages and/or nuclei were removed provided higher incomes than control colonies, and colonies from which nuclei were removed showed the highest incomes (Table II). Treatments involving nuclei (except three-nuclei, treatment five) were able to produce as much honey as the control or package-only treatments (treatments one, two and three) (Fig. 4), so that the higher income from nuclei sales resulted in greater total incomes. Treatment five (three nuclei removed) did not produce as much honey as the other treatments but was still ranked among the top four treatments for total income due to the high nucleus income. Thus, packages and nuclei represent an additional source of income for commercial beekeepers in the Lower Fraser Valley. Also, hobby beekeepers not interested in investing in the equipment needed to produce packages and nuclei could sell their excess bees to a commercial producer.

Additional research at Simon Fraser University has investigated the timing of package removal, removal of four packages, and incorporation of two-queen management with package production. The results from the timing of package production study indicate that package production can begin by 7 April, a week earlier than the first package and/or nucleus production in this study (Winston and Mitchell in preparation). Removal of four packages has also proven to be biologically and economically sound (Winston *et al*. 1985). Package production using a two-queen management system, did not appear to be economical (Winston and Mitchell in preparation). Further research is needed to determine the limits of spring package and nucleus production. The effects of removing more than three packages and/or nuclei over a period from 1 April to 15 May should be investigated. It may be economically feasible to deplete a colony to the point where no surplus honey is produced. In this instance honey income would be replaced by package and nucleus incomes, and possibly provide a greater income than package and nucleus production in combination with honey production.

Total incomes could be expected to be higher than those presented in Table II due to the following reasons. Honey income presented in Table II is based on bulk honey sales. In the Lower Fraser Valley 95% of honey is sold directly to the consumer and only 5% is sold in bulk to a packer (McCutcheon, personal communication). This type of sale increases the honey income dramatically, since income from direct sales is approximately double that of bulk sales. However, labor and equipment costs have not been taken into consideration when determining honey income in Table II, which would lower this figure. In addition, the colonies used for package and nucleus production were not moved for pollination or to fireweed both of which could have resulted in higher incomes being realized. A recent study in the Okanagan Valley of B.C. combined package and nucleus production with pollination and found this management practice provided higher profits than colonies managed for pollination or honey production only (Scott and Winston 1985). The economic analysis done by the B.C. Ministry of Agriculture and Food was based on producing 32 packages from 16 colonies. The nuclues income was determined by using the guidelines outlined in this economic analysis. Both package and nucleus production costs would decrease when produced on a larger scale, thus increasing total incomes.

In order to present the most conservative estimate of package and nucleus income, all production costs were included in the package and nucleus calculations. Honey income does not include production costs, and the net profits presented are also conservative since they are based on bulk rather than direct honey sales.

The results indicate that package and nucleus production is both biologically feasible and provides greater economic returns than honey production alone in the Lower Fraser Valley. Beekeepers in B.C. are beginning to produce packages and nuclei and all indications are that this industry will continue to grow. In 1984, 983 packages and 1,183 nuclei were produced and sold in B.C. (McCutcheon 1984a). Winston *et al.* (1985) estimated that at present colony densities B.C. has the potential to produce 75,520 spring packages each year, and increased colony density and a higher level of commercial beekeeping could elevate this figure. Continued and increased package and nucleus production coupled with increased wintering and queen production could result in a high degree of Canadian self-sufficiency within the next few years.

CHAPTER 4

PERFORMANCE OF PACKAGES AND NUCLEI

4.1 Introduction

Colonies may be established in the spring from either a package or a nucleus. A package consists of 0.9–1.8 kg of bees (7,500–17,000 bees) plus a queen. The bees are transported in a wooden box covered on each side with wire screen to provide ventilation. A metal can containing sugar syrup hung inside the box allows the bees to feed during transit. A nucleus usually consists of three to five frames of bees, brood, honey and pollen plus a queen, and is commonly transported in a cardboard box with a screened lid to allow for ventilation. Before the First World War, nuclei were widely used in the U.S. and Canada for establishing colonies. Fear of the transmission of disease reduced the demand and the package bee business developed, so that packages purchased from shippers in the southern states replaced the nuclei used earlier (Johansson and Johansson 1970). Recently, a renewed interest in nuclei has been shown by beekeepers (Winston 1983a). However, if nuclei are to be accepted commercially, research on the comparative biological performance and economic returns to the purchaser from use of packages and nuclei must be available.

Nuclei are more expensive to purchase than packages; $35.00 for a four-frame nucleus versus $29.70 for a 0.9 kg package (McCutcheon 1984c). In addition, nuclei must be inspected to ensure they are disease free, and standards for nuclei are not as precise as for packages. The bee population and brood, honey or pollen areas may vary greatly among producers of nuclei. However, nuclei have one principal advantage over packages. A nucleus contains drawn comb, stored honey and pollen, and most importantly brood, all of which should enhance early population growth. This may be a critical factor in regions with short growing seasons, as in most of Canada.

The objective of this research was to compare the biological performance and economic returns from 0.9 kg packages and four-frame nuclei established in April in both the Lower Fraser Valley and Peace River areas of B.C.

4.2 Materials and Methods

A. Lower Fraser Valley

This study was conducted from April to August 1984 at a single apiary site in Langley (Figure 3 G), which is located in the Lower Fraser Valley area of southwestern British Columbia. A total of 20 colonies were established on 17 April, each in a single super (drawn comb) of standard Langstroth equipment (497 mm x 420 mm x 241 mm deep). Ten colonies were established from 0.9 kg packages and 10 colonies from four-frame nuclei (produced as described in Chapter Three). All colonies were headed by Italian (*Apis mellifera ligustica* L.) queens imported from Florida.

Colonies were managed throughout the season for honey production using standard techniques. A second brood super and either one or two honey supers were added as required (standard Langstroth equipment). Sixteen and a half liters of sugar syrup was fed to all colonies between 17 April and 26 May to facilitate the growth of the colonies. As well, oxytetracycline hydrochloride mixed in icing sugar was fed to all colonies from 22 April to 12 July for brood disease prevention.

Five colony characteristics (sealed brood, honey and pollen areas, colony weight, and frames of bees) were measured approximately every 21 days from 10 May to 1 August using the same methods as described in Chapter Three. Extracted honey was determined in August by weighing supers before and after frames of honey were extracted. All colonies were left with a minimum of six full frames of honey after the honey removal in August. For economic analyses, honey was valued at $1.12 per kg, the average sale price of bulk honey in B.C. in 1984 (McCutcheon 1984c). The purchase price of 0.9 kg packages and four-frame nuclei were valued at $29.70 and $35.00 respectively (McCutcheon 1984c).

Student's t-test was used to test for significant differences between experimental treatments ($P \leq 0.05$).

B. Peace River

On 17 April, 1984 ten 0.9 kg packages and ten four-frame nuclei (produced as described in Chapter Three) were transported by truck to a 1500-colony commercial beekeeping operation in the Peace River region of British Columbia, and maintained throughout the season by the cooperating beekeeper (D. Hansen). The packages and nuclei were established in a single super (drawn comb) of standard Langstroth equipment and managed throughout the season for honey production using standard techniques. All colonies were headed by Italian queens imported from Florida.

Colonies were weighed twice during the season; 5 June and 3 July. Extracted honey was determined in August by weighing supers before and after frames of honey were extracted. The same figures listed in part A were used for economic analyses.

Student's t-test was used to test for significant differences between experimental treatments ($P \leq 0.05$).

4.3 Results

A. Lower Fraser Valley

By 1 August the biological characteristics did not differ significantly between packages and nuclei ($P > 0.05$) except for colony weight where the nuclei weighed significantly more than the packages ($P = 0.019$) (Fig. 5). Significant differences in biological characteristics occurred on various earlier measurement dates, with nuclei always recording higher measurements than packages. The nuclei produced significantly more honey than did the packages ($P = 0.025$) (Fig. 5). Both nuclei and packages recorded deficits of $12.94 and $18.28 respectively (Table III).

B. Peace River

Colony weight on both measurement dates and extracted honey did not differ significantly between packages and nuclei ($P > 0.05$) (Fig. 6 and 7). Packages provided higher incomes than nuclei, $57.77 and $52.36 respectively (Table IV).

4.4 Discussion

By 1 August the packages and nuclei in the Lower Fraser Valley differed significantly in only colony weight and extracted honey (Fig. 5). The packages produced significantly less extracted honey than the nuclei, due to a smaller foraging force during the nectar flow. In the Langley area the major nectar flow is in July (McCutcheon 1982). On 20 June (approximately one week before the

Figure 5: Biological (sealed brood, honey and pollen areas, frames of bees and colony weight) and economic (extracted honey) characteristics on five measurement dates for colonies established from 0.9 kg packages and four-frame nuclei in the Lower Fraser Valley. Standard errror is represented by bars above each histogram. (*=$P \leq 0.05$, **=$P \leq 0.01$, ***=$P \leq 0.005$).

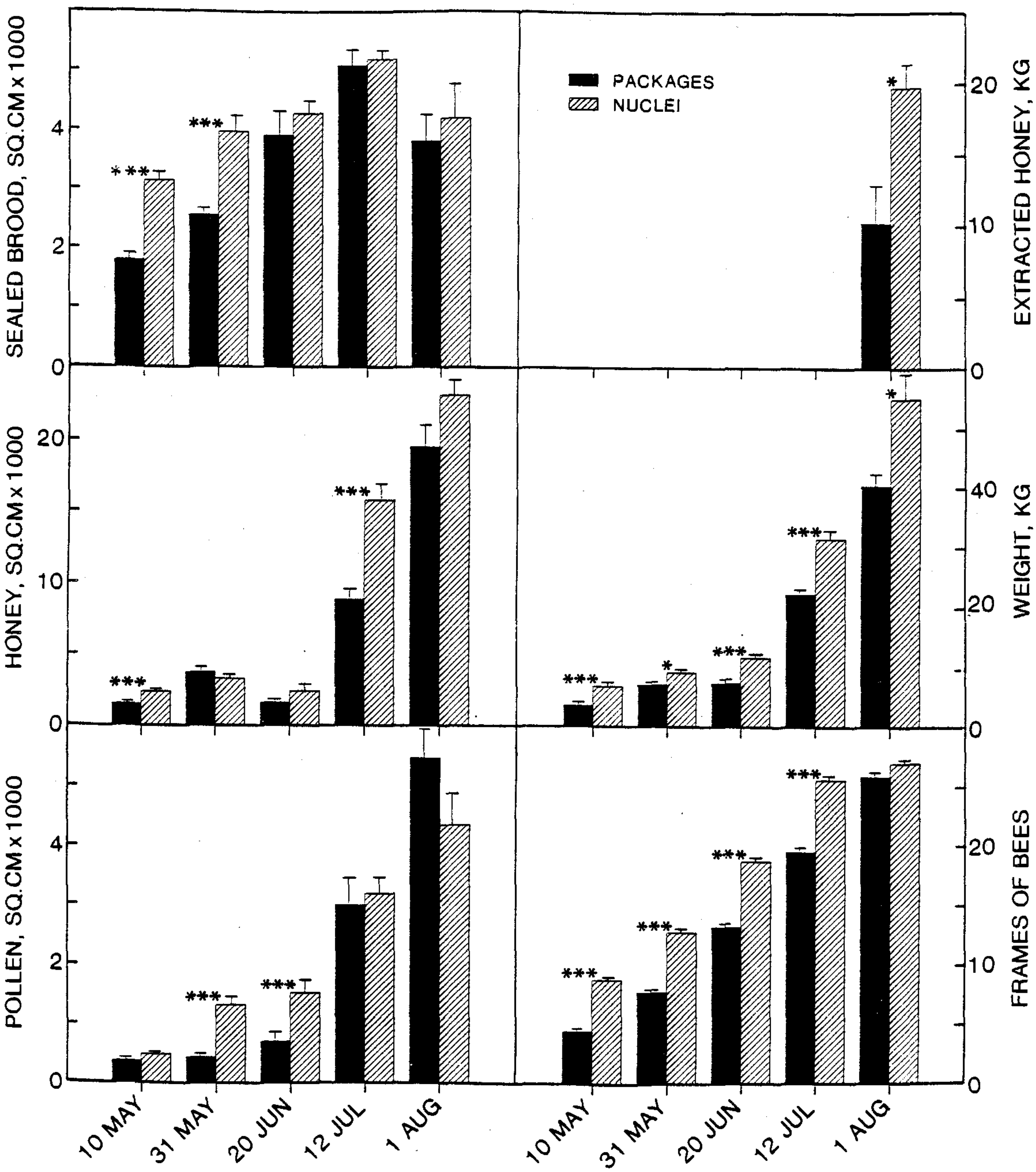

PACKAGES
NUCLEI
SEALED BROOD, SQ.CM x 1000
EXTRACTED HONEY, KG
HONEY, SQ.CM x 1000
WEIGHT, KG
POLLEN, SQ.CM x 1000
FRAMES OF BEES
10 MAY
31 MAY
20 JUN
12 JUL
1 AUG

Table III: Incomes from colonies established from 0.9 kg packages and four-frame nuclei in the Fraser Valley.

Treatment	Purchase Price ($)	Extracted Honey (kg)	Honey Income ($)	Total Income ($)
Package	29.70	10.2	11.42	-18.28
Nucleus	35.00	19.7	22.06	-12.94

Figure 6: Colony weight on two measurement dates for colonies established from 0.9 kg packages and four-frame nuclei in the Peace River. ($P > 0.05$ on both dates).

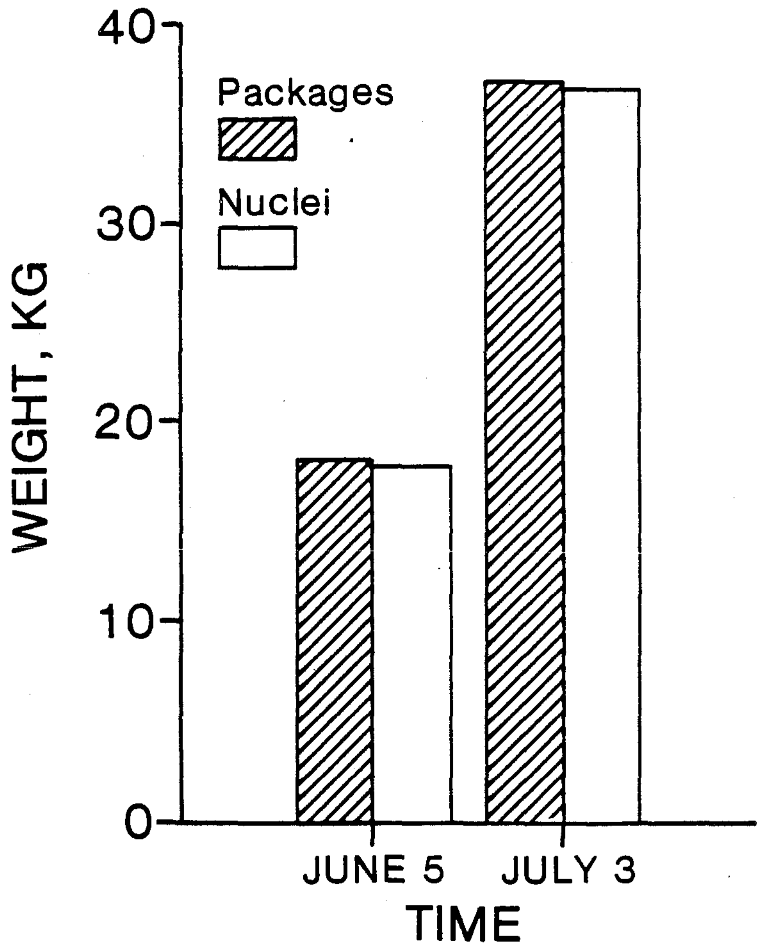

40
30
20
10
0
Packages
Nuclei
WEIGHT, KG
JUNE 5
JULY 3
TIME

Figure 7: Extracted honey for colonies established from 0.9 kg packages and four-frame nuclei in the Peace River. ($P>0.05$).

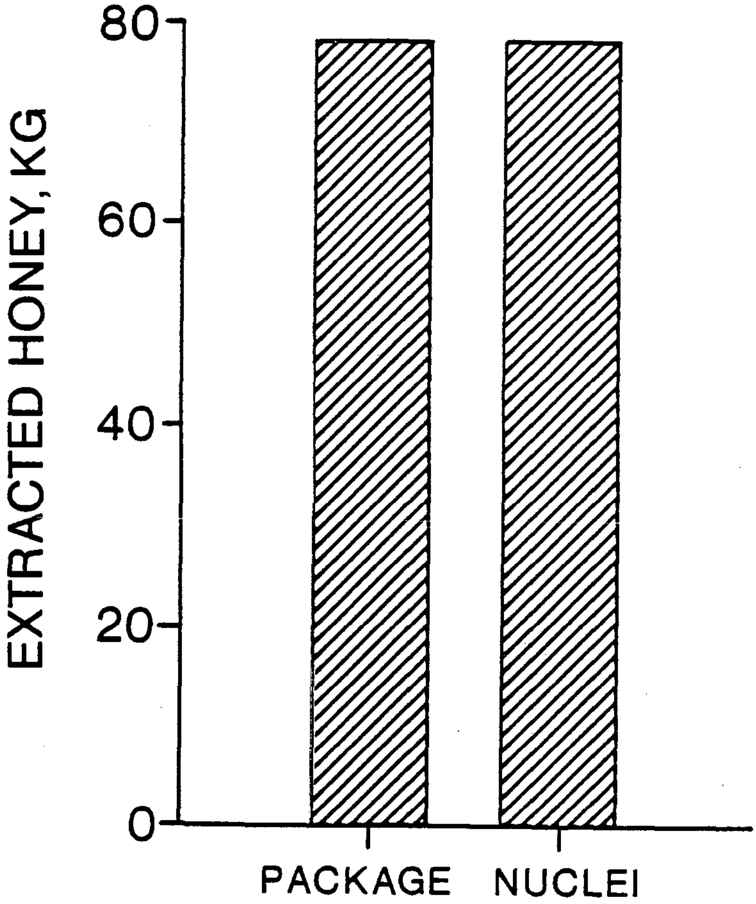

80
60
40
20
0
EXTRACTED HONEY, KG
PACKAGE
NUCLEI

Table IV: Incomes from colonies established from 0.9 kg packages and four-frame nuclei in the Peace River.

Treatment	Purchase Price ($)	Extracted Honey (kg)	Honey Income ($)	Total Income ($)
Package	29.70	78.1	87.47	57.77
Nucleus	35.00	78.0	87.36	52.36

beginning of the nectar flow) and 12 July (during the nectar flow) the packages had a significantly smaller worker population than the nuclei, but both treatments were maintaining equivalent brood areas (Fig. 5). This meant that the packages had a greater proportion of their worker population involved in brood rearing, resulting in a small foraging force. Previous research has reported the tendency of small colonies to allocate a high proportion of available resources to brood rearing, resulting in low honey production (Farrar 1968). Intense brood rearing will eventually result in an increase in the colony population and foraging force. However, the timing of the maximum foraging force must correspond to the nectar flow dates. The worker population in colonies started from packages peaked after the nectar flow (1 August) (Fig. 5), resulting in a significantly lower honey yield than the nuclei.

On 31 May and 20 June the honey area did not differ significantly between the packages and nuclei even though the nuclei had a larger population. This was because a nectar dearth period occurs during late May and June in the Langley area (McCutcheon 1982). Even though the nuclei had a larger foraging force available at this time, there was a lack of nectar to collect. However, pollen was available and the effect of this larger foraging force in the nuclei is shown by significantly greater pollen areas on 31 May and 20 June as compared to the packages. In addition, when the nectar flow began in July the nuclei recorded a significantly greater honey area than the packages on 12 July.

The packages and nuclei in the Peace River were not monitored as closely as those in the Lower Fraser Valley. The colonies in the Peace River had only colony weight measured (on two dates) and extracted honey determined at the end of the season. Packages and nuclei in the Peace River produced equivalent amounts of extracted honey (Fig. 7), whereas in the Lower Fraser Valley, nuclei produced significantly more extracted honey than packages (Fig. 5). This difference was probably due to the later honey flow in the Peace River, which begins in mid-July, two weeks later than in the Lower Fraser Valley. This allows packages to "catch up" to nuclei before the honey flow, therefore, producing equivalent amounts of extracted honey. In the Lower Fraser Valley, the honey flow began before the packages were biologically equivalent to the nuclei, therefore, they did not produce as much extracted honey. The suitability of packages and nuclei for honey production would appear to be at least partially dependent on the timing of the honey flow in an area. The one biological characteristic monitored for the Peace River, colony weight, was not significantly different between packages and nuclei, whereas in the Lower Fraser Valley study, colony weight was significantly different on all measurement dates. Had 1983 been a severe spring rather than mild in the Peace River the nuclei may have performed better than the packages due to their initial advantage of brood and a slightly larger worker population (D. Hansen, personal communication). Equivalent monitoring of nuclei and packages in both studies, would have allowed for a more detailed comparison between the performance of nuclei and packages between the two areas.

Economically, the results from the Lower Fraser Valley and the Peace River also differed. In the Lower Fraser Valley, neither nuclei or packages provided an income (Table III), whereas both packages and nuclei provided incomes in the Peace River (Table IV). In the Lower Fraser Valley, nuclei and packages produced deficits of $12.94 and $18.28 respectively. A minimum of 26.5 and 31.3 kg of extracted honey respectively would have had to be produced before nuclei or packages provided an income. In seasons with both a good nectar flow and good weather, both nuclei and packages may possibly provide an income in the Lower Fraser Valley. Under such conditions nuclei would likely provide the greater income, because they have been shown to have a larger foraging force available at the time of the nectar flow in the Lower Fraser Valley, resulting in higher honey yields. In addition, the colonies were not moved to pollination or fireweed, both of which are common managment practices in the Lower Fraser Valley. Incorporating both of these practices into a management scheme might produce higher incomes. Furthermore, if honey was sold directly to the customer instead of in bulk, the nuclei would have provided an income of $11.39. However, the packages would still have recorded a defecit (-$5.68). In the Lower Fraser Valley approximately 95% of honey is sold directly to the consumer (McCutcheon, personal communication). In the Peace River, both packages and nuclei yielded incomes, but packages provided a higher income ($57.77) than nuclei ($52.36) due to their lower purchase price (Table IV).

The beekeeping operation in the Peace River to which the packages and nuclei were sent has traditionally been based on spring package management. The cooperating beekeeper found the nuclei more labor-intensive from the standpoint of transportation and installation (D. Hansen, personal communication). However, this may have been because his operation was set up to accomodate packages, not nuclei. In the Lower Fraser Valley study no difference was noted in ease of transportation of packages and nuclei, and the nuclei were considered to be slightly easier to install than the packages.

Numerous researchers have made biological and economic comparisons between packages of different sizes established on different dates (reviewed in Nelson and Jay 1972). However, comparisons between packages and nuclei have been lacking. To my knowledge, this experiment represents the only comparison made between packages and nuclei. If Canadian beekeepers are to become self-sufficient, both packages and nuclei will have to be incorporated into beekeeping operations. This preliminary research indicates that nuclei are superior to packages both biologically and economically in the Lower Fraser Valley, and packages provide greater economic returns than nuclei in the Peace River. However, research for more than one season and in various beekeeping areas of the province is needed to establish the suitability of packages versus nuclei for honey production.

SUMMARY

Present management systems leave Canadian beekeepers dependent on package bee and queen importations from the southern United States each spring. Restrictions on the importation of bees from the U.S. are already in place due to the discovery of the mite, *Acarapis woodi*, in the U.S. in 1984. Further limitations or a ban on importations are possible due to this pest plus another mite, *Varroa jacobsoni*, and the Africanized bee, both of which are rapidly expanding their ranges northward from South and Central America. Due to these threats a move towards a self-sufficient Canadian industry is essential and requires the following adaptations: 1) increased wintering; 2) production of queens for spring and summer use and; 3) the production of packages and nuclei in the spring. The research presented in this thesis addressed the third adaptation necessary for self-sufficiency, spring package and nucleus production.

The objectives and conclusions of this research were:

1. Objective: To investigate methods of establishing colonies in the fall for bee production the following spring.

   Conclusion: Two-super colonies wintered outdoors are significantly better than smaller colonies wintered indoors or outdoors for spring package production in the Lower Fraser Valley.

2. Objective: To investigate the biological and economic impact of packages and/or nucleus production on colonies.

   Conclusion: Spring package and/or nucleus production is biologically possible and provides greater economic returns per hive than honey production alone in the Lower Fraser Valley.

3. Objective: To evaluate the biological and economic performance of packages

and nuclei in the Lower Fraser Valley and Peace River regions.

Conclusion: In the Lower Fraser Valley, nuclei were superior to packages both biologically and economically. In the Peace River packages and nuclei were biologically equivalent and packages provided greater economic returns than nuclei.

Over the past few years Canadian beekeepers have begun to work towards self-sufficiency. There has been an increase in the number of hives wintered, management practices which decrease the dependence on spring packages and nuclei have been investigated, and beekeepers in British Columbia and Alberta have initiated both queen rearing and spring package and nucleus production. It is hoped that the results presented in this thesis will provide guidelines for beekeepers interested in producing or using spring packages and nuclei in the Lower Fraser Valley area of B.C.

One of the most interesting results of this research, which should be investigated further, is the "rebound effect". The colonies from which packages and/or nuclei were removed did not differ significantly from the control colonies in almost all of the biological characteristics by August. This is a remarkable result considering the amount of brood and workers removed in April. Numerous studies have shown that under nonstressed conditions honey bee workers are lethargic and spend much of their time standing in the hive (reviewed in Winston and Fergusson 1985). Colonies, therefore, have a reserve force that can respond to both natural (swarming, predation, disease or sudden weather changes) and management (package and nucleus removal) population loss. Two possible mechanisms used by colonies to "rebound" from population loss are: accelerating their division of labor schedule so that tasks such as foraging are initiated at earlier stages (Winston and Fergusson 1985); and alloting a high proportion of available resources to brood rearing. More research is needed on division of labor in stressed colonies to fully understand this "rebound effect".

This research was preliminary and helped to highlight areas where future research should be focused. Further research is needed on: the biological and economic impact of removing more than three packages and/or nuclei from two-super colonies; more detailed economics of package and nucleus production; and package and nucleus comparisons for more than one season and in different areas of B.C.

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