POPULATION GROWTH STUDIES
OF PACKAGE BEE COLONIES IN MANITOBA

A Thesis

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by

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ABSTRACT

An analysis of four groups of honey bee colonies, initiated with one, two, three and four pounds of bees, was done in order to determine the growth patterns for each size.

In this study 32 colonies were used in 1968 and 1969 and 40 colonies in 1970, to investigate the changes in brood areas, adult numbers, honey production, flight activity and pupal weights. The four sizes of packages were hived on approximately 4 May each year.

Package size had a large effect on the above-mentioned factors for the four groups but after 50 days of development there was usually little difference. However, in 1969 differences in the above were evident for a longer period of time. The inability of the smaller sized colonies to keep pace with the other colonies in brood production is attributed to pollen and nectar shortages and probably to some extent cool weather.

The larger packages supported greater amounts of brood at least up to 50 days of development but the smaller packages were more efficient in their rearing of brood.

The adult numbers were directly affected by the length of time a group developed. The larger package size allowed for faster development early in the year.

The growth and performance of the four groups are analysed in this thesis.

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	LITERATURE REVIEW	3
	A. The General Development and Performance of Honey Bee Colonies	3
	B. The Development and Performance of Package Bee Colonies	4
	C. Methods Used to Measure Brood and Adult Numbers	9
	D. The Nutrition and Development of the Immature Stages of the Honey Bee	10
	E. Entrance Activity	11
III.	GENERAL METHODS	13
	A. Project Design	13
	B. Colony Management	14
	C. Seasonal Measurements	15
	(1) 1968 Measurements	15
	(a) Brood	15
	(b) Adults	16
	(c) Pupal Weights	16
	(2) 1969 Measurements	16
	(a) Brood	16
	(b) Adults	18

CHAPTER PAGE

(c) Pupal Weights 18

(3) 1970 Measurements 18

(a) Brood 18

(b) Adults 22

(c) Pupal Weights 22

D. Other Measurements 22

(1) Scale Colonies 22

(2) Entrance Activity 22

IV. ESTIMATING NUMBERS OF HONEY BEES ON LANGSTROTH FRAMES (USING PHOTOGRAPHS) 24

A. Introduction 24

B. Methods 24

(1) Single Frame Estimations 24

(2) Whole Colony Estimations 26

C. Results 29

(1) Single Frames 29

(2) Whole Colonies 30

D. Discussion and Conclusions 38

V. RESULTS AND DISCUSSION 40

A. Results and Discussion of Seasonal Measurements of Experimental Colonies 40

(1) 1968 Seasonal Measurements 40

(a) Brood 40

(i) Total Brood 40

(ii) Sealed Brood 41

CHAPTER PAGE

(iii) Unsealed Brood 42

(b) Adults 43

(c) Pupal Weights 43

(2) 1969 Seasonal Measurements 54

(a) Brood 54

(i) Total Brood 54

(ii) Sealed Brood 55

(iii) Unsealed Brood 56

(b) Adults 57

(c) Pupal Weights 66

(d) Brood to Adult Ratios 66

(i) Total Brood Cells to Adult Number Ratio 67

(ii) Sealed Brood Cells to Adult Number Ratio 67

(iii) Unsealed Brood Cells to Adult Number Ratio 68

(3) 1970 Seasonal Measurements 75

(a) Brood 75

(i) Sealed Brood 75

(b) Adult Numbers 76

(c) Brood Ratios 82

(i) Sealed Brood to Adult Number Ratio. 82

(d) Pupal Weights 82

B. Other Measurements 88

CHAPTER PAGE

(1) Scale Weights (Nectar Flow) 88

(a) 1969 88

(b) 1970 88

(2) Honey Production 89

(a) 1969 89

(b) 1970 89

(3) Entrance Activity 93

(a) Pollen Collectors 93

(b) Non-Pollen Collectors 94

(c) Total Foragers 94

C. General Comparisons of Results (1968, 1969, 1970) 98

(1) Brood Measurements 98

(a) Total Brood 98

(b) Sealed Brood 98

(c) Unsealed Brood 99

(2) Adult Population 99

(3) Ratios of Brood Cells to Adult Numbers 100

(4) Pupal Weights 101

(5) Scale Colonies 101

(6) Honey Production 101

(7) Entrance Activity 102

VI. MISCELLANEOUS STUDIES AND OBSERVATIONS 103

A. Abnormal Colonies 103

(1) 1969 103

(a) Queen Losses 103

CHAPTER PAGE

(b) Queen Failure 103

(c) Swarming 104

(2) 1970 104

(a) Queen Losses 104

(b) Queen Failure 105

(c) Supersedure 105a

(d) Swarming 105a

(3) Summary of Abnormal Colonies 105a

B. Drone Brood 112

C. Colony Management Problems of the Four Experimental Groups 114

VII. GENERAL SUMMARY 115

REFERENCES 118

APPENDIX 125

LIST OF FIGURES

FIGURE		PAGE
1.	Tracing of brood areas on glass with one inch squares	17
2.	Apparatus used to trace brood areas in 1968 and 1969	17
3.	Apparatus used to photograph sealed brood in 1970 ...	20
4.	Equipment used to count sealed brood areas from negatives (1970)	20
5.	Traps used to monitor entrance activity in 1970	21
6.	Graded series of photographs	28
7.	Apparatus used to obtain counts of single frame estimations	28
8.	Total brood areas of the four experimental groups (1968)	47
9.	Sealed brood areas of the four experimental groups (1968)	48
10.	Unsealed brood areas of the four experimental groups (1968)	49
11.	Mean weight of pupae taken from the four experimental groups (1968)	52
12.	Maximum and minimum temperatures (1968)	53
13.	Total brood areas of the four experimental groups (1969)	61
14.	Sealed brood areas of the four experimental groups (1969)	62

FIGURE PAGE

15. Unsealed brood areas of the four experimental groups (1969) 63

16. Adult numbers of the four experimental groups (1969) . 64

17. Ratio of the number of total brood cells to adult bees (1969) 71

18. Ratio of the number of sealed brood cells to adult bees (1969) 72

19. Ratio of the number of unsealed brood cells to adult bees (1969) 73

20. Maximum and minimum temperatures (1969) 74

21. Sealed brood areas of the four experimental groups (1970) 79

22. Adult numbers of the four experimental groups (1970). 80

23. Ratio of the number of sealed brood cells to adult bees (1970) 85

24. Mean weight of pupae of the four experimental groups (1970) 86

25. Maximum and minimum temperatures (1970) 87

26. Nectar flow records of one scale colony from each of the four experimental groups (1969) 95

27. Nectar flow records of one scale colony from each of the four experimental groups (1970) 96

28. Foraging activity of the four experimental groups (1970) 97

LIST OF TABLES

TABLE		PAGE
I.	Summary of errors of five observers during sixteen hours of estimating numbers of bees on Langstroth frames (Group 1, 1968)	32
II.	Summary of errors of four observers during eight hours of estimating numbers of bees on Langstroth frames (Group 2, 1968)	33
III.	Summary of errors of six observers estimating the number of bees on Langstroth frames (1969)	34
IV.	Summary of eight observers estimating numbers of bees on Langstroth frames (1970)	35
V.	Whole colony estimations of adult honey bee numbers (1969)	36
VI.	Whole colony estimations of adult honey bee numbers (1970)	37
VII.	Summary of brood development within the four experimental groups (1968)	44
VIII.	Group differences of total, sealed and unsealed brood (1968)	46
IX.	Linear regression equations of brood areas and time of development (1968)	50
X.	Mean weights of pupae of the four experimental groups (1968)	51

TABLE		PAGE
XI.	Group differences of weight in pupae (1968)	51
XII.	Summary of brood and adult development within the four experimental groups (1969)	58
XIII.	Group differences of total, sealed, unsealed brood and adults (1969)	60
XIV.	Linear regression equations of brood areas, adult numbers and time of development (1969)	65
XV.	Ratios of the number of brood cells to adult bees (1969)	69
XVI.	Linear regression equations of the ratios of the number of brood cells to adult bees, and time of development (1969)	70
XVII.	Summary of brood and adult development within the four experimental groups (1970)	77
XVIII.	Group differences of sealed brood and adult numbers (1970)	78
XIX.	Linear regression equations of sealed brood area and time of development (1970)	81
XX.	Linear regression equations of adult numbers and time of development (1970)	81
XXI.	Linear regression equations of the ratios of the number of sealed brood cells to adult bees, and time of development (1970)	81
XXII.	Ratio of the number of sealed brood cells to adult bees (1970)	83

TABLE PAGE

XXIII. Mean weight of pupae of the four experimental groups (1970) 84

XXIV. Honey production of the four experimental groups (1969) 90

XXV. Honey production of the four experimental groups (1970) 91

XXVI. Differences in honey production of the four experimental groups (1969) 92

XXVII. Differences in honey production of the four experimental groups (1970) 92

XXVIII. Relative foraging activity of the four experimental groups (June and July, 1970) 96a

XXIX. Relative foraging activity of the four experimental groups (August, 1970) 96b

XXX. Relationships between forager activity, hive population, and honey production 96c

XXXI. Performance of abnormal colonies (1969) 106

XXXII. Performance of abnormal colonies (1970) 109

XXXIII. Sealed drone brood present in the 1969 and 1970 normal experimental colonies 113

CHAPTER I

INTRODUCTION

The commercial beekeeping industry in the Prairie Provinces is based on colonies initiated from package bees (*Apis mellifera* L.). These packages are imported from the southern United States each spring, and can be purchased in packages containing different numbers of bees (i.e., one, two, three, or four pound lots; one pound of bees equals about 3500 bees). The customary size used by commercial beekeepers is the two pound package but some beekeepers also use the three pound package.

Some studies have been done in the United States to determine the most efficient size of package to use. However, few data which apply to Western Canadian conditions are available.

This study was designed to investigate certain parameters which could be used to determine the efficiency and development of the honey bee colony. These parameters, e.g., total, sealed and unsealed brood, adult numbers, pupal weights, honey production, and forager activity, were then used to measure the performance of the four sizes of packages. In 1968 and 1969 thirty-two colonies (eight in each group) and in 1970 forty colonies (ten in each group) were studied in order to evaluate the performance of each size of package. Data for each of the four groups were pooled to obtain averages for each parameter measured.

Data obtained from this study are applicable not only to the honey industry but also in the pollination of specific crops of economic importance.

CHAPTER II

LITERATURE REVIEW

The following review of literature includes:

A. The general development and performance of honey bee colonies;

B. The development and performance of package bee colonies;

C. Methods used to measure brood and adult numbers;

D. The nutrition and development of the immature stages of the honey bee;

E. Entrance activity.

A. The General Development and Performance of Honey Bee Colonies

Nolan (1925a, 1925b) measured the sealed brood produced by 16 colonies for one season and showed a correlation between changes in quantities of sealed brood and various factors of the environment, including queen performance. He considered that maximum bee populations, of honey producing colonies, should be produced to coincide with the period of the main nectar flow.

Farrar (1931) outlined a relationship between the number of adult worker bees and brood production. A colony of ten thousand bees was considered to be the most efficient for producing sealed brood; a population of forty thousand adult worker bees produced maximum quantities of sealed brood. The relationship between

declining brood rearing efficiency and adult populations, as a colony increases in number, has been shown to be generally true for the Hymenopterous social insects (Michener, 1964).

The increasing efficiency of honey production per bee as colony population increases has been calculated by Farrar (1937). Increasing population levels theoretically allow each worker to spend a greater proportion of her life in foraging and less in brood production duties (see also Moeller, 1961; and Free, 1968).

Bodenheimer (1937a, 1937b) and Bodenheimer and Nerya (1937) studied the seasonal changes in populations and the activities of honey bee colonies. These studies included foraging populations of bees of different ages, as well as rate of growth of the colonies in the active season. Bodenheimer and Nerya outlined an empirical method of calculating the population age structure of a colony from measurements of sealed brood quantities taken at various intervals throughout the season.

Jeffree (1955) studied the changes in colony populations throughout the season. The effect of Nosema disease on population levels and the effect of colony population on honey production were also measured.

B. The Development and Performance of Package Bee Colonies

The beekeeping industry of the North Central United States and Western Canada is dependent on package bees for establishing colonies each spring. While general principles of colony develop-

ment apply to these colonies, specific knowledge of the establishment and development of a colony initiated from a package is needed but little specific information is available.

Braun (1936) showed, in experiments conducted over an eleven year period with 164 colonies, that early hived colonies (April 25 - May 8) produced more honey than the late hived colonies (May 10 - June 8) (see also Michener, 1931).

Kelty (1948) in Michigan tested the effect of package size on honey production over a three year period. The two and three pound packages gave the most consistent results, but in general there was no relationship between package size and resulting honey crop. The differences in honey production of colonies initiated from packages of different sizes were found to be non-significant by L'Arrivee and Geiger (1966).

Package size and spring hiving dates were investigated by Nolan (1932). One each of one, two, three, four and five pound packages were hived at ten week intervals in Maryland, U.S.A. The smaller packages (one and two pounds) developed more efficiently, while the larger packages (three, four and five pounds) attained a higher absolute population more quickly. He recommended that the installation of package bees be done eight to nine weeks before the main nectar flow.

L'Arrivee and Geiger (1966) studied the effect of one, one and one half, two, three, and four pound packages on brood and honey production. The one pound packages were significantly lower in honey production than the other sizes. The three and four pound

package colonies produced larger quantities of brood in May and June, but by mid-July the amount of brood was very similar for all sizes.

Factors, both within the colony as well as outside of it, set limits on the rate of growth and the ultimate numerical size it will attain; this, in turn, affects its honey production or pollination capabilities. Factors within the colony include such things as queen performance, brood survival, adult population, diseases, food supply, etc., while factors outside of the colony include such things as forage availability, weather conditions, drifting, etc.

The queen's performance is considered to be the major factor contributing toward variation in colony performance (Kelty, 1948; L'Arrivee and Geiger, 1966; Nolan, 1925a, 1925b, 1932; Simpson, 1969). The egg-laying capacity of the queen limits the absolute adult population of a colony (Moeller, 1961). Viability of the eggs produced (Cale, 1952; Roberts and Mackensen, 1951) as well as the production of queen substance (Butler, 1959) are important in queen effectiveness. Correlations between high egg-laying rate of the queen and pollen foraging ability of her progeny (Cale, 1967) and honey production of a colony (Soller and Bar-Cohen, 1967) have been demonstrated.

Brood survival is affected by many factors, e.g., cold weather (Geiger, 1967; Pankiw, 1968), disease (Farrar, 1947; Jay, 1966), and/or eggs may be eaten by worker bees (Nolan, 1925; Myser, 1952; Brian, 1965).

Merrill (1924b) found a considerable variation in the percent-

age of eggs which reached the sealed brood stage. Fukuda and Sakagami (1968) found the survival-per-stage function to be: 100.0 eggs, 94.2 unsealed brood, 86.4 sealed brood, and 85.1 adults.

Allen and Jeffree (1956) found a positive correlation between the amounts of pollen and brood in a colony, and Wilson (1923) found that removing pollen from colonies in the spring reduced brood rearing. The need for pollen to maintain brood rearing has been demonstrated by Farrar (1934, 1936), Allen and Jeffree (1956), Moeller (1967), and Cale (1967). Without pollen or supplemental proteins brood rearing will eventually cease (Haydak, 1935). Besides stimulating egg-laying (Free and Spencer-Booth, 1961; Cale, 1967; Doull, 1968) there are reports that pollen and supplemental feeding increases the amount of brood a colony will rear (e.g., Free and Spencer-Booth, 1961; Hagedorn and Moeller, 1967; Weaver and Chauthani, 1967; Langridge, 1969). Wahl (1954) found that the amount of brood reared depended on the quality of the food obtained by the nurse bees.

The number of adult worker bees present influences the rate of colony growth (Farrar, 1931) by determining the brood area maintained, i.e., total brood area and percent brood survival (Fukuda and Sakagami, 1968); brood survival markedly decreases at peripheral areas within the hive.

Nosema disease in package bees and queens is common (Farrar, 1947; Jay, 1966). Cantwell and Shimunuki (1969) have reviewed recent research involving Nosema disease. American and European foulbrood can be transmitted by package bees (Pankiw and Corner,

1965; 1966). Gochnauer (1965) has reviewed the effect of these two diseases on colony life.

Restriction of space for egg-laying by the queen, where brood cells have been used for nectar storage, has been observed by Nolan (1925). Cell space for egg-laying may be restricted when three and four pound packages are used (L'Arrivee and Geiger, 1966). Farrar (1927) observed a tendency for smaller package colonies to place nectar in the brood nest initially, thus restricting egg-laying by the queen.

Cool spring temperatures have been found to restrict brood rearing (Pankiw, 1968; Geiger, 1967). Cold periods may cause a decrease in honey production (Nolan, 1925a), while temperatures of 80 to 100 degrees Fahrenheit appear to favor foraging during the nectar flow (Moffat and Parker, 1953). Nectar secretion by plants is also largely determined by weather conditions (Moffat and Parker, 1953).

Drifting results in redistribution of colony populations. This inhibits the development of some colonies and results in inefficient brood rearing and swarming problems in others which have gained bees (Smirl, 1970). Drifting may occur at spring hiving time (Kelty, 1948), during the active season (Ribbands, 1953; Free, 1958), and due to environmental factors (Jay, 1965).

Each of the above factors contributes to the performance of honey bee colonies and must be noted carefully when comparing two or more groups of colonies.

C. Methods Used to Measure Brood and Adult Numbers

When measuring colony development researchers have had to consider labor requirements, measurement accuracy, and the degree of colony disturbance resulting from the method used.

Actual counts of eggs (Berlepsch, 1860) or of eggs, larvae, and pupae (Baldridge, 1861; Dufour, 1901) are useful for small scale studies or for determining life tables (Sakagami and Fukuda, 1968), but inherent in these methods is the problem of killing brood in cool weather.

Brunnich (1922) used the length and depth of the eliptical brood area and the formula, height x breadth x 1.6, to calculate the brood area on the two comb sides. The reliability of this method depends on a compact brood nest. Ebert (1922), and Bodenheimer and Nerya (1937) used a similar method for measuring brood areas.

Photographic reproductions of sealed brood areas were used by Nolan (1925, 1932), Pankiw (1968), and Free and Racey (1968); these methods were adapted by the author in 1970 (for details see Chapter III).

A calibrated wire grid placed over the comb for visual counts was used by Moeller (1961), Geiger (personal communication), Pankiw (1968) and Jeffree (1958). The method developed and used by Smirl (1970), whereby brood areas were traced on a glass plate (ruled in one inch squares) and then counted, was also used during the first part of this study. In using the above methods, one operator is required to do all of the measurements in order to avoid variations

in estimation of combs with "spotty" brood.

Adult population estimates have generally been made by weighing the bees in a hive, and then converting the weight to a number by counting a representative weighed sample (Farrar, 1937; Jeffree, 1955; Moeller, 1961).

Jeffree (1951) developed a system of comparing frames of bees to a graded set of calibrated bee photographs. This method has been altered for use with Langstroth frames by the author for this study (for details see Chapter IV).

Farrar (1952), Geiger (1967) and Smirl (1970) killed representative colonies to obtain adult population data.

Bodenheimer and Nerya (1937) calculated the population of a honey bee colony by using measured sealed brood quantities.

Simpson (1969) measured adult population in a colony by recording the number of frames occupied by the bees and then determining the average density of bees; he found this to be 1095 per standard frame.

D. The Nutrition and Development of the Immature Stages of the Honey Bee

Rapid growth of larvae is only possible if nutritious substances are available and supplied by the nurse bees. The amount and quality of this food determine the final size and weight of a larva (and hence the adult bee) within its hereditary possibilities (Velich, 1930; Buchner, 1953).

Undersized worker adults can result when pollen and nectar become scarce (e.g., Nelson and Sturtevant, 1924; Leuenberger, 1936; Levin and Haydak, 1951), when the colony is diseased (Fyg, 1959; Bailey, 1960), when the brood is reared early in the spring (e.g., DeGroot, 1950; Levin and Haydak, 1951) or when the colonies are low in numbers of workers (e.g., Levin and Haydak, 1951). The sizes and weights of adults are also affected by the ages of the nurse bees (e.g., Peterka, 1928; Buchner, 1953), the ratio of the number of nurse bees to the number of brood being reared (Gontarski, 1953) and the size of the cell (e.g., Gontarski, 1935; Grout, 1937; Buchner, 1953). Jay (1963) showed that starvation of the three castes of honey bees under natural or laboratory conditions produced some dwarfs and intercastes.

E. Entrance Activity

The proportion of foragers carrying pollen loads or nectar loads varies, being largely dependent upon the availability of forage and the colony requirements (Ribbands, 1953). Filmer (1932) showed that the proportion of pollen gatherers increased with the quantity of brood. Todd and Bishop (1941) found brood rearing trends parallelled pollen income, and that the springtime egg-laying peak coincided with the peak of pollen collection.

Lundie (1925) noted that strong colonies tended to fly at somewhat lower temperatures than did weak ones. Ribbands (1953) suggested that in the early part of a season the rate of brood rear-

ing is directly proportional to colony size, but at the height of the season the rate of brood rearing in large colonies drops off. The number of bees flying from developing colonies is proportional to colony size (Free, 1960). Moeller (1958) found a correlation between the rate of egg-laying in colonies and the amount of honey they produced, indicating that the amounts of honey stored by mature colonies of different sizes are directly proportional to their populations.

CHAPTER III

GENERAL METHODS

A. Project Design

Packages containing one, two, three, and four pounds of bees (1 lb. = about 3500 bees) were hived 6 May 1968, 3 May 1969 and 2 May 1970.

In each of the three years, package bees of a yellow strain were obtained from the same California shipper. The four package sizes (referred to as groups No. 1, No. 2, No. 3 and No. 4 after the time of hiving) were formed by removing the feeder cans, accounting for the package weight, and adding or removing bees to give the desired bee weights (± 2 oz.).

The packages in each year were hived in the evening or after dark to eliminate possible drifting and bee loss caused by variations in weather conditions between the three years (Jay, 1965).

The packages were hived in brood chambers containing four combs of honey, two combs with mostly pollen, and three empty brood combs. In 1968 and 1969 there were eight colonies of each package size in each group; the colonies of each group were arranged in a horseshoe pattern to prevent "drifting" (Jay, 1969). In 1970 there were ten colonies in each group; these were arranged in semi-circles with colony entrances facing various directions.

In 1969 sugar syrup was fed to groups No. 2, No. 3 and No. 4, and pollen substitute was given to all four groups (Farrar, 1968). In all years, second brood chambers and supers were added as required and the queens were allowed access to all supers.

In 1968 honey was removed only when the colonies were killed in the fall (no weights available). In 1969 honey was removed at the end of July and at the end of August, after which time the colonies were killed. In 1970 honey was removed at the end of July, in the middle of August, and at the end of August, after which time the colonies were killed.

B. Colony Management

In all years (1968 - 70) management of the colonies was more intensive than that done in commercial apiaries. This was necessary because of the specialized nature of the project, including removal of frames from the hives, and frequent queen checks.

In 1968 all brood measurements began at the end of May (after the colonies were known to have normal queens) and continued at 12 day intervals. A 12 day cycle allowed sealed brood measured on one reading date to hatch and thus provide a record of all sealed brood produced by each colony. In 1969 brood measurements began at 13 days after hiving and continued at 12 day intervals. In 1970 brood readings began near the end of May, after the queens were actively laying and capped brood was increasing (26 days after hiving). In all years the 12 day intervals were $\pm$ 24 hours from the scheduled "reading" date.

During the 1969 and 1970 seasons, queen replacement was done up to one week after hiving in colonies where queens were lost or showed poor performance; these requeened colonies were considered to be normal in this study. However, data for colonies showing queen losses, queen failure, or swarming after the first week was excluded from the study.

Drugs were administered in all years for the control of foulbrood and Nosema at recommended times and in recommended doses.

C. Seasonal Measurements (1968 - 1970)

(1) 1968 Measurements

(a) Brood In 1968 all stages of brood (eggs, larvae, and sealed cells) in each of the eight colonies within the four groups were recorded. It was often difficult to distinguish accurately between eggs and larvae so they were combined and termed "unsealed brood" for calculation purposes. A distinction was not made between worker and drone brood in these measurements.

Brood areas were traced on to glass plates divided into one inch squares (Figure 1). In cool weather two glass plates were used, one on each side of the brood, but during warm weather only the top tracing plate was used. When light conditions were poor, flood lights connected to a portable generator were used to see the unsealed brood. Brood was moved from the hive to the tracing apparatus by placing combs from one chamber containing brood, into a "transfer box" (Figure 2); the frames were numbered, and therefore

could be replaced in proper sequence. Because the frames and bees from each chamber were kept intact in this manner, chilling of the brood in the early readings was probably negligible. Sometimes bees had to be shaken from the frames to expose unsealed brood.

An analysis (Smirl, 1970) of the maximum variation between the same and a different person's tracing brood areas and between the same and a different person's reading the brood areas, showed that the average of the maximum variation of five trials between different "readers" was 5.1 to 7.2 percent depending on the type of area counted; the variation in two countings by one "reader" was usually 4 to 5 percent.

(b) Adults No adult readings were done in 1968.

(c) Pupal Weights Pupal weights were measured every 12 days, by removing 30 pupae from each of the three hives in each group, and weighing them separately. A central frame of sealed brood was removed from a hive and several cells were uncapped to determine whether pupae in that frame were of the proper age. If the pupae appeared to be of the right age, thirty pupae (five more than required for individual weights) with a distinct darkening of the eye, but without body coloration, were selected (Jay, 1962). The pupae were individually weighed on a precision torque balance to the nearest mg.

(2) 1969 Measurements

(a) Brood In 1969 brood in unsealed and sealed cells was measured in each of the eight hives within the four groups (worker

FIGURE 1 - TRACING OF BROOD AREAS ON GLASS WITH ONE INCH SQUARES

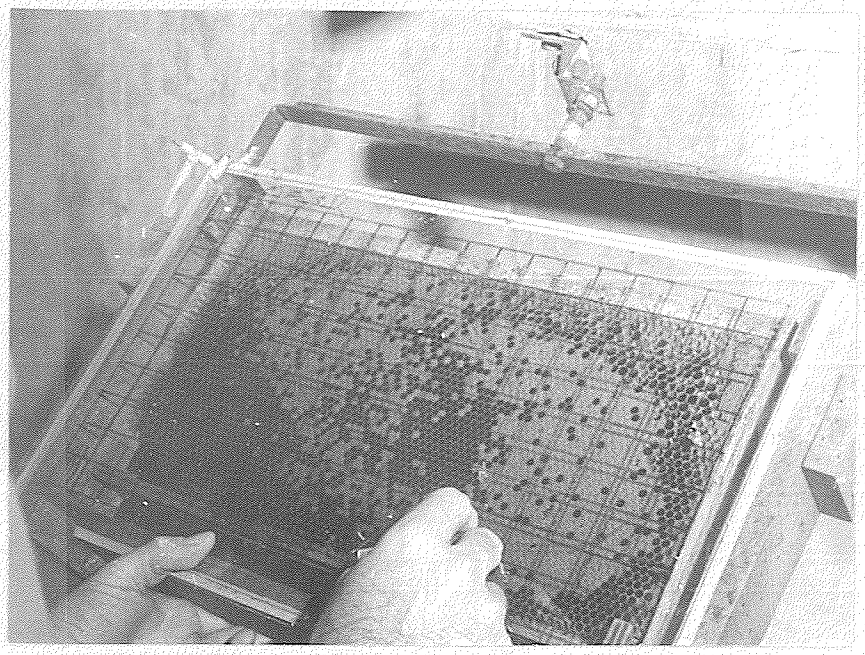
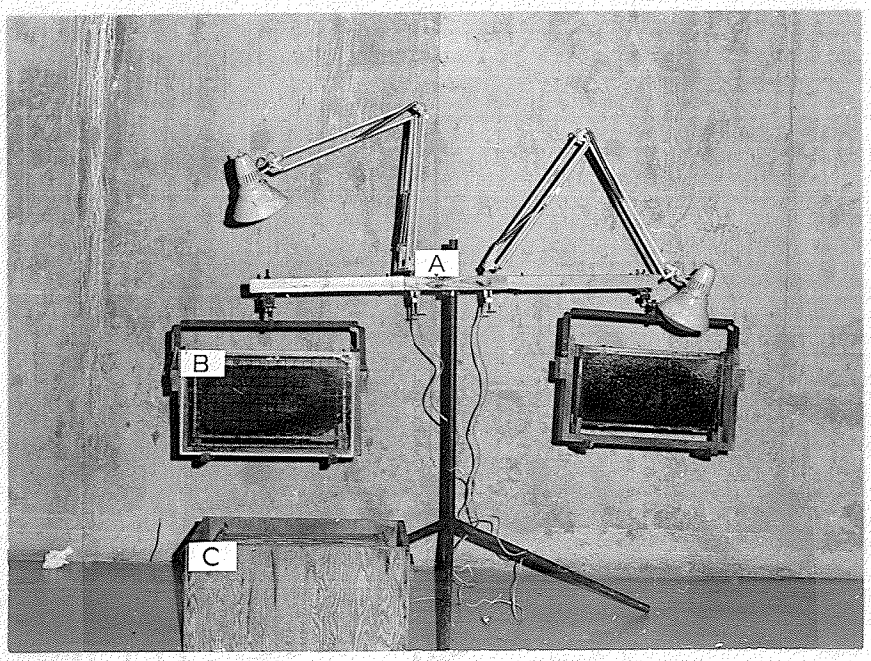


FIGURE 2 - APPARATUS USED TO TRACE BROOD AREAS IN 1968 AND 1969



A - support stand with lights
B - frame holder
C - transfer box

and drone sealed brood were recorded separately, but their sum was used in all tables except in Chapter VI, on Drone Brood).

Brood was measured in the same manner and with the same equipment as in 1968.

(b) Adults Jeffree's (1951) method was modified wherein frames of bees were compared to a graduated series of mounted photographs and their numbers estimated (see Chapter IV details and discussion of adult estimations).

Estimations of adult bees by this method must be made early in the morning before flight activity begins. The procedure takes about ten minutes per hive during time of peak populations (i.e., August).

(c) Pupal Weights Pupal weights were measured in the same manner as was used in 1968. In 1969, however, only one colony per group was measured.

(3) 1970 Measurements

(a) Brood In 1970 only sealed brood was measured in each of ten colonies within the four groups. Measurements were made by photographing the sealed brood and projecting the negatives onto frosted glass plates marked in square inches.

The apparatus in Figure 3 was used to photograph the sealed brood. It consisted of a Nikon camera with motor drive (250 exposure capacity) and a pivoting frame holder placed at a fixed distance from the camera. Changeable identification numbers, representing date, hive, chamber, and frame number and frame side, were

placed just under the frame holder so they would show on each negative.

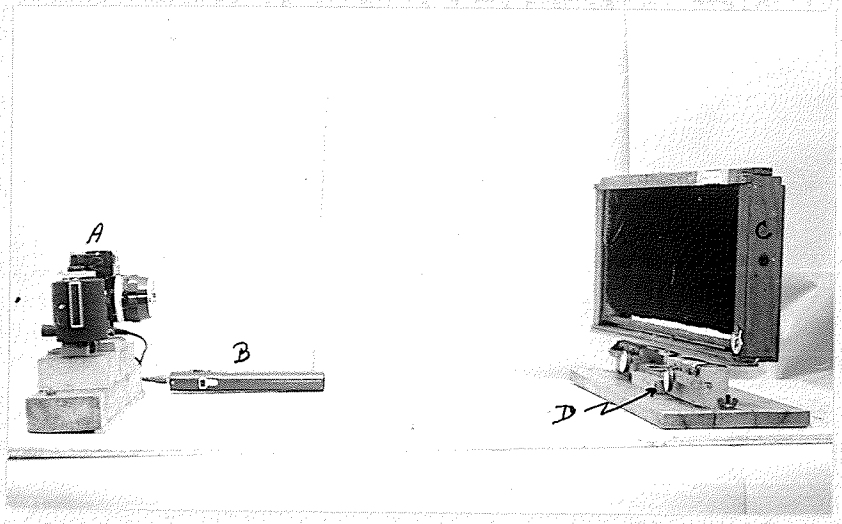
Each hive, in turn, was opened and combs containing sealed brood were taken from each hive and placed in a transfer box (Figure 2). The transfer box was taken to the camera apparatus which was on a table of working height. Each frame was placed in the frame holder and a picture taken of each side. Usually two individuals are required to operate the camera apparatus, one placing combs into the frame holder and another changing the identification numbers and taking the pictures.

Bees usually had to be shaken from the combs to expose the sealed brood; this was done by holding the frame inside the bottom chamber and giving it a quick downward shake. This keeps the bees within the brood chamber and allows them to climb onto combs, cuts down on the number of flying bees, and ensured that the queen remains within the hive. The method worked well and a team of five or six people could photograph the sealed brood of sixty colonies in about four hours.

When the photographing was complete the film was developed in special tanks that could handle two 250 exposure developing reels. The developing was done immediately so that the negatives could be checked in case of improper exposure or developing.

The negatives, when dry, were fed into a film strip projector and projected onto a sheet of frosted mylar plastic, placed between two sheets of glass, one of which had been ruled in square inches within the outline of a standard brood frame. With the projector

FIGURE 3 - APPARATUS USED TO PHOTOGRAPH SEALED BROOD IN 1970



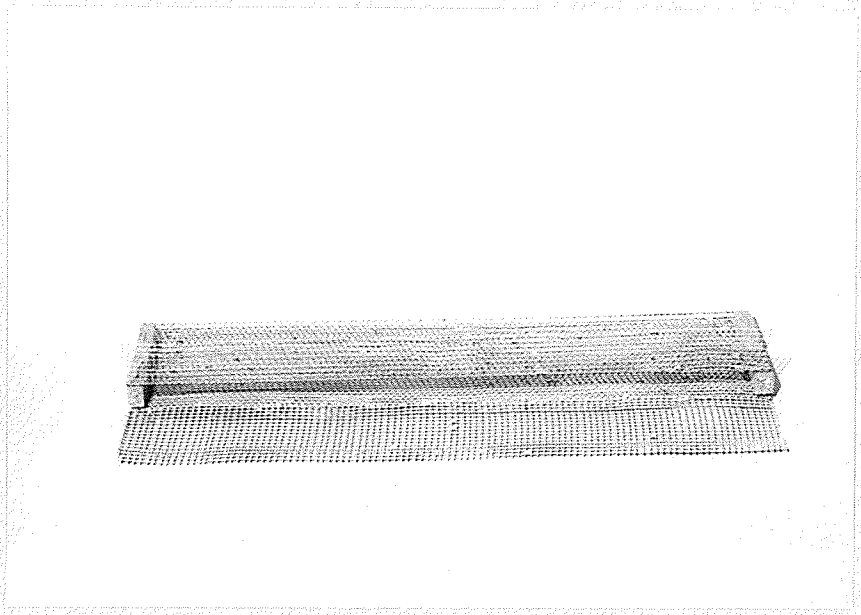
A - camera with motor drive
B - battery pack
C - frame holder
D - numbers to indicate hive, frame, etc.

FIGURE 4 - EQUIPMENT USED TO COUNT SEALED BROOD AREAS FROM NEGATIVES (1970)

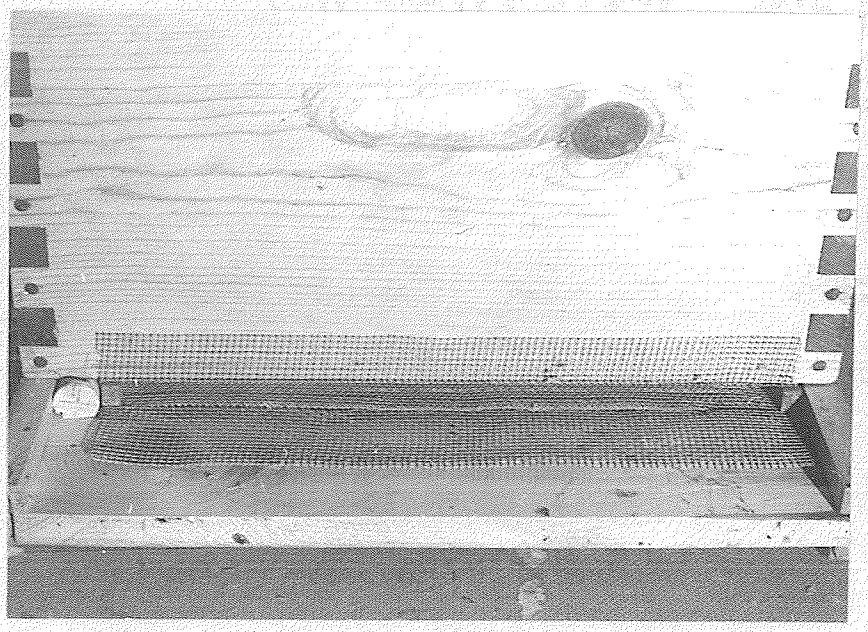
A - stand holding frosted glass with square inch grid
B - electic counter
C - film strip projector

FIGURE 5 - TRAPS USED TO MONITOR ENTRANCE ACTIVITY (1970)

A - trap measures $14\frac{1}{4} \times 3 \times \frac{1}{2}$ inches



B - trap in hive entrance



at a fixed distance from the glass grid, the negatives filled the brood comb outline and the square inches of brood were counted, with the aid of an electric digital counter (Figure 4).

During peak brood production (end of July and early August) the negatives for sixty colonies could be counted in about eight hours.

(b) Adults Adult estimations were done in the same manner as had been done in 1969.

(c) Pupal Weights These were done as in 1968 except that the total weight of 25 pupae per colony was recorded.

D. Other Measurements

(1) Scale Colonies Platform scales were used in 1969 and 1970 to monitor the nectar flows. The changes in scale weights showed the period of the nectar flow and the time of the peak flow for each of the two years and for each group being studied.

(2) Entrance Activity Entrance activity was measured only during 1970. The measurement was done using three colonies in each of the four groups, by trapping incoming bees. Traps made of hardware cloth (Figure 5) were placed in the entrance of each hive for 30 seconds, then removed and the number of pollen collectors and non-pollen collectors counted.

If a colony developed a queen problem, it was either eliminated from further measurements or another colony was selected to

replace it. Entrance activity was measured between 1300 and 1600 hours C.D.T. on days suitable for foraging, i.e., sunny with temperatures greater than 75°F.

CHAPTER IV

ESTIMATING NUMBERS OF HONEY BEES ON LANGSTROTH FRAMES (USING PHOTOGRAPHS)

A. Introduction

Various studies of honey bees require a method of periodic measurement of adult populations which is rapid and does not disrupt the activity of the colony. Such a method was developed by Jeffree (1951) in Scotland using a numerically graded series of photographs of bees on frames $8\frac{1}{2}$" x 14". Described below are the methods used and the results obtained when bees were estimated on $9\frac{1}{8}$" x $17\frac{5}{8}$" Langstroth frames commonly used in North America.

B. Methods

(1) Single Frame Estimations

A large number of photographs were taken of various numbers of bees on Langstroth frames (containing honey and brood). Near actual size prints of these were made, bees counted on each, and a series of photographs (Figure 6) were selected at 150 bee increments, with no photograph giving more than 1.6 percent error of the increment number they represented. The photographs were mounted in numerical order on a portable easel and covered with clear plastic

for protection.

According to Jeffree (1951), it is possible for 1500 bees to form a single layer on one side of a 14" x 8½" frame. This would indicate that possibly 2000 bees could form a single layer on one side of a Langstroth frame (9½" x 17⅝"). However, seldom were more than about 1350 bees found on one side of a Langstroth frame, in a single layer.

Double or triple layers of bees were formed when more than 1350 bees occupied one side of a frame and in estimating these frames, each layer was estimated from the appropriate photograph, thus resulting in a composite estimate. With some estimating experience the observer could estimate quite accurately.

An apparatus (Figure 7) was built to test an estimator's accuracy using bees on single frames. It consisted of an upper glass-walled chamber, into which the bee-covered comb was introduced. Bees could not move from one side of a frame to the other because of a tight fitting lid and side bar arrangement. It should be noted that only good frames, without holes in the combs were selected for this procedure, to prevent the bees from passing through the comb to the other side.

After the bees had been estimated on both sides of the comb (the apparatus could be rotated so that the observers could remain in one position) cyanide gas was introduced into the upper chamber, through a cork-filled hole; the dead bees, from each side, were then collected separately in plastic bags and labelled. The dead bees were usually counted immediately so that the exact number of

bees could be compared to the estimate.

From the single frame estimations (Tables I, II, III and IV) it is evident that positive and negative estimates, by an individual, tend to cancel each other when 20 - 40 frames of bees are estimated. Because the method was developed to estimate numbers of bees in whole colonies several times during their development, accuracy of the method was also tested by estimating and killing whole colonies (Tables V, VI). Most colonies used for this procedure were killed when the brood measurements and honey production for the season were completed. The colonies are normally killed at this time anyway.

To obtain an accurate bee count two or three samples of 500 bees, for each bag of bees from each colony, were counted and weighed (these were averaged); the remaining bees were then weighed and the total number of bees in each colony was calculated by a weight conversion.

(2) Whole Colony Estimations

When estimating the number of bees in a colony, the following procedure was used: Before bee flight in the morning, the entrance of the hive was gently smoked and the cover and supers loosened; then, if required, the top super was smoked after raising the cover slightly. This was usually done for an entire group (i.e., eight - ten hives) before estimation commenced; this allowed the bees to settle down before they were estimated. The hive cover was removed, and any bees on it were estimated before placing it on the ground

upside down at one corner of the hive. An empty hive body was placed in an offset position on the cover, in such a way that the hive body was supported by the sides of the cover (this prevented any crushing of bees when frames were placed within the hive body). Smoke was applied gently to the top super if required, while all of the frames were loosened. The frames were then removed, from left to right; each side was shown to the observer who compared the bees on each frame side with the graded series of photographs and then recorded the number of the series (i.e., 300, 450, 600, etc.) which best approximated the number of bees on that frame side. The estimated frames were then placed in the empty super which was on the hive cover. This was repeated for each frame, and when the frames had all been estimated in that super the empty hive body was placed on top of the hive body that now contained the estimated frames. It was also necessary to estimate bees that remained on the sides of each hive body. Each super was managed in this manner down to the brood chamber. At this point an estimate usually had to be made of the number of bees on the side walls of the bottom chamber and on the bottom board. This was usually done by comparing each side of the hive body and the bottom board to the photographs; it worked well when there were less than 3000 bees to be estimated. When estimations were completed, the bottom chamber was removed from the bottom board and all of the supers were re-stacked in their in their original positions.

Usually two teams, each consisting of a beekeeper and an "observer", were able to estimate 15 colonies each, between 6.00 or

FIGURE 6 - GRADED SERIES OF PHOTOGRAPHS

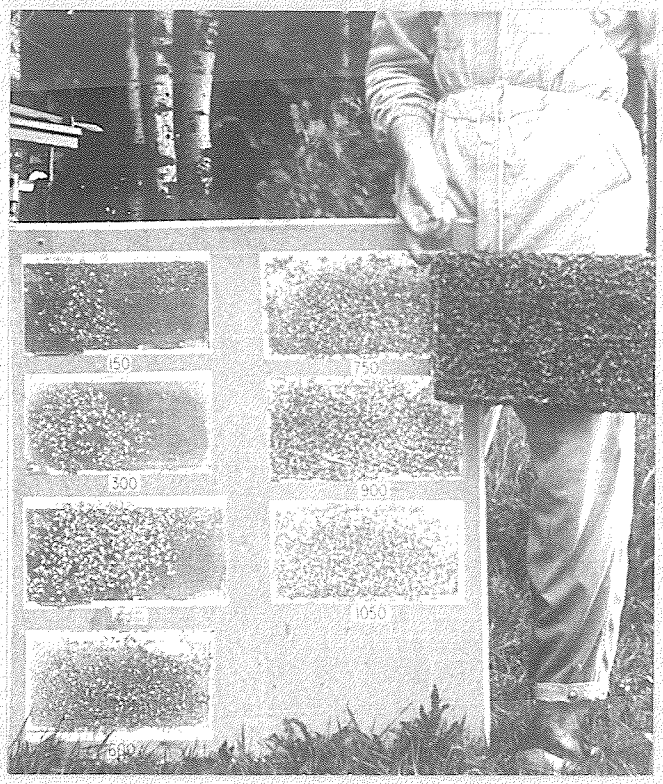


FIGURE 7 - APPARATUS USED TO OBTAIN COUNTS OF SINGLE FRAME ESTIMATIONS

6.30 a.m. and 8.00 a.m., by which time bee flight usually commenced.

During 1969 and 1970 this method was used for adult estimations. Observer A estimated the odd numbered colonies and Observer B estimated the even numbered ones within each group.

C. Results

(1) Single Frame Estimations (1968, 1969, 1970)

In 1968 two groups of observers were used, none of whom had had previous experience in estimating bee populations. Group 1 consisted of three women (Observers A, C and F, Table I) and two men each with at least two seasons' experience managing bees; they spent 16 hours over a ten day period late in August estimating numbers of bees on individual frames. Group 2 consisted of one woman (Observer I, Table II) with no experience managing bees but who had studied the bee photographs (Figure 6) extensively, and three men with at least two seasons' experience managing bees. This latter group spent eight hours estimating bees on some of the same frames used by Group 1 during their last five days of estimating bee numbers.

The results are shown in Tables I and II. Most of the observers from both groups had errors less than 5% in most of the estimates. Greatest percent error occurred when estimating low numbers of bees (i.e., less than 150 to 200); these were usually underestimates but this had very little effect on the over-all error.

In 1969 and 1970 single frame estimations were continued in

order to maintain a check on the method and also to check the accuracy of each observer, some of whom were new estimators. In 1969 the error was usually less than 5% for each observer, based on the total number of bees estimated. However, in 1970 three of the eight observers (J, L and N) had percent errors between 5 and 10 percent (Table IV).

(2) Whole Colony Estimations (1969, 1970)

Whole colony estimations were usually done late in the season after all brood measurements had been completed (see Tables V and VI). In general, it appeared that observers were able to estimate colonies more accurately before the end of the nectar flow than after it (Tables V and VI, parts a and b). This difference is attributed to a tighter clustering of the bees caused by honey super removal and seasonal changes in the colony, in the latter half of August. Diminishing brood areas may also cause adults to crowd together and create artificial congestion (Simpson, 1966). It is therefore believed that estimations made before the end of nectar flow and by observers with four to six hours of training on photographs and/or single frame estimations during that year, are able to remain within a 5 to 8 percent error on whole colonies. However, after the end of nectar flow the percent error may be as high as 10 to 15 percent for some observers; for practical studies, however, these late measurements are not required.

From the data on single frame estimations and whole colony estimations it is apparent that some observers are not as adept

(e.g., Table IV Observer N, Table VI Oberver O) as others in estimating numbers of bees. For this reason the four to six hour period of estimation is necessary not only to familiarize the person with the method but also to ascertain if the person has the ability to use the method effectively. Observers M, P and Q (Table VI) for example had had no experience with bees before "learning" to estimate numbers of bees by this method, and yet their results were generally quite satisfactory.

TABLE I - SUMMARY OF ERRORS OF FIVE OBSERVERS DURING SIXTEEN HOURS OF ESTIMATING NUMBERS OF BEES ON LANGSTROTH FRAMES (GROUP 1, 1968)

Ranges of estimates per frame side	Observer A				Observer B				Observer C				
	1*	2	3	4	1	2	3	4	1	2	3	4	1
1-150	14	880	1185	-25.7	19	1730	2085	-17.0	17	1375	1680	-18.2	11
151-300	25	5850	5675	+ 3.1	17	3910	4245	- 7.9	14	3450	3335	+ 3.4	15
301-450	37	14925	16120	- 7.4	35	13975	14515	- 3.7	29	11670	10110	+15.4	25
451-600	39	21025	21585	- 2.6	33	17225	17785	- 3.2	42	23025	22270	+ 3.4	14
601-750	27	19025	19220	- 1.0	25	16725	16095	+ 3.9	25	17625	16530	+ 6.6	16
751-900	23	20225	21200	+ 0.1	34	27800	27380	+ 1.5	37	31575	28875	+ 9.4	14
901-1050	12	11750	12255	- 4.1	16	15150	15580	- 2.8	12	11550	11860	- 2.6	6
1051-1200	2	2400	2590	- 7.3	2	2250	2510	-10.4	3	3350	3470	- 3.5	4
TOTALS	179	96080	99830	- 3.8	181	98765	100195	- 1.4	179	103620	98130	+ 5.6	105

1* - number of frame sides estimated

2 - estimated number of bees

3 - actual number of bees

4 - percent error

ING NUMBERS OF

Observer C			Observer D				Observer E				Totals			
2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
375	1680	-18.2	11	905	1115	-18.8	14	970	1270	-26.6	75	5860	7335	-20.1
450	3335	+ 3.4	15	3640	4245	-14.3	11	2650	2530	+ 4.7	82	19500	20030	- 2.7
570	10110	+15.4	25	10375	12370	-16.1	31	12050	12015	+ 0.3	157	62995	65130	- 3.3
025	22270	+ 3.4	14	7375	8725	-15.5	31	16425	17060	- 3.7	159	85075	87425	- 2.7
625	16530	+ 6.6	16	10325	10480	- 1.5	19	13425	12270	+ 9.4	112	77125	74595	+ 3.4
575	28875	+ 9.4	14	11300	11580	- 2.4	40	33350	31055	+ 7.4	148	124250	120090	+ 3.5
550	11860	- 2.6	6	5550	5515	+ 0.6	11	10825	11490	- 5.8	57	54825	56700	- 3.3
350	3470	- 3.5	4	4450	4545	- 2.1	4	4400	3995	+10.1	15	16850	17110	- 1.5
620	98130	+ 5.6	105	53920	58575	- 8.0	161	94095	91685	+ 2.6	805	446480	448415	- 0.4

TABLE II - SUMMARY OF ERRORS OF FOUR OBSERVERS DURING EIGHT HOURS OF ESTIMATING NUMBERS OF BEES ON LANGSTROTH FRAMES (GROUP 2, 1968)

Ranges of estimates per frame side	Observer F				Observer G				Observer H				
	1*	2	3	4	1	2	3	4	1	2	3	4	1
1-150	4	425	470	- 9.6	4	400	420	- 4.8	3	190	255	-25.5	7
151-300	10	2575	2630	- 2.1	7	2025	1765	+14.7	11	2510	2665	- 5.8	11
301-450	9	3850	3630	+ 6.1	11	4275	4115	+ 3.9	10	3625	3495	+ 3.7	12
451-600	10	5450	5765	- 5.5	7	3700	3670	+ 0.8	13	6775	6840	- 1.0	5
601-750	6	4150	5485	-24.3	6	4200	3975	+ 5.7	9	6025	5620	+ 7.2	4
751-900	6	5075	4945	+ 2.6	9	7500	7910	- 5.2	10	8325	9025	- 7.8	12
901-1050	-	-	-	-	1	925	1070	-13.6	4	3850	3305	+16.5	7
1051-1200	-	-	-	-	-	-	-	-	1	1075	995	+ 8.0	1
TOTALS	45	21525	22925	- 6.1	45	23025	22925	+ 0.4	61	32375	32200	+ 0.5	59

1* - number of frame sides estimated

2 - estimated number of bees

3 - actual number of bees

4 - percent error

IGHT HOURS OF ESTIMATING NUMBERS OF

OUP 2, 1968)

er G		Observer H					Observer I			Totals			
3	4	1	2	3	4	1	2	3	4	1	2	3	4
420	- 4.8	3	190	255	-25.5	7	550	875	-37.1	18	1565	2020	-22.5
1765	+14.7	11	2510	2665	- 5.8	11	2670	3275	-18.5	39	9780	10335	- 5.4
4115	+ 3.9	10	3625	3495	+ 3.7	12	4410	4970	-18.4	42	16160	16210	- 0.3
3670	+ 0.8	13	6775	6840	- 1.0	5	2650	2730	- 2.9	35	18575	19005	- 2.3
3975	+ 5.7	9	6025	5620	+ 7.2	4	2700	2320	+16.4	25	17075	17400	- 1.9
7910	- 5.2	10	8325	9025	- 7.8	12	10100	9145	+10.4	37	31000	31025	- 0.1
1070	-13.6	4	3850	3305	+16.5	7	6755	7265	- 7.0	12	11530	11640	- 1.0
-	-	1	1075	995	+ 8.0	1	1150	975	+17.9	2	2225	1970	+12.9
22925	+ 0.4	61	32375	32200	+ 0.5	59	30985	31555	- 1.8	210	107910	109605	- 1.6

ctual number of bees

ercent error

TABLE III - SUMMARY OF ERRORS OF SIX OBSERVERS ESTIMATING THE NUMBER OF BEES ON LANGSTROTH FRAMES (196

Estimate per frame side	Observer A				Observer B				Observer D				Observer J			
	1*	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
300	6	1800	1850	- 2.7	3	900	905	- 0.6	5	1500	1390	+ 7.9	6	1800	1940	- [illegible].2
450	8	3600	3775	- 4.6	6	2700	2525	+ 6.9	5	2250	2025	+11.1	7	3150	3235	- [illegible].6
600	4	2400	2660	- 9.8	6	3600	3075	+17.1	9	5400	5065	+ 6.6	4	2400	2460	- [illegible].4
750	4	3000	3035	- 1.2	5	3750	3680	+ 1.9	3	2250	2190	+ 2.7	5	3750	3685	+ [illegible].8
900	2	1800	2065	-12.8	2	1800	1950	- 7.7	5	4500	5000	-10.0	2	1800	2085	-1[illegible].7
1050	4	4200	4530	- 7.3	5	5250	5980	-12.2	2	2100	2080	+ 1.0	6	6300	6615	- [illegible].8
1200	9	10800	10905	- 1.0	6	7200	7310	- 1.5	9	10800	10015	+ 7.8	9	10800	11740	- [illegible].0
1350	8	10800	10240	+ 5.5	8	10800	9665	+11.7	8	10800	10395	+ 3.9	9	12150	11480	+ [illegible].8
1500	4	6000	5500	+ 9.1	5	7500	6630	+13.1	3	4500	4200	+ 7.1	2	3000	2925	+ [illegible].6
>1500	6	12050	11630	+ 3.6	8	14600	14180	+ 3.0	7	14300	12925	+10.6	5	9600	10030	- [illegible].3
TOTALS	55	56450	56190	+ 0.5	54	58100	55900	+ 3.9	56	58400	55285	+ 5.6	55	54750	56195	- [illegible].6

1* - number of frame sides estimated

2 - estimated number of bees

3 - actual number of bees

4 - percent error

TROTH FRAMES (1969)

Observer J				Observer K				Observer F				Totals			
2	3		4	1	2	3	4	1	2	3	4	1	2	3	4
1800	1940	-	.2	7	2100	2655	-20.9	6	1800	1830	- 1.6	33	9900	10570	- 6.3
3150	3235	-	.6	7	3150	3770	-16.4	7	3150	3395	- 7.2	40	18000	18725	- 3.9
2400	2460	-	.4	5	3000	2865	+ 4.7	4	2400	2510	- 4.4	32	19200	18635	+ 3.0
3750	3685	+	.8	-	-	-	-	3	2250	2520	-10.7	20	15000	15110	- 0.7
1800	2085	-1	.7	4	3600	3685	- 2.3	-	-	-	-	15	13500	14785	- 8.7
6300	6615	-	.8	5	5250	6430	-18.4	9	9450	11210	-15.7	31	32550	36845	-11.7
0800	11740	-	.0	7	8400	8080	+ 4.0	6	7200	7315	- 1.6	46	55200	55365	- 3.0
2150	11480	+	.8	7	9450	8570	+10.3	3	4050	3920	+ 3.3	43	58050	54270	+ 7.0
3000	2925	+	.6	6	9000	9100	- 1.1	6	9000	9925	- 9.3	26	39000	38280	+ 1.9
9600	10030	-	.3	6	11200	10260	+ 9.2	3	5450	5735	- 5.0	35	67200	64760	+ 3.8
4750	56195	-	.6	54	55150	55415	- 0.5	47	44750	48360	- 7.5	321	327600	327345	+ 0.1

TABLE IV - SUMMARY OF ERRORS OF EIGHT OBSERVERS ESTIMATING NUMBERS OF BEES ON LANGSTROTH FRAMES

1970

Estimate per frame side	Observer A				Observer B				Observer J				Observer L			
	1*	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
750	2	1500	1865	-19.6	2	1500	1845	-18.7	5	3750	4610	-18.7	6	4500	6290	-28.5
900	2	1800	1855	- 3.0	8	7200	7750	- 7.1	9	8100	9665	-16.2	13	11700	13460	-13.1
1050	14	14700	15180	- 3.2	8	8400	8545	- 1.7	13	13650	15720	-13.2	11	11550	12865	-10.2
1200	16	19200	19560	- 2.8	15	18000	18175	- 1.0	5	6000	6555	- 8.5	13	15600	17410	-10.4
1350	10	13500	13685	- 1.4	7	9450	9080	+ 4.1	4	5400	5300	+ 1.9	4	5400	5425	- 0.5
1500	6	9000	7840	+14.8	6	9000	8780	+ 2.5	2	3000	2870	+ 4.5	3	4500	4440	+ 0.1
>1500	6	11550	9845	+17.3	9	15800	14590	+ 8.3	2	3450	3130	+10.2	6	11250	9940	+13.2
TOTALS	56	71250	69830	+ 2.0	55	69350	68765	+ 0.9	40	43350	47850	- 9.4	56	64500	69830	- 7.6

1* - number of frame sides estimated

2 - estimated number of bees

3 - actual number of bees

4 - percent error

OTH FRAMES

Observer L			Observer M				Observer N				Observer O				Observ	
2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
4500	6290	-23.5	6	4500	6045	-25.6	12	9000	12275	-26.7	3	2250	3130	-28.1	5	3750
11700	13460	-13.1	10	9000	10595	-15.1	8	7200	9090	-20.8	10	9000	10900	-17.4	7	6300
11550	12865	-10.2	12	12600	13770	- 8.5	8	8400	9725	-13.6	9	9450	10800	-12.8	11	11500
15600	17410	-10.4	8	9600	10775	-10.9	5	6000	6790	-11.6	3	3600	4090	-12.0	7	8400
5400	5425	- 0.5	9	12150	12145	+ 0.1	3	4050	4575	-11.5	3	4050	3885	+ 4.3	5	6750
4500	4440	+ 0.1	3	4500	3895	+15.5	1	1500	1335	+12.4	4	6000	5230	+14.7	4	6000
11250	9940	+13.2	7	13550	11550	+17.3	2	3450	3020	+14.2	5	10000	6730	+48.6	2	3450
64500	69830	- 7.6	55	65900	68775	- 4.2	39	39600	46810	-15.4	37	44350	44765	- 0.9	41	46200

	Observer O				Observer Q				Total			
4	1	2	3	4	1	2	3	4	1	2	3	4
-26.7	3	2250	3130	-28.1	5	3750	4290	-12.6	41	30750	40350	-23.8
-20.8	10	9000	10900	-17.4	7	6300	7865	-19.9	67	60300	71180	-15.3
-13.6	9	9450	10800	-12.8	11	11500	12050	- 4.2	86	90300	98655	- 8.5
-11.6	3	3600	4090	-12.0	7	8400	8755	- 4.1	72	86400	92110	- 6.2
-11.5	3	4050	3885	+ 4.3	5	6750	6895	- 2.1	45	60750	60990	- 0.4
+12.4	4	6000	5230	+14.7	4	6000	5460	+ 9.9	29	43500	39850	+ 9.2
+14.2	5	10000	6730	+48.6	2	3450	3130	+10.2	39	72500	61935	+17.1
-15.4	37	44350	44765	- 0.9	41	46200	48445	- 4.6	379	444500	465070	- 4.4

TABLE V - WHOLE COLONY ESTIMATIONS OF ADULT HONEY BEE NUMBERS (1969)

		Observer A		Observer B		Observer D		Observer K		Observer J	
1**	2	3	4	3	4	3	4	3	4	3	4
(a)*											
18880	1	19225	+ 1.8	19250	+ 2.0	17000	-10.0	21900	+16.0	19950	+ 7.5
26385	2	24025	- 8.9	21500	-18.5	23140	-12.3	24425	- 7.4	24225	- 8.2
33555	3	30025	-10.5	30600	- 8.8	26775	-20.2	29900	-10.7	31530	- 6.0
34820	4	34075	- 2.1	35775	+ 2.7	37450	+ 7.6	40200	+15.5	35100	+ 0.8
73050	5	66925	- 8.4	69500	- 4.8	61500	-15.8	70350	- 3.7	63050	-13.7
Mean of % error			- 5.6		- 5.5		-10.1		- 1.9		- 4.3

		Observer A		Observer B		Observer D	
(b) 1	2	3	4	3	4	3	4
14980	1	12175	-18.7	12050	-19.6	11300	-24.6
20120	2	18500	- 8.1	17725	-11.9	22200	+10.3
22910	3	25400	+10.9	22270	- 2.8	22950	+ 0.2
27940	4	25350	- 9.3	25300	- 9.5	25150	-10.0
30375	5	31850	+ 4.9	30050	- 1.0	32750	+ 7.8
32710	6	28800	-12.0	29400	-10.1	26550	-18.8
34100	7	28825	-15.5	29125	-14.6	31900	- 6.5
55980	8	42450	-24.2	39300	-29.8	42550	-24.0
56910	9	45025	-20.9	45200	-20.6	46500	-18.3
Mean of % error			-10.3		-13.3		- 9.3

1** Actual bee count (by weight); 2 = Hive no.; 3 = Estimation; 4 = % error

(a)* Colonies estimated before the end of nectar flow.

(b) Colonies estimated after the end of nectar flow.

TABLE VI - WHOLE COLONY ESTIMATIONS OF ADULT HONEY BEE NUMBERS (1970)

		Observer A		Observer B		Observer L		Observer M		Observer N		Observer O		Obser
1**	2	3	4	3	4	3	4	3	4	3	4	3	4	3
(a)*														
34545	1	35350	+ 2.3	33750	- 2.3	34400	- 0.4	33415	- 3.3	34100	- 1.3	-	-	32600
36000	2	42350	+17.6	-	-	39800	+10.6	39100	- 8.6	37400	+ 3.9	31225	-13.3	34300
37830	3	36550	- 3.4	34950	- 7.6	32100	-15.2	32290	-14.6	-	-	35900	- 5.1	33600
40170	4	37575	- 6.5	-	-	39325	- 2.1	36975	- 8.0	32450	-19.2	31875	-20.7	33225
Mean of % error			+ 2.5		- 5.0		- 1.8		- 8.9		- 5.5		-13.0	

		Observer A		Observer B		Observer L		Observer M		Observer N		Observer O		Obser
1	2	3	4	3	4	3	4	3	4	3	4	3	4	3
(b)														
28895	1	26925	- 6.8	25500	-11.8	24475	-15.3	24900	-13.8	23050	-20.2	-	-	19750
33585	2	27950	-16.8	28500	-15.1	27325	-18.6	29400	-12.5	31600	- 5.9	32685	- 2.7	27350
34945	3	34400	- 1.6	35150	+ 0.6	29600	-15.3	30550	-12.6	31910	- 8.7	-	-	28475
39125	4	33450	-14.6	29400	-24.9	28900	-26.1	34850	-10.9	-	-	29550	-24.5	26850
39885	5	39350	- 1.3	36925	- 7.4	37375	- 6.3	39575	- 0.8	40775	+ 2.2	51275	+28.6	36700
43010	6	43625	+ 1.4	37135	-13.7	36675	-14.7	46925	+ 9.1	40800	- 5.1	40325	- 6.2	43175
45125	7	41050	- 9.0	39900	-11.6	38900	-13.7	44500	- 1.4	41600	- 7.8	51500	+14.1	37050
Mean of % error			- 6.9		-12.0		-15.7		- 8.7		- 7.6		+ 9.3	

1** - Actual bee count (by weight); 2 - Hive no.; 3 - Estimation; 4 - % error.

(a)*- Colonies estimated before the end of nectar flow.

(b) - Colonies estimated after the end of nectar flow.

DULT HONEY BEE NUMBERS (1970)

	Observer M		Observer N		Observer O		Observer P		Observer J		Observer Q	
	3	4	3	4	3	4	3	4	3	4	3	4
	33415	- 3.3	34100	- 1.3	-	-	32600	- 5.6	33550	- 2.9	35550	+ 2.9
	39100	- 8.6	37400	+ 3.9	31225	-13.3	34300	- 4.7	36550	+ 1.5	41400	+15.0
	32290	-14.6	-	-	35900	- 5.1	33600	-11.7	33800	-10.7	36275	- 4.1
	36975	- 8.0	32450	-19.2	31875	-20.7	33225	-17.3	32475	-19.2	36975	- 8.0
		- 8.9		- 5.5		-13.0		- 9.7		- 7.8		+ 1.5

	Observer M		Observer N		Observer O		Observer P	
	3	4	3	4	3	4	3	4
3	24900	-13.8	23050	-20.2	-	-	19750	-31.7
5	29400	-12.5	31600	- 5.9	32685	- 2.7	27350	-18.6
3	30550	-12.6	31910	- 8.7	-	-	28475	-18.5
1	34850	-10.9	-	-	29550	-24.5	26850	-31.4
3	39575	- 0.8	40775	+ 2.2	51275	+28.6	36700	- 8.0
7	46925	+ 9.1	40800	- 5.1	40325	- 6.2	43175	+ 0.4
7	44500	- 1.4	41600	- 7.8	51500	+14.1	37050	-17.9
7		- 8.7		- 7.6		+ 9.3		-18.0

o.: 3 - Estimation; 4 - % error.

tar flow.

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D. Discussion and Conclusions

A knowledge of adult populations in a colony at various intervals during development is basic to many studies involving growth, nutrition, queen testing, genetics, disease, etc. The use of a numerically graded series of photographs, as devised by Jeffree (1951), appears to be a relatively rapid, easy, and accurate method of estimating adult numbers and is much less disruptive to colony life than most methods devised to date. Notable among the latter is the practice of removing bees from their combs and calculating their total numbers on the basis of their weight.

Most difficulties in using the photographic technique occur late in the summer season when high numbers of adults are present in the hive; bees at this time are also more difficult to manage. Most colonies in Manitoba are initiated with two pounds of bees in late April or early May and usually average 40,000 to 50,000 bees by the end of August; the photographic technique can be used successfully with populations in this range.

Almost all observers show a negative percent error for estimations of whole colonies (Tables V and VI).

It appears that some observers, with no previous experience at estimating numbers of bees, are better suited for this task than others. In choosing a potential estimator one can test him by using the apparatus shown in Figure 7. Allow him to estimate two or three frames, count the bees, and repeat this procedure with various numbers of bees. In this manner his estimations can be checked and

adjustments can be made by the oberver, accordingly in the next trials. The ability of a potential observer can thus be judged within a day using 10,000 to 15,000 bees for the estimations.

Considerable practising can be done in the laboratory using a large reference collection of photographs of known numbers of bees along with the graded series. In fact, one observer (Observer I, Table II) was trained entirely by using photographs. It appears that after an initial training period of four to six hours using bees on combs, that the observers improve little in accuracy. Finally, it is suggested that an observer who is making estimations over a long period of time, be checked periodically for accuracy with actual counts of bees so that greater than normal errors may be detected and adjusted.

CHAPTER V

RESULTS AND DISCUSSION

A. Results and Discussion of Seasonal Measurements of Experimental Colonies

(1) 1968 Seasonal Measurements

(a) Brood In 1968 brood measurements included total brood, sealed brood and unsealed brood as shown for all colonies in Table I (Appendix). Table VII summarizes the above data for normal hives in each experimental group and normal colony development is shown in Figures 8, 9 and 10. Table VIII shows statistical comparisons of the four experimental groups up to the time of maximum brood production.

(i) Total Brood Figure 8 and Table VIII show the relative effect of the four package sizes on total brood production. Groups No. 3 and No. 4 did not produce different amounts of total brood at any time during the study (Table VIII). Groups No. 2 and No. 3 were significantly different in total brood produced ($P \leq 0.05$), but only up to 3 June.

Table VII and Figure 8 show that group No. 4 > No. 3 > No. 2 > No. 1 in total brood produced up to 19 July, but differences never existed between all groups at any one time. Most of the significant differences in total brood produced occurred between group

No. 1 and the other three groups (Table VIII).

It is important to note that by 8 July there was no difference between groups No. 1 and No. 4, indicating that the efficiency of the smaller colonies enabled them to catch up to the larger colonies and produce about the same amount of brood.

All groups reached maximum total brood production at the same time (Figure 8) which indicates that a certain period of development is required, no matter what size of package is initiated.

Table IX (A) shows the regression equations for the total brood produced in each of the four groups up to 19 July, the time of maximum total brood production. The correlation coefficients (r) show that there is a high linear correlation, in each group, between total brood area and time of development. The regression coefficient indicates that the slope of the line for each group differs little. The intercept value differs for each line, indicating that there was a difference in the amount of brood produced, in each group, by the first reading date (also shown in Table VII).

(ii) Sealed Brood Figure 9 and Table VIII show the relative effect of the four package sizes on sealed brood production.

On 21 May (first reading) there was no difference in sealed brood between any of the groups (Table VIII). After this date, differences did occur and the development pattern for the groups was similar to that described for total brood. As shown for total brood, the main differences in sealed brood occurred between group No. 1 and the other three groups (Table VIII).

The amount of sealed brood produced differed ($P \leq 0.05$) up to

8 July between group No. 1 and groups No. 3 and No. 4, but only to 26 June between groups No. 1 and No. 2.

Figure 9 and Table VII show that group No. 4 > No. 3 > No. 2 > No. 1 in sealed brood production up to 19 July, but only on 3 June is there a significant difference ($P \leq 0.05$) between all groups (Table VIII).

Table IX (B) shows the regression equations for the sealed brood of each group up to 19 July, the time of maximum sealed brood production. The correlation coefficient shows a high linear correlation between sealed brood area and time of development. The slope of the lines shows more variance for sealed brood than for total brood (Table IX (A)). The intercept again indicates that there was a considerable difference in the amount of sealed brood produced by the first reading on 21 May.

(iii) Unsealed Brood Figure 10 and Table VIII show the relative effect of the four package sizes on unsealed brood production.

On 21 May there was a significant difference ($P \leq 0.05$) between all of the groups, except between groups No. 1 and No. 2 (Table VIII). By 3 June this had changed and the only groups that did not show a difference in amount of unsealed brood were groups No. 3 and No. 4. Most of the differences in amount of unsealed brood produced, occurred between group No. 1 and the other three groups.

Figure 10 and Table VII show that group No. 4 > No. 3 > No. 2 > No. 1 in unsealed brood produced up to 19 July.

Regression equations for unsealed brood are shown in Table IX (C).

(b) Adult Measurements None in 1968.

(c) Pupal Weights Table X shows the mean weight of 25 pupae taken from three colonies per group. Figure 11 shows the mean of the three colonies in each of the four experimental groups. Individual pupal weights of each hive are shown in Table IV (Appendix).

The factors that influence changes in pupal weights appear to do so in a similar manner in all four experimental groups. The decrease in pupal weights during the month of June is probably due to some nutritional factor, because temperatures were not abnormally low (Figure 12 and Appendix Table VII) and no decrease in sealed brood was recorded during this period. Figure 10 shows a slow increase in amount of unsealed brood for group No. 1 during this period and this group also shows the lowest pupal weights (Figure 11).

In general, pupal weights (Figure 11 and Table X) indicate that group No. 4 > No. 3 > No. 2 > No. 1 for any particular date. When a decline in weight occurred, group No. 1 had the lowest pupal weights while group No. 4 had the highest. The same held true when the weights were on the increase; group No. 1 had the lightest pupal weight and group No. 4 the heaviest. As shown by Table XI there was no significant difference between the pupal weights of the groups until 24 July.

TABLE VII - SUMMARY OF BROOD DEVELOPMENT WITHIN THE FOUR EXPERIMENTAL GROUPS (1968)

		Group No. 1				Group No. 2			
		UN[1]	S	T	No[2]	UN	S	T	No
21 May		118.9[3]	52.6	171.4	7	137.8	70.5	208.3	8
	SD	21.6	18.5	33.5		31.7	34.7	49.2	
3 June		163.6	117.7	281.3	7	258.1	230.3	488.4	8
	SD	40.5	16.6	37.9		42.8	45.4	78.5	
14 June		205.7	209.3	415.0	7	352.5	390.3	742.8	8
	SD	27.0	52.7	72.5		60.1	77.2	117.5	
26 June		361.9	331.1	693.0	7	459.6	592.1	1051.8	8
	SD	98.4	65.0	148.5		118.6	122.5	192.7	
8 July		571.8	549.3	1122.6	6	501.3	659.9	1161.1	8
	SD	122.7	115.6	233.4		80.6	100.9	132.1	
19 July		514.2	692.5	1206.6	6	635.1	696.0	1331.0	7
	SD	111.9	86.6	175.2		153.8	118.4	173.2	
1 Aug.		644.2	676.6	1320.8	5	636.1	693.4	1329.6	7
	SD	85.3	76.9	156.0		99.7	106.3	156.0	
13 Aug.		378.8	642.8	1021.6	4	473.3	622.8	1096.0	4
	SD	97.6	42.1	126.8		94.7	156.0	213.9	

continued.....

TABLE VII (1968) - Continued

		Group No. 3				Group No. 4			
		UN	S	T	No	Un	S	T	No
21 May		187.1	106.7	293.9	7	253.0	68.6	322.9	7
	SD	46.1	66.8	92.4		32.6	41.7	53.7	
3 June		338.7	322.1	660.9	7	356.8	429.0	785.8	6
	SD	58.9	72.8	128.0		82.2	66.4	118.3	
14 June		405.0	469.4	874.4	7	400.2	526.5	925.2	6
	SD	90.1	124.2	185.2		132.4	108.7	201.2	
26 June		530.7	673.0	1203.7	6	537.4	812.6	1350.0	5
	SD	75.6	138.8	198.6		38.1	119.8	130.1	
8 July		539.2	758.8	1298.0	6	646.6	732.2	1378.8	5
	SD	76.2	124.2	172.3		78.1	126.0	194.8	
19 July		648.5	738.7	1387.2	6	664.2	754.6	1418.8	5
	SD	106.7	92.5	191.9		150.0	148.5	220.6	
1 Aug.		580.8	692.8	1273.7	6	655.7	792.0	1447.7	3
	SD	176.7	111.3	248.0		80.3	59.9	130.8	
13 Aug.		478.0	519.5	997.5	3	531.0	665.0	1196.0	2
	SD	106.0	143.5	249.6		41.0	94.8	53.7	

1 - UN = unsealed brood; S = sealed brood; T = total brood; S.D. = standard deviation.

2 - No = number of "normal" colonies in group mean (initially 8 hives per group).

3 - Mean for group in square inches.

TABLE VIII - GROUP DIFFERENCES OF TOTAL, SEALED AND UNSEALED BROOD (1968)

	1 - 2[1]			1 - 3			1 - 4			2 - 3			2 - 4			3 - 4		
	T[2]	S	UN	T	S	UN	T	S	UN	T	S	UN	T	S	UN	T	S	UN
21 May	NS	NS	NS	*	NS	*	*	NS	*	*	NS	*	*	NS	*	NS	NS	*
3 June	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	NS	*	NS
14 June	*	*	*	*	*	*	*	*	*	NS	NS	NS	NS	*	NS	NS	NS	NS
26 June	*	*	NS	*	*	*	*	*	*	NS	NS	NS	*	*	NS	NS	NS	NS
8 July	NS	NS	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
19 July	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-

[1] Mean of group no.1 compared to mean of group no. 2 (See Table VII)

[2] T = Total brood; S = Sealed brood; UN = Unsealed brood

* Significant ($P \leq 0.05$)

NS = Not significant

FIGURE 8 - TOTAL BROOD AREAS OF THE FOUR EXPERIMENTAL GROUPS. (1968)

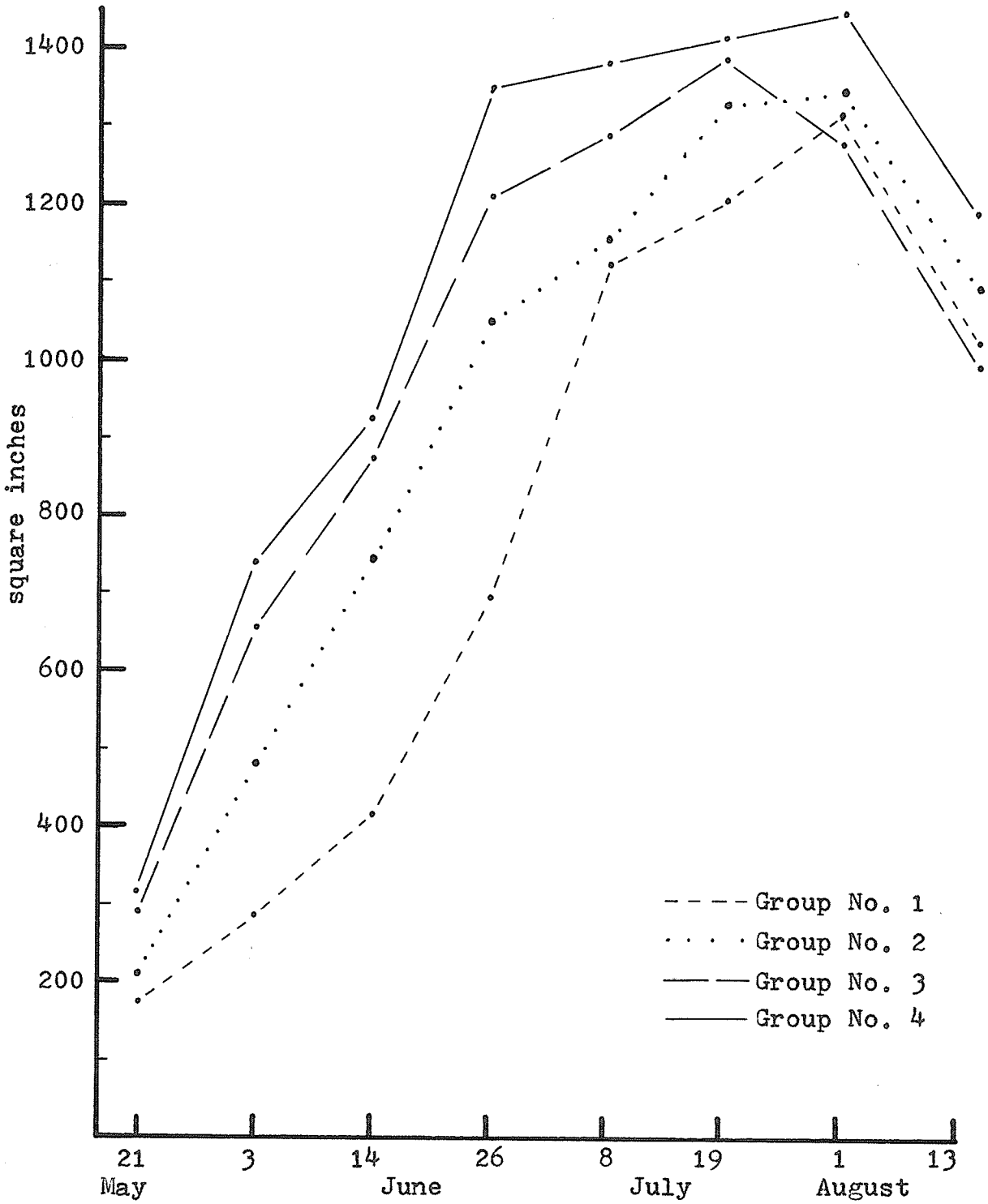


FIGURE 9 - SEALED BROOD AREAS OF THE FOUR EXPERIMENTAL GROUPS. (1968)

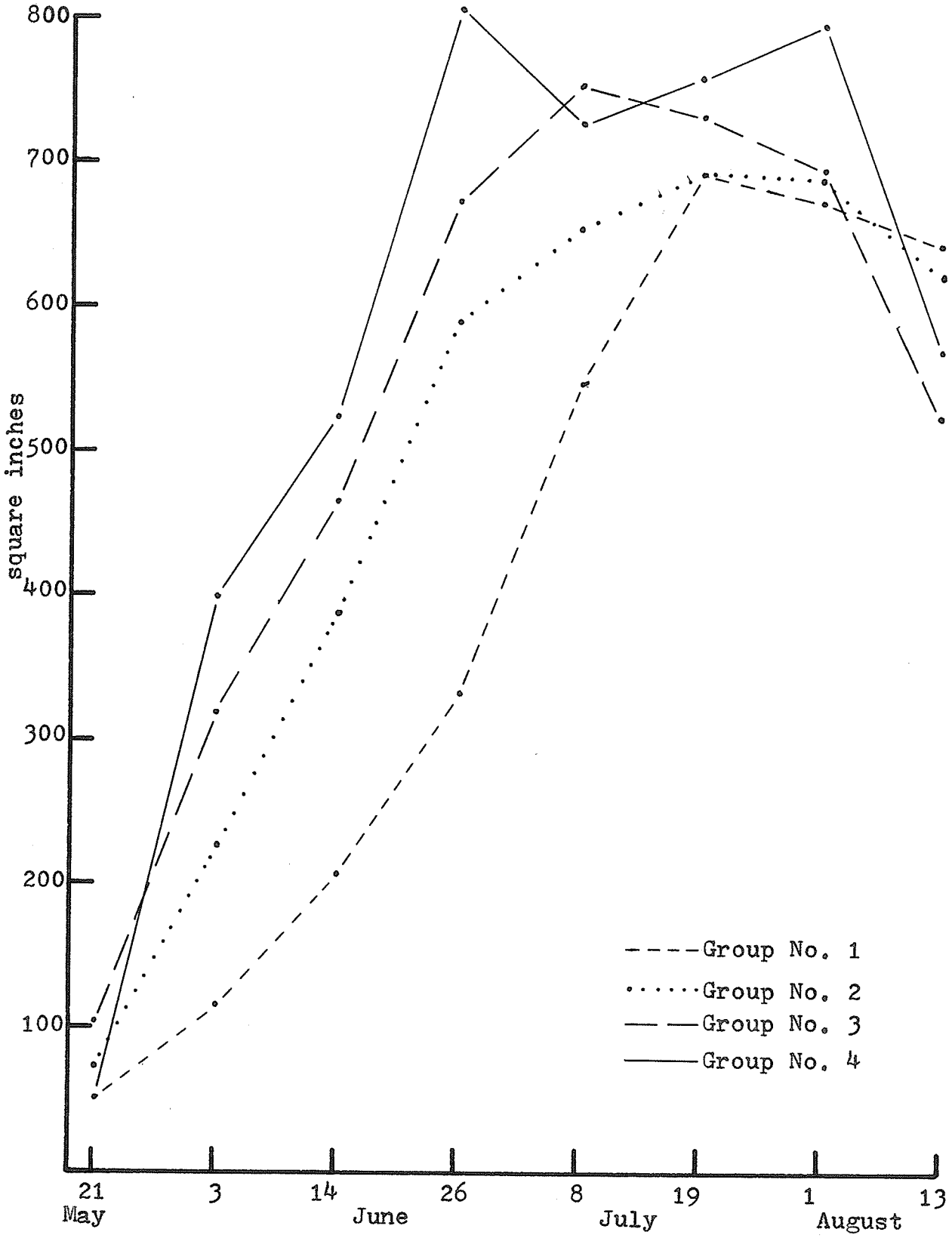


FIGURE 10 - UNSEALED BROOD AREAS OF THE FOUR EXPERIMENTAL GROUPS. (1968)

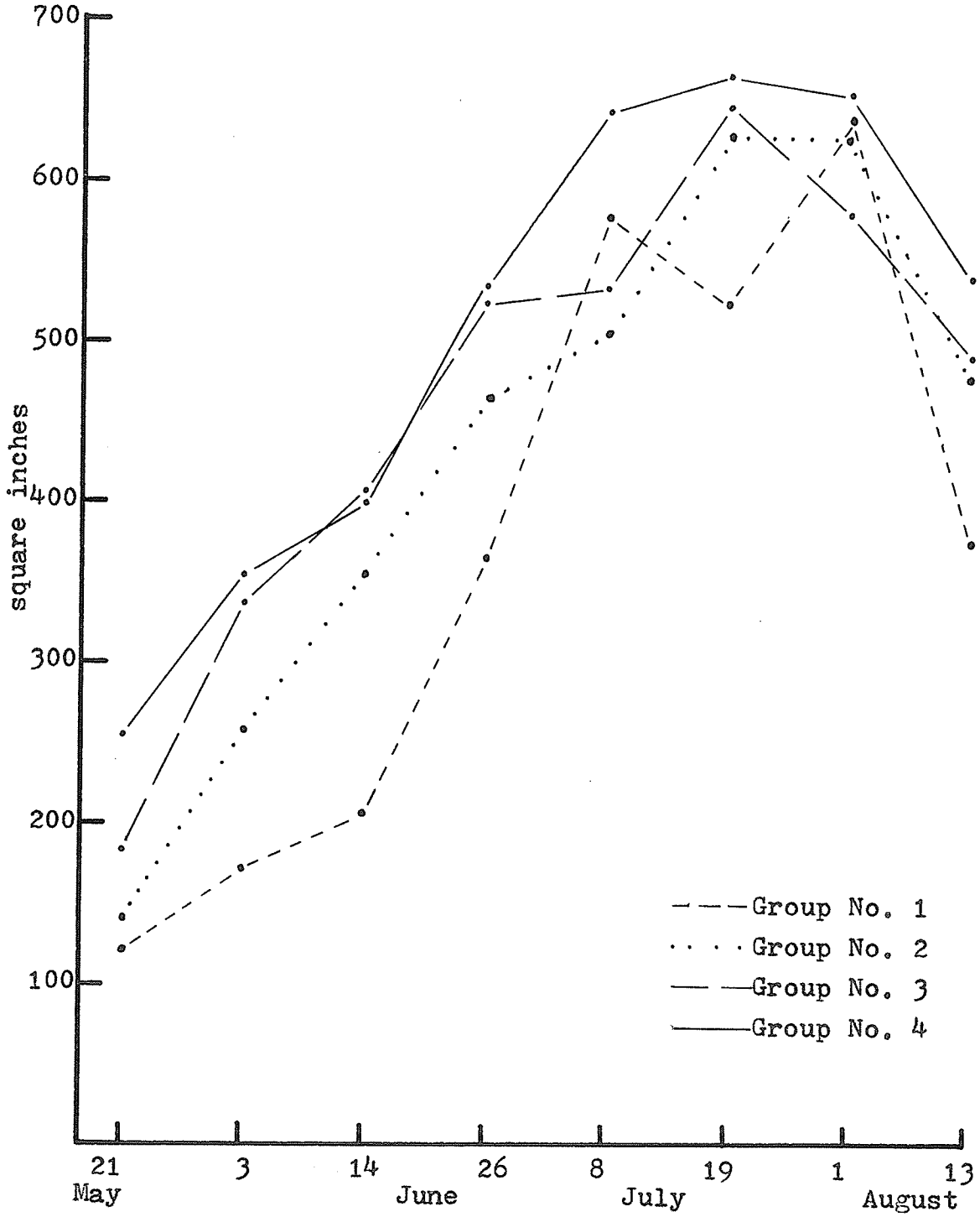


TABLE IX - LINEAR REGRESSION EQUATIONS OF BROOD AREAS AND TIME OF DEVELOPMENT[1] (1968)

(A) RELATIONSHIPS OF TOTAL BROOD AND TIME OF DEVELOPMENT

Group No.	Regression Equation Y = Intercept	Regression Coefficient	Correlation Coefficient (r)
1	- 149.47	+ 227.94 X	.976*
2	36.473	+ 226.88 X	.989*
3	182.30	+ 220.20 X	.973*
4	226.02	+ 226.56 X	.948*

(B) RELATIONSHIPS OF SEALED BROOD AND TIME OF DEVELOPMENT

1	- 110.04	+ 120.68 X	.972*
2	- 73.56	+ 154.06 X	.992*
3	- 30.53	+ 165.51 X	.992*
4	- 18.97	+ 175.25 X	.932*

(C) RELATIONSHIPS OF UNSEALED BROOD AND TIME OF DEVELOPMENT

1	- 13.24	+ 96.05 X	.943*
2	58.41	+ 94.94 X	.994*
3	138.11	+ 86.69 X	.980*
4	128.34	+ 96.16 X	.986*

[1] Equations based on data from 21 May (1st reading) to 19 July (peak brood production)

* Significant ($P \leq 0.05$)

TABLE X - MEAN WEIGHTS OF PUPAE OF THE FOUR EXPERIMENTAL GROUPS (1968)

Date	Group No. 1	Group No. 2	Group No. 3	Group No. 4
28 May	127.0*	128.8	127.0	133.7
12 June	123.8	125.0	125.5	129.9
28 June	123.0	119.7	123.2	126.3
12 July	136.1	134.4	143.5[2]	141.9
24 July	134.1	141.5	143.5[2]	149.7
6 August	140.9	145.1	151.7[2]	149.4[1]
30 August	138.9[1]	134.2[1]	144.5[1]	141.6[1]

* Average of 3 hives per group except where indicated otherwise (for mean of individual colonies see Table IV appendix)

[1] only 1 hive [2] only 2 hives

TABLE XI - GROUP DIFFERENCES OF WEIGHT OF PUPAE (1968)

	1 - 2[1]	1 - 3	1 - 4	2 - 3	2 - 4	3 - 4
28 May	N	N	N	N	N	N
12 June	N	N	N	N	N	N
28 June	N	N	N	N	N	N
12 July	N	N	N	N	N	N
24 July	*	*	*	N	*	*
6 August	*	*	*	N	N	N

* Significant ($P \leq 0.05$)

N = Not significant

[1] (ie) Mean of group no. 1 compared to mean of group no. 2.

FIGURE 11 - MEAN WEIGHT OF PUPAE TAKEN FROM THE FOUR EXPERIMENTAL GROUPS.(1968)

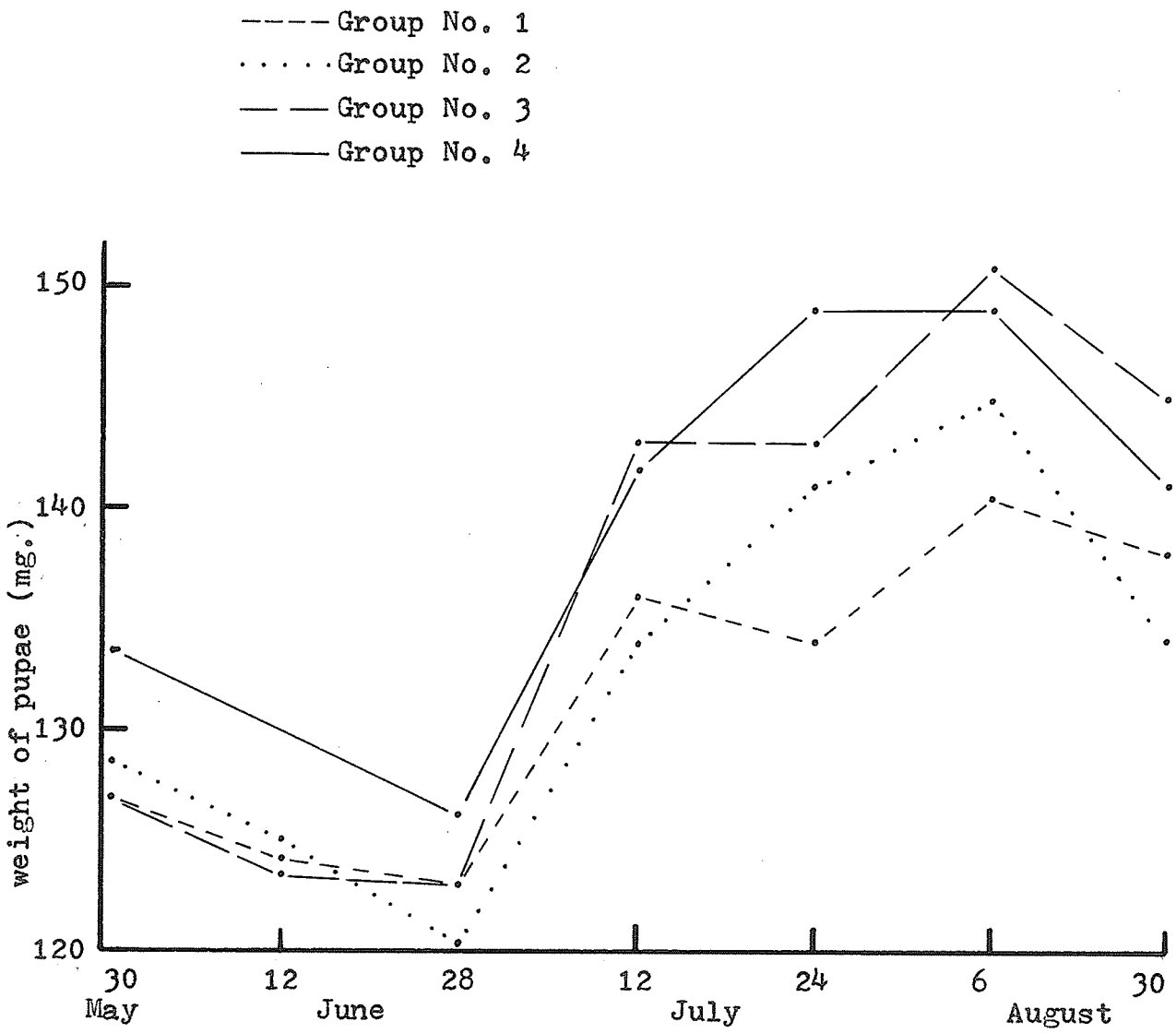
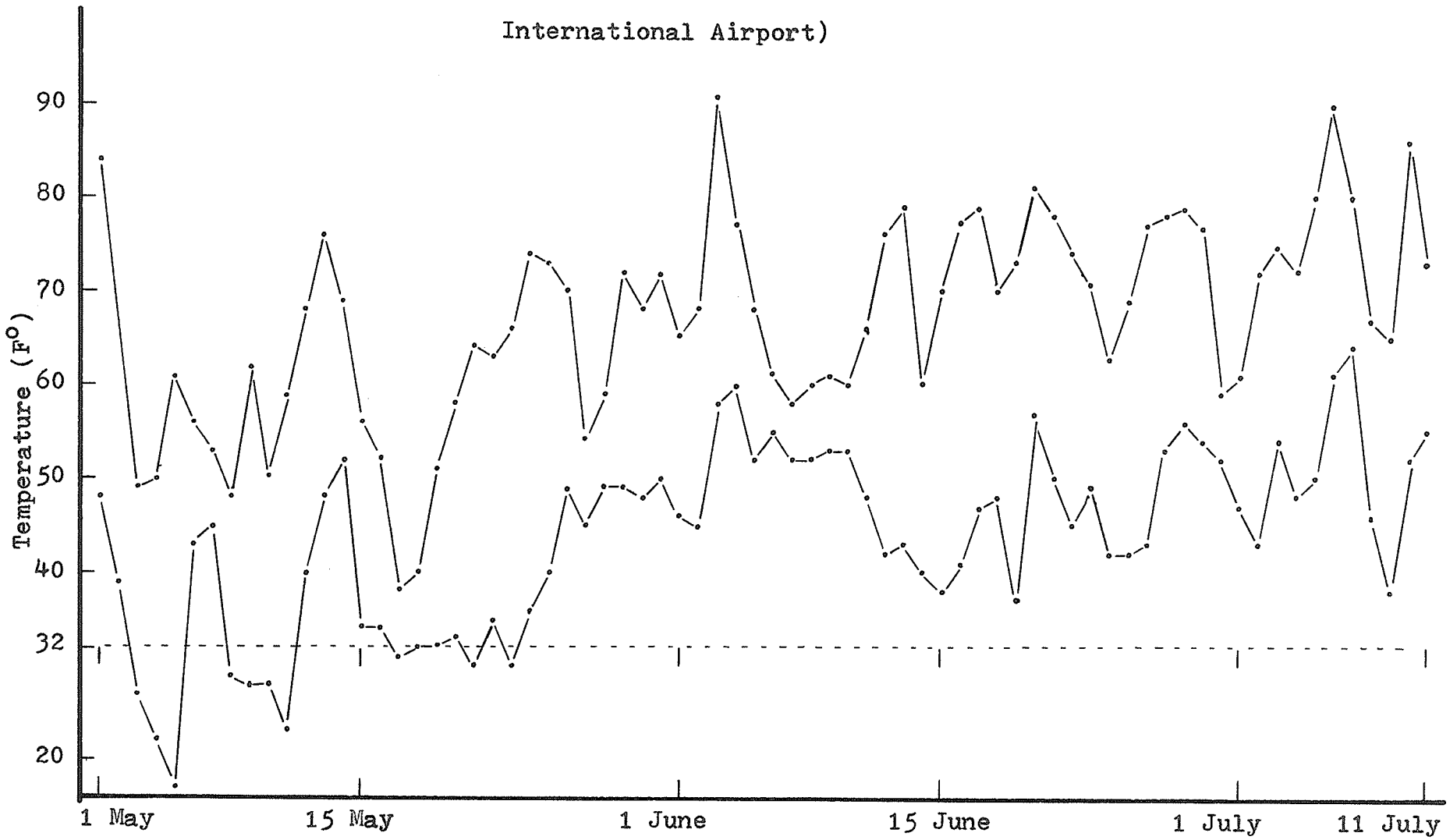


FIGURE 12 - MAXIMUM AND MINIMUM TEMPERATURES. (1968)

(Recorded by Department of Transport, Winnipeg International Airport)



(2) 1969 Seasonal Measurements

(a) Brood In 1969 brood measurements included total brood, sealed brood, and unsealed brood as shown for all colonies in Table II (Appendix). Table XII summarizes the above data for normal colonies of each of the four experimental groups and normal colony development is shown in Figures 13, 14 and 15. Table XIII shows the statistical comparisons of the four experimental groups up to the time of maximum brood production.

(i) Total Brood Table XIII and Figure 13 show the relative effect of the four package sizes on total brood production. On 16 May there were differences in total brood produced ($P \leq 0.05$) in all combinations of the four experimental groups, except between groups No. 4 and No. 3.

On 28 May and 9 June there were differences ($P \leq 0.05$) between all combinations of the four experimental groups. In general, after 9 June significant differences exist when group No. 1 is compared to the other three groups. This continued until 16 July, when the final total brood readings were made for groups No. 1 and No. 4. Figure 13 shows that groups No. 2 and No. 3 peaked at this date as probably did groups No. 1 and No. 4. With the data available in 1969, it appears that group No. 1 did not catch up with the other groups in total brood production as it did in 1968. This was probably due to a pollen shortage that occurred, along with abnormally cool weather, during June (Figure 20 and Table VII Appendix).

As reported in the Annual Meteorological Summary (1969), Winnipeg; a new record low mean temperature for June of 54.0°F was

set; on 12 June 0.1 inches of snow fell and was the latest date for a trace or more of snow; on 13 June a new record low minimum temperature of 29.4°F was set (see Figure 20).

As seen in total brood production (Figure 13), the deficiency of pollen and nectar, plus cool weather, caused the greatest decrease in the groups with the greatest brood area and largest populations (see Table XII and Figure 16 for adult numbers); namely groups No. 4 and No. 3. The amount of brood reared was affected by the pollen and nectar shortages during much of June, and the cool weather (including 29°F temperatures; see Figure 20) probably caused brood mortality, especially in groups No. 4 and No. 3 which had developed large brood nests, and could not maintain them under these conditions.

Group No. 1 did not show a decrease in total brood production (Figure 13) probably because the brood nests had not expanded to the extent of groups No. 4 and No. 3 and therefore could be maintained at the proper temperature.

Table XIV (A) shows the regression equations for total brood of the four experimental groups up to 16 July. The correlation coefficient (r) shows that group No. 4 does not fit a linear regression (not significant, $P \leq 0.05$) due to the greater decrease in total brood as seen in Figure 13. The regression coefficients show that the slope was greatest for group No. 1 and least for group No. 4. The intercept shows that group No. 4 produced much more brood during the period up to the first reading date.

(ii) <u>Sealed Brood</u> Table XIII and Figure 14 show the rela-

tive effect of package size and sealed brood production in 1969. On 16 May, there were differences in sealed brood shown in all group combinations except between groups No. 3 and No. 4 (Table XIII). Generally, the difference holds until 9 June and thereafter only when group No. 1 is compared to the other three groups, up to 3 July. At this date the lowest point of the sealed brood curve, caused by the pollen shortage and the very cool weather, was reached in groups No. 4, No. 3 and No. 2. As shown in total brood, the group with the largest population and the greatest brood areas had the greatest decrease in sealed brood (Figure 14). However, group No. 4 recovered and went on to produce almost 800 square inches of brood on 28 July as did group No. 1.

It is interesting that groups No. 4 and No. 1 increased to the peak that they did (Figure 14) while groups No. 2 and No. 3 failed to reach such a high peak, although they did peak at the same time. Part of the explanation for this situation in group No. 2 could be that the adult numbers (Figure 16) leveled out at this time, but that the population of group No. 3 was always on the increase. The other factor that may give some insight into these differences is the brood to adult ratios, which are discussed later in this chapter.

Table XIV (B) shows the regression equations of the four experimental groups to 18 July. The correlation coefficient (r) for each line shows that the groups fit the linear equation, in spite of the decrease in brood rearing discussed previously.

(iii) Unsealed Brood Table XIII and Figure 15 show the

relative effect of package size on the unsealed brood produced.

On 16 May there was a difference ($P \leq 0.05$) between all combinations of the groups (see Table XIII). This difference holds on 28 May except between groups No. 3 and No. 2. Thereafter, differences occur only when group No. 1 is compared with the other three groups to 21 June; except for 9 June which shows a difference between groups No. 2 and No. 4.

Table XIV (C) shows the regression equations of each group. The correlation coefficient (r) is significant for all groups but No. 4. This is caused by the fluctuation in brood produced during June.

(b) Adult Numbers Table XII and Figure 16 show the relative difference in adult numbers of the four experimental groups. Table XIII shows the differences that occur between groups during development.

Table XII and Figure 16 show that group No. 4 > No. 3 > No. 2 > No. 1 in numbers of adults produced up to 28 July. It appears that this relationship holds until time of peaking. Figure 16 shows that group No. 2 has only a slight increase in adults between 31 July and 20 August, dropping below the adult numbers of group No. 1. This is due to the small sample size at the last adult reading (Table XII) and does not show the general trend for this group.

It should be noted that peak adult numbers have not been reached by 20 August (also reported for two and three pound packages by Smirl, 1970). This indicates that much of the population

TABLE XII - SUMMARY OF BROOD AND ADULT DEVELOPMENT WITHIN THE FOUR EXPERIMENTAL GROUPS (1969)

		Group No. 1					Group No. 2				
		UN[1]	S	T	Ad	No[2]	UN	S	T	Ad	No
16 May		105.6[3]	132.6	238.1	2930	7	199.0	245.3	444.3	5906	8
	SD	16.5	35.7	41.8	556		34.7	34.5	60.2	688	
28 May		247.4	113.0	360.4		7	403.9	222.5	626.4		8
	SD	53.4	36.0	47.4			51.9	23.9	55.9		
9 June		357.6	274.1	631.7	7793	7	484.5	480.5	965.0	15525	8
	SD	61.2	74.7	108.8	1521		107.6	39.2	119.7	2039	
21 June		416.9	255.3	672.1		7	531.4	443.0	974.4		8
	SD	67.3	81.5	134.4			73.5	81.7	146.0		
3 July		521.6	349.6	871.1	12893	7	540.1	430.9	971.0	25956	8
	SD	90.4	33.9	108.5	1509		45.7	85.6	97.7	5874	
16 July		522.8	587.2	1110.0	21930	5	662.1	582.9	1245.0	30184	8
	SD	99.3	53.5	149.0	2121		48.5	55.3	60.2	6763	
28 July		-	791.0	-	29449	7	625.7	574.7	1200.4	34289	7
	SD		109.8		3193		109.8	48.3	115.9	4202	
18 Aug.		-	717	-		7	624.0	508.0	1132.0		7
	SD		154.5				35.8	107.8	127.8		
20 Aug.		-	-	-	40040	5	576.8	509.2	1086.0	34675*	5
	SD				11489		62.6	100.2	110.2	3783	

continued.....

TABLE XII (1969) - Continued

		Group No. 3					Group No. 4				
		UN	S	T	Ad	No	UN	S	T	Ad	No
16 May		283.9	311.9	595.7	8611	7	338.4	305.4	643.8	9475	8
	SD	60.7	24.4	75.5	1144		26.7	41.1	52.9	786	
28 May		413.3	349.9	763.1		7	527.9	471.0	998.9		8
	SD	53.1	45.3	60.7			107.0	41.6	127.2		
9 June		623.4	512.6	1136.0	19350	7	685.8	630.9	1316.6	21722	8
	SD	54.2	59.7	95.0	1359		72.5	73.4	130.7	1148	
21 June		587.9	500.1	1088.0		7	571.1	571.8	1142.9		8
	SD	62.8	85.5	137.6			99.9	73.0	152.1		
3 July		605.1	467.7	1072.9	30182	7	600.3	458.7	1058.9	33969	8
	SD	79.8	84.0	140.3	3271			69.5	96.8	3324	
16 July		765.8	554.2	1328.0	34125	6	626.8	736.3	1363.0	44675	4
	SD	113.5	128.2	159.3	3056		99.9	79.7	133.7	5305	
28 July		512.2	596.8	1109.0	42550	5	-	777.6	-	49020	5
	SD	68.2	121.5	161.2	7017			124.0		1967	
18 Aug.		439.8	488.6	942.0		4	-	581.8	-		5
	SD	147.3	148.5	281.9				122.8			
20 Aug.		372.3	317.6	689.5	50013	4	-	-	-	55500	4
	SD	200.7	211.8	410.5	8749					9131	

1 - UN = unsealed brood; S = sealed brood; T = total brood; Ad = adults; SD = standard deviation.

2 - No = number of "normal" colonies in group mean (initially 8 hives per group)

3 - Mean for group in square inches.

* - Mean of only 2 hives.

TABLE XIII - GROUP DIFFERENCES OF TOTAL, SEALED, UNSEALED BROOD, AND ADULTS (1969)

	1 - 2[1]				1 - 3				1 - 4				2 - 3				2 - 4				3 - 4			
	T[2]	S	UN	Ad	T	S	UN	Ad	T	S	UN	Ad	T	S	UN	Ad	T	S	UN	Ad	T	S	UN	Ad
16 May	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	NS	NS	*	NS
28 May	*	*	*	-	*	*	*	-	*	*	*	-	*	*	NS	-	*	*	*	-	*	*	*	-
9 June	*	*	*	*	*	*	*	*	*	*	*	*	*	NS	NS	*	*	*	*	*	*	*	NS	*
21 June	*	*	*	-	*	*	*	-	*	*	*	-	NS	NS	NS	-	*	*	NS	-	NS	NS	NS	-
3 July	NS	*	NS	*	*	*	NS	*	*	*	NS	*	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	*
16 July	*	NS	*	-	*	NS	*	-	*	*	NS	-	NS	NS	*	-	NS	*	NS	-	NS	*	*	-
28 July	-	-	-	*	-	-	-	*	-	-	-	*	-	-	-	*	-	-	-	*	-	-	-	NS

[1] Mean of group no. 1 compared to mean of group no. 2. (See Table XII)

[2] T = Total brood; S = Sealed brood; UN = Unsealed brood; Ad = Adults

* Significant ($P \leq 0{,}05$) NS = Not significant

FIGURE 13 - TOTAL BROOD AREAS OF THE FOUR EXPERIMENTAL GROUPS. (1969)

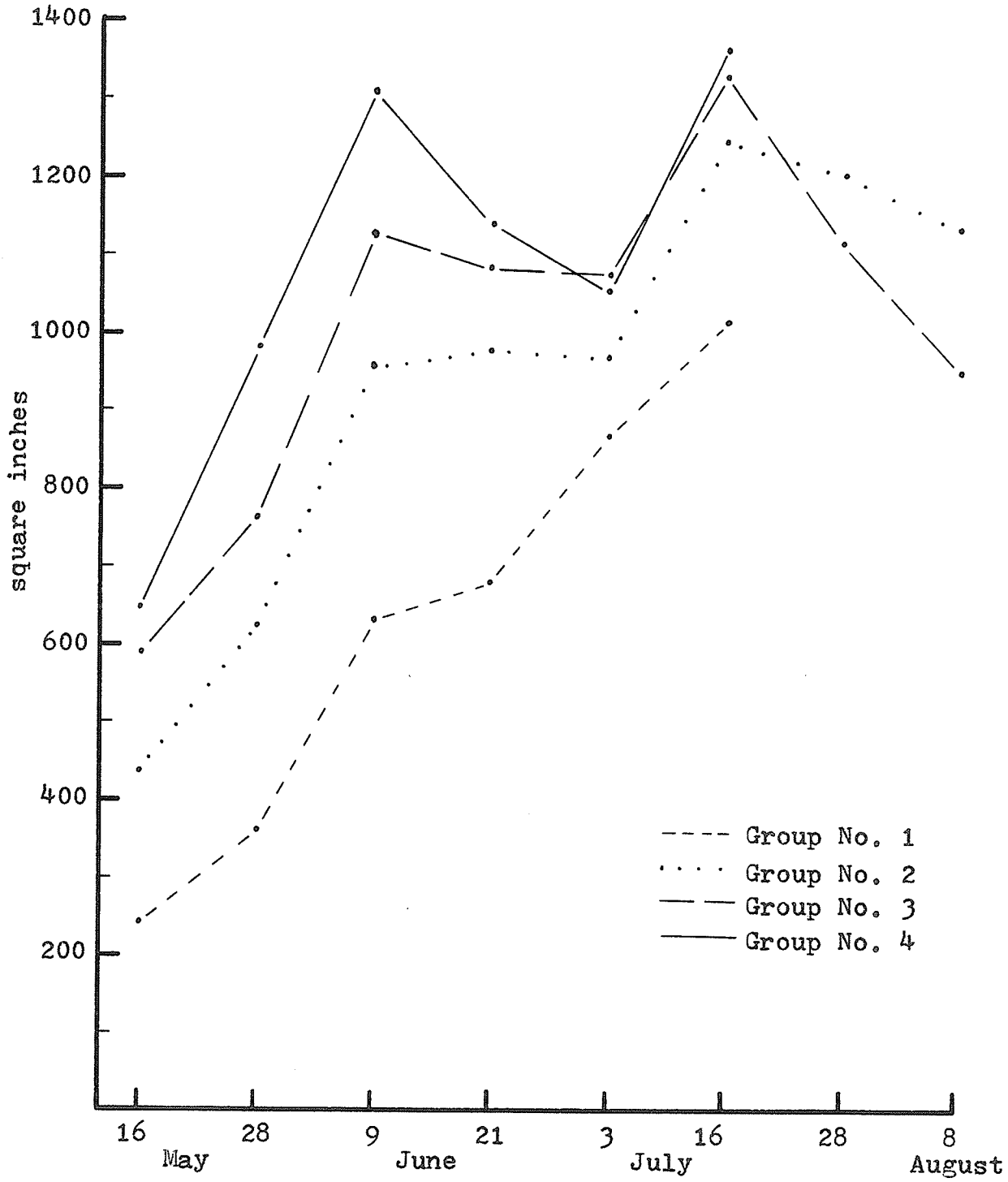


FIGURE 14 - SEALED BROOD AREAS OF THE FOUR EXPERIMENTAL GROUPS. (1969)

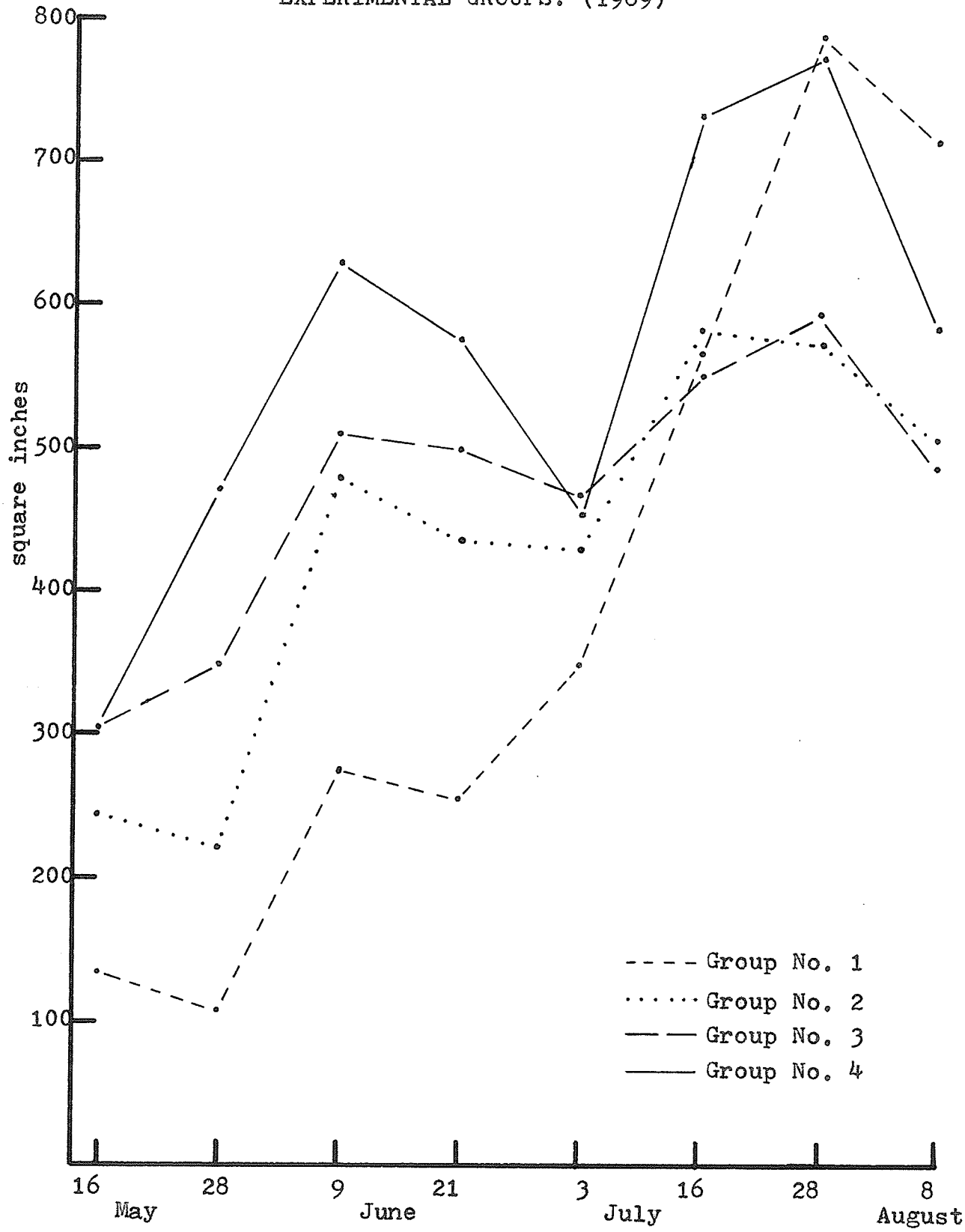


FIGURE 15 - UNSEALED BROOD AREAS OF THE FOUR EXPERIMENTAL GROUPS. (1969)

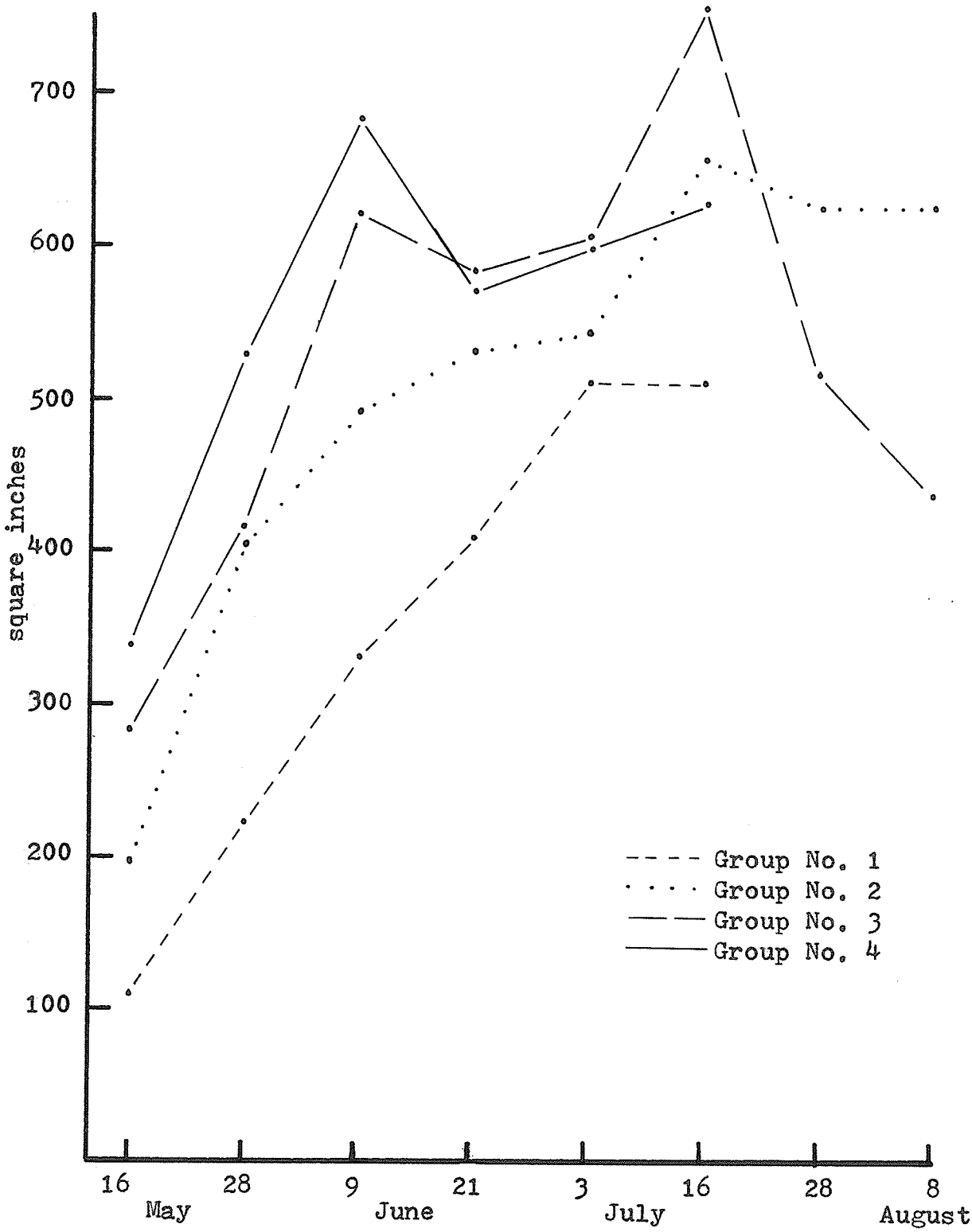
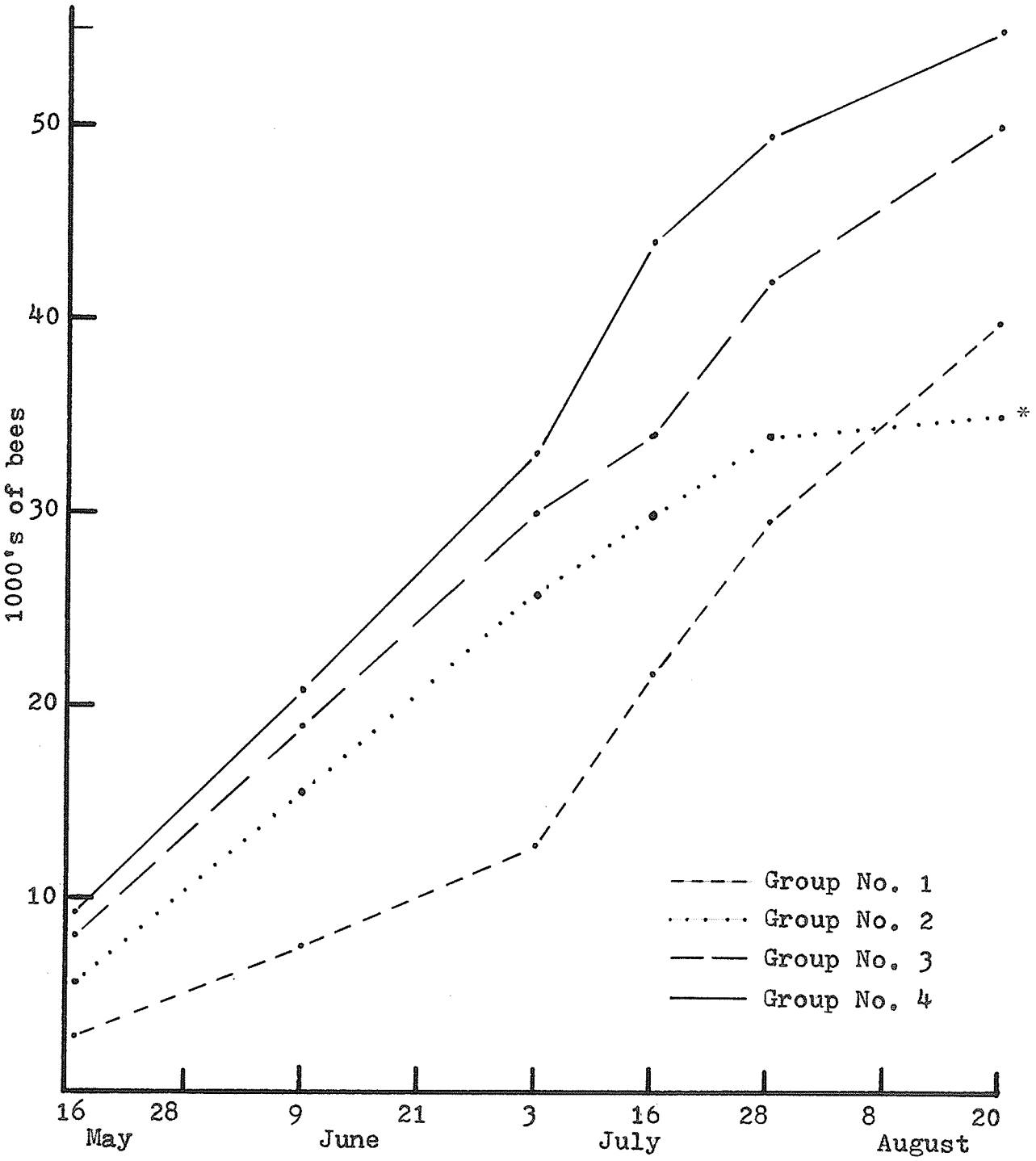


FIGURE 16 - ADULT NUMBERS OF THE FOUR EXPERIMENTAL GROUPS. (1969)



* mean of only two colonies on last reading.

TABLE XIV - LINEAR REGRESSION EQUATIONS OF BROOD AREAS, ADULTS NUMBERS, AND TIME OF DEVELOPMENT[1] (1969)

(A)[2] RELATIONSHIPS OF TOTAL BROOD AND TIME OF DEVELOPMENT

Group No.	Regression Equation Y = Intercept	Regression Coefficient	Correlation Coefficient (r)
1	84.03	+ 163.05 X	.985*
2	366.34	+ 144.19 X	.941*
3	542.99	+ 129.79 X	.907*
4	721.25	+ 104.12 X	.741

(B)[3] RELATIONSHIPS OF SEALED BROOD AND TIME OF DEVELOPMENT

1	-70.90	+ 107.11 X	.934*
2	188.62	+ 59.26 X	.890*
3	296.40	+ 43.51 X	.901*
4	310.95	+ 63.35 X	.821*

(C)[2] RELATIONSHIPS OF UNSEALED BROOD AND TIME OF DEVELOPMENT

1	65.19	+ 84.79 X	.972*
2	193.06	+ 79.17 X	.942*
3	248.96	+ 85.41 X	.924*
4	403.93	+ 44.12 X	.687

(D)[4] RELATIONSHIPS OF ADULT NUMBERS AND TIME OF DEVELOPMENT

1	-4979.55	+4662.41 X	.966*
2	4382.15	+3877.58 X	.965*
3	3594.29	+5268.23 X	.997*
4	4392.26	+6064.75 X	.989*

[1]Equations based on data from 16 May (1st reading) to time of peaking, (see 2, 3 and 4).
[2]Peaked about 16 July
[3]Peaked about 28 July
[4]Did not peak before last reading, 20 August.
* Significant ($P \leq 0.05$)

produced by each colony at this late date, is of little use for honey production, because it is produced after the main nectar flow.

Since this study was mainly concerned with colony development up to and including honey flow, the study did not include development past mid-August. However, in my work and in personal conversation with Smirl and Soehngen, both doing similar work, it is evident that most two-pound colonies that are initiated in early May do not have peak adult numbers until the first week of September.

Table XIII shows differences ($P \leq 0.05$) between all combinations of the four experimental groups analyzed to 28 July. Table XIV (D) shows the regression equations of adult numbers for the four experimental groups.

(c) Pupal Weights Only pupae from one colony per group were weighed; these weights showed no seasonal trends, probably because of the food and weather problem. The small sample did not allow for any statistical analyses.

(d) Ratios of the Number of Brood Cells to Adult Bees It is known that the ratio of the number of brood cells to the number of adult bees decreases during the development of a colony. Farrar (1930, 1937) concluded that a colony will develop more slowly, in proportion to its total strength, as the population increases above 10,000 bees. He also stated that a colony of 10,000 bees will have approximately 85 percent as many cells of sealed brood as it has bees, and this percentage tends to decrease at a rate of 10 to 12 percent for each increase in 10,000 bees up to 60,000 bees. However,

to my knowledge these ratios have not been calculated for colonies initiated from different sizes of packages.

(i) Ratios of the Number of Total Brood Cells to Adult Bees

Table XV and Figure 17 show the relative differences between the four experimental groups when comparing their ratios of the number of total brood cells to adult bees.

Group No. 1 starts with a higher ratio (i.e., is more efficient in brood production) and holds this level of efficiency until 9 June. However, as seen in Figure 16 the adult population of group No. 1, at this time, is well under 10,000 bees. As Farrar (1930, 1937) states, the greatest efficiency in brood production occurs at about 10,000 bees. Since groups No. 2, No. 3 and No. 4 all have adult numbers greater than 10,000 by 28 May, their ratios are lower and are steadily declining. Figure 17 shows that the ratios decrease when plotted against time of development. This indicates that for a certain colony population, the amount of brood reared is fairly constant. But, with different sized packages the number of adults available differs for the same length of development time, and thus different brood ratios for each size of package occur.

(ii) Ratios of the Number of Sealed Brood Cells to Adult Bees

Sealed brood is less vulnerable to adverse environmental conditions and therefore is the most reliable measure to use in studying colony growth.

Table XV and Figure 18 show the relative differences between the ratios of the number of sealed brood cells and adult bees of

each group. The ratios are similar to that shown for total brood cells to adult number ratios. The efficiency of group No. 1 starts higher than the other three groups, and with one exception, finishes higher (Figure 18).

In the discussion of sealed brood, groups No. 2 and No. 3 did not produce as much sealed brood as did groups No. 4 and No. 1 (Figure 14). Although this was understandable for group No. 2 because of a stable population level, it was not clear why group No. 3, with an increasing population, did not produce more sealed brood.

Figure 18 shows that the ratio for groups No. 4 and No. 1, although quite different in value, were not decreasing between 16 July and 28 July, whereas the ratios for groups No. 2 and No. 3 were decreasing.

Generally, the ratios for these four groups varies at different times of the season, but all are decreasing.

(iii) Ratios of the Number of Unsealed Brood Cells to Adult Bees Table XV and Figure 19 show the difference between the ratios of the number of unsealed brood cells to adult bees of the four experimental groups.

Figure 19 shows that groups No. 2, No. 3 and No. 4 have about the same ratios as development time progresses. Group No. 1 is quite different. Part of this effect was caused by the low numbers of adults up to 3 July (see Figure 16).

TABLE XV - RATIOS OF THE NUMBER OF BROOD CELLS TO ADULT BEES (1969)

	Group No. 1							Group No. 2						
Date	Ad[1]	T	Rt	S	Rs	UN	Run	Ad	T	Rt	S	Rs	UN	Run
16 May	2930	5925	2.03	3315	1.13	2640	.90	5906	1107	1.88	6132	1.04	4975	.84
9 June	7793	15792	2.03	6852	0.88	8940	1.15	15525	24125	1.55	12012	.77	12112	.78
3 July	12893	21777	1.69	8740	0.68	13040	1.01	25956	24275	0.95	10772	.42	13502	.52
16 July	21930	27750	1.27	14680	0.67	13070	0.61	30147	31125	1.03	14572	.48	16552	.55
28 July	29449	- -	- -	19775	0.67	- -	- -	34289	30010	.88	14367	.42	15642	.46
8 Aug.	35000	- -	- -	17947	0.51	- -	- -	- -	- -	- -	- -	- -	- -	- -
20 Aug.	40040	- -	- -	- -	- -	- -	- -	34675*	27150	.78	12730	.37	14420	.42

	Group No. 3							Group No. 4						
Date	Ad	T	Rt	S	Rs	UN	Run	Ad	T	Rt	S	Rs	UN	Run
16 May	8661	14892	1.72	7797	0.90	7097	0.82	9475	16095	1.70	7635	0.81	8460	0.89
9 June	19350	28400	1.47	12815	0.66	15585	0.81	21722	32915	1.52	15772	0.73	17145	0.79
3 July	30182	26822	0.89	11962	0.39	15127	0.51	33969	26449	0.78	11440	0.34	15007	0.44
16 July	34125	33200	0.97	13855	0.41	19345	0.57	44675	34075	0.76	18407	0.41	15670	0.35
28 July	42550	27725	0.65	14920	0.35	12805	0.31	49020	- -	- -	19440	0.40	- -	- -
8 Aug.	- -	- -	- -	- -	- -	- -	- -	52000	- -	- -	14545	0.28	- -	- -
20 Aug.	50013	17237	0.34	7932	0.16	9307	0.19	55500	- -	- -	- -	- -	- -	- -

[1] Ad = Adult number; T = Total brood cells; Rt = T/Ad; S = Sealed brood cells; Rs = S/Ad; UN = Unsealed brood cells; Run = UN/Ad.

* Mean of only 2 hives.

TABLE XVI - LINEAR REGRESSION EQUATIONS OF THE RATIOS OF THE NUMBER OF BROOD CELLS TO ADULT BEES, AND TIME OF DEVELOPMENT[1] (1969)

(A) RELATIONSHIPS OF T/Ad[2] AND TIME OF DEVELOPMENT

Group No.	Regression Equation Y = Intercept	Regression Coefficient	Correlation Coefficient (r)
1	2.410	- 0.262 X	-.937*
2	1.919	- 0.212 X	-.907*
3	1.935	- 0.265 X	-.969*
4	2.080	- 0.356 X	-.937*

(B) RELATIONSHIPS OF S/Ad AND TIME OF DEVELOPMENT

1	1.16	- 0.081 X	-.967*
2	1.02	- 0.085 X	-.918*
3	0.940	- 0.089 X	-.978*
4	0.885	- 0.078 X	-.926*

(C) RELATIONSHIPS OF UN/Ad AND TIME OF DEVELOPMENT

1	1.175	- 0.104 X	-.575
2	0.898	- 0.087 X	-.933*
3	0.993	- 0.132 X	-.954*
4	1.11	- 0.197 X	-.968*

[1]For time of development see Table XV.

[2]T/Ad ratio of total number of brood cells to adult bees.
S/Ad ratio of sealed number of brood cells to adult bees.
UN/Ad ratio of unsealed number of brood cells to adult bees.

* Significant ($P \leq 0.05$)

FIGURE 17 - RATIO OF THE NUMBER OF TOTAL BROOD CELLS TO ADULT BEES. (1969)

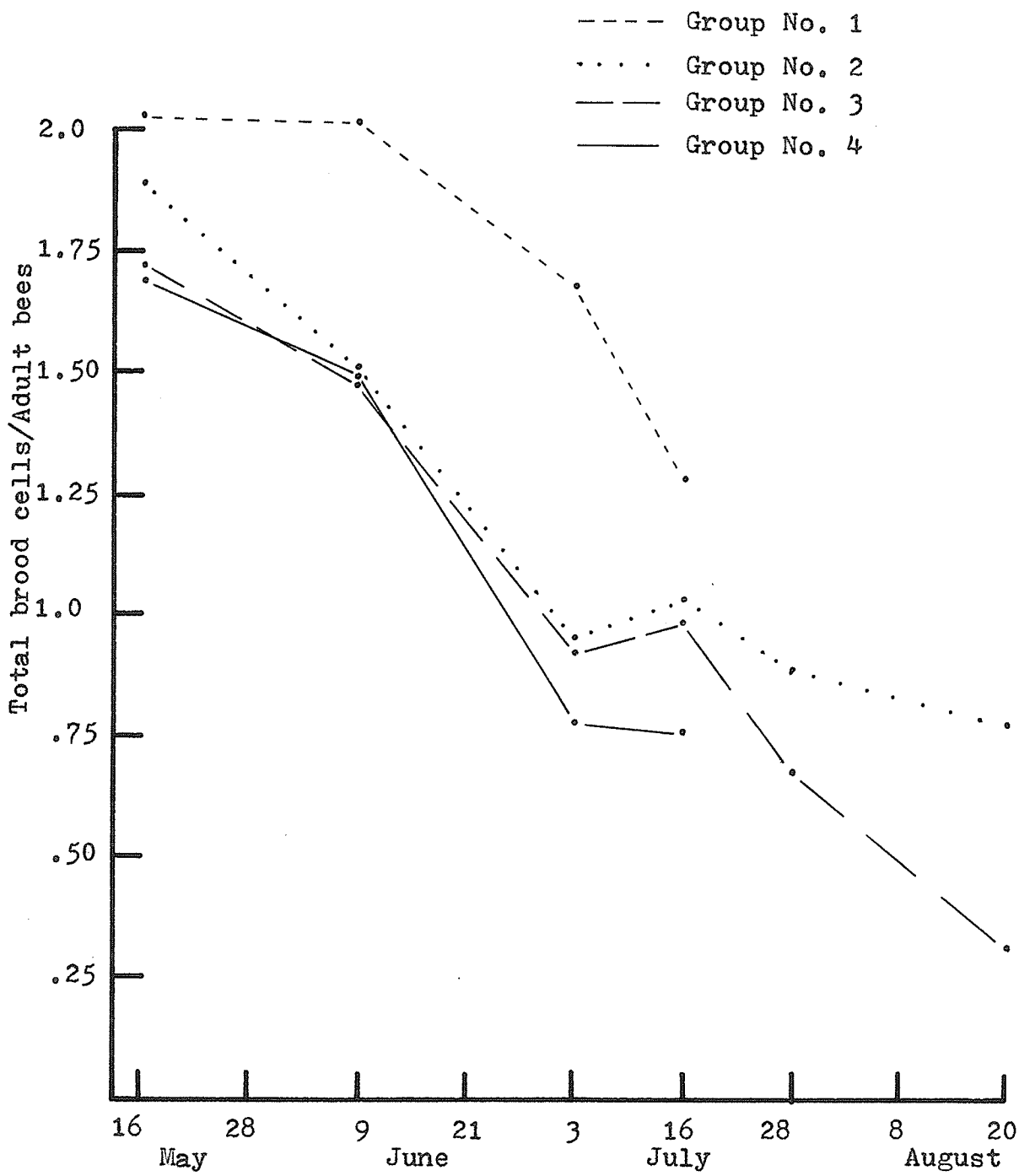


FIGURE 18 - RATIO OF THE NUMBER OF SEALED BROOD CELLS TO ADULT BEES. (1969)

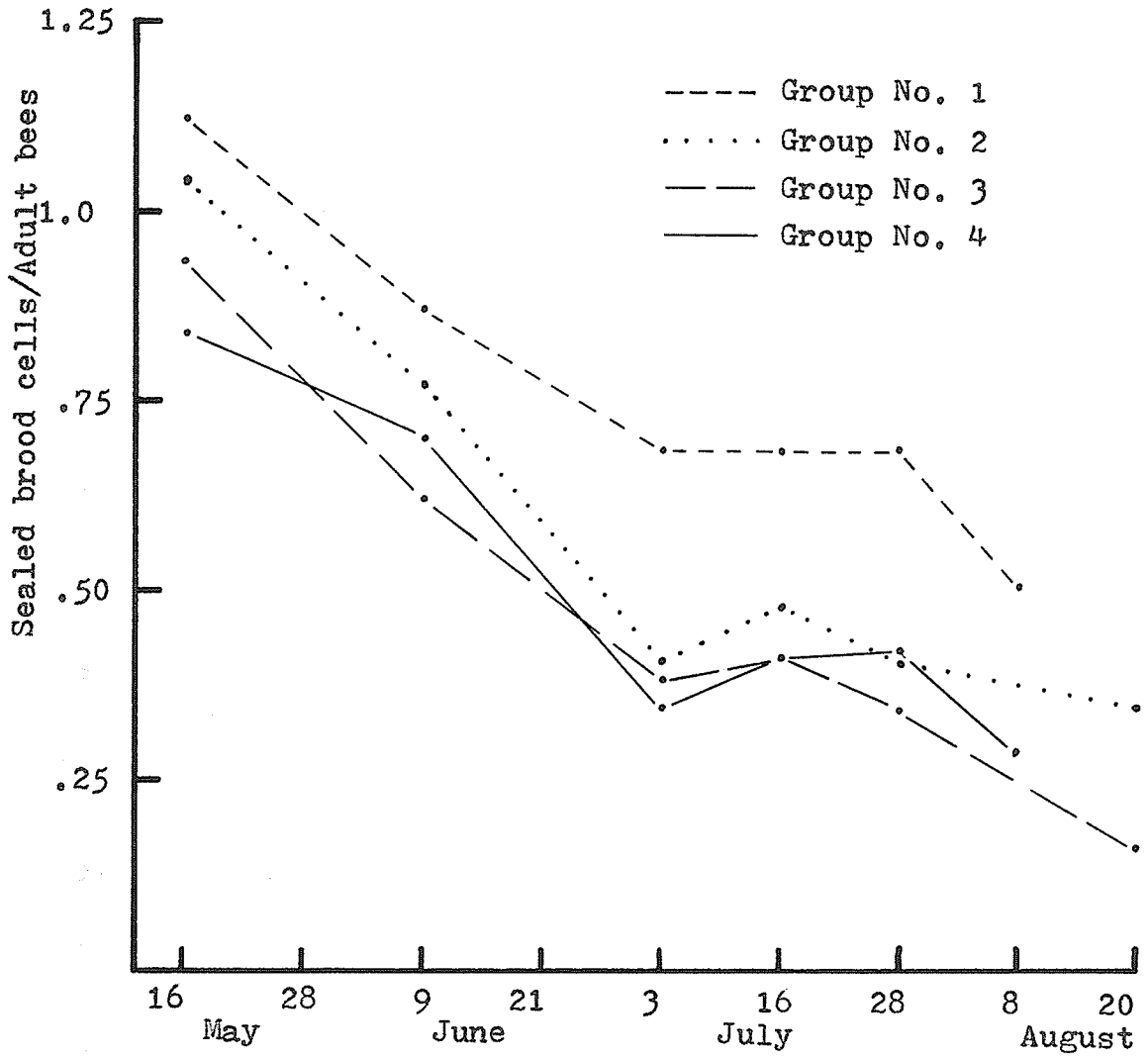


FIGURE 19 - RATIO OF THE UNSEALED BROOD CELLS TO ADULT BEES. (1969)

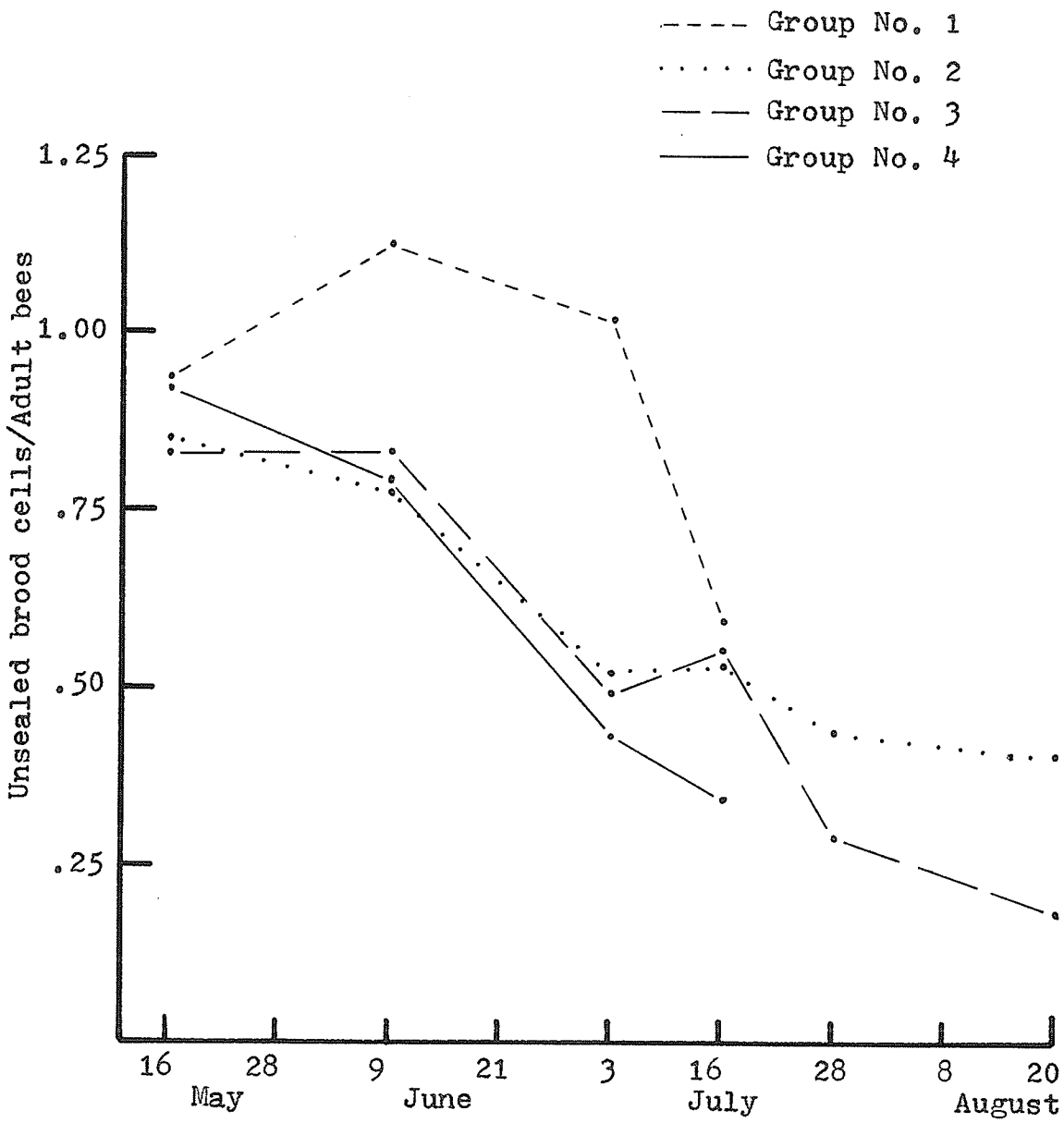
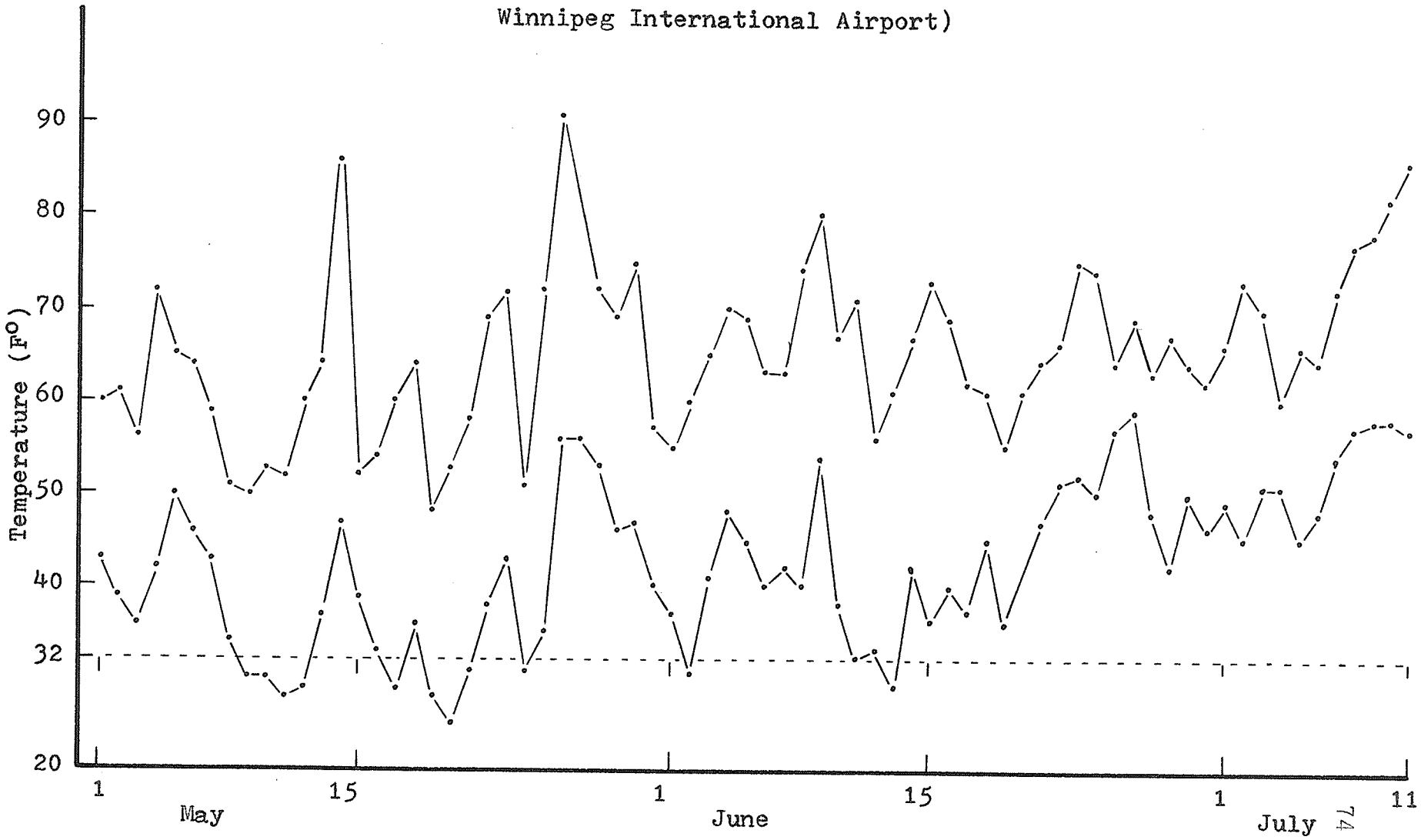


FIGURE 20 - MAXIMUM AND MINIMUM TEMPERATURES. (1969)

(Recorded by Department of Transport,

Winnipeg International Airport)



(3) 1970 Seasonal Measurements

(a) Brood In 1970 only sealed brood was measured. The sealed brood was photographed (see Methods and Materials) to reduce the time and labor required to make such readings.

Table III (Appendix) shows development for all colonies of each group. Table XVII summarizes the data for normal colonies of each experimental group; normal colony development is shown in Figure 21. Table XVIII shows statistical comparisons between the four experimental groups up to the time of maximum brood production.

(i) Sealed Brood Table XVII and Figure 21 show the relative effect of package size on sealed brood production.

Group No. 4 begins with more sealed brood on 28 May and continues to produce the greater amount right up to time of peaking, 4 July.

Statistical analyses of sealed brood (Table XVIII) show that there is a difference ($P \leq 0.05$) between combinations of the four experimental groups. In 1970 no difference was found between groups No. 2 and No. 3 or between groups No. 3 and No. 4. Most of the differences occurred between group No. 1 and the other three groups (Table XVIII).

Figure 21 shows that up to time of peaking (4 July) group No. 4 > No. 3 > No. 2 > No. 1 in sealed brood production; all groups peaked at the same time although group No. 1 levelled off, whereas the other groups had an immediate decline.

The sealed brood peaked earlier but did not reach the maximum area of sealed brood observed in 1968 (Figure 9) and 1969 (Figure

14). This was probably due to the favorable temperatures (Figure 25 and Table VII Appendix) and the good apiary location in 1970. Soehngen (1971) reports similar results for the same three years.

Table XIX shows the regression equations for sealed brood produced in each of the four groups up to 4 July (i.e., time of peaking). As shown by the correlation coefficient (r) all groups show a high linear correlation. The regression coefficient shows that the slopes are similar. The intercept shows that the four sizes produced differing amounts of sealed brood up to the time of the first reading date (28 May).

(b) Adult Numbers Table XVII and Figure 22 show the increase in adult numbers as each of the four groups developed. Table XVIII shows the difference between the combinations of the four groups. On 28 May there was a difference in numbers ($P \leq 0.05$) in all combinations, except between groups No. 2 and No. 3 which never showed a difference. Most of the differences in adult numbers occurred between group No. 1 and the other three groups (Table XVIII).

Figure 22 shows that group No. 4 > No. 3 > No. 2 > No. 1 in adult numbers throughout the season except on 16 July. The apparent levelling off of group No. 4 was probably caused by the low number of normal colonies making up the 10 August adult number reading.

Table XX shows the regression equations for adults of the four experimental groups. The correlation coefficient is high, showing a linear increase. However, the intercept shows that the

TABLE XVII - SUMMARY OF BROOD AND ADULT DEVELOPMENT WITHIN THE FOUR EXPERIMENTAL GROUPS (1970)

		Group No. 1			Group No. 2			Group No. 3			Group No. 4		
		S[1]	Ad	No[2]	S	Ad	No	S	Ad	No	S	Ad	No
28 May		169.7[3]	4322	8	264.8	6731	9	316.1	6972	9	340.4	10197	8
	SD	28.7	670		55.6	685		102.6	1041		56.9	1997	
9 June		262.9		7	408.8		9	428.8		9	481.0		8
	SD	67.6			91.0			58.5			38.3		
22 June		434.6	11736	7	509.5	18944	8	501.7	22928	9	526.7	24244	7
	SD	62.3	2182		72.3	2292		99.0	4134		61.8	4270	
4 July		548.4		7	645.3		7	630.4		9	633.3		7
	SD	53.4			66.5			110.2			76.4		
16 July		560.1	33771	7	499.0	41100	7	588.4	47014	7	481.7	46417	6
	SD	99.5	3962		64.2	8777		107.2	9842		44.6	3678	
28 July		486.7		7	442.0		4	527.3		6	435.3		4
	SD	95.1			143.6			115.6			69.2		
10 Aug.		439.6	42465	7	353.3	50821	4	442.4	51710	5	441.3	46900	3
	SD	257.5	6202		82.3	12659		118.2	11623		26.1	4689	

1 - S = sealed brood; Ad = adults; SD = standard deviation.

2 - No = number of normal colonies in group mean (initially 10 colonies)

3 - Mean for group in square inches.

TABLE XVIII - GROUP DIFFERENCES OF SEALED BROOD AND ADULT NUMBERS (1970)

	1 - 2[1]		1 - 3		1 - 4		2 - 3		2 - 4		3 - 4	
	S[2]	Ad	S	Ad	S	Ad	S	Ad	S	Ad	S	Ad
28 May	*	*	*	*	*	*	NS	NS	*	*	NS	*
9 June	*	-	*	-	*	-	NS	-	NS	-	NS	-
22 June	*	*	NS	*	NS	*	NS	NS	NS	*	NS	NS
4 July	*	-	NS	-	*	-	NS	-	NS	-	NS	-
16 July	NS	NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS

[1] (ie) mean of group no. 1 compared to mean of group no. 2 (see table XVII).

[2] S = sealed brood Ad = adult number

* = significant ($P \leq 0.05$)

NS = not significant

FIGURE 21 - SEALED BROOD AREA OF THE FOUR EXPERIMENTAL GROUPS. (1970)

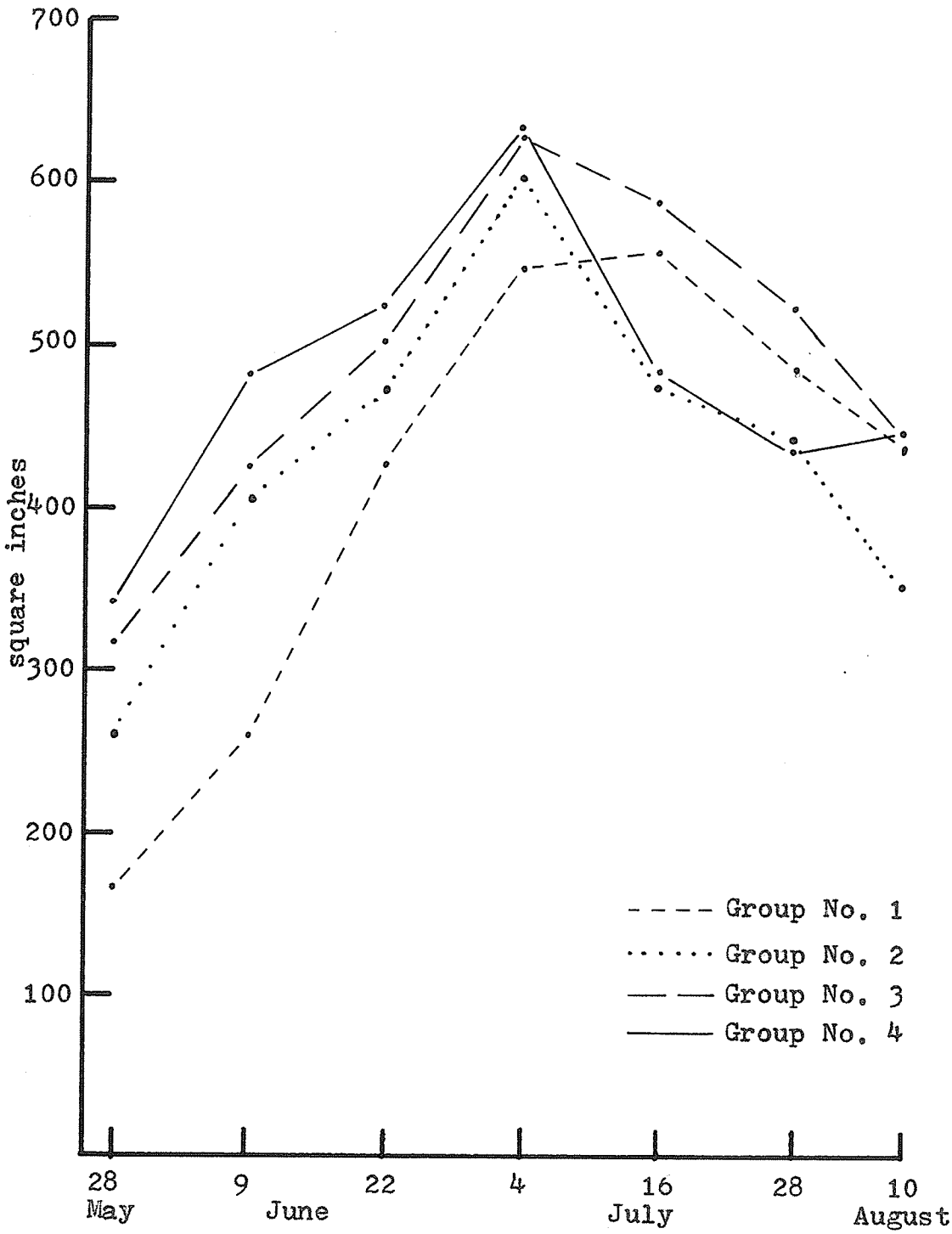
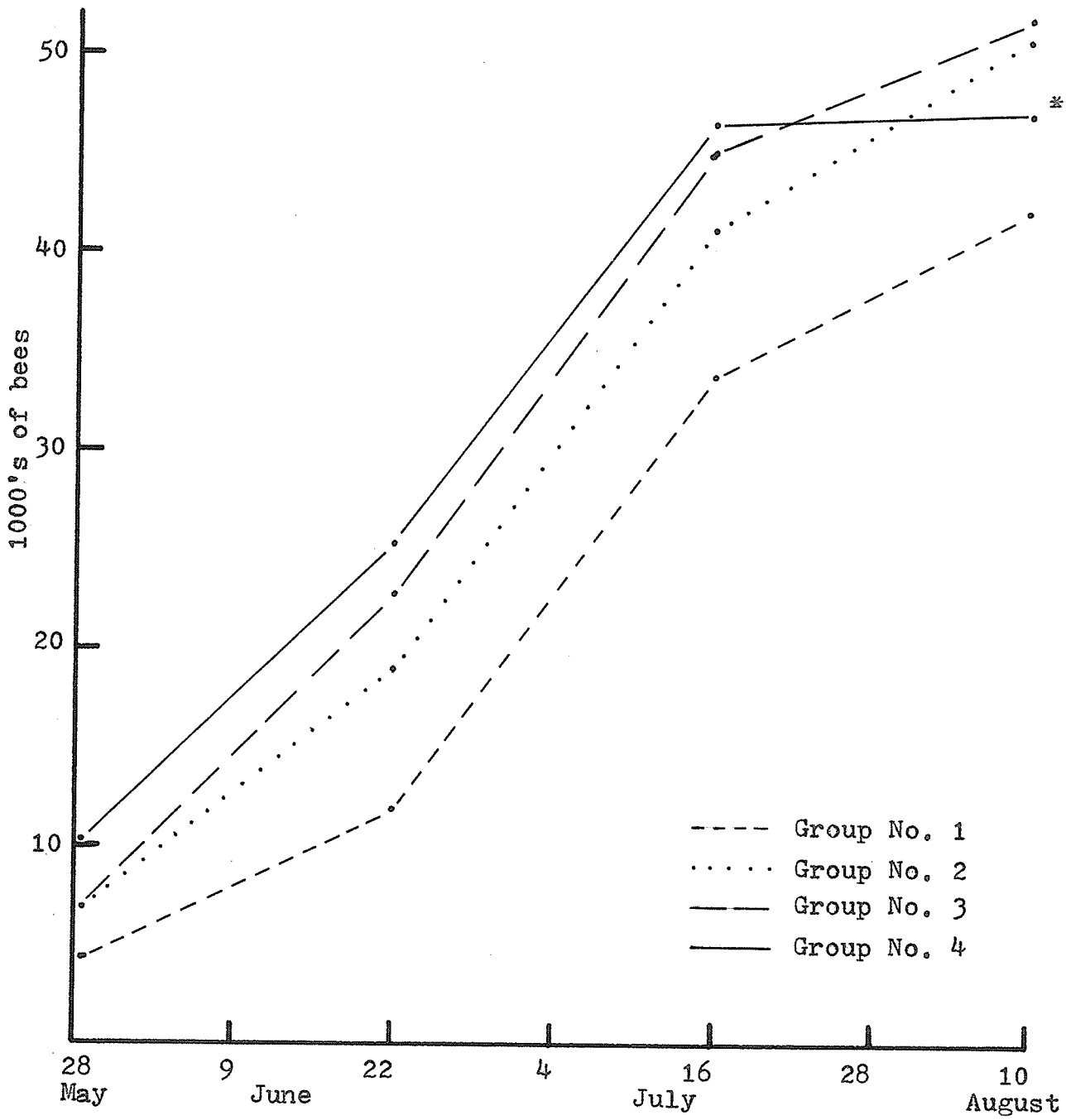


FIGURE 22 - ADULT NUMBERS OF THE FOUR EXPERIMENTAL GROUPS. (1970)



* mean of only three colonies on last reading

TABLE XIX - LINEAR REGRESSION EQUATIONS OF SEALED BROOD AREA AND TIME OF DEVELOPMENT[1] (1970)

Group No.	Regression Equation Y = Intercept	Regression Coefficient	Correlation Coefficient
1	26.95	+ 130.78 X	.994*
2	167.55	+ 108.16 X	.991*
3	215.30	+ 101.58 X	.995*
4	265.45	+ 92.08 X	.983*

TABLE XX - LINEAR REGRESSION EQUATIONS OF ADULT NUMBERS AND TIME OF DEVELOPEMENT[2] (1970)

1	-4219.30	+6823.20 X	.973*
2	-1486.20	+7721.30 X	.989*
3	499.50	+7913.50 X	.973*
4	5448.10	+6629.10 X	.953*

TABLE XXI - LINEAR REGRESSION EQUATIONS OF THE RATIOS OF THE NUMBER OF SEALED BROOD CELLS TO ADULT BEES, AND TIME OF DEVELOPMENT[2] (1970)

1	1.181	- .134 X	-.951*
2	1.072	- .139 X	-.980*
3	1.159	- .152 X	-.938*
4	0.886	- .104 X	-.952*

[1]Equations based on date from 28 May (1st reading) to time of peaking (4 July).

[2]Equations based on data from 28 May to 10 August.

build up, to time of the first reading, varies considerably between groups. Part of this variance is due to the difference in numbers of bees hived. The slopes differ only slightly as indicated by the regression coefficient.

(c) Brood Ratios 1970

(i) Ratios of the Number of Sealed Brood Cells to Adult Bees

Table XXII and Figure 23 show the differences in ratios between the number of sealed brood cells and adult numbers of each group with development time.

Generally, the smaller groups start with a higher ratio than the larger groups. After the first two readings the differences shown occur only between group No. 1 and the other three groups (Figure 23).

The ratios of the four groups vary somewhat with time of development; however, if the ratios are plotted against adult numbers rather than time of development, the ratio of each group at a particular population will be very close in value.

(d) Pupal Weights Table XXIII and Figure 24 show how the pupal weights change during the season for the four experimental groups. Table IV (Appendix) gives the weights for each of three hives measured in the four groups during the season.

Figure 24 shows a steady increase in the weight of pupae for all four groups although the rate of increase varies. Group No. 4 did not increase as expected when compared to the other groups.

TABLE XXII - RATIO OF THE NUMBER OF SEALED BROOD CELLS TO ADULT BEES (1970)

	Group No. 1			Group No. 2			Group No. 3			Group No. 4		
Date	Ad	S	Rs	Ad	S	Rs	Ad	S	Rs	Ad	S	Rs
28 May	4322	4242	0.98	6731	6620	0.98	6972	7915	1.14	10197	8540	0.84
22 June	11736	10865	0.93	18944	11872	0.63	22928	12542	0.55	24244	13167	0.54
16 July	33771	14001	0.41	41100	11877	0.29	47014	14710	0.31	46417	12042	0.26
10 Aug.	42465	10990	0.26	50821	8832	0.17	51710	11060	0.21	46900*	11032	0.24

* Mean of only 3 colonies.

TABLE XXIII - MEAN WEIGHT OF PUPAE OF THE FOUR EXPERIMENTAL GROUPS (1970)

Date		Group No. 1	Group No. 2	Group No. 3	Group No. 4
21 May	Mean	124.2[1]	123.6	126.5	130.8
	S.D.	4.4	5.0	4.0	2.9
16 June	Mean	125.1	125.0	130.0	131.7
	S.D.	5.1	1.9	4.4	4.1
12 July	Mean	129.8	134.3	134.9	131.7
	S.D.	7.9	0.5	2.8	5.3
4 August	Mean	137.4	140.3	138.0	135.5[2]
	S.D.	9.7	1.5	2.7	0.4
26 August	Mean	138.7	139.1	142.6	139.5[2]
	S.D.	6.1	4.9	4.2	3.8

1 - Mean of three colonies

2 - Mean of only two colonies

Note: No significant differences shown in mean weight of pupae ($P \leq 0.05$)

FIGURE 23 - RATIO OF THE NUMBER OF SEALED BROOD CELLS TO ADULT BEES. (1970)

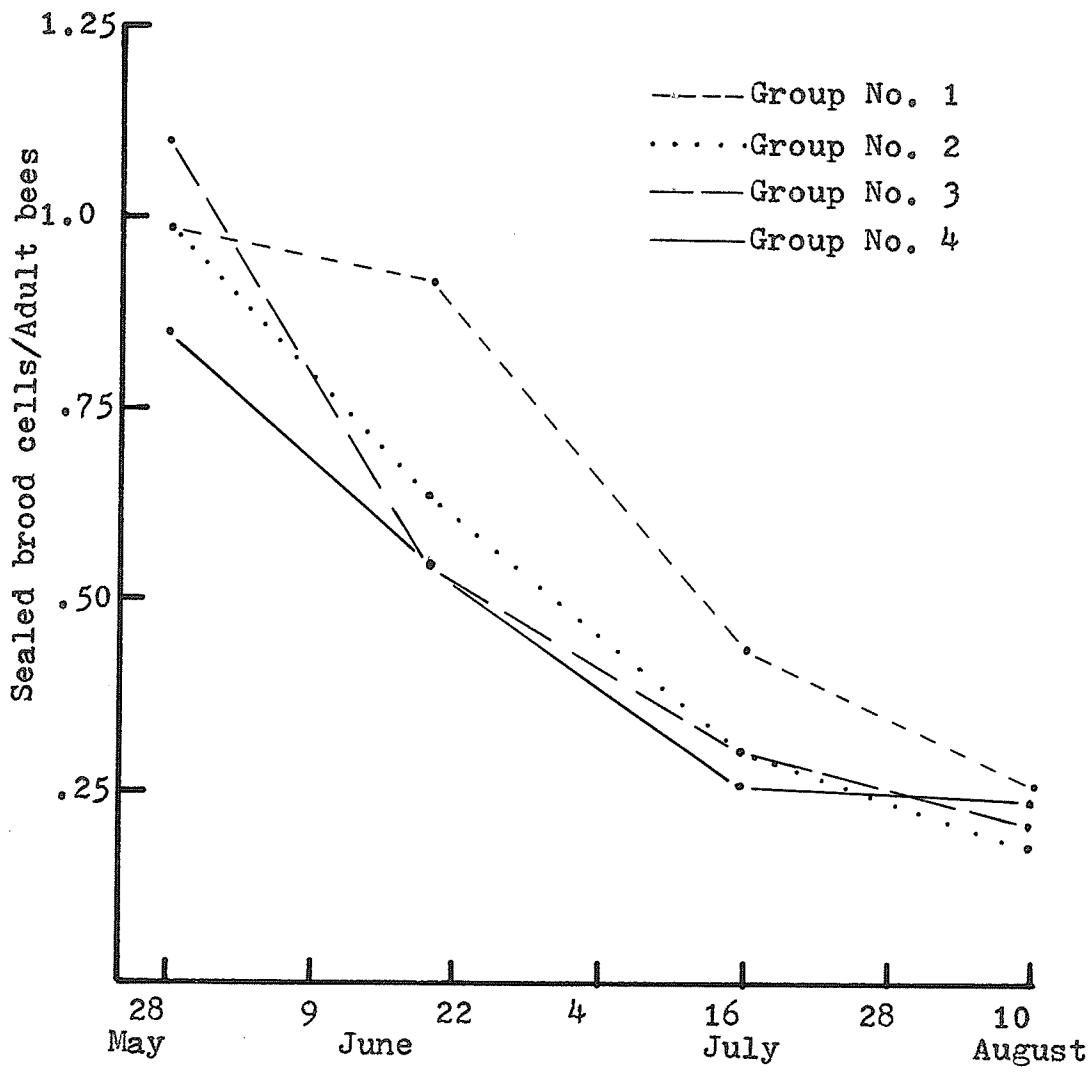


FIGURE 24 - MEAN WEIGHT OF PUPAE OF THE FOUR EXPERIMENTAL GROUPS. (1970)

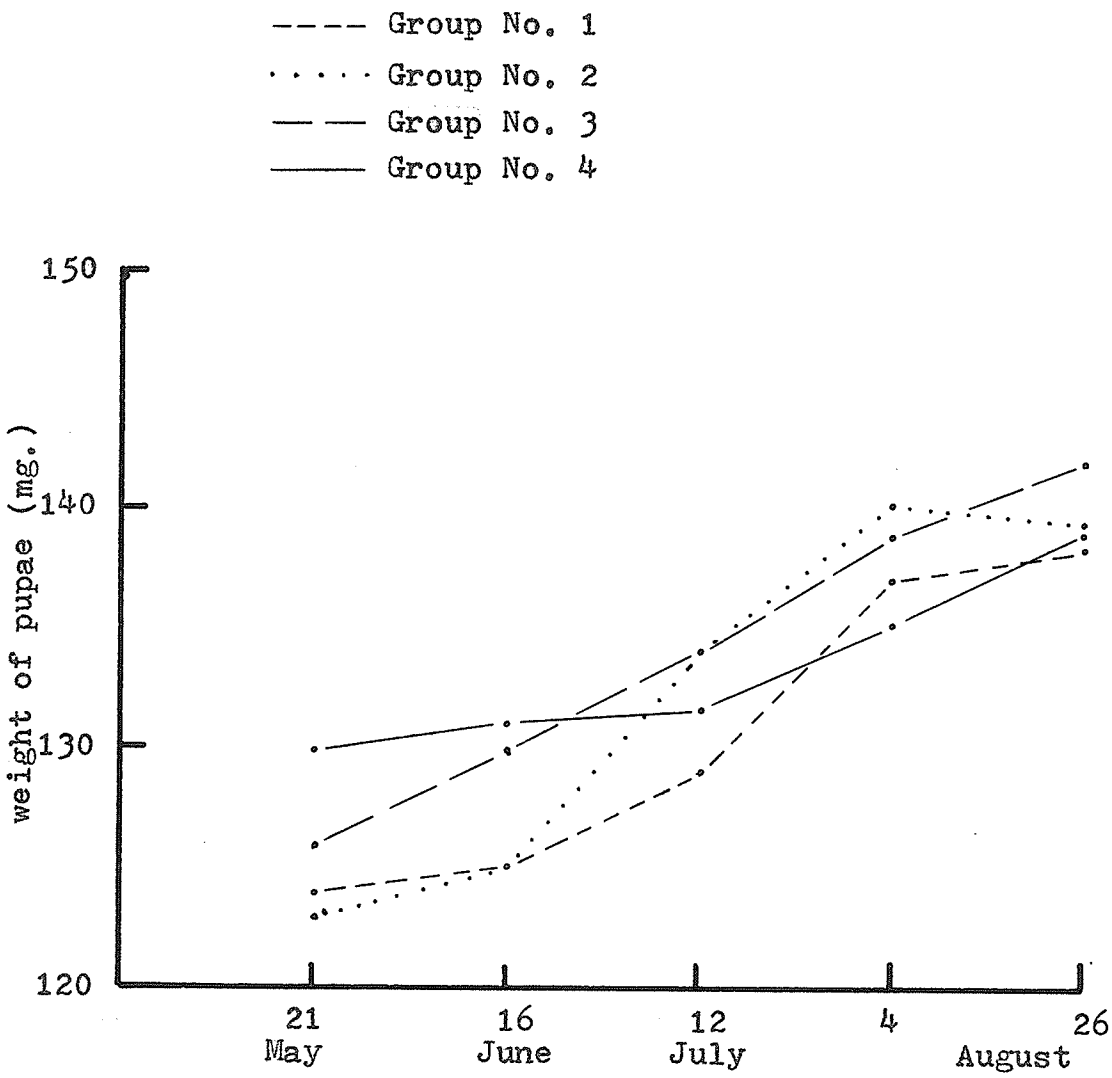
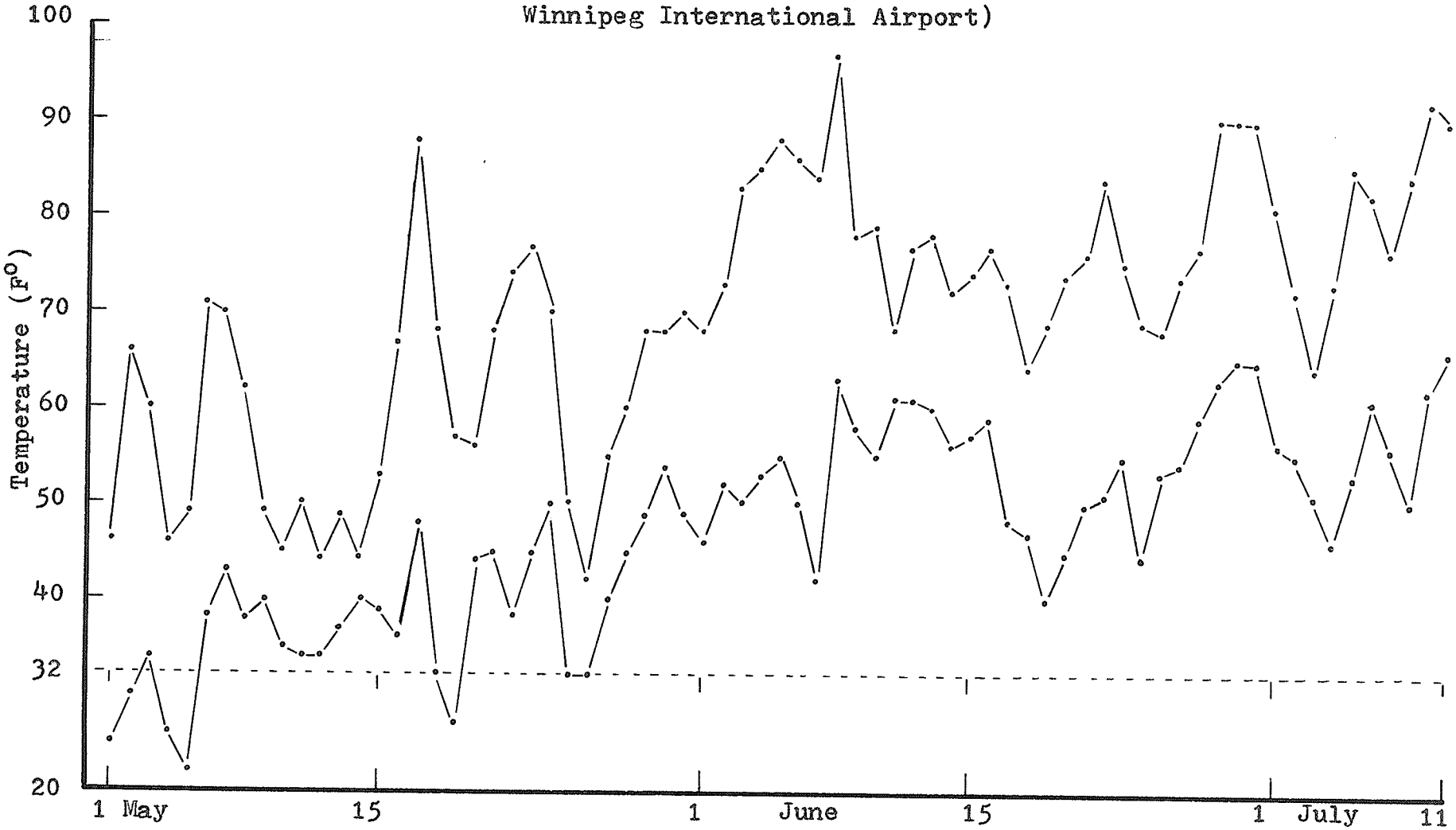


FIGURE 25 - MAXIMUM AND MINIMUM TEMPERATURES. (1970)

(Recorded by Department of Transport,

Winnipeg International Airport)



B. Other Measurements

(1) Scale Weights (Nectar Flow)

During 1969 and 1970 only one scale colony per group was used to monitor the nectar flow. Although incoming pollen and the increasing population will affect weight recorded, the increase is primarily a reflection of the increase of incoming nectar.

(a) 1969 Figure 26 shows the relative differences in the amount of nectar gathered by each group as monitored by a single scale colony. Two peaks in nectar flow were recorded by all four groups, 9 - 13 July and 3 - 7 August. In general, group No. 4 > No. 3 > No. 2 > No. 1 in gains during any five day period. However, Figure 26 shows that group No. 1 was almost equal to group No. 4 during the peak of 3 - 7 August. It is not possible to do statistical analysis based on one colony per group. The maximum gain of 37 lbs. during a five day period occurred between 9 - 13 July by the scale colony of group No. 4. The very cool weather in June (Figure 20 and Table VII, Appendix) could have contributed to this effect; however, little nectar was available in the vicinity of the apiary and this was probably the chief factor responsible for the effect. This is borne out by the very low gains observed in late July and early August, which is usually the best period for nectar gains.

(b) 1970 Figure 27 shows the relative difference in the amount of nectar gathered by each group as monitored by a single colony. As mentioned previously the apiary location in 1970 was

an excellent one and this is reflected in the gains shown in Figure 27. The maximum five day gain of 79 lbs. occurred during 3 - 7 August by the scale colony of group No. 4. All other groups had maximum gains at this time but they were lower. Generally, group No. 4 > No. 3 > No. 2 > No. 1 as shown in Figure 27.

(2) Honey Production

Honey production records are available for 1969 and 1970.

(a) 1969 The apiary was in a poor location and the availability of forage was sparse, especially during the latter part of July and the first part of August. Figure 26 shows that group No. 4 appeared to take better advantage of the flow. This probably was due to the higher colony population and hence greater foraging numbers. Table XXIV shows the honey production of each colony and Table XXVI shows the significance of the group combinations. Group No. 4 produced the most honey, group No. 2 was next, and group No. 1 produced the least amount. The size of package significantly affected honey production in 1969 ($P \leq 0.05$) indicating that in a low nectar year (or in a low nectar location) the larger population can take better advantage of available nectar. It is not known why group No. 2 out-produced group No. 3. Group No. 2 had a stable population during late July and early August whereas group No. 3 was still increasing in adult population (Figure 16). However, the sealed brood to adult ratio was lower for group No. 3 than for group No. 2 during this period.

(b) 1970 In 1970 the apiary location was excellent and

TABLE XXIV - HONEY PRODUCTION OF THE FOUR EXPERIMENTAL GROUPS (1969)

	Group No. 1		Group No. 2		Group No. 3		Group No. 4	
	Hive No.	lbs.	Hive No.	lbs.	Hive No.	lbs.	Hive No.	lbs.
	1	64	1*	34	1*	78	1	132
	2	86	2	75	2	47	2	115
	3	53	3	102	3	134	3*	37
	4	40	4	88	4	41	4	95
	5*	46	5	86	5*	62	5	145
	6	30	6	115	6	124	6	139
	7	55	7	104	7	88	7	94
	8	57	8	84	8*	65	8	108
Means								
All colonies	53.9		86.0		79.9		108	
S.D.	16.8		24.7		34.0		34.6	
Normal colonies	55.0		93.4		86.8		118.3	
S.D.	17.8		13.9		42.7		20.7	

* abnormal colony (not included in means for normal colonies) (see Appendix Table II)

S.D. = standard deviation

TABLE XXV - HONEY PRODUCTION OF THE FOUR EXPERIMENTAL GROUPS (1970)

	Group No. 1		Group No. 2		Group No. 3		Group No. 4	
	Hive No.	lbs.	Hive No.	lbs.	Hive No.	lbs.	Hive No.	lbs.
	1	142	1*	171	1*	168	1	301
	2	254	2*	275	2	305	2*	104
	3*	117	3*	265	3	262	3*	122
	4*	208	4	323	4	314	4	278
	5	240	5*	199	5*	136	5	215
	6	185	6*	185	6*	243	6*	out
	7	241	7*	out	7*	175	7*	219
	8	264	8	317	8	228	8*	194
	9	246	9*	184	9*	149	9*	229
	10*	out	10	322	10	336	10	200
Means								
All colonies	210.8		249.0		231.6		206.9	
S.D.	52.3		64.5		72.5		63.9	
Normal colonies	224.6		320.7		289.0		264.7	
S.D.	44.3		3.2		43.4		44.5	

* abnormal colony (not included in mean for normal colonies) (see Appendix Table III)

S.D. = standard deviation

TABLE XXVI - DIFFERENCES IN HONEY PRODUCTION OF THE FOUR EXPERIMENTAL GROUPS (1969)

	1-2[1]	1-3	1-4	2-3	2-4	3-4
All hives	*	NS	*	NS	NS	NS
Hives normal to 17 July	*	NS	*	NS	*	NS

TABLE XXVII - DIFFERENCES IN HONEY PRODUCTION OF THE FOUR EXPERIMENTAL GROUPS (1970)

	1-2[1]	1-3	1-4	2-3	2-4	3-4
All hives	NS	NS	NS	NS	NS	NS
Hives normal to 16 July	NS	NS	NS	NS	NS	NS

* significant ($P \leq 0.05$)

N.S. - not significant

1 (ie) mean of group no. 1 compared to mean of group no. 2 (see tables XXIV and XXV)

forage was readily available. Figure 27 shows the relative nectar flows for each group; group No. 4 appeared to take better advantage of the flow. However, when the colonies of each group were averaged together (Table XXV) there was no difference ($P \leq 0.05$) in honey production between the groups (Table XXVII). Group No. 2 had the highest average honey production per colony, group No. 3 was next, and group No. 1 the lowest.

Because a number of colonies showed problems before the test was completed it is difficult to make general statements concerning honey yields in 1970.

(3) Entrance Activity

Table XXVIII shows entrance activity counts for 29 June and 9 July and their means for these two dates. Table XXIX shows the counts for 5, 7 and 12 August and the means for these three dates. Figure 28 shows comparisons between these two collecting periods.

(a) Pollen Collectors The percentage of pollen collectors to total foragers is quite different between groups and between the different trapping dates. The means in Tables XXVIII and XXIX show that group No. 1 had the highest percentage of pollen collectors but that group No. 4 does not have the lowest percentage. Other than group No. 1 having the highest percentage of pollen collectors, there does not seem to be any pattern to the percentage of pollen collectors of the other groups.

In general the percentage of pollen collectors within each group decreases as the season progresses. This is probably because

peak brood production occurs in mid-July; also, more intensive collection of nectar occurs at this time.

(b) Non-pollen Collectors As the percentage of pollen collectors decreases the percentage of non-pollen collectors increases; although the vast majority of non-pollen collectors are nectar collectors, some of them are water collectors and/or are young bees on orientation flights. The number of non-pollen collectors increased within each group as the season progressed (Figure 28). Group No. 1 appeared to have a higher percentage of non-pollen collectors than expected; some of this effect can be attributed to a high collection from one of three colonies monitored on 5 August (Table XXIX).

(c) Total Foragers Total foragers increased for each of the four groups during the season (Figure 28). It appears that total foragers did not differ for the four groups (except that group No. 2 was quite low). Group No. 2 probably had fewer foragers because several hives within the group experienced trouble during August.

To obtain a complete understanding of the relationship between entrance activity and various factors (e.g., population, ratio of brood area to adult numbers, etc.) within the hive a separate intensive study would have to be undertaken; this was not possible for the present study.

FIGURE 26 - NECTAR FLOW RECORDS OF ONE SCALE COLONY FROM EACH OF THE FOUR EXPERIMENTAL GROUPS. (1969)

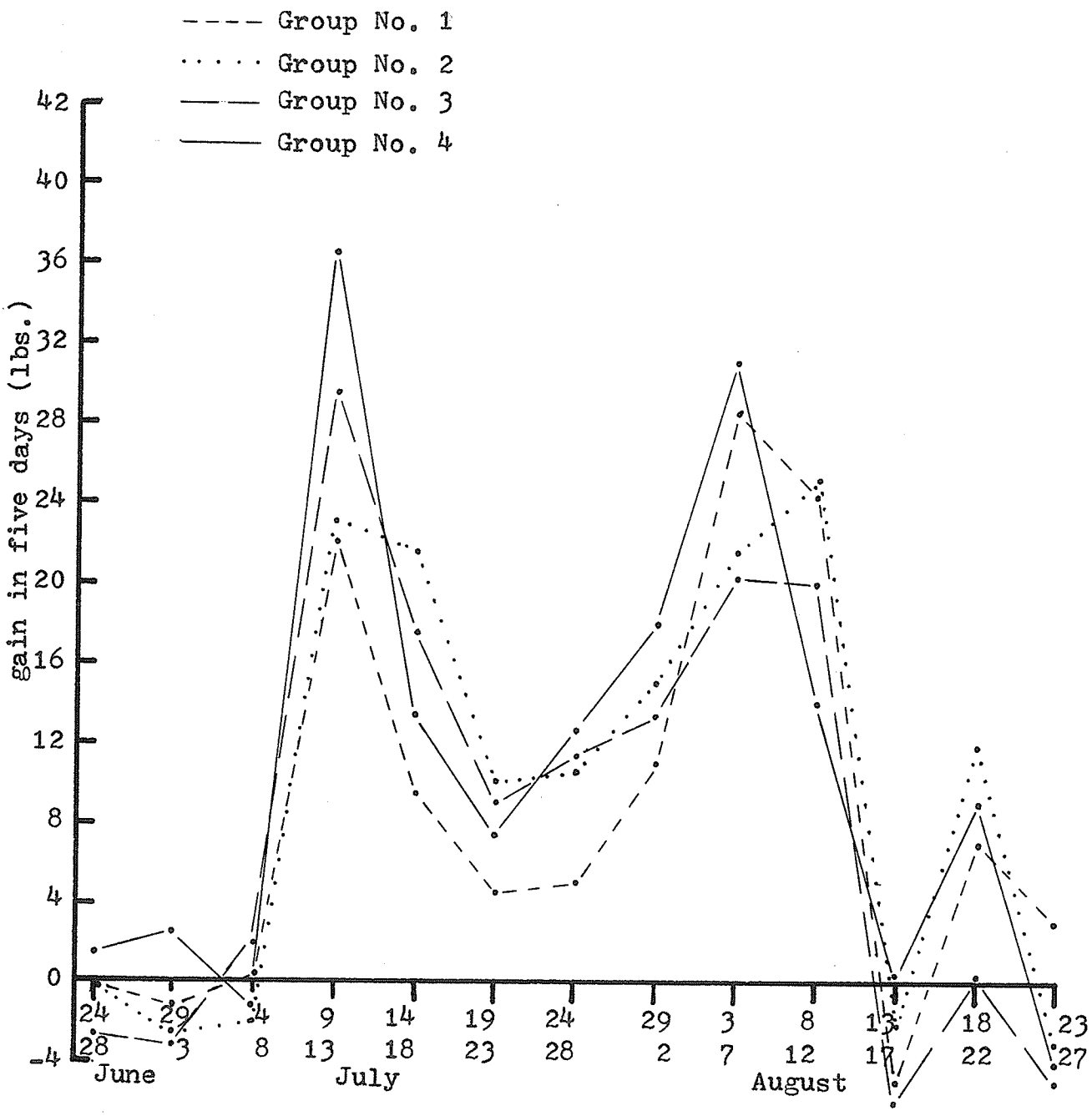


FIGURE 27 - NECTAR FLOW RECORDS OF ONE SCALE COLONY FROM EACH OF THE FOUR EXPERIMENTAL GROUPS. (1970)

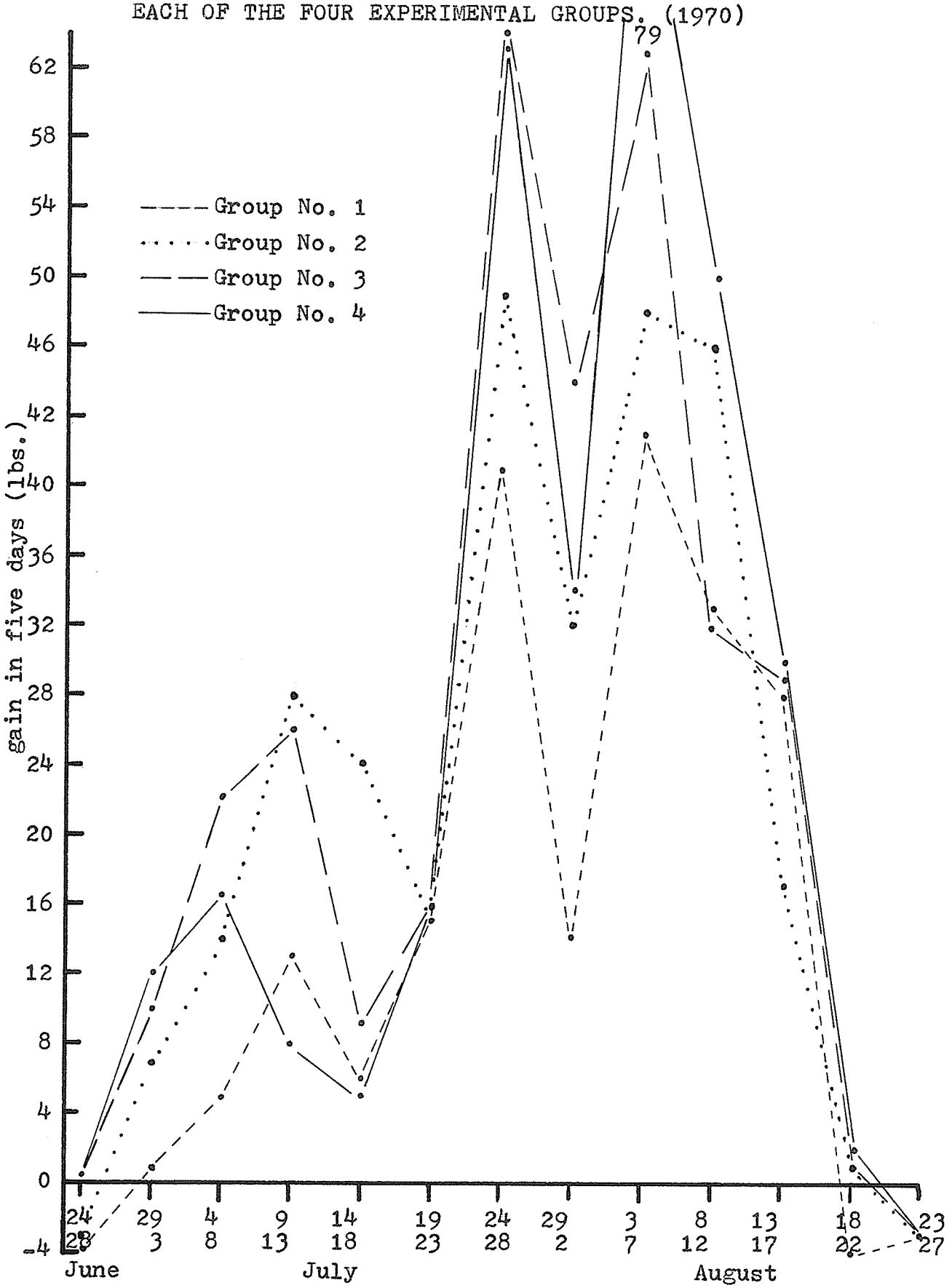


TABLE XXVIII - RELATIVE FORAGING ACTIVITY OF THE FOUR EXPERIMENTAL GROUPS (JUNE and JULY, 1970)

Date		Group No. 1 Bees per 30 Sec.	SD	Group No. 2 Bees per 30 Sec.	SD	Group No. 3 Bees per 30 Sec.	SD	Group No. 4 Bees per 30 Sec.	SD
29 June	PC[1]	8.2[2]	6.0	5.4	4.1	5.8	2.1	8.6	5.1
	NPC	28.9	9.9	35.3	19.3	42.2	18.9	40.0	19.2
	TF	37.1		40.7		48.0		48.6	
	%PC of TF	22.1		13.3		12.1		17.7	
9 July	PC	4.8	3.5	2.8	2.3	4.0	2.4	6.7	2.7
	NPC	37.2	17.1	28.5	26.8	54.8	16.4	48.8	18.2
	TF	42.0		31.3		58.8		55.5	
	%PC of TF	11.4		8.9		6.8		12.1	
Mean	PC	6.5	2.4	4.1	1.8	4.9	1.3	7.7	1.3
	NPC	33.1	5.9	31.9	4.8	48.5	8.9	44.4	6.2
	TF	39.6	3.5	36.0	6.6	53.4	7.4	52.1	4.9
	%PC of TF	16.4		11.4		9.2		14.8	

1 = PC - pollen collectors; NPC - non-pollen collectors; TF - total foragers.

2 = Incoming bees caught per 30 sec.; Mean of three colonies per group.

S.D. standard deviation

TABLE XXIX - RELATIVE FORAGING ACTIVITY OF THE FOUR EXPERIMENTAL GROUPS (AUGUST, 1970)

		Group No. 1		Group No. 2		Group No. 3		Group No. 4	
		Bees per 30 Sec.	SD	Bees per 30 Sec.	SD	Bees per 30 Sec.	SD	Bees per 30 Sec.	SD
5 August	PC[1]	9.3[2]	3.5	1.7	2.0	5.7	2.9	7.0	3.7
	NPC	73.7	22.5	37.0	17.1	54.3	20.3	57.0	17.7
	TF	83.0		38.7		60.0		64.0	
	%PC of TF	11.2		4.4		9.5		10.9	
7 August	PC	3.7	2.4	2.7	1.0	3.5	1.4	3.0	1.7
	NPC	33.7	10.2	30.7	13.4	43.3	13.1	34.2	16.1
	TF	47.4		33.4		46.8		37.2	
	%PC of TF	7.8		8.1		7.5		8.1	
12 August	PC	3.0	2.4	2.3	2.3	5.7	2.0	2.8	2.9
	NPC	47.0	17.0	54.7	27.6	75.0	34.0	69.3	64.5
	TF	50.0		57.0		80.7		72.1	
	%PC of TF	6.0		4.0		7.1		3.9	
Mean	PC	5.3	3.5	2.2	0.5	5.0	1.3	4.3	2.4
	NPC	51.5	24.4	40.8	12.4	57.5	16.1	53.5	17.8
	TF	60.0	19.8	43.0	12.4	62.5	17.1	57.8	18.3
	%PC of TF	8.8		5.1		8.0		7.4	

1 - PC = pollen collectors; NPC = non-pollen collectors; TF = total foragers.

2 - Incoming bees caught per 30 sec.; Mean of three colonies per group.

S.D. - standard deviation

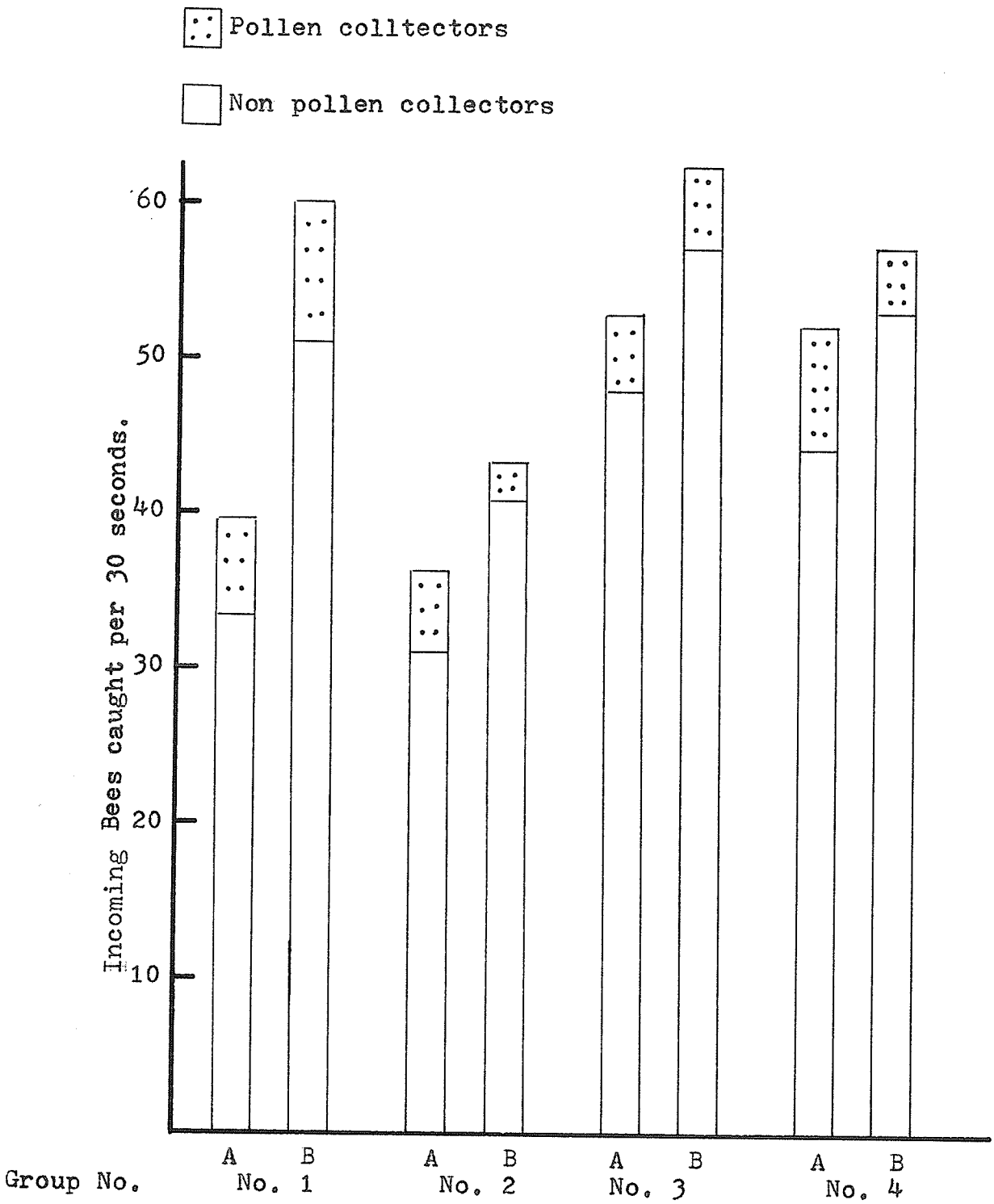
TABLE XXX - RELATIONSHIPS BETWEEN FORAGER ACTIVITY, HIVE POPULATION, AND HONEY PRODUCTION

	Group No.	Period of Activity	Bee[1] Activity	Population Est.	%[2] of Foragers	Population Index	Forager Index	Honey Prod. Index
	1		65	22753	.286	1.00	1.05	1.00
	2	29 June	62	30022	.207	1.32	1.00	1.43
A	3	1 July	87	34971	.249	1.54	1.40	1.29
	4		86	35330	.243	1.55	1.39	1.18
	1		114	42465	.268	1.00	1.33	1.00
	2	5 August	86	50821	.169	1.20	1.00	1.43
B	3	7 August	125	51710	.242	1.22	1.45	1.29
	4	12 August	116	46900	.247	1.10	1.35	1.18
Mean of A and B								
	1					1.00	1.19	1.00
	2					1.26	1.00	1.43
	3					1.38	1.43	1.29
	4					1.33	1.37	1.18

1 - No. of incoming bees, captured in 30 seconds.

2 - % of foragers captured in 30 seconds.

FIGURE 28 - FORAGING ACTIVITY OF THE FOUR EXPERIMENTAL GROUPS (1970)



A - Mean of 29 June and 9 July

B - Mean of 5, 7, and 12 August

C. General Comparisons of Results (1968, 1969, 1970)

(1) Brood Measurements

Although unsealed and total brood areas were measured and studied in 1968 and 1969, sealed brood appears to be the most important brood measurement to consider for development studies of package bees.

(a) Total Brood In 1968 and 1969 maximum total brood areas reached around 1400 square inches after 74 days of colony development. Generally speaking, in both years total brood of group No. 4 > > No. 3 > No. 2 > No. 1; most of the significant differences in amount of total brood produced occurred between group No. 1 and the other three groups up to 50 days of colony development.

(b) Sealed Brood Sealed brood areas were measured in 1968, 1969, and 1970. The lowest mortality occurs in this stage and it is the easiest of the three brood stages to measure.

In 1968 and 1969 most of the experimental groups produced at least 700 square inches of sealed brood at the time of maximum production; several groups produced almost 800 square inches of sealed brood. However, in 1970 the maximum amount of sealed brood produced was just over 600 square inches. It is not known why this difference occurred in 1970. However, a fast build up and an earlier peaking of sealed brood was observed, which may have affected in some way the amount of sealed brood at the time of maximum sealed brood production.

The number of days required to produce maximum sealed brood

areas differ in all three years; approximately 74 days were required in 1968, 86 days in 1969, and 63 days in 1970. The sealed brood probably would have peaked at around 74 days in 1969 if the food supply and cool weather had not caused an interruption in brood rearing.

In general, a significant difference occurred between group No. 1 and the other three groups, which lasted about 50 days, except in 1970 when the difference lasted only 40 days. In all years, generally speaking, group No. 4 > No. 3 > No. 2 > No. 1 in the amount of sealed brood produced, up to the time of maximum production (peaking).

(c) Unsealed Brood Unsealed brood was measured in 1968 and 1969. The main difference in amount of unsealed brood produced, occurred between group No. 1 and the other three groups; in both years maximum unsealed brood production occurred after 74 days of colony development.

(2) Adult Population

Adult numbers were recorded in 1969 and 1970 (see Chapter IV). In both years colonies were still increasing in adult numbers when the study was ended (i.e., at approximately 100 days of development). The main point is that maximum adult numbers are occurring late in honey flow or even after it is over, so that large numbers of bees are produced too late for use on a honey flow; these bees therefore add little to the honey production of a colony.

In general, in both years, the major differences in adult

numbers occurred between group No. 1 and the other three groups. In 1969 differences in adult numbers occurred between most combinations of the groups, up to about 87 days of colony development. However, in 1970 differences between groups only lasted up to 75 days of colony development. This shows that in a year with cold spring weather or where an apiary location provides little nectar and pollen (i.e., 1969), the extra bees in the larger packages aid the colonies in general development; in a year with mild spring weather or where an apiary location provides sufficient nectar and pollen (i.e., 1970), the extra bees in the larger packages initially aid colony development but soon the smaller colonies tend to catch up (being more efficient) and no difference in adult numbers is observed.

(3) Ratios of Brood Cells to Adult Bees

Ratios of brood cells to adults were calculated from the data of 1969 and 1970. In 1969 these ratios were calculated using total, sealed, and unsealed brood; in 1970 only sealed brood was used.

All groups showed a decreasing brood to adult ratio as the season progressed. The most important ratio, i.e., the sealed brood to adult ratio, showed that in both years (1969 and 1970) generally speaking, group No. 1 > No. 2 > No. 3 > No. 4 throughout the season. The main difference in both years occurred between group No. 1 and the other three groups.

(4) Pupal Weights

Pupal weights were recorded in 1968 and 1970. In 1968 a decrease in pupal weights of all groups occurred (probably a nutritional factor) until 28 June, followed by a steady increase until 6 August. In 1970 the pupal weights of all groups increased to 26 August.

(5) Scale Colonies

Scale colonies were used in 1969 and 1970 to monitor the amount of incoming nectar of each experimental group. The nectar flows varied for the two years, largely because of the differences in apiary locations. In each year there were two peaks in nectar flow; the magnitude of these peaks varied greatly. Although the four experimental groups peaked at about the same time, group No. 4 consistently collected more nectar during the period of the peak nectar flow.

(6) Honey Production

Honey production was measured in 1969 and 1970. In 1969 differences in honey yield existed between group No. 1 and groups No. 2 and No. 4, but in 1970 no differences in honey production existed between any of the groups. In a year of cool spring weather or where an apiary location provides little nectar and pollen, it appears that package size does affect honey production.

(7) Entrance Activity

Entrance activity was monitored in 1970. Entrance activity of all groups increased as the season progressed; while the percent of the foragers collecting pollen decreased. The total number of foragers appears to be fairly uniform for all groups during nectar flow.

CHAPTER VI

MISCELLANEOUS STUDIES AND OBSERVATIONS

A. Abnormal Colonies

During the three years certain colonies developed abnormalities due to; (a) queen loss, usually caused by manipulation of equipment during a brood reading (b) queen failure; i.e., the queen is present but brood rearing is below normal (c) supersedure; i.e., queen is replaced by the colony, and (d) swarming. In this study only the 1969 and 1970 data are considered (Tables XXXI and XXXII).

(1) 1969

(a) Queen Losses Queen loss sometimes occurred accidently during a brood measurement or adult reading.

Group No. 3, Colony No. 5 was requeened on 6 May and was considered normal until it "lost" its queen on 30 July. Its population never reached 40,000 bees during the season and its low honey yield probably is a reflection of the low population it produced early in the season.

(b) Queen Failure Queen failure is difficult to evaluate and probably often results in supersedure. However, it is believed that the following colonies fit this category.

Group No. 1, Colony No. 5 began brood rearing at a low rate

and continued with below normal brood production; the maximum population attained was less than 30,000 bees. Its honey yield was also below the mean shown for the normal colonies.

Group No. 3, Colony No. 8 showed a marked decline in brood rearing, starting 28 July. The 8 August reading indicates a supersedure problem or perhaps a swarming problem. Its honey yield was below normal, but higher than expected, considering its low population.

(c) Swarming Group No. 2, Colony No. 1 swarmed on 29 July. The swarm was lost and although the colony was above average in both brood production and adult population to this date, its honey yield was only about one-third of the group average.

Group No. 3, Colony No. 4 swarmed in the last week of July and although it showed above average performance to this time, its honey production was about one-half of the group average.

Group No. 4, Colony No. 3 swarmed in mid-July. Although brood data were not available after 16 July, the adult population reached 50,000 bees indicating that the swarm may have returned, but the honey yield was only about one-third of the group average.

(2) 1970

(a) Queen Losses Group No. 1, Colony No. 3 lost its queen during the 28 May reading and was requeened 1 June. Its brood production was up to the group average by 16 July and remained above the average thereafter. However, its honey yield was about one-half of the normal colony average, probably due to its low

adult population.

Group No. 2, Colony No. 5 lost its queen probably during the 4 July reading. Its brood production was above average on 28 July and 10 August but the honey yield was two-thirds of the normal colony average.

Group No. 3, Colony No. 5 lost its queen during the 16 July reading but was promptly requeened. Brood production was very low during the rest of the season and the honey yield was about one-half of the normal colony average.

Group No. 3, Colony No. 7 lost its queen around 28 July and its honey yield fell well below the normal colony average.

Group No. 4, Colonies No. 2 and No. 7 lost their queens in early August and both fell below the normal colony average.

(b) Queen Failure Group No. 2, Colony No. 9 showed that the queen was "failing" after the 9 June reading and thereafter did not produce an average amount of brood. Its honey yield was less than the normal colony average.

Group No. 2, Colonies No. 1, No. 2 and No. 3 showed signs of queen "failure" starting 28 July although only Colony No. 1 had an obvious reduction in honey produced.

Group No. 4, Colony No. 3 had a failing queen about 16 July but the colony probably did not supersede her.

Group No. 4, Colony No. 9 had a failing queen about 16 July and probably superseded her. The honey production for this colony was high although the adult population never reached 30,000 bees.

Group No. 4, Colony No. 10 had a failing queen about 10 Aug-

ust yet had a good honey yield.

(c) Supersedure Group No. 1, Colony No. 4 superseded its queen about 9 July. The brood rearing and adult numbers were below normal for the entire season, resulting in a below normal honey yield.

Group No. 2, Colony No. 7 superseded its queen in late May, and became queenless near the end of June. Requeening was not successful and the colony was removed from the test.

Group No. 3, Colony No. 1 superseded its queen in mid-May and although it reared substantial amounts of brood and adult populations, its honey yield was about one-half of the normal colony average.

Group No. 4, Colony No. 9 superseded its queen in late May followed by a queen failure in mid-July. In spite of this, the honey yield was only 30 lbs. less than the normal colony average.

(d) Swarming Group No. 3, Colony No. 5 swarmed around 16 July. Up to this time its brood production had been above average, but the loss of adult bees greatly reduced honey production.

Group No. 4, Colony No. 8 swarmed around 22 June; the swarm was captured and replaced in the hive. Although by 16 July a failing queen was evident, honey production was quite high.

(3) Summary of Abnormal Colonies

In all cases honey production of abnormal colonies was less than the normal colony average for each group. Several of the

TABLE XXXI - PERFORMANCE OF ABNORMAL COLONIES (1969)

Group	Hive		May 16	May 28	June 9	June 21	July 3	July 16	July 28	August 8	Honey Prod.
No. 1	5	UN[1]	56	103	207	167	375	564	-	-	46
		S	80	76	74	313	287	587	789	749	
		T	181	179	281	480	662	1151	-	-	
		Ad	2195	-	3275	-	9450	19850	26375	-	
		P	(b)								
	group mean	UN	105	247	357	417	522	523	-	-	55
		S	132	113	274	255	350	587	791	717	
		T	238	360	631	672	871	1110	-	-	
		Ad	2930	-	7793	-	12893	21930	29449	-	
No. 2	1	UN	232	429	589	683	553	655	256	11	34
		S	289	256	536	581	611	673	566	284	
		T	521	685	1125	1264	1164	1328	822	295	
		Ad	6225	-	17450	-	38650	36950	45675	-	
		P							(d)		
	group mean[2]	UN	199	404	484	531	540	662	626	624	93
		S	245	222	480	443	430	583	574	508	
		T	444	626	965	974	971	1245	1200	1132	
		Ad	5906	-	15525	-	25956	30184	34289	-	

continued.....

TABLE XXXI (1969) - Continued

Group	Hive		May 16	May 28	June 9	June 21	July 3	July 16	July 28	August 8	Honey Prod.
No. 3	4	UN[1]	350	366	672	683	705	962	611	36	41
		S	328	423	577	629	613	401	673	434	
		T	678	789	1249	1312	1318	1363	1284	470	
		Ad	8650	-	19900	-	29100	36300	40050	-	
		P								(d)	
	5	UN	20	336	345	465	542	617	715	44	62
		S	114	183	451	340	444	595	624	474	
		T	134	519	796	805	986	1212	1339	518	
		Ad	9225	-	9950	-	21850	30475	39500	-	
		P	(a)							(b)	
	8	UN	247	466	706	574	571	648	242	165	65
		S	323	343	553	415	349	532	558	230	
		T	570	809	1259	989	920	1180	800	395	
		Ad	8150	-	17650	-	24375	19525	18375	-	
		P						(b)			
	group mean	UN	284	413	623	588	605	767	512	440	86
		S	312	350	513	500	468	554	597	489	
		T	596	763	1136	1088	1073	1328	1109	942	
		Ad	8611	-	19350	-	30182	34125	42550	-	

continued.....

TABLE XXXI (1969) - Continued

Group	Hive		May 16	May 28	June 9	June 21	July 3	July 16	July 28	August 8	Honey Prod.
No. 4	3	UN[1]	322	455	595	543	555	-	-	-	37
		S	271	436	525	564	486	-	-	-	
		T	593	891	1120	1107	1041	-	-	-	
		Ad	8850	-	19450	-	29475	-	40975	50625	
		P						(d)			
	group mean	UN	338	528	686	571	600	627	-	-	118
		S	305	471	631	572	459	736	778	582	
		T	644	999	1317	1143	1059	1363	-	-	
		Ad	9475	-	21722	-	33969	44675	49020	-	

1 - UN = unsealed; S = sealed; T = total brood; Ad = adults; P = problem and time.

2 - Group mean (ie) mean of normal colonies at each date.

* Problem and time of occurence
(a) queen loss
(b) queen failure
(c) supersedure
(d) swarmed

TABLE XXXII - PERFORMANCE OF ABNORMAL COLONIES (1970)

Group	Hive		May 28	June 9	June 22	July 4	July 16	July 28	August 10	Honey Production
No. 1	3	S[1]	83	0	279	277	536	578	650	117
		Ad	2775	-	3650	-	15450	-	24550	
		P	(a)							
	4	S	63	194	343	465	565	426	377	208
		Ad	4900	-	10400	-	33400	-	35350	
		P		(c)						
	group mean	S[2]	169	262	434	548	560	486	439	224
		Ad	4322	-	11736	-	33771	-	42465	
No. 2	5	S	246	492	592	0	120	497	421	199
		Ad	6450	-	19600	-	46850	-	44600	
		P				(a)				
	7	S	247	104	401	-				-
		Ad	3300	-	8850	-	out			
		P	(c)							
	9	S	250	300	198	309	308	359	320	184
		Ad	6550	-	15900	-	2900	-	37250	
		P			(b)					
	1	P						(b)		171
		P						(b)		275
		P						(b)		265
	group mean	S[2]	264	408	509	645	499	422	353	320
		Ad	6731	-	18944	-	41100	-	50821	

continued.....

TABLE XXXII (1970) - Continued

Group	Hive		May 28	June 9	June 22	July 4	July 16	July 28	August 10	Honey Production
No. 3	1	S	365	401	376	-	507	219	463	168
		Ad	6725	-	20800	-	29700	-	45350	
		P	(c)							
	5	S	422	441	553	657	483	312	-	136
		Ad	7525	-	24500	-	-	-	37300	
		P					(d)			
	9	S	236	396	461	535	471	160	101	149
		Ad	5750	-	18750	-	33800	-	34050	
							(a)			
	6	P							(b)	243
	7							(a)		175
	group mean	S	316	428	501	630	588	527	442	289
		Ad	6972	-	22928	-	47014	-	51710	

continued.....

TABLE XXXII (1970) - Continued

Group	Hive		May 28	June 9	June 22	July 4	July 16	July 28	August 10	Honey Production
No. 4	3	S	350	528	616	741	565	147	9	122
		Ad	8550	-	21300	-	27400	-	35750	
		P					(b)			
	8	S	381	466	304	412	-	40	387	194
		Ad	11100	-	28650	-	43300	-	26400	
		P					(d)			
	9	S	62	428	485	554	381	71	211	229
		Ad	8025	-	17200	-	22450	-	24945	
		P	(c)				(b)			
	2	P						(a)		104
	7	P						(a)		219
	10	P							(b)	200
	6	P	Drone Layer, out!							-
	group mean	S	340	481	526	633	481	435	441	264
		Ad	10197	-	24244	-	46417	-	46900	

1 - UN = unsealed; S = sealed; T = total brood; Ad = adults; P = problem and time.

2 - Group mean - (ie) mean of normal colonies at each date.

(a) queen loss
(b) queen failure
(c) supersedure
(d) swarmed

colonies however, had a good honey yield. It should be noted that there was considerable variation in the honey production of the colonies considered to be normal.

It appears that if a colony is requeened or if supersedure occurs early in the season (i.e., within two to three weeks of hiving) that normal quantities of brood are eventually produced. Honey production of these colonies may be less than the normal colony average and yet usually lies within the variation shown by the normal colonies.

Queen loss or queen failure during the season appears to result in below normal brood areas even if the colony is requeened successfully; honey production of these colonies is usually about one-half of the normal colony average.

Swarming usually results in the greatest loss in honey production, often being one-third to one-half of that of the normal colony average.

B. Drone Brood

The quantities of drone brood in colonies has been shown to be significantly affected by the time of the season and the amount of drone comb present (Allen, 1963, 1965; Free, 1967).

Allen (1965) showed that drone brood increases during summer. She found no significant difference in honey production between colonies with "normal" amounts of drone brood and colonies in which the amount of drone brood had been artificially increased, nor was a correlation between swarming tendency and drone production observed

TABLE XXXIII - SEALED DRONE BROOD PRESENT IN THE 1969 AND 1970 NORMAL EXPERIMENTAL COLONIES

Date	Group No. 1	Group No. 2	Group No. 3	Group No. 4
(1969)				
11 June	0.4[1]	2.3	3.1	2.7
23 June	0.6	3.3	5.2	4.2
5 July	1.6	8.2	6.9	3.4
16 July	5.3	6.0	4.9	10.2
28 July	9.0	4.4	2.6	14.2
10 August	6.5	6.0	1.4	10.1
20 August	-	4.6	1.3	-
Mean percent	5.3	5.0	4.0	7.0
(1970)				
9 June	1.0	3.0	5.2	4.9
22 June	5.1	2.8	3.0	4.2
4 July	3.4	2.5	6.1	7.4
16 July	4.3	3.2	3.2	4.3
28 July	2.7	2.3	4.0	8.5
10 August	2.7	1.1	3.5	1.2
Mean percent	3.4	2.7	4.3	5.3

1 - as a percent of the total sealed brood (ie.) worker and drone.

(Allen, 1963, 1965).

In 1969 maximum sealed drone brood production occurred at different times but in general it occurred from mid-July to the end of July (Table XXXIII).

In 1970 all groups showed maximum sealed drone production in mid-July (Table XXXIII). The amount of sealed drone brood produced was less in 1970; this same trend occurred in sealed worker brood. This may indicate that in a year of low nectar production drone production increases.

C. Colony Management Problems of the Four Experimental Groups

During this three year study, abnormalities occurred with greater frequency in the larger groups, i.e., group No. 4 > No. 3 > No. 2 > No. 1. There were generally more queen cells produced and a greater frequency in swarming, probably due to the higher population. The extent of the swarming was minimal in this study and and probably less than normal, mainly because of the frequent attention given to this problem.

In 1970 groups No. 2, No. 3 and No. 4 all had a high incidence of queen problems (see Chapter VI) and only three to five normal colonies were remaining in each group by 10 August. On the other hand, group No. 1 experienced much less trouble, in that few queen cells were built and no tendency to swarm was apparent; the honey yield was just as high as that of the other groups in 1970.

CHAPTER VII

GENERAL SUMMARY

This investigation was designed to study the development and performance of honey bee colonies in Manitoba when different sizes of packages of bees were established in hives.

Chapter III

In this three year study total brood (1968 and 1969), unsealed brood (1968 and 1969), sealed brood (1968, 1969 and 1970), adult populations (1969 and 1970), pupal weights (1968 and 1970), nectar flows (1969 and 1970), honey production (1969 and 1970), and forager activity (1970) were measured in hives initiated from one, two, three and four pound packages.

Brood measurements (1968 and 1969) were done by tracing brood patterns on glass sheets ruled in one inch squares and in 1970 by photographing the sealed brood. Adult populations were estimated by comparing each frame of bees to a series of photographs of frames showing a graded series of bees.

Chapter IV

The method of adult estimation using photographs is described.

Over a three year period sixteen different people estimated bees on single frames, and within whole colonies. The method was

found to be fast and efficient and caused little disturbance of the colonies; most observers could estimate the total number of adults within eight percent after an initial four to six hour training period.

Chapter V

This study showed that hives initiated from the four pound packages produced more brood than did the other three sizes of packages; however, the main differences in brood production occurred between group No. 1 and the other three groups.

The maximum amount of brood was produced after about 74 days of colony development in 1968 and 1969, and at about 63 days in 1970.

Adult populations increased during this study up to 100 days, indicating that maximum populations were produced after the end of the main honey flow. The two year average of adult populations for a development period of 100 days for groups No. 1, No. 2, No. 3 and No. 4 are 41,250, 42,740, 50,860, 51,200 respectively.

Ratios of brood cells to adult numbers decreased throughout the season for all groups but the rate of decrease was less for group No. 1, indicating that they were more efficient in producing brood.

Pupal weights tended to increase throughout the season with group No.4 producing the heaviest pupae.

In 1969 honey production was significantly greater for group No. 4 than for the other three groups, but in 1970 no statistical differences in honey production occurred.

Entrance activity increased during the season for all groups and in general all groups had similar numbers of foragers during honey flow.

Chapter VI

Abnormal colonies (e.g., lost queen, superseded queen, swarming, etc.) produced less honey than did normal ones.

Similar amounts of sealed drone brood were produced by each group in each of the two years studied; but the amount of sealed drone brood produced in the two years differed considerably.

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APPENDIX TABLE I - BROOD MEASUREMENTS OF THE FOUR EXPERIMENTAL GROUPS, HIVED 6 MAY 1968

Hive Reading	1 lb. Group*				2 lb. Group				3 lb. Group				4 lb. Group		
	H**	UN	S	T	H	UN	S	T	H	UN	S	T	H	UN	S	T
21 May	1	116	58	174	1	147	115	262	1(b)	112	0	112	1	244	133	377
	2	89	46	135	2	115	100	215	2	284	143	391	2	200	25	225
	3	121	76	197	3	162	81	243	3	149	14	163	3	265	14	279
	4	103	50	153	4	135	102	237	4	143	194	337	4(b)	144	15	159
	5	124	47	171	5	181	61	242	5	185	45	230	5	308	62	370
	6(a)	0	83	83	6	150	16	166	6	191	157	348	6	254	83	337
	7	120	20	140	7	136	49	185	7	249	134	383	7	268	61	329
	8	159	71	230	8	76	40	116	8	145	60	205	8	241	102	343
3 June	1	122	148	270	1	278	274	522	1	116	123	239	1	422	467	889
	2	144	108	252	2	259	187	446	2	335	352	687	2	284	301	585
	3	158	111	269	3	238	249	487	3	248	254	502	3	349	483	832
	4	220	110	330	4	327	239	566	4	316	278	594	4	215	231	446
	5	147	98	245	5	308	298	606	5	362	330	692	5	376	442	818
	6	161	47	208	6	217	216	433	6	386	336	722	6(a)	0	231	231
	7	133	130	263	7	215	222	437	7	426	458	884	7	246	461	707
	8	221	119	340	8	223	157	380	8	298	247	545	8	464	420	884
14 June	1	185	220	405	1	404	446	850	1	180	168	348	1	519	598	1117
	2	189	200	389	2	310	415	725	2	386	545	931	2	303	355	658
	3	262	261	523	3	342	304	646	3	397	248	645	3	477	477	954
	4	207	232	439	4	450	534	984	4	326	478	801	4	241	270	511
	5	187	137	324	5	352	369	721	5	381	403	784	5	456	515	971
	6	142	297	439	6	277	402	679	6	385	556	941	6	- -	- -	- -
	7	197	144	341	7	394	303	697	7	602	626	1228	7	176	540	716
	8	216	271	484	8	291	349	640	8	358	433	791	8	470	674	1144

Continued.

APPENDIX TABLE I (1968) - Continued.

Hive Reading	1 lb. Group*				2 lb. Group				3 lb. Group				4 lb. Group			
	H**	UN	S	T	H	UN	S	T	H	UN	S	T	H	UN	S	T
26 June	1	241	349	590	1	611	793	1404	1	155	242	397	1	516	971	1487
	2	343	352	695	2	365	600	965	2(a)	- -	- -	- -	2(b)	249	358	607
	3	393	366	760	3	388	515	903	3	615	669	1284	3	598	799	1397
	4	428	379	807	4	564	572	1136	4	486	621	1107	4	141	170	312
	5	256	206	462	5	584	658	1242	5	421	582	1003	5	507	642	1149
	6	399	330	729	6	384	456	840	6	552	661	1213	6	290	0	290
	7	347	281	628	7	291	703	994	7	609	943	1552	7	514	789	1303
	8	524	385	909	8	490	440	930	8	501	562	1063	8	552	862	1414
8 July	1	416	443	859	1	614	768	1382	1	416	171	587	1	598	747	1345
	2	614	590	1204	2	593	534	1127	2	0	0	0	2	224	415	639
	3	637	613	1250	3	405	617	1022	3	533	784	1317	3	561	628	1189
	4	543	568	1111	4	459	807	1266	4	620	787	1407	4	27	325	352
	5	474	384	858	5	500	640	1140	5	400	585	985	5	621	626	1247
	6	608	693	1301	6	465	527	992	6	532	961	1493	6	448	492	940
	7(a)	0	0	698	7	411	691	1102	7	559	743	1302	7	701	725	1426
	8	756	698	1454	8	563	695	1258	8	591	693	1284	8	752	935	1687
20 July	1	428	660	1088	1	894	756	1650	1	337	410	747	1	538	846	1384
	2	499	711	1210	2(b)	273	428	701	2	190	0	190	2	204	328	532
	3	578	680	1258	3	533	696	1249	3	738	818	1556	3	501	598	1099
	4	670	693	1363	4	389	887	1276	4	682	756	1438	4	0	140	140
	5	356	572	928	5	710	720	1430	5	510	576	1086	5	809	587	1396
	6	480	869	1349	6	599	497	1096	6	708	739	1447	6	1	465	465
	7	0	6	6	7	637	636	1273	7	736	833	1569	7	647	862	1509
	8	554	839	1393	8	664	680	1344	8	517	710	1227	8	826	880	1706

continued.

APPENDIX TABLE I (1968) - Continued.

Hive Reading	1 lb. Group*				2 lb. Group				3 lb. Group				4 lb. Group		
	H**	UN	S	T	H	UN	S	T	H	UN	S	T	H	UN	S	T
1 August	1	557	593	1150	1	753	866	1619	1	296	513	809	1	563	741	1304
	2	645	725	1370	2	605	439	1044	2	501	403	904	2	- -	- -	- -
	3	770	734	1504	3	695	724	1419	3	903	849	1752	3(d)	0	220	220
	4(a)	0	320	320	4	444	724	1168	4	421	654	1075	4	- -	- -	- -
	5	575	592	1167	5	629	723	1352	5	545	553	1098	5(a)	- -	- -	- -
	6	452	857	1309	6	612	570	1182	6	465	719	1184	6	- -	- -	- -
	7	462	185	647	7	704	552	1256	7	498	780	1278	7	702	858	1560
	8	674	739	1413	8	616	695	1311	8	653	602	1255	8	702	777	1479
13 August	1	351	689	1040	1	361	602	963	1	- -	- -	- -	1	560	593	1153
	2	410	645	1055	2	514	491	1005	2	453	620	1070	2	- -	- -	- -
	3	349	592	941	3	441	617	1058	3	553	621	1174	3	- -	- -	- -
	4	- -	- -	- -	4	583	826	1409	4	403	418	821	4	- -	- -	- -
	5	- -	- -	- -	5	- -	- -	- -	5	- -	- -	- -	5	- -	- -	- -
	6	- -	- -	- -	6	508	446	954	6	- -	- -	- -	6	- -	- -	- -
	7	366	611	977	7	- -	- -	- -	7	- -	- -	- -	7	502	727	1229
	8	518	671	1189	8	- -	- -	- -	8	- -	- -	- -	8	- -	- -	- -

All brood in square inches.
* ie. each hive in this group was initiated with one pound of bees.
** H = Hive number, UN = Unsealed brood, S = Sealed brood, T = Total brood.
(a) Queen lost
(b) Queen failure
(c) Superceded
(d) Swarmed

APPENDIX TABLE II - BROOD AND ADULT MEASUREMENTS OF THE FOUR EXPERIMENTAL GROUPS, HIVED 3 MAY 1969

	1 lb. Group*					2 lb. Group				
	H**	UN	S	T	Ad	H	UN	S	T	Ad
16 May	1	126	150	276	2525	1	232	289	521	6225
	2	119	120	239	3055	2	156	225	381	4350
	3	93	184	277	2850	3	205	284	489	6100
	4	115	129	244	2645	4	204	280	484	5550
	5(b)	56	24	80	2100	5	238	217	455	6325
	6	101	80	181	2195	6	185	224	409	6150
	7	78	103	181	3400	7	227	243	470	6525
	8	107	162	269	3840	8	145	200	345	6025
28 May	1	242	137	379		1	429	256	685	
	2	345	61	406		2	348	203	551	
	3	170	148	318		3	450	229	679	
	4	242	103	345		4	355	227	582	
	5	103	76	179		5	454	178	632	
	6	213	68	281		6	356	242	598	
	7	257	136	393		7	471	229	700	
	8	263	138	401		8	368	216	584	
11 June	1	346	311	657	9000	1	589	536	1125	17450
	2	361	356	717	7950	2	420	457	877	12950
	3	455	204	659	9525	3	536	519	1055	18025
	4	252	143	395	8300	4	646	450	1096	17975
	5	207	74	281	3275	5	433	459	892	13550
	6	357	276	633	4875	6	299	491	790	14600
	7	338	314	652	7000	7	482	509	991	15450
	8	394	315	709	7900	8	471	423	894	14200

continued.....

APPENDIX TABLE II (1969) - Continued

	3 lb. Group					4 lb. Group				
	H	UN	S	T	Ad	H	UN	S	T	Ad
	1	330	301	631	10375	1	365	323	688	9450
	2	194	294	488	8275	2	303	303	606	9875
	3	299	283	582	9900	3	322	271	593	8850
	4	350	328	678	8650	4	337	247	584	10125
16	5(a)	20	114	134	9225	5	350	350	700	10225
May	6	229	300	529	6975	6	304	307	611	9725
	7	338	354	692	8300	7	352	368	720	9500
	8	247	323	570	8150	8	374	274	648	10050
	1	460	389	849		1	481	452	933	
	2	478	295	773		2	428	451	879	
	3	356	355	711		3	455	436	891	
28 May	4	366	423	789		4	706	431	1137	
	5	336	183	519		5	592	516	1108	
	6	399	342	741		6	410	469	879	
	7	368	302	670		7	511	462	973	
	8	466	343	809		8	640	551	1191	
	1	628	466	1094	21000	1	684	675	1359	22300
	2	455	430	985	19425	2	632	537	1169	22250
	3	639	458	1097	19975	3	595	525	1120	19450
11	4	672	577	1249	19900	4	822	671	1493	21375
June	5	345	451	796	9950	5	707	655	1362	22850
	6	575	568	1143	20175	6	639	584	1223	20725
	7	589	536	1125	17325	7	660	730	1390	22650
	8	706	553	1259	17650	8	747	670	1417	22175

APPENDIX TABLE II (1969) - Continued

	1 lb. Group					2 lb. Group				
	H	UN	S	T	Ad	H	UN	S	T	Ad
23 June	1	460	347	807		1	683	581	1264	
	2	389	305	694		2	503	454	957	
	3	488	359	847		3	481	400	881	
	4	380	201	581		4	528	405	933	
	5	167	313	480		5	489	342	831	
	6	293	157	450		6	593	533	1126	
	7	453	235	688		7	456	461	917	
	8	455	183	638		8	518	368	886	
5 July	1	568	418	986	12415	1	553	611	1164	38650
	2	683	361	1044	14025	2	608	439	1047	25500
	3	489	344	833	14250	3	487	477	964	27100
	4	556	321	877	13650	4	588	395	983	21550
	5	375	287	662	9450	5	564	379	943	22150
	6	434	317	751	10250	6	517	390	907	28200
	7	419	349	768	11650	7	483	430	913	24750
	8	502	337	839	14000	8	521	326	847	19750
16 July	1	- -	- -	- -	27725	1	655	673	1328	36950
	2	581	585	1166	20550	2	642	583	1225	22400
	3	637	645	1282	24400	3	720	605	1325	30100
	4	546	635	1181	19820	4	653	514	1167	33375
	5	564	587	1151	19850	5	627	617	1244	41525
	6	- -	- -	- -	- -	6	749	524	1273	28800
	7	384	520	904	22950	7	602	614	1216	23600
	8	466	551	1017	- -	8	649	533	1182	24725

continued.....

APPENDIX TABLE II (1969) - Continued

	3 lb. Group					4 lb. Group				
	H	UN	S	T	Ad	H	UN	S	T	Ad
23 June	1	643	538	1181		1	527	485	1012	
	2	600	482	1082		2	450	600	1050	
	3	570	585	1155		3	543	564	1107	
	4	683	629	1312		4	626	693	1319	
	5	465	340	805		5	488	475	963	
	6	488	433	921		6	697	548	1245	
	7	557	419	976		7	514	572	1086	
	8	574	415	989		8	724	637	1361	
5 July	1	628	473	1101	32000	1	552	425	977	32700
	2	692	484	1176	29450	2	664	445	1109	31475
	3	474	502	976	30550	3	555	486	1041	29475
	4	705	613	1318	29100	4	671	589	1260	38700
	5	542	444	986	21850	5	574	425	999	34500
	6	563	393	956	35200	6	602	493	1095	32500
	7	603	460	1063	30600	7	526	437	963	33500
	8	571	349	920	24375	8	658	361	1019	38900
16 July	1	563	486	1049	49150	1	- -	- -	- -	41200
	2	702	520	1222	32500	2	541	636	1177	38250
	3	753	558	1311	32600	3(d)	- -	- -	- -	40975
	4	962	401	1363	36300	4	770	722	1492	48750
	5	617	595	1212	30475	5	584	827	1411	42400
	6	630	536	1166	30925	6	- -	- -	- -	34250
	7	822	756	1578	38300	7	612	760	1372	49300
	8(b)	648	532	1180	19525	8	- -	- -	- -	- -

continued.....

APPENDIX TABLE II (1969) - Continued

	1 lb. Group					2 lb. Group				
	H	UN	S	T	Ad	H	UN	S	T	Ad
28 July	1		842		33340	1(d)	256	566	822	45675
	2		834		32850	2	471	544	1015	36950
	3		895		28125	3	667	521	1188	42025
	4		813		30775	4	752	524	1276	32350
	5		789		26375	5	742	586	1328	31150
	6		811		24100	6	658	640	1298	33800
	7		554		28950	7	505	576	1081	34475
	8		788		28000	8	585	632	1217	29275
10 August	1		671			1	11	284	295	
	2		777			2	653	469	1122	
	3		874			3	644	618	1262	
	4		796			4	570	398	968	
	5		749			5	579	461	1040	
	6		723			6	655	411	1066	
	7		398			7	620	511	1131	
	8		786			8	647	688	1335	
20 August	1				56550	1	- -	- -	- -	- -
	2				46150	2	498	468	966	37350
	3				- -	3	- -	- -	- -	- -
	4				- -	4	571	435	1006	32000
	5				- -	5	668	417	1085	- -
	6				30800	6	- -	- -	- -	- -
	7				28700	7	550	575	1125	- -
	8				38000	8	597	651	1248	- -

continued.....

APPENDIX TABLE II (1969) - Continued

	3 lb. Group					4 lb. Group				
	H	UN	S	T	Ad	H	UN	S	T	Ad
	1(d)	123	255	378	53225	1		647		49725
	2	506	404	910	38050	2		758		46425
	3	472	600	1072	48100	3		- -		50625
28	4	611	673	1284	40050	4		- -		61950
July	5	715	624	1339	39500	5		981		49800
	6	540	723	1263	34950	6		726		51450
	7	432	584	1016	51600	7		- -		50625
	8	242	558	800	28375	8		776		47700
	1	4	60	64		1		583		
	2	580	495	1075		2		494		
	3	287	488	775		3		337		
10	4(d)	36	434	470		4		- -		
August	5	44	474	518		5		716		
	6	551	718	1269		6		462		
	7	341	308	649		7		- -		
	8	165	230	395		8		654		
	1	- -	- -	- -	- -	1				44725
	2	345	235	580	39500	2				51900
	3	183	122	305	58400	3				- -
20	4	- -	- -	- -	- -	4				- -
August	5	- -	- -	- -	- -	5				59750
	6	655	616	1271	46250	6				- -
	7	306	296	602	55900	7				- -
	8	46	584	630	- -	8				65650

All brood in square inches.
* ie. each hive in this group was initiated with one pound of bees.
** H - Hive number, UN - Unsealed brood, S - Sealed brood, T - Total brood, Ad - Adults
(a) queen lost (b) queen failure (c) superceded (d) swarmed

APPENDIX TABLE III - SEALED BROOD AND ADULT MEASUREMENTS OF FOUR EXPERIMENTAL GROUPS

HIVED, 2 MAY 1970

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
	H**	S	Ad	H	S	Ad	H	S	Ad	H	S	Ad
	1	167	4150	1	302	6450	1(c)	365	6725	1	390	12450
	2	120	3550	2	258	6375	2	434	7350	2	379	11750
	3(a)	83	2775	3	286	8000	3	403	6175	3	350	8550
28	4	63	4900	4	345	7700	4	331	8200	4	343	11600
May	5	209	5125	5	246	6450	5	422	7525	5	216	6675
	6	149	3450	6	142	6100	6	209	7300	6(a)	- -	8650
	7	189	4725	7(c)	247	3300	7	150	5150	7	306	8700
	8	175	5025	8	261	6900	8	382	7300	8	381	11100
	9	179	4230	9	250	6550	9	236	5750	9(c)	62	8025
	10(a)	- -	2925	10	293	6050	10	278	8000	10	358	10750
	1	297		1	535		1	401		1	422	
	2	211		2	411		2	499		2	516	
	3	0		3	482		3	463		3	528	
9	4(c)	194		4	440		4	452		4	498	
June	5	159		5	492		5	441		5	481	
	6	216		6	269		6	380		6	out	
	7	344		7	104		7	379		7	433	
	8	296		8	406		8	339		8	466	
	9	317		9	300		9	396		9	428	
	10	out		10	339		10	510		10	504	

continued.....

APPENDIX TABLE III (1970) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
	H**	S	Ad	H	S	Ad	H	S	Ad	H	S	Ad
22 June	1	361	13650	1	626	19250	1	376	20800	1	504	27900
	2	479	9750	2	493	20100	2	587	28950	2	506	22600
	3	279	3650	3	454	18450	3	688	24700	3	616	21300
	4	343	10400	4	498	21300	4	441	22550	4	466	25550
	5	403	8250	5	592	19600	5	553	24500	5	609	17700
	6	360	10850	6	446	14650	6	383	20250	6	out	
	7	448	13250	7	401	8850	7	397	15650	7	518	20800
	8	466	14050	8	544	21350	8	461	26900	8(d)	304	28650
	9	525	12350	9(b)	198	15900	9	461	18750	9	485	17200
	10	out		10	423	19900	10	544	24100	10	468	29450
4 July	1	503		1	598		1	- -		1	635	
	2	599		2	683		2	654		2	688	
	3(a)	277		3	628		3	815		3	741	
	4	465		4	584		4	664		4	647	
	5	514		5(a)	0		5	657		5	641	
	6	467		6	588		6	467		6	out	
	7	568		7(a)	- -		7	499		7	502	
	8	603		8	768		8	683		8	412	
	9	585		9	309		9	535		9	554	
	10	out		10	668		10	700		10	579	

continued.....

APPENDIX TABLE III (1970) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
	H**	S	Ad	H	S	Ad	H	S	Ad	H	S	Ad
16 July	1	442	35350	1	463	26800	1	507	29700	1	484	47450
	2	688	31150	2	525	45850	2	640	56500	2	461	49450
	3	536	15450	3	512	49050	3	754	61550	3(b)	565	27400
	4	565	33400	4	399	44550	4	561	44250	4	468	47850
	5	595	34050	5	120	46850	5(d)	483	- -	5	529	39150
	6	457	30700	6	586	38600	6	403	41900	6	out	
	7	523	38600	7	out		7	545	31450	7	415	48000
	8	683	28200	8	454	48750	8	584	48100	8	- -	43300
	9	533	38350	9	308	29000	9(a)	471	33800	9	381	22450
	10	out		10	554	46200	10	632	45350	10	533	46600
28 July	1	302		1(b)	83		1	219		1	467	
	2	504		2(b)	361		2	526		2(a)	311	
	3	578		3(b)	301		3	640		3	147	
	4	426		4	256		4	610		4	483	
	5	550		5	497		5	312		5	356	
	6	630		6	468		6	318		6	- -	
	7	449		7	out		7(a)	0		7(a)	204	
	8	598		8	637		8	494		8	40	
	9	474		9	359		9	160		9	71	
	10	out		10	490		10	576		10	355	

continued.....

APPENDIX TABLE III (1970) - Continued

	1 lb Group			2 lb. Group			3 lb. Group			4 lb. Group		
	H**	S	Ad	H	S	Ad	H	S	Ad	H	S	Ad
	1	201	32650	1	96	33050	1	463	45350	1	414	51200
	2	405	46850	2	- -	22075	2	298	60650	2	0	32750
	3	650	24550	3	385	50400	3	494	65500	3	9	35750
10	4	377	35350	4	257	45235	4	486	47350	4	466	47600
August	5	516	44450	5	421	44600	5	- -	37300	5	444	41900
	6	453	34350	6	83	41100	6(b)	211	- -	6	- -	- -
	7	448	46900	7	- -	- -	7	109	33050	7	133	43100
	8	128	45555	8	446	66800	8	588	48950	8	387	26400
	9	926	46500	9	320	37250	9	101	34050	9	211	24945
	10	- -	- -	10	390	54000	10	346	36100	10(b)	- -	49400

All brood in square inches.
* ie. each hive in this group was initiated with one pound of bees.
** H = Hive number, S = Sealed brood, Ad = Adults.
(a) Queen lost
(b) Queen failing
(c) Superceded
(d) Swarmed

APPENDIX TABLE IV - WEIGHT OF PUPAE FROM THE FOUR EXPERIMENTAL GROUPS, HIVED 6 MAY 1968

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No.	1	3	5	1	3	4	2	4	6	1	5	6
	124	133	136	126	129	138	124	126	123	131	135	136
	119	127	136	124	119	134	135	128	121	126	135	134
	123	139	117	123	136	133	130	126	124	124	132	129
	122	119	130	131	126	127	131	130	122	131	141	138
	123	128	133	144	123	137	131	130	129	124	129	141
	123	142	122	135	125	139	127	125	127	124	130	134
30	120	129	131	129	120	131	132	131	124	133	134	130
May	126	129	136	134	119	138	128	132	125	129	134	140
	130	127	121	141	133	126	133	133	119	136	132	136
	120	130	124	135	124	135	128	128	130	126	126	134
weight	123	134	130	137	125	120	137	131	124	132	129	136
in mg.	134	136	129	135	132	129	133	126	128	135	149	144
	122	127	129	129	121	120	129	122	128	129	134	140
	120	126	139	136	121	120	126	130	123	131	140	138
	117	132	122	127	124	133	125	119	127	132	138	142
	124	124	120	121	125	122	127	120	126	132	131	138
	128	133	130	121	128	124	133	129	120	131	132	133
	120	125	122	119	132	125	131	128	130	123	129	139
	115	126	116	133	127	125	137	119	120	128	135	139
	130	127	135	127	129	121	127	130	128	132	134	141
	122	126	136	133	127	126	129	129	120	135	139	140
	129	128	123	131	124	132	130	128	122	130	123	146
	119	124	141	131	131	133	128	125	127	130	135	140
	124	130	134	137	124	139	115	126	123	125	126	143
	120	128	128	129	125	135	127	127	125	129	139	136
Mean	123.1	129.2	128.8	130.7	126.0	129.7	129.3	127.1	124.6	129.5	133.6	137.9
S.D.	4.4	5.0	7.0	6.3	4.5	6.5	4.6	3.8	3.3	3.7	5.5	4.1

continued.....

APPENDIX TABLE IV (1968) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No.	1	3	5	1	3	4	2	4	6	1	5	7
	115	137	124	127	127	130	121	125	128	131	129	137
	114	129	129	129	131	128	127	123	127	133	122	132
	121	121	120	130	128	129	127	131	122	133	130	125
	117	119	120	131	124	127	123	123	126	126	140	138
	119	123	124	125	131	131	125	132	126	136	124	136
	121	130	129	127	125	130	125	124	130	129	130	132
	119	129	132	124	126	122	124	138	122	136	123	134
	118	132	130	120	120	126	126	125	128	133	128	130
	110	124	121	133	126	129	126	127	124	136	127	123
	118	126	131	126	121	123	117	136	131	131	133	131
	127	124	131	125	114	131	128	133	125	130	128	135
12	115	123	131	118	117	123	128	122	130	129	131	138
June	123	130	121	126	118	133	120	129	128	137	129	128
	120	119	127	123	124	133	126	123	132	134	128	113
	119	129	121	119	121	129	131	130	117	137	141	136
weight	109	129	122	133	125	132	125	130	127	133	125	128
in mg.	120	135	123	125	122	128	121	120	127	135	125	130
	118	132	126	122	126	127	128	125	131	132	126	125
	113	129	124	120	118	129	117	126	121	140	126	134
	129	125	131	125	124	122	134	122	130	134	121	116
	126	131	120	121	124	122	120	118	113	130	119	134
	126	124	120	119	124	117	127	117	124	131	119	127
	122	129	118	130	123	123	123	128	125	134	128	115
	130	126	120	121	125	122	122	119	130	129	131	127
	119	126	122	125	125	118	135	114	125	133	129	125
Mean	119.5	127.2	124.7	125.0	123.4	126.6	125.0	125.6	126.0	132.9	127.7	129.2
S.D.	5.4	4.6	4.6	4.4	4.0	4.5	4.5	5.9	4.5	3.2	5.3	7.0

continued..

APPENDIX TABLE IV (1968) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No	1	3	5	1	3	4	2	4	6	1	5	7
	122	122	126	128	115	125	132	124	115	137	124	122
	127	123	115	123	119	126	126	125	127	137	123	124
	119	126	133	123	117	120	123	121	127	143	124	122
	119	122	125	127	115	123	128	121	120	139	120	117
	119	121	111	118	115	123	128	119	120	142	114	126
	120	125	126	114	115	123	128	116	119	141	114	121
	124	122	125	124	115	123	137	126	124	144	126	130
	128	128	125	122	111	122	132	126	126	131	116	125
	117	125	111	126	111	121	127	127	125	143	124	120
	117	129	122	126	109	123	126	115	125	134	120	119
28	115	118	133	119	120	120	129	124	121	138	118	128
June	121	119	122	121	120	134	123	127	116	145	127	126
	114	130	113	125	117	128	130	119	125	139	129	123
	120	137	122	111	111	130	126	120	119	120	118	122
	119	139	126	118	116	121	120	122	119	140	124	117
	112	127	126	117	115	128	127	128	119	134	118	122
weight	124	125	118	123	123	127	126	120	119	137	121	125
in mg.	121	126	121	120	115	120	126	129	116	136	112	116
	117	126	120	119	124	110	133	124	121	129	120	127
	117	128	121	119	110	121	127	124	121	138	110	126
	116	120	126	107	126	118	121	116	122	139	114	117
	125	132	118	119	109	115	122	117	115	133	116	116
	130	127	117	121	116	118	123	120	119	139	124	121
	130	128	119	122	119	122	127	118	112	140	117	121
	134	126	126	122	115	126	129	123	121	133	118	116
Mean	121.1	126.1	121.9	120.6	115.9	122.7	127.0	122.0	120.5	137.2	119.6	122.0
S.D.	5.5	5.0	5.8	4.9	4.5	4.9	3.9	4.0	4.0	5.4	4.9	4.1

continued.....

APPENDIX TABLE IV (1968) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No	1	3	5	1	3	4	2	4	6	1	5	7
	144	139	144	137	135	128		152	140	143	130	139
	143	131	137	138	128	138		145	144	145	133	146
	135	130	145	142	130	135		145	136	152	134	144
	138	133	132	136	127	140	Hive	152	140	144	130	150
	140	142	143	132	133	140		139	138	143	135	139
	129	134	148	124	136	141	ab-	147	145	152	138	150
	137	134	142	133	136	138	normal	141	149	145	126	151
	140	130	141	137	123	139		150	144	139	143	154
	132	129	143	139	129	143		147	140	154	140	143
	137	131	130	128	139	129		154	142	148	138	144
12	130	134	133	132	136	135		139	140	145	132	155
July	140	133	139	150	131	141		146	151	140	131	145
	128	127	143	134	138	135		141	141	145	131	151
	142	135	146	135	136	139		153	129	145	132	154
	130	133	136	144	133	129		150	141	141	137	146
weight	139	131	141	133	134	137		154	140	153	134	148
in mg.	135	136	130	134	134	136		150	136	130	128	146
	144	142	141	133	129	138		149	138	147	131	144
	138	123	152	132	130	130		144	134	143	133	147
	126	128	125	142	135	130		143	140	140	141	149
	132	125	144	127	130	141		146	138	134	129	156
	140	127	144	135	128	125		145	140	142	131	148
	140	137	140	136	124	139		151	142	147	136	140
	134	133	147	129	131	137		145	134	148	135	152
	133	126	135	138	133	140		148	139	142	139	144
Mean	136.2	132.1	140.0	135.2	131.9	136.1		147.0	140.0	144.3	133.9	147.4
S.D.	5.2	4.9	6.4	5.7	4.1	4.9		4.4	4.6	5.5	4.3	4.8

continued....

APPENDIX TABLE IV (1968) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No	1	3	5	1	3	4	2	4	6	1	5	7
	135	145	134	142	146	142		142	152	155	143	155
	140	128	145	136	146	145		132	138	159	138	157
	132	132	127	134	143	139		145	146	145	145	163
	131	135	120	140	142	143		141	144	155	147	161
	131	134	128	140	144	143		146	144	147	136	155
	139	135	132	139	143	148		145	140	146	130	158
	134	130	124	140	140	135		144	142	148	147	157
	141	135	132	143	148	137	Hive	144	145	150	150	155
	143	138	129	125	147	142		144	150	150	156	150
	130	133	125	145	147	137	ab-	142	143	148	139	151
	140	132	128	134	148	144	normal	138	144	153	147	151
24	141	133	124	135	132	152		145	145	153	145	153
July	139	150	131	144	143	140		145	151	146	147	150
	135	145	132	142	143	143		134	141	147	147	151
	137	138	133	128	143	136		136	147	159	139	156
weight	135	143	125	142	145	140		148	151	158	151	157
in mg.	134	146	128	143	139	140		152	141	153	138	148
	128	140	133	133	149	135		156	137	156	152	138
	127	131	133	135	143	148		138	146	141	148	153
	140	131	133	140	149	136		131	148	155	154	150
	136	138	130	139	149	144		130	149	151	149	141
	134	142	132	141	140	134		139	146	145	149	150
	137	135	137	144	144	143		144	147	150	151	150
	132	135	127	142	141	150		142	152	149	154	147
	138	140	122	142	148	149		134	149	151	151	155
Mean	135.6	137.0	129.8	138.7	144.1	141.8		141.5	145.5	150.8	146.1	152.3
S.D.	4.3	5.7	5.2	5.1	3.9	5.0		6.3	4.2	4.7	6.4	5.5

continued....

APPENDIX TABLE IV (1968) - Continued

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No	1	3	5	1	3	4	2	4	6	1	5	7
	142	140	141	148	153	137		145	154	153		143
	142	141	138	143	161	139		146	157	150		144
	143	148	153	147	161	142		146	156	149		149
	146	144	139	140	160	144		148	153	154		158
	138	131	130	134	157	150		143	153	155		159
	145	142	152	133	150	132		157	147	157		151
	152	147	130	143	150	143		148	159	148		147
	144	134	135	147	164	140		136	152	150		145
	153	147	144	136	167	146		141	145	157		151
	141	139	129	140	161	139	Hive	157	148	129		147
	141	138	128	146	151	143		151	147	156		148
6	133	143	151	146	162	136	ab-	145	148	151		140
August	141	147	139	144	154	139	normal	144	144	157		146
	147	136	142	134	151	142		167	152	149		149
	133	131	137	134	150	139		151	147	148		152
	140	133	143	142	145	140		152	147	149		143
weight	140	127	139	150	153	140		149	143	151		151
in mg.	150	140	145	131	144	144		150	127	151		154
	152	142	151	150	148	147		179	148	153		139
	152	145	143	143	140	139		167	142	155		151
	130	155	148	142	149	142		174	146	148		143
	135	137	140	148	150	143		181	159	151		150
	139	145	136	138	147	137		182	149	152		145
	134	144	136	139	149	144		158	143	151		142
	131	145	136	137	148	137		163	140	145		150
Mean	141.8	140.8	140.2	141.4	153.0	141.0		155.2	148.2	150.8		147.9
S.D.	6.8	6.4	7.2	5.7	6.9	3.9		13.1	6.9	5.6		5.1

APPENDIX TABLE V - WEIGHT OF PUPAE FROM THE FOUR EXPERIMENTAL GROUPS HIVED 2 MAY, 1970

	1 lb. Group			2 lb. Group			3 lb. Group			4 lb. Group		
Hive No	2	6	8	3	5	8	2	9	10	3	7	10
21 May	128.0*	119.4	125.4	122.7	129.0	119.2	128.2	122.0	129.4	132.8	132.1	127.5
16 June	126.2	119.5	129.5	124.0	123.9	127.2	132.6	124.9	132.6	136.4	128.6	130.2
12 July	137.0	121.4	131.0	134.7	133.7[1]	134.5	132.0	137.6	135.1	135.4	125.6	134.1
4 Aug.	142.2	126.2	143.7	141.4	140.8	138.6	139.5	139.5[2]	134.9	135.3[3]	135.8	- -
26 Aug.	140.6	131.8	143.6	135.9	144.8	136.6	138.2	146.6	143.2	142.2	136.8	- -

* Mean weight of 25 pupae, in mgs. (weighed as one sample)

1 - Hive no. 2 used from this date on.
2 - Hive no. 4 used from this date on.
3 - Hive no. 5 used from this date on.

APPENDIX TABLE VI - FIVE DAY GAINS (LBS.) OF ONE SCALE COLONY IN EACH OF THE FOUR EXPERIMENTAL GROUPS (1969 AND 1970)

Date	Group	1969 No 1	1969 No 2	1969 No 3	1969 No 4	1970 No 1	1970 No 2	1970 No 3	1970 No 4
June	19-23	-1	-6	-3	-4	-3	-2	-1.5	-1.5
	24-28	0	0	-2.5	+1.5	- .5	-1	0	- .5
	29- 3	-1	-2.5	-3.0	+2.5	+1	+7	+10.5	+11.5
June	gains	-2	-8.5	-8.5	0	-3.5	+4	+9.0	+ 9.5
July	4- 8	0	-2	2	-1	+6	14	22	16.5
	9-13	22*	23	29.5	36.5	12.5	28.5*	26	9.5
	14-18	9.5	21.5	17.5	13.5	6	24	9	4.5
	19-23	4.5	10	9.0	7.5	17.5	15	16	16*
	24-28	5.0	10.5	11.5	-*	41	51	66	65
	29- 2	11	15	13.5	18.0	14	32	46.5	34
July	gains	52	78	83.0	74.5	97	164.5	185	145.5
Aug.	3- 7	28.5	21.5	20.5	31	34	50	60	79
	8-12	24.5	25	20	14	44.5	56.5	33.5	48
	13-17	-5	-2	-8.5	0	28.5	26.5	29	30
	18-22	+7	+12	0	9	-5	+1	+1	+2
	23-27	+3	-3	-5.5	-4	+3	-2.5	-3	-2.5
Aug.	gains	58	53.5	26.5	50	105	131.5	120.5	156.5
Total	gains	108	123	101	124.5	198.5	300	314.5	311.5

* scale placed under different colony in the group.

APPENDIX TABLE VII - MAXIMUM, MINIMUM AND MEAN TEMPERATURES FOR THE MONTHS OF MAY, JUNE, JULY AND AUGUST (1968-1970) WINNIPEG, MANITOBA

Month	Normal* Max.	Normal* Min.	Normal* Mean	1968 Max.	1968 Min.	1968 Mean	1969 Max.	1969 Min.	1969 Mean	1970 Max.	1970 Min.	1970 Mean
May	64.1	40.6	52.4	60.6	37.0	48.8	63.0	38.7	50.9	59.4	38.1	48.8
June	72.6	50.8	61.7	70.8	48.4	59.6	65.0	42.7	54.0	78.0	53.9	66.0
July	79.7	56.8	68.3	75.0	52.4	63.7	75.5	55.0	65.3	79.8	57.9	68.9
August	77.5	54.5	66.0	69.0	50.8	59.9	81.2	57.9	69.6	79.4	52.5	66.0

* Normal yearly average based on a thirty year period 1931-1960.