THE EFFECT OF INDOOR WINTERING ON HONEY BEE COLONIES IN MANITOBA

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Barry Gordon Fingler

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ABSTRACT

Fingler, Barry Gordon, M.Sc. The University of Manitoba, October, 1980. The Effect of Indoor Wintering on Honey Bee Colonies in Manitoba. Major Professor: Dr. S. C. Jay.

The wintering of honey bee colonies in an environmentally controlled building was undertaken using various hive preparations. The size of the hive to be wintered, the age of the queen and the food given to the bees in the fall were examined. No significant differences were found in the rate at which food was consumed by the bees between treatments with single chambered hives or between treatments with double chambered hives. However, the bees in double chambered hives consumed more food over the winter storage period than did the bees in single chambered hives. Syrup appeared to be a good substitute for honey as a winter food for the bees.

Nosema disease occurred in many of the wintered hives, with the majority of the hives sampled having infections ranging from 0-10%. No correlation was found between the hive treatments and the occurrence of *Nosema apis*. Dead bees infected with *N. apis* were found to contaminate a water supply, especially if the bees were heavily infected. Water consumption by the bees during the winter storage period was extremely variable. It was found that many colonies consumed water, but that the level of nosema infection in the colonies had no bearing on the amount consumed.

Honey bees wintered indoors yielded colonies the following year which were similar in population to those wintered outdoors. The

requeening of some of the colonies was done too late in the year to be successfully evaluated.

The drifting and loss of honey bees after they were removed from winter quarters was examined. Drifting occurred in both an eastward and westward direction, with no pattern being evident. The loss of bees from the hives was initially quite substantial, but lessened with time.

I. INTRODUCTION

Currently, beekeepers in Western Canada have two alternatives for managing their honey bee colonies after the year's honey crop has been removed. One approach is to dispose of the bees in the fall, and purchase packages of bees from the southern United States the following spring. The other option is to protect the hives from the cold temperatures and harsh winds during the winter months in such a manner that they will survive and be productive the following year.

The concept of wintering honey bees is by no means new. Beekeepers have practiced both outdoor and indoor wintering for many years. Outdoor wintering generally requires that the beekeeper protect the hives from sudden fluctuations in temperature by wrapping them in an insulating material such as wood shavings or fibreglass and covering them with tar paper or plastic to reduce the amount of cool air penetrating the hives. Cellar wintering, popular in the mid-1800's and early 1900's involved the placement of the bees in specially constructed cellars, thereby providing a more moderate climate for them.

Early research into cellar wintering suggested that it was inferior to outdoor wintering, based on the higher winter mortality and lower productivity of the cellar wintered hives.

Nonetheless, the recent increases in the price of packages of bees, in addition to the intensive labour requirements of outdoor wintering, have prompted commercial beekeepers to re-evaluate their management systems and look toward practical and economical means of wintering honey bees indoors.

In 1976, the Manitoba Research Council funded a five-year research program to study the feasibility of wintering honey bees in an environmentally controlled building. The facility was constructed on campus at the University of Manitoba.

The main objective of this thesis was to observe how various hive preparations are affected by indoor wintering. This was evaluated by measuring food and water consumption of the hives, monitoring them for disease and following their population development the following spring. Population development of hives was studied using queens of different ages. The drift and loss of honey bees upon their removal from winter quarters in the spring was also examined.

It is hoped that beekeepers may view indoor wintering of honey bees in environmentally controlled buildings as another viable alternative to the existing methods of wintering.

II. LITERATURE REVIEW

Extensive research has been done concerning the wintering of honey bee colonies. Investigations into hive temperature during the winter months were carried out by various researchers (Phillips, 1914; Corkins & Gilbert, 1930; Farrar, 1952 and Owens, 1971). This brought about studies concerning various types of packing paterials used to insulate hives wintered outdoors. The type and amount of hive insulation used varied with the geographical location and the severity of the winters.

Phillips & Demuth (1918) recommended packing hives in wooden cases lined with several inches of wood shavings where they were to be wintered outdoors in cold climates. Haydak (1958) also found packing to be a necessity for wintering colonies in cold climates. In Minnesota, the average winter mortality from 1944-1954 was 18.4%, 6.4% and 2.9% for non-packed, lightly packed and heavily packed hives respectively. Additionally, in the sping, there was 25% more brood in the heavily packed hives and 19.2% more in the lightly packed hives than in those hives with no packing. Gooderham (1930) stated that for regions of Canada having cold winters, hives wintered in blocks of four in wooden cases were most economical in that less packing material per hive was required. This system of outdoor wintering has been the one generally adopted by beekeepers in the past, especially those in the Prairie Provinces. However, the materials used in packing and wrapping the hives have changed through the years from wooden cases lined with wood shavings to the use of fibreglass covered with black tar paper. The latter materials have proven to be fairly durable, easy to handle, economical and above all, a successful means of outdoor wintering.

Early research into indoor wintering of honey bees required the use of specially constructed bee cellars, designed so as not to be affected by changes in outdoor temperature. The cellars were generally built into the side of a hill and were ventilated by means of air shafts situated along the bottom of the cellars and through the ceilings. They were kept completely dark inside. The greatest problem involved in cellar wintering was the maintenance of steady temperatures.

Recommendations of hive preparation and management and on the construction of bee cellars were made by various authors (e.g., Phillips & Demuth, 1918; Jager, 1923; Gooderham, 1930; Gilbert, 1939 and Braun & Geiger, 1955).

In Manitoba, preliminary research into indoor wintering of honey bees was carried out at the Dominion Experimental Farm at Brandon. Early records reported that small numbers of hives were wintered in a cellar almost every year from 1889 to 1920 with reasonably good success. Bee research was then moved to the Horticultural Research Station at Morden, Manitoba in 1920 and remained there until 1934. Braun (1934) summarized 12 years of wintering results at Morden by stating that cellar wintered hives generally had a higher winter mortality and were less populous in the spring than those hives wintered outdoors. Double chambered hives showed less mortality during the winter, were stronger in the spring and produced more honey than single chambered hives wintered either indoors or outdoors.

In 1935, the government apiary was relocated at Brandon. Geiger & L'Arrivee (1965) found that the records at Brandon of the food consumption of hives wintered in cellars between 1934 to 1958 showed an average winter

loss in weight of approximately 15 kilograms. Little difference was found in this respect between indoor and outdoor wintered hives. They also stated that of the hives wintered indoors, those colonies in double chambers had larger populations in the spring than did those in single chambers; the former having bees covering ten frames after removal from winter quarters while the latter had bees covering six frames.

Indoor wintering has recently become somewhat more elaborate through the use of environmentally controlled buildings. Such buildings have been described by Barker (1975), Wrubleski & Bland (1976) and McCutcheon (1977). Nelson & Henn (1977) reported that colonies prepared in the fall in single brood chambers and which received a second brood chamber of honey when they were moved indoors proved to be a good method of wintering. They found more bees and brood in those colonies the following spring than in those which were prepared in the fall and wintered as single or double chambered hives.

It is important to ensure that the colonies to be wintered are provided with plenty of food in the fall. Gooderham (1930) recommended that hives wintered indoors in single chambers should have a minimum food supply of 18 kilograms. Farrar (1945) stated that 32 to 40 kilograms of honey was sufficient for hives to be wintered in double chambers. It was also shown by Farrar (1952) that the colonies that consumed the most food over the winter months produced the greatest honey yields. Free & Racey (1968) found that food consumption in wintered hives decreased with increased colony size and that spring colony size was directly related to fall colony size. It was suggested that in temperate areas, 40 kilograms of honey should be provided for each of the colonies

wintered in double chambers (Johansson & Johansson, 1969; Furgala, 1975 and Moeller, 1977).

The amount of pollen in the hives is also a very important consideration to ensure successful wintering. Allen & Jeffree (1956) reported the volume of pollen stored and colony size in wintered hives were correlated but that each independently influenced brood rearing. Jeffree (1956) discovered that brood rearing in wintered hives dropped to a minimum in October and November and rose to a maximum in February and March. The need for an adequate supply of pollen in the hives is therefore quite evident. Farrar (1945, 1952) suggested that 3125 cm^2 (500 in^2) of pollen should be present in each of the hives to be wintered. If it is not available to the bees, a pollen substitute or supplement should be fed to the bees the following spring (Farrar, 1934, 1945 and 1952). Johansson & Johansson (1977) outlined several methods for preparing and feeding various types of pollen substitutes.

Providing bees, wintered indoors, with water was reported by several authors to be necessary for the bees to liquefy granulated honey (Worsley, 1910; Barker, 1975 and Kessler, 1976). Rea (1931) and Doull (1976) found that water had to be provided to keep the hive humidity high enough to allow eggs to hatch and to prevent larvae from desiccating.

Beekeepers must prevent the widespread occurrence of Nosema disease in honey bee colonies, whether they are wintered or initiated from packages of bees. Zander (1909) first demonstrated that small oval bodies found in the epithelial cells of the ventriculus of the adult honey bee were spores of a microsporidian, which he named *Nosema apis*. White (1919) found that inoculation of the spores occurred when ingested

by the bees. Bailey (1955) discovered that the spores germinated soon after entering the ventriculus of the bee, and that infection can occur from an inoculum containing few spores. Wang & Moeller (1969, 1971) showed that the hypopharangeal glands of infected nurse bees became atrophied and that the infected bees aged physiologically. They concluded that these pathological and physiological changes significantly reduced the production of royal jelly by the nurse bees and were responsible for the dwindling of package and wintered colonies during the critical periods of colony growth in the spring. The discovery of fumagillin as a chemical agent against Nosema infection by Katznelson & Jamieson (1952) has aided beekeepers in obtaining strong, healthy and productive honey bee colonies.

III. GENERAL DESCRIPTION OF INDOOR WINTERING BUILDING

The indoor wintering building is of wooden construction and houses four bee storage rooms, a hallway and an equipment room (Figure 1).

Each storage room contains three platforms on which the hives are placed. Screened slots cut into these platforms serve to direct any carbon dioxide-laden air, should it accumulate, along the floor and out of the rooms via four exhaust ports cut into the outer walls. These ports are designed to exclude the possibility of outdoor light entering the rooms; a simple light baffle is painted black inside and placed over each port.

Temperature is thermostatically controlled in each storage room. In addition, a second thermostat is connected to an alarm system which is on 24-hour alert. This is a precaution taken to guard against overheating which may occur in any of the rooms.

The equipment room contains all the machinery required to control the atmospheric environment in each storage room. Four forced-air electric furnaces[1] serve to heat the rooms and each furnace is capable of circulating 17.8 cubic metres of air per minute. Two air conditioning units[2] are connected, one unit to two furnaces, with each having a cooling capacity of 31,579 kilojoules per hour.

Figure 2 illustrates the building's air circulation system. Fresh air is drawn from outside the building, heated by the furnaces to approximately 4°C and is forced by fan into the rooms through ducts suspended from the ceiling. Some of the air is vented through the

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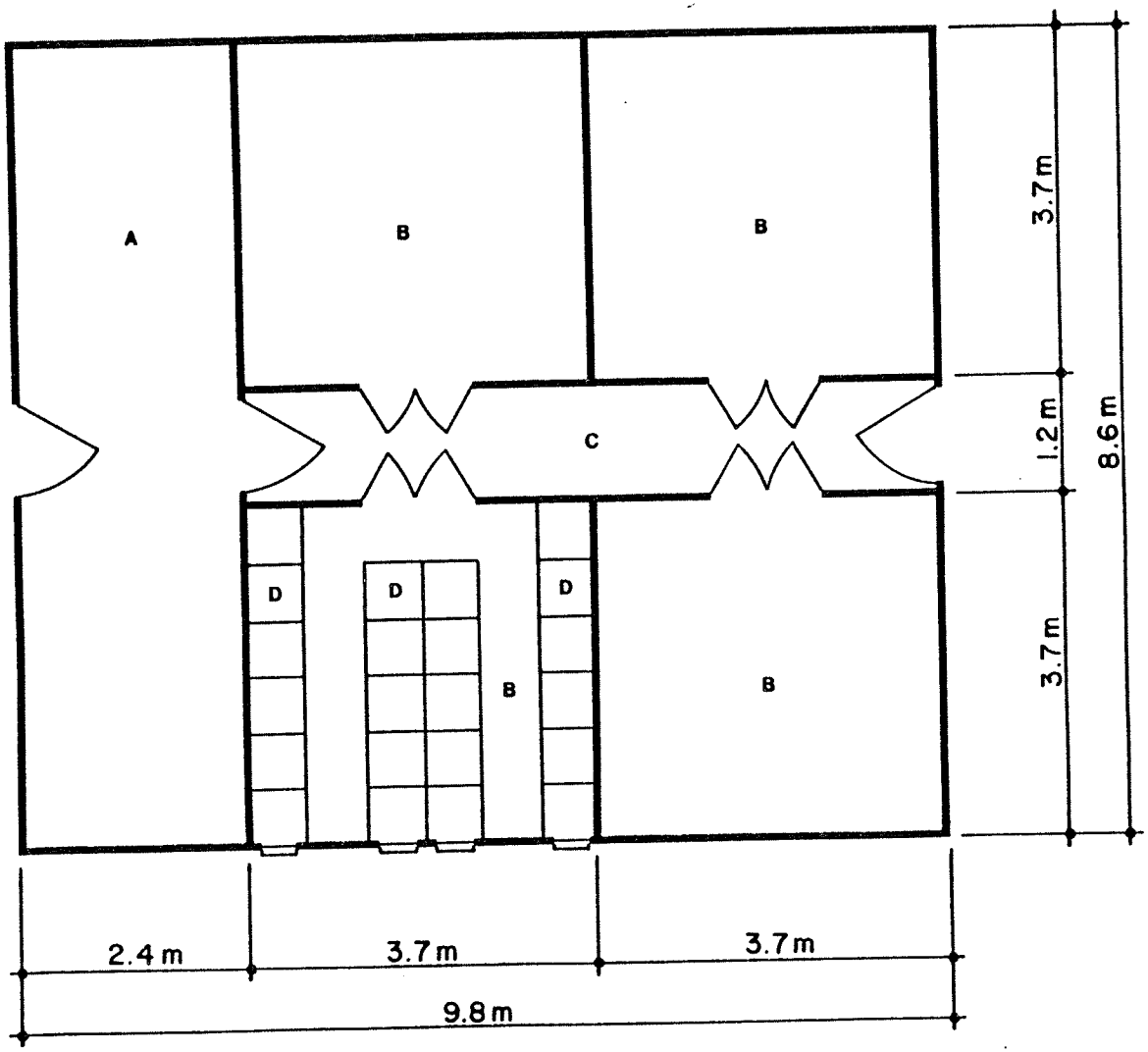
[1] *Inter-City Model EL-10.*

[2] *Tecumseh Model AH4540EC.*

FIGURE 1. General structure and dimensions of indoor wintering building.

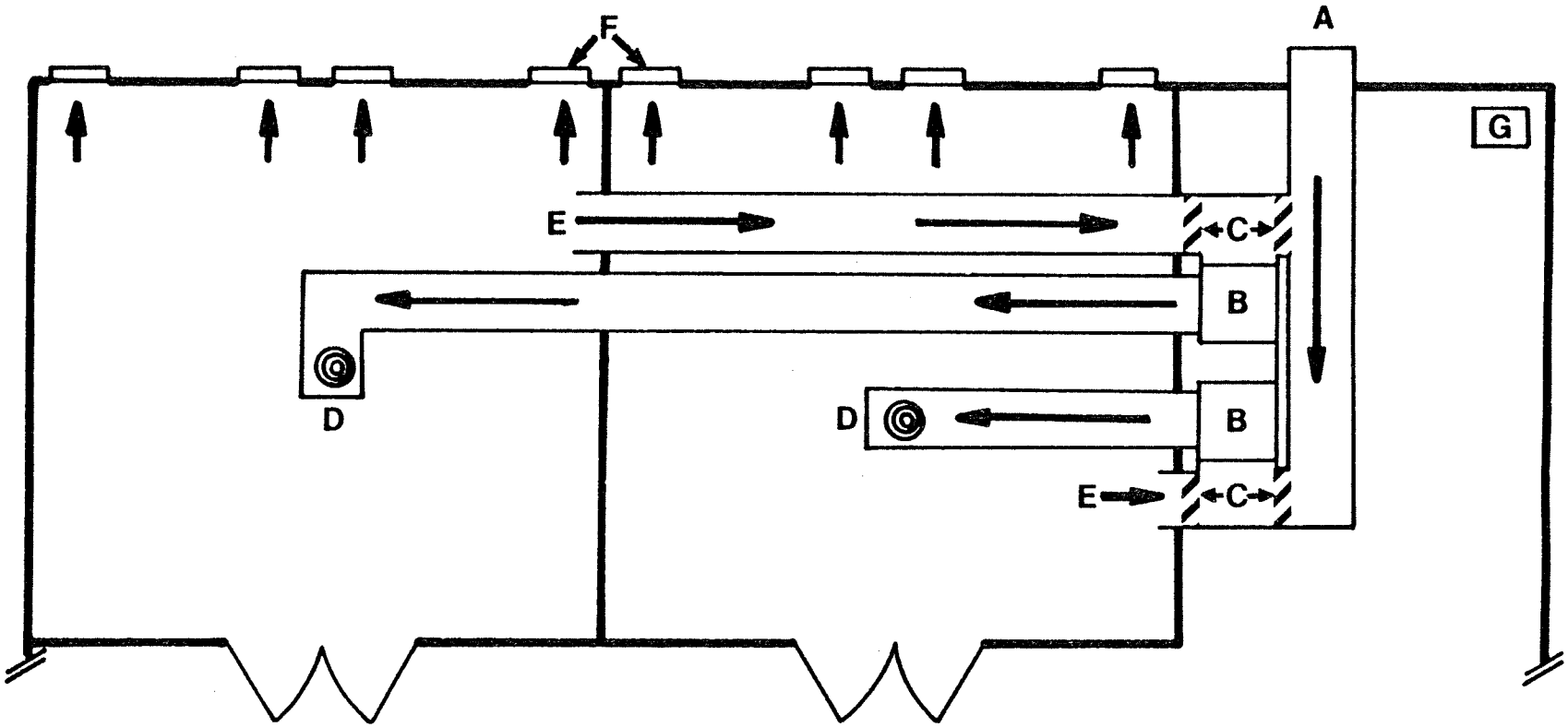


LEGEND

A. Equipment room
B. Storage rooms
C. Hallway
D. Platforms with hives in place

Scale: 2cm = 1m

FIGURE 2. Air circulation system within the indoor wintering building.



LEGEND

A. Air intake
B. Furnaces
C. Air baffles in ducts
D. Air ducts to storage rooms
E. Return air ducts to furnaces
F. Exhaust ports
G. Air conditioning unit

exhaust ports, while a greater portion returns to the furnaces through another set of ducts for recirculation into the rooms. The mixture of outside and recirculated air is regulated through adjustable baffles located in the duct-work.

Temperature and humidity levels were recorded within each storage room by means of hygrothermographs[3]. Daily records of the maximum, minimum and mean temperatures and the maximum and minimum relative humidities for the entire confinement period of the bees are given in the Appendix, Tables 1-6.

[3] *Bendix Model 594.*

IV. THE EFFECT OF AGE OF QUEEN ON THE POPULATION DEVELOPMENT OF PACKAGE AND INDOOR WINTERED HIVES

A. Introduction

The object of this study was: 1) to record the reproductive capabilities of queens reared in the current season and queens reared in the previous year when placed into hives initiated from packages of bees and into hives wintered indoors for one winter and, 2) to monitor the entrance activities of the bees of these hives as a measure of their foraging abilities.

B. Materials and Methods

1. General

In 1977, ten indoor wintered hives were standardized in single chambers as to the number of adult bees and the amount of brood they contained. Each hive consisted of one frame of adult bees (approximately 2,800 individuals) and three brood frames, one of which contained between 280 and 375 square centimetres of capped brood. The remaining frames consisted of pollen and honey, with sugar syrup being provided by means of a frame feeder.

Ten package[1] hives were also standardized in single chambers, with each hive containing approximately two pounds (0.9 kilograms) of bees, three empty brood frames, two frames of pollen mixed with honey, three honey frames and a frame feeder containing sugar syrup.

Queens that had laid eggs for one full season, and then subsequently wintered, were termed one-year old queens, while queens that were shipped with the packages of bees were termed "new" queens.

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[1] *Package hives, in beekeeping vernacular, refers to hives initiated from packages of bees shipped from the United States to Canada in the spring.*

None of the hives, whether wintered or made up from packages, were allowed to retain their original queens. All wintered hives were de-queened and then moved from the University of Manitoba apiary at night to a site approximately 25 to 30 kilometres away. After three days, five of the wintered hives were each requeened with a one year old queen while the other five were each requeened with a new queen. The packages of bees were hived without their queens and left for three days, after which five of the hives each received a one year old queen and five received new queens.

The treatments were as follows:

Group A: five wintered hives, each with a one year old queen

Group B: five wintered hives, each with a new queen

Group C: five package hives, each with a one year old queen

Group D: five package hives, each with a new queen

No attempt was made to compare the winter hives with the package hives as to their population development and entrance activity. Although the wintered hives were standardized as far as possible, their small initial populations only allowed valid comparisons to be made between Groups A and B and between Groups C and D.

The adult populations within the hives were estimated visually as a percentage of a full frame of bees. A frame covered on both sides with bees was considered 1.0 frames of bees; a half-covered frame of bees equalled 0.5 frames of bees, etc. The estimations were made every 24 days from the time the experiment began until the main honey flow period began. The hives were examined early in the morning, usually at dawn, before the bees began to fly.

The amount of capped brood within the hives was recorded by placing a grid (Figure 3), divided into square inches over the frame, and counting the number of square inches of capped brood appearing on each side of the frames. These data were taken every 12 days up to the honey flow period.

These data were recorded only up to the honey flow period for two reasons. The period preceeding the main honey flow is the critical period in colony development. The egg-laying abilities of the queens could be adequately evaluated during this period for each of the treatments. Secondly, the estimations involved opening up the hive and examining every brood frame and the disruption of the colonies during the honey flow would adversely affect honey production.

In order to monitor the entrance activities of the hives, a two-way entrance device for counting honey bees entering the hives (Figure 4) was fitted to three of the five hives within each treatment. The apparatus effectively separated incoming and outgoing bees. Figure 5 shows an entrance device in place. The hives were given about two weeks to become accustomed to the modified entrances before the first counts were taken.

Three 30-second counts per colony per hour were carried out from 0800 to 1900 hours, or until the entrance activities of the hives diminished appreciably.

Entrance counts were taken on days which were preceeded by at least two warm sunny days in succession. This was done to ensure that most bees flying during the "test" day were foraging and not flying to void

FIGURE 3. Measurement of capped brood using a grid composed of one-inch squares.

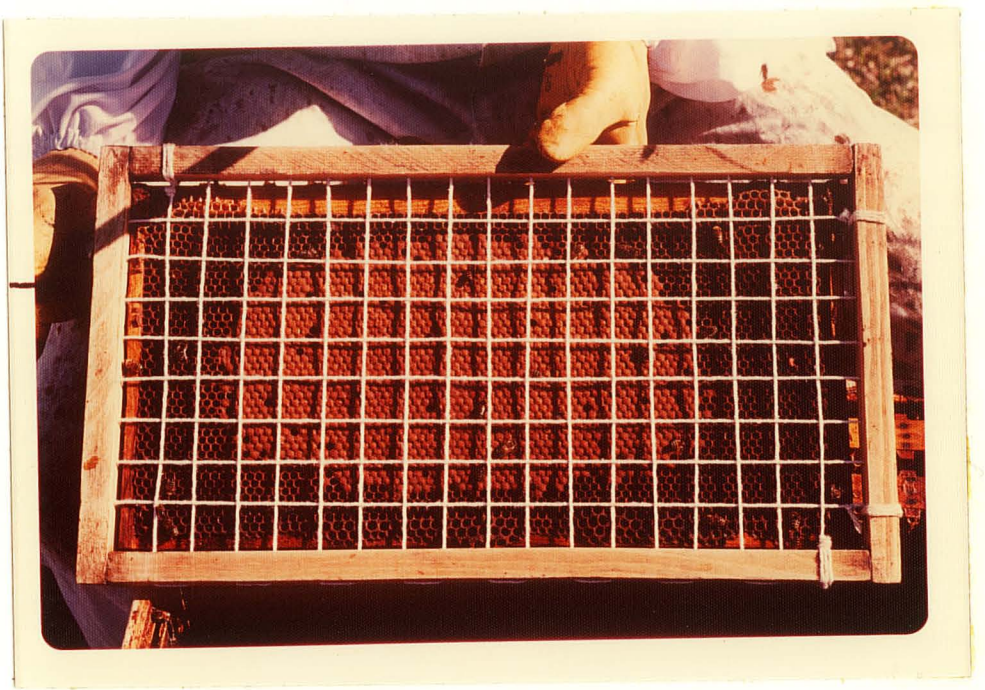
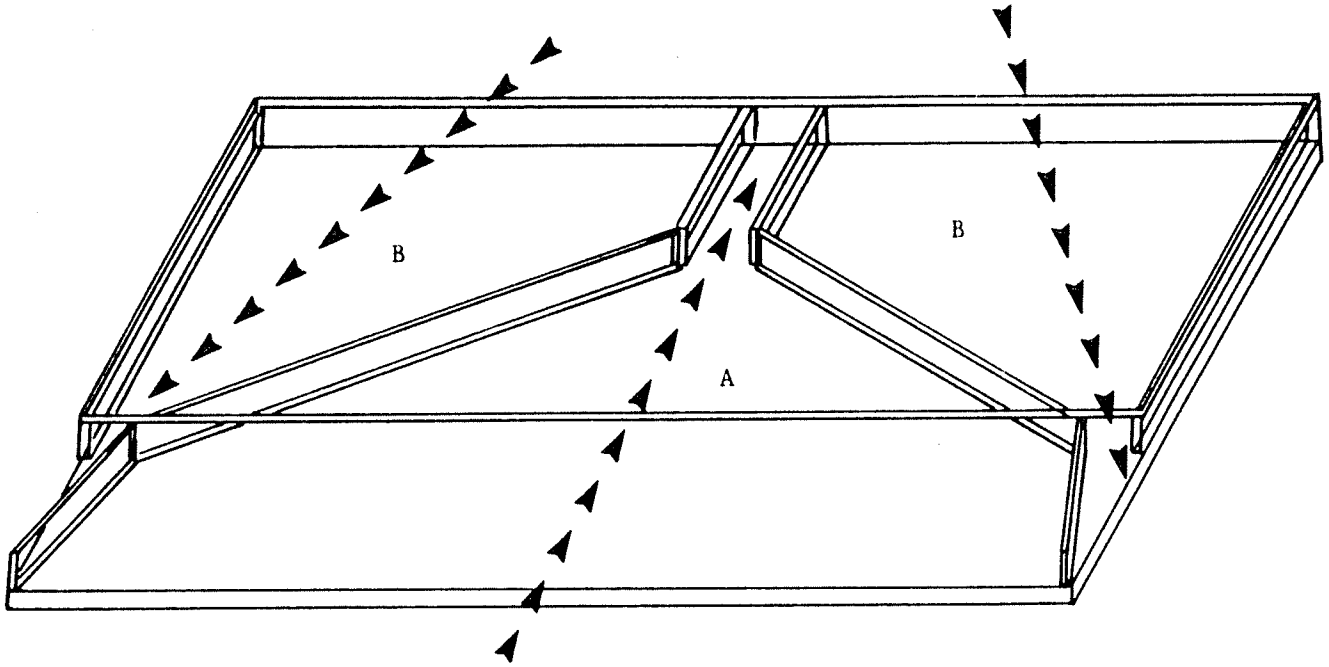


FIGURE 4. Two-way entrance device used to monitor hive activity.



A. Incoming Honey Bees.

B. Outgoing Honey Bees

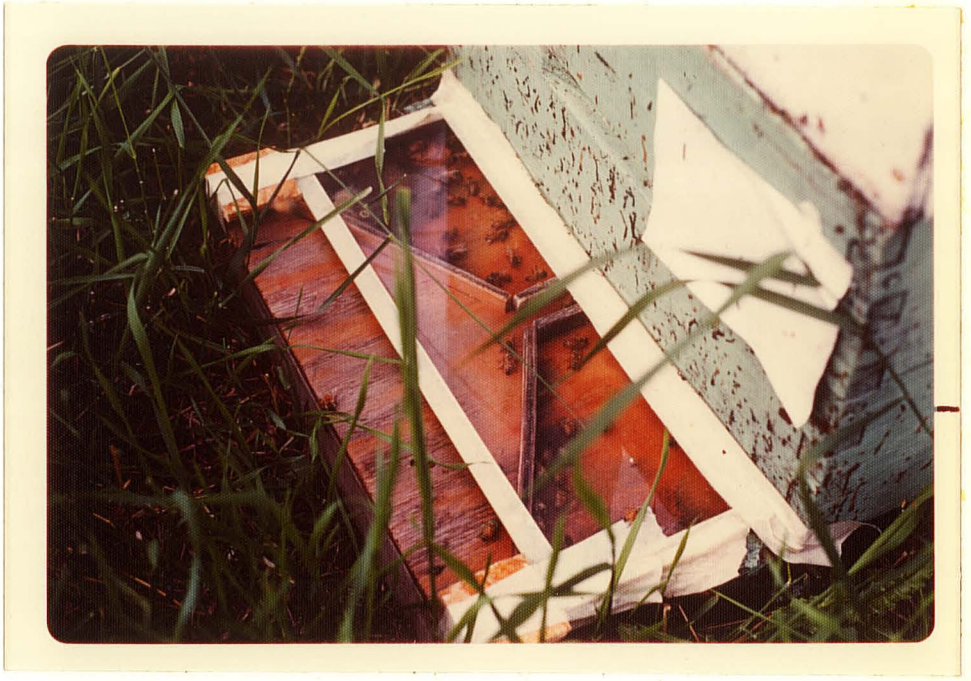
Specifications:

Length:	38.4 cm.
Width:	14.0 cm.
Height:	2.2 cm.

Materials:

Top:	0.3 cm. glass
Funnel and Sidewalls:	0.3 cm. plexiglass or 0.6 cm. plywood
Bottom:	0.6 cm. plywood

FIGURE 5. Two-way entrance device in place.



faeces accumulated over a period of days due to poor weather. The numbers of incoming pollen and non-pollen foragers, as well as the total number of incoming foragers were recorded on one day before (pre-honey flow), during (honey flow) and after (post-honey flow) the period of the main nectar secretion.

2. Statistical Analysis

a) Adult Population

The data were analyzed by first adding the individual frame estimates for each hive together to arrive at a total number of frames of bees per hive for each time examined. These figures were then multiplied by 2,800 to approximate the number of adult bees per hive at a given time.

A $\log_{10} x$ transformation was done on the number of adult bees to make the variances independent of the means. To test for differences between the means of Groups A and B and between Groups C and D, an unpaired t-test was used.

b) Capped Brood

The total amount of capped brood per hive, for each examination period was converted from square inches to square centimetres. A square root transformation was performed on the data to make the variances independent of the means. An unpaired t-test was used to test for differences between the treatment means of Groups A and B and between the treatment means of Groups C and D.

TABLE 1. Adult honey bee populations and amounts of capped brood in Groups A and B.

Treatment	Adult population	t	Capped brood (cm^2)	t
Group A[1]	10,346.0 ± 2064.5[2]		1543.7 ± 206.5	
		0.22^{ns}		0.34^{ns}
Group B	10,178.0 ± 2160.1		1484.7 ± 218.7	

Note:

[1] *Group A: 5 wintered hives, each with a one year old queen.*
Group B: 5 wintered hives, each with a new queen.

[2] *Mean and Standard Error*
Critical values of t: adults - $t_{.05[38]} = 2.026$
capped brood - $t_{.05[58]} = 2.000$

TABLE 2. Number of pollen foragers, non-pollen foragers and total incoming foragers observed in Groups A and B during the pre-honey flow, honey flow and post-honey flow periods (1977).

	Pre-honey flow (June 22)						Honey flow (July 25)						Post-honey flow (August 17)					
Treatment	Pollen foragers	t	Non-pollen foragers	t	Total incoming foragers	t	Pollen foragers	t	Non-pollen foragers	t	Total incoming foragers	t	Pollen foragers	t	Non-pollen foragers	t	Total incoming foragers	t
Group A[1]	3.50 ± 0.49[2]		13.89 ± 1.62		17.39 ± 1.66		4.25 ± 0.53		31.78 ± 3.48		35.43 ± 3.90		2.05 ± 0.42		19.06 ± 2.48		2.083 ± 2.74	
		3.23*		4.62*		5.65*		2.05*		0.27		0.60		0.81		0.12		0.06
Group B	1.61 ± 0.22		4.59 ± 0.53		6.71 ± 0.54		7.23 ± 1.00		33.68 ± 3.62		40.96 ± 4.31		2.29 ± 0.33		17.12 ± 2.36		19.53 ± 2.59	

Note:

[1] *Group A = 5 wintered hives, each with a one year old queen.*
Group B = 5 wintered hives, each with a new queen.

[2] *Mean and Standard Error*

* *Significant at the 5% level.*
Critical values of t = pre-honey flow - $t_{.05[58]} = 2.000$

honey flow - $t_{.05[70]} = 1.997$

post-honey flow - $t_{.05[64]} = 1.999$.

TABLE 3. Adult honey bee populations and amounts of capped brood in Groups C and D.

Treatment	Adult population	t	Capped brood (cm^2)	t
Group C[1]	13986.0 ± 2262.7[2]		2030.1 ± 220.4	
		0.50^{ns}		1.22^{ns}
Group D	16226.0 ± 2824.5		2560.6 ± 294.9	

Note:

[1] *Group C: 5 package hives, each with a one year old queen.*
Group D: 5 package hives, each with a new queen.

[2] *Mean and Standard Error*
Critical values of t: adults - $t_{.05[38]} = 2.026$
capped brood - $t_{.05[58]} = 2.000$

TABLE 4. Number of pollen foragers, non-pollen foragers and total incoming foragers observed in Groups C and D during the pre-honey flow, honey flow and post-honey flow periods (1977).

	Pre-honey flow (June 22)						Honey flow (July 25)						Post-honey flow (August 17)					
Treatment	Pollen foragers	t	Non-pollen foragers	t	Total incoming foragers	t	Pollen foragers	t	Non-pollen foragers	t	Total incoming foragers	t	Pollen foragers	t	Non-pollen foragers	t	Total incoming foragers	t
Group C[1]	7.82 ± 0.85[2]		19.39 ± 1.95		27.20 ± 2.32		5.56 ± 0.74		45.30 ± 4.91		50.82 ± 5.38		2.83 ± 0.48		23.75 ± 2.55		26.68 ± 2.91	
		0.32		0.28		0.22		0.38*		1.38		1.51		0.86		1.50		1.81
Group D	7.56 ± 0.79		18.36 ± 2.13		25.91 ± 2.41		10.12 ± 1.23		56.36 ± 4.70		67.35 ± 5.70		3.59 ± 0.60		35.65 ± 3.53		39.23 ± 3.90	

Note:

[1] *Group C: 5 package hives, each with a one year old queen.*
Group D: 5 package hives, each with a new queen.

[2] *Mean and Standard Error*

* *Significant at the 5% level.*
Critical values of t = pre-honey flow - $t_{.05[58]} = 2.000$

honey flow - $t_{.05[70]} = 1.997$

post-honey flow - $t_{.05[64]} = 1.999$.

c) Foraging Activity

Three 30-second counts per colony per hour were averaged to yield an hourly mean for each hive. These figures were log $_{10}(x + 1)$ transformed and the resulting data subjected to a t-test to see if there were any differences in the mean numbers of incoming pollen foragers, incoming non-pollen foragers or total incoming foragers between Groups A and B and between Groups C and D.

C. Results

1. Wintered Hive Treatments

The analysis of the results shown in Table 1 show that there were no significant differences between Groups A and B as to the mean number of adults or the mean amount of capped brood. Both groups of queens, whether new or one year old, produced similar populations up to the main honey flow period when placed in wintered hives.

Table 2 shows the results of the entrance activities of the two wintered hive treatments. On 22 June, during the pre-honey flow period, significantly more ($p < .05$) pollen foragers, non-pollen foragers and total incoming foragers were observed flying into hives of Group A than into hives in Group B. On 25 July, during the honey flow period, significantly more ($p < .05$) pollen foragers were observed flying into hives in Group B than into those in Group A. No other significant differences were found between the two treatments.

2. Package Hive Treatments

The results (Table 3) show that there are no significant differences between Groups C and D in mean adult population or in mean amounts of

capped brood. The new and one year old queens were found to produce similar populations up to the main honey flow period when placed in package hives.

The results of the entrance activities of Groups C and D are shown in Table 4. On 25 July, significantly more ($p < .05$) pollen foragers were observed returning to hives in Group D than to those in Group C. No other significant differences were found between the two treatments.

D. Discussion

Requeening, i.e., replacing the old queen in the hive with a young mated queen is a management practice familiar to most commercial beekeepers. Installing a young queen does not necessarily guarantee that she will be productive; rather, it is done to lessen the chances of queen-related problems occurring within the hive, which are often attributed to the failure[1] or death of the old queen.

The rate at which a queen lays eggs can be influenced by her hive (Merrill, 1925; Free and Williams, 1972). Ribbands (1953) stated that the rate of brood rearing is directly proportional to hive population and that with larger populations, this rate diminishes slightly as the main honey flow begins.

Each of the wintered hives in Groups A and B had a small spring population consisting of only one frame of bees. Since a portion of the worker bees in a hive clean and prepare cells to receive the eggs laid by the queen, it would seem that the queens in both treatments were limited by their hives' small populations as to the number of eggs each

[1] *Failure is a general term used to describe a situation where a queen is unable to maintain a normal rate of egg-laying.*

could lay. The fact that a small amount of capped brood was in the hives to begin with had no noticeable effect on the population growth of Groups A and B.

In the package hives of Groups C and D, initial populations were somewhat larger, consisting of approximately three to four frames of bees. However, the population growth of the package hives with one year old queens was similar to those with new queens.

The results suggest that if an old queen is physiologically capable of maintaining her normal egg-laying rate through a second year, she can stimulate the population growth of a hive in the spring as effectively as a new young mated queen can, subject to initial hive population. This appeared to be the case with both the wintered hives and the hives initiated from packages. The wintered hives used in this experiment were not representative of the populations generally considered needed to initiate spring colony development; i.e., they were quite small in the number of adults present after removing the hive from its winter quarters. Such hives should contain from 5-10 frames of bees to support the rapid increase in spring brood production needed for productive hives. Future researchers should include the study of the effects of requeening more populous wintered colonies in the spring with new and one year old queens on their population development.

The availability of forage and the "needs" of the hive are the main factors affecting the proportions of foragers which carry pollen or nectar (Ribbands, 1953). Filmer (1932) showed that the proportions of pollen foragers increased as the amount of brood in the hive increased. However, hives with similar amounts of brood can differ greatly in

foraging behavior, making it difficult to establish valid relationships between the amount of brood in the hives and their foraging activities (Free, 1967). Hives within the same apiary may also differ in the proportions of their foragers visiting the various flowering plant species in the immediate area (Eckert, 1943; Synge, 1947). This has been, in part, attributed to the genetic background of the bee (Nye & Mackensen, 1965; 1970; Free & Williams, 1972) and by the earlier foraging experiences of the bees of a hive and the discovery of crops by their scout bees (Free, 1970).

The greater foraging activity seen in Group A compared to Group B during the pre-honey flow period may be due to one or more of these extrinsic factors. During the honey flow period, more pollen foragers were observed returning to hives in Group B than to those in Group A. Similarly, on the same day, more pollen foragers flew to hives in Group D than to those in Group C. These differences may be due to the pollen sources discovered by the bees, the distance of the crops from the hives and the pollen requirements of the hives at the time. Two crops in the immediate area, that were in bloom, were rapeseed (which was located approximately 1.6 kilometres west of the apiary) and alfalfa (located approximately 1 kilometre east of the apiary). Pollen was not taken from the hives during the experiment, so information as to its source was unavailable.

Free & Preece (1969) stated that the number of bees foraging from a developing hive is proportional to its population. The population and foraging data collected during this experiment suggest, for the most part, that this statement is true. A comparison of Groups A and B show

that the total number of incoming foragers was significantly different ($p < .05$) in the pre-honey flow period, but during the honey flow and post-honey flow periods, there were no differences in the total number of incoming foragers. Groups C and D showed no differences in the total incoming foragers observed during the experimental period.

V. THE EFFECTS OF VARIOUS TREATMENTS ON INDOOR WINTERED HIVES

A. Introduction

Various methods are used by the beekeepers in Canada to prepare their hives for winter storage. Although these methods differ, depending chiefly on the location, climate and system of wintering chosen by the beekeeper, the objectives are basically the same. Furgala (1975) has listed these:

1. Hives should each have a young, productive queen. Leaving the old queen in a hive may result in:
   a) supersedure[1] in the fall occurring too late for a virgin queen to mate. This invariably results in a drone-laying queen.
   b) the old queen fails at a time when brood production is needed in the spring for colony growth.
   c) the old queen dies during the winter, leaving the hive queenless in the spring.

2. Hives should be properly protected from extreme climatic conditions. If the hives are wintered outdoors, they should be insulated in such a manner as to prevent extreme temperature changes within the hive. They must also have an upper entrance to allow the bees passage to and from the hive and to vent water vapor released by the bees during respiration. Hives wintered indoors are not subjected to climatic extremes, since the environmental temperature is held as uniform as possible. Therefore the hives need not be insulated, nor do they require upper entrances.

3. Hives must be assured adequate stores of food. The amount of honey

[1] *Supersedure is the replacement of the old queen with a new queen reared by the worker bees.*

and pollen fed varies with the size of the unit being wintered. Honey must be of good quality, that is, it should not be granulated to such an extent that the bees cannot use it as food. It must also be placed within the hive in such a way that the bees can maintain constant contact with it throughout the winter.

4. Hives must be disease free. Careful examination of the hives in the fall, along with treatment with the recommended prophylactic drugs (see Gochnauer *et al.*, 1975), should ensure that they remain disease free.

The following experiments were done to ascertain how various combinations of hive size, queen age and the bees' diet might affect hives wintered indoors. The weight loss of the hives, occurrence of nosema disease and water consumption by the hives were examined during the storage period. The following spring, the indoor wintered treatments were compared, in population development, to that of package hives.

B. General Preparation of the Hives

All hives, to be wintered, were prepared during the first three weeks of September, 1977. Hives within each of the selected apiaries were checked for the presence of queens. If a queen was found, or appeared to be present (eggs and young larvae seen), the hive was reduced in size by shaking all of the bees into the bottom brood chamber. These chambers were supplied with two frames of capped brood (placed in the center of the bottom chamber), two frames of pollen mixed with honey (one on each side of the brood frames) and five frames of honey. All hives were left to stabilize for about one week, after which they were re-inspected for the presence of a queen and divided into treatments as follows:

Treatment I: Single chamber, new queen and fed honey

Treatment II: Single chamber, old queen and fed syrup

Treatment III: Single chamber, old queen and fed honey

Treatment IV: Double chamber, new queen and fed honey

Treatment V: Double chamber, old queen and fed syrup

Treatment VI: Double chamber, old queen and fed honey (indoors)

Treatment VII: Double chamber, old queen and fed honey (outdoors)

Colonies that were to receive new queens were dequeened and left in that state for approximately three days. A new queen was introduced into a hive by placing her on a frame of emerging brood and covering her with a push-in cage. This is a small wire screen cage (7.5 x 7.5 x 1.5 cm) designed to be placed over the queen and then set lightly into the face of the comb. This method of introduction reduces the movement of the queen in the hive and allows the bees to gradually become accustomed to her. After three days, the queens were released and after

another seven days, the hives were checked to ascertain if they were accepted by their respective hives. If a queen could not be found, and there were no signs of her presence, (i.e., eggs and young larvae) the procedure was repeated until that hive accepted a new queen.

The bees were fed with either honey or a sugar syrup, the latter being made by mixing 120 kilograms of beet sugar with enough water to fill a 204.5 litre (45 gallon) drum.

Hives receiving syrup had all of their frames of honey removed and replaced with empty frames. Those hives to be wintered as double chambered units had a super of empty frames placed on top of the brood chamber. The hive lids were removed and replaced with wooden covers made of aspenite (48.7 x 39.7 x 1 cm). All of the covers had holes, approximately eight centimetres in diameter, drilled in their centers.

Thirty-pound plastic honey pails were used as gravity feeders. Each lid had a hole approximately five centimetres in diameter cut out of its centre and a piece of forty-mesh brass wire screen fastened over it. Once the pails were filled with syrup and the lids fastened, they were inverted over the holes in the covers of the hives. The bees then moved through the holes in the covers and fed on the syrup through the screens.

Bees fed on honey, received frames of capped honey, while those hives wintered as double chambered units had supers of honey frames placed on top of their brood chambers.

Fifteen hives were prepared for outdoor wintering. They were made up as double chambered units, each containing the old queen and fed on

a diet of honey. Once moved to the University apiary, the hives were arranged in blocks of four, with entrances of two of the hives facing north and the other two facing south. The bottom entrances were five centimetres wide; each hive was also provided with an upper (or top) entrance approximately four centimetres wide.

The sides and tops of the hives were wrapped in fibreglass (R7 value); the tops received a double thickness of insulation to reduce heat loss through the lids. Tar paper was then placed around the fibreglass and secured with twine. Holes were cut through the insulation to expose the upper entrances, and the wrapping was then stapled to the hive bodies around each upper entrance to prevent bees from becoming trapped between the insulation and the hive.

All of the hives were fed until the gross weights amounted to 36-39 kilograms for single chambered hives and 57-59 kilograms for double chambered hives.

Treatment VIII consisted of ten package hives. The brood chambers were each provided with three empty frames, two frames of pollen mixed with honey, three frames of honey and a frame feeder of syrup. The packages of bees (0.9 kilograms) were hived during the evening of 24 April, 1978. They were then left undisturbed for three days to allow the bees to stabilize. If any queen-related problems were observed (i.e., queenless hives, supersedure or drone laying queens), replacement queens were introduced into those hives.

C. The Effect of Various Hive Treatments on Their Weight Loss During the Winter

1) Materials and Methods

All of the hives which were to be wintered indoors (Treatments I to VI) were weighed just prior to being placed into storage for the winter. They were weighed three more times; twice while in storage (on the 66th and 108th days of the storage period) and again as they were removed from the building (on the 150th day).

The storage rooms were kept at a temperature of $4.4 \pm 1.1^{\circ}C$ for the confinement period. No attempt was made to control the relative humidity in the rooms.

Comparisons in hive weight loss were made between the single chambered hives in Treatments I, II and III and between the double chambered hives in Treatments IV, V and VI. All of the hives were weighed on a platform scale in pounds; these data were converted later to kilograms. Linear regression was performed on the data and the regression lines for each treatment were compared by analysis of covariance for parallelism between pairs of lines. A significance level of 1% was used.

The food consumption of the single chambered hives was compared to that of the double chambered hives by means of an unpaired t-test.

Only those hives alive at the end of the storage period were considered in the analysis. Each dead hive was examined in an attempt to ascertain the reasons for death. These data are summarized in the Appendix, Table 7.

2) Results and Discussion

Figures 6-8 show the regression lines for Treatments I, II and III, respectively and Figure 9 shows a comparison of these lines. The single chambered hives in Treatments I, II and III showed no significant differences in their rates of food consumption. The mean amounts of food consumed per treatment were 11.34 kg (Treatment I), 9.13 kg (Treatment II) and 11.94 kg (Treatment III).

Similarly, the regression lines for Treatments IV, V and VI are shown in Figures 10-12, and a comparison of these in Figure 13. No significant differences in food consumption rates were found between the double chambered hives in Treatments IV, V and VI. The mean amount of food consumed by hives in Treatment IV was 17.36 kg, in Treatment V, 15.65 kg and in Treatment VI, 17.27 kg.

The double chambered hives consumed significantly more ($P < .01$) food during the storage period than did the single chambered hives.

The type of food originally fed to the bees (i.e., honey or syrup) had no effect on the rate at which it was consumed over the storage period. This was quite likely due to the storage temperature being low enough to slow the bees' metabolism and movement within the hives.

When the dead hives were examined, granulation of honey and the depletion of stores (starvation) were the two most common situations found. Many of the colonies which died had frames of feed containing granulated honey (Figure 14). Figure 15 shows an accumulation of granulated honey on the bottom board of a hive. The bees would have had to reliquefy the crystals to utilize it as food. Some dead hives

FIGURE 6. Weight loss of indoor wintered hives. Treatment 1: single chamber, new queen and fed honey.

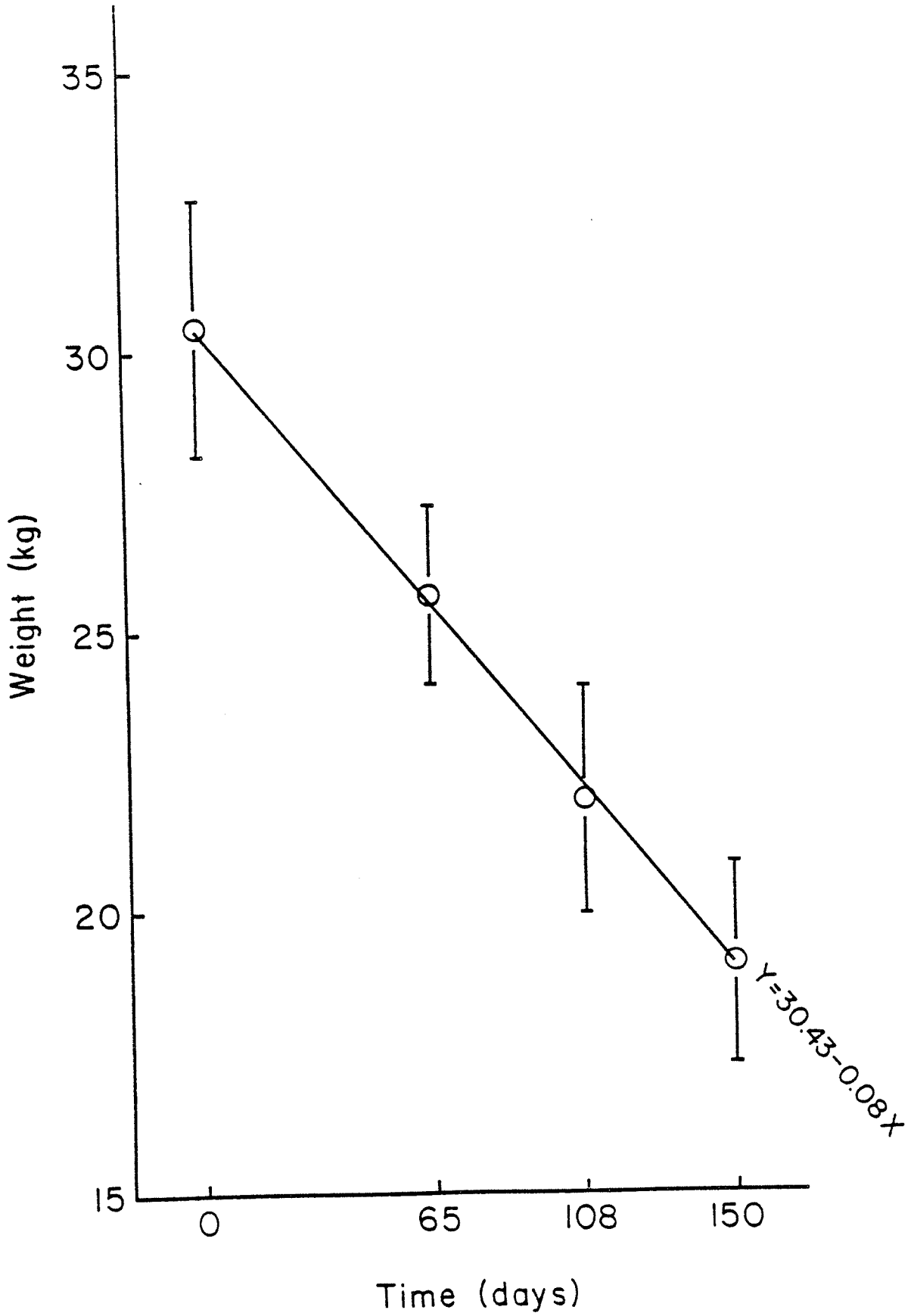

35
30
25
20
15
Weight (kg)
0
65
108
150
Time (days)
Y=30.43-0.08X

FIGURE 7. Weight loss of indoor wintered hives. Treatment II: single chamber, old queen, and fed syrup.

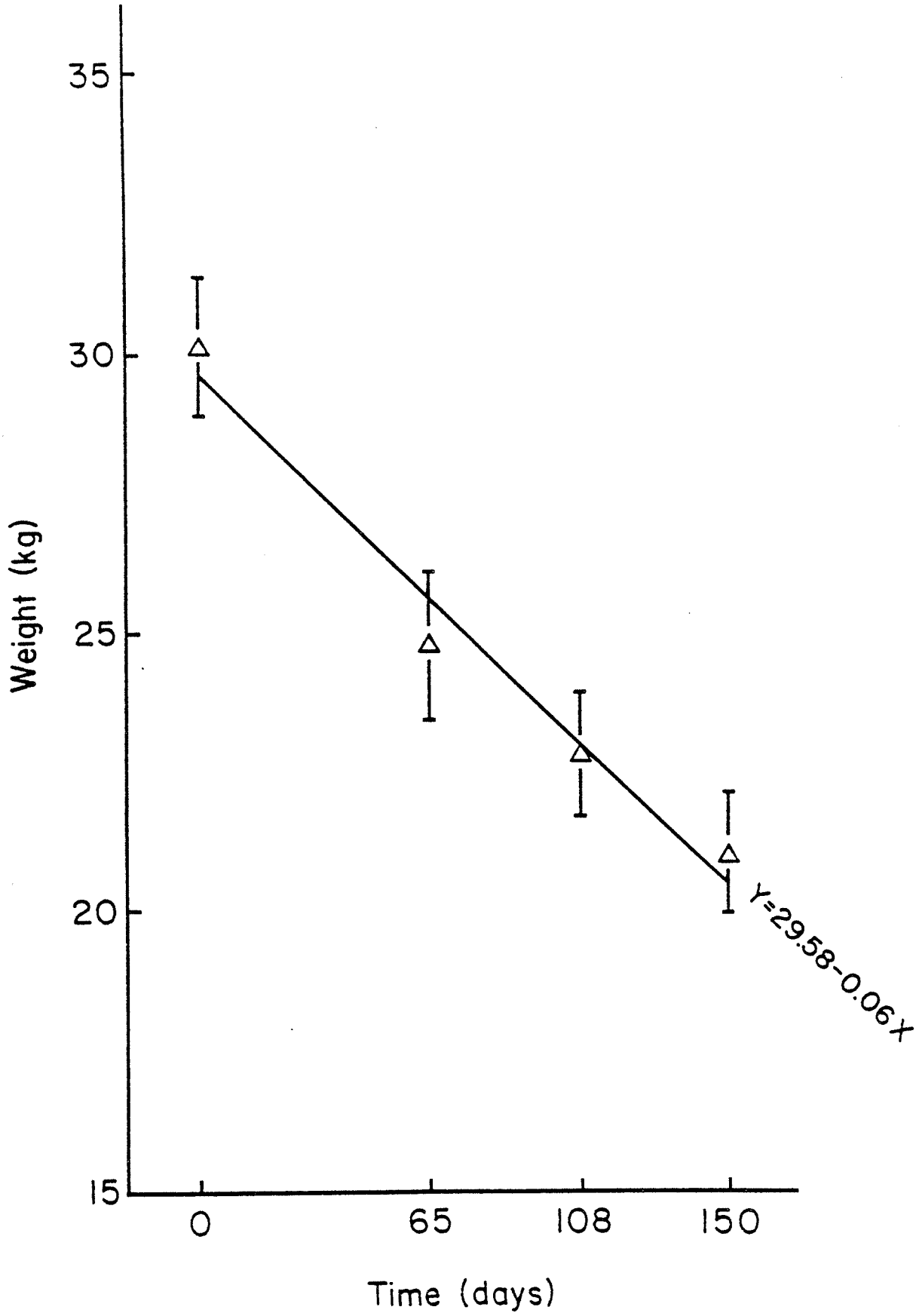

35
30
25
20
15
Weight (kg)
0
65
108
150
Time (days)
Y=29.58-0.06X

FIGURE 8: Weight loss of indoor wintered hives. Treatment III: single chamber, old queen, and fed honey.

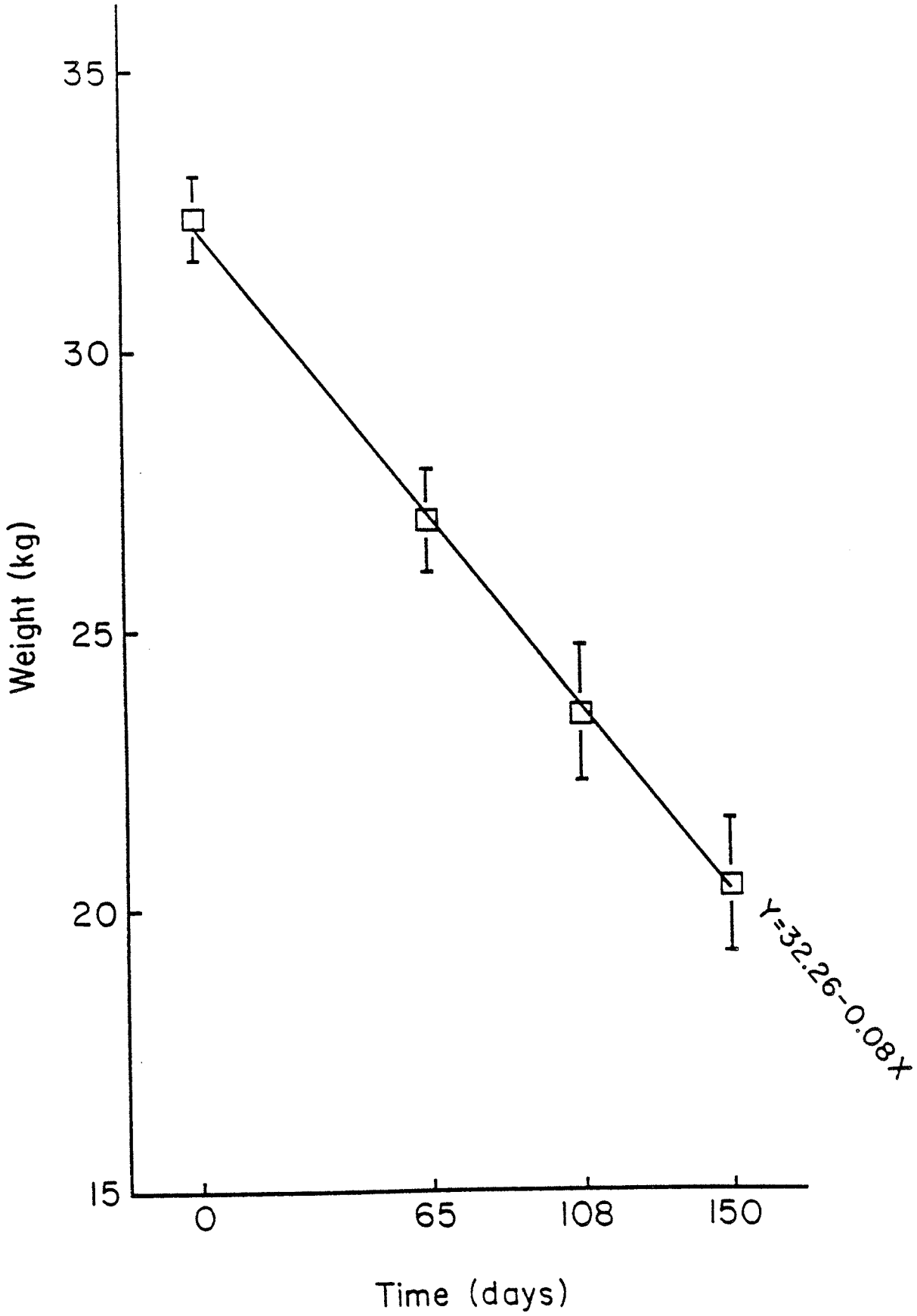

35
30
25
20
15
Weight (kg)
0
65
108
150
Time (days)
Y=32.26-0.08X

FIGURE 9: Comparison of the weight loss of indoor wintered hives.
Treatment I: single chamber, new queen and fed honey.
Treatment II: single chamber, old queen and fed syrup.
Treatment III: single chamber, old queen and fed honey.

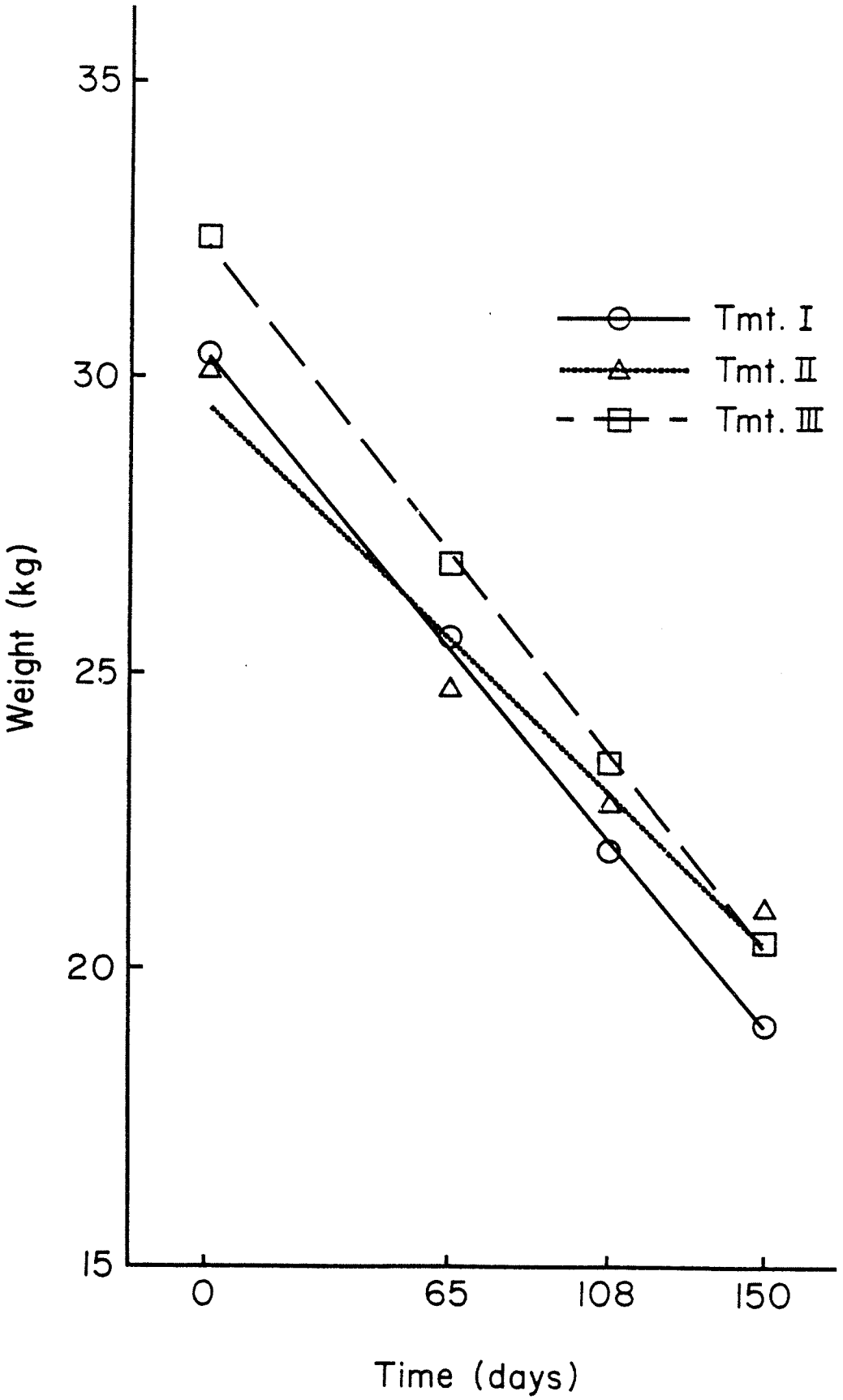

35
30
25
20
15
Weight (kg)
0
65
108
150
Time (days)
Tmt. I
Tmt. II
Tmt. III

FIGURE 10. Weight loss of indoor wintered hives. Treatment IV: double chamber, new queen and fed honey.

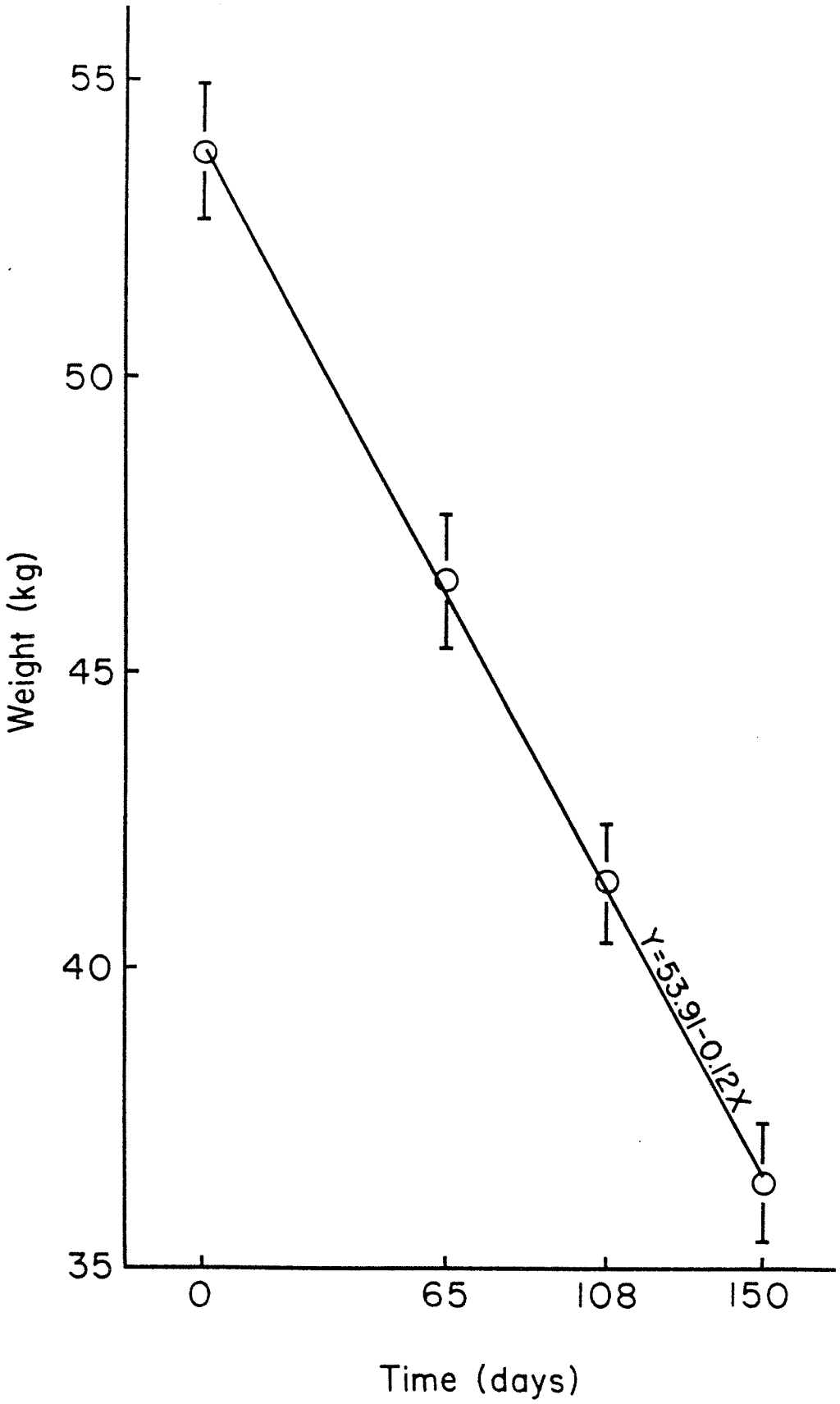

55
50
45
40
35
Weight (kg)
0
65
108
150
Time (days)
Y=53.91-0.12X

FIGURE 11: Weight loss of indoor wintered hives. Treatment V: double chamber, old queen and fed syrup.

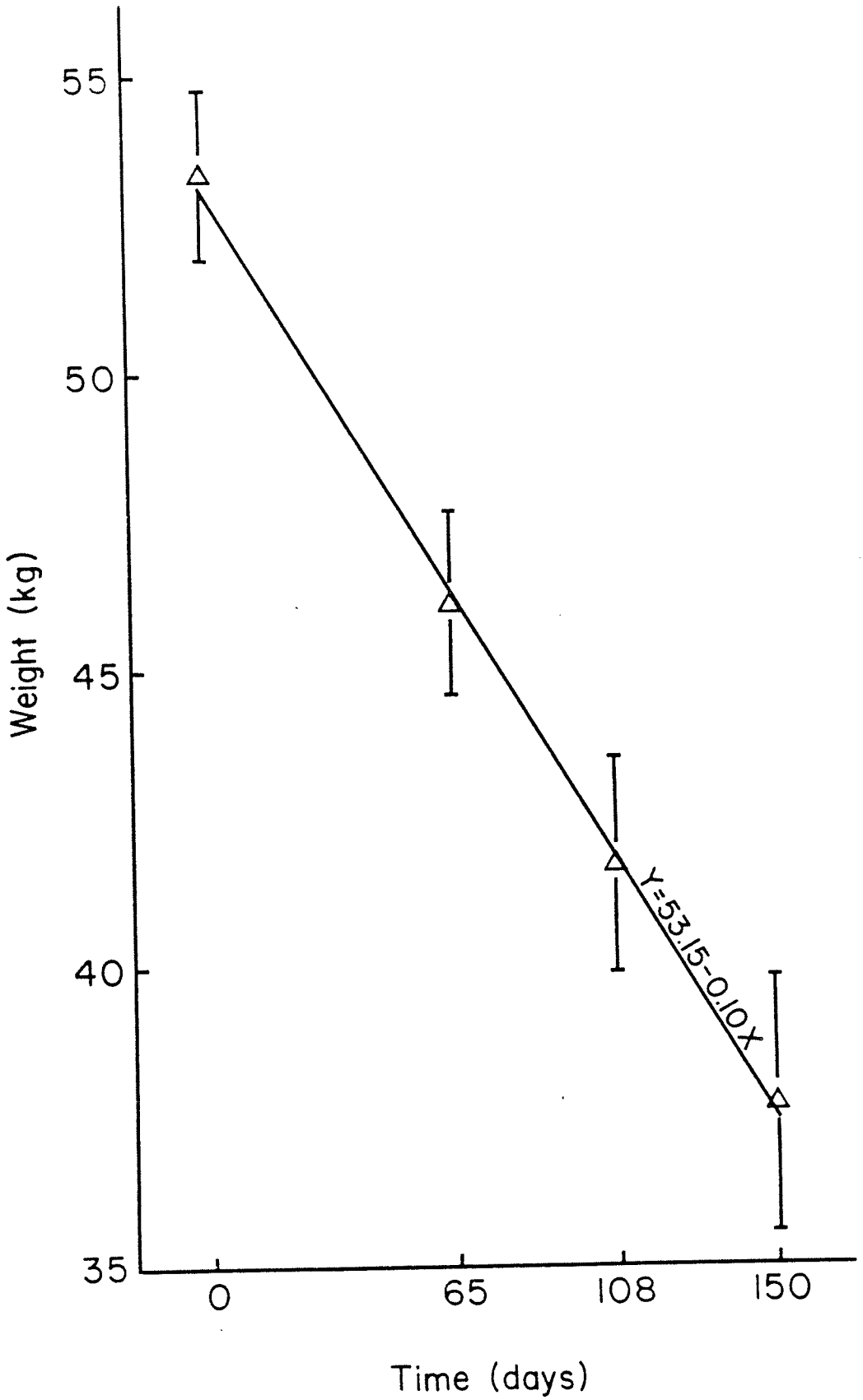

55
50
45
40
35
Weight (kg)
0
65
108
150
Time (days)
Y=53.15-0.10X

FIGURE 12. Weight loss of indoor wintered hives. Treatment VI: double chamber, old queen and fed honey.

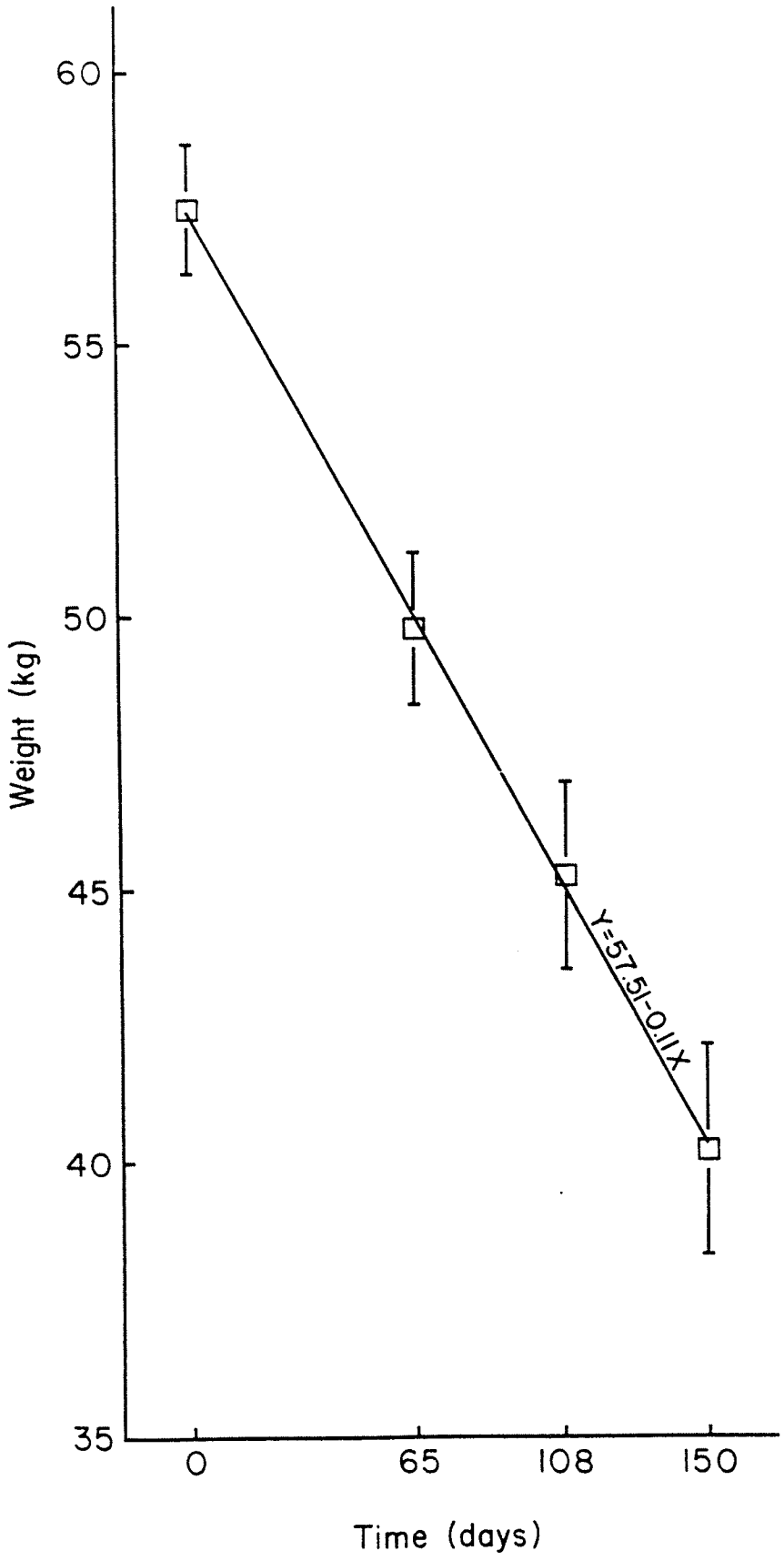
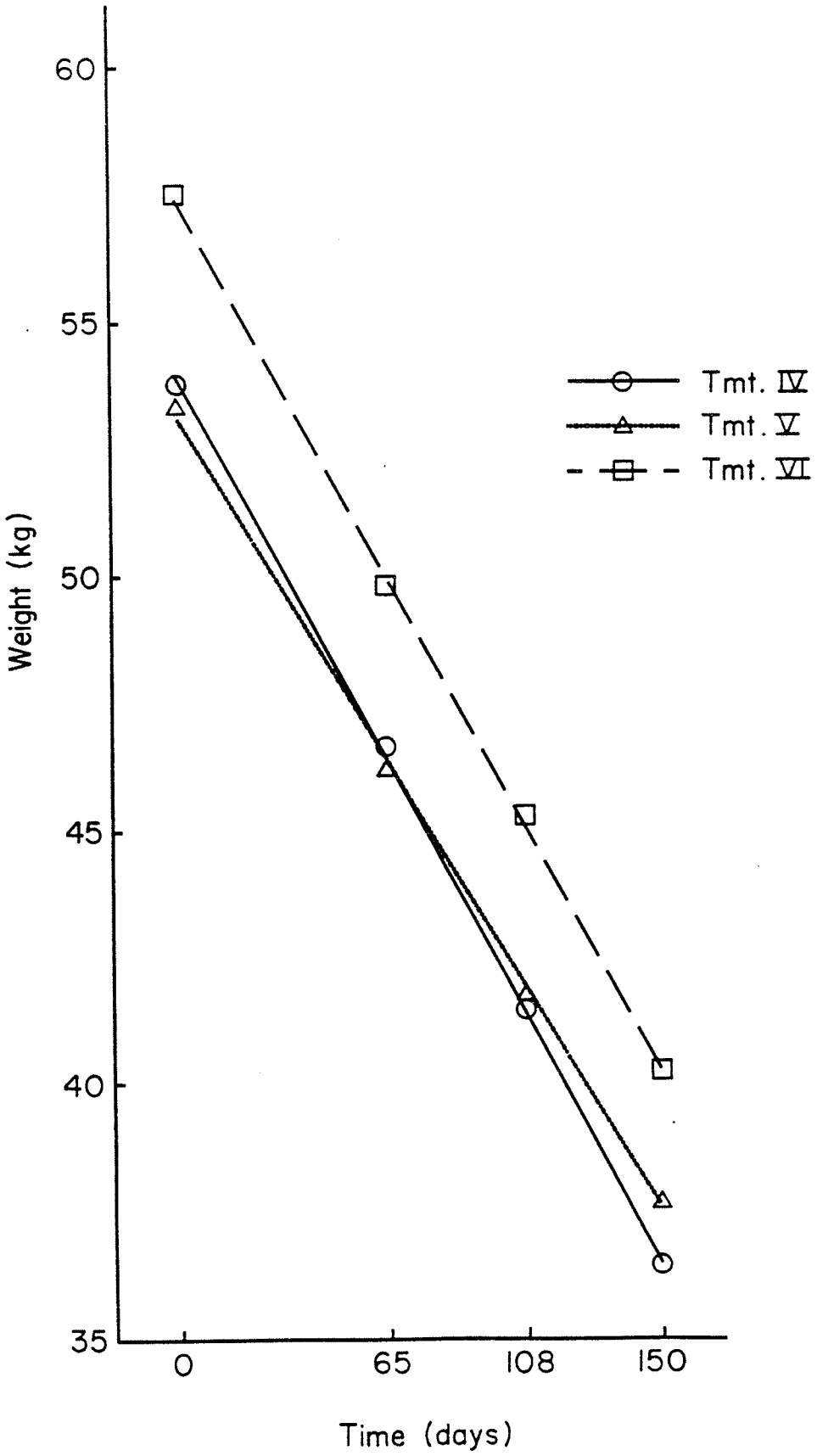

60
55
50
45
40
35
Weight (kg)
0
65
108
150
Time (days)
Y=57.51-0.11X

FIGURE 13. Comparison of weight loss of indoor wintered hives.
Treatment IV: double chamber, new queen and fed honey.
Treatment V: double chamber, old queen and fed syrup.
Treatment VI: double chamber, old queen and fed honey.


60
55
50
45
40
35
Weight (kg)
0
65
108
150
Time (days)
Tmt. IV
Tmt. V
Tmt. VI

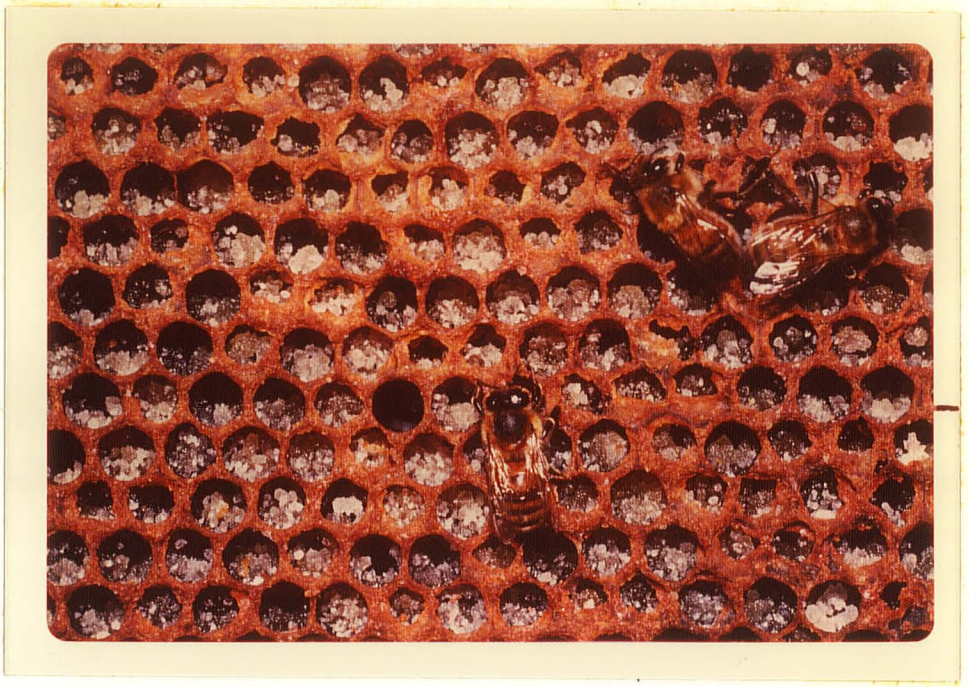


FIGURE 14. Granulated honey in cells of a frame.

FIGURE 15. A bottom board on which granulated honey has accumulated.

had queen cells on the face of several combs, indicating that supersedure occurred at some time between the time the treatments were applied to the hives and the time they were moved into the building.

Another problem encountered was the requeening of hives in Treatment I and IV. This was originally scheduled to take place in August. However, the inclement weather during this particular month made the rearing and mating of queens very difficult. As a result, mated queens were finally obtained through local beekeepers and the Agriculture Canada Research Station, Beaverlodge, Alberta; these were introduced into the hives during the latter part of September. This is generally considered to be too late in the year to be requeening hives for the reasons outlined earlier in the "Introduction" (see page 28). However, some degree of success was achieved, with two out of fifteen hives in Treatment I and seven out of fifteen hives in Treatment IV coming through the storage period alive. The low number of surviving hives in Treatment I may have been due to a combination of queenlessness (i.e., queens not accepted by the hive or died over the winter), starvation and granulation of honey. Treatment IV seemed somewhat better, due perhaps to the additional feed they received during the winter months.

The granulation of honey may have been aided somewhat by the low relative humidity in the storage rooms during the winter (see the Appendix, Tables 1-6). Relative humidities of 30-40% were recorded for extended periods during December, January and February. Honey has hygroscopic properties, i.e., it can remove moisture from the air. Martin (1939) found honey (17.4% moisture) to be in equilibrium with air at 58% relative humidity. Thus honey would gain moisture if exposed

to air with a greater moisture content and lose moisture when exposed to air drier than 58 percent relative humidity. Thus, the dry air in the storage rooms in December, January and February likely caused moisture in the honey to be lost, resulting in granulation.

The results of this study seem to indicate that hives should be wintered indoors as double chambered units unless the beekeeper is willing to provide hives in single chambers with additional feed during the storage period to prevent starvation. This procedure would be quite laborious and would involve replacing the empty frames with frames of honey or providing the bees with syrup using feeders. Care must be taken to provide honey that will not granulate easily because the bees would have difficulty in utilizing it as a food and may die of starvation. Syrup seems a good substitute for honey as a winter feed and can be used alone or to supplement the honey given to the bees in the fall. Requeening, if done at all, should be done early enough in the year to avoid the possible problems of queen acceptance and supersedure by the bees of the hives. Further attempts to study what effects temperature and relative humidity have on hives wintered indoors is required to ascertain the optimum levels of each for indoor wintering.

D. The Occurrence of Nosema Disease in Hives of Various Treatments Wintered Indoors

1) Materials and Methods

Samples of 25 dead worker bees each were taken from the entrances of the hives of Treatments I to VI and examined for the presence of *Nosema apis*. The samples were taken three times during the winter storage period (January 13, February 15 and March 21, 1978). Two or three days prior to each sampling, the entrances of the hives were cleaned to ensure that any bees taken at the time of sampling had died within that period. All samples, once collected, were stored at -23°C (-10°F) until examined.

The apparatus used in examining the bees for Nosema spores is shown in Figure 16. The rectal contents of each bee was squeezed onto a glass slide (23 x 1.5 x 0.2 cm) and one drop of water added to each sample. A clean applicator stick was used to mix each of the fecal samples. The samples were then examined for the presence of *N. apis* spores on a positive or negative basis. The number of positive samples per hive were then totalled and multiplied by four to obtain a percent infection.

It should be noted that the hives were not treated with the drug fumagillin in the fall to control Nosema disease.

2. Results and Discussion

The results are shown in Table 5.

Infection of honey bees with *N. apis* was generally found to be at a relatively low level (0-10%) throughout the sampling period. The

FIGURE 16. Apparatus used to examine dead bee samples for Nosema spores.

A. microscope
B. applicator sticks
C. flask of water with dropper
D. sample of dead bees
E. glass slides

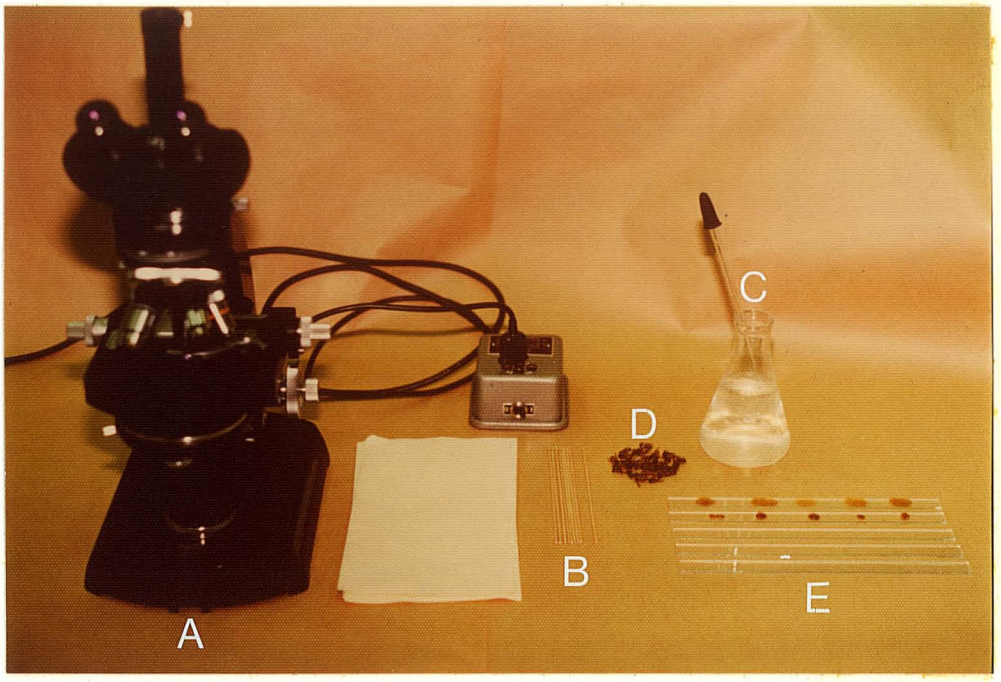

A
B
C
D
E

Table 5. Percent infection of honey bees by *Nosema apis* from hives wintered indoors.

Date samples taken	Level of infection (%)						Total no. of hives
	0-10	11-20	21-30	31-50	51-75	76-100	
Jan. 13, 1978	62	13	6	4	0	0	85
Feb. 15, 1978	65	11	2	3	0	2	82
Mar. 21, 1978	60	8	1	8	4	4	75
Total number of samples	177	32	9	14	4	6	242

majority of the hives sampled on each date had infections ranging from 0-10%. However, as time progressed, some of the hives began showing increased levels of infection. Figure 17 shows a fecal sample heavily infected with spores of *N. apis*. On February 15, six hives had infections of 20% or higher and on March 21, 17 hives had the same infection.

No correlation was found between the hive treatments and the occurrence of *N. apis*. None of the treatments exhibited a tendency toward high or low infection levels.

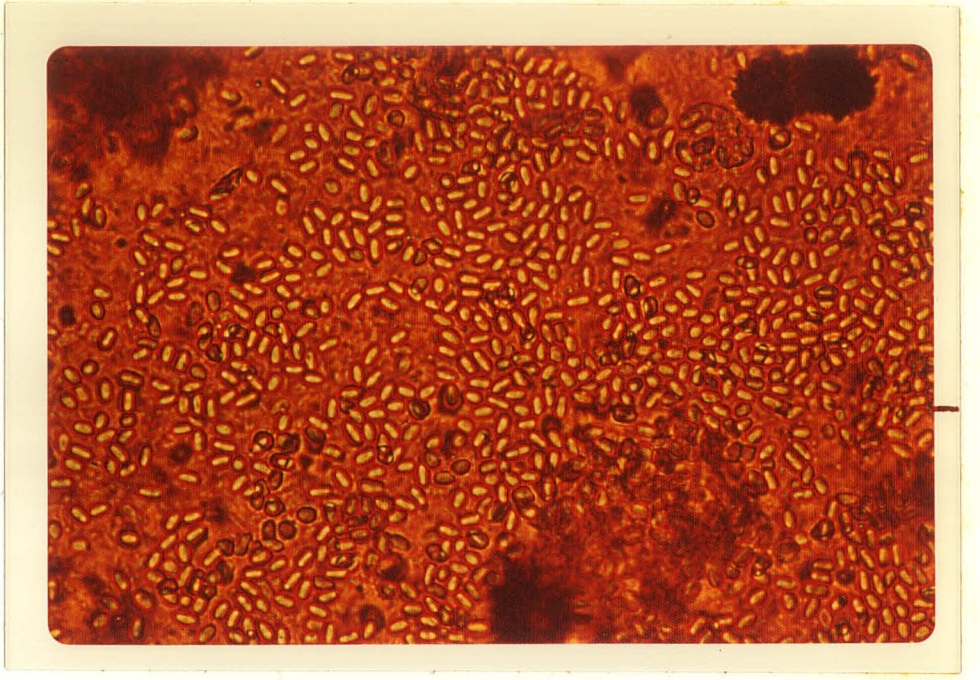
The data collected in the study suggest that *Nosema apis* can accumulate and spread within the hives during the winter storage period and depends on several factors. How severely the hive has contracted the disease will obviously dictate how rapidly it will spread. Figure 18 shows an infected hive with fecal material on the outside of the front wall. Whether or not the hive equipment is free of infectious spores is important in that nosema spores can remain viable for long periods of time and can also resist freezing. Therefore, storage of contaminated equipment in unheated buildings during the winter will not kill the spores. Disinfection of hive equipment that may harbor *N. apis* is generally accomplished through fumigation with acetic acid or ethylene oxide.

In general, beekeepers recognize the value of administering the drug fumagillin to hives in the spring and fall as a measure to prevent the spread of Nosema disease in both package and wintered hives.

Therefore these control measures should be incorporated into the

FIGURE 17. A fecal sample heavily infected with *Nosema apis* (mag. X600).

FIGURE 18. A nosema-infected hive showing fecal material on outside front wall.




V-8-3

management practises to combat the occurrence and spread of nosema disease in hives.

E. Contamination of a Water Supply with Honey Bees Infected with *Nosema apis*

1) Materials and Methods

Samples of honey bees were collected from two hives, one having a 4% and the other an 88% nosema infection. From both of these samples, three replicates, each containing 25, 50, 75 and 100 bees were placed into water-filled containers and stored at $4^{o}C$ for 24, 48 and 72 hours.

After the required time period had passed, each container of water was examined for the presence of nosema spores. Care was taken not to agitate the water containers before examination. A micropipette was used to obtain water samples at various depths and locations; on the surface, in the middle, at the bottom and at the center and side of the water column. The contents of the micropipette was placed on a glass slide and examined under a microscope for the presence of nosema spores.

2) Results and Discussion

The results obtained from the bees with a low infection (see Table 6) indicated that over 24 and 48 hours, very few containers were found to have nosema spores in the water. After 48 hours, two out of three replicates yielded spores on the bottoms of the containers. After 72 hours, more containers began showing signs of contamination, with spores detected along the bottoms of the containers.

When bees from hives with a higher infection were examined, spores were detected at all depths within the columns of water after 24 hours (see Table 7). After 48 hours had elapsed, almost every container, regardless of the number of bees, yielded spores throughout the water

Table 6. The incidence of nosema spores when examined at various intervals from water-filled containers. (Low infection)

Time of spore counts (hr)	No. of bees/ container	Location of spores within the container					
		Surface		Middle		Bottom	
		Center	Side	Center	Side	Center	Side
24	25[1]	0[2]	0	0	0	0	0
	50	0	0	0	0	0	0
	75	0	0	0	0	0	0
	100	0	0	0	0	0	0
48	25	0	0	0	0	0	0
	50	0	0	0	0	0	0
	75	0	0	0	0	0	0
	100	0	0	0	0	0	2
72	25	0	0	0	0	0	0
	50	0	0	0	0	0	0
	75	0	0	0	0	1	2
	100	0	0	0	0	1	1

Note:

[1] *Twenth-five dead bees with low Nosema infection placed on the surface of the water.*

[2] *Number of replications (of 3) with Nosema spores.*

Table 7. The incidence of nosema spores when examined at various time intervals from water-filled containers. (High infection)

Time of spore counts (hr)	No. of bees/ container	Location of spores within the container					
		Surface		Middle		Bottom	
		Center	Side	Center	Side	Center	Side
24	25[1]	0[2]	1	1	3	2	2
	50	1	2	2	2	3	3
	75	1	3	2	2	3	3
	100	3	3	3	2	3	3
48	25	0	2	0	2	3	3
	50	1	2	1	2	3	3
	75	1	2	2	3	3	3
	100	2	2	3	2	3	3

Note:

[1] *Twenty-five dead bees with high Nosema infection placed on the surface of the water.*

[2] *Number of replications (of 3) with Nosema spores.*

columns. However, nosema spores were detected consistently along the bottoms of the containers, suggesting that the spores fall and collect there. Some spores were detected at the surface and in the middle of the water columns. These spores were likely in the process of sinking to the bottom.

The degree of nosema infection in the bees appears to be an important factor in how rapidly the water is contaminated. The bees with the higher level of infection contaminated the water with spores after 24 hours whereas the bees with the lower level of infection were found to have contaminated the water to a considerably lesser extent after 48 hours.

The number of infected bees in the water indicated that where bees with a light infection were used, many (75-100) were needed to effect detectable contamination. As few as 25 bees having a heavier infection contaminated the water sufficiently for spores to be detected at all of the sampling locations within the water column.

Beekeepers wintering hives indoors sometimes provide water for the bees by placing a styrofoam cup or a similar container filled with water on the hive entrance. The bees crawl up and inside the container to drink and while some of them make it back to the hive, a small number will drown and remain floating on the surface. In addition, some bees possibly infected with *Nosema apis*, may defecate on the side of the container and on the water surface thereby contaminating the water. In light of the information collected, it seems important that a float of some type be placed in the containers to provide the bees a surface to stand on when feeding or that an alternate type of water feeder be used,

as described in the next section.

F. Water Consumption of Indoor Wintered Hives Infected with *Nosema apis*

1) Materials and Methods

A preliminary study was done to investigate the possibility of any trends occurring in the water consumption of indoor wintered hives which were lightly infected (0-10%) and heavily infected (40-100%) with *Nosema apis*.

Water feeders were fashioned using plastic containers (400 ml) with friction-fit lids. The containers were graduated, and each lid perforated with 16 holes approximately 1.5 mm in diameter (see Figure 19).

Once filled with water and sealed, the containers were inverted onto a V-shaped strip of hardware cloth (Figure 20) and placed on the hive entrances in Figure 21. The hardware cloth facilitated the bees' access to the water from below the container.

Six hives from each of Treatments I to VI, three lightly infected and three heavily infected with *Nosema apis*, were monitored at three day intervals for water consumption between February 7 and March 28, 1978.

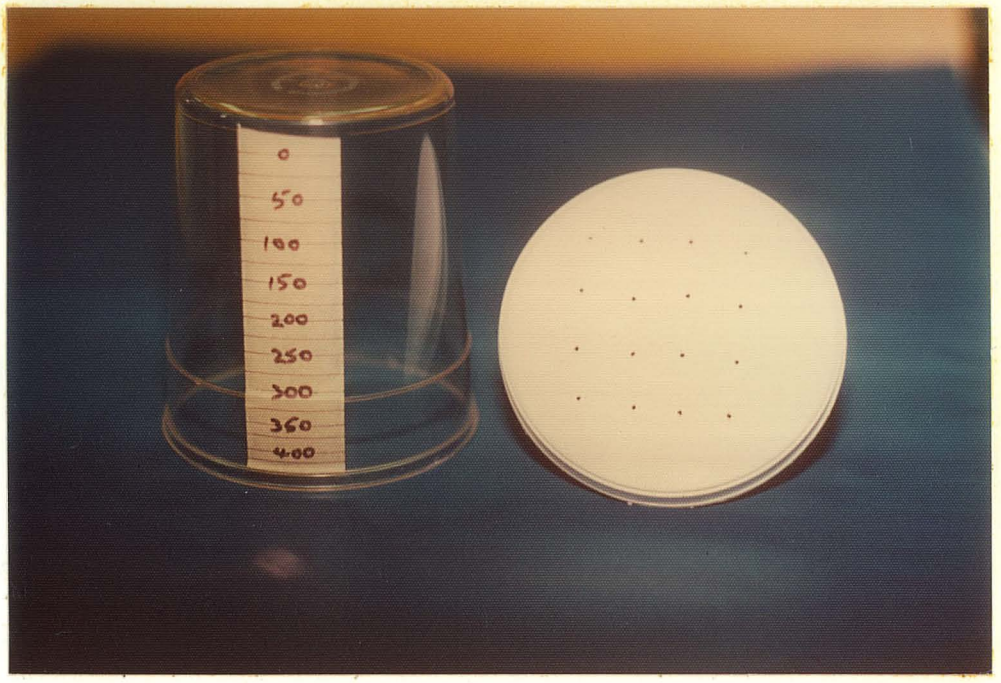
2) Results and Discussion

The water consumption of the hives is shown in Table 8. It is evident from the data that there is no definite trend or pattern in the amount of water consumed by hives with bees infected with *Nosema apis*. There was considerable variability as to both the amount and time the water was consumed by the bees. Several of the colonies consumed no water over the entire trial period; others consumed well in excess

FIGURE 19. A graduated plastic water feeder with a perforated lid.

FIGURE 20. Water feeder placed on top of a V-shaped strip of screen.

FIGURE 21. Water feeder in position on a hive entrance.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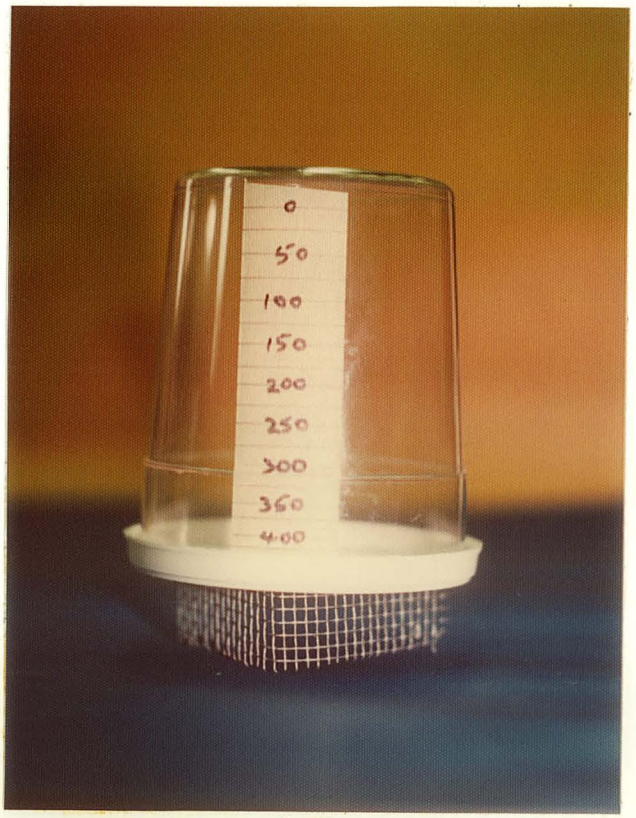
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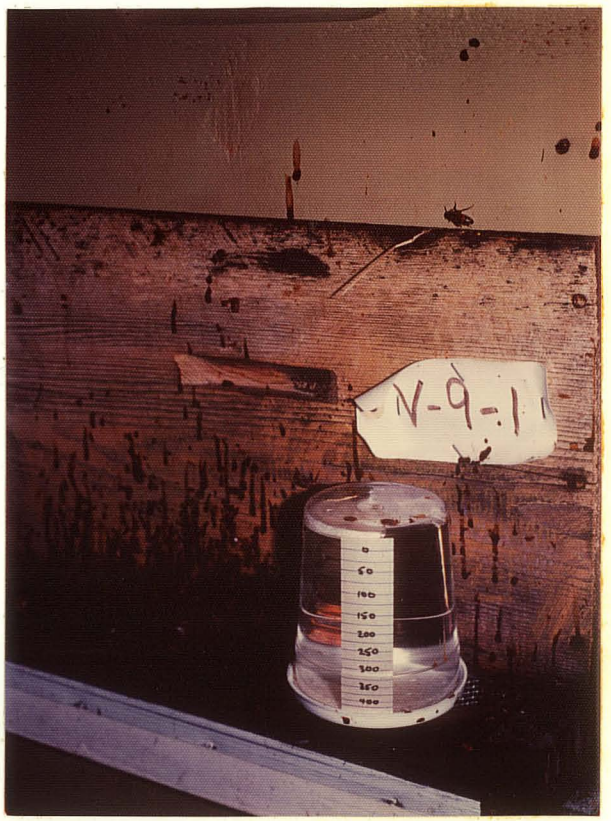
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Table 8. Cumulative water consumption of indoor wintered hives infected with *Nosema apis* (1978).

	Cumulative water consumption (millilitres)															
Hive No.	Feb 7	Feb 14	Feb 17	Feb 20	Feb 23	Feb 26	Mar 1	Mar 4	Mar 7	Mar 10	Mar 13	Mar 16	Mar 19	Mar 22	Mar 25	Mar 28
M-I-3*	0	0	5	5	20	25	25	25	25	25	25	25	25	25	dead	
M-I-5	0	25	dead													
01-I-2	0	0	5	10	15	25	25	25	25	250	250	255	260	275	280	340
01-I-5*	0	0	0	0	0	5	10	10	10	10	10	10	10	dead		
V-I-1	0	40	50	50	50	50	dead									
V-I-4*	0	10	10	15	15	dead										
M-II-1*	0	0	20	30	70	80	120	120	120	120	120	120	120	120	120	120
M-II-4	0	150	225	225	225	225	225	230	235	235	240	240	245	245	250	250
01-II-1*	0	100	130	140	150	175	175	175	175	175	175	175	175	175	175	dead
01-II-4	0	0	0	0	10	15	20	20	20	20	20	20	20	20	20	20
V-II-3*	0	0	0	5	15	20	20	20	20	20	20	20	20	dead		
V-II-5	0	0	0	5	15	25	45	50	50	60	70	70	70	70	70	75
M-III-1*	0	0	20	60	130	250	380	380	380	380	400	415	415	415	415	415
M-III-2	0	0	0	0	0	0	10	10	10	10	10	10	10	10	15	20
01-III-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-III-5*	0	10	15	15	20	25	25	30	30	75	80	105	140	160	175	200
V-III-1*	0	0	0	15	10	dead										
V-III-3	0	50	55	60	70	75	75	75	75	100	105	105	120	125	125	125
M-IV-3	0	200	225	225	410	450	595	645	805	945	980	1015	1060	1095	1100	1110
M-IV-4*	0	450	450	470	825	900	900	1225	1350	1600	1675	1685	1750	1800	1830	1830
01-IV-1*	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10
01-IV-3	0	0	5	20	125	160	200	210	375	375	400	475	575	650	665	700
V-IV-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V-IV-3*	0	25	25	30	30	40	45	45	45	45	45	45	45	45	45	45
M-V-2	0	0	0	dead												
M-V-4*	0	0	0	0	5	10	15	15	15	15	15	15	15	30	30	30
01-V-2	0	275	450	450	475	550	605	605	605	680	695	820	1055	1255	1405	1470
01-V-4*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V-V-1	0	0	0	0	10	10	15	15	15	15	15	15	15	15	15	15
V-V-3*	0	60	80	80	100	100	dead									
M-VI-1*	0	20	25	25	30	30	50	50	50	100	150	175	180	200	200	200
M-VI-4	0	50	110	210	325	450	450	500	525	530	575	575	580	580	580	580
01-VI-1	0	0	0	0	0	0	0	0	15	15	20	20	20	20	20	20
01-VI-4*	0	25	35	40	50	60	70	80	185	390	390	390	415	420	420	420
V-VI-3*	0	0	25	25	30	50	55	55	55	55	55	55	55	55	55	55
V-VI-4	0	10	10	10	15	25	25	25	25	25	25	25	25	25	25	25

Note:

* *Heavily infected hives.*

of 500 mls by the mid-way point of the experiment. No patterns were evident when comparing the amount of water consumed by the single chambered hives with that of the double chambered hives. Several colonies died during the experimental period, but it was not determined whether they had done so due to infection by *Nosema apis* or if the type and amount of food, particularly honey, may have been the cause. Speculation would support the latter in that some of the dead colonies had a severe honey granulation problem when inspected, while others had simply used up their food stores and starved.

The important point in this study is that bees wintered indoors do require water, regardless of the amount they consume or the time at which they consume it. Beekeepers should therefore ensure that their hives are supplied with water for the entire duration of the indoor storage period. The bees will consume it as it is required by them. The variability of the amount consumed may be due to a combination of increased brood rearing in the spring, the type of food stores the colony has been provided with or the number of bees present in the hive.

G. Population Development of Honey Bee Colonies Receiving Various Treatments

1. Materials and Methods

The hives were removed from the wintering building on 17 April, 1978. Their populations were measured by estimating the amount of capped brood in each hive at 12 day intervals up to the commencement of the main honey flow. This was done by using a grid composed of one-inch squares which was placed over a frame of capped brood (see Chapter IV, Section B). These data were converted later to square centimetres.

Each colony was given a sugar syrup and pollen supplement (brewers' yeast fortified with pollen), a practise generally carried out to stimulate brood rearing in the spring.

In addition, the populations of hives wintered outdoors and hives initiated from packages of bees were measured in the same manner.

Due to the loss of some of the wintered colonies (because of starvation and queenlessness) the number of remaining hives per treatment varied as follows:

Treatment I: Single chamber, new queen and fed honey - (1)

Treatment II: Single chamber, old queen and fed syrup - (5)

Treatment III: Single chamber, old queen and fed honey - (5)

Treatment IV: Double chamber, new queen and fed honey - (1)

Treatment V: Double chamber, old queen and fed syrup - (2)

Treatment VI: Double chamber, old queen and fed honey (indoor) - (5)

Treatment VII: Double chamber, old queen and fed honey (outdoor) - (3)

Treatment VIII: Hives initiated from packages of bees - (9)

Those colonies which superseded their queens were subsequently excluded from this study, due to the gap in brood rearing caused by the absence of a queen.

In light of these extreme variations in the number of hives per treatment, no statistical analysis was performed on the data. For each examination period, the mean amount of capped brood per treatment was calculated and graphed to provide a visual representation of the population development of each of the treatments over time.

2. Results and Discussion

Figure 22 shows the amount of capped brood occurring in the treatments from 24 April to 6 July, 1978.

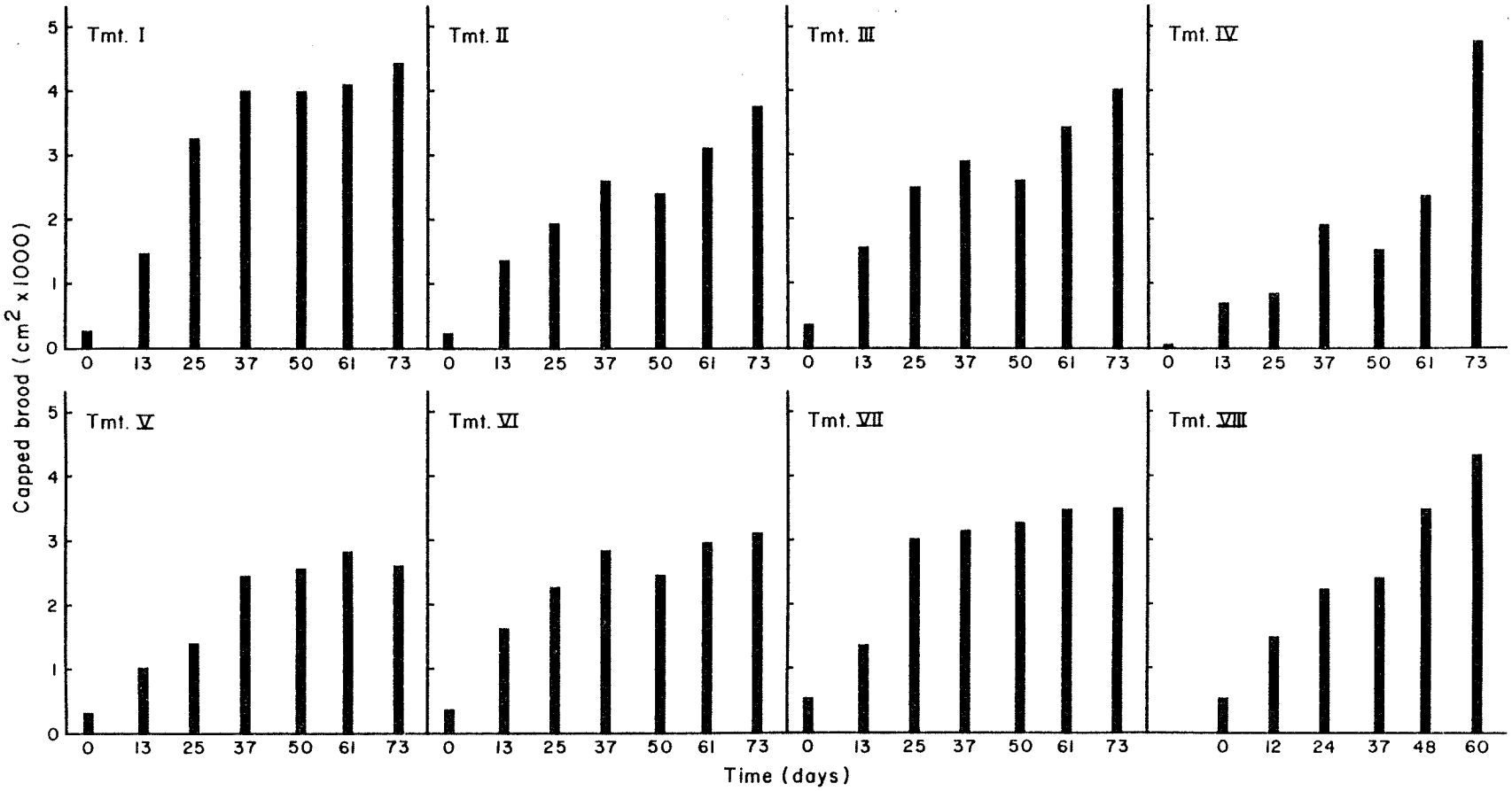
Treatments II, III, V, VI and VII showed similar population development patterns, with the first "peak" in brood production occurring on the 37th day (30 May). Treatments II and III differed slightly from Treatments V, VI and VII in that the former showed a slight decrease in brood production on the 50th day (12 June), followed by a sharp increase thereafter; that of the latter remained relatively unchanged between the 37th and 73rd day.

Treatment I showed a rapid increase in capped brood, reaching 4,000 cm^2 by the 37th day and maintaining that level for the duration of the study.

The population growth in Treatments IV and VIII appeared similar, with both developing brood slowly at first. However, at the time the final estimations were done, each colony had over 4,000 cm^2 of capped brood.

FIGURE 22. Mean amount of capped brood recorded in various hive treatments from 24 April to 6 July, 1978.

Treatment I: Single chamber, new queen and fed honey.
Treatment II: Single chamber, old queen and fed syrup.
Treatment III: Single chamber, old queen and fed honey.
Treatment IV: Double chamber, new queen and fed honey.
Treatment V: Double chamber, old queen and fed syrup.
Treatment VI: Double chamber, old queen and fed honey (indoor).
Treatment VII: Double chamber, old queen and fed honey (outdoor).
Treatment VIII: Hives initiated from packages of bees (April 24, 1978).


Tmt. I
Tmt. II
Tmt. III
Tmt. IV
Tmt. V
Tmt. VI
Tmt. VII
Tmt. VIII
Capped brood (cm² x 1000)
Time (days)
0 13 25 37 50 61 73
0 12 24 37 48 60
0 1 2 3 4 5

The colonies wintered indoors, in general, showed rapid growth after removal from the building, as did the colonies which were wintered outdoors. Both the indoor and outdoor wintered treatments had a minimum of 2,500 cm^2 of capped brood by the 37th day (30 May). Colonies in Treatments VIII, although established on 24 April (seven days after the removal of the hives from the wintering building), had approximately 2,100 cm^2 of capped brood by 30 May.

On the basis of these population development patterns, it appears that wintering indoors will yield hives comparable in colony strength to that of outdoor wintered hives. The populations of both the indoor and outdoor wintered hives increased quite rapidly in the spring, with the exception of Treatment IV, which seemed to parallel the package hives in colony growth.

Due to the variation in the number of hives per treatment, this experiment bears repeating. However, care should be taken to requeen the hives during the warm summer months to allow the new queens time to become established in their new colonies. If honey is being used as a food for the bees for the winter, it should be of a type which does not readily granulate. Honey from rapeseed should be avoided as a winter feed if at all possible. Finally, provision of adequate amounts of food to support the colonies through the winter is an absolute necessity to avoid possible starvation of the colonies. This also eliminates the laborious task of feeding the hives while inside the wintering building.

VI. DRIFTING AND LOSS OF HONEY BEES AFTER REMOVAL FROM WINTER QUARTERS

A. Introduction

Beekeepers wintering bees indoors may be faced with several problems in the spring when it comes time to remove the hives. Among others, these include inaccessibility of spring apiary sites due to impassible roads, spring flooding of these sites or the presence of snow. These will necessitate the selection of new and perhaps less favorable locations where the hives may be set out temporarily before moving them to the preferred locations.

The following study was carried out to ascertain if any differences might occur in the amount of drifting and loss of honey bees when moved close to ("temporary site") and far from ("permanent site") their winter quarters in the spring.

B. Methods and Materials

1. General

Fifteen hives were used in each of four treatments. They were arranged in three rows of five (each row a replicate), spaced one metre apart and facing south. Approximately eight to ten metres separated each row of hives. The hive entrances were reduced to five centimetres in width to limit the amount of cool air entering the hives.

The four treatments consisted of:

Treatment A: 15 hives moved close to the wintering building

Treatment B: 15 hives moved far from the wintering building

Treatment C: 15 hives moved close to the wintering building and then to a distant site

Treatment D: 15 hives moved far from the wintering building

All hives were removed from the wintering building at night and placed on bare ground within a windbreak. Jay & Harris (1979) found this method best reduced drifting and loss of bees moved from winter quarters.

During the night, after the hives had been set out, 200 worker bees were randomly selected for marking in the center hive of each row with a dot of colored paint. This was accomplished, with the aid of a flashlight, by removing a frame and marking the bees as they stood on it. The paint was applied to the thorax using a technique described by Harris (1979). Bees of a hive were marked with the same color. Care was taken not to smear the paint into the region between the head and thorax or near the base of the wings, thereby hampering a bee's movement. Any bees so marked were destroyed during the marking procedure. The frames of bees were returned to their respective hives when the marking was completed.

After 13 days had elapsed, the hives of Treatment A were moved to the permanent location at night. The marking was repeated for all treatments, this time marking another 200 worker bees in the center hive of each row with a different color.

Therefore, Treatment B and D were the same treatments, with two different sets of worker bees marked in the center hive of each row; the second set being marked when Treatment A was moved. Treatment A had one set of bees marked in the center hive of each row. After Treatment A was moved to the permanent location, a second set of bees was marked in the center hive of each row, representing Treatment C.

Drifting and loss of bees was determined by examining frames in all of the hives in each row and counting the number of marked bees in each hive. This was carried out at dawn to ensure that the bees had not yet begun foraging. The examinations were done 58 hours after removal from the wintering building and at subsequent seven-day intervals, until the number of marked bees approached zero. The initial examination was to be carried out 24 hours after the bees were removed from the wintering building but cool, rainy weather forced a delay of an additional 24 hours.

2. Statistical Analysis

Drifting was examined by recording the total number of bees per replicate that drifted west or east along the south facing rows of hives.

The percentages of marked bees lost on each examination were angularly transformed using an arcsin transformation. The first two examinations for Treatments A and B (those taken before the hives in Treatment A were moved) were analyzed using a two-way analysis of variance. The remaining data for all of the treatments were subjected to linear regression and subsequently to analysis of covariance to determine if parallelism existed between Treatments A and B and between Treatments C and D.

C. Results and Discussion

Table 9 shows the number of marked bees that drifted along the rows of hives. Drift occurred in both an eastward and westward direction, with no definite patterns being evident except that if on the first examination, marked bees in a replicate drifted predominantly east or west, they tended to drift in that direction for the remainder of the experiment.

Table 9. Total number of marked bees that drifted west and east along south-facing rows of hives.

Treatment number	Replicate number	Total and % drifted west	Total and % drifted east
A*	1	84 (49%)	88 (51%)
	2	150 (69%)	68 (31%)
	3	10 (16%)	53 (84%)
B	1	27 (53%)	24 (47%)
	2	55 (28%)	139 (72%)
	3	160 (85%)	25 (14%)
C	1	129 (78%)	37 (22%)
	2	91 (81%)	22 (19%)
	3	4 (25%)	12 (75%)
D	1	5 (29%)	12 (71%)
	2	14 (26%)	40 (74%)
	3	44 (96%)	2 (4%)

Note:

* *A: 15 hives moved close to wintering building*
B: 15 hives moved far from wintering building
C: 15 hives first moved close to wintering building, and then to a distant site
D: 15 hives moved far from wintering building

The loss of marked bees between Treatments A and B on the first two examinations showed no significant differences ($P < .01$). There appeared to be a significant difference ($P < .01$) between the two treatments in the number of bees lost with time. This difference was due, however, to the fact that the first examination was done after two days and the second was done after eight days. After Treatment A was moved a second time, there was no significant difference in the rate at which marked bees were lost from Treatments A and B. This is shown in Figure 23 by means of the regression lines for each treatment. Similarly, after the second sets of marked bees were examined in Treatments C and D, no significant difference was found in the rate at which marked bees were lost (see Figure 24).

Jay (1971), through drifting experiments performed in established colonies in temperate and tropical zones, suggested that the position of the sun was an important factor in the drifting of bees from hives situated in the center of the rows of hives to those located near the ends of the rows. He observed a westward drift of bees in south-facing rows of hives which, he postulated, was due to the apparent westward movement of the sun across the sky.

Jay & Harris (1979) found that when hives were removed from their indoor wintering quarters in the spring, the bees tended to drift eastward along south-facing rows of hives. They suggested that this was due to the bees being confined in the dark for a long period of time and thus became highly attracted to light during their flights in the early morning.

In view of the data obtained in this study, it seems that additional

FIGURE 23. Percent loss of marked bees upon removal from winter quarters.

Treatment A: 15 hives moved close to the wintering building.
Treatment B: 15 hives moved far from the wintering building.

Note: t = 0 represents 13 days after the first set of bees were marked.

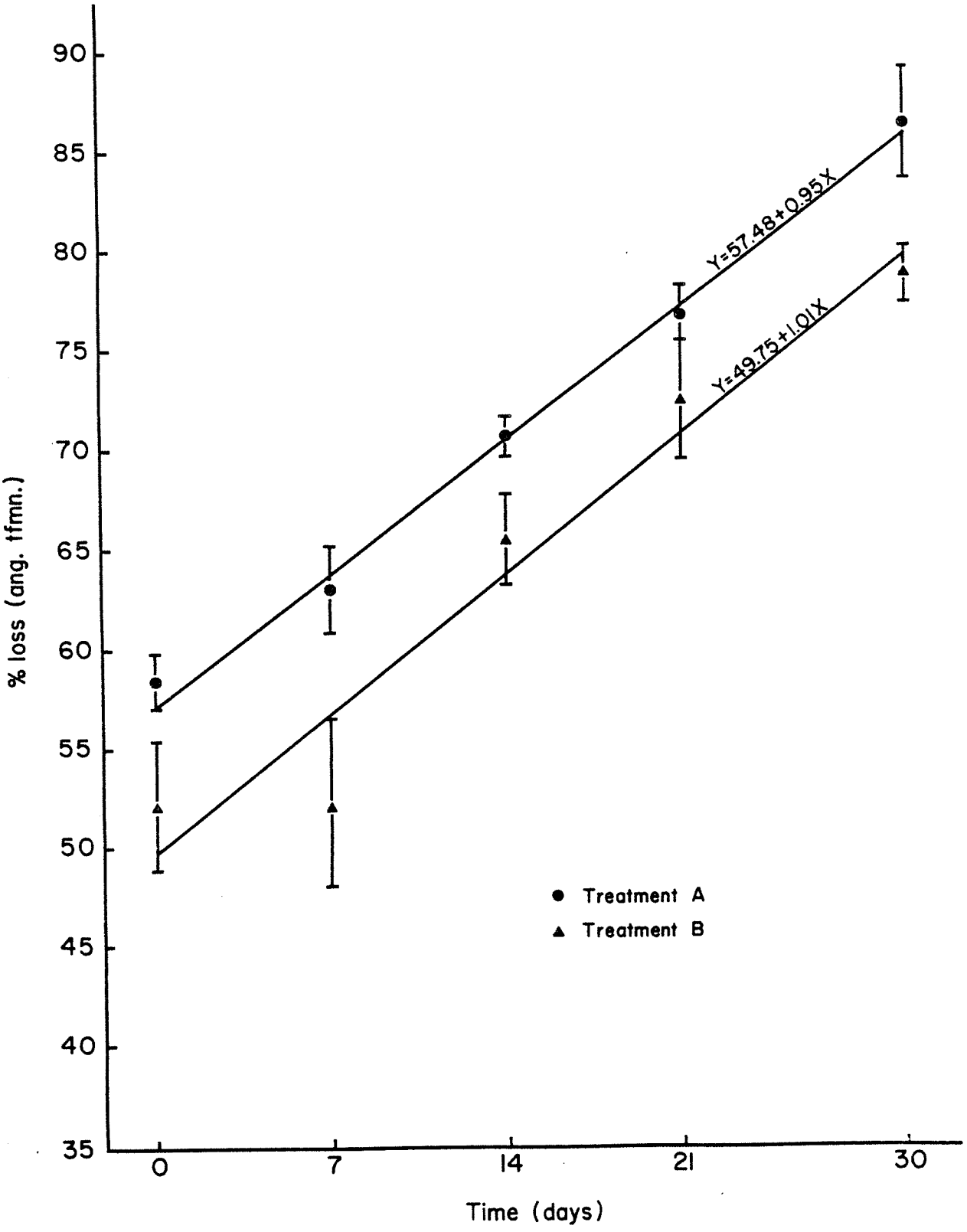
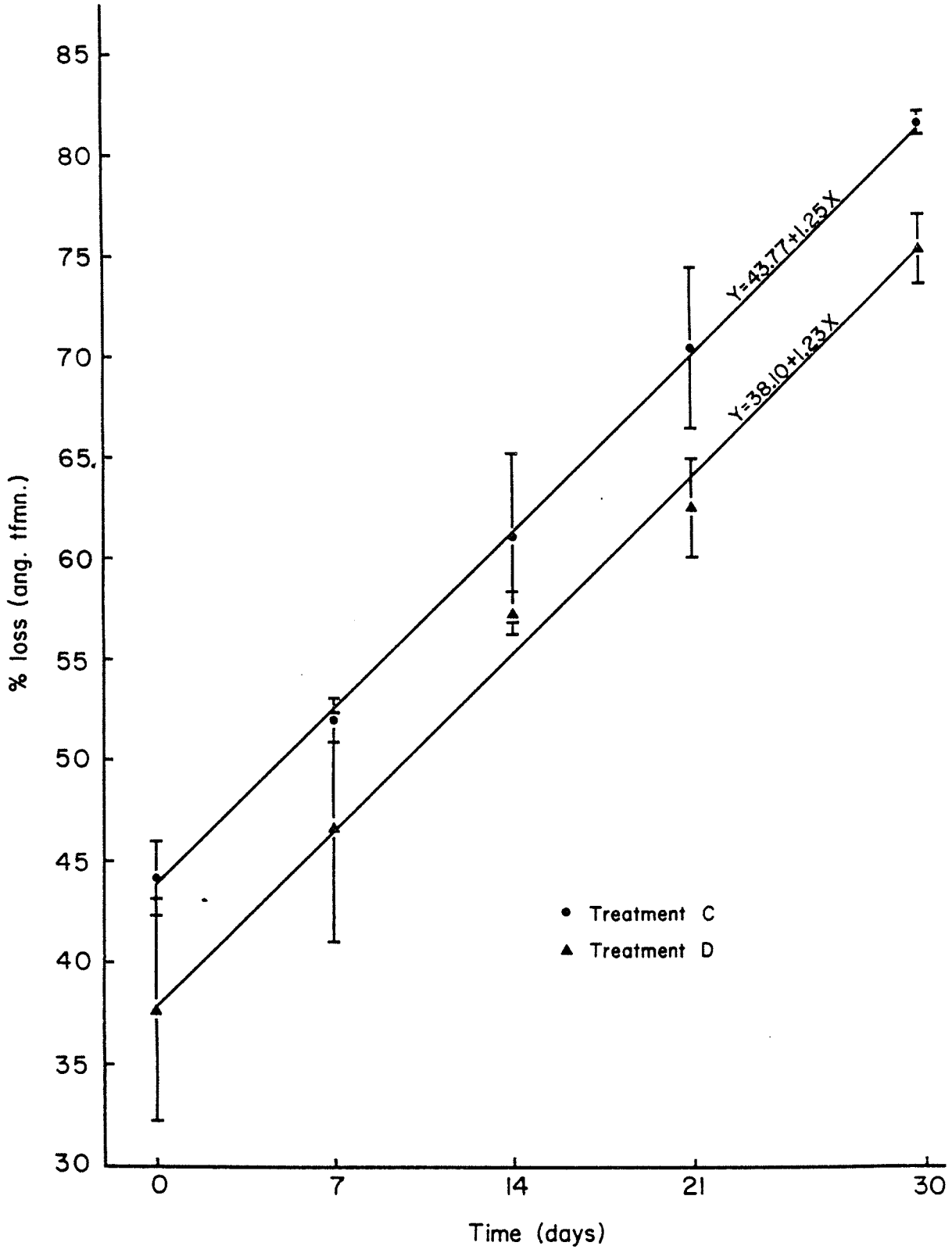

90
85
80
75
70
65
60
55
50
45
40
35
% loss (ang. tfmn.)
0
7
14
21
30
Time (days)
Y=57.48+0.95X
Y=49.75+1.01X
Treatment A
Treatment B

FIGURE 24. Percent loss of marked bees upon removal from winter quarters.

Treatment C: 15 hives first moved close to the wintering building, and then to a distant site.
Treatment D: 15 hives moved far from the wintering building.

Note: t = 0 represents 24 hours after the second set of bees were marked.


85
80
75
70
65
60
55
50
45
40
35
30
% loss (ang. tfmn.)
0
7
14
21
30
Time (days)
Y=43.77+1.25X
Y=38.10+1.23X
Treatment C
Treatment D

research concerning the drifting of bees upon removal from winter quarters is required since five of the replicates (see Table 9) exhibited a westward drift, five an eastward drift and the remaining two replicates drifted almost evenly both eastward and westward.

The loss of bees appeared to be quite substantial during the first few days of bee flight subsequent to the removal of the hives from the wintering building. Thereafter, bees were lost at a much lesser rate, as is indicated in Figures 23 and 24. This phenomenon verifies the research of Jay & Harris (1979).

APPENDIX

Appendix Table 1. Daily temperature and relative humidity, November, 1977.

Date	Outdoor					Room 1					Room 2					Room 3				
	Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)	
	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.
1	12.3	0.0	6.2	93	50	9.4	5.0	7.2	100	58	6.7	3.3	5.0	98	90	6.7	3.9	5.3	84	55
2	17.8	0.0	8.9	76	27	8.3	3.8	6.1	87	67	8.3	2.8	5.6	90	60	8.3	3.3	5.8	84	75
3	8.3	- 2.6	2.9	72	47	7.2	4.4	5.8	78	67	5.6	2.8	4.2	79	68	5.0	4.4	4.7	84	64
4	7.8	- 5.7	1.1	83	45	6.7	3.3	5.0	76	62	5.0	1.7	3.4	77	65	5.6	2.8	4.2	80	61
5	9.9	2.3	6.1	84	53	8.9	6.1	7.5	94	74	6.1	4.4	5.3	95	73	5.6	3.9	4.6	84	78
6	13.0	4.8	8.9	89	70	8.3	6.7	7.5	100	94	8.3	4.4	6.4	100	92	8.3	3.9	6.1	84	84
7	11.7	7.2	9.5	95	78	7.2	5.6	6.4	98	61	8.9	6.7	7.8	80	66	8.9	6.7	7.8	85	84
8	7.6	0.5	4.1	88	60	10.0	6.1	8.1	70	54	7.8	5.0	6.4	64	51	6.7	5.6	6.2	74	53
9	0.6	- 3.5	- 1.5	77	43	6.1	4.4	5.3	55	46	5.0	3.3	4.2	52	42	5.6	5.0	5.3	54	42
10	1.9	- 9.4	- 3.8	86	52	5.0	2.8	3.9	52	41	5.0	1.7	3.4	49	39	5.6	3.3	4.5	50	47
11	- 0.6	- 6.5	- 3.6	84	54	5.3	3.9	4.6	54	46	5.0	3.9	4.5	49	41	5.6	4.4	5.0	52	43
12	0.4	- 6.8	- 3.2	85	58	6.7	3.3	5.0	50	45	6.7	3.9	5.3	46	41	7.2	3.9	5.6	46	42
13	4.3	- 6.0	- 0.9	92	56	6.1	4.4	5.3	58	50	6.1	4.4	5.3	56	45	6.7	5.6	6.2	56	46
14	2.3	- 6.9	- 2.3	97	75	4.4	3.3	3.9	55	40	4.4	3.3	3.9	80	50	10.0	5.0	7.5	80	50
15	2.8	- 3.2	- 0.2	97	74	13.8	4.4	9.1	90	68	11.1	7.2	9.2	73	65	11.1	9.4	10.3	78	74
16	2.8	- 1.2	0.8	100	66	13.3	10.0	11.7	83	65	11.7	8.3	10.0	67	59	10.6	8.3	9.5	76	70
17	- 0.8	- 7.2	4.0	98	80	10.0	6.7	8.4	65	56	8.3	5.0	6.7	62	56	8.3	6.7	7.5	72	60
18	- 2,2	-10.8	- 6.5	93	81	6.7	3.9	5.3	56	50	5.0	2.2	3.6	57	52	6.7	5.0	5.6	60	51
19	- 4.1	-11.5	- 8.1	93	84	8.3	3.3	5.8	66	48	4.4	1.7	3.1	56	50	6.1	4.4	5.3	48	58
20	- 4.4	-11.3	- 7.9	96	86	9.4	4.4	6.9	56	50	5.0	2.2	3.6	59	53	5.6	5.0	5.3	64	52
21	-11.3	-20.0	-15.7	86	69	6.1	5.6	5.9	50	40	4.4	1.1	2.8	53	40	3.9	2.2	3.1	52	32
22	-15.2	-23.2	-19.2	87	73	3.9	2.7	3.3	42	34	0.6	0.0	0.3	43	38	4.4	3.3	3.9	39	34
23	-14.2	-22.5	-18.4	83	69	4.4	2.8	3.6	41	37	7.2	-0.6	3.3	42	25	4.4	2.8	3.6	39	37
24	-20.5	-25.3	-22.9	81	64	7.8	2.8	5.3	36	30	7.2	4.4	5.8	26	25	6.1	1.7	3.9	36	27
25	-13.2	-23.1	-18.2	84	65	7.8	6.7	7.3	32	29	4.4	4.4	4.4	29	27	6.1	2.8	4.5	33	27
26	-12.6	-22.5	-17.6	88	76	6.1	5.6	5.9	38	30	4.4	4.4	4.4	34	28	5.6	5.0	5.3	34	28
27	-10.6	-17.4	-14.0	89	68	5.6	5.0	5.3	39	36	4.4	4.4	4.4	36	32	5.6	5.0	5.3	38	34
28	- 8.7	-18.7	-13.7	89	83	5.0	4.4	4.7	32	28	4.4	3.9	4.2	53	36	7.2	5.0	6.1	50	33
29	0.4	-11.5	- 5.6	96	85	9.4	6.1	7.8	61	50	7.2	3.9	5.6	66	49	10.0	4.4	7.2	61	48
30	1.5	- 9.0	- 3.8	100	81	10.6	5.0	7.8	62	49	7.8	4.4	6.1	66	48	10.0	7.8	8.9	61	47

Appendix Table 2. Daily temperature and relative humidity, December, 1977.

Date	Outdoor					Room 1					Room 2					Room 3				
	Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)	
	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Man.	Min.
1	-8.6	-15.5	-12.1	86	78	5.6	5.6	5.6	49	40	4.4	4.4	4.4	48	39	8.9	5.0	7.0	46	40
2	-13.2	-21.2	-17.2	85	69	5.2	4.4	4.8	40	30	4.4	3.3	3.9	39	29	5.6	4.4	5.0	42	27
3	-19.8	-25.3	-22.3	86	71	5.0	4.4	4.7	30	24	5.0	3.3	4.2	29	22	5.0	4.4	4.7	38	18
4	-14.4	-25.6	-20.0	85	79	5.6	4.4	5.0	31	22	5.0	3.3	4.2	30	21	5.0	3.3	4.2	28	17
5	-14.4	-20.8	-17.6	89	77	5.6	4.4	5.0	32	28	4.4	3.9	4.2	32	27	5.0	4.4	4.7	30	24
6	-17.9	-25.0	-21.5	87	76	5.6	4.4	5.0	30	26	3.9	3.3	3.6	28	24	1.7	1.1	1.4	28	25
7	-19.1	-27.7	-23.4	87	77	5.6	4.4	5.0	28	24	4.4	3.3	3.9	28	22	4.4	0.6	2.5	29	24
8	-19.1	-28.2	-23.7	86	76	6.1	4.4	5.3	28	22	4.4	3.3	3.9	29	24	5.0	3.9	4.5	29	23
9	-27.3	-32.5	-29.9	87	64	6.7	5.0	5.9	22	18	3.9	3.3	3.6	24	22	4.4	3.3	3.9	24	20
10	-25.0	-33.8	-29.4	89	76	6.1	3.3	4.7	19	17	3.9	3.3	3.6	22	21	5.0	2.8	3.9	22	19
11	-11.0	-26.5	-18.8	86	74	6.1	3.9	5/0	36	18	4.4	3.9	4.2	37	22	5.6	3.3	4.5	42	21
12	-10.7	-19.0	-14.9	87	78	6.1	5.0	5.6	40	32	4.4	3.9	4.2	41	34	5.6	3.3	4.5	45	34
13	-11.0	-18.2	-14.6	89	76	6.1	5.6	5.9	40	34	5.0	4.4	4.7	42	32	6.1	4.6	5.9	46	36
14	- 7.3	-18.2	-12.8	93	81	5.6	4.4	5.0	40	34	5.0	4.4	4.7	44	32	5.6	5.0	5.3	50	36
15	- 3.7	- 7.3	- 5.5	96	84	5.0	3.9	4.6	66	50	4.4	3.9	4.2	62	45	7.2	5.0	6.1	59	50
16	1.2	- 4.0	- 1.4	100	93	5.6	5.6	5.6	88	66	5.0	3.9	4.6	79	62	7.2	7.2	7.2	80	59
17	1.2	- 0.1	0.6	100	90	5.6	5.0	5.3	88	83	5.0	3.3	4.2	80	78	7.2	7.2	7.2	80	76
18	1.8	- 3.8	- 1.0	97	83	5.0	4.4	4.7	87	72	5.6	5.0	5.3	80	77	7.8	7.2	7.5	80	68
19	- 3.6	-10.2	- 6.9	91	79	5.6	3.9	4.8	72	50	5.6	4.4	5.0	77	50	7.2	6.1	6.7	68	48
20	- 7.0	-20.0	-13.5	91	75	4.4	3.3	3.9	50	31	5.0	4.4	4.7	52	32	5.6	5.0	5.3	48	33
21	-14.0	-23.4	-18.7	83	65	4.4	4.4	4.4	38	34	4.4	4.4	4.4	36	34	5.6	5.0	5.3	40	36
22	-13.7	-21.6	-17.7	87	77	4.4	4.4	4.4	38	34	4.4	4.4	4.4	36	34	5.6	4.4	5.0	40	36
23	-14.0	-19.7	-16.9	87	75	4.4	4.4	4.4	38	35	4.4	4.4	4.4	36	34	5.6	4.4	5.0	40	36
24	-16.9	-28.3	-22.6	81	67	4.4	3.9	4.2	34	27	4.4	4.4	4.4	32	26	5.6	4.4	5.0	38	30
25	-19.2	-28.5	-23.9	81	67	4.4	3.9	4.2	30	26	4.4	3.9	4.2	28	26	5.6	4.4	5.0	35	30
26	-24.3	-29.6	-27.0	78	68	4.4	3.9	4.2	28	26	4.4	3.9	4.2	28	25	5.6	4.4	5.0	32	28
27	-10.2	-28.9	-19.5	89	68	5.0	4.4	4.7	42	30	4.4	4.4	4.4	40	29	5.6	4.4	5.0	43	33
28	-11.4	-26.7	-19.1	86	72	4.4	3.9	4.2	42	31	4.4	4.4	4.4	40	30	5.6	4.4	5.0	43	32
29	-17.5	-26.3	-21.9	84	72	4.4	3.9	4.2	32	29	4.4	4.4	4.4	31	28	5.6	4.4	5.0	34	29
30	-19.6	-29.2	-24.4	86	68	4.4	3.9	4.2	29	26	4.4	3.9	4.2	28	26	5.0	4.4	4.7	32	28
31	-17.6	-28.0	-22.8	80	75	4.4	3.9	4.4	32	26	4.4	3.9	4.2	30	25	5.0	4.4	4.7	33	27

Appendix Table 3. Daily temperature and relative humidity, January, 1978.

Date	Outdoor					Room 1					Room 2					Room 3				
	Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)	
	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.
1	- 9.8	-19.0	-14.4	88	75	4.4	4.4	4.4	44	32	4.4	4.4	4.4	40	30	5.6	4.4	5.0	42	32
2	-10.2	-14.8	-12.5	89	75	5.0	4.4	4.7	42	38	5.0	4.4	4.7	40	36	5.6	5.0	5.3	44	40
3	-13.5	-22.0	-17.8	86	77	5.0	4.4	4.7	38	36	5.0	4.4	4.7	38	34	5.6	4.4	5.0	40	36
4	-20.4	-26.3	-23.4	86	70	4.4	3.9	4.2	46	31	4.4	4.4	4.4	35	30	5.6	4.4	5.0	38	31
5	-20.5	-25.0	-22.8	82	72	4.4	3.9	4.2	32	30	5.0	4.4	4.7	30	28	5.0	3.9	4.5	32	29
6	-14.9	-20.5	-17.7	84	77	5.0	3.9	4.5	36	32	5.0	4.4	4.7	34	30	5.0	4.4	4.7	37	29
7	-14.8	-24.9	-19.9	86	73	4.4	3.9	4.2	36	29	5.0	4.4	4.7	34	28	5.6	4.4	5.0	38	30
8	-24.6	-28.9	-26.8	86	68	4.4	3.9	4.2	29	27	5.0	4.4	4.7	29	27	5.0	4.4	4.7	31	28
9	-25.6	-33.1	-29.4	97	73	4.4	3.9	4.2	29	25	4.4	4.4	4.4	29	26	5.6	4.4	5.0	34	28
10	-20.3	-32.0	-26.2	78	61	4.4	3.9	4.2	31	30	5.0	4.4	4.7	30	29	5.6	4.4	5.0	34	32
11	-15.4	-22.0	-18.7	81	62	4.4	3.9	4.2	36	30	5.0	4.4	4.7	34	30	5.6	4.4	5.0	37	32
12	-14.0	-22.1	-18.1	87	74	5.0	3.9	4.5	37	31	4.4	3.9	4.2	34	29	5.6	4.4	5.0	37	31
13	-15.0	-23.2	-19.1	84	76	5.6	3.9	4.8	37	32	5.0	4.4	4.7	33	30	5.6	4.4	5.0	36	30
14	-15.8	-22.0	-18.9	86	72	5.0	3.9	4.5	35	30	5.6	4.4	5.0	36	29	5.6	4.4	5.0	38	30
15	-17.0	-30.1	-23.6	83	59	5.0	3.9	4.5	34	28	5.0	4.4	4.7	34	29	5.6	4.4	5.0	35	29
16	-24.5	-33.3	-28.9	88	71	4.4	3.3	3.9	28	26	5.0	4.4	4.7	28	26	5.6	4.4	5.0	31	28
17	-17.0	-29.1	-23.1	86	62	5.6	5.0	5.3	31	28	5.0	4.4	4.7	32	28	5.6	3.3	4.5	40	34
18	-18.1	-29.2	-23.7	83	64	6.1	3.3	4.7	32	28	6.1	1.7	3.9	36	28	5.6	3.3	4.5	35	28
19	-19.9	-27.5	-23.7	79	67	5.6	5.0	5.3	30	28	5.6	4.4	5.0	30	28	5.6	3.3	4.5	32	28
20	-18.7	-26.4	-22.6	80	64	5.6	5.0	5.3	30	28	5.0	4.4	4.7	30	27	5.6	3.3	4.5	34	28
21	-16.6	-23.9	-20.3	80	73	5.6	5.0	5.3	33	28	5.0	4.4	4.7	32	29	5.6	3.3	4.5	36	30
22	-11.2	-21.0	-16.1	85	76	5.6	5.6	5.6	37	30	5.6	5.0	5.3	40	32	5.6	3.3	4.5	44	32
23	- 2.1	-11.6	- 6.9	96	73	6.1	5.0	5.6	60	37	6.7	5.0	5.9	59	40	5.6	3.9	4.8	58	44
24	- 7.3	-15.0	-11.2	91	72	7.2	5.6	6.4	52	43	6.1	5.6	5.9	51	41	7.2	6.1	6.7	52	45
25	-10.9	-29.5	-20.2	87	67	6.1	3.3	4.7	47	33	5.6	4.4	5.0	47	30	6.7	4.4	5.6	48	30
26	-23.5	-31.9	-27.7	80	63	5.0	5.0	5.0	32	30	5.0	4.4	4.7	30	27	5.6	3.9	4.8	33	28
27	-22.0	-31.0	-26.5	81	74	5.6	5.0	5.3	31	29	5.0	5.0	5.0	28	26	5.6	3.9	4.8	34	28
28	-20.0	-25.9	-23.0	82	71	5.6	5.0	5.3	32	30	5.0	5.0	5.0	30	28	5.6	4.4	5.0	36	32
29	-20.0	-26.3	-23.2	81	70	5.6	5.6	5.6	32	30	5.6	5.0	5.3	30	28	5.6	3.9	4.8	35	31
30	-19.1	-28.0	-23.6	81	66	5.6	5.0	5.3	32	30	5.6	5.0	5.3	30	28	5.6	3.9	4.8	33	30
31	-19.2	-29.5	-24.4	82	70	6.1	5.6	5.9	34	33	-	-	-	-	-	5.0	3.9	4.5	36	33

Appendix Table 4. Daily temperature and relative humidity, February, 1978.

	Outdoor					Room 1					Room 2					Room 3				
	Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)	
Date	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.
1	-23.5	-33.2	-28.4	88	60	4.4	4.4	4.4	34	30	--	--	--	--	--	6.1	4.4	5.3	36	30
2	-22.0	-31.0	-26.5	87	61	4.4	3.9	4.2	30	28	--	--	--	--	--	6.1	4.4	4.3	32	28
3	-15.2	-29.7	-22.5	96	58	4.4	3.9	4.2	30	28	--	--	--	--	--	5.6	4.4	5.0	31	27
4	-14.9	-31.3	-23.1	84	70	4.4	3.9	4.2	36	28	--	Machine Malfunction			--	6.1	4.4	5.3	38	27
5	-20.5	-36.0	-28.3	91	69	4.4	4.4	4.4	38	30	--	--	--	--	--	6.1	4.4	5.3	39	29
6	-13.7	-25.8	-19.8	79	67	4.4	3.9	4.2	30	28	--	--	--	--	--	5.6	4.4	5.0	32	28
7	-13.5	-21.7	-17.6	83	62	6.1	5.6	5.9	34	30	5.6	5.0	5.3	32	30	6.7	3.3	5.0	42	38
8	-10.5	-23.5	-17.0	94	73	6.1	5.6	5.9	35	30	6.7	5.0	5.9	32	29	6.7	3.3	5.0	48	38
9	-14.2	-26.6	-20.4	87	77	5.6	5.0	5.3	38	32	5.6	5.0	5.3	36	30	6.7	3.3	5.0	45	38
10	-11.5	-23.5	-17.5	87	74	6.7	5.6	6.2	42	34	5.0	5.0	5.0	39	32	6.7	3.3	5.0	43	36
11	-13.5	-23.8	-18.7	85	75	5.6	5.0	5.3	42	38	5.0	5.0	5.0	38	32	5.7	3.3	5.0	48	38
12	-11.0	-21.6	-16.3	84	76	6.1	5.6	5.9	44	39	6.1	5.6	5.9	38	34	5.0	3.3	4.2	42	32
13	-11.5	-23.9	-17.7	84	74	5.6	5.0	5.3	44	39	5.6	5.0	5.3	40	35	5.6	3.3	4.2	46	40
14	-12.0	-16.0	-14.0	87	76	5.6	5.6	5.6	45	42	5.6	5.0	5.3	41	38	--	--	--	--	--
15	-12.5	-20.5	-16.5	86	75	5.0	5.0	5.0	43	40	5.6	5.0	5.3	39	37	--	--	--	--	--
16	-11.7	-22.2	-17.0	84	69	6.1	5.0	5.6	43	40	5.0	4.4	4.7	40	36	--	--	--	--	--
17	-10.7	-19.4	-15.1	86	68	5.0	4.4	4.7	42	38	4.4	4.4	4.4	38	34	--	--	--	--	--
18	-13.3	-23.0	-18.2	83	73	6.7	4.4	5.6	45	39	6.7	4.4	5.6	40	34	6.7	3.3	5.0	43	35
19	- 9.7	-18.5	-14.1	87	79	5.0	4.4	4.7	43	35	6.1	5.6	59	38	30	6.7	2.8	4.8	42	36
20	- 9.4	-22.7	-16.1	85	63	6.1	4.4	5.3	48	44	5.0	5.0	5.0	40	38	--	--	--	--	--
21	- 9.2	-19.2	-14.2	87	75	5.0	4.4	4.7	45	40	5.6	4.4	5.0	39	35	5.0	3.3	4.2	45	38
22	- 1.0	-11.1	- 6.1	90	78	5.0	4.4	4.7	49	39	4.4	4.4	4.4	42	34	5.0	3.3	4.2	46	36
23	- 1.0	- 9.0	- 5.0	94	66	10.0	4.4	7.2	58	48	6.7	4.4	5.6	57	42	6.7	3.3	5.0	56	44
24	- 4.0	-16.0	-10.0	94	76	10.0	6.7	8.4	6.1	50	5.6	4.4	5.0	60	50	--	--	--	--	--
25	-13.9	-21.2	-17.6	83	72	5.0	6.7	5.9	64	48	5.0	4.4	4.7	62	42	--	--	--	--	--
26	-12.7	-24.5	-18.6	81	75	4.4	3.9	4.2	47	42	4.4	4.4	4.4	42	35	--	--	--	--	--
27	-12.2	-22.6	-17.4	88	79	5.0	3.9	4.5	45	38	4.4	3.9	4.2	38	29	--	--	--	--	--
28	-14.6	-28.3	-21.5	86	58	6.1	5.6	5.9	48	43	5.6	5.0	5.3	42	38	5.6	4.4	5.0	45	37

Appendix Table 5. Daily temperature and relative humidity, March, 1978.

	Outdoor					Room 1					Room 2					Room 3				
	Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)	
Date	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.
1	-13.5	-26.3	-19.9	87	65	5.6	4.4	5.0	40	36	5.0	4.4	4.7	42	32	5.6	4.4	5.0	36	30
2	-12.5	-25.5	-19.0	87	66	5.0	2.8	3.9	43	33	5.0	4.4	4.7	35	28	6.1	3.9	5.0	40	28
3	-11.8	-26.7	-19.3	86	66	5.0	2.8	3.9	51	34	5.6	2.8	4.2	42	27	6.1	3.9	5.0	38	28
4	-12.0	-21.8	-16.9	84	63	3.9	2.8	3.4	46	38	4.4	3.9	4.2	38	30	6.1	3.9	5.0	37	27
5	-12.4	-24.0	-18.2	87	68	3.9	2.8	3.4	44	38	4.4	3.9	4.2	38	30	6.1	3.9	5.0	36	27
6	-10.1	-26.3	-18.2	86	68	3.9	2.8	3.4	44	36	4.4	3.9	4.2	35	29	6.1	3.9	5.0	34	25
7	- 6.2	-21.2	-13.7	88	77	3.3	3.3	3.3	46	38	3.9	3.3	3.6	38	28	6.1	3.9	5.0	36	24
8	0.1	-14.2	- 7.1	89	80	5.0	3.3	4.2	52	37	3.9	3.3	3.6	48	30	6.1	3.9	5.0	46	26
9	0.8	-14.6	- 6.9	93	77	8.9	2.8	5.9	66	49	6.7	3.9	5.3	68	42	7.2	3.3	5.3	70	38
10	4.5	-15.2	- 5.4	90	62	10.0	4.4	7.2	66	55	7.2	3.9	5.6	68	51	8.3	4.4	6.4	70	50
11	- 2.7	-11.9	- 7.3	87	60	6.1	2.8	4.5	81	50	5.0	3.3	4.2	75	44	6.7	3.9	5.3	84	41
12	-11.5	-16.0	-13.8	73	43	5.0	3.3	4.2	78	49	3.9	3.3	3.6	72	44	5.6	4.4	5.0	76	40
13	- 6.7	-17.1	-11.9	79	60	2.8	2.8	2.8	49	41	3.3	3.3	3.3	44	34	5.6	3.3	4.5	32	28
14	- 4.2	-15.5	- 9.9	89	55	6.1	5.6	5.9	46	40	4.4	3.3	3.9	42	34	5.6	3.3	4.5	39	28
15	- 4.6	-16.7	-10.7	90	61	6.1	5.6	5.9	56	40	4.4	3.9	4.2	54	37	5.6	3.9	4.8	51	32
16	- 5.5	-21.6	-13.6	84	49	6.1	5.6	4.9	54	44	3.9	3.9	3.9	54	44	5.6	3.9	4.8	52	42
17	- 3.6	-16.4	-10.0	88	62	6.1	5.6	5.9	50	39	4.4	3.9	4.2	48	37	5.6	3.9	4.8	46	32
18	3.5	- 6.8	- 1.7	93	55	6.1	5.6	5.9	60	41	3.9	3.9	3.9	59	40	5.6	3.9	4.8	58	35
19	- 1.2	-11.5	- 6.4	95	60	6.7	5.6	6.2	60	74	4.4	3.9	4.2	73	59	5.6	3.9	4.8	77	59
20	3.8	- 6.2	- 1.2	97	71	6.1	5.6	5.9	73	52	4.4	3.9	4.2	68	50	5.0	4.4	4.7	73	49
21	5.6	- 1.6	2.0	93	67	6.1	5.0	5.6	82	72	5.0	4.4	4.7	78	74	5.0	4.4	4.7	84	76
22	0.8	-10.2	- 4.7	92	62	6.1	5.0	5.6	88	80	6.7	3.9	5.3	80	75	5.0	3.9	4.5	84	80
23	- 8.2	-17.5	-12.9	85	59	5.0	4.4	4.7	88	50	5.6	3.9	4.8	80	51	4.4	3.3	3.9	84	44
24	- 0.2	-14.7	- 7.5	90	58	5.0	4.4	4.7	50	40	4.4	3.9	4.2	52	40	4.6	3.3	4.5	60	30
25	1.5	- 2.4	- 0.5	97	66	5.0	4.4	4.7	62	38	4.4	3.9	4.2	58	36	5.6	3.3	4.5	84	58
26	3.6	0.6	2.1	97	87	5.6	4.4	4.7	84	62	4.4	4.4	4.4	77	56	5.6	4.4	5.0	84	84
27	4.5	- 1.7	1.4	97	68	6.1	5.0	5.6	94	84	6.7	4.4	5.6	84	77	5.6	5.0	5.3	84	84
28	0.6	- 5.8	- 2.6	91	67	6.7	6.1	6.4	94	84	7.8	5.6	6.7	83	73	5.6	5.6	5.6	84	84
29	2.0	- 6.2	- 2.1	88	72	5.6	4.4	5.0	82	66	6.7	4.4	5.6	76	61	5.6	4.4	5.0	82	54
30	5.8	- 1.0	2.4	94	63	5.6	4.4	5.0	83	62	5.0	4.4	4.7	74	60	5.6	4.4	5.0	80	54
31	5.0	- 6.7	0.9	100	74	7.2	4.4	5.8	87	82	7.8	5.0	6.4	75	72	5.6	5.0	5.3	84	80

Appendix Table 6. Daily temperature and relative humidity, April, 1978.

	Outdoor					Room 1					Room 2					Room 3				
	Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)		Temperature (°C)			Relative humidity (%)	
Date	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.	Max.	Min.	Mean	Max.	Min.
1	- 2.4	-10.4	- 6.4	87	72	6.7	4.4	5.6	94	65	7.8	4.4	6.1	83	60	5.6	3.3	4.5	84	59
2	- 0.5	- 4.0	- 2.3	94	69	4.4	4.4	4.4	65	54	4.4	3.9	4.2	62	52	5.0	3.3	4.2	60	40
3	1.8	- 2.5	- 0.4	94	80	5.0	4.4	4.7	80	52	5.0	3.9	4.5	71	60	5.0	4.4	4.7	77	56
4	3.0	- 3.2	- 0.1	93	63	5.0	4.4	4.7	88	80	6.7	4.4	5.6	78	70	5.6	5.0	5.3	84	72
5.	4.0	- 3.2	- 0.4	91	61	5.0	3.9	4.5	88	72	6.7	5.6	6.2	63	78	5.6	5.0	5.3	84	66
6	7.7	- 5.6	1.1	97	67	4.4	3.9	4.2	90	74	6.7	5.0	4.9	78	67	5.6	5.0	5.3	84	68
7	- 1.0	- 9.1	- 5.1	88	62	7.2	4.4	5.8	94	64	8.9	4.4	6.7	81	61	6.1	4.4	5.3	84	60
8	3.9	- 5.0	- 0.6	90	43	4.4	4.4	4.4	66	50	4.4	4.4	4.4	60	50	5.6	3.3	4.5	60	38
9	8.9	0.6	4.8	100	66	5.6	4.4	5.0	85	62	5.0	4.4	4.7	77	60	5.0	3.3	4.2	84	56
10	4.3	- 0.5	1.9	90	65	7.2	5.0	6.1	96	85	7.8	5.0	6.4	89	77	5.6	5.0	6.3	84	84
11	3.0	- 2.8	0.1	89	60	5.6	4.4	5.0	88	70	6.7	4.4	5.6	81	67	5.6	4.4	5.0	84	63
12	- 0.4	- 3.5	- 2.0	92	65	10.6	8.9	9.8	76	58	5.6	4.4	5.0	77	66	9.4	4.4	6.9	72	60
13	3.3	- 2.5	0.4	81	60	8.9	5.0	7.0	80	58	5.0	3.9	4.5	74	59	9.4	6.7	8.1	64	44
14	6.0	- 2.6	1.7	85	47	5.0	4.4	4.7	79	60	5.0	3.9	4.5	73	61	--	--	--	--	--
15	6.5	- 3.9	0.9	92	48	9.4	4.4	6.9	80	62	11.7	3.9	7.8	71	60	--	--	--	--	--
16	10.5	- 3.1	3.7	82	37	10.5	10.0	10.3	76	56	8.9	8.3	8.6	63	55	--	--	--	--	--
17	14.5	3.3	8.9	65	36	10.5	10.0	10.3	58	51	9.4	7.8	8.6	66	56	--	--	--	--	--
18	13.5	- 1.0	6.3	85	38	10.0	9.4	9.7	68	53	11.7	8.9	10.3	70	61	--	--	--	--	--
19	- 0.8	- 6.2	- 3.5	84	67	--	--	--	--	--	11.1	6.7	8.9	74	47	--	--	--	--	--
20	5.8	- 6.1	- 0.2	79	27	--	--	--	--	--	7.2	6.7	7.0	48	44	--	--	--	--	--
21	12.0	- 5.9	3.1	89	25	--	--	--	--	--	7.8	6.7	7.3	49	34	--	--	--	--	--
22	15.1	1.0	8.1	78	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
23	16.1	2.8	9.5	82	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24	17.1	- 0.2	8.5	87	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	17.3	2.3	9.8	83	36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	18.0	0.8	9.4	97	39	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
27	21.6	3.7	12.7	83	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28	22.7	6.3	14.5	76	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	14.6	2.3	8.5	78	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	16.2	0.1	8.2	51	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Appendix Table 7. Number of colonies that died while in the indoor wintering building.

Reason for death	Treatments I	II	III	IV	V	VI	Total
Honey granulation	4	1	3	5	1	2	16
Starvation	3	8	1	3	6	0	21
Other*	1	2	0	0	0	1	4
Total	8	11	4	8	7	3	41

* Note: *may be due to queenlessness, supersedure, laying worker or a drone-laying queen.*

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