STUDIES OF HONEY BEES (*APIS MELLIFERA* L.) ON FABABEANS (*VICIA FABA* L.)

A Thesis

Presented to

The Department of Entomology

Faculty of Agriculture

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Savitree Malaipan

May, 1979

STUDIES OF HONEY BEES (*APIS MELLIFERA* L.) ON FABABEANS (*VICIA FABA* L.)

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

This study was done in 1976 - 1978 at the University of Manitoba Campus and at the Glenlea Research Station, and involved: (1) the growth and development of the four cultivars of fababeans, (Ackerperle, Diana, Erfordia, and Herz Freya) and their flowers, (2) the plant characters of these cultivars thought to attract honey bees, (3) the daily and seasonal activities of honey bees on these cultivars, and (4) the value of honey bees as pollinators of these cultivars. In addition the activities of two species of Bombus were also observed on these cultivars.

Erfordia had the highest growth rate and grew the tallest of the four cultivars, while Diana had the lowest growth rate and was the shortest. Diana flowered earlier than the other cultivars while Herz Freya flowered later; Herz Freya also had the shortest flowering period. The flowering period, for the four cultivars, was 32-40 days. Floral development for Ackerperle was 3.5-6.5 days from green bud to bloom stage; buds located at the bottom of a raceme developed faster than did the upper ones. Each flower opened for 2-6 consecutive days and closed at night. Old blooms opened early in the day, while the new blooms opened late in the afternoon.

The following plant characters were studied and

thought to attract bees: floral perfume, floral numbers over time, floral size, floral colour, pollen (i.e. number of pollen grains per flower, dehiscence), and nectar (i.e. amount and concentration). The highest number of full blooms occurred in the late afternoon and these produced the strongest scent of any floral type. Diana had the largest flowers, which also contained the largest number of pollen grains and ovules per flower. Although Ackerperle had the smallest flowers, there was no difference in the number of pollen grains and ovules per flower in Ackerperle, Erfordia or Herz Freya. Dehiscence occurred in the white bud stage. White petals occurred more frequently in Ackerperle and Diana than in Herz Freya and Erfordia; the latter usually had pink or purple pigments.

Nectar was sampled from both floral and extra-floral nectaries in open plots and in cages at two hour intervals between 0800-2200 h; the sugar concentration of the nectar from the honey sacs was also measured under different field conditions. The mean amount of nectar from the floral nectaries in the open plots of Ackerperle, Diana, Erfordia, and Herz Freya was 0.84-1.12, 0.89-1.05, 0.87-0.92, and 1.12-1.14 microlitres per flower respectively. The mean amount of nectar from the extrafloral nectaries in the open plots of Ackerperle, Diana, Erfordia and Herz Freya was 0.24-0.26, 0.26-0.29, 0.16-0.20, and 0.30-0.45 microlitres per stipule respectively. The overall mean amount of nectar from the

open plots at two sites was 0.9-1.1 microlitres per flower and 0.2-0.5 microlitres per stipule. In the cages the overall mean amount of nectar from the floral nectaries was 1.0-1.1 microlitres per flower while the extrafloral nectaries yielded 0.2-0.22 microlitres per stipule. The mean sugar concentration of nectar from the floral nectaries in the open plots of Ackerperle, Diana, Erfordia, and Herz Freya was 32-35, 31-33, 38-41, and 30-39% respectively. The mean sugar concentration of nectar from the extrafloral nectaries in the open plots of Ackerperle, Diana, Erfordia, and Herz Freya were 21-23%, 16-20%, 24-25%, and 20-21% respectively. The overall mean sugar concentration of the nectar from the floral nectaries in the open plots of two sites was 33-37% while the extrafloral nectaries yielded 21-22%. In the cages the overall mean sugar concentration from the floral nectaries was 35-42%, and 25-39% from the extrafloral nectaries. The sugar concentration of the nectar from the honey sacs of positive foragers and extrafloral nectar foragers, collected at two sites, was 45-60% and 13-30% respectively.

Both the sugar concentration and the amount of nectar, produced by the floral or extrafloral nectaries, were greater in the early and middle flowering period than in the late flowering period. The amount of nectar from the floral and extrafloral nectaries was high in the early morning and the late evening, while the sugar concentration of these nectars was high in the late afternoon and the evening.

Foraging activities were observed as follows: positive foragers preferred to visit flowers in full bloom rather than those in early bloom or late bloom. They spent 11.3-13.1 sec. per flower, visited 1.7-2.0 flowers per plant before changing plants, and moved 142-189 cm per min. The extrafloral nectar foragers preferred to collect nectar from the stipules at the top of a plant rather than from the lower part of a plant; they spent 2.8-4.8 sec per stipule, visited 3.1-4.6 stipules per plant, and moved 70-142 cm per min. There were no differences in foraging times, number of flowers visited per plant, or distances foraged by the bees throughout the day or the flowering period on the four cultivars. Nectar-pollen foragers and negative foragers were observed on the fababeans in the late afternoon and evening while the extrafloral nectar foragers were observed on the plants during the early part of the afternoon; of these the nectar-pollen foragers were most numerous throughout the day. Fewer bees of each type, were observed on the fababeans during the late flowering period. More positive foragers visited Ackerperle than they did Diana or Herz Freya; the lowest number of positive foragers were observed on Erfordia but this cultivar received the highest number of extrafloral nectar foragers.

Because negative foragers occur in low numbers on all cultivars it is unlikely that this should affect the pollination of fababeans.

The mean number of pollen grains counted on the various body parts of the positive honey bee foragers was as follows: third pair of legs (101,600 ± 4,610), head (4,408 ± 131), thorax (1730 ± 314), second pair of legs (1727 ± 146), abdomen (1397 ± 182), and first pair of legs (1257 ± 149). There was a wide range in amount of fababean pollen collected in traps by honey bees throughout the day (i.e. 3 - 57%); most of the fababean pollen was collected during the late afternoon.

Bombus borealis was observed in low numbers on the fababeans; this species always made positive visits and appeared to be a good pollinator of this crop; B. terricola was also present but usually made negative visits.

Plants in cages grew taller than those in open plots. There was no difference in the number of flowers produced in the cages and in the open plots. There was a greater number of pods per plant, seeds per plant, seeds per pod, and total weight of seeds per plant in the open plots than in the cage in which bees were present or absent. There was a greater number of pods per plant and total weight of seeds per plant in cages with bees than in cages without bees. Although Ackerperle and Diana had only slightly higher seed yields when bees were present, Erfordia and Herz Freya produced high seed yields when honey bees were present.

ACKNOWLEDGEMENTS

This thesis could not have been completed without the assistance of my supervisor, Dr. S. C. Jay of the Department of Entomology, University of Manitoba. I wish, therefore, to express my deepest appreciation and gratitude to him for his encouragement, guidance, advice, kindness, and understanding during the course of my studies.

I wish to extend my sincerest gratitude to Dr. A. Grant Robinson, Head, of the Department of Entomology, University of Manitoba for providing research facilities and for his advice and criticism of the manuscript. I wish to thank Dr. K. W. Clark, of the Department of Plant Science, University of Manitoba, and Dr. R. W. Shuel of the Department of Environmental Biology, University of Guelph for their constructive criticism of this thesis.

I am grateful to Dr. N. J. Holliday, of the Department of Entomology, University of Manitoba for his assistance with the statistical treatment of the data. Acknowledgements also go to Dr. D. Brown, Dr. K. G. A. Hamilton, Dr. J. McNamara, and Dr. W. R. Richards, of the Research Branch Biosystematics Research Institute, Agriculture, Canada, and Dr. T. D. Galloway of the Department of Entomology, University of Manitoba for their help in the identification of insects.

Special thanks are extended to Mr. J. Watson of the Department of Plant Science, University of Manitoba, for his assistance, preparing experimental sites and all cultural practices during this study. Thanks are extended to Dr. S. Audette for permission to use his fields for this study. Additionally, my appreciation is expressed to Mr. J. Serger, of the Department of Entomology, University of Manitoba, for his technical assistance. As well I wish to thank all of my friends for their encouragement and assistance, especially Mr. D. L. Nelson and Mr. B. G. Fingler, for their correction of my writing. Thanks are also extended to the students, Ms. J. Casey, Ms. M. Duff, Ms. S. Bookbinder, Mr. B. Gassman and Mr. G. MacGregor for their assistance in field work.

I am deeply indebted to Mrs. G. Ferguson for her patience and accuracy in typing this thesis.

Finally, I wish to express my sincere appreciation to my deceased parents, Captain Sati Malaipan and Mrs. Songsri (Virayasiri) Malaipan, throughout all my studies. Special thanks are due to my sister and brothers for their encouragement, support and understanding.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Vicia faba L. var. *minor* (Peterm.) Beck, commonly known as fababean in Canada, have in Europe the common names horse bean, tick bean and field bean etc. Fababeans are an important crop in Western Canada and are used as a protein food for livestock, often substituting for soy beans (C.D.A. 1975; Faculty of Agriculture U. of M. 1977). Fababeans can be grown in Western Canada because they have a short growing period and produce high yields.

Although four cultivars of fababeans (i.e. Ackerperle, Diana, Erfordia, and Herz Freya) are grown in Western Canada, little information is available about their pollination requirements and the value of honey bees as pollinators of this crop. Generally, fababeans are self-pollinated plants, and therefore set seed by themselves without the assistance of insect pollinators (Avetisyan *et al*. 1963; Free, 1966; Pritsch, 1970; Scriven *et al*, 1961; Tasei, 1976; Watt and Marshall, 1961; Wafa and Ibrahim 1960). However, it has been observed that when honey bees are available, seed yields of fababeans are increased (Alex, 1950; Fyfe and Bailey 1951; Hue, 1943; Rowland, 1958; Sirks, 1923); other bees also assist in cross pollination. The average frequency of cross-pollination of this crop in Britain is about 33% (Fyfe,1954).

Little information is known about the various plant characters of the four cultivars, which attract honey bees to them, i.e. flowering period, stage of flower, floral perfume, floral number, floral size, floral colour, dehiscence, amount of pollen, and amount and sugar concentration of the nectar. Beekeepers are particularly interested in this latter characteristic as their livelihood is largely dependent upon nectar flows of major crops.

Finally, little is known about the effect of competition from other crops or the daily and seasonal behavioral patterns of honey bees on the four cultivars of fababeans. Such activities include: type of visit, foraging time, foraging distance in a period of time, number of flowers visited per plant, stage of flower visit, type and location of nectaries, bee populations during the day and flowering period, and also the number of pollen grains that a bee carries on various parts of its body when foraging on fababean flowers. Knowledge of the above, coupled with experiments in cages where bees are excluded or included, should allow one to predict the usefulness of honey bees for pollinating fababeans.

It should be noted that in this thesis the various literature reviews have been included within the individual chapters, primarily to provide a logical sequence of ideas associated directly with the observations and experiments made by the author.

CHAPTER II

GENERAL METHODS

2.1 Fababean Cultivars

The four licensed fababean cultivars, (Ackerperle, Diana, Erfordia, and Herz Freya) grown in Manitoba, were used in the research program reported in this thesis. These cultivars tend to be high in seed yield and protein content, are disease and shatter resistant, and have a short maturation period.

Three of the cultivars originated from commercial stocks as follows: Ackerperle from Manitoba Pool (Winnipeg, Man.), Diana from Northern Sales (Winnipeg, Man.), and Herz Freya from A. Roy Seeds (Lorette, Man.). The Plant Science Department (University of Manitoba) supplied the seed for the cultivar Erfordia.

2.2 Experimental Site and Seeding Dates

In 1976 about 0.3 ha of each of the cultivars Ackerperle, Diana, and Herz Freya were seeded on 26 April at the Glenlea Research Station (Glenlea site), while 1 ha of the cultivar Ackerperle was seeded on a plot at the University of Manitoba Campus (U. of M. site) on 22 April. In addition to these field sites, a farmer's 2 ha field of the

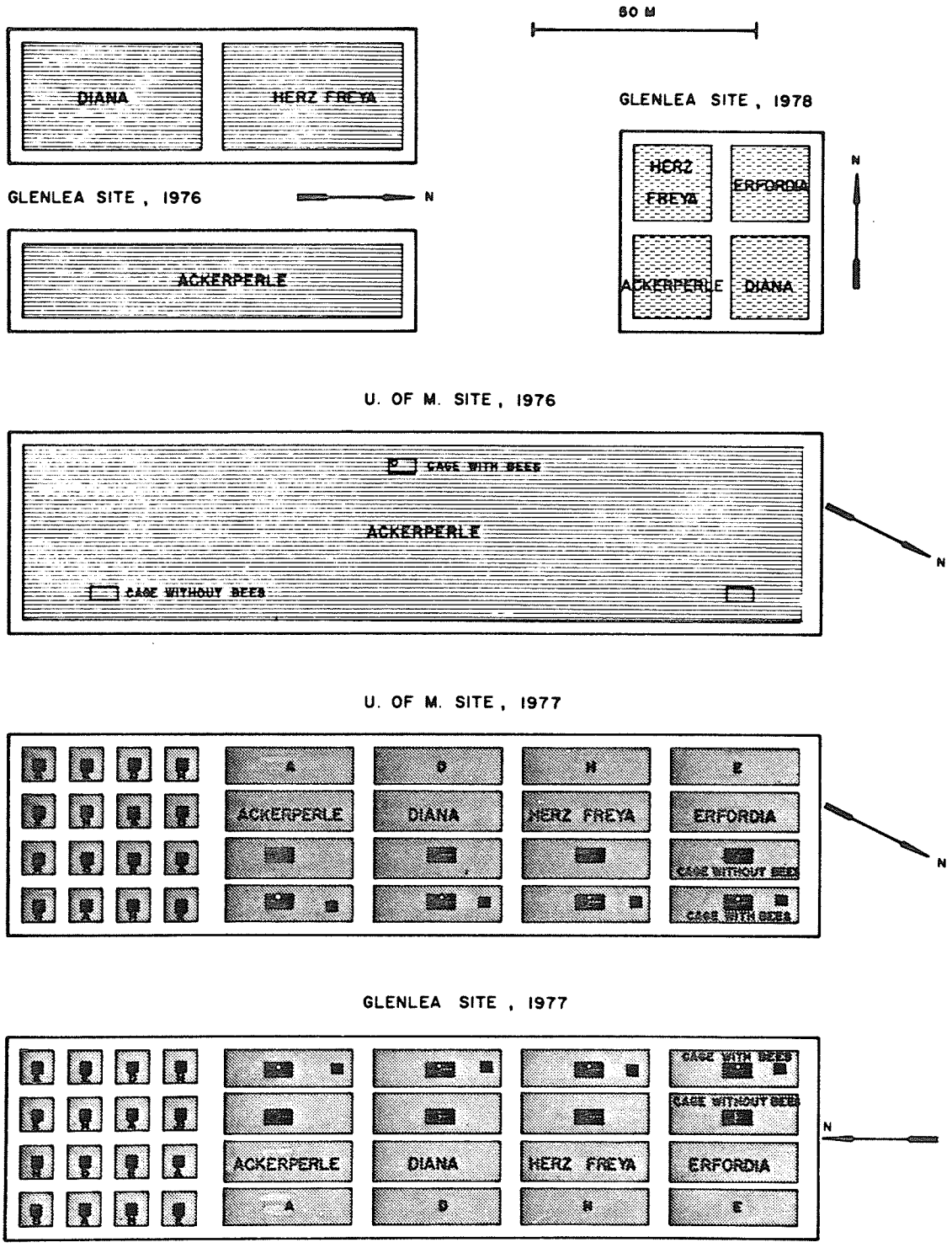


Figure 1: Experimental plot designs

cultivar Ackerperle located at Ile des Chenes, Man., and a small experimental plot of the cultivar Diana located at Carman, Man. were used in this study. Unfortunately, due to flooding, drought, and weed problems the cultivars Diana and Herz Freya at the Glenlea site had to be ploughed under on 20 July before the experiments and observations were completed (Fig. 1).

Only one observer was involved in collecting the data in most of the trials so the seeding dates were spaced in 1977 to allow for a longer experimental period. About 0.25 ha of each of the four cultivars were seeded on 15 April at the U. of M. site and on 17 May at the Glenlea site.

In 1978 about 0.04 ha of each of the four cultivars was seeded on June 6 at the Glenlea site.

2.3 Harvesting Dates

The average growing period of field beans, from seeding to ripening in Canada is as follows: Ackerperle 99 days (range 84-114); Diana 98 days (range 83-112); Erfordia 106 days (range 87-116); and Herz Freya 95 days (range 85-105) (C.D.A., 1972; Evans and Rogalsky, 1974; Furgal, 1979).

In Western Canada, the beans must be swathed when 10% of the pods have darkened (Evans and Rogalsky, 1974), or when the lowest two pods show signs of blackening. In this stage the moisture content of the bean will be in the

range of 35-45% (C.D.A., 1972), a level that prevents severe losses due to shattering.

In the 1976 trials, all fababean plants (cultivar Ackerperle) at the U. of M. site, were harvested on 3 August; the total growing period was 110 days. At the Glenlea site all of the plants (Ackerperle) were harvested on 16 August; the total growing period was 114 days.

In the 1977 trials, the fababean plants, at both sites, were harvested later because of wet weather. The harvesting dates were 8-9 August, 1977 and 12-14 September, 1977 at the U. of M. site and at the Glenlea site respectively. The total growing periods were 116-117 days at the U. of M. site, and 119-121 days at the Glenlea site.

2.4 Cultural Practices

Fababean seeds were treated with dry inoculum to promote nitrogen fixation. Seeds were spaced about 15 cm within a row and 15 cm between rows; the seeding rate was 180 kg per ha (i.e. 160 lb. per acre) in all experimental sites.

No herbicides, fertilizers or insecticides were applied to the fababean fields during the three growing seasons. Weeds were eliminated by mechanical methods.

CHAPTER III

PLANT AND FLORAL GROWTH STUDIES

Introduction

In order to provide information which would be essential for studies of fababean pollination, the following were investigated using four cultivars: growth rates at two sites, floral development (i.e. floral stages, development times of these stages, and position of the flowering node in the raceme), and flowering period at two sites.

3.1 Plant Growth Studies

3.1.1 Literature Review

Ishag (1973), while working in England, found that there was no significant difference in the growth rates of four cultivars of fababeans (i.e. Albyn Tick, Blue Rock, Herz Freya and Maris Bead). Vegetative growth was most rapid before the first pods were formed; however when the pods did begin to form the vegetative growth decreased, and continued to do so until the end of the growing season.

It is believed that many environmental factors affect the growth rate of fababeans. Therefore, growth rate studies are necessary and basic to pollination studies.

In this chapter the growth rates of the four cultivars, grown in two sites, were reported.

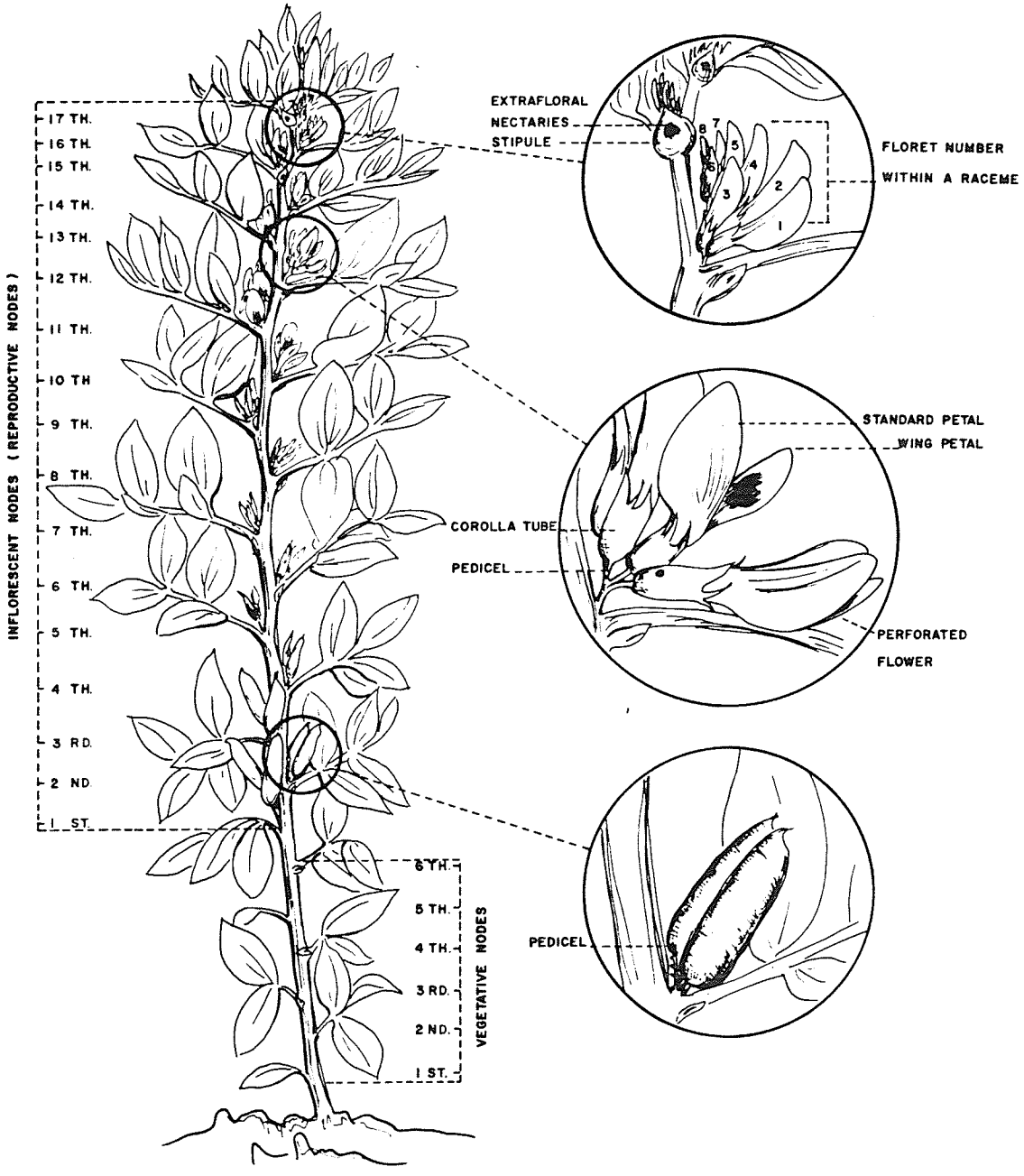


Figure 2: Typical fababean plant showing terminology used in this study.

3.1.2 Materials and Methods

In 1976, five fababean plants were selected at random from each of the three cultivars (see p. 3) grown at the Glenlea site, and ten plants of Ackerperle grown at the U. of M. site. These were tagged and their heights measured at various times (see Table I) throughout the growing season. This experiment was repeated in 1977 at both the U. of M. site and the Glenlea site except that forty plant samples were chosen at random from each of the four cultivars.

Height data were transformed to growth rates by dividing the height of the plant by the time, in days, that the plant had been growing.

The height of the four cultivars of fababean plants (both sites, 1977) were analysed by a Two-Way ANOVA followed by a SNK Multiple Range Test (Snedecor and Cochran, 1978).

3.1.3 Results and Discussion

In the 1976 trials, the height and growth rate of the cultivar Ackerperle, grown at U. of M. site, was much greater than that of plants grown at the Glenlea site ($P<0.01$). The height and growth rate of the cultivar Herz Freya was greater than that of the cultivars Ackerperle and Diana ($P<0.05$) (Table I).

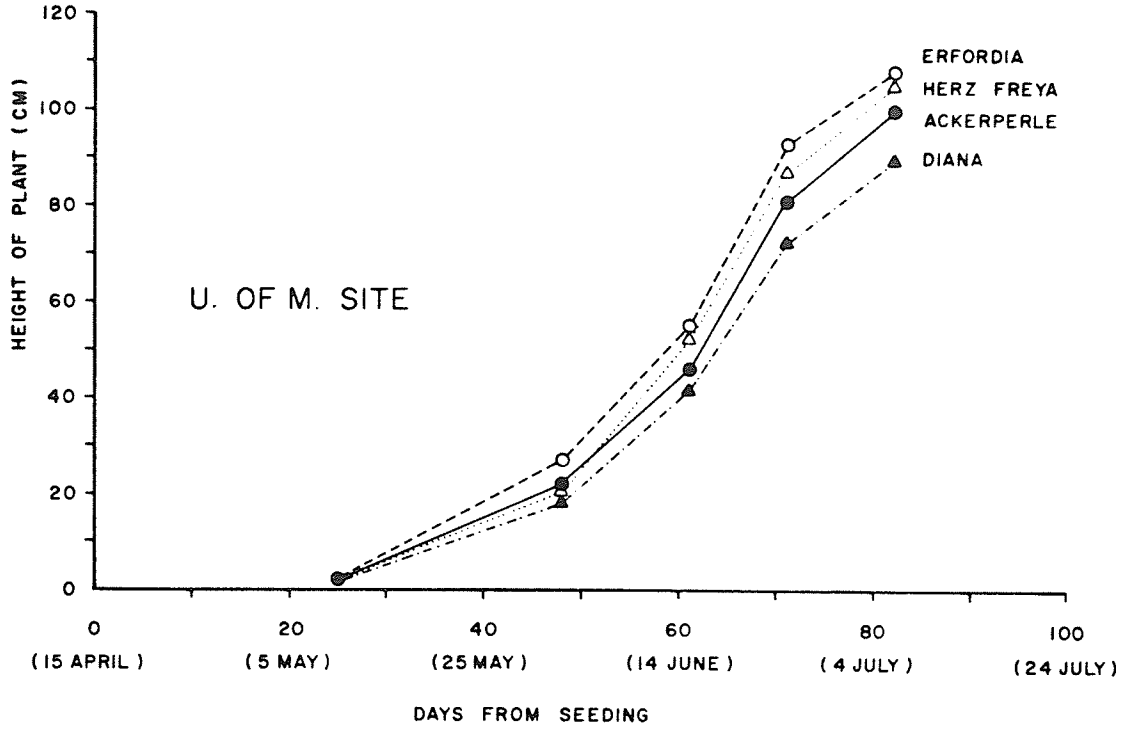
The maximum growth rate of the cultivar Ackerperle, grown in the U. of M. site in 1976, occurred between 67 and

71 days after seeding. The mean growth rate, from seeding to full plant maturity was 7.24 cm per wk. At the Glenlea site the growth rate of the fababeans was affected by periods of flooding during the seedling stage and by drought during the vegetative stage. Weed problems also hindered plant growth. These problems appeared to retard growth, so that the plants at the Glenlea site were much shorter, and about 10 days behind those at the U. of M. site in attaining full growth. The mean growth rate of the cultivars Ackerperle, Diana, and Herz Freya, at the Glenlea site, was about 3.53, 2.91, and 3.96 cm per wk. respectively at 92 days after seeding (Table I).

In the 1977 trials (Fig. 3, Appendix Table I) the mean height of the fababean plants at the U. of M. site showed differences within cultivars ($P<0.01$) with the tallest to the lowest plants occurring as follows: Erfordia, Herz Freya, Ackerperle, and Diana. This was also true at the Glenlea site (Fig. 3, Appendix Table I). In general the plants at the Glenlea site, were taller than those at the U. of M. site. Analysis of variance showed that the cultivar Diana was significantly shorter than the other cultivars regardless of site ($P<0.01$); however there was no significant difference in mean height between the cultivars Ackerperle, Erfordia, and Herz Freya.

In 1977, plants at the Glenlea site grew faster than those at the U. of M. site (Fig. 4), and reached their maximum growth rate about 30 days before those did at the

Figure 3: A comparison of the height of four cultivars of fababeans at two sites (1977)


HEIGHT OF PLANT (CM)
120
100
80
60
40
20
0
U. OF M. SITE
ERFORDIA
HERZ FREYA
ACKERPERLE
DIANA
0
(15 APRIL)
20
(5 MAY)
40
(25 MAY)
60
(14 JUNE)
80
(4 JULY)
100
(24 JULY)
DAYS FROM SEEDING

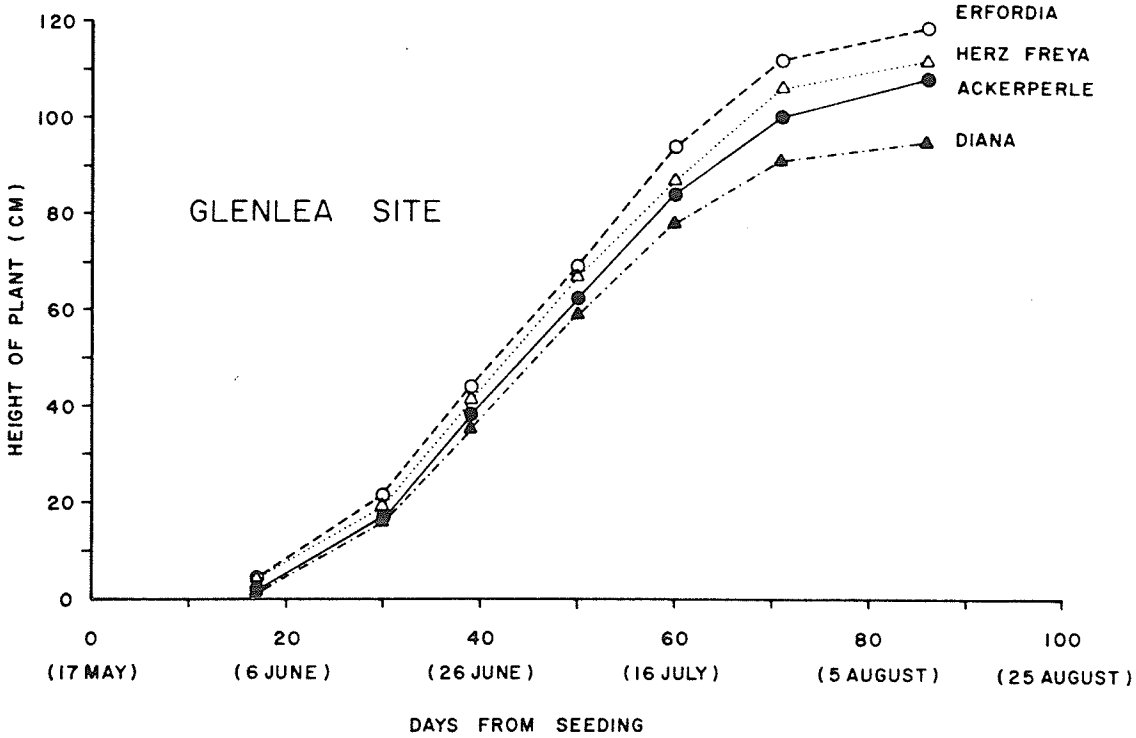
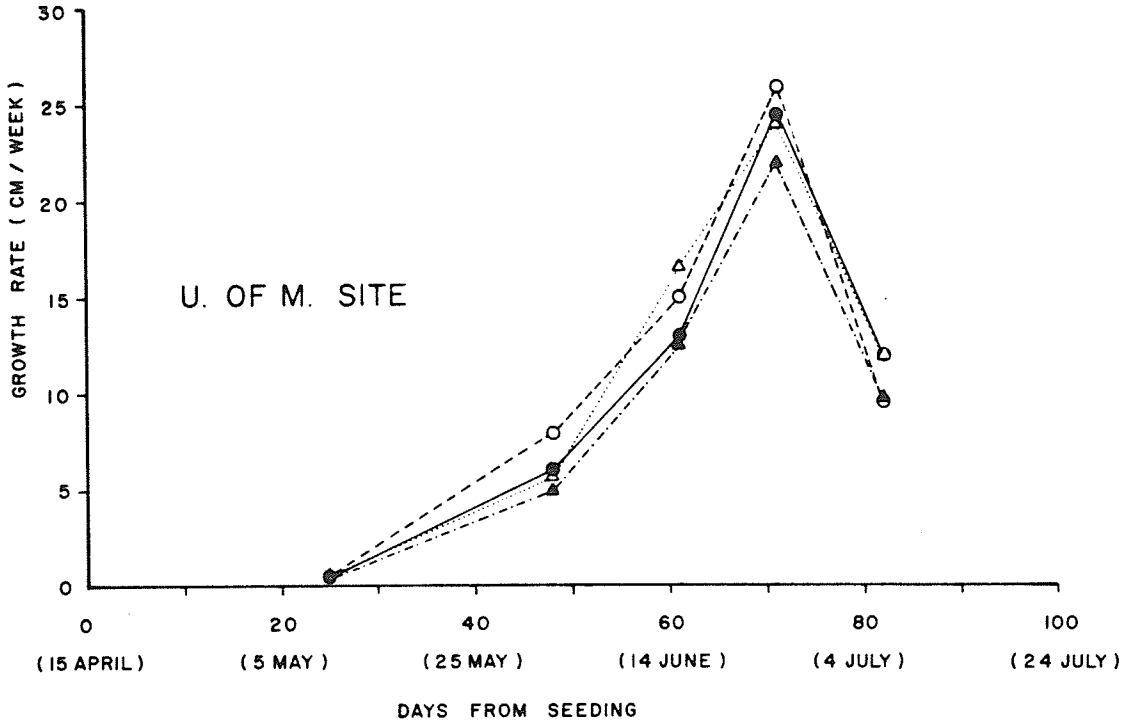
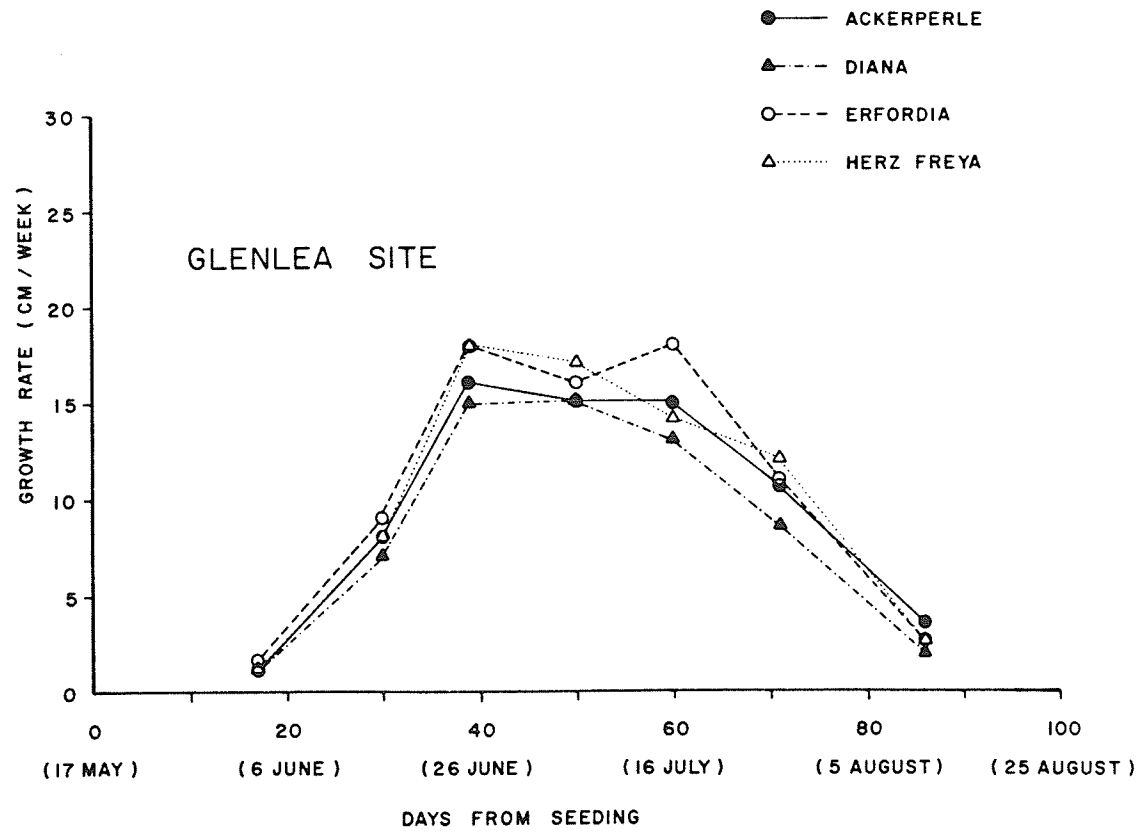

HEIGHT OF PLANT (CM)
120
100
80
60
40
20
0
GLENLEA SITE
ERFORDIA
HERZ FREYA
ACKERPERLE
DIANA
0
(17 MAY)
20
(6 JUNE)
40
(26 JUNE)
60
(16 JULY)
80
(5 AUGUST)
100
(25 AUGUST)
DAYS FROM SEEDING

Figure 4: A comparison of the growth rate of four cultivars of fababeans at two sites (1977)


U. OF M. SITE
GROWTH RATE (CM / WEEK)
30
25
20
15
10
5
0
0
20
40
60
80
100
(15 APRIL)
(5 MAY)
(25 MAY)
(14 JUNE)
(4 JULY)
(24 JULY)
DAYS FROM SEEDING


ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
GLENLEA SITE
GROWTH RATE (CM / WEEK)
30
25
20
15
10
5
0
0
20
40
60
80
100
(17 MAY)
(6 JUNE)
(26 JUNE)
(16 JULY)
(5 AUGUST)
(25 AUGUST)
DAYS FROM SEEDING

U. of M. site. At the Glenlea site the plants grew higher and had a wider range in growth rate between 30 to 60 days after seeding.

The growth rates of the four cultivars were compared throughout the growing period (82 days at U. of M. site, and 86 days at Glenlea site). The fastest to the slowest growth rates occurred as follows: Erfordia, Herz Freya, Ackerperle, and Diana. The mean growth rate of all cultivars at the Glenlea site was higher than at the U. of M. site. This was probably due to the greater amount of moisture available at the Glenlea site (Appendix Fig. 2). There appeared to be no difference in hours of sunshine occurring at each site (Appendix Fig. 3).

The growth rate of each of the cultivars appears to depend upon environmental factors as well as on its own genetic make up. In both years (and in both sites), Diana showed the slowest growth rate and was shorter than all of the other cultivars; Ackerperle was next, followed by Herz Freya. Erfordia was the tallest cultivar and had the highest growth rate.

TABLE I

HEIGHT OF THREE CULTIVARS OF FABABEAN PLANTS, ON DIFFERENT DATES THROUGHOUT THE SEASON AT TWO SITES (1976)

Site	Date	No. Days After Seeding	No. Plants	Height of Plants (cm) Cultivar Ackerperle	Diana	Herz Freya
U. of M.	28 June	1-67	25	48.88 ± 1.40*	-	-
	2 July	67-71	10	68.30 ± 1.34	-	-
	8 July	71-77	10	82.50 ± 3.03	-	-
	16 July	77-85	10	95.62 ± 2.06	-	-
	3 August	85-104	50	107.52 ± 1.37	-	-
Glenlea	6 July	1-71	5	30.45 ± 2.68	28.65 ± 4.97	33.55 ± 4.87
	12 July	71-77	5	31.10 ± 2.38	29.10 ± 6.32	42.90 ± 5.04
	27 July	77-92	5	46.40 ± 1.21	38.30 ± 2.90	52.00 ± 4.42
	16 August	92-108	5	51.08 ± 3.20	-	-

*Mean and standard error.

TABLE II

GROWTH RATE OF THREE CULTIVARS OF FABABEANS AT TWO SITES,(1976)

Site	Date	No. Days After Seeding	No. Plants	Growth Rate of Cultivars (cm/wk) Ackerperle	Diana	Herz Freya
U. of M.	28 June	1-67	25	5.11	-	-
	2 July	67-71	10	33.98	-	-
	8 July	71-77	10	16.57	-	-
	16 July	77-85	10	11.48	-	-
	3 Aug.	85-104	50	4.38	-	-
	3 Aug.	7-104	50	7.24	-	-
Glenlea	6 July	1-71	5	3.10	2.82	3.31
	12 July	71-77	5	0.76	0.52	10.91
	27 July	77-92	5	7.14	4.29	4.25
	16 Aug.	92-108	5	2.05	-	-
	2 July	1-92	5	3.53	2.91	3.96

3.2 Flowering Period

3.2.1 Literature Review

Field beans commence flowering in the lowest inflorescences on the stem and continue flowering at each successive node along the stem (Poulsen, 1974).

The flowering period of field beans in Denmark extends from 26-33 days (Poulsen, 1973). According to pollen studies at Rothamsted, field bean pollen is available from 30 May to 14 June (15 days) (Synge, 1947).

The first flower on the main stem of broad beans usually opens first, and the first flower on the lateral branches open in the order in which the branches emerge from the main stem (Inoue et al, 1963). It takes about 39.0-47.8 days from emergence to the appearance of the first flower, and 8.9 — 10.5 vegetative nodes are produced before the first inflorescent nodes appear (Jones, 1963).

More flowers are produced and the flowering period is prolonged under high temperature conditions and growth rate and floral formation is retarded in field beans and broad beans (Blondon, 1971, 1975; Evans, 1959; Graman, 1972; Inako et al, 1960; Ivaskina, 1968; Sugiyama et al, 1949; Ueki, 1955, 1956; Ueki and Igawa, 1959).

An increase in photoperiod increases the rate of flower initiation, but reduces flower number (Blondon, 1971, 1975; Evans, 1959; Tamaki et al, 1974).

3.2.2 Materials and Methods

Flowering periods for each cultivar were recorded in 1976 and 1977 at the U. of M. and Glenlea sites. The first and the last day that flowers were seen in the "full bloom stage" (see p. 28), at both sites, were also recorded. In 1976, the first and the last node that contained flowers was recorded from 100 plants taken at random after the plants matured.

In 1977, at selected time intervals (see Fig 5, TableIII) during the growing period, 40 plants of each cultivar were chosen at random from the Latin Square plots at each site (i.e. 10 plants, 1 plot). Two measurements were made at each time period: 1) the number of plants of each cultivar with flowers in the full bloom stage were recorded, and 2) the (number of the) position of the last inflorescent node with flowers in full bloom.

3.2.3 Results and Discussion

In the 1976 trials, the flowering period of the fababean cultivar Ackerperle, at the U. of M. site, was about 23 days (i.e. 15 June to 18 July, or about 54-87 days after seeding). The flowers started blooming at node 8.0 ± 0.2 and ceased at node 22.1 ± 0.6 measured from ground level. The total number of inflorescent nodes which occurred during the growing season was about 14.2.

In 1976 the flowering period of the fababeans

(cultivar Ackerperle, Diana, and Herz Freya), at the Glenlea site, was about 40 days (i.e. 21 June, to 31 July, or 60-100 days after seeding). The first node in Ackerperle with flowers occurred at node 9.0 $\pm$ 1.2 and the last node with flowers was node 17.3 $\pm$ 0.5 measured from ground level. The total number of inflorescent nodes was 12.3.

The flowering period data for 1977 are shown in Fig. 5,6 Table III . The flowering period, at the U. of M. site, began about a week later than at the Glenlea site. Possibly the cold and drought conditions occurring at the U. of M. site retarded seed emergence. The number of vegetative nodes, below the first inflorescent node at the Glenlea site, was always greater than at the U. of M. site. This trend supports Jones's (1963) observations relating to the effect of water levels on broad beans.

It appears, from my data, that there is a direct correlation between the number of vegetative nodes and the time the first flowers appear, e.g. when there is a larger number of vegetative nodes the first day of flowering is delayed.

The flowering period, at the U. of M. site was 36.5 $\pm$ 1.5 days, range 33-38, but at the Glenlea site it was 33.15 $\pm$ 1.19 days, range 32-37. Great variability occurred in the number of flowering days among the cultivars at both sites. The shortest flowering period occurred in Herz Freya at both sites; this is probably because Herz Freya had the lowest number of inflorescent nodes.

Figure 5: The flowering periods of four cultivars of fababeans at two sites (1977).

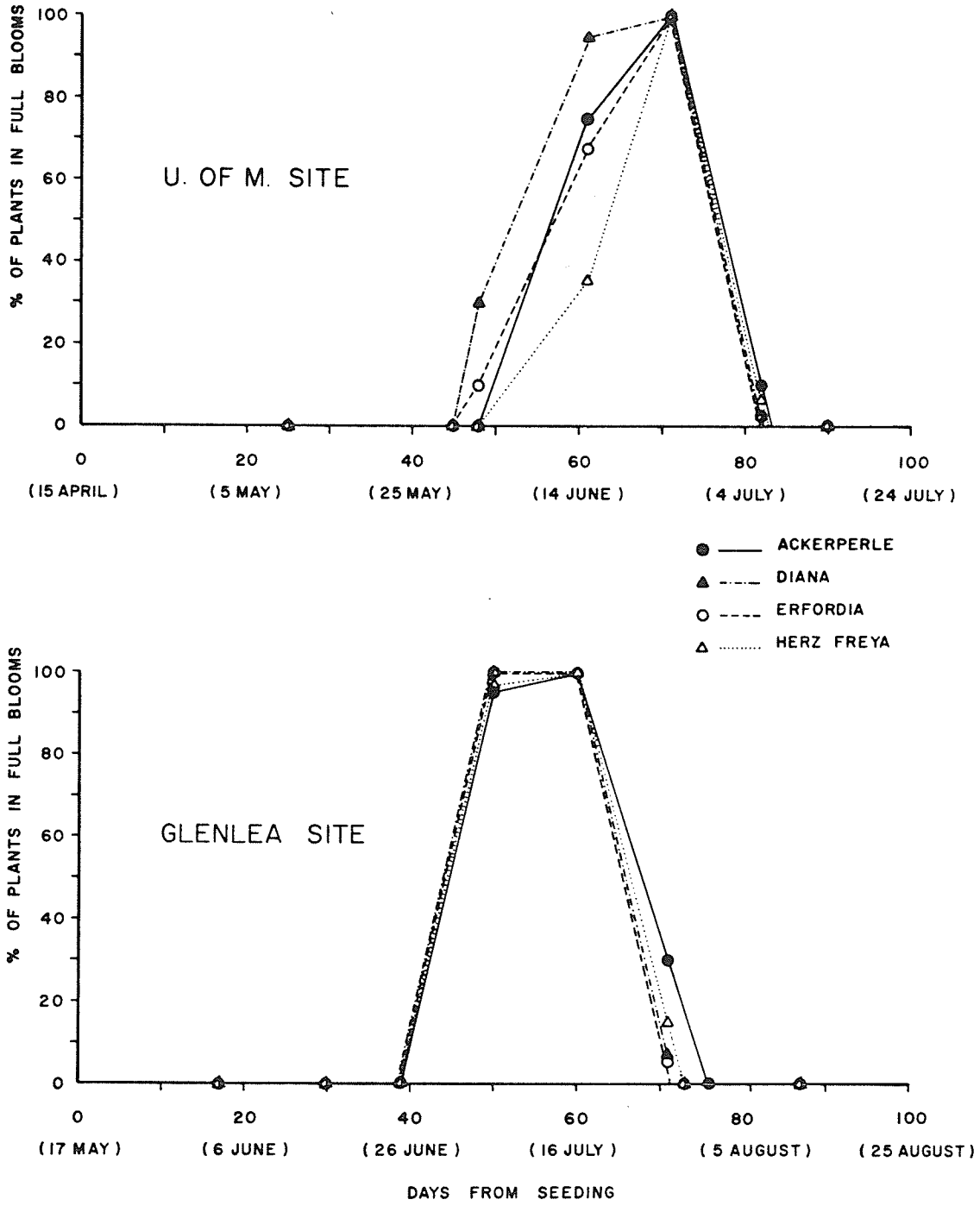

% OF PLANTS IN FULL BLOOMS
U. OF M. SITE
0
20
40
60
80
100
(15 APRIL)
(5 MAY)
(25 MAY)
(14 JUNE)
(4 JULY)
(24 JULY)
ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
% OF PLANTS IN FULL BLOOMS
GLENLEA SITE
(17 MAY)
(6 JUNE)
(26 JUNE)
(16 JULY)
(5 AUGUST)
(25 AUGUST)
DAYS FROM SEEDING

Figure 6: Numerical comparison of inflorescent nodes in four cultivars of fababeans at two sites (1977).

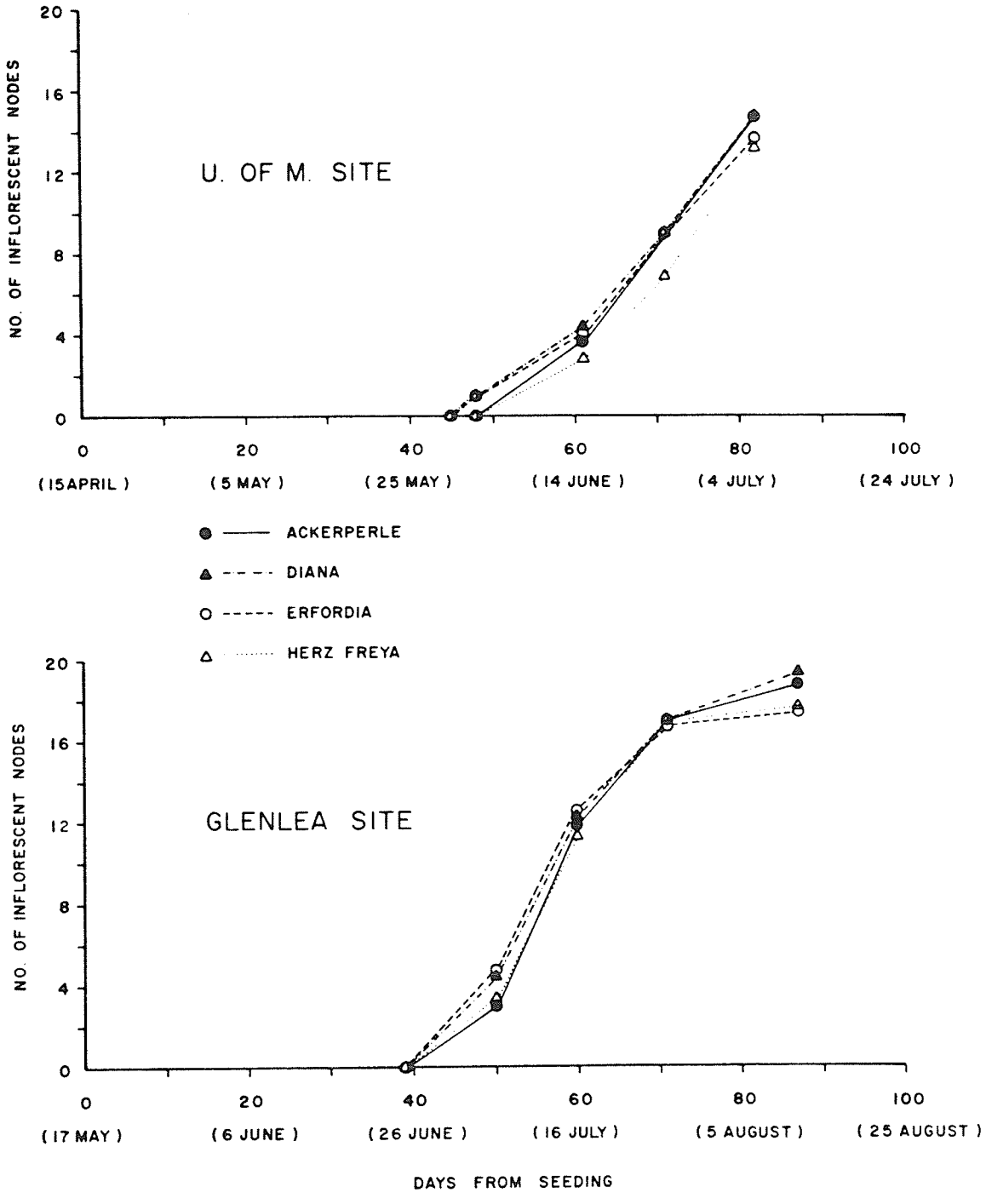

NO. OF INFLORESCENT NODES
U. OF M. SITE
0
4
8
12
16
20
0
20
40
60
80
100
(15APRIL)
(5 MAY)
(25 MAY)
(14 JUNE)
(4 JULY)
(24 JULY)
ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
NO. OF INFLORESCENT NODES
GLENLEA SITE
0
4
8
12
16
20
0
20
40
60
80
100
(17 MAY)
(6 JUNE)
(26 JUNE)
(16 JULY)
(5 AUGUST)
(25 AUGUST)
DAYS FROM SEEDING

TABLE III

FLOWERING PERIODS OF FABABEANS AT TWO SITES (1977)

	Cultivar			
	Ackerperle	Diana	Erfordia	Herz Freya
U. of M. Site				
Flowering periods	6 June - 10 July	30 May - 7 July	28 May - 7 July	7 June - 9 July
No. days after seeding	52-87	45-83	43-83	53-86
Total flowering days	35	38	40	33
No. of vegetative nodes before inflorescent nodes	7.71 ± 0.26*	6.43 ± 0.07	7.31 ± 0.05	8.80 ± 0.18
No. of inflorescent nodes	14.72 ± 0.38	14.67 ± 0.38	13.60 ± 0.46	12.70 ± 0.33
Glenlea Site				
Flowering periods	27 June - 3 Aug.	27 June-30 July	27 June-29 July	29 June-31 July
No. days after seeding	41-78	41-74	41-73	43-75
Total flowering days	37	33	32	32
No. of vegetative nodes before inflorescent nodes	9.05 ± 0.15	7.38 ± 0.17	8.23 ± 0.04	10.03 ± 0.18
No. of inflorescent nodes	18.70 ± 0.49	19.40 ± 0.40	17.50 ± 0.60	17.70 ± 0.33

*Mean and standard error.

At the Glenlea site the flowers bloomed earlier and in greater number than at the U. of M. site. The drought conditions (mentioned earlier) which occurred at the U. of M. site probably retarded floral formation (see Jones, 1963). Also, the mean temperature during the flowering period in June (i.e. the flowering period at the U. of M. site) was lower than that occurring in July (i.e. the flowering period at the Glenlea site) and therefore may be the reason more flowers were produced at the Glenlea site (Appendix Fig. 1). There was greater variation in the number of plants that had flowers early in the flowering period, at the U. of M. site than at the Glenlea site. Herz Freya in particular seemed to be sensitive to the environmental conditions which occurred at the U. of M. site. (see Fig. 5).

The different moisture levels at the two sites in 1976 appeared to affect the seedling stage in particular of the fababeans, e.g. the total number of inflorescent nodes at the Glenlea site was 12.3 compared to 14.2 at the U. of M. site, and the flowering period of the Glenlea site was about 40 days compared to 33 days at the U. of M. site.

3.3 Floral Development

3.3.1 Literature Review

In the development of flower buds in field beans, it has been observed that a bud, in the "early pointed stage" (i.e. green bud stage, see Page 28) takes from two to three days to reach the "hood stage" (i.e. white bud stage, see Page 28) and an additional two to three days to become an open flower (Kambal, 1969). In inflorescences of broad beans the lower flowers usually open one day earlier than do the upper ones (Inoue et al, 1963).

Synge (1947) found that in field beans each flower opens for three consecutive days, and closes each night.

It is known that many factors influence the activities of honey bees on flowering crops. Of these I studied the following in fababeans: floral stages, development times of these stages, and position of the flowering node in the raceme.

3.2.2 Materials and Methods

Observations were made in 1977 at the U. of M. site on the cultivar Ackerperle. Nine plants were chosen at random (about 60 days after seeding) and the first 16 racemes that appeared at the top of the nine plants were marked with tags. For 14 days thereafter, at 1200h and 1800h, the development of each flower, from the bud stage to the wilting stage (see below), was recorded.

The development of flowers was divided into stages as follows:

Stage I. Bud Stage

IA. Early green bud;

Bud just developing from the growing point, all petals are covered by the corolla tube; during this stage both the buds and the corolla are green in colour.

IB. Late green bud stage;

The petals begin to appear and are light green in colour.

IC. Early white bud stage;

The petals are totally exposed, and are whitish - green in colour.

ID. Late white bud stage;

Similar to IC except that the petals are now white in colour and still tightly closed.

Stage II. Bloom Stage

IIA. Early bloom;

The standard petal is open at an angle of 45-90^{o} and the wing petals and keel petal are released from the standard petal for the first time. Each is white in colour.

IIB. Full bloom;

The standard petal is fully open at an angle of about 180^{o} and is white in colour.

IIC. Late bloom;

The standard petal is fully open and folded backwards,

and is white in colour.

IID. Semi-opened bloom;

The standard petal opens again to an angle of 45-90°, and therefore appears similar to stage IIA above; however, the standard petal appears older, softer, and whiter than stage IIA flowers.

IIE. Closed bloom;

The standard petal closes and loosely covers the wing and keel petals.

IIF. Wilted bloom;

The standard and wing petals wilt and do not open again.

3.3.3 Results and Discussion

The results are shown in Fig. 7.

First Floret (within a raceme)

It took about 3.5 days for buds in Stage IA to develop to Stage IIA. About half of the Stage IIA blooms occurred during the afternoon and the other half in the evening. About half of all of the flowers in Stage IIB were observed in the evening of the second and third days while about 25% bloomed on the evening of the fourth day. Almost all of the flowers closed their petals during the morning. Some flowers were still in the semi-open bloom stage, at noon on the third or fourth day.

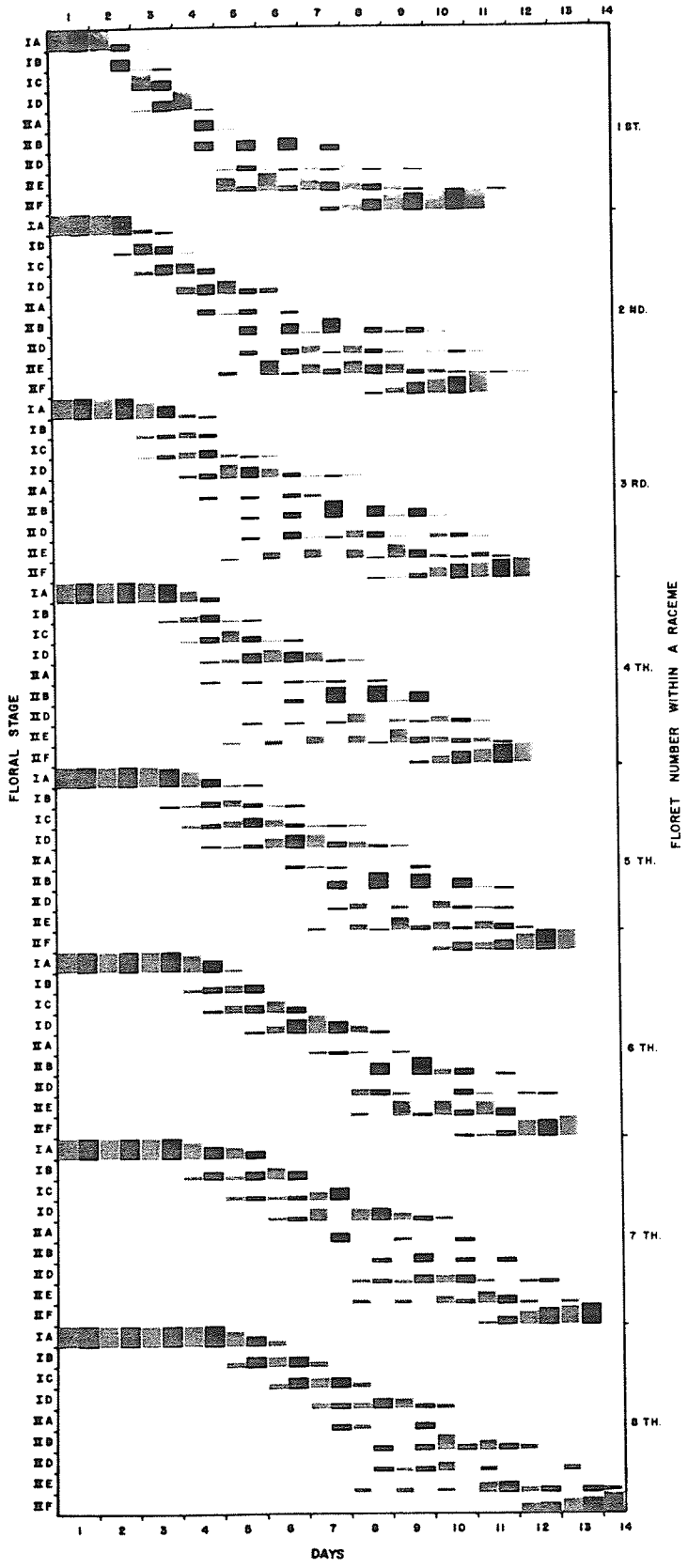
Second Floret

Stage IIA blooms occurred 3.5 - 5.5 days after those

Figure 7: Floral development within a raceme (cultivar Ackerperle, 1977).

Legend: ▒ - % of flowers or buds observed at 1200 h

■ - % of flowers or buds observed at 1800 h


1 2 3 4 5 6 7 8 9 10 11 12 13 14
IA
IB
IC
ID
IIA
IIB
IID
IIE
IIF
1 ST.
2 ND.
3 RD.
4 TH.
5 TH.
6 TH.
7 TH.
8 TH.
FLORAL STAGE
FLORET NUMBER WITHIN A RACEME
DAYS

of Stage IA. Almost all of Stage IIA blooms occurred in the evening. Stage IIB blooms were prolonged 4-5 days.

Third Floret

Three and a half days to six days were required for Stage IA buds to develop to Stage IIA blooms. Stage IIA blooms, which develop early tend to open their petals in the evening, but those that develop later show a tendency to open at noon. The Stage IIB blooms last 5-5.5 days.

Fourth Floret

Development from Stage IA to Stage IIA took 3.5 - 7.5 days. These flowers continue to bloom in the evening for about 4 days. Any flowers which were three to five days old tended to bloom before noon or during the early afternoon.

Fifth Floret

It took 5.5 - 9 days for Stage IA buds to develop to Stage IIA. These flowers remained in Stage IIB for 3-5 days. Stage IIB blooms tended to open during early afternoon while Stage IIA blooms occurred around noon.

Sixth Floret

It took 6 -8.5 days for the buds to change from Stage IA to Stage IIA. The flowers bloomed about 3-4 days. Three-day-old flowers tended to open before noon or during early afternoon.

Seventh Floret

Six and a half to nine and a half days were required for Stage IA buds to develop to Stage IIA. These flowers

(i.e. Stage IIB) opened for 4 days. The percentage of flowers that reached Stage IIB was very low.

Eighth Floret

Six and a half days to nine days were required for Stage IA buds to develop to Stage IIA. These flowers opened for 4 days but the percentage of buds which reached stage IIB was very low; they showed a greater tendency to open around noon.

In general, buds in Stage IA developed to Stage IB in 1.5 - 5.5 days depending on their position on the raceme; the lowest buds developed faster than the highest ones. One to two days were required for Stage IB buds to develop to Stage IC; it also took one to two days for these latter buds to develop to Stage ID. It took about a day for the buds of Stage ID to change to Stage IIA; this latter stage changed to Stage IIB within half a day. Generally the flowers bloomed for 2-5 days during the afternoon and evening, but they always closed at night. Stage IIA blooms, located at the lower nodes (i.e. 1-4), tended to bloom in the late afternoon or evening but those at the upper nodes (i.e. 5-8) bloomed in the morning or around mid-day.

Stage IIB blooms, which were one day old, and located at the lower nodes (i.e. 1-4) of the raceme bloomed all afternoon and evening. Stage IIB blooms, located at the upper nodes (i.e. 5-8) and Stage IIB blooms 3-4 days located at all nodes, bloomed all morning and throughout the afternoon.

Stage IID blooms generally occurred twice each day when Stage IIE blooms changed to Stage IIB blooms during the day and back again at night; all Stage IID blooms later changed to IIF blooms but they never returned to Stage IIB. However, at the upper nodes, Stage IID blooms often alternated daily between Stage IID and Stage IIE and they changed directly to Stage IIF without passing through Stage IIB. Sometimes when wet, cold, cloudy days prevailed Stage IIB changed to Stage IID.

Regardless of the position of the Stage IIE blooms on the raceme they occurred in high numbers while Stage IIB blooms occurred in low numbers; the opposite was also true.

Two days after Stage IIA flowers bloomed a high number of them changed to Stage IIE during the morning. Therefore it appears that Stage IIB blooms, observed in the morning, were likely flowers that had bloomed for a least two days or were flowers located on the upper part of the raceme.

Newly formed Stage IIB blooms usually occurred in the late afternoon for two reasons; (1) they changed from Stage IIA in the early afternoon of the same day, or (2) they changed from Stage IIA during the evening of the previous day.

When my data, relating to daily blooming periods, was compared to that of Synge (1947), it was observed that: (1) one-day-old flowers bloom in the early afternoon and

two-day-old flowers bloom in the morning; and (2) the daily blooming period was delayed about 2-3 hours for flowers in the Winnipeg area compared to flowers in the Hertfordshire, England area (3) it appears that all other daily blooming patterns, in the two studies, are similar.

CHAPTER IV

FLORAL ATTRACTANT STUDIES

Introduction

Fababean flowers, like many legume flowers, require bees to pollinate them. The bees visit the flowers to collect nectar and pollen as food for the adults or for the brood. The plants have various means of attracting bees.

The various attractants are classified into two categories: (a) primary attractants which fulfill the demand of the bees both in terms of food, e.g. pollen and nectar, which may vary in quantity and quality. (b) secondary attractants which directly or indirectly stimulate the sensory organs of the bees and influence them to visit the flowers. Examples of these attractants are scent, colour, and form of the flower. The attractants may have the same origin, e.g. the pollen is a food ("primary attractant") and it has attractive odours ("secondary attractant").

The production of floral attractants is a periodic phenomenon and is affected by various environmental factors, e.g. relative humidity, soil moisture, fertilizer, temperature, photoperiod, and physiological factors.

In this chapter various factors relating to the fababean plants and flowers, which might attract honey bees to them, were examined. These included floral numbers, floral colour, floral size, and the production of perfume. A more intensive study of the amount and sugar concentration of the nectar produced under various conditions was included. Studies of pollen dehiscence, number of pollen grains produced by the four cultivars, number of pollen grains carried by honey bees, and analyses of pollen collected in traps were also done to ascertain their importance in the pollination of fababeans.

4.1 General Studies

4.1.1 Floral Number

4.1.1.1 Literature Review

During the late afternoon, field beans have a maximum number of open flowers, the young flowers (i.e. those that are about one day old) open later than do the older ones (i.e. those that are more than two days old). About 20% of all open flowers are new ones (i.e. one-day old) (Percival, 1955, 1956; Poulsen, 1971, 1972; Synge, 1947). Synge (1947) reported that the field bean flowers begin opening at about 1400 h on the first day, at 1100 h on the second day, and at 0800 h on the third day.

During the flowering period of field beans in Denmark, the highest number of flowers estimated by Poulsen

(1971) was about 5,000,000 flowers per ha per day. The number of flowers varied negatively with photoperiod in field beans (Blondon, 1971, 1975; Evan, 1959; Tamaki et al, 1974).

Ivaskina (1968) reported that on average, 40-70 flowers, and 10-15 inflorescences, were found per plant. Inoue et al. (1963) found that the number of flowers per inflorescence is smaller at both the upper and lower nodes than at the central nodes of a stem.

Generally speaking there is a positive correlation between the number of fababean flowers occurring at various times of day and the number of honey bees that forage on them. In this study I examined this relationship in detail using four cultivars of fababeans.

4.1.1.2 Materials and Methods

Five plants were selected at random from each plot of four cultivars (Ackerperle, Diana, Erfordia, and Herz Freya) on 15 July, 1977 (59 days after seeding, i.e. about the mid flowering period), and again on 3 August, 1977 (78 days after seeding, i.e. about the end of the flowering period) at the Glenlea site. The number of flowers in the early bloom stage and the open bloom stage (i.e. full bloom stage and late bloom stage combined) (see Ch. III, 3.3) were recorded separately on each plant at two hour intervals between 900 h and 2100 h each day.

On 28 June, 1977, 50 plants were selected at random in five height categories (i.e. 30 ± 5, 50 ± 5, 70 ± 5, and

90 ± 5 cm) from plots of the cultivar Ackerperle at the U. of M. site. The number of flowers occurring on these plants at about 1800 h were recorded.

The number of flowers occurring on 100 full grown plants of each cultivar at both sites (1977), was obtained by counting the floral pedicels on these plants. The plants were chosen at random from the Latin Square plots. The numbers of inflorescent nodes were also recorded at the same time and, by dividing the number of flowers per plant by the number of inflorescent nodes, the number of flowers per inflorescent node was obtained.

A count of the number of flowers occurring at each inflorescent node of the cultivar Ackerperle was obtained from five full grown plants, each of which had exactly 15 flowering nodes. These plants were chosen at random from within the plots at each site.

The counts of the number of flowers per plant, the inflorescent nodes per plant, and the flowers per inflorescent node on four cultivars at both sites (1977) were each analyzed by a One-Way ANOVA followed by a SNK Multiple Range Test; the number of flowers per plant in Ackerperle at different plant heights at the U. of M. site (1977) were also analyzed in this way. The counts of the number of flowers per plant found in four cultivars at different times of the day (Glenlea site, 1977) were analyzed by a Two-Way ANOVA followed by a SNK Multiple Range Test; a log 10 (x+1)

transformation was used to stabilize the variance.

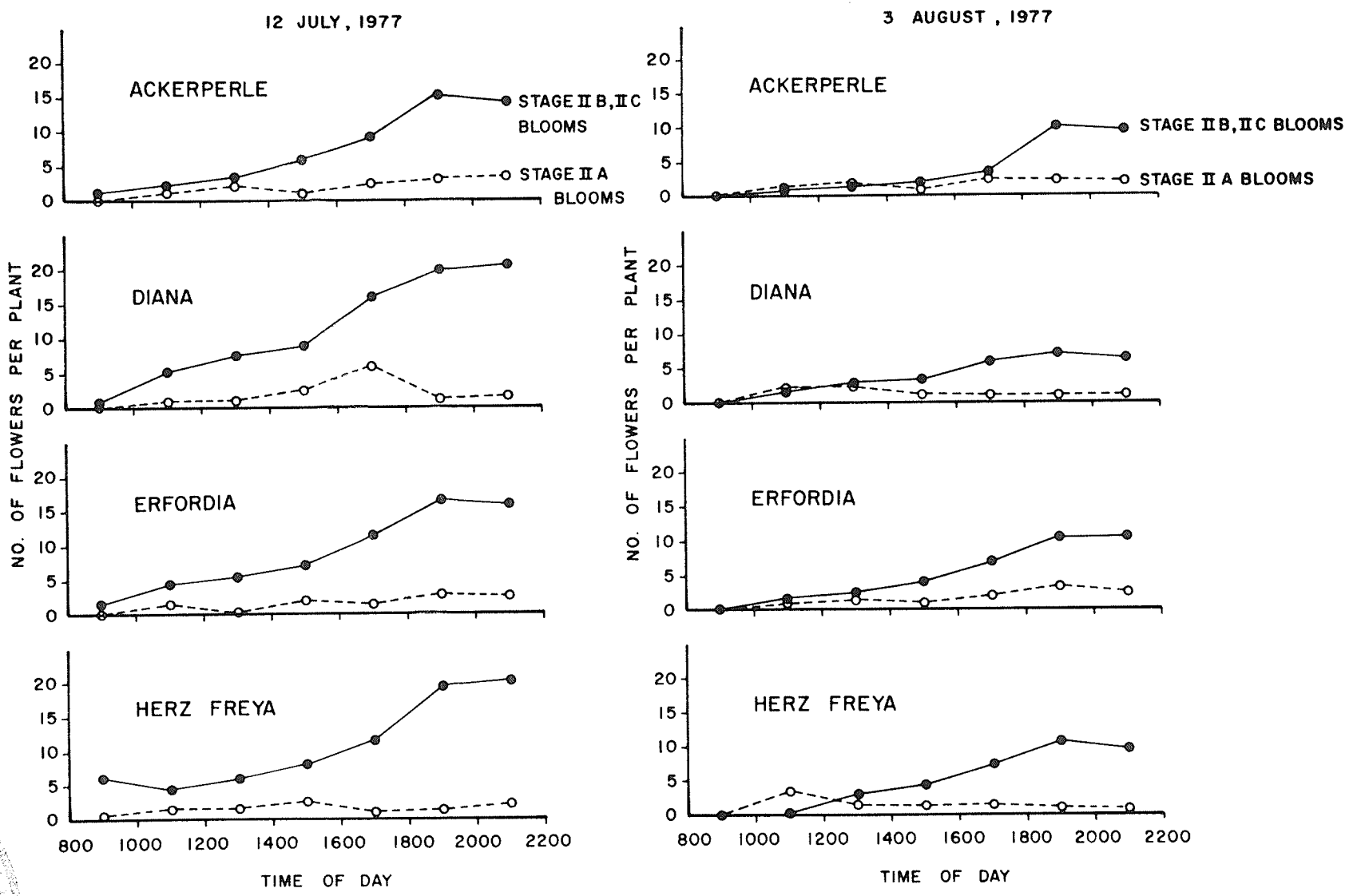
4.1.1.3 Results and Discussion

The results are shown in Fig. 8, and Appendix Table III.

On the first day of observation, a few flowers of the cultivars Ackerperle, Diana, and Erfordia were blooming around 900 h, but some flowers of the cultivar Herz Freya were open before this time. Significantly fewer flowers of Ackerperle were found in the morning than flowers of Diana Erfordia or Herz Freya ($P<0.01$). More flowers were observed during the morning of the first day than during the second day ($P<0.05$). The number of flowers observed in the cultivar Diana, Erfordia and Herz Freya was significantly higher than in Ackerperle in the two day counts. There was no significant difference in the number of flowers among the former three cultivars, on the first day of observation. The number of open flowers observed on Diana and Herz Freya tended to be higher than on Ackerperle and Erfordia, but on the second day of observation the number on Diana tended to be the lowest. There was a significantly greater ($P<0.01$) number of flowers produced per plant (on all cultivars), on the first day of observation.

With each succeeding two-hour count there was a significant increase in the number of flowers observed for all cultivars ($P<0.01$); one exception occurred between the 1300-1500 h reading and the 1900-2100 h reading. A particularly high increase in the number of flowers occurred between 1500-1900 h. All of the flowers of each cultivar closed up after sunset.

Figure 8: Number of flowers in various stages of development in four cultivars of fababeans at different times throughout the day (Glenlea site, 15 July and 3 August, 1977).


12 JULY, 1977
3 AUGUST, 1977
ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
STAGE II B, II C BLOOMS
STAGE II A BLOOMS
NO. OF FLOWERS PER PLANT
TIME OF DAY
0
5
10
15
20
800
1000
1200
1400
1600
1800
2000
2200

The number of early blooms was very low on all cultivars on both days. There was no significant difference in the number of early blooms produced between the various two-hour periods within, and between, the four cultivars. Early blooms were not observed before 900 h.

Synge (1947) reported that the field bean flowers in Hertfordshire, England attained their maximum number at 1600 h, but after that the number declined sharply between 1800-1900 h; after this all flowers closed. At Winnipeg, by contrast, the number of fababean flowers reached their maximum about three hours later than in Hertfordshire; furthermore the flowers bloomed until 2100 h or later.

The taller plants of the cultivar Ackerperle produced more flowers than did the shorter ones on the same day (Table IV). There was no significant difference in the number of flowers observed on the plants which were 70 ± 5 and 90 ± 5 cm high. However, these plants produced significantly more flowers than did the plants which were 30 ± 5 and 50 ± 5 cm high ($P < 0.01$). Plants which were 30 ± 5 cm high had significantly fewer flowers than did plants which were 50 ± 5 cm high ($P < 0.01$).

The number of inflorescent nodes per plant, the number of flowers per plant, and the number of flowers per inflorescent nodes are shown in Table V.

Floral production was significantly higher at the Glenlea site than at the U. of M. site ($P < 0.01$). The

TABLE IV

NUMBER OF FLOWERS PER PLANT IN FULL BLOOM FOUND IN ACKERPERLE AT DIFFERENT PLANT HEIGHTS (U. OF M. SITE, 1977)

Height of Plant (cm)	30±5	50±5	70±5	90±5
No. of Flowers Per Plant	$8.68 \pm 0.36^{C*}$	9.84 ± 0.39^{B}	11.32 ± 0.52^{A}	11.42 ± 0.54^{A}

* Mean and standard error

A, B, C: means followed by different upper case superscripts differ significantly $P < 0.01$.

TABLE V

FLORAL PRODUCTION ON FOUR CULTIVARS OF FABABEANS

AT TWO SITES (1977)

Site	Characters	CULTIVAR			
		Ackerperle	Diana	Erfordia	Herz Freya
U. of M.		*			
	Flowers/plant	64.93 ± 2.24^{AB}	69.38 ± 2.17^{A}	61.76 ± 1.98^{B}	52.03 ± 1.70^{C}
	Inflorescent nodes/plant	12.42 ± 0.32^{AB}	13.17 ± 0.31^{A}	11.94 ± 0.28^{BC}	11.16 ± 0.25^{C}
	Flowers/inflorescent node	5.14 ± 0.09^{A}	5.20 ± 0.07^{A}	5.11 ± 0.08^{A}	4.59 ± 0.07^{B}
Glenlea					
	Flowers/plant	93.11 ± 2.43^{a}	92.75 ± 6.36^{a}	81.73 ± 2.77^{a}	87.52 ± 2.68^{a}
	Inflorescent nodes/plant	15.62 ± 0.33^{A}	13.90 ± 0.33^{B}	13.14 ± 0.32^{B}	13.95 ± 0.30^{B}
	Flowers/inflorescent node	5.93 ± 0.08^{a}	6.15 ± 0.10^{a}	6.14 ± 0.10^{a}	6.19 ± 0.09^{a}

* Mean and standard error

A, B, C: means followed by different upper case superscripts differ significantly $P < 0.01$.

a, b, c: means followed by different lower case superscripts differ significantly $P < 0.05$.

(Single character compared between columns)

TABLE VI

THE EFFECT OF POSITION OF INFLORESCENT NODES ON THE NUMBER OF FLOWERS PER RACEME OF FABABEAN (CULTIVAR ACKERPERLE, AT TWO SITES, 1977)

	Inflorescent From the Base Upwards														
Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
U. of M.	4.4±0.4*	6.2±0.2	6.2±0.4	6.2±0.7	6.6±0.5	6.8±0.4	5.8±0.5	5.8±0.5	5.6±1.0	5.6±0.4	4.6±0.7	3.8±0.6	4.0±0.0	2.8±0.4	2.4±0.5
Glenlea	5.6-0.7	6.8-0.6	6.4-0.4	7.4-0.6	7.2-0.6	7.2-0.6	7.6-0.8	6.0±0.9	6.2±0.9	5.2±0.9	5.2±0.9	4.4±1.0	3.4±0.5	3.6±0.4	2.4±0.3

* Mean and standard error.

cultivars Ackerperle, Erfordia, and Herz Freya produced a significantly higher number of inflorescent nodes per plant, number of flowers per plant, and number of flowers per inflorescent node at the Glenlea site ($P<0.01$). The cultivar Diana produced a higher, but non-significant, number of flowers per plant, and number of flowers per inflorescent node, at the Glenlea site.

Herz Freya had a significantly lower number of inflorescent nodes per plant than did the other three cultivars at U. of M. site ($P<0.01$), but there was no significant difference between Erfordia and Ackerperle or between Ackerperle and Diana. At the U. of M. site, the cultivar Ackerperle and Diana had a significantly greater number of inflorescent nodes per plant than did Herz Freya ($P<0.01$), and Diana had a significantly greater number of inflorescent nodes per plant than did Erfordia ($P<0.01$); however no significant differences occurred between Ackerperle and Diana or between Erfordia and Herz Freya. At the Glenlea site, there was a significantly greater number of inflorescent nodes per plant in Ackerperle than in Diana, Erfordia, or Herz Freya ($P<0.01$), but there was no significant difference between the latter three cultivars.

At the U. of M. site, there were significantly more flowers per plant produced in Diana than in Erfordia or Herz Freya ($P<0.01$), and Ackerperle had significantly more flowers per plant than did Herz Freya ($P<0.01$). There was no significant difference in the number of flowers per

plant between Ackerperle and Diana. Herz Freya had significantly fewer flowers per plant than did the other three cultivars ($P < 0.01$). There was no significant difference in the number of flowers per plant produced by the four cultivars at the Glenlea site.

At the U. of M. site, Herz Freya had significantly fewer flowers per inflorescent node than did the other three cultivars ($P<0.01$); there was no significant difference within these three cultivars. However, at the Glenlea site, there was no significant difference in the number of flowers per inflorescent node within the four cultivars.

The number of flowers produced at various inflorescent nodes on the cultivar Ackerperle (Table VI) showed that the highest number of flowers per inflorescent node was produced from about the middle of the inflorescent nodes of the plants or from the nodes below the middle of the plants. The first inflorescent nodes at the bottom of the plants produced fewer flowers than did the upper ones.

4.1.2 Floral Colour

4.1.2.1 Literature Review

Fababean flowers of any cultivar range in colour from white to pink to purple. As a rule colours through the range pink - red - violet - blue are due to anthocyanins, while yellow - red - purple colours are due to carotinoids or flavones. White is due to multiple reflection in the intercellular spaces between the uncoloured cells, while black is due to a similar reflection between the layers of complementary colours. Ecologically, green is not considered a "colour". Chlorophyll is frequently present before anthesis, but later on it is generally broken down. Very rarely are green colours due to substances other than chlorophyll (Benl, 1938).

Bees recognize four colour groups: yellow, blue-green, blue, ultraviolet, but not red (Kuhn and Pohl, 1924). Most red blossoms contain a blue component, so they will appear blue or ultraviolet to a bee. However, Kugler (1936) has shown that red-marked flowers are not regularly visited by bees.

Nectar guides seen on the standard petals of fababean flowers consist of radiating lines pointing toward the center of the flower. These lines occur in various colours within a cultivar, e.g. light grey, black, pink, and purple.

Because of difficulties inherent in perfume analyses,

little is known about the localization of scent in blossoms. However odour guides are known, which may be, in fact, combined with visual nectar guides.

Loper and Waller (1970) found that bees are attracted more to the light purple flowered clones than to the green-yellow flowered clones in alfalfa. He also noticed that the purple-flowered clones had a sweet, pleasant scent while the greenish-yellow flowers had a musty "green" scent.

4.1.2.2 Materials and Methods

Combinations of colours in fababean flowers selected for study were as follows:

Type A 1: Standard petal white, veins (i.e. nectar guides) light in colour and barely visible.

Type A 2: Standard petal white, veins black.

Type A 3: Standard petal white or with purple pigments, veins purple.

Type B 1: Corolla tube green.

Type B 2: Corolla tube green mixed with red or purple pigmented spots.

Twenty five plants were selected at random from each of four cultivars (Ackerperle, Diana, Erfordia, and Herz Freya) grown at the Glenlea site in 1978. The colours of the standard petals and corolla tube were recorded for the full bloom stage of each plant.

Variation in frequency of colour types in the four

cultivars (Glenlea site, 1978) was analysed by a Chi-Square Test.

4.1.2.3 Results and Discussion

The results are shown in Table VII.

The cultivar Ackerperle had significantly more Type A 1 flowers than did either Diana or Erfordia ($P < 0.01$) while significantly more Type A 2 flowers were observed in Diana than in Ackerperle or Erfordia ($P < 0.01$). The cultivar Erfordia had significantly more Type A 3 flowers than did Ackerperle ($P < 0.01$), Diana ($P < 0.01$) or Herz Freya ($P < 0.05$).

The cultivar Ackerperle had significantly more Type B 1 corolla tubes than Type B2 corolla tubes ($P < 0.05$); it also had significantly more Type B 1 corolla tubes than did Diana ($P < 0.01$), Erfordia ($P < 0.01$), or Herz Freya ($P < 0.05$).

In summary the results show that the flowers of the cultivar Ackerperle tend to be pure white in colour, without purple pigments on the petals and corolla tubes. Diana has white petals with black veins, and corolla tubes with purple pigments. Erfordia has a large number of flowers with purple pigments which occur on their petals, nectar guides, and corolla tubes. The flowers of the cultivars Herz Freya show greater variation in colour, some have and some have not purple pigments on the petals and corolla tubes.

Although there is a variation in floral colour in fababeans, it is possible to identify some cultivars using

TABLE VII

COLOUR VARIATION OBSERVED IN THE STANDARD PETALS AND COROLLA TUBES OF FOUR CULTIVARS OF FABABEANS (GLENLEA, 1978)

	Colours of Standard Petals and Corollas					
	A_1		A_2		A_3	
Cultivar	B_1	B_2	B_1	B_2	B_1	B_2
Ackerperle	48*	20	16	8	4	4
Diana	0	4	8	88	0	0
Erfordia	0	0	0	28	4	68
Herz Freya	12	16	20	32	4	16

*Percentage of Flowers Observed.

A_1 Standard petal white, veins light in colour and barely visible.

A_2 Standard petal white, veins black.

A_3 Standard white or with purple pigments, veins purple.

B_1 Corolla tube green

B_2 Corolla tube green mixed with red or purple pigmented spots.

the above method.

Bond et al (1964 ab, 1966) concluded that male-sterility in fababeans is associated with pink diffuse pigments in the flowers and this character is controlled by a simple recessive gene. It is possible that many of the plants within my experimental cultivar Erfordia were self-sterile, or that there were more male-sterile plants within this cultivar than the others.

4.1.3 Size of Flowers

4.1.3.1 Literature Review

Kambal et al (1976) found that there are four aspects of the floral structure which seem to allow a ventral passage for the pollen and which could be associated with some degree of self-pollinating ability. They are as follows:

a) A short style

b) A large angle of the style with the ovary. This has the effect of bringing the stigma away from the keel-petal ridge.

c) Reduced hairs on the style, especially on the ventral side.

d) The keel-petal ridge being less pronounced, or at a wide angle to the style, or curving away from the style.

It seems important, from the above, to know the size of flowers of the four cultivars of fababeans because this

may affect the number of bee visits, reproductive units (i.e. pollen grains, and number of ovules), attractants, and the chance of pod set.

4.1.3.2 Materials and Methods

On 16 June 1977, (i.e. about the early flowering period) 40 fababean flowers, in the full bloom stage, were chosen at random from each of the four cultivars. The length of the corolla tube, pistil tube, keel, wings and standard petals (Fig. 9) of each of the flowers were measured.

The various floral measurements in each treatment, were analysed by a One-Way ANOVA followed by a SNK Multiple Range Test.

4.1.3.3 Results and Discussion

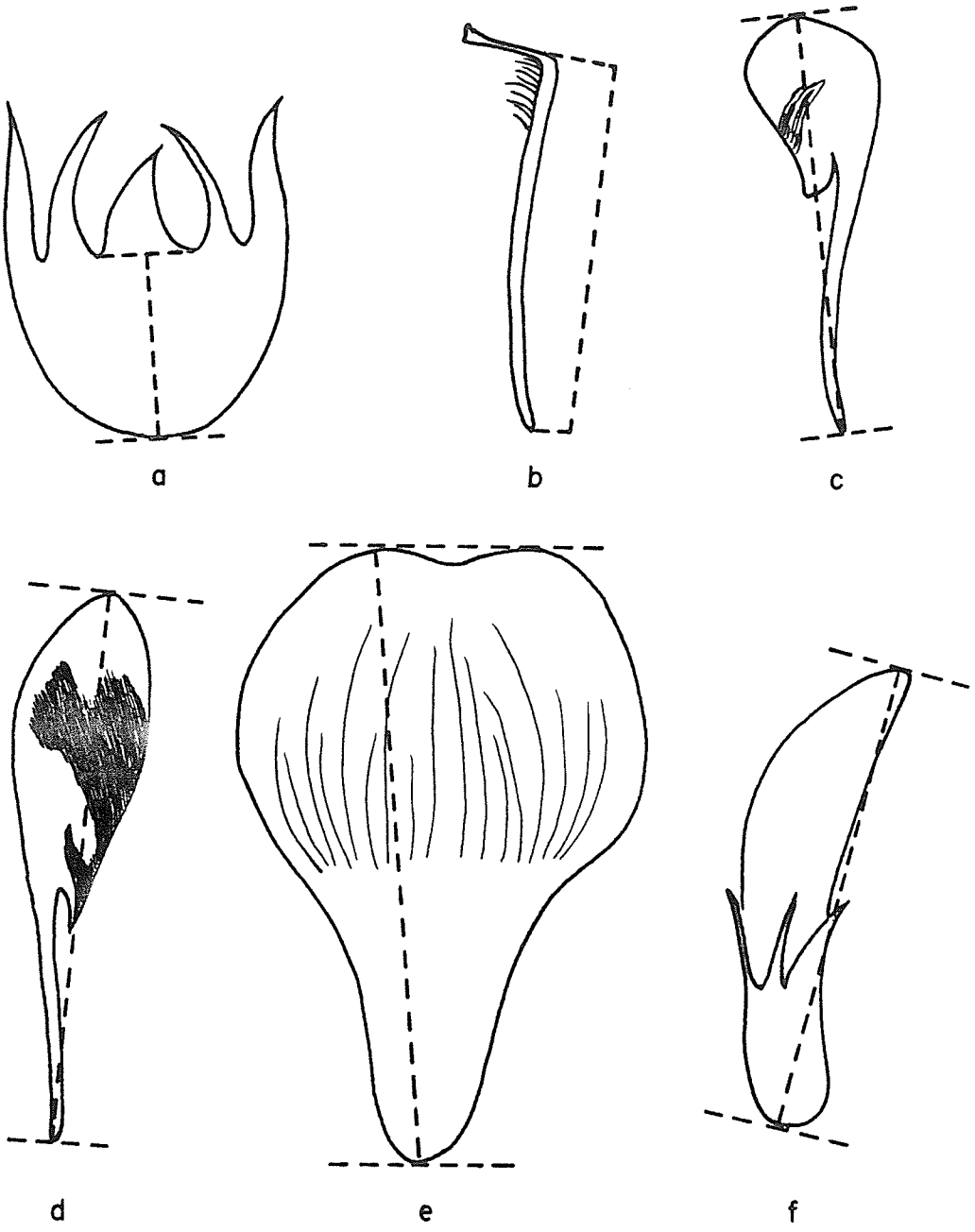
The results are shown in Table VIII.

Corolla Tube

The corolla tubes of the cultivar Diana were significantly longer than those of the other three cultivars ($P < 0.01$) but there was no significant difference in corolla tube length between the cultivars Ackerperle, Erfordia, and Herz Freya.

The pistils of the cultivar Herz Freya were significantly longer than those of the cultivar Ackerperle ($P < 0.01$) and Erfordia ($P < 0.05$) but there was no significant differ-

FIGURE 9



FLORAL MEASUREMENTS

a Corolla tube length
b Pistil tube length
c Keel length
d Wing petal length
e Standard petal length
f Bud length

TABLE VIII

MEASUREMENTS OF VARIOUS FLORAL PARTS OF FOUR CULTIVARS

OF FABABEANS AT THE U. OF M. SITE

(16 JUNE, 1977)

	Length of Floral Parts (MM)					Ratio of Keel Length to Pistil Length
Cultivar	Corolla	Pistil	Keel	Wings	Standard	
Ackerperle	B * 7.07±0.11	Bc 17.12±0.16	B 18.96±0.15	B 26.56±0.21	Bc 28.84±0.26	1.11
Diana	A 7.47±0.10	Aa 18.35±0.10	A 20.44±0.10	A 28.14±0.25	Aa 31.36±0.19	1.11
Erfordia	B 7.06±0.08	AB 17.92±0.13	A 20.26±0.12	A 27.87±0.23	Bb 29.77±0.26	1.13
Herz Freya	B 6.85±0.10	Aa 18.46±0.11	A 20.39±0.12	A 27.79±0.25	Bb 29.7 ±0.20	1.11

* Mean and standard error.

A, B, C, Means followed by different upper case superscripts differ significantly $P < 0.01$.

a, b, c, Means followed by different lower case superscripts differ significantly $P < 0.05$.

(Single character compared between cultivars)

ence in pistil length between the cultivar Herz Freya and the cultivar Diana. The pistil tubes of the cultivar Ackerperle were significantly shorter than those of the other three cultivars ($P < 0.01$).

Keel

The keels of the cultivar Ackerperle were significantly shorter than those of the other three cultivars ($P < 0.01$), but there was no significant difference in keel length between the cultivars Diana, Erfordia, and Herz Freya. A ratio of keel length to pistil length showed that the cultivars Ackerperle, Diana and Herz Freya were all the same (i.e. 1.11); only Erfordia had a different ratio (i.e. 1.13), which was higher than the other three cultivars.

Wing Petals

The length of the wing petals of the cultivar Ackerperle, was significantly shorter than those of the cultivars Diana, Erfordia, or Herz Freya ($P < 0.01$); there was no significant difference in the length of the wing petals of the latter three cultivars.

Standard Petals

The standard petals of the cultivar Diana were significantly longer than those of Ackerperle, Erfordia or Herz Freya ($P < 0.01$). There was no significant difference in the length of the standard petal of Erfordia and Herz Freya, but they each had standard petals which were significantly longer than those of the cultivar Ackerperle ($P < 0.05$).

In summary, the above results show that the flowers of the cultivar Diana tend to be larger, that the flowers of Erfordia and Herz Freya are very similar in size, and that the flowers of the cultivar Ackerperle tend to be the smallest in size. Of interest is the fact that the length of the pistil of Erfordia is significantly shorter than that of Herz Freya. The author also noticed that the petals and corolla tubes of Diana were thicker than those of the other cultivars.

4.1.4 Perfume

4.1.4.1 Literature Review

Honey bee visits to fababeans are likely influenced by floral colour, floral scent, pollen availability, nectar volume and sugar concentration, or any combination of these factors. Manning (1957) observed that, in general, a change of floral scent provokes a stronger discrimination of flowers by honey bees than does a change of floral pattern or shape. Koltermann (1969) concluded that scent was more important in conditioning honey bees to visit various flowers than is colour, form, or time of day. Unfortunately, little information is available about the effect of scent of field beans on honey bee behaviour, nor do we know the substances that make up the scent, or the relationship between scent and floral colour.

The principle source of floral scent in most plants is the petals; nectar may also absorb some of the petal scent (Hampton, 1925; Loper and Lapiolo, 1971).

Honey bees respond to differences in floral scent within different clones of alfalfa. The bees are attracted to the scent of such substances, as ocimene, myrcene, and limonene, which occur at different levels within alfalfa clones (Loper and Waller, 1970; Loper et al, 1974; Waller et al, 1974).

Generally speaking, one would expect a high population of honey bees on fababeans during the time when a large number of flowers are blooming and when floral scent is at its greatest.

4.1.4.2 Materials and Methods

During the fababean flowering period of 1976, the scent of the flowers was tested subjectively (i.e. smelled) by the author at various times between 800 and 2200 h. Five categories were used to read the strength of the floral scent, i.e. no scent, very weak scent, weak scent, strong scent and very strong scent.

In 1976, at the U. of M. site twenty buds and blooms of the cultivar Ackerperle were collected at random from each of late white bud stage (ID), early bloom (IIA), full bloom (IIB, one to two days old) and old full bloom (IIB, more than three days old). (See page 28). Each of these groups

was sealed in plastic bags (17 x 21 cm) one hour before a test was done. Each bag was opened carefully and its aromatic contents were smelled by the author and its strength recorded.

4.1.4.3 Results and Discussion

The fababeans gave off little or no scent in the morning, became weak in the early afternoon and stronger in the late afternoon (i.e. after 1400 h.). The strongest scent occurred between 1600-1800 hrs. and slowly declined after this period; after sunset the scent disappeared.

In descending order from strongest to weakest the scent of the blooms or buds occurred as follows: full bloom stage (II B, one to two days old), old full bloom stage (II B, more than three days old), early bloom stage (II A), and white bud stage (I D). It appeared that the scent observed in the fields was the strongest at or between 1600-1800 h when the greatest number of full blooms and old full blooms occurred (i.e. 1800-2000 h., see Fig. 8).

4.2 Nectar Studies

4.2.1 Nectar from Fababean Plants

4.2.1.1 Literature Review

Nectar productivity of field beans depends on growing techniques, (i.e. the second growth after cutting gives more sugar and this in turn depends on the cultivar (Cherkasova, 1966). Soper (1952) reported that nectar flow in field beans appears to increase with rise in temperature.

The most vigorous plants produce the most flowers, without any decrease in the sugar concentration of the nectar (Smaragdova et al, 1966).

Weaver (1954) found that there were differences in nectar concentration between the early flowering and late flowering periods in hairy vetch (Vicia villosa); in the early period the nectar had about 55% sugar which decreased to 40% in the late flowering period. When Weaver repeated this experiment, the sugar concentration in the nectar ranged between 45 and 50% throughout the season.

Koreshkov (1966) reported that nectar productivity of field beans can be increased by increasing the density of plants and by applying specific fertilizers.

The sugar content of the nectar per flower in field beans is greater (0.88 mg) in white-flowered forms than in forms with coloured flowers (0.51 mg) (Smaragdova et al, 1966).

Vicia beans can secrete nectar in another way, i.e. through extrafloral nectaries which are on the underside of the stipules (the small leaf-like parts at the base of the leaf). It is presumed that these nectaries function throughout the vegetative period of the plant, and that repeated removal of nectar stimulates further production; however, total nectar yields, from these nectaries, are small (Free, 1962; Koreshkov, 1967; Smaragdova et al, 1966. Svendsen (1969) reported that nectar from the extra-

floral nectaries, has the same sugar content as floral nectar (under Danish conditions). According to Darwin (1876), the secretion from the extrafloral nectaries depends upon the amount of sunshine.

Nectar is the major carbohydrate food source of honey bees. Therefore, the amount and the concentration of the nectar in different cultivars throughout the day should directly affect the number of bee visits and hence the pollination of the flowers. Also flowering periods may affect the production of nectar. There is little information about the amount and concentration of nectar occurring in the extrafloral nectaries in fababeans. To elucidate the above I used cages over the four cultivars in my experiments.

4.2.1.2 Materials and Methods

Glass capillary tubes, 0.5 mm in diameter and 10 cm in length, were used to collect nectar from the nectaries. Flowers in the full bloom stage were chosen at random and tested to determine if nectar was present. A capillary tube was inserted through the base of the flower between the upper part of the sexual column and the standard petal. The tube was then withdrawn and checked for nectar. If there was nectar in the tube, the flower was removed from the plant and the same capillary tube was inserted into the base of the flower again. At the same time the base of the corolla

was gently pressed between the authors' fingers after which the tip of the tube was slowly withdrawn, all the while in contact with the inner side of the standard petal. Using this method all of the nectar was removed from the flower.

Five flowers, in the full bloom stage, were chosen at random from plots at two sites, and the amount of nectar each floral nectary contained was measured; after this was done the five samples were combined and the sugar concentration measured.

Measurements of nectar, from extra floral nectaries (found in stipules), were made as follows: the amount of nectar from five stipules, chosen at random, was collected in a capillary tube (see above) and measured. This was replicated five times after which the nectar from these tubes was combined and a sugar concentration measurement taken. In collecting the nectar it is necessary to touch the nectary 2-3 times, or until all of the nectar has been collected.

The volume of nectar was measured in mm of nectar seen in the capillary tube, and converted to microliters by multiplying this figure by 0.1578. An Abbe refractometer was used to determine the sugar concentration of the nectar.

The nectar tests were done at two hour intervals from 800 h to 2200 h in 1977 on two dates at each site (i.e. 23 June, and 9 July at the U. of M. site; 7 July and 21 July at the Glenlea site). Nectar samples were taken

from four cultivars within open plots and within caged plots (see Ch. VII, Fig. 1).

The amount of nectar in the open plot experiments (both sites, 1977), and the sugar concentration data (both sites, 1977) were each analysed using a Four-Way Factorial ANOVA followed by a SNK Multiple Range Test.

The sugar concentration data in the open plot experiments (both sites, 1977), and the amount of nectar in the cage trials (both sites, 1977), were analysed by a Three-Way Factorial ANOVA followed by a SNK Multiple Range Test, and a Five-Way ANOVA followed by a SNK Multiple Range Test respectively.

A $\log_{10}(x+1)$ transformation was used for analysing the nectar amounts and a $\log_{10}(x)$ transformation was used for analysing sugar concentrations of nectar.

4.2.1.3 Results and Discussion

The results are shown in Tables IX, X, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI, XXII, XXIII, XXIV, XXV, XXVI, Figs. 10, 11, 12.

Nectar Amount

Significantly more nectar was produced from the nectaries of Ackerperle, Diana, and Herz Freya, in both sites, on 23 June and 7 July (i.e. about early flowering period) than on 9 July and 21 July (i.e. about the late flowering period) ($P<0.01$) (Table IX, X). Erfordia showed less difference ($P<0.05$) than the above cultivars at the Glen-

Figure 10: Amount and sugar concentration of nectar collected from four cultivars at different times throughout the day (U. of M. site, 23 June and 9 July, 1977).

Legend:
A1 - Floral nectaries, open plots, 23 June
A2 - Floral nectaries, caged plots, 23 June
A3 - Extrafloral nectaries, open plots, 23 June
A4 - Extrafloral nectaries, caged plots, 23 June
B1 - Floral nectaries, open plots, 9 July
B3 - Extrafloral nectaries, open plots, 9 July

 - Sugar concentration of nectar (%),
Floral nectaries (collected from 5 flowers)
Extrafloral nectaries (collected from 25 stipules)

 - Amount of nectar,
Floral nectaries (microlitre/flower)
Extrafloral nectaries (microlitre/stipule)

●—- Relative Humidity
o---- Temperature (°C)

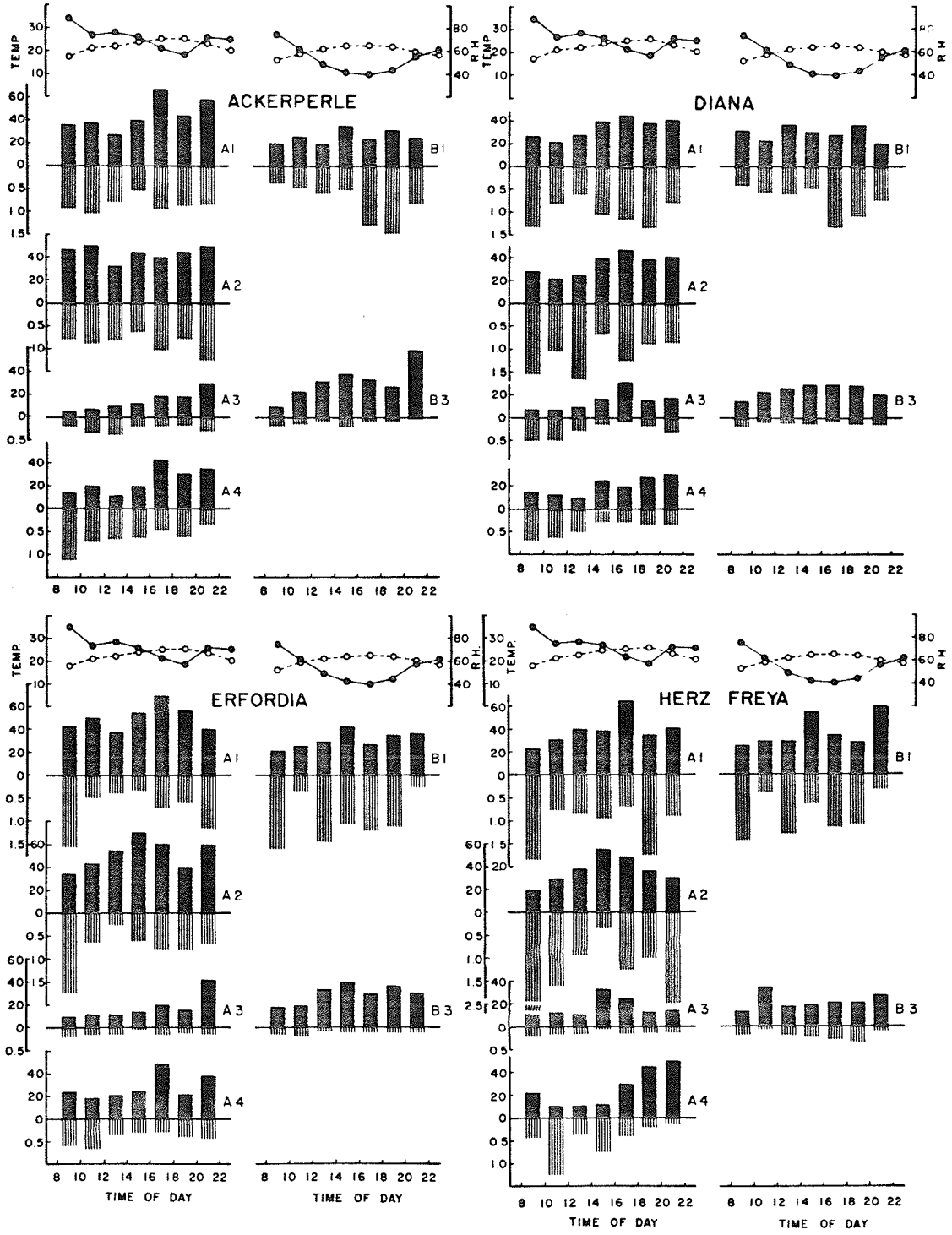

ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
TEMP.
R.H.
A1
B1
A2
A3
B3
A4
8 10 12 14 16 18 20 22
TIME OF DAY

Figure 11: Amount and sugar concentration of nectar collected from four cultivars at different times throughout the day (Glenlea site, 7 July and 21 July, 1977).

Legend: C1 - Floral nectaries, open plots, 7 July
C2 - Floral nectaries, caged plots, 7 July
C3 - Extrafloral nectaries, open plots, 7 July
C4 - Extrafloral nectaries, caged plots, 7 July
D1 - Floral nectaries, open plots, 21 July
D2 - Floral nectaries, caged plots, 21 July
D3 - Extrafloral nectaries, open plots, 21 July
D4 - Extrafloral nectaries, caged plots, 21 July

 - Sugar concentration of nectar (%),
Floral nectaries (collected from 5 flowers)
Extrafloral nectaries (collected from 25 stipules)

 - Amount of nectar,
Floral nectaries (microlitre/flower)
Extrafloral nectaries (microlitre/stipule)

●— Relative Humidity
o--- Temperature (°C)

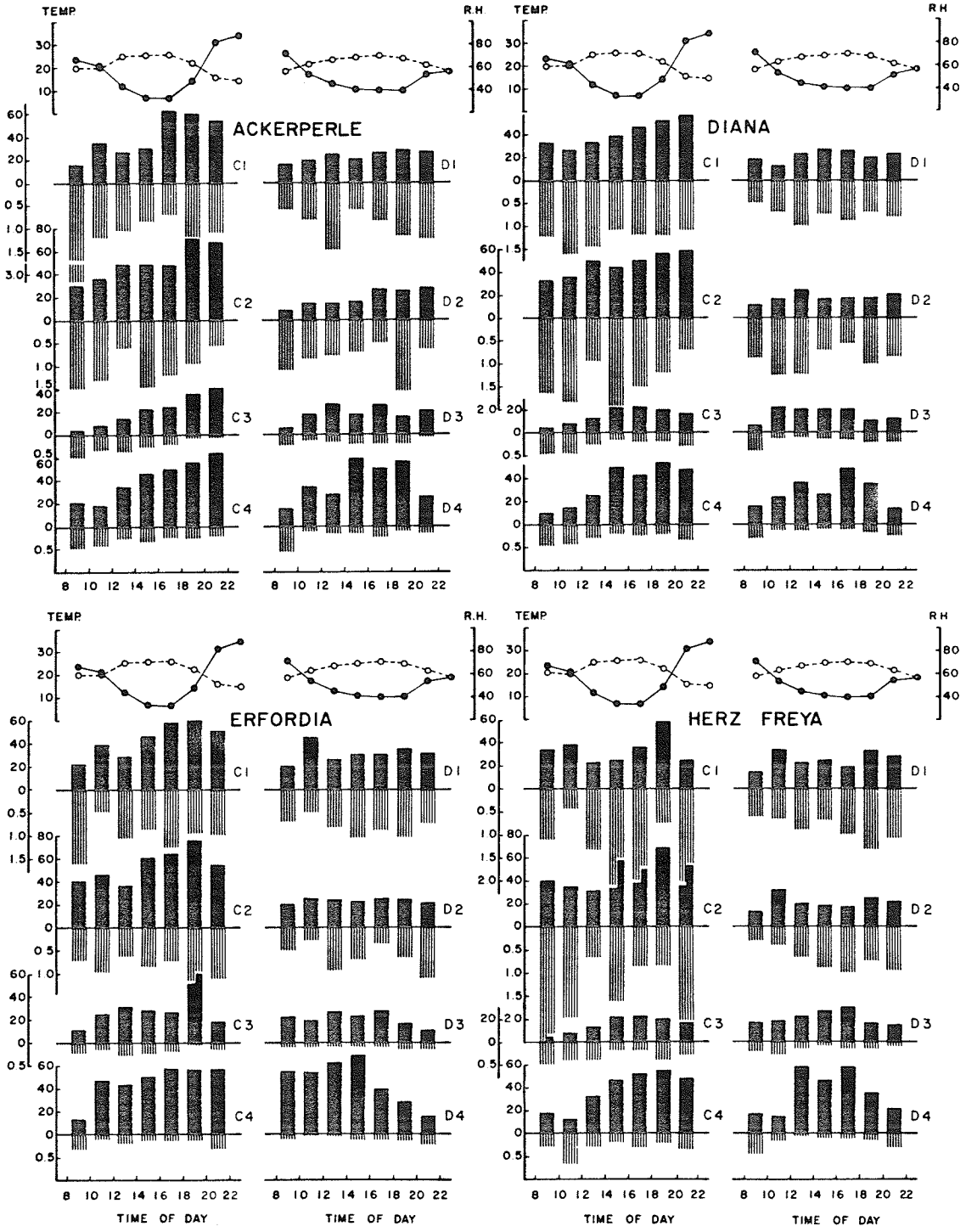
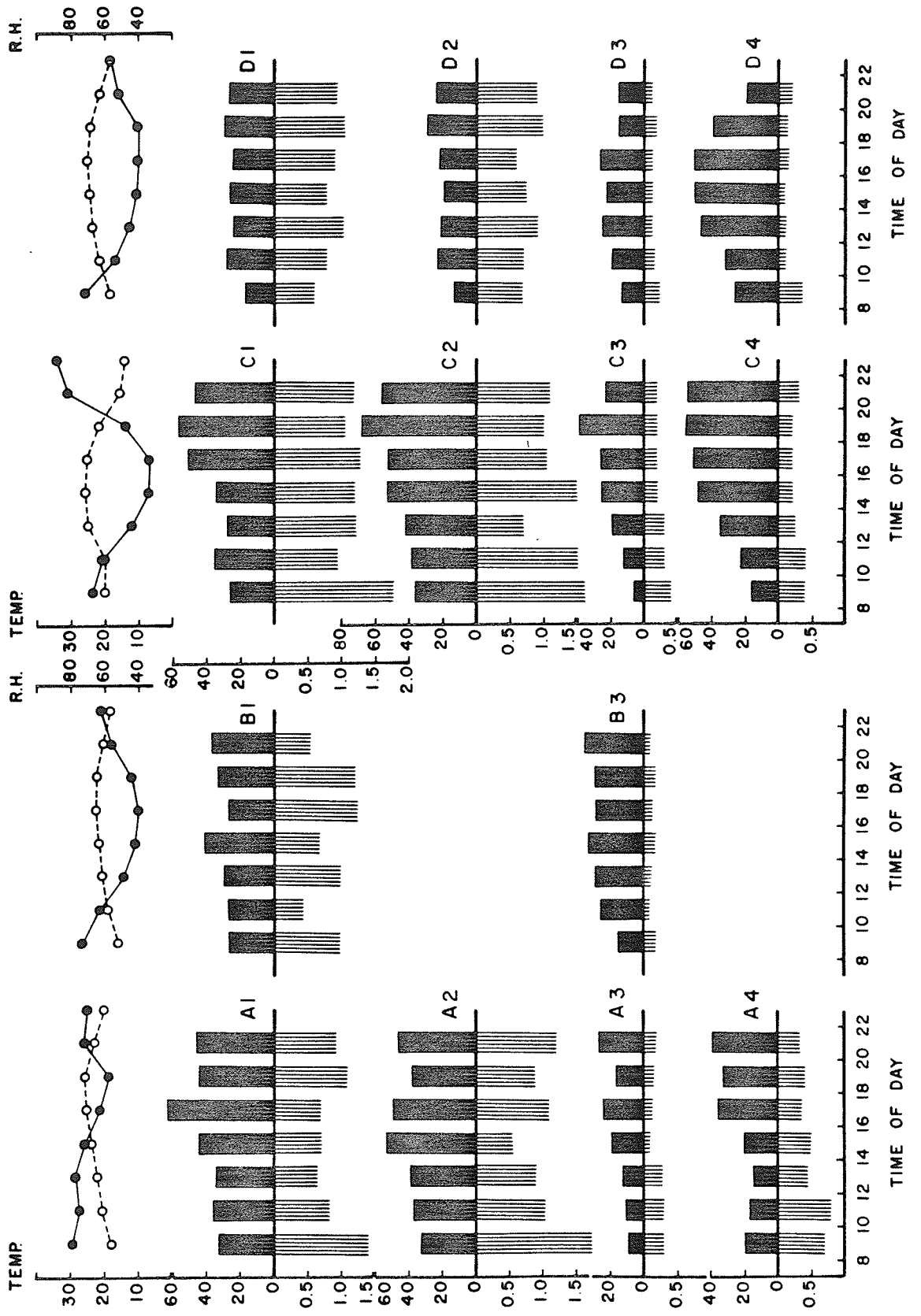

TEMP
R.H.
ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
C1
C2
C3
C4
D1
D2
D3
D4
8 10 12 14 16 18 20 22
TIME OF DAY

Figure 12: Mean amount and sugar concentration of nectar collected from four cultivars at different times throughout the day (U. of M. and Glenlea site, 1977).

Legend:
- A1 - Floral nectaries, open plots, U. of M. site, 23 June
- A2 - Floral nectaries, caged plots, U. of M. site, 23 June
- A3 - Extrafloral nectaries, open plots, U. of M. site, 23 June
- A4 - Extrafloral nectaries, caged plots, U. of M. site, 23 June
- B1 - Floral nectaries, open plots, U. of M. site, 9 July
- B3 - Extrafloral nectaries, open plots, U. of M. site, 9 July
- C1 - Floral nectaries, open plots, Glenlea site, 7 Jule
- C2 - Floral nectaries, caged plots, Glenlea site, 7 July
- C3 - Extrafloral nectaries, open plots, Glenlea site, 7 July
- C4 - Extrafloral nectaries, caged plots, Glenlea site, 7 July
- D1 - Floral nectaries, open plots, Glenlea, 21 July
- D2 - Floral nectaries, caged plots, Glenlea, 21 July
- D3 - Extrafloral nectaries, open plots, Glenlea, 21 July
- D4 - Extrafloral nectaries, caged plots, Glenlea, 21 July
- ▮ - Sugar concentration of nectar (%),
  Floral nectaries (collected from 20 flowers)
  Extrafloral nectaries (collected from 100 stipules)
- ||| - Amount of nectar,
  Floral nectaries (microlitre/flower)
  Extrafloral nectaries (microlitre/stipule)
- ●— - Relative Humidity
- o---- Temperature (^{o}C)


TEMP
R.H.
TEMP
R.H.
A1
A2
A3
A4
B1
B3
C1
C2
C3
C4
D1
D2
D3
D4
TIME OF DAY
8 10 12 14 16 18 20 22

lea site and no difference at the U. of M. site.

On 23 June at the U. of M. site, significantly more nectar was secreted by Herz Freya than by the other three cultivars ($P<0.01$) (Table XIII). There was no significant difference between the amount of nectar secreted by Diana and Ackerperle but both secreted significantly more nectar than did Erfordia ($P<0.01$). Similar results were obtained on 7 July at the Glenlea site except that there were no significant differences between Herz Freya and Diana, and Ackerperle and Erfordia (Table XIV). On 9 July and 21 July, there were no significant differences in the amount of nectar secreted by the four cultivars at both sites.

About four or five times more nectar was secreted from the floral nectaries than from the extrafloral nectaries. There was no significant difference in the amount of nectar produced from the floral nectaries or the extrafloral nectaries of each cultivar at both sites and in each day of observation, except that significantly more nectar was produced in the extrafloral nectaries of Herz Freya than in those of the other three cultivars at the U. of M. site ($P<0.01$).

Nectar from the four cultivars was available in high amounts between 800 to 1000 h and decreased gradually in amount throughout the rest of the day at both sites (See Fig. 10, 11, 12, Tables XIII, XIV).

TABLE IX

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS

AT DIFFERENT TIMES THROUGHOUT THE DAY

(OPEN PLOTS, U. OF M. SITE, 23 JUNE AND 9 JULY, 1977)

Time Of Day	Date					
	23 June		9 July		Total Mean	
	T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	1.67*±0.27	1.66±0.05	0.96±0.21	0.95±0.14	1.32±0.18	1.31±0.14
1000-1200	0.97±0.14	2.78±0.35	0.44±0.10	0.61±0.11	0.70±0.09	1.70±0.34
1200-1400	0.68±0.11	1.48±0.18	1.00±0.22	0.66±0.12	0.84±0.13	1.07±0.12
1400-1600	0.57±0.11	1.44±0.37	0.69±0.14	0.78±0.12	0.63±0.09	1.11±0.20
1600-1800	1.02±0.23	1.10±0.26	1.14±0.17	0.66±0.16	1.08±0.14	0.88±0.16
1800-2000	0.97±0.17	0.86±0.10	1.19±0.18	0.90±0.19	1.08±0.12	0.88±0.10
2000-2200	1.20±0.19	0.97±0.14	0.55±0.13	0.52±0.13	0.87±0.13	0.74±0.10
Total Mean	1.01±0.07	1.47±0.12	0.85±0.07	0.73±0.05	0.93±0.05	1.10±0.07

* Mean and standard error
T.N.: Type of nectary.
F.N.: Floral nectary (microlitre/flower)
E.N.: Extrafloral nectary (microlitre/5 stipules)

TABLE X

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, GLENLEA SITE, 7 JULY AND 21 JULY, 1977)

Time of Day	Date				Total Mean	
	7 July		21 July			
	T.N.		T.N.		T.N.	
	F.N.	E,N.	F.N.	E.N.	F.N.	E.N.
800-1000	1.77±0.33*	2.04±0.29	0.60±0.06	1.15±0.20	1.18±0.19	1.60±0.19
1000-1200	0.93±0.21	1.53±0.23	0.80±0.11	0.81±0.16	0.87±0.12	1.17±0.15
1200-1400	1.21±0.14	1.54±0.16	1.05±0.15	0.59±0.10	1.13±0.10	1.06±0.12
1400-1600	1.23±0.23	1.29±0.13	0.80±0.09	0.67±0.09	1.02±0.13	0.98±0.09
1600-1800	1.27±0.22	1.07±0.13	0.91±0.12	0.69±0.06	1.09±0.13	0.88±0.08
1800-2000	1.06±0.14	0.92±0.18	1.06±0.12	0.85±0.09	1.06±0.09	0.88±0.10
2000-2200	1.19±0.16	0.83±0.13	0.96±0.16	0.64±0.08	1.07±0.11	0.73±0.08
Total Mean	1.24±0.08	1.32±0.08	0.88±0.05	0.77±0.05	1.06±0.05	1.04±0.05

* Mean and standard error
T.N. Type of Nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)

TABLE XI

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, U. OF M. SITE, 23 JUNE,1977)

Time of Day	Cultivar A		D		E		H		Total Mean	
	T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	0.82	5.48	1.55	3.49	1.75	3.62	2.81	2.08	1.73±0.28*	3.52±0.48
1000-1200	0.88	0.88	1.07	3.12	0.63	3.28	1.60	6.30	1.05±0.16	3.40±0.57
1200-1400	0.82	3.19	1.64	2.52	0.26	1.75	0.93	1.85	0.91±0.15	2.33±0.25
1400-1600	0.66	3.09	0.68	1.58	0.60	1.41	0.32	3.76	0.57±0.09	2.40±0.30
1600-1800	1.07	2.39	1.26	1.34	0.79	1.49	1.26	2.13	1.10±0.19	1.84±0.33
1800-2000	0.79	3.39	1.39	1.68	0.79	1.91	1.01	1.07	0.99±0.16	2.01±0.25
2000-2200	1.26	1.80	0.88	1.77	0.66	2.17	1.99	0.62	1.20±0.17	1.59±0.24
Total Mean	0.90	2.88	1.21	2.21	0.78	2.15	1.42	2.54	1.08	2.45
S.E.	0.08	0.33	0.14	0.19	0.10	0.20	0.20	0.39	0.07	0.15

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)
* Mean and Standard Error

TABLE XII

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, GLENLEA SITE, 7 JULY AND 21 JULY, 1977)

Time of Day	Date: 7 July T.N. F.N.	7 July T.N. E.N.	21 July T.N. F.N.	21 July T.N. E.N.	Total Mean T.N. F.N.	Total Mean T.N. E.N.
800-1000	1.59±0.26*	1.90±0.33	0.68±0.10	1.76±0.40	1.14±0.16	1.83±0.26
1000-1200	1.51±0.20	2.02±0.37	0.70±0.14	0.53±0.10	1.10±0.14	1.27±0.22
1200-1400	0.70±0.10	1.28±0.26	0.83±0.11	0.47±0.10	0.78±0.07	0.83±0.14
1400-1600	1.52±0.20	1.08±0.16	0.74±0.10	0.58±0.08	1.13±0.13	0.83±0.09
1600-1800	1.03±0.16	1.08±0.13	0.60±0.09	0.71±0.14	0.87±0.10	0.90±0.10
1800-2000	1.03±0.19	1.06±0.13	0.97±0.13	0.68±0.09	1.00±0.11	0.87±0.08
2000-2200	1.11±0.18	1.47±0.24	0.89±0.11	1.12±0.15	1.00±0.10	1.30±0.14
Total Mean	1.21±0.08	1.41±0.10	0.77±0.05	0.84±0.08	1.00±0.05	1.12±0.06

*Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)

TABLE XIII

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, U. OF M. SITE, 1977)

Time of Day	Cultivar							
	Ackerperle		Diana		Erfordia		Herz Freya	
	T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	0.67±0.12*	1.00±0.20	0.90±0.34	1.76±0.32	1.58±0.14	0.87±0.16	2.12±0.51	1.59±0.35
1000-1200	0.77±0.19	1.25±0.24	0.69±0.18	1.40±0.37	0.41±0.07	0.85±0.14	0.94±0.25	3.29±1.19
1200-1400	0.71±0.15	1.24±0.30	0.61±0.15	1.01±0.26	0.92±0.29	0.56±0.13	1.12±0.37	1.46±0.21
1400-1600	0.56±0.16	0.92±0.22	0.78±0.23	0.63±0.18	0.69±0.18	0.37±0.09	0.48±0.13	2.51±0.54
1600-1800	1.14±0.20	0.76±0.19	1.25±0.39	0.43±0.08	0.95±0.18	0.58±0.06	0.99±0.33	1.74±0.51
1800-2000	1.18±0.26	0.77±0.13	1.23±0.26	0.82±0.16	0.86±0.18	0.56±0.09	1.04±0.29	1.39±0.31
2000-2200	0.85±0.18	0.61±0.13	0.79±0.18	1.22±0.31	0.70±0.28	0.60±0.13	1.15±0.34	0.55±0.11
Total Mean	0.84±0.07	0.94±0.08	0.89±0.10	1.04±0.11	0.87±0.08	0.63±0.05	1.12±0.13	1.79±0.23

* Mean and Standard Error
T.N. Type of nectary
F.N. Floral nectary (microlitre/flowers)
E.N. Extrafloral nectary (microlitre/5 stipules)

TABLE XIV

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, GLENLEA SITE, 1977)

Time of Day	Cultivar							
	Ackerperle		Diana		Erfordia		Herz Freya	
	T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	1.87±0.65*	1.78±0.48	0.87±0.16	2.03±0.45	1.15±0.27	0.89±0.13	0.85±0.18	1.67±0.29
1000-1200	1.01±0.26	1.17±0.32	1.40±0.29	1.15±0.30	0.49±0.09	0.69±0.10	0.57±0.12	1.66±0.37
1200-1400	1.26±0.24	1.24±0.27	1.22±0.17	0.71±0.12	0.93±0.20	0.95±0.23	1.10±0.23	1.36±0.29
1400-1600	0.73±0.13	1.17±0.13	0.98±0.17	1.28±0.26	0.96±0.13	0.83±0.13	1.39±0.44	0.65±0.13
1600-1800	0.77±0.20	0.84±0.19	1.02±0.30	1.14±0.19	1.09±0.12	0.75±0.11	1.48±0.32	0.80±0.11
1800-2000	1.26±0.16	0.64±0.16	0.95±0.18	1.07±0.17	0.99±0.21	0.56±0.14	1.04±0.17	1.27±0.24
2000-2200	0.93±0.30	0.35±0.10	0.95±0.11	0.79±0.16	0.86±0.14	0.87±0.10	1.56±0.26	0.92±0.21
Total Mean	1.12±0.12	1.03±0.11	1.05±0.08	1.17±0.10	0.92±0.07	0.79±0.05	1.14±0.10	1.19±0.10

*Mean and standard error

T.N. Type of nectary

F.N. Floral nectary (microlitre/flower)

E.N. Extrafloral nectary (microlitre/5 stipules)

TABLE XV

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, GLENLEA SITE, 1977)

Time of Day	Cultivar							
	Ackerperle		Diana		Erfordia		Herz Freya	
	T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
	*							
800-1000	1.27±0.27	2.54±0.63	1.26±0.07	1.86±0.18	0.62±0.15	1.04±0.30	1.41±0.50	1.87±0.56
1000-1200	1.07±0.16	1.34±0.42	1.53±0.11	1.35±0.18	0.62±0.13	0.36±0.06	1.18±0.39	2.03±0.54
1200-1400	0.58±0.06	1.01±0.28	1.09±0.05	1.00±0.09	0.79±0.17	0.67±0.28	0.65±0.14	0.82±0.42
1400-1600	1.07±0.31	1.18±0.26	1.31±0.26	0.76±0.16	0.76±0.12	0.60±0.06	1.37±0.27	0.78±0.19
1600-1800	0.76±0.26	1.17±0.26	1.03±0.20	0.87±0.19	0.56±0.13	0.64±0.09	0.92±0.14	0.91±0.20
1800-2000	1.22±0.20	0.89±0.23	1.10±0.17	0.91±0.16	0.90±0.35	0.82±0.11	0.78±0.07	0.87±0.16
2000-2200	0.61±0.11	0.86±0.18	0.76±0.16	1.44±0.39	1.11±0.14	1.31±0.22	1.53±0.27	1.58±0.30
Total Mean	0.94±0.08	1.28±0.14	1.15±0.08	1.17±0.13	0.77±0.07	0.78±0.08	1.12±0.11	1.27±0.15

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)

TABLE XVI

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS ON DIFFERENT DATES (OPEN PLOTS, TWO SITES, 1977)

		Cultivar							
		Ackerperle		Diana		Erfordia		Herz Freya	
		T.N.		T.N.		T.N.		T.N.	
Site	Date	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
U.ofM.	23 June	0.86±0.09*	1.24±0.12	1.04±0.14	1.42±0.17	0.75±0.11	0.67±0.06	1.40±0.20	2.54±0.39
	9 July	0.83±0.11	0.63±0.08	0.75±0.13	0.65±0.09	0.99±0.13	0.59±0.08	0.84±0.16	1.04±0.15
	Total Mean	0.84±0.07	0.94±0.08	0.89±0.10	1.04±0.11	0.87±0.08	0.63±0.05	1.12±0.13	1.79±0.23
Glenlea	7 July	1.27±0.21	1.28±0.20	1.26±0.13	1.48±0.15	1.03±0.11	0.91±0.08	1.40±0.18	1.60±0.14
	21 July	0.97±0.12	0.78±0.08	0.85±0.07	0.85±0.13	0.82±0.08	0.67±0.06	0.89±0.08	0.78±0.10
	Total Mean	1.12±0.12	1.03±0.11	1.05±0.08	1.17±0.10	0.92±0.07	0.79±0.05	1.14±0.10	1.19±0.10

* Mean and standard error
T.N. type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)

TABLE XVII

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS ON DIFFERENT DATES (CAGED PLOTS, TWO SITES, 1977)

		Cultivar							
		Ackerperle		Diana		Erfordia		Herz Freya	
		T.N.		T.N.		T.N.		T.N.	
Site	Date	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
U.ofM.	23 June	0.90±0.08*	2.88±0.33	1.21±0.14	2.21±0.19	0.78±0.10	2.15±0.20	1.42±0.20	2.54±0.39
Glenlea	7 July	1.05±0.14	1.58±0.19	1.39±0.12	1.51±0.22	0.88±0.12	1.97±0.13	1.53±0.19	1.59±0.20
Glenlea	21 July	0.84±0.09	0.99±0.20	0.91±0.09	0.82±0.09	0.65±0.08	0.59±0.06	0.69±0.08	0.94±0.20
Total Mean		0.93±0.07	1.82±0.16	1.17±0.07	1.52±0.12	0.77±0.06	1.23±0.11	1.21±0.10	1.69±0.17

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)

Nectar Concentration

When the data were pooled, the statistical analyses showed that sugar concentration of floral nectar was significantly higher on 23 June than on 9 July at the U. of M. site ($P < 0.01$) and on 7 July than on 21 July at the Glenlea site ($P < 0.01$) (Table XVIII, XIX, XXV). There was no significant difference in the sugar concentration of the nectar of the four cultivars at both sites, except that at the Glenlea site the sugar concentration of the cultivar Erfordia was significantly greater than that of Diana ($P < 0.05$) (Table XXII, XXIII, XXV). At both sites the sugar concentration of the four cultivars showed the same tendency, i.e. Diana had the lowest sugar concentration and Erfordia had the highest. The nectar secreted from the floral nectaries had a significantly higher sugar concentration than did the extrafloral nectaries ($P < 0.01$) at both sites.

There was a tendency (non-significant) for the nectar from both sources of the four cultivars to have the lowest concentration in the early morning, to increase gradually throughout the day, and to have the highest concentration after 1600 h.

Nectar From the Caged Plots

The results are shown in Tables XI, XII, XV, XVII, XX, XXI, XXIV, XXVI.

Nectar secreted from floral, or extrafloral nectaries of plants in the caged plots was significantly greater

TABLE XVIII

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, U. OF M. SITE,23 JUNE AND 9 JULY, 1977)

Time of Day	Date				Total Mean T.N.	
	23 June T.N.		9 July T.N.			
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	32.50±4.47*	8.50±1.15	25.00±2.58	14.13±1.63	28.75±2.83	11.31±1.31
1000-1200	35.50±6.00	10.13±1.15	26.13±1.15	24.75±3.06	30.81±3.34	17.44±3.07
1200-1400	33.38±3.27	10.63±1.15	29.25±3.46	28.00±3.46	31.31±2.27	19.31±3.63
1400-1600	43.50±3.83	19.25±4.76	41.00±5.16	31.75±4.62	42.25±3.02	25.50±3.89
1600-1800	61.75±5.66	23.50±2.83	28.25±2.31	28.50±2.31	45.00±6.93	26.00±1.93
1800-2000	43.75±4.76	15.50±1.04	33.25±1.63	28.50±3.06	38.50±3.07	22.00±2.78
2000-2200	45.25±4.32	25.75±6.43	38.25±7.66	34.25±8.08	41.75±4.28	30.00±5.01
Total Mean	42.23±2.18	16.18±1.16	31.59±1.65	27.13±1.54	36.91±1.41	21.65±1.00

* Mean and Standard Error
T.N. Type of Nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XIX

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, GLENLEA SITE, 7 JULY AND 21 JULY, 1977)

Time of Day	Date					
	7 July		21 July		Total Mean	
	T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	26.50±4.32*	6.50±1.15	17.38±1.15	13.50±3.65	21.94±2.67	10.00±2.07
1000-1200	35.13±2.58	13.38±4.00	28.00±7.02	19.50±1.15	31.56±3.70	16.44±2.14
1200-1400	28.00±1.15	19.50±3.83	24.00±0.92	24.25±1.45	26.00±0.93	21.88±2.00
1400-1600	35.38±4.90	24.88±1.15	25.75±2.00	22.25±1.63	30.56±2.98	23.56±1.07
1600-1800	50.88±6.00	25.88±1.15	25.25±2.00	25.88±1.15	38.06±5.66	25.88±0.76
1800-2000	57.50±2.00	39.25±9.38	29.00±3.27	15.38±1.15	43.25±5.68	27.31±6.30
2000-2200	46.75±7.30	23.50±5.77	27.25±1.63	15.00±1.63	37.00±5.01	19.25±3.25
Total Mean	40.02±2.40	21.84±2.10	25.23±0.01	19.39±1.85	32.63±1.47	20.62±0.58

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XX

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, U. OF M. SITE, 23 JUNE, 1977)

Time of	Cultivar A		D		E		H		Total Mean	
	T.N.		T.N.		T.N.		T.N.		T.N.	
The Day	F.N.*	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	47.50	15.00	28.00	14.50	34.50	24.00	19.50	22.00	32.38 ± 5.90	19.13 ± 2.28
1000-1200	50.00	20.50	22.50	12.00	43.00	19.00	30.00	11.00	36.38 ± 6.21	15.50 ± 2.33
1200-1400	32.50	12.50	25.50	10.00	55.00	21.00	38.00	11.50	37.75 ± 6.29	13.75 ± 2.47
1400-1600	44.00	20.00	40.00	25.00	70.00	24.50	55.00	12.00	52.25 ± 6.71	20.38 ± 3.01
1600-1800	40.00	43.00	47.00	20.00	61.00	48.00	49.00	30.00	49.25 ± 4.37	35.25 ± 6.34
1800-2000	45.00	31.00	29.00	28.00	40.00	22.00	36.00	45.00	37.50 ± 3.38	31.50 ± 4.87
2000-2200	50.00	35.00	40.50	31.00	60.00	38.00	30.00	50.00	45.13 ± 6.42	38.50 ± 4.09
Total Mean	44.14	25.29	33.21	20.07	51.93	28.07	36.79	25.93	41.52	24.84
S.E.	2.36	4.25	3.48	3.10	4.90	4.07	4.56	6.17	2.32	2.21

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XXI

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, GLENLEA SITE, 1977)

Time of Day	Date				Total Mean	
	7 July		21 July			
	T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	36.50±2.51*	15.88±2.52	13.38±2.21	25.88±9.38	24.94±4.63	20.86±4.87
1000-1200	38.50±2.53	23.13±8.03	22.38±4.17	32.25±8.62	30.44±3.79	27.69±5.71
1200-1400	41.75±4.55	34.00±3.54	21.13±2.18	45.63±8.42	31.44±4.54	39.81±4.76
1400-1600	53.25±3.75	48.50±0.87	18.50±1.56	50.00±8.90	35.88±6.83	49.25±4.15
1600-1800	53.25±3.64	50.63±3.00	21.75±2.50	49.13±3.91	37.88±6.42	49.88±2.30
1800-2000	68.25±4.03	55.38±0.47	23.38±1.86	39.00±6.26	45.83±8.72	47.19±4.24
2000-2200	58.50±3.78	54.50±3.75	21.63±2.76	19.00±2.80	40.06±7.29	36.75±7.05
Total Mean	50.00±2.39	40.29±3,14	20.30±3.84	37.27±3.24	35.15±2.39	38.78±2.24

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XXII

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, U. OF M. SITE, 1977)

Time of Day	Cultivar							
	Ackerperle		Diana		Erfordia		Herz Freya	
	T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
800-1000	28.50±8.49*	8.00±2.00	29.50±2.83	10.75±4.00	32.50±10.20	14.75±4.00	24.50±1.50	11.75±1.00
1000-1200	32.00±5.66	15.00±56.00	22.50±0.50	14.75±7.48	38.25±12.96	16.50±2.83	30.50±0.50	23.50±10.20
1200-1400	23.00±4.00	21.00±10.95	32.50±4.00	18.25±8.94	34.00±4.00	23.50±11.31	35.00±4.90	14.50±2.83
1400-1600	37.50±2.83	25.00±12.96	35.50±4.90	23.50±6.32	49.00±5.66	27.50±12.65	47.00±8.00	26.00±6.93
1600-1800	45.00±21.91	25.50±7.48	36.50±8.49	30.50±0.50	48.50±21.35	25.00±4.90	50.00±14.97	23.00±2.00
1800-2000	37.50±6.93	22.50±4.00	38.00±1.00	22.00±6.93	46.50±10.58	26.50±10.58	32.00±2.83	17.00±4.00
2000-2200	41.50±16.49	44.00±13.86	36.00±4.90	19.00±2.00	39.00±2.00	36.50±5.66	50.50±9.80	20.50±6.32
Total Mean	35.11±3.69	23.00±3.84	32.93±1.83	19.82±2.26	41.11±3.57	24.32±2.94	38.50±3.42	19.46±1.99

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XXIII

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, GLENLEA SITE, 1977)

Time of Day	Cultivar							
	Ackerperle		Diana		Erfordia		Herz Freya	
	T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
	*							
800-1000	16.25±0.50	6.25±2.83	26.00±6.93	6.25±2.83	21.50±2.83	16.50±4.90	24.00±9.80	11.00±5.66
1000-1200	27.50±7.48	13.50±4.90	20.25±6.93	15.00±6.93	42.00±2.83	22.00±2.83	36.50±2.83	15.25±2.83
1200-1400	26.00±1.00	20.50±6.32	28.00±4.90	17.25±4.00	27.25±2.83	28.75±2.00	22.75±1.00	21.00±1.00
1400-1600	25.75±4.90	20.50±2.83	33.00±5.66	21.50±0.50	38.50±8.49	25.25±2.83	25.00±0.00	27.00±0.00
1600-1800	44.50±18.55	25.50±0.50	36.25±10.20	22.00±1.00	44.00±13.86	27.25±0.50	27.50±8.49	28.75±1.00
1800-2000	44.00±16.00	27.25±8.94	36.00±16.00	15.50±4.00	47.50±12.33	40.50±24.49	45.50±12.65	26.00±10.20
2000-2200	40.50±13.27	31.00±9.80	40.25±16.73	15.25±1.50	40.75±10.20	14.25±4.00	26.50±2.83	16.50±1.50
Total Mean	32.07±4.13	20.64±2.67	31.39±3.43	16.11±1.57	37.36±3.41	24.93±3.46	29.68±2.84	20.79±2.12

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XXIV

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, GLENLEA SITE, 1977)

Time of Day	Cultivar							
	Ackerperle		Diana		Erfordia		Herz Freya	
	T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
	*							
800-1000	20.00±11.00	18.75±2.25	22.75±10.75	13.00±3.00	30.25±10.75	33.75±20.25	26.50±13.50	18.00±1.00
1000-1200	26.00±11.00	26.50±8.50	26.25±9.75	19.25±4.75	35.50±10.50	51.00±4.00	34.00±1.00	14.00±1.00
1200-1400	32.00±17.00	31.75±3.25	37.00±13.00	30.00±4.00	30.25±5.75	52.50±9.50	26.50±5.50	45.00±13.00
1400-1600	32.5 ±16.50	53.00±6.00	31.00±14.00	38.50±11.50	42.00±19.00	59.00±9.00	38.00±20.00	46.50±0.50
1600-1800	37.5 ±10.50	50.25±0.25	34.00±16.00	46.00±3.00	44.50±19.50	48.25±9.25	34.00±17.00	55.00±3.00
1800-2000	48.75±22.25	56.50±0.50	37.50±19.50	45.00±9.00	50.00±26.00	42.00±14.00	47.00±22.00	45.25±10.25
2000-2200	48.75±20.25	45.00±19.00	37.00±22.00	31.00±17.00	37.00±16.00	36.00±21.00	37.50±15.50	35.00±14.00
Total Mean	35.07±5.27	40.25±4.40	32.21±4.57	31.82±4.05	38.46±4.99	46.07±4.48	34.82±4.61	36.96±4.60

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XXV

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS ON DIFFERENT DATES (OPEN PLOTS, TWO SITES, 1977)

		Cultivar							
		Ackerperle		Diana		Erfordia		Herz Freya	
		T.N.		T.N.		T.N.		T.N.	
Site	Date	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
U.of M.	23 June	44.50±5.09*	14.50±3.09	34.57±3.27	14.71±3.15	50.71±4.19	18.36±4.09	39.14±4.98	17.14±3.15
	9 July	25.71±2.14	31.50±5.59	31.29±1.75	24.93±1.95	31.50±2.76	30.39±3.02	37.86±5.20	21.79±2.54
	Total Mean	35.11±3.69	23.00±3.84	32.93±1.83	19.82±2.26	41.11±3.57	24.32±2.94	38.50±3.42	19.46±1.99
Glenlea	7 July	40.79±6.85	21.95±5.13	41.14±4.14	15.43±2.69	43.79±5.35	29.21±6.50	34.36±4.58	20.79±4.00
	21 July	23.36±1.75	19.36±2.23	21.64±1.75	16.79±2.14	30.93±2.96	20.64±2.05	25.00±2.76	20.79±2.14
	Total Mean	32.07±4.13	20.64±2.67	31.39±3.43	16.11±1.57	37.36±3.41	24.93±3.46	29.68±2.84	20.79±2.12

* Mean and standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

TABLE XXVI

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS ON DIFFERENT DATES (CAGED PLOTS, TWO SITES 1977)

		Cultivar							
		Ackerperle		Diana		Erfordia		Herz Freya	
		T.N.		T.N.		T.N.		T.N.	
Site	Date	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
U. of M.	23 June	44.14±2.36*	25.29±4.25	33.21±3.48	20.07±3.10	51.93±4.90	28.07±4.07	36.79±4.56	25.93±6.17
Glenlea	7 July	50.57±5.64	41.57±6.61	47.21±3.68	35.07±6.80	53.86±5.33	46.29±5.85	48.36±5.01	38.21±6.41
Glenlea	21 July	19.57±2.88	38.93±6.28	17.21±1.38	28.57±4.62	23.14±0.81	45.86±7.27	21.29±2.44	35.71±7.06
Total Mean		38.10±3.67	35.26±3.55	32.55±3.18	27.91±3.09	42.98±3.89	40.07±3.73	35.48±3.35	33.29±3.77

* Mean and Standard error
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

in amount and concentration than that of plants in the open plots on each day of observation.

When data from the open and caged plots were combined, significantly less nectar was secreted from the plants of Erfordia than from those of Ackerperle ($P < 0.01$), Diana ($P < 0.01$), or Herz Freya ($P < 0.01$) (Table XVI, XVII). There was significantly more nectar in the plants of Diana than in those of Ackerperle ($P < 0.05$). The nectar of Erfordia had a significantly higher sugar concentration than did Ackerperle, Diana, or Herz Freya ($P < 0.01$), and the nectar of Ackerperle was significantly higher in sugar concentration than in Diana ($P < 0.01$) (Table XXV, XXVI). The nectar of Diana had the lowest sugar concentration, which in turn was significantly lower than that of Herz Freya ($P < 0.01$). No significant difference, in sugar concentration, occurred in the plants of Ackerperle and Herz Freya. Sugar concentration from plants, between 1400 h and 2200 h, was significantly higher than the nectar occurring between 800 h and 1400 h. The sugar concentration and amount of nectar showed a tendency to be highest between 2000 h and 2200 h.

There was no significant difference in the concentration of nectar produced in the floral nectaries of plants in the open plots and the caged plots, but the nectar from the extrafloral nectaries in the caged plots was significantly higher in sugar concentration than in those of the

open plots ($P<0.01$). The concentration of the nectar in the floral nectaries was significantly higher than in the extrafloral nectaries ($P<0.05$) within the caged plots, but there was no significant difference in the sugar concentration of the nectar from both types of nectaries at the Glenlea site. There was no significant difference in sugar concentration between the four cultivars within the caged plots.

The amount of nectar, produced by the cultivar Ackerperle, or by Diana was significantly higher in the caged plots than in the open plots ($P<0.01$). Plants of the cultivar Erfordia produced significantly less nectar than those of the other three cultivars.

Both the sugar concentration and the amount of nectar, of all cultivars in the caged plots at the Glenlea site were higher on 7 July than on 21 July. The sugar concentration of the floral nectaries on 21 July was only half that on 7 July but the amount only declined slightly on 21 July. Nectar produced from the extrafloral nectaries declined slightly both in sugar concentration and amount of nectar, on 7 July compared to 21 July.

In summary I observed that a greater amount of nectar was produced by the fababean plants during the early flowering period; this nectar also had a higher sugar concentration.

The nectar of the cultivar Diana was produced in large amounts but had a low sugar concentration, while

Erfordia produced nectar in small amounts with a high sugar concentration. However the cultivar Ackerperle produced an amount of nectar between that of Diana and Erfordia; this was also true of its sugar concentration. Herz Freya produced large amounts of nectar but the sugar concentration was similar to that of Ackerperle.

Nectar produced in the morning was highest in volume but lowest in sugar concentration, but in the late afternoon it showed a tendency to be higher in volume and in sugar concentration. It would appear that relative humidity was positively correlated with nectar volume and negatively correlated with sugar concentration. On the other hand, temperature appeared to be correlated negatively with the amount of nectar produced and positively correlated with nectar concentration throughout the day (see Fig. 10, 11, 12).

Plants, covered with cages (i.e. no bees present) produced more nectar and sugar (which had a higher sugar concentration) than those plants in the open plots.

In the preliminary tests (1976) I also found that no nectar was secreted by the flowers in the early bloom stage but nectar was secreted in flowers throughout the full bloom stage, the late full bloom stage, and the closed bloom stage to the early wilted stage. The nectar produced from flowers in the old full bloom stage had a lower sugar concentration than did flowers in the new full bloom stage. The nectar of extrafloral nectaries, occurring toward the top of the plants (i.e. the most recent nectaries), had a

higher sugar concentration than did those toward the bottom of the plant (i.e. the oldest nectaries produced).

4.2.2 Nectar from Honey Sacs

4.2.2.1 Literature Review

Weaver (1954) found that the sugar concentration of hairy vetch (Vicia villosa) was 40-50%, according to honey sac analyses.

Alex et al (1950) concluded that vetch is erratic in its attraction for bees and that nectar production and vetch honey is of high quality and of excellent flavour. He also observed that nectar weight, from the honey sac of a nectar forager without pollen, is about 19.8 mg while that of a nectar forager with pollen loads, is about 14.7 mg.

Little is known about the sugar concentration of the nectar in the honey sacs of honey bees which visit the floral or extrafloral nectaries of fababeans. The sugar concentration in the honey sacs probably varies according to the type of nectary, cultivar, or time of day. The sugar concentration of nectar, from the two types of nectaries on four cultivars at different times of day, was studied (see Ch. IV, 4.2.1.).

It would be of use to know if there is a direct correlation between the sugar concentration of the nectar collected directly from the plants and that occurring in the honey sacs of bees foraging on fababeans because samples are much easier to take from honey sacs.

4.2.2.2 Materials and Methods

One hundred and fourteen positive foragers and 41 extrafloral nectar foragers were removed from the Ackerperle plots at the U. of M. site and a total of 200 positive foragers and 83 extrafloral nectar foragers were removed from the plots of the four cultivars at the U. of M. site in 1977.

The honey sac of each bee was removed and a refractometer was used to measure the sugar concentration of the nectar it contained.

It was often difficult to collect specific types of foragers at certain times of the day due to their low members. Therefore, it was necessary to collect these foragers when they were available on the plants.

4.2.2.3 Results and Discussion

The results are shown in Table XXVII, XXVIII.

At the U. of M. site honey sac data were collected during 11 days in the mid to late flowering period. The sugar concentration of nectar in the honey sacs of bees foraging on the floral nectaries of Ackerperle was twice that of bees foraging on extrafloral nectaries. The sugar concentration of nectar in the sacs of the positive foragers ranged between 33 and 63%, but generally it was between 50-60% when the relative humidity (R.H.) was 45-65% and the temperature was 20-25°C. The sugar concentration of nectar in the sacs of extrafloral nectar foragers ranged between

TABLE XXVII

THE EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE SUGAR CONCENTRATION OF THE NECTAR COLLECTING HONEY BEES ON FABABEANS CULTIVAR ACKERPERLE AT DIFFERENT TIMES THROUGHOUT THE DAY (U. OF M. SITE, 1977)

Time	Date (1977)	Temp. (°C.)	R.H. (%)	Bees Foraging on Floral Nectaries		Bees Foraging on Extrafloral Nectaries	
				No. of Bees Observed	Sugar Conc. (%)	No. of Bees Observed	Sugar Conc. (%)
0800—1000	23 June	18.0	88	1	43.00±0.00	—	—
1000—1200	2 July	21.2	57	—	—	1	17.00±0.00*
	9 July	19.4	58	1	33.00±0.00	—	—
	10 July	21.3	65	—	—	1	33.00±0.00
1200—1400	29 June	21.1	56	6	60.67±4.16	2	30.50±6.50
	3 July	23.5	52	1	53.00±0.00	4	25.75±2.28
	6 July	25.9	51	—	—	3	29.33±7.05
	9 July	21.0	46	—	—	1	24.00±0.00
1400—1600	23 June	24.1	73	1	43.00±0.00	—	—
	3 July	23.8	53	5	52.20±4.15	—	—
	9 July	22.1	40	—	—	2	23.50±1.50
1600—1800	23 June	25.6	61	1	51.50±0.00	—	—
	1 July	21.0	46	11	56.82±1.60	1	28.00±0.00
	3 July	24.5	53	12	54.08±1.50	5	22.00±0.89
	9 July	22.5	40	4	61.00±2.83	2	41.50±9.50
	14 July	21.1	64	9	51.89±2.80	1	14.00±0.00
1800—2000	23 June	25.0	60	1	50.50±0.00	—	—
	1 July	19.9	48	10	56.50±1.95	2	25.00±5.00
	3 July	24.0	53	13	56.77±2.04	2	17.50±0.50
	5 July	22.0	96	7	47.87±1.79	—	—
	6 July	24.5	49	—	—	1	20.00±0.00
	7 July	21.0	53	5	56.80±3.58	—	—
	9 July	22.2	42	12	54.54±1.52	9	22.40±1.66
	14 July	20.3	63	1	63.00±0.00	—	—
2000—2200	23 June	21.0	75	1	46.00±0.00	—	—
	1 July	16.0	67	6	57.67±1.05	2	21.00±2.00
	3 July	21.3	67	6	56.00±2.06	2	17.00±0.00
Total No. of Bees Observed				114		41	

*Mean and standard error

17 and 41%, but generally it was between 20-30% when the R.H. was 40-60%, and the temperature was 20-25°C. Both types of foragers showed a high variation in sugar concentration during the day but no peak in concentration was evident. There was no apparent relationship between the sugar concentration of nectar in the sacs of various foragers and R.H., or temperature, during this study.

At the Glenlea site, data were collected during 6 days in the late flowering period. The sugar concentration of nectar in the sacs of the bees, which foraged on floral nectaries (four cultivars of fababeans), was also twice that found in the sacs of bees foraging on the extrafloral nectaries (see above). The sugar concentration of nectar in the sacs of the positive foragers ranged between 35 and 60% but was generally between 45-57% when the R.H. was 35-60%. The sugar concentration of nectar in the sacs of the extrafloral nectar foragers ranged between 13 and 34%, but was generally between 13 and 27% when the R.H. was 37-57% and the temperature was 20-28°C. No peak in sugar concentration was evident in the sacs of positive foragers but the extrafloral nectar foragers tended to have a higher concentration at noon. Sugar concentration of nectar in the honey sacs of positive foragers showed no differences between the four cultivars, but extrafloral nectar foragers on Erfordia tended to have a higher concentration of sugar in their sacs than did those on the other three cultivars. Again, temperature and R.H. did not appear to affect the sugar concentration in

TABLE XXVIII

THE EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE SUGAR CONCENTRATION OF THE NECTAR COLLECTED BY HONEY BEES ON FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (GLENLEA SITE, 1977)

					Bees Foraging on Floral Nectaries		Bees Foraging on Extrafloral Nectaries	
Cultivar	Time	Date (July, 1977)	Temp. (°C)	R.H. (%)	No. of Bees Observed	Sugar Conc. (%)	No. of Bees Observed	Sugar Conc.
Ackerperle	1000 –1200	22	25.1	48	4	50.75±5.36	5	23.80±1.53*
	1200 –1400	22	26.1	53	1	53.00±0.00	2	28.00±7.00
		23	27.6	43	—	—	1	14.00±0.00
		25	22.0	32	2	54.50±2.50	1	28.00±0.00
	1400 –1600	20	23.2	43	3	59.33±5.92	—	—
		22	28.8	42	3	55.83±1.83	2	23.00±5.00
		23	28.5	33	5	35.60±2.84	4	23.12±3.99
	1600 –1800	20	23.2	42	10	56.55±1.83	2	23.00±3.00
		23	27.7	38	4	41.25±2.05	3	20.17±1.09
	1800 –2000	22	26.8	51	6	52.17±3.65	4	17.00±1.08
		23	26.2	47	17	47.97±1.85	3	21.67±3.84
	2000 –2200	21	20.0	59	3	56.00±0.58	—	—
		22	24.6	57	14	53.14±2.67	1	15.00±0.00
Diana	1000 –1200	22	25.1	48	—	—	2	13.50±8.50
	1200 –1400	22	26.1	53	—	—	3	20.83±2.59
	1400 –1600	22	28.8	42	2	51.50±2.50	5	25.00±2.32
		23	28.5	33	1	51.00±0.00	1	16.00±0.00
	1600 –1800	23	27.7	38	3	56.33±4.98	2	16.50±3.00
	1800 –2000	20	22.1	47	8	53.00±2.73	3	27.17±1.83
		22	26.8	51	3	58.00±1.52	2	13.50±0.50
		23	26.2	47	4	52.00±3.85	—	—
	2000 –2200	22	24.6	57	8	49.62±2.06	3	17.00±1.53
Erfordia	1000 –1200	22	25.1	48	—	—	2	16.50±0.52
	1200 –1400	22	26.1	53	4	49.50±2.40	2	34.00±5.00
	1400 –1600	22	28.8	42	5	47.80±2.96	5	32.30±2.76
		23	28.5	33	5	46.50±1.94	—	—
	1600 –1800	23	27.7	38	17	43.91±1.52	2	26.50±3.50
	1800 –2000	20	22.1	47	16	54.09±1.51	1	29.00±0.00
		22	26.8	51	5	52.60±2.79	—	—
		23	26.2	47	—	—	4	18.75±2.93
	2000 –2200	22	24.6	57	8	54.75±1.39	1	20.00±0.00
Herz Freya	1000 –1200	20	21.4	54	2	49.75±2.25	—	—
	1200 –1400	22	26.1	53	1	52.00±0.00	4	29.75±6.65
	1400 –1600	22	28.8	42	1	57.00±0.00	—	—
		23	28.5	33	1	51.00±0.00	4	22.62±5.94
	1600 –1800	23	27.7	38	5	37.40±2.40	2	22.00±3.00
	1800 –2000	20	22.1	47	8	53.31±1.80	1	24.00±0.00
		22	26.8	51	2	49.00±2.00	1	17.00±0.00
		23	26.2	47	9	47.39±2.12	2	14.50±3.50
		24	19.5	60	1	60.00±0.00	—	—
	2000 –2200	22	24.6	57	8	54.12±1.68	3	17.00±1.53
Total No. of Bees Observed					200		83	

*Mean and standard error

the sacs of either the floral or extrafloral nectar foragers at the Glenlea site.

The sugar concentration of the nectar in the honey sacs of both positive foragers and extrafloral nectar foragers tended to be higher at the U. of M. site than at the Glenlea site.

It seems that during the experiment the R.H. at the U. of M. site was higher than at the Glenlea site but the opposite was true of the temperature. Generally, the sugar concentration of the nectar varies directly with changes in R.H. and temperature (Burch, 1963; Beutler, 1953); there is a negative correlation with R.H., but a positive correlation with temperature.

However, it would appear that the sugar concentration of the honey sacs of bees collected at the two sites in the present study did not follow these rules. In Chapter IV, 4.2.1, it was shown that the sugar concentration of the nectar from flowers was higher during the early to middle flowering period than during the late flowering period. In this study the sacs of honey bees, at the U. of M. site, were sampled in the middle to late flowering period while the sacs of bees at the Glenlea site were sampled quite late in the flowering period. Therefore, it would appear that the time during the flowering period when the honey sacs are sampled has more effect on the sugar concentration of the nectar in the honey sacs than does temperature or R.H.

4.3 Pollen Studies

4.3.1 Dehiscence

4.3.1.1 Literature Review

Anther dehiscence starts at the "mid-pointed' stage (i.e. early white bud stage) but no pollen is detected on the stigma until the "late pointed" stage (i.e. late white bud stage) (See Ch. III, 3.3), and the flower opens 3-4 days after dehiscence (Ivaskina, 1968; Kambal, 1969). Percival (1955) found that the lowest temperature at which anthesis occurs was $12^{o}c$.

In this study I compared dehiscence times of the four cultivars of fababeans by using the size of the white bud stage as a criterion.

4.3.1.2 Materials and Methods

Observations were made on the four cultivars (Ackerperle, Diana, Erfordia, and Herz Freya) at 79 days after seeding in 1977. Flowers, in the early white bud stage, were separated into various groups according to the length of the buds (Fig. 9). These groups were 16, 17, 18, 19, 20, 21, and 22 mm. Ten buds of each size from each cultivar, were dissected, and the number of anthers that had opened and released their pollen grains was recorded.

4.3.1.3 Results and Discussion

The results are shown in Table XXIX.

The buds of Ackerperle (which are the smallest)

TABLE XXIX

PERCENTAGE OF DEHISCED ANTHERS FOUND IN DIFFERENT SIZED BUDS OF THE FOUR CULTIVARS OF FABABEANS (U. OF M. SITE, 1977)

Late White Bud Stage (I D) Length (mm)	Cultivar			
	Ackerperle	Diana	Erfordia	Herz Freya
16	0*	0	0	0
17	2	0	2	0
18	11	0	8	7
19	96	7	36	38
20	92	24	95	80
21	100	57	100	75
22	100	90	100	100
23	100	100	100	100

*Percentage of dehisced anthers

showed a tendency to dehisce earlier than did Erfordia and Herz Freya (which have medium size buds); Diana, which has the longest buds, dehisces later than do all of the other cultivars.

It therefore appears that there is a direct correlation between the size of the buds and flowers (see Ch. IV,4.1.3) and time of dehiscence.

The white buds start to dehisce when they are 17-19 cm long and reach one hundred percent when they are 21-23 mm long; this occurs about one or two days before the petals open.

4.3.2 Number of Pollen Grains per Flower

4.3.2.1 Literature Review

Hybrids produce more pollen grains than do their respective parents and there are differences among hybrids as well as among inbred lines in the quantities of pollen they produce. Genotypes with the highest quantity of pollen are not necessarily the most autofertile. On the contrary, a correlation exists between high autofertility and low pollen production. In the hybrids, as well as in the inbred lines, there is also a correlation between seed size and pollen quantity, e.g. the winter and spring "horse" types produce more pollen than do the small seed types. Kambal et al. (1976) found that the numbers of pollen grains in field bean flowers range between 1347-2847.

Drayner (1959) suggested that pollen may be more abundant, and less diffuse in hybrid, than in inbred, plants.

Herbicides are regarded as an effective pollen sterilizer and induce a marked increase in pollen grain size when applied to the soil (Hakeem and Schehab, 1973 a, b).

In this study I counted the pollen grains in the flowers of the four cultivars because pollen is known to be highly attractive to honey bees (see Ch. IV,4.3.3) and therefore may influence the pollination of the plant. In addition, counts of pollen grains may show inter-cultivar differences as well as plant age differences.

4.3.2.2 Materials and Methods

In 1977 ten IC buds (i.e. early white bud stage, see Ch. III,3.3) from each of four cultivars, were collected from plants at the Glenlea site on 15 July and 3 August. On July 15 the buds were collected from any position in a raceme located at the 7th or 8th inflorescent node of a plant, but on 3 August the buds were collected from the 13th or 14th inflorescent node.

In 1978 the above experiment was repeated, except that one group of buds was collected from the 1st or 2nd inflorescent nodes and the other group was collected from the 4th or 5th inflorescent nodes. Buds were also collected from the lowest position on the raceme.

The keels of a flower were put into a glass vial,

and a glass rod was used to tear open the keels and anthers to release the pollen grains. Ten cc of distilled water, mixed with 0.001 cc of a liquid detergent ("Ivory"), was added to the vial to assist in the dispersion of the pollen grains. The contents of the vials were stirred and shaken vigorously to give a uniform suspension of pollen grains in the liquid.

A small drop of this suspension was placed on a haemocytometer slide (1x1 mm^2/square, 0.1 mm in depth) and magnification of 100 diameters was used. This procedure was repeated until the pollen grains on each of 400 units (i.e. 0.1 mm^3 unit) had been counted.

The following method was used to calculate the number of pollen grains per bud.

a = Total number of pollen grains per count in X squares.

b = Volume of water (10 cc, i.e. 10,000 mm^3)

c = Volume of suspension in squares (0.1 x X mm^3)

d = Number of flower samples (i.e. 10 flowers in this experiment).

$$\text{Number of pollen grains per bud} = \frac{a \times b}{c \times d}$$

The number of pollen grains per flower from the four cultivars of fababeans (Glenlea site, 1977, 1978) were analysed by a Two-Way ANOVA followed by a SNK Multiple Range Test. A $\log_{10}(x)$ transformation was required for analysing the data.

4.3.2.3 Results and Discussion

The results are shown in Tables XXX and XXXI.

The results in 1977 showed that there were significantly fewer pollen grains produced in buds located on the 13th or 14th inflorescent nodes than at the 7th or 8th inflorescent nodes ($P<0.01$); this was true for each of the cultivars ($P<0.01$). The total number of pollen grains observed in the buds of Diana was significantly greater than in Ackerperle, Erfordia, or Herz Freya ($P<0.01$). Diana had a significantly greater number of pollen grains than did each of the other three cultivars on 3 August ($P<0.01$).

The number of pollen grains produced in the buds of Diana on 15 July were significantly greater than in Ackerperle ($P<0.05$) or Erfordia ($P<0.01$). There was no significant difference in the number of pollen grains per bud within the cultivars Ackerperle, Erfordia or Herz Freya.

In 1978 Diana also had significantly more pollen grains per bud than did the other three cultivars ($P<0.01$). Significantly more pollen grains were produced in the buds located at the 4th or 5th inflorescent nodes than at the 1st or 2nd inflorescent nodes in Erfordia ($P<0.01$); no significant differences were observed within the other cultivars. There was a non-significant tendency for pollen grains to occur in greater numbers in the buds of the 4th or 5th inflorescent nodes than at the 1st or 2nd inflorescent nodes

TABLE XXX

NUMBER OF POLLEN GRAINS FOUND IN FLOWERS OF FOUR CULTIVARS OF FABABEANS (GLENLEA SITE, 1977)

Cultivar	Number of Pollen Grains Per Flower — Days From Seeding: 59 Days (15 July,77)	78 Days (3 August,77)	Mean Total
Ackerperle	39275.00 ± 835.24 ABbc*	27325.00 ± 772.63 B	33300.00 ± 1210.27 B
Diana	44550.00 ± 1632.94 Aa	33325.00 ± 1168.89 A	38937.50 ± 1411.28 A
Erfordia	36350.00 ± 1110.48 Bc	28350.00 ± 889.85 B	32350.00 ± 1003.00 B
Herz Freya	41000.00 ± 1031.51 ABab	28675.00 ± 1060.64 B	34837.50 ± 1324.59 B
Mean	40293.75 ± 690.43	29418.75 ± 561.81	34856.25 ± 655.44

* Mean and standard error.

A,B: Means followed by different upper case superscripts differ significantly $P < 0.01$.

a,b,c: Means followed by different lower case superscripts differ significantly $P < 0.05$.

(Each column compared between cultivars.)

TABLE XXXI

NUMBER OF POLLEN GRAINS FOUND IN FLOWERS OF FOUR CULTIVARS OF FABABEANS (GLENLEA SITE, 1978)

Cultivar	Number of Pollen Grains Per Flower		
	Level of Flowering Nodes		
	Flowering Nodes 1 and 2	Flowering Nodes 4 and 5	Mean Total
Ackerperle	32975.00 ± 1851.84 ABb*	29675.00 ± 970.25 B	31325.00 ± 1070.16 B
Diana	37975.00 ± 1408.75 Aa	41175.00 ± 1786.75 A	39575.00 ± 1155.45 A
Erfordia	29625.00 ± 1351.25 Bb	36900.00 ± 1195.25 B	33262.50 ± 1101.89 B
Herz Freya	31175.00 ± 1652.50 ABb	34475.00 ± 1360.01 B	32825.00 ± 1093.64 B
Mean	32937.50 ± 866.08	35556.25 ± 845.91	34246.88 ± 614.23

* Mean and Standard Error

A,B: Means followed by different upper case superscripts differ significantly $P<0.01$.

a,b: Means followed by different lower case superscripts differ significantly $P<0.05$.

(Each column compared between cultivar.)

in the cultivars Ackerperle, Diana and Herz Freya.

In summary I found that Diana had a greater number of pollen grains per bud than did Ackerperle, Erfordia, or Herz Freya, and the number of pollen grains produced in fababeans was highest in the buds located at the inflorescent nodes near the middle of the plant, and lowest at the top of the plant.

The number of pollen grains observed in the fababeans in this experiment was about ten times that found by Kambal et al. (1976); possibly this is because I used a different technique, different cultivar, etc. However, in my counts I found that there were at least two thousand pollen grains per anther and therefore one bud should have at least twenty thousand pollen grains.

4.3.3 Number of Pollen Grains on Various Body Parts of Bees

4.3.3.1 Literature Review

A positive honey bee (see Chapter V5.1) collects nectar and pollen from fababean flowers; the pollen is carried on its body as it moves from flower to flower and from plant to plant. The fababean flower is a closed type which require tripping, and in which the pollen grains have less chance to contact the bee's body than would occur with open flower types. It is important to know how many pollen grains are carried by a honey bee foraging on fababeans and on what part of its

body they are carried, as this undoubtedly affects cross-pollination of this crop.

Therefore in this study, positive foragers were collected from fababeans and the pollen grains, found on various parts of their bodies, were counted.

4.3.3.2 Materials And Methods

Positive foragers, while collecting both pollen and nectar, were caught at random on Ackerperle plots at the U. of M. site on 25 and 26 July 1977. Three samples of ten bees each were collected, between 1800 and 1900 h on each day (see Ch. V, 5.2). with forceps and dropped immediately into wide-mouth glass jars containing a mixture of dry ice and ethanol. The frozen bee samples were then separated as follows: heads, thoraces, 1st pair of legs, 2nd pair of legs, 3rd pair of legs and abdomens. Each of these groups of body parts were kept separately in small vials.

A 0.1% solution of detergent ("Ivory") was added to the various body parts as follows: 1 cc for heads and 1st and 2nd pairs of legs, 2 cc for thoraces and abdomens, and 15 cc for 3rd pairs of legs. The samples were centrifuged and stirred carefully before slides, and counts of the pollen grains, were made (see Ch. IV, 4.3.2).

The number of pollen grains, found on the various body parts, was analysed by a Two-Way ANOVA followed by a SNK Multiple Range Test. A $\log_{10}(x)$ transformation was required for the analyses.

4.3.3.3 Results and Discussion

The results are shown in the Table XXXII.

More pollen grains were found on the third pair of legs than on any other part of the body of positive foragers ($P < 0.01$). The pollen grains, observed on the heads of the positive foragers, were significantly greater in number than those observed on the thoraces, the first pair of legs, the second pairs of legs or the abdomens ($P < 0.01$). The pollen grains observed on the first pairs of legs of the positive foragers were significantly fewer in number than those found on the thoraces ($P < 0.01$), the second pairs of legs ($P < 0.01$), or the abdomens ($P < 0.01$); there were no significant difference in number of pollen grains on these three latter body parts of the bees.

Despite the small area of the first pairs of legs, compared to the other body parts, they are coated with a large amount of pollen. The heads also carry a large number of pollen grains. It seems reasonable therefore that as a positive forager moves from flower to flower in fababeans there is a good chance it may cross-pollinate flowers that have not been previously self-pollinated.

Free and Williams (1972) also found that when a high percentage of one pollen species (i.e. 70-99%) occurs on a positive forager's body it is probably visiting only one crop species.

TABLE XXXII

NUMBER OF POLLEN GRAINS FOUND ON VARIOUS BODY PARTS OF BEES WHICH WERE COLLECTING POLLEN AND NECTAR FROM FABABEANS (ACKERPERLE, U. OF M. SITE, 1977)

Date	No. of bees observed	Parts of body					
		Head	Thorax	1st. pair of legs	2nd. pair of legs	3rd. pair of legs	Abdomen
	10	4530±581 *	1280±98	650±149	1460±118	114000±8289	1660±280
25 July	10	3180±99	560±127	2230±119	1630±208	68250±6869	640±86
	10	3340±293	1480±101	470±47	1210±134	49950±3043	980±204
	10	5450±484	1180±110	1340±216	1580±123	131400±8698	1360±323
26 July	10	4370±407	960±127	960±110	1310±130	105150±2223	880±163
	10	5580±194	4920±499	1890±327	3170±55	140850±10709	2860±447
Mean Total	60	4408±131 Bb	1730±314 Cc	1257±149 Dd	1727±146 Cc	101600±4610 Aa	1397±182 CDc

A, B, C, D: Means followed by different upper case superscripts differ significantly $P < 0.01$.

a, b, c, d; Means followed by different lower case superscripts differ significantly $P < 0.05$.

* Mean and standard error

4.3.4 Pollen Traps

4.3.4.1 Literature Review

In areas where field beans are grown close to Brassica and Trifolium species little field bean pollen is found in pollen traps located on hives of bees (Bond and Hawkins, 1967; Synge, 1947).

Synge (1947) suggested that most field bean pollen is available in the late afternoon when the young flowers are first opening. Pollen collected from traps showed that field bean pollen is brought into the hive late in the day and reaches a peak at about 1600 h.

Free and Williams(1974) reported that the percentage of field bean pollen from pollen traps increases during the day, although the amount collected is greatest between 1100 and 1500h.

Percival (1956) stated that 75 percent of Vicia faba pollen is collected in the afternoon. The heaviest loads were collected by the bees between 1200 and 1400 h, with a peak occurring at 1300 h.

In this study I used pollen traps on hives to determine when the bees visit fababeans for pollen as well as what competing crops are visited for pollen.

4.3.4.2 Materials and Methods

In 1977, an OAC pollen trap was placed under each of two strong colonies at both sites. The colonies were fitted with pollen traps at least one day before an experiment began.

The traps were emptied at two hour intervals beginning at 800 h and ending at 2200 h, on 3 July and 6 July (U. of M. site) and on 12 July and 18 July (Glenlea site). All pollen loads were stored in a deep freeze until they were counted.

Pellets of a given colour were compared to those taken from bees which had visited flowers of known species. Then the pollen in the pellets was examined under a microscope to verify that the pellets of one colour were from one species of plant.

Fababean pollen pellets, which are light to dark grey in colour, were separated from the other pellets. The number, weight, and size of the pellets were recorded in each treatment. The size of pollen loads was determined by measuring the volume of 100 pellets in a 10 ml cylinder. A calculation of the trips made by a forager during a given time period was done by dividing the number of pellets in the traps by two (each bee carries two pellets).

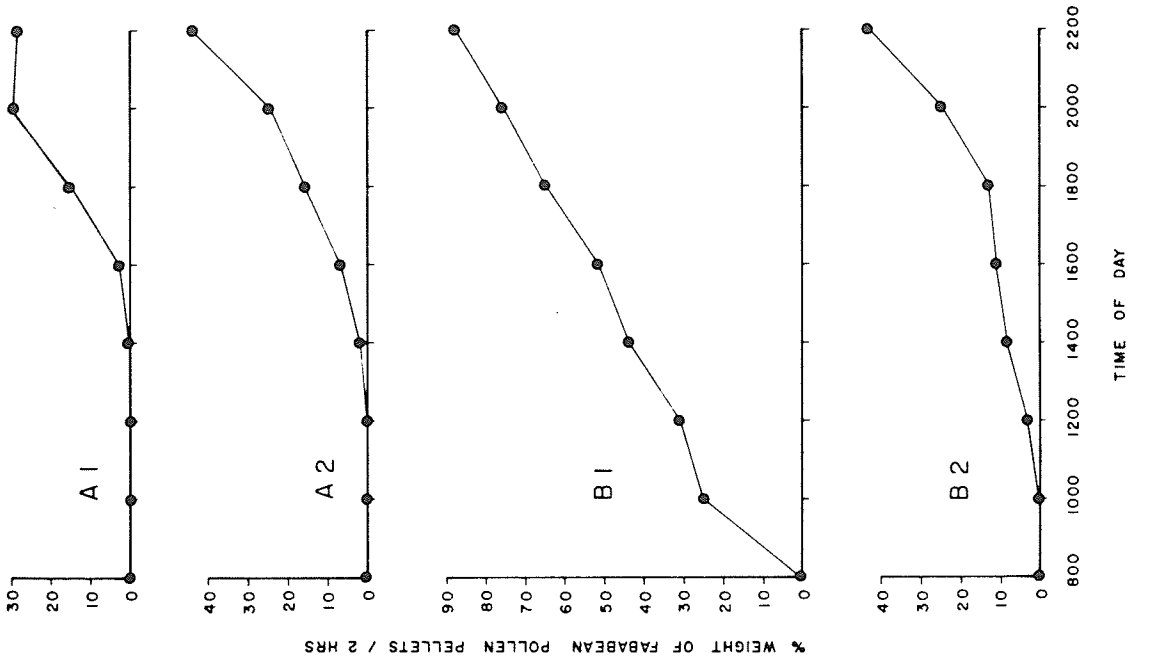
4.3.4.3 Results and Discussion

The results are shown in Tables XXXIII, XXXIV, XXXV and Fig. 13.

The number and total weight of fababean pollen pellets collected during a two hour period, and the percentage of the total weight of pollen collected during each of the two days was highest at about 2000 h at both sites. Fababean pollen pellets (calculated from volume measurements) were largest between 1600 and 1800 h, which was usually two to four hours before the highest number of pollen pellets were collected.

Figure 13: Weight of pollen pellets of fababeans collected by honey bee colonies at different times throughout the day (U. of M. and Glenlea sites, 1977).

Legend: A1 - U. of M. site, 3 July
A2 - U. of M. site, 6 July
B1 - Glenlea site, 12 July
B2 - Glenlea site, 18 July


A 1
A 2
B 1
B 2
% WEIGHT OF FABABEAN POLLEN PELLETS / 2 HRS
TIME OF DAY

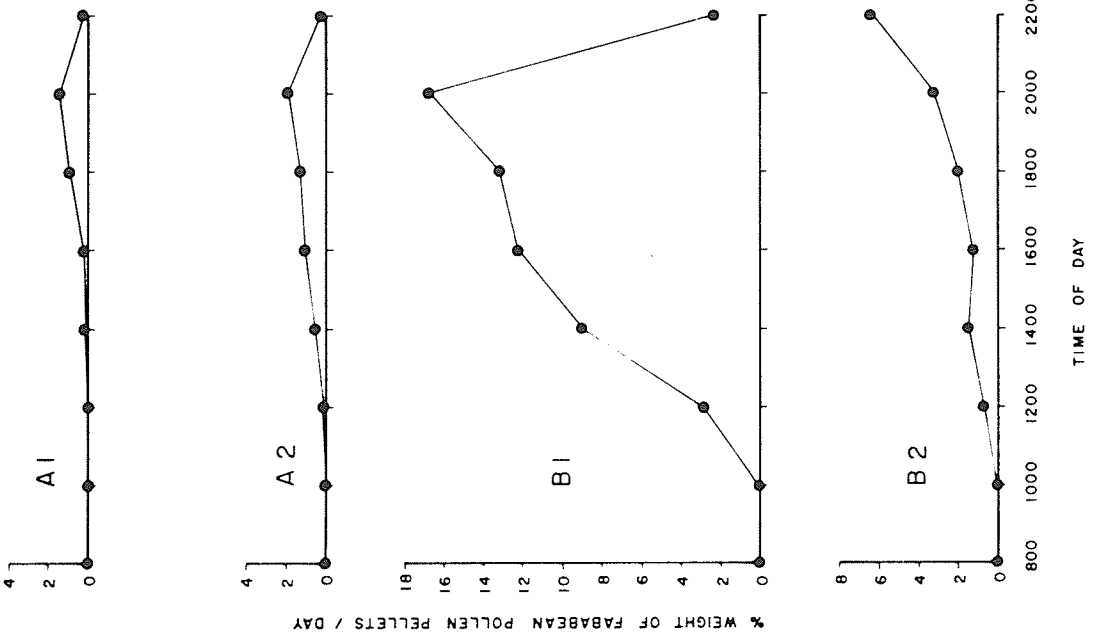

A 1
A 2
B 1
B 2
% WEIGHT OF FABABEAN POLLEN PELLETS / DAY
TIME OF DAY

TABLE XXXIII

NUMBER, WEIGHT, AND VOLUME OF POLLEN PELLETS OF FABABEANS COLLECTED BY HONEY BEE COLONIES AT DIFFERENT TIMES THROUGHOUT THE DAY (BOTH SITES, 1977)

Site	Date	Pollen Measurements	Time When Pollen Was Removed From the Hive									
			8 00	10 00	12 00	14 00	16 00	18 00	20 00	22 00	Total	Total Mean
U. of N.	3 July 1977	Weight Mean (gm)	0.01±0.01*	0.00±0.00	0.00±0.00	0.02±0.02	0.25±0.00	1.08±0.06	1.22±0.32	0.11±0.03	2.71±0.44	
		% Wt./day	0.01±0.01	0.00±0.00	0.00±0.00	0.02±0.02	0.27±0.01	1.18±0.05	1.33±0.33	0.12±0.03	2.95±0.40	
		% Wt./2 hrs.	0.22±0.23	0.00±0.00	0.00±0.00	0.14±0.14	2.58±0.10	15.42±0.42	29.35±4.35	18.43±3.63		
		Vol./100 pellets (ml)	0.50±0.00	-	-	0.71±0.00	0.74±0.06	0.83±0.01	0.68±0.02	0.49±0.06		0.67±0.00
		Wt./100 pellets (gm)	0.33±0.00	-	-	0.36±0.00	0.46±0.03	0.45±0.06	0.39±0.02	0.31±0.01		0.40±0.01
		No. collecting trips /2 hrs.	1.50±1.50	0.00±0.00	0.00±0.00	3.50±3.50	27.00±2.00	121.50±8.50	156.50±34.50	18.50±4.50	328.50±34.50	
U. of N.	6 July 1977	Weight (gm)	0.00±0.00	0.00±0.00	0.00±0.00	0.44±0.08	0.87±0.25	1.02±0.18	1.52±0.18	0.25±0.05	4.13±0.72	
		% Wt./day	0.00±0.00	0.00±0.00	0.00±0.00	0.50±0.05	0.97±0.20	1.15±0.11	1.76±0.03	0.28±0.03	4.68±0.43	
		% Wt./2 hrs.	0.00±0.00	0.00±0.00	0.00±0.00	1.92±0.20	5.69±1.22	15.60±1.41	25.45±0.54	43.96±0.48		
		Vol./100 pellets (ml)	-	-	-	0.74±0.02	0.76±0.01	0.73±0.03	0.67±0.01	0.55±0.01		0.69±0.01
		Wt./100 pellets (gm)	-	-	-	0.43±0.01	0.42±0.01	0.42±0.01	0.41±0.01	0.34±0.01		0.40±0.01
		No. collecting trips /2 hrs.	0.00±0.00	0.00±0.00	0.00±0.00	51.00±9.00	101.00±28.00	120.00±19.00	188.00±14.00	38.50±7.50	498.50±77.50	
Glenlea	12 July 1977	Weight (gm)	0.00±0.00	0.21±0.11	2.27±0.88	6.30±2.00	9.16±4.33	10.10±5.21	11.61±3.13	1.49±0.19	41.16±15.84	
		% Wt./day	0.00±0.00	0.27±0.04	2.78±0.48	8.91±0.32	12.15±1.81	13.16±2.69	16.71±1.45	2.26±0.52	56.60±2.38	
		% Wt./2 hrs.	0.00±0.00	24.82±5.86	30.81±5.77	44.26±2.90	51.70±3.45	64.91±1.81	75.80±2.28	87.60±0.35		
		Vol./100 pellets (ml)	-	1.05±0.01	1.33±0.08	1.40±0.13	1.44±0.07	1.39±0.05	1.20±0.04	1.32±0.04		1.30±0.04
		Wt./100 pellets (gm)	-	0.50±0.04	0.69±0.04	0.79±0.08	0.82±0.03	0.77±0.10	0.68±0.04	0.61±0.04		0.69±0.06
		No. collecting trips/ 2 hrs.	0.00±0.00	20.00±8.00	160.50±52.51	387.50±85.51	545.50±241.53	624.50±258.54	838.00±180.03	120.50±6.50	2695.00±832.62	
Glenlea	18 July 1977	Weight (gm)	0.00±0.00	0.00±0.00	0.50±0.16	0.90±0.23	0.85±0.25	1.23±0.43	1.97±0.67	0.18±0.03	5.65±1.77	
		% Wt./day	0.00±0.00	0.00±0.00	0.81±0.01	1.47±0.13	1.38±0.04	1.94±0.13	3.11±0.18	6.31±0.05	9.01±0.08	
		% Wt./2 hrs.	0.00±0.00	0.00±0.00	2.71±0.21	8.33±1.22	10.81±1.94	12.59±2.87	24.49±2.75	41.99±0.32		
		Vol./100 pellets (ml)	-	-	0.79±0.04	0.84±0.01	0.82±0.05	0.85±0.06	1.02±0.01	0.73±0.02		0.84±0.00
		Wt./100 pellets (gm)	-	-	0.49±0.06	0.60±0.08	0.51±0.01	0.50±0.01	0.54±0.01	0.38±0.07		0.50±0.01
		No. collecting trips /2 hrs.	0.00±0.00	0.00±0.00	50.00±10.00	74.00±9.00	84.00±25.00	123.00±46.00	182.00±65.01	26.00±9.00	539.00±164.02	

*Mean and standard error (from 2 hives)

The number and total weight of fababean pollen pellets, collected during a two hour period, and the percentage of the total weight of pollen and the weight of a single pellet collected during a day were lower at the U. of M. site than at the Glenlea site; the size of the fababean pollen pellets was also smaller at the U. of M. site. The bees foraged on fababeans earlier at the Glenlea site than at the U. of M. site, especially on 12 July when they began foraging in the early morning (Table, XXXIII and Fig. 13).

The main crops from which bees collected pollen at the U. of M. site were Brassica spp. and Trifolium spp. Less Melilotus spp. pollen was found in the pollen traps than was fababean pollen. The other pollen species found in the traps at the U. of M. site were: birdsfoot trefoil (Lotus corniculatus L.), Compositae e.g. dandelion (Taraxacum officinale Weber, and common burdock (Arctium minus (Hill) Bernh.). The Brassica pollen species were rapes (B. camprestris L., B. napus L.) and mustard (Brassica spp.). The main crops of Trifolium found in the pollen traps were alsike (T. hybridum L.) and white clover (T. repens L.) (Table XXXIV).

At the Glenlea site the honey bees collected high amounts of pollen from fababeans on 12 July (i.e. up to 57%). The main pollen species in the traps at this site were from Trifolium spp. which contained alsike (T. hybridum), white clover (T. repens), and red clover (T. pratense L.). The Brassica pollen species included rape and mustard. Other pollen species were mainly from Compositae plants and

TABLE XXXIV

PERCENTAGE WEIGHT TYPES PER DAY OF POLLEN COLLECTED BY HONEY BEE COLONIES AT DIFFERENT TIMES THROUGHOUT THE DAY (U. OF M. SITE, 1977)

		TIME When Pollen was Removed From the Hive								
Date	Plant Species	8 00	10 00	12 00	14 00	16 00	18 00	20 00	22 00	% Total/Day
3 July	Vicia faba	0.01±0.01*	0.00±0.00	0.00±0.00	0.02±0.02	0.27±0.01	1.18±0.05	1.33±0.33	0.12±0.03	2.95±0.43
	Trifolium spp.	0.58±0.16	0.86±0.27	6.62±2.72	4.80±1.29	2.89±0.54	2.95±0.76	2.27±0.33	0.40±0.08	21.37±6.15
	Medicago spp.	0.24±0.02	0.49±0.05	0.63±0.17	0.45±0.13	0.52±0.01	0.03±0.04	0.00±0.00	0.04±0.04	2.42±0.05
	Brassica spp.	2.90±1.09	16.28±2.63	22.57±1.72	13.19±1.87	6.55±1.17	3.01±0.32	0.72±0.11	0.05±0.01	65.31±8.93
	Misc.	0.17±0.08	2.63±0.66	2.96±1.79	1.13±0.35	0.36±0.04	0.53±0.37	0.14±0.09	0.05±0.01	7.95±2.29
	Total	3.89±1.00	20.27±1.63	32.79±2.96	19.59±0.33	10.59±0.59	7.71±0.08	4.47±0.47	0.66±0.06	100
6 July	Vicia faba	0.00±0.00	0.00±0.00	0.00±0.00	0.50±0.05	0.97±0.20	1.15±0.11	1.76±0.03	0.28±0.03	4.68±0.43
	Trifolium spp.	0.00±0.00	0.68±0.39	9.33±1.48	12.45±1.22	10.73±1.44	4.58±0.32	4.11±0.11	0.29±0.06	42.14±4.15
	Medicago spp.	0.01±0.01	0.14±0.03	0.36±0.14	0.41±0.02	0.35±0.21	0.40±0.21	0.39±0.23	0.02±0.02	2.10±0.13
	Brassica spp.	0.00±0.00	8.30±0.47	14.45±4.93	8.31±2.57	2.29±2.21	0.59±0.11	0.22±0.13	0.00±0.00	34.20±9.46
	Misc.	0.13±0.01	2.68±1.05	5.78±1.73	4.26±1.18	2.83±0.69	0.66±0.11	0.45±0.04	0.05±0.03	16.88±4.74
	Total	0.13±0.01	11.81±1.94	29.96±1.82	25.92±0.14	17.17±.009	7.04±0.02	6.94±0.01	0.64±0.08	100

*Mean and standard error as a % of the total of weight of pollen collected (800-2200 h).

TABLE XXXV

PERCENTAGE WEIGHT TYPES PER DAY OF POLLEN COLLECTED BY HONEY BEE COLONIES AT DIFFERENT TIMES THROUGHOUT THE DAY (GLENLEA SITE, 1977)

Date	Plant Species	Time at Which Pollen was Removed from the Hive								
		8 00	10 00	12 00	14 00	16 00	18 00	20 00	22 00	% Total/Day
12 July	*Vicia faba*	0.00±0.00*	0.27±0.04	2.78±0.48	8.91±0.32	12.15±1.81	13.16±2.69	16.71±1.45	2.26±0.52	56.60±2.38
	Trifolium spp.	0.00±0.00	0.57±0.16	5.48±1.15	9.88±1.34	10.08±0.27	6.28±0.95	4.14±0.09	0.14±0.03	36.66±1.27
	Brassica spp.	0.00±0.00	0.20±0.01	1.69±0.47	1.41±0.40	1.08±0.10	0.71±0.04	1.06±0.01	0.17±0.06	6.36±1.51
	Misc.	0.00±0.00	0.10±0.01	0.15±0.04	0.06±0.02	0.08±0.04	0.01±0.01	0.00±0.00	0.00±0.00	0.38±0.05
	Total	0.00±0.00	1.14±0.10	10.44±1.53	20.26±2.04	23.38±1.95	20.17±3.59	22.00±1.25	2.58±0.61	100
18 July	*Vicia faba*	0.00±0.00	0.00±0.00	0.81±0.01	1.47±0.09	1.38±0.03	1.94±0.09	3.11±0.13	0.31±0.04	9.01±0.08
	Trifolium spp.	0.08±0.06	6.06±1.38	22.34±1.13	10.43±0.26	8.24±1.85	10.33±3.11	6.15±1.05	0.14±0.00	63.61±3.15
	Brassica spp.	0.25±0.00	0.81±0.30	6.01±1.05	4.27±0.23	3.82±0.08	3.62±0.15	3.06±0.61	0.29±0.06	22.14±1.41
	Misc.	0.00±0.00	0.94±0.42	0.75±0.23	1.73±1.16	1.43±1.02	0.14±0.02	0.27±0.11	0.00±0.00	5.25±2.08
	Total	0.30±0.06	7.36±1.24	28.20±2.50	16.89-1.60	14.03-0.75	15.08-2.59	12.45-1.27	0.58-0.08	100

*Mean and standard error as a % of the total of weight of pollen collected (800-2200h).

birdsfoot trefoil (Table, XXXV).

The greatest amount of pollen from all species was found in the traps around noon or early afternoon at both sites. However, fababean pollen is collected late in the day when pollen is not usually available from other crops. Thus the pollination of fababeans likely occurs at this time. Some honey bees tend to forage on certain crops, e.g. red clover and birdsfoot trefoil, throughout the day. Therefore, it is possible that honey bees may delay moving from red clover and birdsfoot trefoil to fababean fields. It would be advisable,therefore,not to grow these crops beside fababean fields.

CHAPTER V

STUDIES OF HONEY BEES ON FABABEANS

Introduction

An attempt was made, in this study, to relate the various floral characteristics and attractants; discussed previously in this thesis, to the number and type of bee visits made to fababeans. These data might elucidate further information about seed yields on fababeans. To do this the author followed individual bees to ascertain their numbers on, and their preferences for, the four cultivars of fababeans. Also examined was the behaviour of positive nectar foragers, negative floral foragers, base foragers, and extrafloral nectar foragers in order to determine their potential as pollinators of fababeans.

5.1 Activities of Honey Bees on Fababeans

5.1.1 Literature Review

Fababeans and vetches, like many kinds of legume plants, require "tripping" to effect pollination. When a bee visits the front of a flower, the tripping mechanism will release the stigma and stamens from the keel petal without "snapping", as occurs in alfalfa flowers. The stigmatic surface is ruptured when the stigma strikes the standard petal, or the head (or thorax) of a bee (Free, 1962;

Weaver 1956). This rupturing of the stigma releases moisture, which Armstrong and White (1935) believe to be necessary for pollen germination.

Kambal et al. (1976) found that as a result of the tripping process, the stigmatic papillae were broken, the stigma was ruptured, and the pollen was pushed into close contact with the stigma thereby enhancing the chances of effective pollination. Furthermore, they found that there were differences in the number of papillae on the stigmas of autosterile and autofertile lines. The autofertile stigma is almost bare of papillae whereas the autosterile has papillae all over the stigma. The contents of the stigma are enclosed within a membrane and can escape only when the membrane is ruptured.

Paul et al. (1977) found that the exudate on the stigma was more available in autofertile flowers, before and after anther dehiscence, than in autosterile flowers. For these reasons self-fertilization probably would be increased in autofertile flowers.

When a positive forager enters the Vicia flower it must trip the blossom, depress the keel, and force its head into the corolla tube. In vetches both tripping of the blossom and reaching the nectar are difficult for a honey bee to accomplish (Weaver, 1956). When collecting pollen, the bees scrape over the anther and therefore contact both the stigma and the stamens (Free, 1962; Weaver, 1956).

It has been observed that pollen collecting honey bees sometimes make more than one visit to the same flower for pollen (Poulsen, 1973). Weaver (1956) observed that "inexperienced" workers are more prone than "experienced" ones in revisiting blossoms upon which they have previously foraged. These foragers spend little time examining the flowers and usually make no contact with the anthers and stigma.

Pollen foragers of field beans are attracted mainly to the male fertile line and visit male sterile plants only by chance (Bond and Hawkins, 1967; Tasei, 1975, 1976).

Individual honey bees usually confine their activity to one type of visit (Free, 1962; Poulsen, 1973), but occasionally, they alternate between negative flower visits and extrafloral visits. Also, some negative nectar foragers become pollen foragers; most negative nectar foragers however, do not carry pollen loads (Poulsen, 1973).

Weaver (1956) followed a bee and recorded its activities in vetch for more than 100 flower visits, and found that periodically this forager changed from a base forager to a tripper; it used its tongue to enter flowers on the right side of the sexual column more often than on the left side. Bees which found the flower difficult to trip often became base foragers.

Ibrahim and Selim (1967) found a positive correlation between pollen gathering activity and air temperature.

An increase of 1°C above the daily average temperature increased the percentage of broad bean pollen gathered by 2.90-6.05.

A negative correlation was observed between R.H. and pollen collection (Ibrahim and Selim, 1967). An increase of 1% in R.H. during the day resulted in a decrease of 0.67-1.17 in the percentage of broad bean pollen gathered.

Generally, honey bees rob nectar by using the holes already bitten in the flowers by bumble bees, and seldom bite the holes themselves. However, Scriven et al. (1961) reported that when plants were caged with honey bee colonies every flower was pierced. Free (1970) commented that bee behaviour in cages might be the result of the abnormal conditions.

Foraging Statistics

a) Time Factors

The times required by honey bees making one type of visit to field beans were as follows: an extrafloral nectary, 4.7 sec; a hole at the flower base, 8.0 sec; a floral nectary 11.9 sec (Free, 1962). Poulsen (1973) reported that positive foragers in Denmark spent 14.0 sec. per flower compared to 11.9 sec. per flower reported by Free. Tasei (1975) reported that positive nectar foragers averaged 8.6 sec. per flower, while pollen foragers averaged 15.0 sec. per flower. Poulsen (1973) observed that honey bees visited 1.8 flowers per plant, and moved frequently from plant to plant.

Weaver (1954, 1955, 1956, and 1957) timed bees foraging on vetch and obtained the following results: pollen foragers, 4.4 sec. per flower (in 1956), and 6.6-17.1 sec. per flower (in 1957); base foragers 8.5 sec. per flower (in 1956) and 12.8 sec. per flower (in 1957); positive nectar and pollen foragers 10.2 sec. per flower (in 1956) and 13.3-19.0 sec. per flower (in 1957); positive nectar foragers 10.5 sec. per flower (in 1956) and 16.0-25.0 sec. per flower (in 1957).

Weaver (1965) found great variation in the speed of bees collecting nectar, which was probably because there were different amounts of nectar in the flowers in various locations, and because some blossoms trip more easily than others. During intense nectar flows there was little difference in the foraging speed of positive nectar foragers and positive nectar pollen foragers. However, after several days, with poor nectar flows, the few remaining nectar foragers were inexperienced foragers.

b) Area Factors

In vetch, the foraging area of a bee is small during a good nectar flow, but as the nectar flow deteriorates the foraging area becomes larger and the bee trips fewer flowers. If the flow improves again, or remains fairly constant, a bee becomes more fixed to a given area (Weaver, 1956, 1957).

Many authors state that honey bees do not assist in the pollination of the field beans. Avetisyan et al. (1963),

in U.S.S.R. reported that only one of four cultivars showed an increase in seed weight when honey bees were used for the pollination of field beans. Free (1966) indicated that bee populations do not greatly increase seed production of field beans, although they do in broad beans.

Another disadvantage, in using honey bees in field bean pollination, is that honey bees seldom visit male sterile plants (Bond and Hawkin, 1967). Therefore, bees probably do not increase hybrid seed yields (Tasei, 1976). Bond and Hawkin suggested that mixing seed, or planting alternate single rows of hybrid and inbred lines, might increase the frequency of chance visits to the male sterile line by bees entering the flowers. According to Avetisyan et al. (1963) honey bees do not seem to increase the percentage of fertile seeds per plant. They found however, that the number of beans per plant, and the yields, decrease as

There are many experiments to show that honey bees are desirable for bean pollination (Alex, 1950; Brandenburg, 1961; Smaragdova et al. 1966; Smith et al, 1973, 1974; Voluzueva, 1971; Wafa and Ibrahim, 1960). Smith et al. (1973, 1974) studied the effectiveness of different insect pollinators of field beans, and found that the best yields were obtained using honey bees; similar results were also obtained by Avetisyan et al. (1963); Smaragdova et al. (1966); and Voluzueva (1971).

Honey bees not only increase seed yields in field

beans and broad beans, but they also help to improve the quality of the seed; in addition the bean pods ripen more uniformly and some pods even mature earlier (Avetisyan et al, 1963; Bohart, 1960; Cherkasova, 1966; Free, 1962; Ivaskina, 1968; Poulsen, 1971, 1972; Smith, 1974; Wafa and Ibrahim, 1960). Nevertheless, some experiments show that flowers which receive negative visits by honey bees produce significantly more pods than do unvisited flowers (Smith et al, 1974; Soper 1952). In bean fields where sufficient bees are present, both seed set and yield can be increased 2.3 times or more as compared to fields without bees (Alex et al, 1950; Kendal and Smith, 1975; Pritsh, 1970).

Foraging honey bees, in field beans, are separated into three categories according to the flowers and type of nectaries they visit, i.e. "positive" honey bee foragers, extrafloral nectar foragers, and "negative" honey bee foragers.

"Positive" Honey Bee Foragers (Type I)

Positive honey bee foragers (or "trippers") are divided into three types (Free, 1962, Poulsen, 1972, 1973; Weaver, 1956) as follows:

Ia) Pollen forager: a bee that enters the flower through the front, trips the flower, and collects only pollen. Therefore this forager has pollen in its pollen baskets (corbiculae).

Ib) Pollen and nectar forager: a bee which behaves

like a pollen forager except that it inserts its proboscis between the keel and the standard petal to collect nectar at the base of the corolla tube; at the same time it collects pollen.

Ic) Nectar forager: a tripping bee that collects only nectar, i.e. no pollen is visible in its pollen baskets.

"Negative" Honey Bee Foragers (Type II)

All negative honey bees collect only nectar from the flowers and do not trip them. The "non-tripper" (i.e. the "negative" forager) in fababeans and vetch, is classified into two types as follows (Bohart, 1960, Bond and Hawkin, 1967; Free, 1962; Poulsen, 1971, 1973; Smith, 1974; Soper, 1952; Scriven et al, 1961; Weaver, 1956).

IIa) Negative floral forager: it takes nectar from the flowers by cutting holes at the base of the corolla tube. It either makes the holes itself or uses holes that have been made by "negative" bumble bees (Bond and Hawkin, 1967; Scholhorn, 1942; Scriven et al. 1961).

IIb) Base forager: This type of bee is found in vetch. It takes nectar by inserting its tongue between the petals of the standard and keel at the base of the corolla tube without tripping the flower (Weaver, 1956).

"Extrafloral Nectar Foragers" (Type III)

Extrafloral nectar foragers collect only nectar from the extrafloral nectaries located on the stipules.

5.1.2 Materials and Methods

The behaviour of positive foragers and extrafloral nectar foragers was observed on the main plots of each cultivar in 1977, at both sites.

Individual bees were followed as they visited ten flowers or stipules, depending on the type of forage. While following extrafloral nectar foragers the number of plants, the number of stipules, the direction of movement, the total time, and the distances travelled between plants, were recorded. While following positive foragers, the number of plants, the type of visit, the type of flower, the total time, the size of pollen loads, and the distance travelled between plants, were recorded.

In 1977, twenty extrafloral nectar foragers, and one hundred nectar-pollen foragers were followed on the cultivar Ackerperle at the U. of M. site during the mid to late flowering period at different times of the day. At the Glenlea site 25 nectar-pollen foragers were followed on each of four cultivars of fababeans (Ackerperle, Diana, Erfordia, and Herz Freya).

The bees' preference for flowers in different stages, the number of plants visited and foraging times and distances were analysed by a TWO-WAY ANOVA followed by a SNK Multiple Range Test.

5.1.3 Results and Discussion

The results are shown in Tables XXXVI, XXXVII, XXXVIII XXXIX.

Individual positive nectar and pollen foragers observed in fababean fields, remained constant to one type of visit. When a forager lands on the wing petals it simultaneously extends its proboscis between the sexual column and the inner side of the standard petal in order to reach the nectaries. Then with the hind legs it pushes the wing petals down which trips the flower; this occurs because the sexual column is released from the keel petal. The hind legs continue to hold the wing petals down while the bee collects nectar and pollen. The front legs of the bee scrabble for pollen from the stamens which remain beneath the ventral side of its head and thorax. Pollen, which has been collected on the front legs, is not transferred to the pollen baskets until the bee leaves the flower (i.e. while in the air).

The positive nectar and pollen foragers display the same behaviour even when visiting flowers which are in the early bloom, full bloom, or late bloom stage. Although the early bloom stage has no nectar, a bee still pushes its head and proboscis into the flower to collect nectar, as it does in the other bloom stages. Alternatively, when a bee visits the late bloom stage, which contains almost no pollen, it still uses its front legs to scrabble for pollen at the

same time that it collects nectar. Thus the bee seems to keep the same foraging behaviour when visiting different types of flowers, but the amount of time it spends on each flower depends on the availability of nectar and pollen. Quite often the author observed that one flower in the full bloom stage was visited by several bees in a short period of time, while some flowers in the full bloom stage were not visited by any bees. Frequently a bee would forage on a particular flower, and then move to an adjacent flower or plant, and finally return to the first flower again. It is possible that flowers at a certain stage of development may have an attractant or pheromone placed on them by foragers, which serves to attract bees back to them.

Positive nectar foragers were seldom found foraging on fababeans. When a positive nectar forager is present, it appears to spend more time collecting nectar from a flower than does a nectar-pollen forager. It moves slowly and displays the same foraging behaviour as does a positive nectar-pollen forager except that it does not scrabble while it is collecting nectar, and hence no pollen is found in the pollen baskets.

A negative floral forager collects nectar either through a hole which a negative bumble bee has made at the upper part of the base of the corolla tube, or through a hole which it has made itself.

A base forager is seldom found on fababeans. If

present it sometimes alternates between being a positive nectar forager and a base forager. A base forager often approaches a flower from the front, alights, and inserts its tongue at the side of it, and then collects only nectar without the flower being tripped.

An extrafloral nectar forager moves very quickly and tends to be more active than do the other types of foragers. It usually lands on the third or fourth nodes from the top of the plant and collects nectar from the extrafloral nectaries. The forager then moves upward to search for, and collect nectar from, the stipules near the top of the plant; however, it seldom moves downward from the top of the plant. Less than one percent of the extrafloral nectar foragers observed by the author became positive foragers and none of the former bees had pollen in their baskets. The movement of both negative floral foragers and extrafloral nectar foragers is similar, i.e. they move quickly and are very "alert".

Observations on Individual Bees at the U. of M. site

The results are shown in Table XXXVI, and XXXVII.

Positive nectar and pollen foragers visited approximately 6.0 plants while foraging on 10 flowers (i.e. 1.7 flowers visited per plant). The positive nectar and pollen foragers preferred to visit flowers in the full bloom stage (II B) more than they did the early blooms (II A) or the late blooms (II C) (i.e. 73%, 19%, and 8% respectively) ($P < 0.01$). There was a nonsignificant tendency for bees to

TABLE XXXVI

FORAGING ACTIVITIES OF A POSITIVE BEE ON TEN FLOWERS OF FABABEANS (ACKERPERLE, U. OF M. SITE, 1977)

Flowering Period	Time of Day	No. of Bees Observed	No. of Plants Visited	No. of Flowers Visited			Foraging Time (sec)	Foraging Distance (cm)
				Stage II A	Stage II B	Stage II C		
Mid Flowering Period (27,28,29 June)	1200 - 1600 hr	23	6.22±0.35*	2.65±0.37	6.78±0.47	0.56±0.26	124.09±6.12	166.96±22.04
	1600 - 2000 hr	15	6.20±0.47	2.73±0.67	6.60±0.58	0.67±0.25	146.80±13.95	141.27±17.12
Late Flowering Period (1,3,5, July)	1200 - 1600 hr	10	6.40±0.47	2.70±0.42	7.20±0.44	0.10±0.10	162.40±11.57	263.50±52.29
	1600 - 2000 hr	52	5.65±0.28	1.19±0.19	7.69±0.26	1.11±0.21	122.85±5.79	203.58±27.18
	Mean Total	100	5.94±0.19	1.91±0.18	7.27±0.20	0.82±0.13	130.68±4.25	188.83±16.29

*Mean and standard error.

TABLE XXXVII

FORAGING ACTIVITIES OF AN EXTRAFLORAL NECTAR FORAGER ON EXTRAFLORAL NECTARIES ON TEN STIPULES OF FABABEANS (ACKERPERLE, U. OF M. SITE, 27 JUNE AND 6 JULY, 1977)

No. of Bees Observed	No. of Plants Visited	No. of Type III Visits to Each Node						Foraging Time (sec)	Foraging Distance (cm)
		1	2	3	4	5	6		
20	3.20 ± 0.22*	51(26%)	60(30)	46(23)	30(15)	12(6)	1(1)	27.90 ± 2.44	66.5 ± 7.66

*Mean and standard error.

1 indicates extrafloral nectaries visited at the top (or first level) of the plant.

visit flowers in the full bloom stage in increasing numbers during the late flowering period.

The positive nectar and pollen foragers spent about 13.1 sec. per flower visit and about 131 sec. visiting 6.0 plants which were about 189 cm apart (i.e. the bees moved about 69 cm per min.). The time spent in foraging was not correlated with the flowering period or the time of day. The foraging distance increased ($P < 0.05$) when the flowers (in full bloom) were low in numbers, i.e. during the early afternoon when they were still closed, or during the late flowering period. There was no correlation between the number of plants visited and the foraging time, or the foraging distance.

The extrafloral nectar foragers visited approximately 3.2 plants while foraging on 10 stipules (i.e. 3.1 stipules visited per plant). This type of forager preferred to collect nectar from the stipules at the top of the plant rather than from the lower part of the plant. The bees spent approximately 28 sec. while visiting 10 stipules (i.e. 2.8 sec. per stipule), located on 3.2 plants which were about 67 cm apart (i.e. the bees moved about 143 cm per min.).

Observations on Individual Bees at the Glenlea Site.

The results are shown in Table XXXVIII and XXXIX.

The positive nectar and pollen foragers visited about 5.0 plants while foraging on 10 flowers (i.e. 2.0 flowers visited per plant) they preferred to visit flowers in the

TABLE XXXVIII

FORAGING ACTIVITIES OF A POSITIVE BEE ON TEN FLOWERS OF FOUR CULTIVARS OF FABABEANS (18, 29 JULY, 1, 2, 3 AUGUST, 1977, GLENLEA SITE)

Varieties	No. of Bees Observed	No. of Plants Visited	No. of Flowers Visited			Foraging Time (sec)	Foraging Distance (cm)
			Stage II A	Stage II B	Stage II C		
Ackerperle	25	5.52±0.33*	0.96±0.24	8.32±0.39	0.72±0.27	110.20±7.29	233.64±32.92
Diana	25	5.08±0.37	0.80±0.20	6.80±0.47	2.40±0.46	119.32±7.06	307.80±71.32
Erfordia	25	4.88±0.43	1.20±0.24	8.08±0.33	0.72±0.21	119.16±7.47	218.96±33.61
Herz Freya	25	4.96±0.37	0.56±0.17	8.32±0.34	1.12±0.32	105.08±6.54	309.60±72.83
Mean Total	100	5.11±0.19	0.88±0.11	7.88±0.20	1.24±0.17	113.44±3.55	267.5±27.95

*Mean and standard error.

TABLE XXXIX

FORAGING ACTIVITIES OF AN EXTRAFLORAL NECTAR FORAGER ON EXTRAFLORAL NECTARIES ON TEN STIPULES OF FABABEANS (ACKERPERLE, GLENLEA SITE, 1, 2, 3 AUGUST, 1977)

No. of Bees Observed	No. of Plants Visited	No. of Type III Visits to Each Node							Foraging Time (sec)	Foraging Distance (cm)
		1	2	3	4	5	6	7		
5	2.20 ± 0.66*	18(36%)#	13(26)	8(16)	5(10)	2(4)	2(4)	2(4)	47.80 ± 7.93	56.00 ± 27.18

#Number of visited stipules

*Mean and standard error.

1 indicates extrafloral nectaries visited at the top (or first level) of the plant.

full bloom stage rather than flowers in the early bloom or the late bloom stage (i.e. 79%, 9%, and 12% respectively, ($P < 0.01$). The positive foragers spent about 11.3 sec. per flower while visiting 5.0 plants which were about 268 cm apart (i.e. the bees moved about 142 cm per min.; mean of four cultivars). There was no significant difference in the foraging time and the foraging distance in the four cultivars, and there was no correlation between the number of plants visited and the foraging time or the foraging distance.

The author also made observations of extrafloral nectar foragers on Ackerperle. The bees visited approximately 2.2 plants while foraging on 10 stipules (i.e. 4.6 stipules visited per plant). The extrafloral nectar foragers preferred to visit extrafloral nectaries at the top of the plant. They spent 48 sec. visiting 10 stipules (i.e. 4.8 sec. per stipule), located on 2.2 plants which were about 56 cm apart (i.e. the bees moved 70 cm per min.).

My observations of the behaviour of each type of forager on fababeans verify the observations of the other researchers as follows: Positive foragers visited 1.7 and 2.0 flowers per plant at the U. of M. and the Glenlea sites respectively; Poulsen (1973) found that positive foragers visited 1.8 flowers per plant. Positive foragers spent 11.3 sec. per flower at the Glenlea site (Free, 1962 found that they spent 11.9 sec. per flower) and 14.0 sec. per flower at the U. of M. site (Poulsen, 1973, found that they spent 14.0

sec. per flower). Extrafloral nectar foragers spent 2.8 and 4.8 sec. per stipule at the U. of M. and the Glenlea sites respectively; these results are similar to those of Free (1962) who found that the bees spent 4.7 sec. per stipule.

Although the behaviour of honey bees on fababeans has been studied by several authors in different countries, the foraging times, and the rate of movement of the bees on the plants and the flowers are remarkably similar.

5.2 Honey Bee Populations

5.2.1 Literature Review

The number of foragers on field beans varies during the flowering period and during the day (Free, 1962; Ibrahim and Selim, 1967; Poulsen, 1971, 1973).

During the flowering period, the greatest foraging activity, occurs during the second and third weeks of the flowering period. However, late in the flowering period there is a gradual decrease in the percentage of extrafloral nectar collectors and negative collectors. The percentage of perforated flowers shows an increase of 6, 22, and 51% in the early, middle, and late flowering periods respectively (Poulsen, 1973).

Free (1962) reported that the percentage of bees collecting nectar from the extrafloral nectaries increases toward the end of flowering period.

The percentage of honey bees collecting pollen is highest during the time of day when the highest number of flowers are blooming, i.e. about 1700 h in field beans (Cherkasova, 1966; Free, 1962; Poulsen, 1971, 1973). In general, relatively few bees are observed at 900 to 1100 h, particularly during the early stages of the flowering period; later in the day about 3-5 times as many bees are usually observed under suitable weather conditions (Poulsen, 1973). Ibrahim and Selim (1967) found that honey bees visited broad beans throughout the day and mostly between 1400-1600 h in Cairo.

The percentage of bees making different types of visits differed considerably during the same day according to Free (1962). He found that the percentage of extrafloral nectary visits usually decreased as the day went on while the percentage of negative floral visits increased or remained the same. The percentage of "positive" visits also increased, except on the first day of the flowering period (Free, 1962).

Poulsen (1973) found that the majority of the nectar collecting honey bees exploited the extrafloral nectaries, while only a limited number made negative flower visits; the negative flower visits and extrafloral nectary visits were equal in number. According to Cherkasova (1966) the population of floral nectar collectors was twice that of extrafloral nectar collectors in field beans.

Nectar collecting by honey bees generally coincides with pollen collecting (Poulsen, 1973). Poulsen also

suggested that negative honey bees do not affect the pollination of field beans.

Hawkins (1965) observed that the proportion of positive foragers was only 18.7-24.1% of the total foragers in a field of winter beans. The number of negative bees varies depending on location and environmental factors. Tasei (1976) reported that 80-95% of the bees visiting field beans were negative bees in the Vienna area; this figure reaches 100% in Germany, according to Scholhorn's observations (1942). It is believed that a negative bee expends less energy in foraging than does a positive bee (Weaver, 1956). It is generally believed that these "robbers" (i.e. negative bees) are unable to bite holes in the flowers by themselves (Free, 1970).

Bond and Hawkins (1967) reported that the proportion of bees making positive visits is significantly greater on male-fertile than on male-sterile plants, but the opposite is true of bees making negative visits; these latter bees prefer to collect nectar from the male-sterile rather than the male-fertile plants.

5.2.2 Materials and Methods

In 1977, a four by four Latin Square (50 x $50M^2$) plot, using four cultivars of fababeans, was planted at the U. of M. and Glenlea sites; this was used to study bee populations and types of bee visits. These plots were separated from each other by a three metre wide pathway, Fig. 1.

All of the bees displaying each type of visit (i.e. Type Ib, positive forager with pollen loads; Type Ic, positive forager without pollen loads; Type IIa, negative floral forager; Type III, extrafloral nectar collecter; were counted in each of the 16 plots every hour between 800 and 2200 h. These observations were done on 20 June and 28 June at the U. of M. site, and on 12 July and 20 July at the Glenlea site.

The number of perforated flowers (i.e. the corolla tube with a hole, which was bitten by a bee) occurring within a random sample of 200 old full blooms (i.e. Type IIB, 4-6 days old) from the Latin Square were recorded on 15, 19, and 28 June, 1977 at the U. of M. site, and on 15, 17 July, and 3 August 1977 at the Glenlea Site.

The bee populations on the four cultivars at both sites (1977) were each analysed by a Three-Way Factorial ANOVA followed by a SNK Multiple Range Test; a $\log_{10}(x+1)$ transformation was required for these analyses. The number of perforated flowers on the four cultivars on three days of observation at both sites were each analysed by a Two-Way ANOVA followed by a SNK Multiple Range Test.

5.2.3 Results and Discussion

The results of the honey bee population studies are shown in Figs. 14, 15, 16 and Tables XXXX, XXXXI, XXXXII, XXXXIII.

U. of M. Site

There was no significant difference between the total number of bees observed in each cultivar on two days of observation. There was a non-significant tendency for Ackerperle to have the highest population of positive foragers with pollen loads; Erfordia had the lowest number, and Herz Freya had a higher number than did Diana. The largest number of extrafloral nectar foragers tended to occur on Erfordia; the other three cultivars had about the same number of these foragers. The negative floral foragers were found in very low numbers on Erfordia and Herz Freya, while none were found on Ackerperle and Diana.

A significantly higher total number of bees, of each type, was observed on 20 June than on 28 June 1977 ($P < 0.01$). The percentage of the mean number of bees, of each type for both days of observation were as follows: positive foragers with pollen loads 82.4%, positive foragers without pollen loads 1.9%, negative floral foragers 0.4%, and extrafloral nectar foragers 15.3%.

The total bees observed for each type of visit, was significantly higher on 20 June than 28 June 1977 ($P < 0.01$). There was no significant difference in the number of bees, of each type, observed on different cultivars on each day of observation, except that the number of extrafloral nectar foragers observed on Erfordia tended to be higher than those observed on the other three cultivars. Erfordia also had

Figure 14: Number of honey bees which were collecting nectar and pollen on four cultivars of fababeans, at different times throughout the day (1977).

Legend: A1 - U. of M. site, 20 June
A2 - U. of M. site, 28 June
B1 - Glenlea site, 12 July
B2 - Glenlea site, 20 July

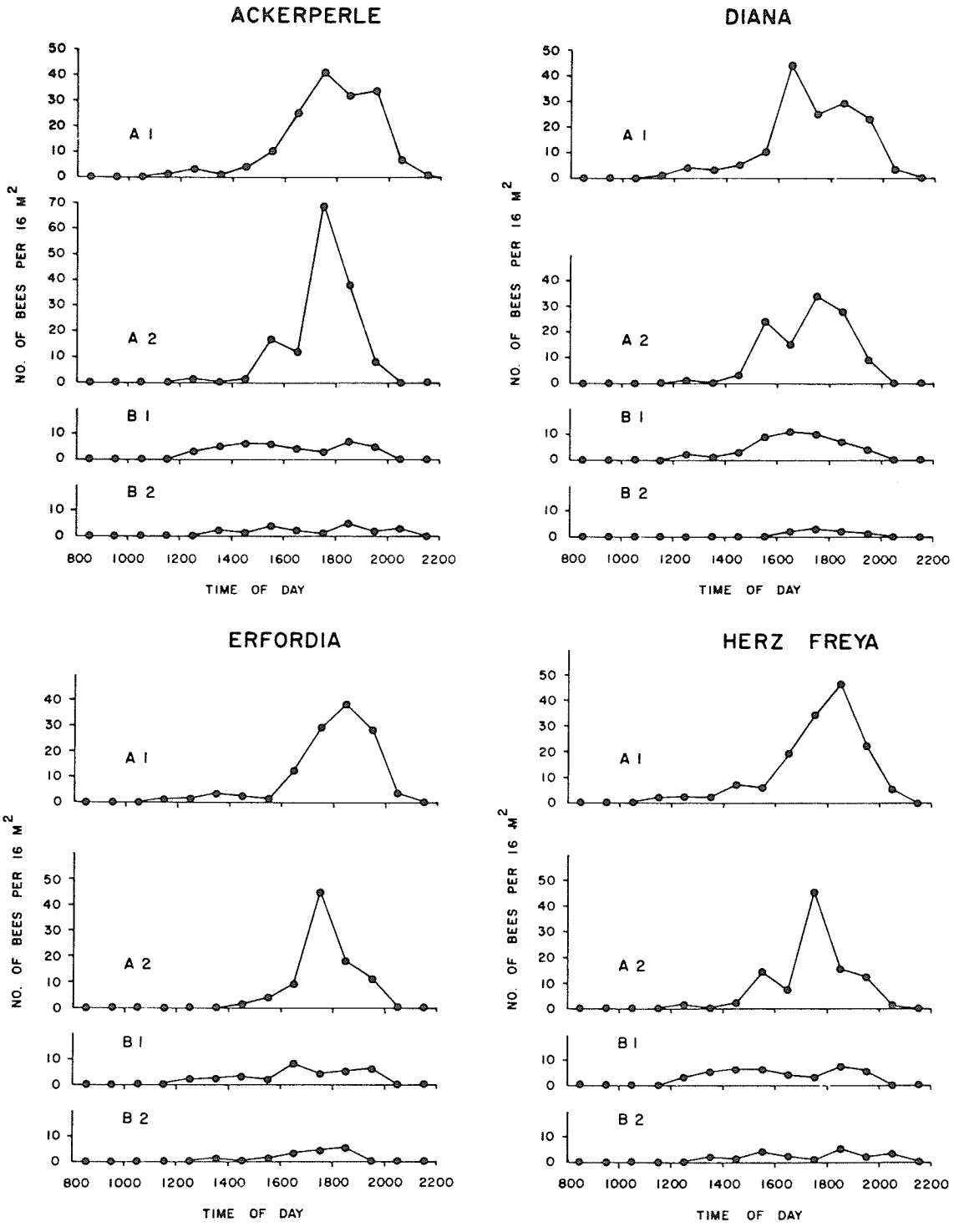

ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
A 1
A 2
B 1
B 2
NO. OF BEES PER 16 M²
TIME OF DAY
800 1000 1200 1400 1600 1800 2000 2200

Figure 15: Number of honey bees which were collecting nectar from the extrafloral nectaries on four cultivars of fababeans, at different times throughout the day (1977).

Legend: A1 - U. of M. site, 20 June
A2 - U. of M. site, 28 June
B1 - Glenlea site, 12 July
B2 - Glenlea site, 20 July

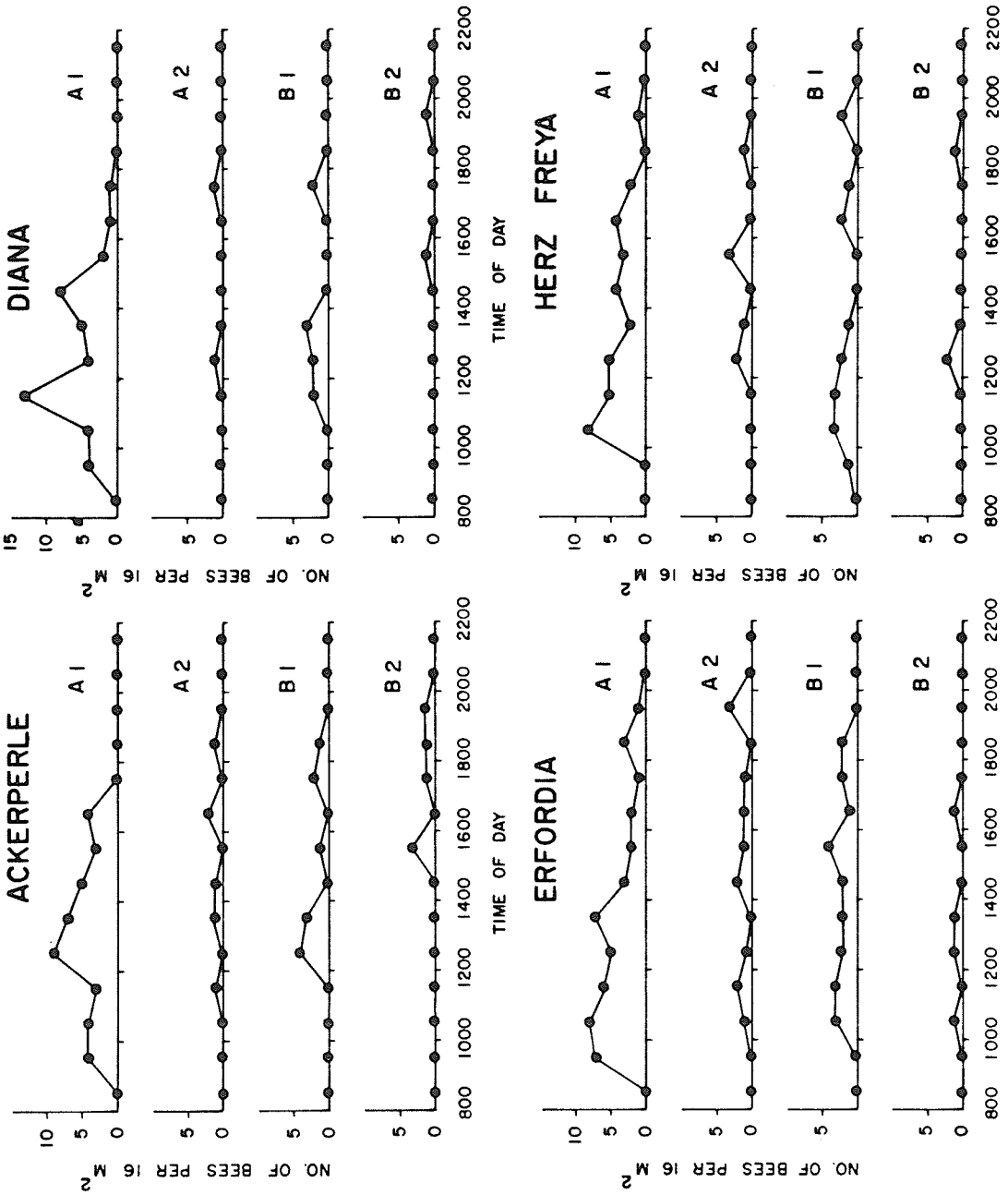

ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
A 1
A 2
B 1
B 2
NO. OF BEES PER 16 M²
TIME OF DAY
800 1000 1200 1400 1600 1800 2000 2200

TABLE XXXX

NUMBER OF HONEY BEES MAKING VARIOUS TYPES OF VISITS WHILE FORAGING ON FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (U. OF M. SITE, 20 JUNE, 1977)

Date	Cultivar	Type of Visit	Times of Day (h) 0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	Total Bees
20 June	Ackerperle	I b	0*	0	0	1	3	1	4	10	25	41	32	34	7	1	159
		I c	0	0	1	0	1	2	0	0	0	0	0	0	0	0	4
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	4	4	3	9	7	5	3	4	0	0	0	0	0	39
	Diana	I b	0	0	0	1	4	3	5	10	44	25	29	23	3	0	147
		I c	0	0	0	0	3	0	3	0	0	0	0	0	0	0	6
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	4	4	13	4	5	8	2	1	1	0	0	0	0	42
	Erfordia	I b	0	0	0	1	1	3	2	1	12	29	38	28	3	0	118
		I c	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
		II a	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
		III	0	7	8	6	5	7	3	2	2	1	3	1	0	0	45
	Herz Freya	I b	0	0	0	2	2	2	7	6	19	34	46	22	5	0	145
		I c	0	0	1	0	0	1	2	0	0	0	0	0	0	0	4
		II a	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
		III	0	0	8	5	5	2	4	3	4	2	0	1	0	0	34
	Total	I b	0	0	0	5	10	9	18	27	100	129	145	107	18	1	569
		I c	0	0	2	0	4	3	8	0	0	0	0	0	0	0	17
		II a	0	0	0	0	0	0	0	0	1	0	2	0	1	0	4
		III	0	15	24	27	23	21	20	10	11	4	3	2	0	0	160

I b Positive forager with pollen loads.
I c Positive forager without pollen loads
II a Negative forager.
III Extrafloral nectar forager
* Observed from $16M^2$ (1 Bee/16 M^2 = 625 bees/hectare).

TABLE XXXXI

NUMBER OF HONEY BEES MAKING VARIOUS TYPES OF VISITS WHILE FORAGING ON FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (U. OF M. SITE, 28 JUNE, 1977)

Date	Cultivar	Type of Visit	Times of day (h) 0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	Total Bees
28 June	Ackerperle	I b	0	0	0	0	1	0	1	17	12	69	38	8	0	0	146
		I c	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	1	0	1	1	0	2	0	1	0	0	0	6
	Diana	I b	0	0	0	0	1	0	3	24	15	34	28	9	0	0	114
		I c	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2
	Erfordia	I b	0	0	0	0	0	0	1	4	9	45	18	11	0	0	88
		I c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	1	2	1	0	2	1	1	1	0	3	0	0	12
	Herz Freya	I b	0	0	0	0	1	0	2	14	7	45	15	12	1	0	97
		I c	0	0	0	0	1	1	0	1	0	0	0	0	0	0	3
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	0	2	1	0	3	0	0	1	0	0	0	7
	Total	I b	0	0	0	0	3	0	7	59	43	193	99	40	1	0	445
		I c	0	0	0	0	1	1	0	4	0	0	0	0	0	0	6
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	1	3	4	2	3	4	3	2	2	3	0	0	27

I b Positive forager with pollen loads.
I c Positive forager without pollen loads.
II a Negative forager.
III Extrafloral nectar forager
* Observed from 16 M^2 (1 Bee/16 M^2 = 625 Bees/Hectare).

significantly more of these foragers than did Diana ($P < 0.01$), which in turn had the lowest number of these foragers.

The highest number of positive foragers with pollen loads on Ackerperle occurred during 1700-1800 h on both days; Diana had peak numbers between 1600-1700 on 20 June, and 1700-1800 on 28 June. Erfordia and Herz Freya had peak numbers between 1800-1900 h on 20 June and 1700-1800 h on 28 June. On 20 June extrafloral nectar foragers were found in the morning and throughout the afternoon, but they ceased foraging in the evening on four cultivars. On 28 June extrafloral nectar foragers were observed in very low numbers with no peak occurring in foraging activity. The positive foragers, without pollen loads, were usually found during early afternoon. The negative floral foragers were found only on 20 June in the evening.

Glenlea Site

The number of bees observed at the Glenlea site was less than one third that observed at the U. of M. site. The highest number of positive foragers, with pollen loads, occurred on Herz Freya on both days. Erfordia had the lowest number while Ackerperle and Diana had about the same number; none of these results were significantly different.

No significant differences were found between the number of positive foragers without pollen loads, and the number of negative floral foragers. The percentage of the mean number of bees making each type of visit on two days was

TABLE XXXXII

NUMBER OF HONEY BEES MAKING VARIOUS TYPES OF VISITS WHILE FORAGING ON FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (GLENLEA SITE, 12 JULY, 1977)

Date	Cultivar	Type of Visit	Times of day (h) 0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	Total Bees
12 July	Ackerperle	I b	0*	0	0	0	3	5	6	6	4	3	7	5	0	0	39
		I c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	0	4	3	0	1	0	2	1	0	0	0	11
	Diana	I b	0	0	0	0	2	1	3	9	11	10	7	4	0	0	47
		I c	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	2	2	3	0	0	0	2	0	0	0	0	9
	Erfordia	I b	0	0	0	0	2	2	3	2	8	4	5	6	0	0	32
		I c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	3	3	2	2	2	4	1	2	2	0	0	0	21
	Herz Freya	I b	0	0	3	3	4	7	6	11	6	4	8	10	0	0	62
		I c	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	1	3	3	2	1	0	0	2	1	0	2	0	0	15
	Total	I b	0	0	3	3	11	15	18	28	29	21	27	25	0	0	180
		I c	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	1	6	8	10	9	2	5	3	7	3	2	0	0	56

I b Positive forager with pollen loads.
I c Positive forager without pollen loads.
II a Negative forager.
III Extrafloral nectar forager.
* Observed from 16 M^2 (1 Bee/16 M^2 = 625 Bees/Hectare).

TABLE XXXXIII

NUMBER OF HONEY BEES MAKING VARIOUS TYPES OF VISITS WHILE FORAGING ON FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (GLENLEA SITE, 20 JULY, 1977)

Date	Cultivar	Type of Visit	Times of Day (h) 0800*	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	Total Bees
20 July	Ackerperle	I b	0	0	0	0	0	2	1	4	2	1	5	2	3	0	20
		I c	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	0	0	0	0	3	0	1	1	1	0	0	6
	Diana	I b	0	0	0	0	0	0	0	0	2	3	2	1	0	0	8
		I c	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
	Erfordia	I b	0	0	0	0	0	1	0	1	3	4	5	0	0	0	14
		I c	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	1	0	1	1	0	0	1	0	0	0	0	0	4
	Herz Freya	I b	0	0	0	0	0	2	0	3	4	2	7	2	3	0	23
		I c	0	0	0	0	0	1	0	0	0	0	1	0	0	0	2
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	0	0	2	0	0	0	0	0	1	0	0	0	3
	Total	I b	0	0	0	0	0	5	1	8	11	10	19	5	6	0	65
		I c	0	0	0	0	0	1	1	0	0	1	2	0	0	0	5
		II a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		III	0	0	1	0	3	1	0	4	1	1	2	2	0	0	15

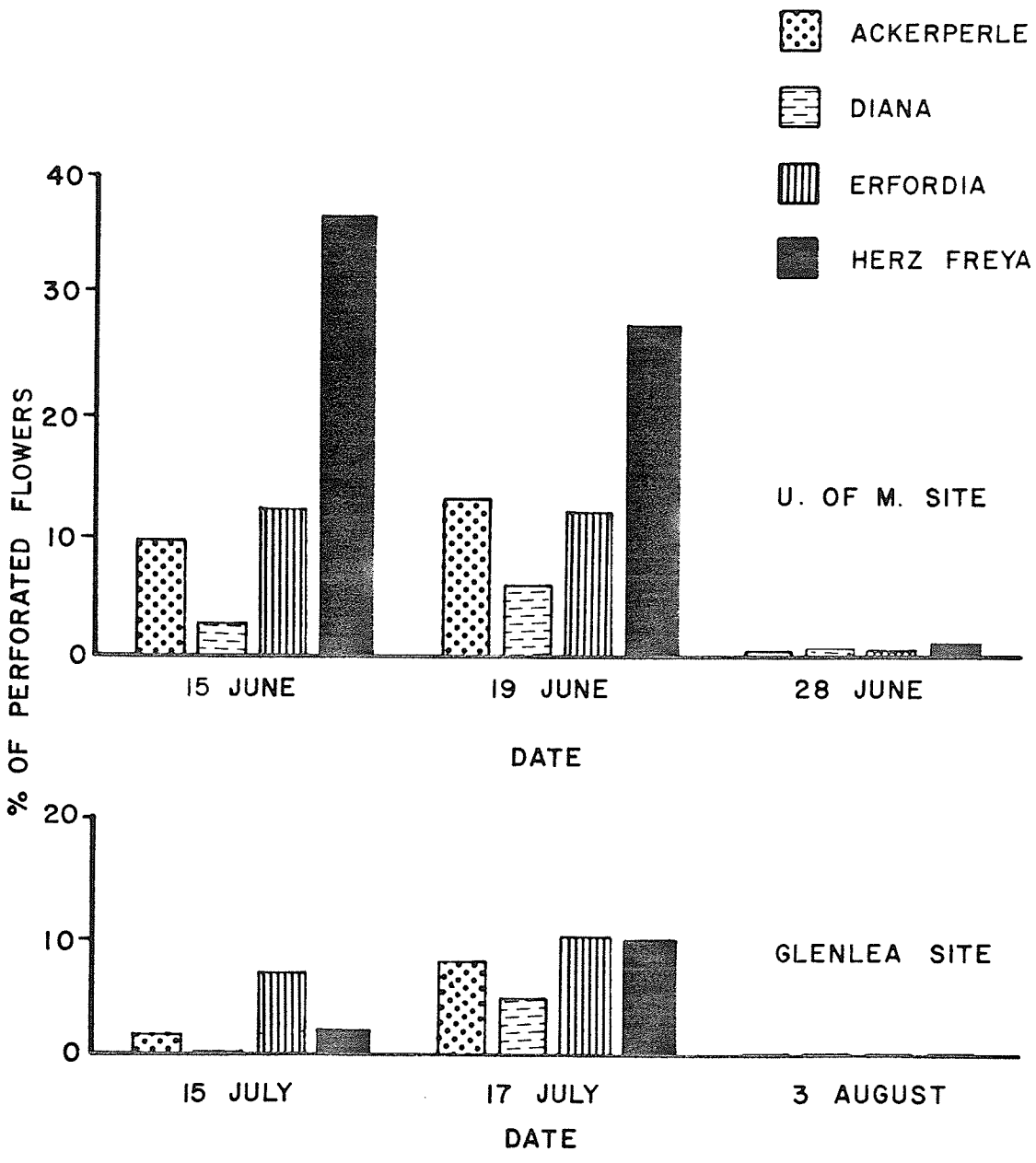
I b Positive forager with pollen loads.
I c Positive forager without pollen loads.
II a Negative forager.
III Extrafloral nectar forager.
* Observed from 16 M^2 (1 Bee/16 M^2 = 625 Bees/Hectare).

as follows: positive foragers with pollen loads 74.7%, positive foragers without pollen loads 4.3%, negative floral foragers 0.0%, and extrafloral nectar foragers 21.1%. There was a significant difference between the number of bees making each type of visit ($P<0.01$).

The total number of positive foragers with pollen loads and the number of extrafloral nectar foragers was significantly higher ($P<0.01$) on 12 July than on 20 July. There was no significant difference in the number of bees of each type on the different cultivars on each day, except on 12 July, when significantly more positive foragers, without pollen loads, were found on Ackerperle than on the other three cultivars ($P<0.01$). A significantly higher number of extrafloral nectar foragers were found on Erfordia than on Diana ($P<0.05$). On 20 July, the number of positive foragers, with pollen loads, was significantly higher on Herz Freya than on Diana ($P<0.05$). Although the number of positive foragers with pollen loads tended to be highest in the late afternoon for each cultivar, they were not significantly different than the numbers occurring at other times of the day. Extrafloral nectar foragers tended to have high numbers between noon and early afternoon. Low numbers of positive foragers without pollen loads, and negative floral foragers were observed at the Glenlea site.

The results of the perforated flower observations are shown in Fig. 16.

Figure 16: A comparison (%) of the number of perforated flowers which occurred in four cultivars of fababeans at two sites (1977)


ACKERPERLE
DIANA
ERFORDIA
HERZ FREYA
40
30
20
10
0
% OF PERFORATED FLOWERS
U. OF M. SITE
15 JUNE
19 JUNE
28 JUNE
DATE
20
10
0
GLENLEA SITE
15 JULY
17 JULY
3 AUGUST
DATE

The number of perforated flowers observed on Diana was significantly lower than that observed on the other three cultivars ($P < 0.01$) at each site. Herz Freya had the highest number of perforated flowers ($P < 0.01$) at the U. of M. site. There was no significant difference in the number of perforated flowers on Ackerperle or Erfordia at both sites. The number of perforated flowers was highest on 15 June at the U. of M. site, and on 17 June at the Glenlea site ($P < 0.01$). Only a few perforated flowers were observed on 28 June at at the U. of M. site and on 3 August at the Glenlea site.

I found that there were more bees making each type of visit in the early flowering period than in the late flowering period. However, fewer positive foragers with pollen loads were observed in Erfordia than on the other three cultivars.

The number of negative floral foragers observed in fababeans during four days of observation was less than 1% compared to 83% for positive visits (both with and without pollen loads), and compared to 16% for extrafloral nectar foragers. The number of negative foragers is so low in Manitoba that this should not affect the pollination of fababeans.

The number of perforated flowers was high during the early to middle flowering period at both sites. The bees often bit holes in the corolla tubes of Herz Freya but seldom did so in Diana; similar results were obtained when

counts of negative honey bees and negative bumble bees (See Ch. VI, 6.1.3) were made at the U. of M. site. It is possible that the corolla tubes of certain cultivars are more difficult to bite through. It is interesting to note that after cloudy, rainy weather occurred each day for a week during the early to middle flowering period at the U. of M. site, I observed a high number of negative floral visits by honey bees in the fababeans, Appendix Fig. 2, 3. However throughout the 1976 and 1978 flowering period and during the latter part of the 1977 flowering period, when only short periods of rain occurred, I never observed honey bees making negative visits. Any holes that were made in the flowers were done by bumble bees (See Ch. VI, 6.1.3) and not honey bees.

Positive visits by honey bees were highest between 1700 and 1900 h; this is about one to three hours later than was observed by Poulsen (1973) in Denmark. Free (1962) however, found that early in the flowering period, positive foragers in England tended to forage about three hours earlier in the day than did the bees in my trials, but as the season progressed, the difference in time was reduced to about one hour because the bees in England foraged later.

Free (1962) found, in England, that in the early flowering period the extrafloral nectar foragers occurred in lower populations than they did in the late flowering period; however under Manitoba conditions I found the opposite to be the case. Both studies showed that extrafloral nectar

foragers visit nectaries primarily during the morning and early afternoon.

My observation that the number of negative floral visitors and the number of perforated flowers were high in the early flowering period agree with the results of Free (1967); however Poulsen (1973) found the opposite to be true in his studies.

CHAPTER VI

OTHER INSECTS ON FABABEANS

6.1 Survey of Possible Insect Pollinators

6.1.1 Literature Review

In Austria, Tasai (1976) found that all visits of Eucera, and Anthophora spp. to field beans are "positive" (see Chapter V.5.1.1), and are responsible for most of the seed produced in the female line. He also observed that about 4% of the insect pollinators in winter field beans were Eucera tuberculara and 0.7% were Anthophora acervorum L.

Anthophora sp. and Xylocopa aestuan are found to be among the most important pollinating insects of field beans in Egypt (Wafa and Ibrahim, 1960); others are Tetralonia lanuginosa and Chalicidoma siculum (El-Berry et al. 1974). Most insects show peaks of activity between 1100-1400 h. (El-Berry, 1974). Weaver (1956) reported that a large number of megachilids pollinate vetch in Texas.

Bond et al. (1964b) used control measures on pollen beetles (Meligethes) found in their experimental field bean plots because they believed they might cross pollinate their crop.

Bumble bees are probably as effective or better than honey bees in pollinating field beans (Avetisyan et al. 1963); Kendall and Smith, 1975; Pritsch, 1970). The foraging activities of bumble bees in field beans are divided into

"positive" visits (i.e. the bees enter the flower through the front, trip the flower,and collect nectar and pollen) and "negative" visits (i.e. bees collect nectar by biting holes at the base of the corolla tube, or use holes already bitten in it).

POSITIVE VISITS

Recent studies on reproduction in field beans show that Bombus agrorum, B. hortorum L., B. lapidarius L. and B. ruderatus F. are the most effective pollinators of this plant (Bond and Hawkin, 1967; Free, 1962; Homola, 1972; Kendall and Smith, 1975; Poulsen, 1973, 1975; Smith et al, 1973, 1974; Tasei, 1975).

Tasei (1975) found that 100% of the visits of Bombus hortorum and B. ruderatus were positive; the visits of B. hortorum were 66% positive, and the visits of B. agrorum were 71% positive (Kendall and Smith, 1975). In Denmark, Poulsen (1975) reported that B. hortorum, B. lapidarius, B. agrorum F., and B. distinguendus Morowitz made only 50% positive visits in field beans.

Three intermediate-tongued bumble bees (Bombus griseocolis Degeer, B. impatiens Cresson, and B. vagans F. Smith, and six long-tongued bumble bees (B. americanorum F, B. auricomus Robertson, B. bimaculatus Cresson, B. borealis, Kirby, B. fervidus F., and B. laboriosus F.) were found foraging on Vicia spp. in Wisconsin (Medler and Carney, 1963).

Observations by Ruszkowski (1971) in Poland and

adjacent countries indicate that bumble bees (Bombus terrestris L., and B. lucorum L.) play an important role in the pollination of Vicia spp.

Bond (1968) found that pollination of the male sterile bean was effected mainly by the bumble bees Bombus hortorum and B. agrorum; members of both of the subgenera Hortobombus and Agrobombus were observed making positive visits to the male-sterile and male-fertile flowers of field beans.

Poulsen (1973) indicated that, on average, approximately twice as many bumble bees per hectare occur on field beans in the afternoon as in the morning.

NEGATIVE VISITS

Soper (1952) found that most bumble bees (Bombus spp.) in Oxford made negative visits to field beans. The short-tongued bumble bees (B. terrestris, and B. lucorum), always collect nectar through the holes that they cut at the bases of the corolla tubes in field beans (Bilinski, 1970; Bond and Hawkins, 1967; Free, 1962; Kendall and Smith, 1975; Poulsen, 1971, 1973; Smith et al, 1972; Tasei, 1976), Bombus occidentalis Greene and B. terrestris show the same behaviour on vetch (Vicia villosa) (Bohart, 1960; Schehorn, 1942). Four short-tongued bumble bees (B. affinis Cresson, B. rufocinctus Cresson, B. ternarius Say and B. terricola Kirby) were reported visiting Vicia spp. in Wisconsin (Medler and Carney 1963).

The visits of Bombus terrestris, B. lucorum, and Terrestribombus to field beans were 90-95% negative, B. pratorum L. were 80-95% and B. agrorum and B. lapidarius were 10-15% (Tasei, 1975, 1976). Kendall and Smith (1975) found 62.9% and 54.8% of the visits of B. terrestris and B. lucorum were negative respectively, whereas Free (1962) found their visits each to be about 66% negative.

The foraging activity of Bombus terrestris on field beans included: 93% negative visits in the early flowering period and 77% negative visits in the late flowering period; one half of these visits occurred early in the day (Poulsen, 1973).

Some negative Bombus terrestris visitors to field beans carried pollen loads of field beans or rape (Free, 1962; Kendall and Smith, 1975; Poulsen, 1973).

Field bean plants which receive negative visits of bumble bees produce less seed than those plants that receive positive visits, and more seed than those plants that receive no visits (Kendall and Smith, 1975).

BUMBLE BEE SPEEDS

Pollen collecting bumble bees usually visit more flowers per plant and many more flowers per minute, than do honey bees (Poulsen, 1973). Free (1962) observed that negative bumble bee visitors spend 6.5 seconds per flower while those that make positive visits spent 3.4 seconds per flower.

Poulsen (1973) reported that of the bumble bee species, Bombus distinguendus is the most rapid visitor to field beans, spending 3.9 seconds per flower; B. agrorum spends 8.6 seconds per flower and is thus the slowest of the species he observed. Poulsen also reported that B. hortorum spends 5.9 seconds per flower while Tasei (1975) found that it spends 4.6 seconds per flower and that B. terrestris spends 7 seconds per flower.

6.1.2 Materials and Methods

Records of any insect thought to be a pollinator of fababeans were made periodically during the flowering season at the U. of M., Glenlea, and Ile des Chenes sites.

As well, samples of all insects making "positive" or "negative" visits to fababean flowers at the observation sites were collected.

When honey bee population studies were being done in the Latin Square plot experiment (see page 141) bumble bee data were also recorded. These data included the number and type of bee visits on the four cultivars of fababeans (Ackerperle, Diana, Erfordia and Herz Freya) collected at hourly intervals (800 h to 2100 h) for two days at each of the U. of M. and Glenlea sites.

6.1.3 Results and Discussion

The results are shown in Tables XXXXIV, XXXXV, XXXXVI, and XXXXVII.

There were three species of insects inside the fababean flowers, i.e. Frankliniella tritici (Thysanoptera), Orius tristicolor (Hemiptera) and Carpophilus sp.(Coleoptera). Whether or not these three species pollinate fababeans is not known. However they are winged insects and as such may carry pollen on their bodies as they move from flower to flower. Although there were high populations of thrips in each flower, no damage was observed, probably because they eat only pollen. Orius tristicolor is predacious and to a lesser extent phytophagous. It feeds mostly on aphids, thrips, mites, other small arthropods, and eggs of insects.

Several species of wasps foraged on the extra-floral nectaries. They were very aggressive to honey bees, sometimes displacing extrafloral nectar foraging honey bees and then collecting from the nectary itself. The wasps foraged quickly and moved from plant to plant quite often, thus controlling a wide area.

There were a large number of moths and butterflies collecting nectar from the flowers, but they never appeared to trip the flowers.

I also observed many species of flies, ichneumon wasps, ants, small wild bees, lace wing bugs, and lady beetles feeding on the extra-floral nectaries.

The farmland surrounding the experimental plots was intensively cultivated, and therefore few wild bees were observed on the fababeans. A few individuals of one species

TABLE XXXXIV

INSECTS OBSERVED ON, AND THOUGHT TO BE POLLINATORS, OF FABABEANS

ORDER	SCIENTIFIC NAME	FOOD AND FEEDING HABITS
Thysanoptera	*Frankliniella tritici* (Fitch)	pollen; live in flower
Hemiptera	*Orius tristicolor* (white)	pollen; predaceous, live in flower
Coleoptera	*Carpophilus* sp.	pollen; live in flower
Lepidoptera	*Colias* spp.	floral nectary
	Danaeus plexippus (L.)	" "
	Pieris rapae L.	" "
	Vanessa atalanta L.	" "
Hymenoptera	*Apis mellifera* L.	Nectar, pollen
	Bombus borealis Kirby	" "
	B. griseocollis (Degeer)	" "
	B. rufocinctus Cresson	" "
	B. terricola Kirby	Nectar
	B. vagans F. Smith	Nectar, pollen
	Megachile inermis Provancher	" "

TABLE XXXXV

SOME INSECTS THAT ARE FOUND FEEDING ON THE EXTRAFLORAL NECTARIES OF FABABEANS

ORDER	SCIENTIFIC NAME
Neuroptera	Chrysopa sp.
Coleoptera	Adalia sp.
	Coccinella transversoguttata
	Hippodamia convergens
	H. tibialis
Diptera	Chephaliodes spp.
	Elophitus spp.
	Murellia micans meiq
	Phomia spp.
	Syrphus spp.
Hymenoptera	Pterocormus laetus (Brulle)
	Vespula arenaria (F.)
	V. consobrina (L.)
	V. maculifrons (Buy)
	V. nervegicoides (SL.)
	V. vulgaris (L.)

of Megachilidae (i.e. Megachile inermis) were seen pollinating fababean plants during the experimental period. Because the fababean flowers were quite large, compared to other legume flowers, the small wild bees seemed to have difficulty in tripping the flowers while collecting nectar and pollen. This may be one of the reasons why the author did not find small wild bees pollinating flowers.

Five species of bumble bees were found in the fababean experimental sites. Only two species of bumble bees were common, i.e. Bombus borealis and B. terricola. Bombus borealis is a long tongued-bumble bee, which makes positive visits to fababean flowers and trips them. It appeared to me that this bee worked faster on each flower than did honey bees, and changed from plant to plant less frequently than did honey bees. Bees of this species were not observed making negative visits.

Bombus terricola was a common negative visitor to the experimental plots; they foraged on fababeans more quickly than did other bumble bee species making positive visits. This species was not observed carrying pollen loads.

A few individuals of Bombus vagans made positive visits, B. rufocinctus made positive and negative visits, and B. griseocolis made positive visits, in the plots. None of the extra-floral nectaries of fababeans were visited by bumble bees.

Data about the number of positive and negative visits

TABLE XXXXVI

NUMBER AND TYPE OF VISIT MADE BY BUMBLE BEES WHILE FORAGING ON FOUR CULTIVARS OF FABABEANS ON DIFFERENT DATES (U. OF M. AND GLENLEA SITES, 1977)

		CULTIVAR									
		Ackerperle		Diana		Erfordia		Herz Freya		Total Visits	
Site	Date	P.V.	N.V.	P.V.	N.V.	P.V.	N.V.	P.V.	N.V.	P.V.	N.V.
U. of M.	20 June	0*	3	3	0	2	3	4	3	9	9
U. of M.	28 June	0	0	0	0	0	0	0	0	0	0
Glenlea	12 July	1	0	2	0	1	0	1	0	5	0
Glenlea	20 July	2	0	0	0	1	0	1	0	4	0
TOTAL		3	3	5	0	4	3	6	3	18	9

P.V. Positive Visits

N.V. Negative Visits

* Observed from 224 M^2

TABLE XXXXVII

NUMBER AND TYPE OF VISIT MADE BY BUMBLE BEES WHILE FORAGING ON FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (U. OF M. AND GLENLEA SITES, 1977)

Site	Date	Type of Visit	Time of Day (hr) 0800 *	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	Total Visits
U. of M.	20 June	P.V.	0	0	1	1	0	1	3	0	1	0	0	1	1	0	9
		N.V.	0	0	1	0	0	0	0	0	2	2	0	2	1	1	9
U. of M.	28 June	P.V.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		N.V.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenlea	12 July	P.V.	0	0	0	0	0	0	0	0	0	0	2	1	2	0	5
		N.V.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenlea	20 July	P.V.	0	0	0	0	0	0	0	1	1	0	2	0	0	0	4
		N.V.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Visits		P.V.	0	0	1	1	0	1	3	1	2	0	4	2	3	0	18
		N.V.	0	0	1	0	0	0	0	0	2	2	0	2	1	1	9

P.V. Positive Visits
N.V. Negative Visits
* Observed from 64 M^2 (1 Bee/64M^2 = 156 Bees/Hectare)

made by the two species of bumble bees, Bombus borealis and B. terricola are shown in tablesXXXXVI, and XXXXVII.

Because, the number of bumble bees foraging on the fababeans was very low, the counts of bees making positive or negative visits at various times of the day were pooled for each cultivar. Also, for the same reason, the number of positive or negative visits made by bumble bees visiting the four cultivars at various times of a given day were pooled.

The highest number of bumble bees, as well as the numbers of negative visits made by them, was recorded on the first observation day at the U. of M. site. The number of bees making positive visits was too low to show any bee preference for a given cultivar of fababeans.

The number of bees making negative visits, was similar in the cultivars Ackerperle, Erfordia, and Herz Freya; however this type of visit was not observed in the cultivar Diana (See Ch. V, 5.2). After four days of observation at both sites I found that about half of the bees made negative visits. These visits occurred mainly on the first observation day at the U. of M. site but no bees were observed making negative visits at the Glenlea site, probably because low populations of Bombus terricola occurred in that area.

Most of the bumble bee foragers, making both types of visits, were found after 1200 h. with most of the visits taking place between 1600-2000h.

CHAPTER VII

POLLINATION TRIALS

Introduction

Prior to undertaking a study of the direct effects which honey bees have on the pollination of fababeans, the author determined the number of ovules within pods of Ackerperle when grown in open plots, in cages with bees, and in cages without bees. Also the number of ovules within pods of four cultivars, grown in the open plots, were compared.

7.1 Number of Immature Seeds per Pod

7.1.1 Literature Review

From Kambals' data (1968), I calculated that there are 3.48 ovules per pod (i.e. immature seeds per pod) in field beans. Other than these data there is little information available about the number of immature seeds per pod in field beans. Almost all of the data are concerned with yield results in terms of number of pods, weight of seed, and flower pod relationships.

Kambal and his partners (1976) have counted the number of pollen grains per flower on various cultivars of field beans; however, they did not determine the number of immature seeds per pod, in field beans. In this study, I

attempted to determine the ovule numbers within four cultivars of fababeans, and to determine the number of ovules which occur at each inflorescent level for the cultivar Ackerperle.

7.1.2 Materials and Methods

Twenty full grown fababean plants (cultivar Ackerperle) were selected at random and removed from each plot (i.e. open field plot, open plot, cage with bees, cage without bees), at the U. of M. and Glenlea sites). The number of ovules per ovary was recorded from the seeds in the pods (including aborted and mature seeds). The position of the pods on the plants was determined by dividing, as near as possible, the total number of inflorescent nodes occurring on each plant into four groups, counting from the first inflorescent node.

In a preliminary study in 1976, twelve flowers, in the full bloom stage from each of the cultivars Ackerperle, Diana, and Herz Freya were collected at random from the Glenlea site. The ovaries of each flower were dissected and the number of ovules (i.e. immature seeds) they contained were recorded.

In 1978, 100 flowers of each of four cultivars of fababeans (Ackerperle, Diana, Erfordia, and Herz Freya) were collected during the mid-flowering period from the Glenlea site. The styles (containing the ovaries) were cut from the flowers and the ovules counted by placing the styles

in front of a lamp. Using this technique the ovules appeared as small dark dots.

The number of ovules per ovary within pods at various sites (1976), the percentage of pods containing various numbers of ovules per ovary (Ackerperle, U. of M. site, 1976), and the number of ovules per ovary within pods at various inflorescent levels (Ackerperle, U. of M. site, 1976) were each analyzed by a One-Way ANOVA followed by a SNK Multiple Range Test.

The number of flowers containing various numbers of ovules per ovary in four cultivars (Glenlea Site, 1978) were analysed by a Two-Way ANOVA followed by a SNK Multiple Range Test.

7.1.3 Results and Discussion

The results are shown in Tables, XXXXVIII, XXXXIX, L, LI, and LII.

There was no significant difference in the number of ovules per ovary taken from the pods of the cultivar Ackerperle in the open plot, in the open field, or in the cages at the U. of M. site.

There were significantly fewer ($P < 0.05$) ovules per ovary found within a pod located at the upper 2-3 inflorescent nodes than within pods located at any other inflorescent nodes on the plant (Table XXXXIX). Also, in the Ackerperle plots, the number of ovules per ovary decreased from the

TABLE XXXXVIII

NUMBER OF OVULES PER OVARY WITHIN PODS OF FABABEANS IN CAGED, AND OPEN PLOTS (ACKERPERLE, U. OF M. SITE, 1976)

Cultivar				
Ackerperle				
Site - U. of M.				
Open Plot ($4\ m^2$)	Random in Field	Cage I without bees	Cage II without bees	Cage III with bees
4.30 ± 0.03*	4.24 ± 0.03	4.17 ± 0.06	4.25 ± 0.04	4.30 ± 0.04

*Mean and standard error

TABLE XXXXIX

NUMBER OF OVULES PER OVARY WITHIN PODS AT VARIOUS INFLORESCENT LEVELS (ACKERPERLE, U. OF M. SITE, 1976)

No. Plant Samples	Inflorescent Level 1 # (1-3)	2 (4-6)	3 (7-9)	4 (10-13)
	ABa	ABa	BCa	Cb
100	4.30 ± 0.03 *	4.28 ± 0.03	4.24 ± 0.03	4.12 ± 0.05

A, B, C : means followed by different upper case superscripts differ significantly ($P < 0.01$)

a, b: means followed by different lower case superscripts differ significantly ($P < 0.05$)

* Mean and Standard error

\# Level 1 includes inflorescent nodes 1-3 measured from the base of the plant.

TABLE L

PERCENTAGE OF PODS CONTAINING VARIOUS NUMBERS OF OVULES PER OVARY (ACKERPERLE, U. OF M. SITE, 1976)

No. Plant Samples	No. of Ovules/Ovary				
	2	3	4	5	6
	C	C	A	B	C
100	0.28±0.28*	3.33±1.60	68.69±1.84	26.33±0.64	1.36±0.34

A, B, C: means followed by upper case superscripts differ significantly ($P < 0.01$).

*Mean and standard error

bottom to the top of the plants, indicating that the blooms which occurred early in the season have a greater number of ovules per ovary.

The number of ovules per ovary within pods of Ackerperle located anywhere on the plant, varied between 2-6 per pod, with a significantly higher number of ovaries containing 4 ovules ($P < 0.01$) rather than 2, 3, 5 or 6 ovules (Table L). There were significantly more pods containing ovaries with 5 ovules ($P < 0.01$) than pods containing 2, 3 or 6 ovules, while no significant differences occurred between the number of ovules per ovary occurring in the latter three categories.

The number of ovules per ovary, within the flowers of the three cultivars Ackerperle, Diana, and Herz Freya, showed no significant differences (Table LI). However, the sample size used in these preliminary studies in 1976 was small.

In 1978, a large number of flowers per cultivar (Ackerperle, Diana, Erfordia, and Herz Freya) were examined from the Glenlea site. Diana had a significantly higher number of ovules per ovary ($P < 0.05$) than did the other three cultivars; the latter three cultivars showed no significant differences in number of ovules per ovary (Table LII).

The highest number of flowers, in the four cultivars, contained 4 ovules per ovary.

The number of ovules per ovary occurred in the following frequencies from highest to lowest: 4, 5, 3, 6

TABLE LI

NUMBER OF FLOWERS CONTAINING VARIOUS NUMBERS OF IMMATURE SEEDS PER POD IN THREE CULTIVARS (ACKERPERLE, DIANA, AND HERZ FREYA) OF FABABEANS (GLENLEA SITE 27 JULY, 1976)

Cultivar	No. of Flowers	No. of immature seeds/pod					Mean Ovules/Ovary
		2	3	4	5	6	
Ackerperle	12	0	0	10	2	0	4.17 ± 0.11* [a]
Diana	12	0	2	10	0	0	3.83 ± 0.11[a]
Herz Freya	12	0	1	11	0	0	4.00 ± 0.12[a]

*Mean and standard error.

[a] Means followed by different lower case superscripts differ significantly ($P < 0.05$).

TABLE LII

PERCENTAGE OF FLOWERS CONTAINING VARIOUS NUMBERS OF IMMATURE SEEDS PER POD IN FOUR CULTIVARS OF FABABEANS (U. OF M. SITE, 1978)

Cultivar	No. of Flowers	No. of immature seeds per pod					Mean immature seed/pod
		2	3	4	5	6	
Ackerperle	100	0	5	82	12	1	4.09 ± 0.04 * b
Diana	100	0	1	59	38	2	4.41 ± 0.05[a]
Erfordia	100	1	11	70	14	4	4.09 ± 0.07[b]
Herz Freya	100	1	13	66	16	4	4.09 ± 0.07[b]

*Mean and standard error.

a, b: means followed by different lower case superscripts differ significantly ($P<0.05$).

and 2 respectively.

The results are comparable to the counts of ovules per ovary within pods observed in the 1976 data (see above).

In summary, it was observed that the mean number of ovules per ovary varied significantly between years, between locations, between cultivars, and according to the position of the flowers (or pods). Also, four ovules per ovary, occurred in the highest frequency regardless of cultivar.

7.2 Pollination Trials

7.2.1 Open Plot Trials

7.2.1.1 Literature Review

Yield Components

Pod Set

In field beans and broad beans, the lower inflorescent nodes produce more mature pods than do the upper nodes, and the percentage of pod set is higher in the early part of the flowering period (Free and Williams 1976; Inoue *et al*, 1963; Ishag, 1973; Kambal, 1969; Lawes, 1973 Martjanova *et al*, 1966; Paulsen, 1972). In both fodder bean and field bean flowers, the lower portions of the individual inflorescences produce more pods than do the upper parts (Kambal, 1969; Mart janova *et al*, 1966).

Free (1970) found that inadequate numbers of insects for pollination limited seed production in broad beans more than in field beans.

Field bean plants could not produce mature pods on more than about one-third of their flowers even when more than one-third were pollinated (Inoue et al, 1963; Riedal and Wort, 1960). Ishag (1973) reported that about one-third of the immature pods shed are from the upper half of the plant.

Various authors reported that a certain percentage of flowers fail to develop into mature pods, i.e. 80-90% (Soper, 1952); 91-85% (Hodgson and Blackman, 1956), 86-91% (Kambal, 1968); 49-91% (Ivaskina, 1968); 86.7-93.7% (Kambal, 1969).

There were no differences in the number of seeds set per flower between plants that were self-or cross-pollinated, followed by emasculation (Toynbee-Clark, 1974).

According to Drayner (1959) the conditions for pod set are as follows:

(1) Pods may be formed independently of bee visitation, but a certain percentage of cross-fertilization may occur from year to year when bees are present.

(2) Bee visitation may be essential to ensure fertilization; the large number of immature pods formed indicated that the bee populations he used were sufficient for pollination.

Environmental Effects on Pod Set

It is well known that many factors are involved in the production of bean seeds, such as fertility, temperature,

plant density, light, soil, water, diseases, insect pests, pollination and harvesting operations.

Fertilizer applications, like potash and phosphate, increase the number of flowers produced (and thus seed set) and decrease the percentage of shed pods (Alex et al, 1950; Hanna and Lawes, 1967; Soper, 1952).

High night temperatures result in a smaller percentage of pod set and accelerate the maturing of seeds (Evans and Rogalsky, 1974, Ueki, 1955, 1956, 1957; Ueki and Igawa, 1959).

In growth-chamber experiments, Pavlov (1972) found that seed yields were highest with a 14-h photoperiod, compared with "natural" day length and continuous light. In the long photoperiods, or under continuous illumination, pod formation was very rapid even under low temperatures (Blondon, 1975).

Jones (1963) suggested that broad beans which are grown in soil with a low water table during the early growth stage have lower yields than when they are grown under higher water table conditions.

In large fields, i.e. of more than 12 ha, the seed yield is greater in plants near the edge than near the centre of the fields (Free and Williams, 1976).

Delayed sowing causes a decrease in flower cycles and seed yields (Inako et al, 1957; Kondra, 1975; Sugiyama et al, 1949).

Total yields from areas with a dense population of plants were greater than from a sparsely populated area, but showed negative results when compared to individual plants (Evans and Rogalsky, 1974, Fyfe, 1954; Hodgson and Blackman 1956; Ishag, 1973; Kondra, 1975; Silc, 1973; Smith, 1972).

Decapitation increases the proportion of immature to mature pods, but when the upper part of the plant is removed, an increase in pod abscission and number of branches occurs; it also decreases the number of flowers and pods which are produced (Hodgson and Blackman, 1957; Sugiyama et al, 1949).

Drayner (1959) reported that spraying the inflorescences with a certain hormone solution was no more effective than spraying them with water.

Pests and Diseases

Hanec (1975) observed the following beetles on beans in Manitoba: (1) the nuttall blister beetle (Lytta nuttali Say), (2) the black blister beetle (Epicauta pensylvanica (De Geer)), and (3) the ash-grey blister beetle (Macrobasis unicolor (Kirby)). He also observed pea aphids (Acyrthosiphon pisum), and cutworms in fababean fields; they are not serious pests and therefore special control measures are not necessary.

Mtyniec (1962) reported that Bombus terrestris and B. lucorum punctured the bases of the corolla tubes of vetch (Vicia villosa), and that most of the damaged flowers fell off and failed to set pods. In India, the broad bean thrips

(Taeniothrips lefroyi) congregate on flowers, and by feeding inside the corolla tube and on the ovary and stamens, prevent pod formation (Hag, 1961).

Seed yields of broad beans and field beans are reduced more than 50% when they are infected by spotting diseases and virus diseases (Koba, 1966; Schmutteror and Thottappilly, 1972).

Testing For Yields

In field beans, seed yield is positively correlated (to the yield per plant) and the pods per plant. The latter is reported to be the most important component of seed yield (Ibrahim, 1954; Ishag, 1973; Kambal, 1969; Rowland, 1955; Yassin, 1973). The mean seed weight is negatively correlated with pod numbers and seed per pod (Yassin, 1973). Furthermore, Ishag (1973) stated that mean seed weight and seed number per pod were affected little by plant density but were significantly affected by differences in cultivars.

According to Ibrahim (1954) and Rowland (1955), the primary yield components in field beans were number of pods per plant, number of seeds per pod, and seed size. The primary components were influenced by a number of secondary ones e.g. first flowering node, first podding node, number of nodes, plant height, number of branches, etc.

Seed Yields

Seed yield of fababeans is about 2200-7100 kg per ha

(Evans and Rogalsky, 1974; Ishag, 1973; Smith et al, 1967). In field beans and fababeans, there are 2.39 - 3.50 seeds per pod (Evans and Rogalsky, 1974; Free, 1966, 1967; Ishag, 1973), and there are about 10 pods per plant (Free, 1966).

It is recommended that two hives per hectare be used for adequate pollination of field beans and vetches (Alex et al. 1950; Scriven et al, 1961). Experiments by Weaver (1954), indicate that although several colonies per hectare are necessary for maximum pollination of vetch (Vicia villosa), the use of more than two hives per hectare is not considered economical.

Some experiments in Texas (Alex et al, 1950) showed that the seed yield of vetch averaged 224.2 - 448.4 kg/ha even in areas where honey bees were scarce; therefore it seems unnecessary to use honey bees for adequate pollination. Bond and Pope (1974) did not find a noticeable percentage increase in the amount of cross-breeding in winter beans when bee hives were placed in these fields. Honey bees did not seem to increase the percentage of fertile seeds per plant, although the number of pods per plant, and the yield, decreased as the bee population decreased in the fields (Avetisyan et al, 1963).

In this study, the author measured various plant characters and yield components of the four cultivars in open plots at two different sites. This was done to ascertain the total effect of two different environments on the plants

themselves. It should be noted that most of the research reported in this thesis was done at these two sites.

7.2.1.2 Materials and Methods

In 1977 counts of honey bee foragers were made at different times throughout the day during the flowering period in the Latin Square plots at both the U. of M. and Glenlea sites. The author observed that there were about four times as many of positive foragers at the U. of M. site as at the Glenlea site (see Ch. V,5.2.3); this difference was probably due to the fact that many more hives were located at the U. of M. site than at the Glenlea site.

In order to obtain yield data from these same plots, the author selected 100 full grown plants (i.e. when the seed pods were mature) from each cultivar in the Latin Square plots at each site. These plants were dried and the following plant characters and yields were recorded from them:

Plant Characters

Height: measured from ground level to the top of the plant.

Number of inflorescent nodes: number of nodes that contain dry racemes.

Number of flowers: determined by the number of dry pedicels present on the racemes.

Number of flowers per inflorescent node: determined by the number of flowers per plant divided by the number of inflorescent nodes per plant.

Yield Components

Number of pods: determined by the number of mature pods.

Percentage of pod set: determined by the number of pods per plant multiplied by one hundred and divided by the number of flowers per plant.

Number of pods per inflorescent node: determined by the number of mature pods per plant divided by the number of inflorescent nodes per plant.

Number of seeds: determined by the number of mature seeds per plant.

Number of seeds per pod: determined by the number of mature seeds per plant divided by the number of mature pods per plant.

Total weight of seed: weight of mature seeds per plant.

Weight per seed: determined by the weight of the total seeds per plant divided by the number of seeds per plant.

Each of the plant characters and each of the yield components was analysed by a One-Way ANOVA followed by a SNK Multiple Range Test.

7.2.1.3 Results and Discussion

U. of M. Site

Plant Characters

Diana had the shortest plants when the four cultivars were compared ($P<0.01$). Herz Freya produced fewer flowers per plant, fewer inflorescent nodes per plant, and fewer flowers per inflorescent node than did the other three cultivars ($P<0.01$); the reverse was true of Diana.

Yield Components

Erfordia produced significantly more pods per plant than did Herz Freya ($P<0.01$), and significantly more pods per

TABLE LIII

COMPARISON OF PLANT CHARACTERS, YIELD, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS (U. OF M. SITE, 1977)

Site	Characters	Cultivar			
		Ackerperle	Diana	Erfordia	Herz Freya
U. of M.					
	Height (cm)	# A 101.89±1.57	B 88.33±0.96	A 104.65±1.13	A 101.62±1.26
	Flowers/plant	AB 64.93±2.24	A 69.38±2.17	B 61.76±1.98	C 52.03±1.70
	Inflorescent nodes/plant	B 12.42±0.32	A 13.17±0.31	BC 11.94±0.28	C 11.16±0.25
	Flowers/inflorescent node	A 5.14±0.09	A 5.20±0.07	A 5.11±0.08	B 4.59±0.07
	Pods/plant	ABa 9.75±0.51	ABa 10.02±0.89	Aa 10.86±0.59	Bb 8.26±0.39
	% Pod set	ABb 14.86±0.53	Bc 13.13±0.36	Aa 16.90±0.57	Aba 15.74±0.50
	Pods/inflorescent node	B 0.75±0.03	B 0.68±0.02	A 0.88±0.04	B 0.72±0.03
	Seeds/plant	a 30.87±1.69	a 27.61±1.33	a 33.28±1.79	a 28.19±1.46
	Seeds/pod	Bb 3.14±0.05	Bc 2.98±0.05	Bbc 3.08±0.04	Aa 3.37±0.04
	Weight seed/plant (gm)	ABbc 11.37±0.66	Bc 10.77±0.57	Aa 14.66±0.79	ABab 13.13±0.72
	Weight/seed (gm)	D 0.36±0.01	C 0.38±0.01	B 0.44±0.01	A 0.46±0.01

\# Mean and standard error

A, B, C, D, Means followed by different upper case superscripts differ significantly, $P<0.01$.

a, b, c, d, Means followed by different lower case superscripts differ significantly, $P<0.05$.

inflorescent node than did the other three cultivars ($P<0.01$). Diana had a significantly lower percentage pod set than did the other three cultivars ($P<0.01$). There was no significant difference in the number of seeds per plant in the four cultivars; however the number of seeds per pod produced by Herz Freya was significantly higher than in the other three cultivars ($P<0.01$). The total weight of seeds per plant produced by Diana was significantly lower than that of Erfordia or Herz Freya ($P<0.05$). The weight per seed was significantly different in the four cultivars; the heaviest to the lightest was as follows: Herz Freya, Erfordia, Diana, and Ackerperle ($P<0.01$).

Glenlea Site

Plant Characters

Diana had the shortest plants when the four cultivars were compared ($P<0.05$). There were no significant differences in the numbers of flowers per plant or the number of flowers per inflorescent node when the four cultivars were compared. The number of inflorescent nodes per plant in Ackerperle was significantly higher than in the other three cultivars ($P<0.01$).

Yield Components

The number of pods per plant produced by Erfordia was significantly higher than that produced by Diana or Herz Freya. Also the percentage of pod set, the number of pods

TABLE LIV

COMPARISON OF PLANT CHARACTERS, YIELD, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS (GLENLEA SITE, 1977)

Site	Characters	Cultivar			
		Ackerperle	Diana	Erfordia	Herz Freya
Glenlea					
	Height (cm)	# Bb 107.95±0.89	Cc 90.93±1.42	Aa 114.14±1.16	ABb 110.20±0.96
	Flowers/plant	a 93.11±2.43	a 92.75±6.36	a 81.73±2.77	a 87.52±2.68
	Inflorescent nodes/plant	A 15.62±0.33	B 13.90±0.33	B 13.14±0.32	B 13.95±0.30
	Flowers/inflorescent node	a 5.93±0.08	a 6.15±0.10	a 6.14±0.10	a 6.19±0.09
	Pods/plant	ABab 12.25±0.70	Bbc 10.74±0.49	Aa 14.24±0.66	Bc 10.12±0.40
	% Pod set	B 12.46±0.42	B 12.64±0.42	A 17.84±0.66	B 11.73±0.37
	Pods/inflorescent node	B 0.74±0.03	B 0.77±0.03	A 1.09±0.04	B 0.72±0.02
	Seeds/plant	B 36.15±1.89	B 31.67±1.52	A 42.88±2.08	B 33.74±1.38
	Seeds/pod	B 3.06±0.04	B 2.94±0.05	B 3.03±0.04	A 3.33±0.04
	Weight seed/plant (gm)	BCc 14.27±0.75	Cc 12.09±0.64	Aa 20.24±1.05	Bb 16.87±0.71
	Weight/seed (gm)	C 0.40±0.01	D 0.38±0.01	B 0.47±0.01	A 0.50±0.01

Mean and standard error

A, B, C, D, Means followed by different upper case superscripts differ significantly, $P<0.01$.

a, b, c, d, Means followed by different lower case superscripts differ significantly, $P<0.05$.

per inflorescent node, the number of seeds per plant, and the total weight of seeds per plant produced by Erfordia was greater than that produced by the other three cultivars ($P<0.01$). Herz Freya had a significantly greater number of seeds per pod than did the other three cultivars ($P<0.01$). The weight per seed was significantly different in the four cultivars; the highest to the lightest was as follows: Herz freya, Erfordia, Ackerperle, and Diana ($P<0.01$).

In the open plots at both sites, where different environmental conditions prevailed and where there were different numbers of foraging bees, the tallest cultivars (Erfordia) produced higher yields than did the other three cultivars. This occurred despite the fact that Erfordia produced fewer flowers and inflorescent nodes than did the other three cultivars.

7.2.2 Cage Trials

7.2.2.1 Literature Review

Vetches, field beans, or broad beans, caged with bees, produced more seed than when these plants were caged without bees; there was no significant difference in seed yields of plants caged with bees and plants located in open plots (Free, 1966; Pritsch, 1970; Scriven et al, 1961; Watt and Marshall, 1961; Wafa and Ibraham 1960; Weaver, 1954).

Riedal and Wort (1960) found that the number of beans per stem in field beans was significantly less in cages with bees than in open plots; also, there was no significant dif-

ference in beans per stem from plants caged with, and without bees.

Oschman (1957) stated that field bean plants, enclosed in cages to exclude bees, produced as many pods as did plants in open plots.

The presence of bees in cages made no significant difference to the proportion of unformed seeds; plants in cages had 15% of their seed undeveloped whereas plants in the open plots had only 7% (Free, 1966). However, bees assist in pollination and seed production of field beans (Alex, 1950; Brandenburg, 1961; Fyfe and Bailey, 1951; Hue, 1943; Rowlands, 1958; Sirks, 1923; Smaradova et al; Smith et al, 1973, 1974; Voluzueva, 1971; Wafa and Ibrahim, 1960).

The use of cages may affect the plants as well as bee activity, (e.g. plants in cages grow taller and produce more flowers than do plants in open plots). Pollination and bee activity in larger cages was comparable to that occurring under natural conditions, but bee activity in the smaller cages was markedly reduced (Berthelm, 1966). Despite these problems it appears that a better technique has not been devised for conducting these types of pollination studies.

In this chapter the four licenced cultivars were studied in open plots, in caged plots with honey bees, and in caged plots without bees with regard to various plant characters and yield components. This comparative study was done to ascertain if honey bees assist in the pollination of fababeans.

7.2.2.2 Materials and Methods

In 1977, the pollination trials were done on four cultivars at both the U. of M. and the Glenlea sites. Eight nylon mesh cages (3 m wide x 6 m long x 1.8 m high) were placed over the fababean plants at each site (see Fig. I) as follows: two cages were placed on each cultivar, one excluded insect pollinators and the other contained a strong colony in a single chamber. The cages and the colonies were placed on each cultivar at each site, i.e. U. of M., 21 June, early to middle flowering period; Glenlea, 4 July, early flowering period. Each cage contained three small plots, one was 2 m x 2 m for counting bee populations and obtaining yield data, and the other two smaller plots (each 1.5 m x 2 m) were used for nectar experiments (see Ch. IV, 4.2).

All the cages were removed from the plots at the end of the flowering period. Twenty-five full grown plants of each cultivar were selected at random from within the cages and from the open plots (i.e. 2 m x 2m) (See Fig. I). The plants were dried and their plant characters and yields (see Ch. VII, 7.2.1.2) were recorded.

Each of the plant characters and yield components was analysed by a Two-Way ANOVA followed by a SNK Multiple Range Test.

A $\log_{10}(x)$ transformation was required for the analyses as follows: height, number of flowers per plant, number of pods per plant, number of pods per inflorescent

node, number of seeds per plant, and total weight of seeds per plant for both sites; only weight per seed was used for the Glenlea site. A $\log_{10}(x + 1)$ transformation was required for the analyses of the percentage of pod set at both sites.

7.2.2.3 Results and Discussion

U. Of M. Site

The results are shown in Tables LV, LVI, LVII.

Plant Characters

The four cultivars in the cage treatments were significantly taller than those in the open plots ($P<0.01$). The number of vegetative nodes before the inflorescent nodes (Table V), the flowers per plant, the inflorescent nodes per plant and the flowers per inflorescent node did not differ significantly between the three treatments for the four cultivars. However the number of flowers per inflorescent node in the open plots was significantly lower than that in the cages without bees for Diana ($P<0.05$); this was also true of Herz Freya. There was no significant difference in the number of inflorescent nodes per plant when the four cultivars and the three treatments were compared. The number of flowers per plant in Diana was significantly greater than those in the other three cultivars in the open plot and in the cage without bees ($P<0.05$), but this was not true in the cage with bees.

TABLE IV

COMPARISON OF PLANT CHARACTERS, AND YIELD COMPONENTS OF FOUR CULTIVARS OF PABABEANS IN OPEN PLOTS, IN CAGES WITH BEES, AND IN CAGES WITHOUT BEES (U. of M. 1977)

		Cultivar			
Treatment	Characters	Ackerperle	Diana	Erfordia	Herz Freya
Open plot	Height (cm)	74.88±2.88*	78.52±1.90	110.68±1.84	92.28±2.18
	Vegetative nodes before inflorescent nodes	8.08±0.35	6.48±0.36	8.16±0.31	7.52±0.27
	Flowers/plant	55.52±4.74	75.04±4.19	59.28±4.15	55.76±3.90
	Inflorescent nodes/plant	11.72±0.63	14.56±0.52	12.20±0.54	11.36±0.46
	Flowers/inflorescent node	4.57±0.19	5.07±0.15	4.78±0.15	4.83±0.17
	Pods/plant	8.56±1.13	10.80±0.93	10.32±1.13	9.92±0.74
	% Pod set	14.77±0.95	14.21±0.77	16.93±1.20	18.26±1.06
	Pods/inflorescent node	0.68±0.06	0.72±0.04	0.82±0.07	0.86±0.05
	Seeds/plant	24.68±2.90	30.24±3.05	34.44±3.61	30.72±2.23
	Seeds/pod	2.98±0.12	2.78±0.09	3.41±0.09	3.14±0.10
	Weight seed/plant (gm)	9.55±1.22	12.68±1.24	17.86±1.97	13.69±1.15
	Weight/seed (gm)	0.38±0.01	0.42±0.01	0.51±0.01	0.44±0.01
Caged with bees	Height (cm)	103.20±2.38	91.92±1.91	132.92±3.20	129.32±2.39
	Vegetative nodes before inflorescent nodes	8.00±0.32	6.08±0.24	8.32±0.28	7.00±0.29
	Flowers/plant	61.36±4.28	64.48±3.73	55.80±3.06	65.56±4.15
	Inflorescent nodes/plant	12.40±0.63	12.20±0.58	11.92±0.48	12.28±0.51
	Flowers/inflorescent node	4.87±0.14	5.27±0.14	4.62±0.11	5.23±0.16
	Pods/plant	9.72±0.95	7.32±0.55	8.96±0.72	10.72±1.03
	% Pod set	15.83±1.09	11.50±0.58	15.78±0.81	16.22±1.20
	Pods/inflorescent node	0.77±0.06	0.60±0.03	0.73±0.05	0.85±0.06
	Seeds/plant	30.32±3.27	21.84±2.25	28.88±2.27	34.32±3.74
	Seeds/pod	3.03±0.08	2.89±0.12	3.27±0.09	3.15±0.08
	Weight seed/plant (gm)	10.16±1.28	9.43±1.06	14.69±1.36	15.18±1.69
	Weight/seed (gm)	0.32±0.01	0.43±0.01	0.50±0.01	0.44±0.01
Caged without bees	Height (cm)	111.92±1.83	99.64±2.78	125.20±2.74	105.80±2.29
	Vegetative nodes before inflorescent nodes	7.24±0.23	6.28±0.33	8.96±0.35	7.12±0.30
	Flowers/plant	65.80±3.93	77.04±3.71	53.12±3.30	58.48±3.18
	Inflorescent nodes/plant	12.80±0.51	13.52±0.50	11.16±0.45	11.08±0.39
	Flowers/inflorescent node	5.07±0.14	5.67±0.13	4.68±0.15	5.23±0.15
	Pods/plant	8.24±0.87	7.56±0.63	7.32±0.67	7.76±0.53
	% Pod set	12.24±0.91	9.71±0.65	14.05±0.94	13.33±0.63
	Pods/inflorescent node	0.63±0.05	0.56±0.04	0.65±0.04	0.69±0.04
	Seeds/plant	27.12±2.64	22.88±2.03	24.84±2.47	25.12±2.17
	Seeds/pod	3.34±0.10	3.05±0.09	3.37±0.11	3.22±0.09
	Weight seed/plant (gm)	9.57±0.98	9.45±0.97	11.18±1.50	10.75±0.99
	Weight/seed (gm)	0.35±0.02	0.40±0.01	0.43±0.02	0.42±0.01

*Mean and standard error.

TABLE LVI

A STATISTIC COMPARISON OF PLANT CHARACTERS, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS, IN CAGES WITH BEES, AND IN CAGES WITHOUT BEES: I COMPARISON BETWEEN TREATMENT (U. OF M. SITE, 1977)

		Cultivar				
Treatment	Characters	Ackerperle	Diana	Erfordia	Herz Freya	Total
Open plot	Height	C	Bc	Bc	C	Bc
	No. vegetative nodes before inflorescent nodes	a	a	a	a	a
	Flowers/plant	a	a	a	a	a
	Inflorescent nodes/plant	a	a	a	a	a
	Flowers/inflorescent node	a	b	a	b	B
	Pods/plant	a	a	a	a	A
	% Podset	a	Aa	a	a	Aa
	Pods/inflorescent node	a	a	a	a	Aa
	Seeds/plant	a	a	a	a	a
	Seeds/pod	b	a	a	a	b
	Weight seed/plant (gm)	a	a	a	a	A
	Weight seed (gm)	Aa	a	A	a	A
Caged with bees	Height	B	Ab	Aa	A	Aa
	No. vegetative nodes before inflorescent nodes	a	a	a	a	a
	Flowers/plant	a	a	a	a	a
	Inflorescent nodes/plant	a	a	a	a	a
	Flowers/inflorescent node	a	ab	a	ab	AB
	Pods/plant	a	b	a	a	A
	% Podset	a	ABb	a	ab	AB
	Pods/inflorescent node	a	ab	a	a	ABa
	Seeds/plant	a	b	a	a	ab
	Seeds/pod	b	a	a	a	b
	Weight seed/plant (gm)	a	a	b	a	A
	Weight seed (gm)	Bc	a	A	a	B
Caged without bees	Height	A	Aa	Ab	B	Ab
	No. vegetative nodes before inflorescent nodes	a	a	a	a	a
	Flowers/plant	a	a	a	a	a
	Inflorescent nodes/plant	a	a	a	a	a
	Flowers/inflorescent node	a	a	a	a	A
	Pods/plant	a	b	a	a	B
	% Podset	b	Bc	a	b	Bc
	Pods/inflorescent node	a	b	a	a	Bb
	Seeds/plant	a	b	a	a	b
	Seeds/pod	a	a	a	a	a
	Weight seed/plant (gm)	a	a	b	a	B
	Weight seed (gm)	ABb	a	B	a	C

TABLE LVII

A STATISTICAL COMPARISON OF PLANT CHARACTERS, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS, IN CAGES WITH BEES, AND IN CAGES WITHOUT BEES: II COMPARISON BETWEEN CULTIVARS (U. OF M. SITE, 1977).

		Cultivars			
Treatment	Characters	Ackerperle	Diana	Erfordia	Herz Freya
Open plot	Height	C	C	B	A
	No. vegetative nodes before inflorescent nodes	Aa	Bb	Aa	ABa
	Flowers/plant	Bb	Aa	ABb	Bb
	Inflorescent nodes/plant	a	a	a	a
	Flowers/inflorescent node	a	a	a	a
	Pods/plant	a	a	a	a
	% Podset	a	a	a	a
	Pods/inflorescent node	b	ab	ab	a
	Seeds/plant	b	ab	a	a
	Seeds/pod	ABbc	Bc	Aa	ABab
	Weight seed/plant (gm)	Bb	ABa	Aa	ABa
	Weight seed (gm)	C	B	A	B
Caged with bees	Height	B	C	A	A
	No. vegetative nodes before inflorescent nodes	Aa	Bc	Aa	ABb
	Flowers/plant	a	a	a	a
	Inflorescent nodes/plant	a	a	a	a
	Flowers/inflorescent node	ab	a	b	a
	% Podset	a	b	a	a
	Pods/inflorescent node	ab	b	a	a
	Seeds/plant	a	b	ab	a
	Seeds/pod	a	a	a	a
	Weight seed/plant (gm)	b	b	a	a
	Weight seed (gm)	C	B	A	AB
Caged without bees	Height	Bb	Cd	Aa	BCc
	No. vegetative nodes before inflorescent nodes	B	B	A	B
	Flowers/plant	ABab	Aa	Bb	ABb
	Inflorescent nodes/plant	a	a	a	a
	Flowers/inflorescent node	Bbc	Aa	Bc	ABb
	Pods/plant	a	a	a	a
	% Podset	ABa	Bb	Aa	Aa
	Pods/inflorescent node	ab	b	ab	a
	Seeds/plant	a	a	a	a
	Seeds/pod	a	a	a	a
	Weight seed/plant (gm)	a	a	a	a
	Weight seed (gm)	B	A	A	A

Yield Components

Ackerperle showed no significant differences in the number of pods per plant, the pods per inflorescent node, the seeds per plant, or the total weight of seeds per plant when the three treatments were compared. However the percentage of pod set in the cage without bees was significantly lower than that in the open plot or in the cage with bees ($P<0.05$). The number of seeds per pod was significantly greater in the cage without bees than in the open plot or in the cage with bees. The weight per seed was significantly lighter in the cage with bees than in the open plots or the cage without bees ($P<0.05$).

Diana showed no significant differences in the number of seeds per pod, the total weight of seeds per plant, and the weight per seed when the three treatments were compared but there was a significantly greater number of pods per plant and percentage of pod set in the open plot than in either of the cage treatments ($P<0.05$). The number of seeds per plant was significantly higher in the open plot than in the cage with, or without, bees ($P<0.05$).

Erfordia showed no significant difference in the number of pods per plant, the percentage of pod set, the number of pods per inflorescent node, the seeds per plant, the seeds per pod between the three treatments. However, the total weight of seeds per plant was significantly heavier in the open plot than in the cages without bees ($P<0.05$),

and the weight per seed in the open plot and in the cage with bees was significantly heavier than in the cage without bees ($P<0.01$).

Herz Freya showed no significant differences in the number of pods per plant, the pods per inflorescent node, the seeds per plant, the seeds per pod, the total weight of seeds per plant and the weight per seed when the three treatments were compared; however the percentage of pod set in the open plot was significantly higher than in the cage without bees ($P<0.05$).

When the three treatments, for each cultivar, were compared at the U. of M. site (see Table LVI) there was a non-significant tendency for the open plots to show the highest yields and the cages without bees to show the lowest yields. However when the data for the four cultivars were combined the results were as follows: the number of pods per inflorescent node and the number of seeds per plant were significantly greater in the open plots than in the cages with, or without, bees ($P<0.05$). The number of pods per plant, the percentage of pod set, the total weight of seeds per plant, and the weight per seed were significantly greater in the open plot and the cages with bees than in the cages without bees ($P<0.01$).

Glenlea Site

The results are shown in Tables LVIII, LIX, and LX.

Plant Characters

The four cultivars were significantly taller in the

TABLE LVIII

COMPARISON OF PLANT CHARACTERS, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS, IN CAGES WITH BEES, AND IN CAGES WITHOUT BEES (GLENLEA SITE, 1977)

Treatment	Characters	Cultivar			
		Ackerperle	Diana	Erfordia	Herz Freya
Open plot	Height	113.76±1.49*	90.80±1.37	110.48±1.47	123.88±2.58
	No. vegetative nodes before inflorescent nodes	9.12±0.34	7.08±0.18	9.96±0.28	8.32±0.28
	Flowers/plant	98.08±5.61	88.04±3.97	75.24±3.36	94.04±6.40
	Inflorescent nodes/plant	15.16±0.63	15.12±0.53	13.84±0.46	14.60±0.67
	Flowers/inflorescent node	6.42±0.21	5.81±0.16	5.42±0.13	6.38±0.23
	Pods/plant	11.64±1.06	12.44±0.99	9.92±0.77	15.04±1.24
	% Podset	11.72±0.66	14.13±0.92	13.46±1.03	16.54±1.22
	Pods/inflorescent node	0.75±0.05	0.82±0.05	0.73±0.06	1.02±0.07
	Seeds/plant	37.04±3.35	39.76±3.03	33.72±2.82	47.60±4.57
	Seeds/pod	3.19±0.08	3.23±0.07	3.38±0.07	3.15±0.08
	Weight seed/plant (gm)	15.36±1.40	16.10±1.34	17.61±1.55	21.51±2.09
	Weight/seed (gm)	0.41±0.01	0.40±0.01	0.52±0.01	0.44±0.01
Caged with bees	Height	120.84±2.73	90.64±1.81	120.36±1.95	125.80±2.99
	No. vegetative nodes before inflorescent nodes	8.96±0.23	7.56±0.29	10.40±0.28	8.24±0.26
	Flowers/plant	77.96±4.21	60.96±3.88	59.96±2.99	79.40±4.32
	Inflorescent nodes/plant	15.12±0.59	11.48±0.61	11.40±0.44	13.00±0.54
	Flowers/inflorescent node	5.13±0.17	5.25±0.15	5.22±0.13	6.07±0.17
	Pods/plant	11.48±1.22	7.16±0.49	8.36±0.66	14.80±1.32
	% Podset	14.51±0.97	12.87±1.09	14.28±1.06	18.47±1.14
	Pods/inflorescent node	0.74±0.06	0.06±0.05	0.74±0.05	1.12±0.07
	Seeds/plant	32.68±4.38	23.28±1.98	25.04±2.15	45.12±4.29
	Seeds/pod	2.71±0.12	3.22±0.11	2.99±0.08	3.02±0.08
	Weight seed/plant (gm)	11.36±1.67	8.58±0.66	13.02±1.06	21.89±2.05
	Weight/seed (gm)	0.34±0.01	0.37±0.01	0.52±0.02	0.49±0.01
Caged without bees	Height	130.56±2.62	127.00±2.28	120.92±2.03	136.28±3.30
	No. vegetative nodes Before inflorescent nodes	9.04±0.27	8.04±0.33	10.08±0.29	8.68±0.35
	Flowers/plant	85.00±4.23	101.72±4.41	63.60±3.01	75.32±5.57
	Inflorescent nodes/plant	15.48±0.51	16.76±0.64	11.44±0.44	12.68±0.76
	Flowers/inflorescent node	5.47±0.18	6.07±0.13	5.58±0.18	5.89±0.21
	Pods/plant	10.56±0.78	7.92±0.57	4.80±0.47	10.24±1.13
	% Podset	12.70±0.94	7.91±0.55	7.45±0.58	13.53±1.07
	Pods/inflorescent node	0.68±0.05	0.48±0.04	0.43±0.04	0.80±0.07
	Seeds/plant	28.24±2.54	22.96±1.94	14.80±1.67	30.08±3.47
	Seeds/pod	2.64±0.10	2.89±0.11	3.02±0.15	2.94±0.10
	Weight seed/plant (gm)	10.91±1.13	10.21±0.96	7.52±0.86	14.06±1.56
	Weight/seed (gm)	0.38±0.01	0.44±0.01	0.51±0.01	0.47±0.01

*Mean and standard error.

TABLE LIX

A STATISTICAL COMPARISON OF PLANT CHARACTERS, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS, IN CAGES WITH BEES, AND IN CAGES WITHOUT BEES: I COMPARISON BETWEEN TREATMENTS (GLENLEA SITE, 1977)

		Cultivar				
Treatment	Characters	Ackerperle	Diana	Erfordia	Herz Freya	Total
Open plot	Height	Bc	B	B	B	Bc
	No. vegetative nodes before inflorescent nodes	a	a	a	a	a
	Flowers/plant	a	A	Aa	a	A
	Inflorescent nodes/plant	a	A	a	a	A
	Flowers/inflorescent node	A	ABa	a	a	Aa
	Pods/plant	a	A	A	A	A
	% Podset	a	Aa	A	ABa	A
	Pods/inflorescent node	a	Aa	A	A	A
	Seeds/plant	a	A	Aa	A	A
	Seeds/pod	A	A	a	a	A
	Weight seed/plant (gm)	A	A	Aa	A	A
	Weight seed (gm)	a	a	a	a	a
Caged with bees	Height	Bb	B	A	B	Bb
	No. Vegetative nodes before inflorescent nodes	a	a	a	a	a
	Flowers/plant	a	B	Ab	a	C
	Inflorescent nodes/plant	a	B	b	a	B
	Flowers/inflorescent node	B	Bb	a	a	Bc
	Pods/plant	a	B	A	A	B
	% Podset	a	Ab	A	Aa	A
	Pods/inflorescent node	a	Ab	A	A	A
	Seeds/plant	a	B	Ab	A	B
	Seeds/pod	B	A	b	a	B
	Weight seed/plant (gm)	B	B	Ab	A	B
	Weight seed (gm)	a	a	a	a	a
Caged without bees	Height	Aa	A	A	A	Aa
	No. vegetative nodes before inflorescent nodes	a	a	a	a	a
	Flowers/plant	a	A	Aab	a	B
	Inflorescent nodes/plant	a	A	b	a	A
	Flowers/inflorescent node	B	Aa	a	a	ABb
	Pods/plant	a	B	B	B	C
	% Podset	a	Bc	B	Bb	B
	Pods/inflorescent node	a	Bc	B	B	B
	Seeds/plant	a	B	Bc	B	C
	Seeds/pod	B	B	b	a	B
	Weight seed/plant (gm)	B	B	Bc	B	C
	Weight seed (gm)	a	a	a	a	a

TABLE LX

A STATISTICAL COMPARISON OF PLANT CHARACTERS, AND YIELD COMPONENTS OF FOUR CULTIVARS OF FABABEANS IN OPEN PLOTS, IN CAGES WITH BEES, AND IN CAGES WITHOUT BEES: II COMPARISON BETWEEN CULTIVARS (GLENLEA SITE, 1977)

Treatment	Characters	Cultivars			
		Ackerperle	Diana	Erfordia	Herz Freya
Open plot	Height	Bb	Cd	Bc	Aa
	No. vegetative nodes before inflorescent nodes	ABb	Cc	Aa	Bb
	Flowers/plant	a	a	a	a
	Inflorescent nodes/plant	a	a	a	a
	Flowers/inflorescent node	Aa	ABb	Bb	Aa
	Pods/plant	ab	ab	a	b
	% Podset	B	AB	AB	A
	Pods/inflorescent node	Bb	ABb	Bb	Aa
	Seeds/plant	a	a	a	a
	Seeds/pod	a	a	a	a
	Weight seed/plant (gm)	a	a	a	a
	Weight/seed (gm)	a	a	a	a
Cages with bees	Height	A	B	A	A
	No. Vegetative nodes before inflorescent nodes	B	C	A	BC
	Flowers/plant	a	b	b	a
	Inflorescent nodes/plant	Aa	Bb	Bb	ABb
	Flowers/inflorescent node	B	B	B	A
	Pods/plant	ABb	Cc	BCc	Aa
	% Podset	ABb	Bb	ABb	Aa
	Pods/inflorescent node	B	B	B	A
	Seeds/plant	B	B	B	A
	Seeds/pod	Bb	Aa	ABa	ABab
	Weight seed/plant (gm)	BC	C	B	A
	Weight/seed (gm)	Bb	ABb	Aa	ABa
Caged without bees	Height	ABb	Bb	Bc	Aa
	No. vegetative nodes before inflorescent nodes	ABb	Bb	Aa	Bbc
	Flowers/plant	ABab	Aa	Bc	Bbc
	Inflorescent nodes/plant	A	A	B	B
	Flowers/inflorescent node	a	a	a	a
	Pods/plant	A	A	B	A
	% Podset	A	B	B	A
	Pods/inflorescent node	A	B	B	A
	Seeds/plant	A	A	B	A
	Seeds/pod	b	ab	a	ab
	Weight seed/plant (gm)	A	A	B	A
	Weight/seed (gm)	b	ab	a	ab

cages without bees than in the open plots or in the cages with bees ($P<0.01$); however Erfordia showed no difference in height in cages with, or without bees. There was no significant difference in the number of vegetative nodes (Table V) occurring before the inflorescent nodes between the three treatments for the four cultivars. There were no significant differences in the number of flowers per plant and the number of inflorescent nodes per plant when the three treatments were compared for Ackerperle; this was also true of Herz Freya. Diana had significantly fewer flowers per plant, and inflorescent nodes per plant in the cage with bees than in the open plot or the cage without bees ($P<0.01$). Erfordia had a significantly greater number of flowers per plant, and inflorescent nodes per plant, in the open plot than in the cage with, or without, bees. There was no significant difference in the number of flowers per inflorescent node when the three treatments were compared for Erfordia; this was also true of Herz Freya. Ackerperle had a significantly greater number of flowers per inflorescent node in the open plot than in the cage with, or without, bees ($P<0.01$).

Yield Components

Ackerperle showed no significant differences in number of pods per plant, pods per inflorescent node, seeds per plant, percentage of pod set, and weight per seed when the three treatments were compared. However, there was a significantly greater number of seeds per pod and total weight of seeds per plant in the open plot than in the cages

with, or without, bees.

Diana showed no significant difference in weight per seed when the three treatments were compared. There was a significantly greater number of pods per plant ($P<0.01$), pods per inflorescent node ($P<0.05$), seeds per plant ($P<0.01$), percentage of pod set ($P<0.05$), and total weight of seeds per plant ($P<0.01$) in the open plot than in the cages with, or without, bees. Also the percentage of pod set and the number of pods per inflorescent node in the cage with bees was significantly greater than in the cage without bees ($P<0.05$). However there was no significant difference in the number of pods per plant, the seeds per plant, and the total weight of seeds per plant in the cage with bees and without bees. The number of seeds per pod was significantly greater in the open plot and in the cage with bees than in the cage without bees ($P<0.01$).

Erfordia showed no significant difference in weight per seed when the three treatments were compared. There was a significant difference in the number of seeds per pod in the open plot than in the cage with, or without bees ($P<0.05$). There was a significant difference in the number of pods per plant, the pods per inflorescent node, the seeds per plant, percentage of pod set, and the total weight of seeds per plant in the open plot and in the cage with bees than in the cage without bees ($P<0.01$). Also the number of seeds per plant, seeds per pod, and total weight of seeds per plant in the cage with bees was significantly higher

than in the cage without bees ($P < 0.05$).

Herz Freya showed no significant differences in number of seeds per pods, or weight per seed when the three treatments were compared; also there were no significant differences in the number of pods per plant, pods per inflorescent node, seeds per plant, percentage of pod set, and the total weight of seeds per plant when the open plot and the cage with bees were compared. There was a significantly greater number of pods per plant ($P < 0.01$), pods per inflorescent node ($P < 0.01$), seeds per plant ($P < 0.01$), percentage of pod set ($P < 0.05$), and total weight of seeds per plant ($P < 0.01$) in the open plot and in the cage with bees than in the cage without bees.

When the yield component data of the four cultivars were combined the following were observed (Table LIX). There was no significant difference, in weight per seed, between the three treatments. There were no significant differences in numbers of seeds per pod obtained in cages with and without bees or in percentage of pod set and number of pods per inflorescent node in open plots and in cages with bees. There was a significantly greater number of pods per plant, seeds per plant, seeds per pod, and total weight of seeds per plant in the open plots than in the cages with and without bees ($P < 0.01$). Also, the number of pods per plant and the total weight of seeds per plant in cages with bees were significantly greater than in cages without bees ($P < 0.01$). The percentage of pod set and the number of pods per inflorescent

node in the open plots and in the cages with bees were significantly greater than the cages without bees ($P<0.01$).

The maximum number of foraging bees in each of the 2m x 2m plots within the cages was about 20-30 bees.

There was no significant difference in the number of seeds per plant, seeds per pod, total weight of seeds per plant and weight per seed in the four cultivars in the open plots. All things considered, Herz Freya showed a tendency in the open plots and in the cages without bees to produce the best yields. In the cage with bees Herz Freya also had the highest yield when compared to the other three cultivars ($P<0.01$), but in cages without bees there was no significant difference in all yield components when Herz Freya was compared to Ackerperle or Diana. However Herz Freya had a significantly greater percentage of pod set and number of pods per inflorescent node than did Diana ($P<0.01$). Erfordia had significantly lower yields in the cages without bees than did the other three cultivars (Table LX).

The above results show that Ackerperle and Herz Freya are probably autofertile or that a large number of plants of these cultivars are hybrids. It would appear that Ackerperle does not require insect pollination to the same extent as does Herz Freya. However the yields of Diana decreased in the cage treatments, when compared to the yields obtained in the open plots. Only Erfordia seems to be autosterile, or else a large number of the plants are inbred and therefore bees are required to increase yields;

however when bees are present this cultivar can produce yields equal to the other three cultivars. Thus it appears that bees improve the yields of all four cultivars.

It seems that when bees were present in the open plots or in the cages at the U. of M. site the yields were not increased compared with yields of plants in cages without bees. This is probably because it was not possible, due to inclement weather, to put the screen cages over the experimental plots until close to the middle of the flowering period (i.e. 21 June, see Ch. III, 3.2). By this time most of the lower flowers would have been pollinated under open field conditions. Riedal and Wort (1960) found also that pod set occurs mainly on this part of the field bean plants, which might partially explain why no differences, in pod set, occurred in the above trials.

Yields in open plots and in cages with bees, at the Glenlea site were higher than in cages without bees, partly because the cages were placed over the experimental plots at the correct time, i.e. in the early flowering period (4 July). Unfortunately, a strong wind damaged the cages so that the plots remained uncovered between 13-19 July while the cages were being repaired. Interestingly enough this appeared to have little effect on the seed yields, presumably because the storm occurred late in the flowering period.

In conclusion one can state that some authors believe that honey bees increase seed production (Fyfe and Bailey, 1951; Hua, 1943; Rowlands, 1958; Sirks, 1923) while other authors (Free, 1966; Oschman, 1957; Riedal and Wort, 1960; Scriven et al, 1961; Watt and Marshall, 1961) believe that honey bees are of little or no use in the production of seed in field beans. My results show that honey bees do increase seed production in fababeans but that the extent of the increase depends on the cultivar grown.

Although the bees did increase seed production in certain cultivars it is unlikely that they had any effect on such plant characters as height, total number of flowers, number of inflorescent nodes or number of flowers per inflorescent node.

CHAPTER VIII

SUMMARY

8.1 Chapter III: Plant and Floral Growth Studies

3.1 Plant Growth Studies

1) In 1976, the height and growth rate of Ackerperle were higher at the U. of M. site than at the Glenlea site; its maximum growth rate occurred 67-71 days after seeding.

2) In 1976, the height and growth rate of Herz Freya were higher than that of Ackerperle and Diana at the Glenlea site; the highest growth rate of the latter two cultivars occurred 77-92 days after seeding, and 71-77 days after seeding for Herz Freya.

3) In 1977, Diana had the slowest growth rate and was shorter than all of the other cultivars at both sites; Ackerperle was next, followed by Herz Freya. Erfordia was the tallest cultivar and had the highest growth rate.

4) In 1977, the plants grown at the Glenlea site were usually taller and had a higher growth rate than those at the U. of M. site.

5) In 1977, the highest growth rate among the four cultivars occurred 61-71 days after seeding at the U. of M. site, but at the Glenlea site, the highest growth rate occurred 30-60 days after seeding.

3.2 Flowering Periods

1) In 1976, the flowering period was about 23 days at the U. of M. site, and about 40 days at the Glenlea site.
2) In 1977, the flowering period was about 37 days at the U. of M. site, and about 33 days at the Glenlea site.

3.3 Floral Development

1) It took 3.5-6.5 days for the buds to develop to the bloom stage depending on their position on the raceme; the lowest buds developed faster than the upper ones.
2) Each flower opened for 2-6 consecutive days and closed each night.
3) The new bloom stage usually occurred in the late afternoon, while the old bloom stage occurred during the morning and afternoon.

8.2 Chapter IV: Floral Attractant Studies

4.1.1 Floral Number

1) The total number of fababean flowers of the four cultivars reached their maximum between 1900-2100 h.
2) At the U. of M. site, the number of full blooms on Ackerperle plants which were 70 ± 5 or 90 ± 5 cm high was greater than on plants which were 30 ± 5 or 50 ± 5 cm high. Ackerperle plants which were 50 ± 5 cm high had more flowers than did plants which were 30 ± 5 cm high.

3) Floral production of the four cultivars was higher at the Glenlea site than at the U. of M. site.

4) At both sites, the cultivar Ackerperle and Diana produced more inflorescent nodes per plant than did Erfordia and Herz Freya.

5) Herz Freya had fewer flowers per plant and flowers per inflorescent node than did the other three cultivars at the U. of M. site but there were no differences in the four cultivars at the Glenlea site.

6) The number of flowers was greatest from the inflorescent nodes near the middle, and from the nodes below the middle of the plants.

4.1.2 Floral Colour

1) Flowers of Ackerperle were pure white in colour, while flowers of Diana had white standard petals with black veins and corolla tubes with purple pigments. Flowers of Erfordia had purple pigments on the standard petals and corolla tubes. Flowers of Herz Freya varied greatly in colour with some having purple pigments on the standard petals and corolla tubes.

4.1.3 Size of Flowers

1) The corolla tubes and the standard petals of Diana were longer than those of the other three cultivars.

2) The pistil tubes, keels, wing petals, and standard petals of Ackerperle were shorter than those of the other three

cultivars. The ratio of keel length to pistil length of Erfordia was higher than that of the other three cultivars. 3) The largest flowers occurred in the cultivar Diana, while the smallest ones occurred in Ackerperle; Erfordia and Herz Freya were similar in size.

4.1.4 Perfume

1) Full blooms gave the strongest scent when compared to white buds, early blooms, or old full blooms.
2) The strongest scent in the fababean fields occurred between 1600-1800 h when the greatest number of full blooms occurred.

4.2.1 Nectar from Fababean Plants

1) The amount and sugar concentration of the nectar produced by fababean plants during the early or middle flowering period were greater than in the late flowering period.
2) In the open plots, the amount and sugar concentration of nectar from the floral nectaries were higher than that from the extrafloral nectaries.
3) The amount of nectar was highest in the early morning but was lowest in sugar concentration at that time; in the late afternoon there was less nectar but it was higher in sugar concentration.
4) Diana produced a large amount of nectar which had a low sugar concentration, while Erfordia produced a small amount of nectar which had a high sugar concentration. Ackerperle

and Herz Freya produced an amount of nectar in between that of Diana and Erfordia; the sugar concentration of this nectar was also between the two groups. Herz Freya produced large amounts of nectar but the sugar concentration was similar to that of Ackerperle.

5) There was no difference in sugar concentration of floral nectar produced from plants in the open plots or in the cages, but a higher sugar concentration was collected from the extrafloral nectaries of plants in the cages, than in the open plots.

4.2.2 Sugar Concentration in the Honey Sacs

1) At the U. of M. site, the sugar concentration of the nectar in the sacs of the positive foragers was generally between 50-60%, while at the Glenlea site it was 45-57%.

2) At the U. of M. site, the sugar concentration of nectar in the sacs of the extrafloral nectar foragers was between 20-30%, while at the Glenlea site it was 13-27%.

4.3.1 Dehiscence

1) The buds of Ackerperle (which were the smallest) dehisced earlier than did those of Erfordia and Herz Freya; Diana (which had the longest buds) dehisced later than did the other cultivars.

4.3.2 Number of Pollen Grains per Flower

1) Diana had a greater number of pollen grains per bud than did Ackerperle, Erfordia, or Herz Freya; there was no difference in the number of pollen grains in the latter three cultivars.

2) The number of pollen grains per bud in fababeans was highest at the inflorescent nodes located at the middle of the stem, and lowest at the inflorescent nodes at the top of the stem.

4.3.3 Number of Pollen Grains on Various Bee Body Parts

1) The number of pollen grains counted on the various parts of the bee's body, arranged from the largest to the lowest number, were as follows: third pair of legs, head, thorax, second pair of legs, abdomen, first pair of legs.

4.3.4 Pollen Traps

1) The largest amount of fababean pollen was found in the pollen traps between 1800-2200 h. The bees collected fababean pollen at the Glenlea site earlier than at the U. of M. site.

2) The total weight of pollen, and the weight of a single pollen pellet was lower at the U. of M. site than at the Glenlea site; this was also true of the pellet size.

3) The main pollen species which were collected by the bees were Brassica spp. and Trifolium spp.; these were found in the traps around noon or early afternoon.

8.3 Chapter V: Studies of Honey Bees on Fababeans

5.1 Activities of Honey Bees on Fababeans

1) Usually the honey bee foragers made one type of visit to fababeans during a given trip(s).

2) The positive nectar and pollen foragers visited 1.7-2.0 flowers per plant, spent 11.3-13.1 sec. per flower visit, and moved about 69-142 cm per min. They preferred to visit flowers in the full bloom stage more than they did the other types of flower.

3) The extrafloral nectar foragers visited 3.1-4.6 stipules per plant, spent 2.8-4.8 sec. per stipule, and moved about 70-143 cm per min. They preferred to visit the extrafloral nectaries at the top of the plant.

5.2 Honey Bee Populations

1) Positive foragers were most numerous between 1700 and 1900 h, while the extrafloral nectar foragers were most numerous in the morning and early afternoon.

2) Foragers, in every category, were most numerous during the early and middle flowering period than during the late flowering period.

3) Less than 1% of the foragers, found in the experimental fields, were negative floral foragers while 83% were positive foragers, and 16% were extrafloral nectar foragers.

4) Positive foragers visited Ackerperle more than they did the other cultivars. A lower number of positive foragers

with pollen loads were observed visiting Erfordia than the other three cultivars, while the highest number of extra-floral nectar foragers were observed on the former cultivar than on the three latter ones.

5) A lower number of negative floral foragers (as well as number of perforated flowers) were observed on Diana than on the other three cultivars, while the highest number of this type of forager was observed on Herz Freya.

8.4 Chapter VI: Other Insects on Fababeans

6.1 Survey of Possible Insect Pollinators

1) Other than honey bees, the main insect pollinators of fababeans were bumble bees; Bombus borealis was a positive forager while B. terricola was a negative forager.

2) Both types of visits by bumble bees occurred between 1600-2000 h in the fababean fields.

3) Negative bumble bees were not observed during the late flowering period at the U. of M. site, and none were observed during the two days of observation at the Glenlea site.

8.5 Chapter VII: Pollination Trials

7.1 Number of Ovules

1) There was no difference in the number of ovules per ovary from plants of the same cultivar grown in the open plots or in the caged plots, but there was a difference in the number of ovules per ovary when plants of the same cultivar were grown at different sites or in different years.
2) Fewer ovules per ovary were produced from flowers during the late flowering period than during the early or mid flowering period.
3) Generally, fababean plants produced ovaries containing about four ovules.
4) Diana produced more ovules per ovary than did the other three cultivars.

7.2.1 Open Plot Trials

In the open plots at the U. of M. and Glenlea sites, Erfordia which had the tallest plants, produced fewer flowers and had the highest yields when the four cultivars were compared. Ackerperle and Diana had high numbers of flowers and inflorescent nodes per plant but did not produce higher yields than the other cultivars. Herz Freya had low numbers of flowers and inflorescent nodes per plant and produced the largest and heaviest seeds as well as the largest number of seeds per pod; the total weight of seeds

per plant was lower than that of Erfordia but higher than that of Ackerperle and Diana.

7.2.2 Cage Trials

1) At the U. of M. site, there was a greater number of pods per inflorescent node, and seeds per plant in the open plots than in the cages with or without bees. There was a greater number of pods per plant, percentage of pod set, total weight of seeds per plant, and weight per seed in the open plots and in the cages with bees than in the cages without bees.
2) At the Glenlea site, there was a greater number of pods per plant, seeds per plant, seeds per pod, and total weight of seeds per plant in the open plots than in the cages with, or without bees. There was a greater number of pods per plant, greater total weight, and more seeds per plant in cages with bees than in cages without bees.
3) At the Glenlea site, Herz Freya had the highest yields of all the cultivars regardless of the open plot, the cage with bees, and the cage without bees.
4) Ackerperle had similar yields whether bees were present or absent. Yields of Diana decreased when plants were covered with cages, and there appeared to be no difference in yield whether bees were present or absent. Erfordia appeared to require bees for pollination, Herz Freya did not require bees to pollinate flowers but when bees were available, the yields of this cultivar increased.

8.6 General Conclusions

High numbers of positive honey bee foragers were observed during the early and middle flowering period. This was probably because there were high numbers of full blooms present, large amounts of nectar which was high in sugar concentration available, and pollen in large amounts.

Positive honey bees foraged on fababeans in high numbers from late afternoon to early evening. This was probably because there were large numbers of new full blooms present at this time; the bees appeared to prefer these blooms because they produced a strong scent and had large amounts of pollen present. In the late afternoon, nectar was also available which was high in sugar concentration.

Positive honey bee foragers visited Ackerperle more than they did Diana or Herz Freya. Erfordia was visited by fewer bees than any of the other cultivars.

Ackerperle had the following plant characters: a) the flowers were white in colour, b) the flowers were small and probably easily tripped by the bees, c) flowers were produced in high numbers per plant, d) low numbers of full blooms were produced per day, e) the flowers produced moderate amounts of nectar with a medium sugar concentration. Cage experiments showed that plants of Ackerperle were partially autofertile and very attractive to bees.

Diana had the following plant characters: a) the flowers were white in colour with black nectar guides,

b) the flowers were large, and were probably difficult for the bees to trip, c) the flowers were produced in high numbers per plant, d) there were moderate numbers of full blooms per day e) the flowers produced high amounts of nectar with low sugar concentration. Of interest is that Diana produced large amounts of pollen and high numbers of ovules per ovary.

Erfordia had the following plant characters: a) the flowers were white with red or purple pigments, b) the flowers were medium in size, c) flowers were produced in low numbers per plant, d) low number of full blooms were produced per day. The cage experiments showed that the plants of Erfordia were partially autosterile.

Herz Freya had the following characters: a) the flowers showed a wide variation in colour, b) the flowers were medium in size, c) flowers were produced in low numbers per plant, d) high numbers of full blooms were produced per day, e) the flowers produced moderate amounts of nectar with a medium sugar concentration.

There was no difference in the foraging time, foraging distance, or number of plants visited by positive honey bee foragers when the four cultivars were compared.

Honey bees were good pollinators of fababeans because: a) they carried large numbers of pollen grains on their bodies, especially on their heads and first pairs of legs, b) the bees moved frequently and quickly from plant to plant, and covered a wide area, c) a high percentage of the bees were positive foragers, (i.e. this means that more

flowers were tripped and hence pollinated), d) the honey bees visited both early blooms and full blooms and carried a large number of viable pollen grains with which to pollinate flowers, e) the honey bees collected nectar and pollen from fababeans in the evening when there was little or no competition from other crops.

Pollination trials showed that Ackerperle had similar yields whether bees were present or absent. Cage experiments showed that for Diana there were no differences in yields when bees were present or absent. Seed yields of Erfordia were very low when bees were absent. Herz Freya did not appear to require bees for pollination but when bees were present, the yields increased.

High numbers of extrafloral nectar foragers were observed during the early and middle flowering period. This is probably because there were many active nectaries in the stipules during this period; these produced large amounts of nectar which was high in sugar concentration.

Extrafloral nectar foragers were high in number during the morning and the early afternoon, probably because large amounts of nectar occurred in the extrafloral nectaries, at this time, which was high in sugar concentration. The bees preferred to visit the extrafloral nectaries at the top of the plants, probably for the same reasons outlined above.

Extrafloral nectar foragers tended to visit Erfordia more than the other cultivars; the nectar secreted from the

extrafloral nectaries of Erfordia was highest in sugar concentration and lowest in amount, when the four cultivars were compared.

Negative honey bee foragers were also high in numbers during the early and middle flowering period. It appears that certain environmental conditions (e.g. inclement weather) caused the bees to become negative foragers.

Negative honey bee and bumble bee foragers were observed on Ackerperle, Erfordia and Herz Freya but not on Diana, despite the fact that the flowers of Diana were large and difficult to trip. The negative bees appeared to have difficulty biting through the thick corolla tubes of Diana which resulted in Diana having fewer perforated flowers than the other cultivars.

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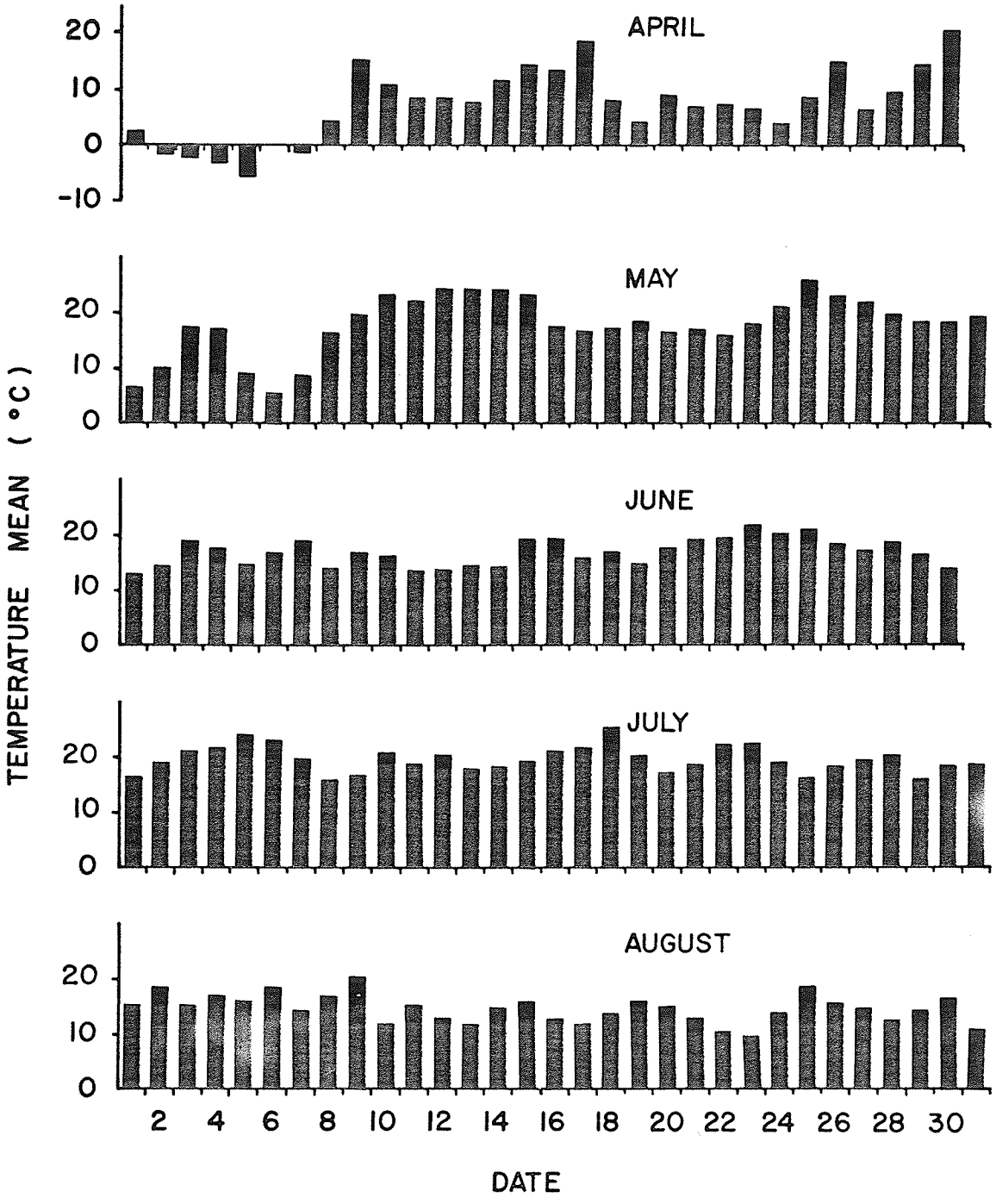
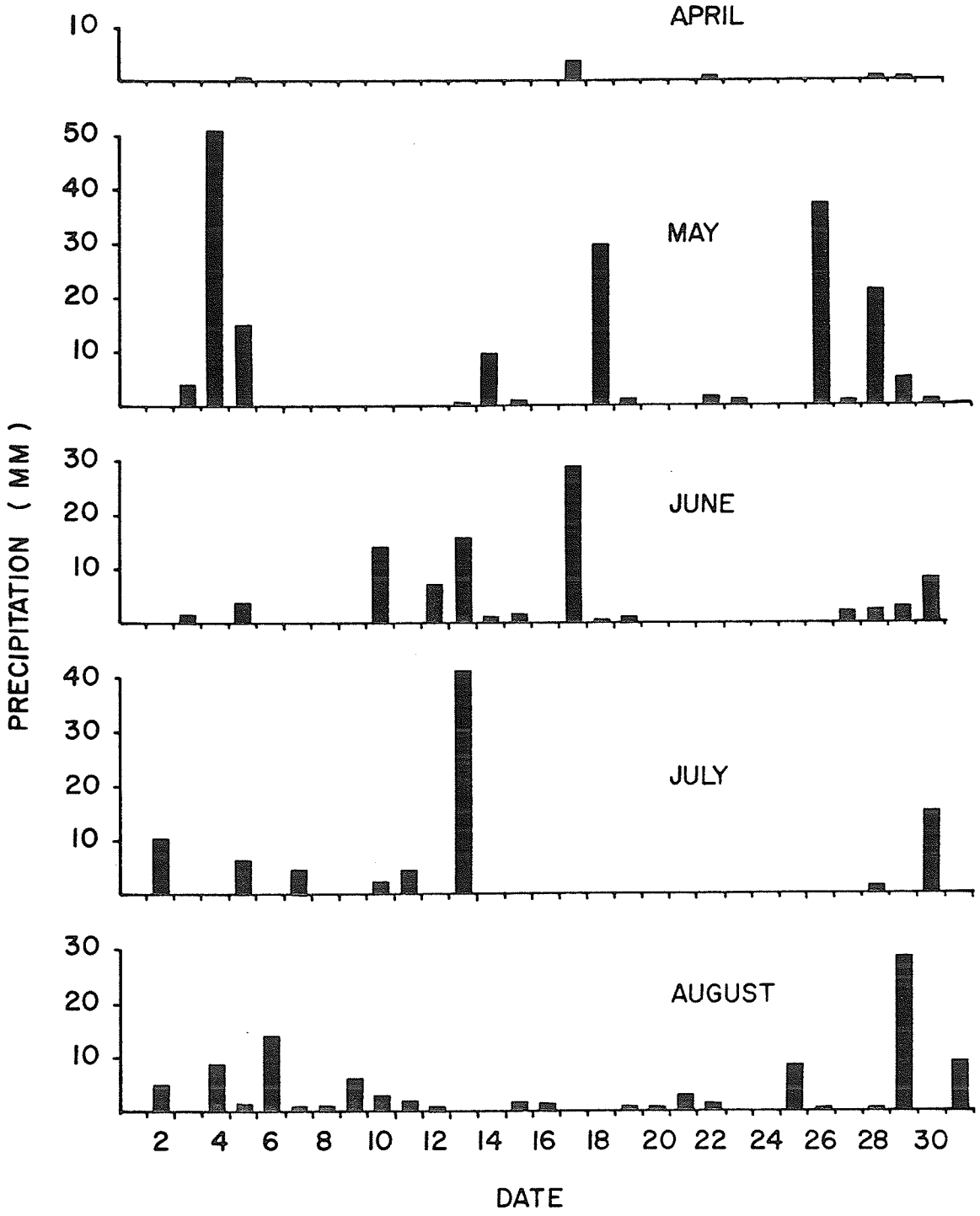
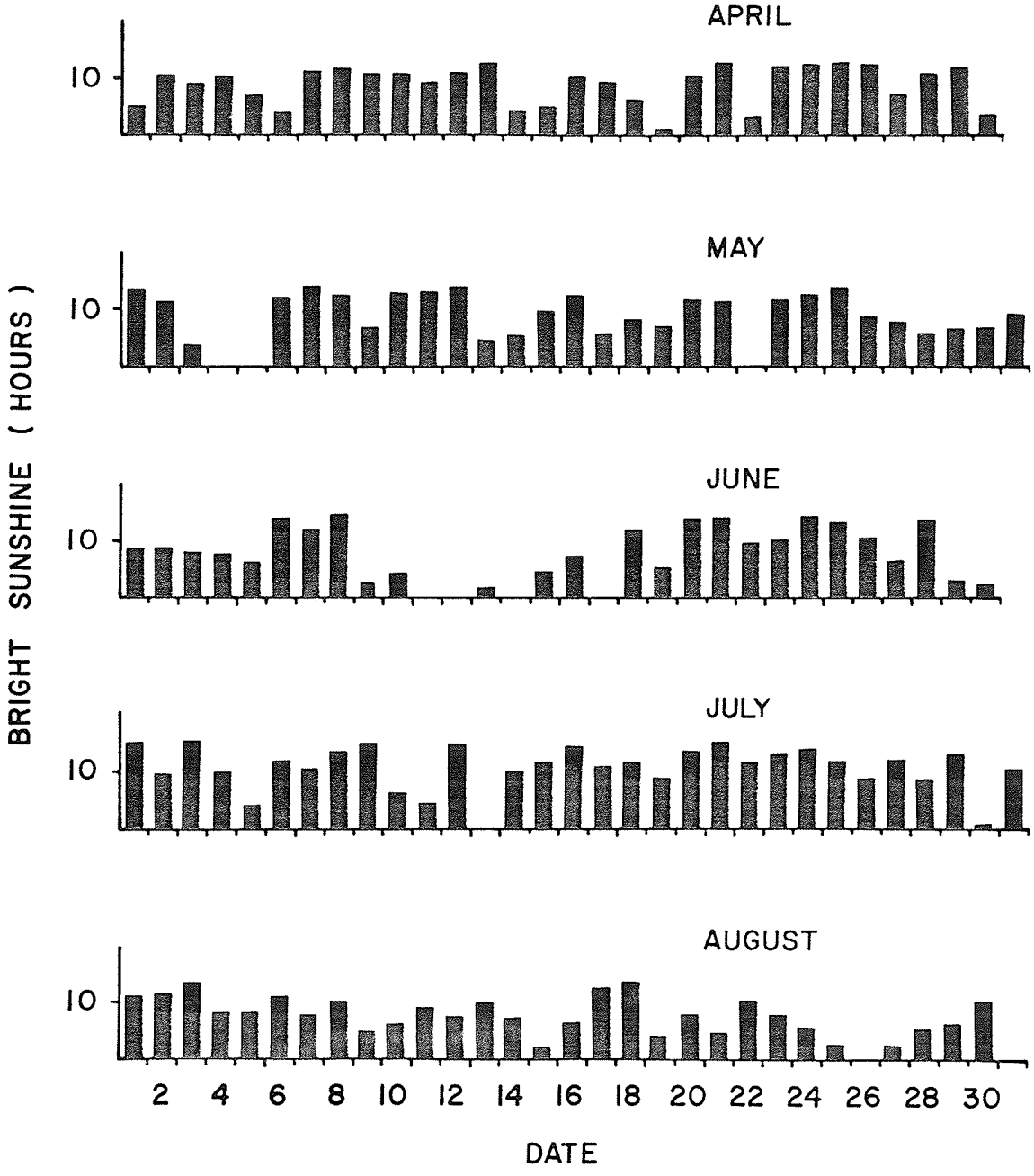
Appendix Figure 1: Daily mean temperatures (April - August 1977, Winnipeg International Airport)


APRIL
MAY
JUNE
JULY
AUGUST
20
10
0
-10
TEMPERATURE MEAN (°C)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DATE

Appendix Figure 2: Daily precipitation (April - August 1977), Winnipeg International Airport)


APRIL
MAY
JUNE
JULY
AUGUST
PRECIPITATION (MM)
DATE
10
50
40
30
20
10
30
20
10
40
30
20
10
30
20
10
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

Appendix Figure 3: Hours of sunshine (April - August 1977). Winnipeg International Airport.


APRIL
MAY
JUNE
JULY
AUGUST
10
BRIGHT SUNSHINE (HOURS)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DATE

APPENDIX TABLE I

HEIGHT OF FOUR CULTIVARS OF FABABEAN PLANTS, ON DIFFERENT DATES THROUGHOUT THE SEASON AT TWO SITES (1977)

Site	Date	No. days after seeding	No. Plants	Height of cultivars (cm)			
				Ackerperle	Diana	Erfordia	Herz Freya
U. of M.	10 May	25	40	2.00 ± -	2.00 ± -	2.00 ± -	2.00 ± -
	2 June	48	40	22.12 ± 0.79*	18.62 ± 0.66	27.37 ± 0.66	21.00 ± 0.59
	15 June	61	40	45.87 ± 1.28	41.70 ± 0.92	55.52 ± 1.10	51.75 ± 0.77
	25 June	71	40	80.75 ± 1.82	73.40 ± 1.31	93.00 ± 1.50	86.40 ± 0.95
	6 July	82	40	99.40 ± 2.18	89.50 ± 1.33	108.10 ± 1.53	105.10 ± 1.19
GLENLEA	3 June	17	40	2.61 ± 0.13	2.21 ± 0.09	3.94 ± 0.13	2.99 ± 0.12
	16 June	30	40	17.20 ± 0.43	15.47 ± 0.47	21.22 ± 0.54	17.70 ± 0.40
	25 June	39	40	37.57 ± 0.75	34.80 ± 1.19	44.27 ± 1.17	40.52 ± 0.79
	6 July	50	40	61.75 ± 0.98	58.85 ± 1.16	68.95 ± 1.10	66.90 ± 0.86
	16 July	60	40	83.50 ± 0.98	77.75 ± 1.63	94.97 ± 1.16	87.22 ± 1.14
	27 July	71	40	100.30 ± 1.03	91.02 ± 1.65	112.12 ± 1.45	106.47 ± 1.31
	13 August	86	40	107.85 ± 1.50	95.37 ± 1.81	117.82 ± 1.41	111.82 ± 1.36

*Mean and standard error.

APPENDIX TABLE II

GROWTH RATE OF FOUR CULTIVARS OF FABABEANS AT TWO SITES, (1977)

Site	Date	No. days after seeding	No. Plants	Growth rate of cultivar (cm/wk)			
				Ackerperle	Diana	Erfordia	Herz Freya
	10 May	1-25	40	0.56	0.56	0.56	0.56
	2 June	25-48	40	6.12	5.06	7.72	5.78
U.ofM.	15 June	48-61	40	12.79	12.43	15.16	16.56
	25 June	61-71	40	24.42	22.19	26.24	24.25
	6 July	71-82	40	11.87	10.24	9.61	11.90
	6 July	1-82	40	8.48	7.64	9.23	8.97
	3 June	1-17	40	1.07	0.91	1.62	1.23
	16 June	17-30	40	7.86	7.14	9.30	7.92
	25 June	30-39	40	15.84	15.03	17.93	17.75
Glenlea	6 July	39-50	40	15.39	15.30	15.70	16.79
	16 July	50-60	40	15.22	13.23	18.21	14.22
	27 July	60-71	40	10.69	8.44	10.91	12.25
	13 Aug.	71-86	40	3.52	2.03	2.66	2.50
	13 Aug.	1-86	40	8.78	7.76	9.59	9.10

APPENDIX TABLE III

NUMBER OF FLOWERS PER PLANT FOUND IN FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES OF THE DAY (GLENLEA SITE, 1977)

Date	Cultivar	Stage of Flowers	TIME OF DAY 800-1000	1000-1200	1200-1400	1400-1600	1600-1800	1800-2000	2000-2200
			*						
12July, 1977	Ackerperle	II A	0.00±0.00	1.20±0.49	2.00±1.05	0.80±0.37	2.40±0.51	3.00±0.55	3.40±0.75
		II B	1.20±0.58	2.00±0.71	3.40±0.40	5.80±1.07	9.40±0.98	15.60±1.25	14.40±0.68
	Diana	II A	0.00±0.00	0.80±0.37	1.00±0.32	2.60±0.81	3.40±1.50	1.00±0.45	1.40±0.40
		II B	0.80±0.58	5.20±0.37	7.60±0.60	9.00±1.14	16.20±2.48	20.00±2.55	20.40±1.63
	Erfordia	II A	0.00±0.00	1.40±0.24	0.20±0.20	1.80±0.49	1.60±0.81	3.00±0.71	2.40±0.40
		II B	1.40±0.87	4.60±1.03	5.60±0.98	7.00±1.30	11.60±2.66	16.40±2.38	16.20±3.57
	Herz Freya	II A	0.80±0.58	1.40±0.93	1.20±0.49	2.40±0.87	0.80±0.37	1.60±0.51	2.20±0.80
		II B	6.20±1.69	4.60±0.75	6.00±1.14	8.20±1.69	11.40±1.03	19.60±2.09	20.20±1.74
3 August, 1977	Ackerperle	II A	0.00±0.00	1.40±0.75	1.80±0.66	0.80±0.49	2.20±0.73	2.20±0.20	1.80±0.37
		II B	0.00±0.00	1.00±1.00	1.60±0.81	1.80±0.97	3.60±1.36	10.20±0.97	9.60±0.81
	Diana	II A	0.00±0.00	2.40±0.51	2.20±0.37	0.80±0.37	1.00±0.32	0.80±0.37	1.20±0.37
		II B	0.00±0.00	1.40±0.51	3.00±0.32	3.60±0.60	6.00±0.45	7.00±0.71	6.40±0.93
	Erfordia	II A	0.00±0.00	1.00±0.32	1.40±0.60	0.80±0.58	2.20±1.20	3.20±0.58	2.40±0.68
		II B	0.00±0.00	1.60±0.51	2.40±0.81	3.80±1.07	6.80±1.59	10.40±1.75	10.40±1.86
	Herz Freya	II A	0.00±0.00	3.60±1.21	1.60±0.40	1.40±0.24	1.40±0.40	1.20±0.20	0.80±0.37
		II B	0.00±0.00	0.20±0.20	3.20±0.49	4.40±0.40	7.40±0.24	10.80±0.73	9.40±0.98

* Mean and standard error (5 plants/sample)
II A: Early bloom stage
II B: Full bloom stage

APPENDIX TABLE IV

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, U. OF M. SITE, 1977)

Time of The Day	Date: 23 June (69 Days After Seeding)								Date: 9 July (85 Days After Seeding)							
	Cultivar								Cultivar							
	A		D		E		H		A		D		E		H	
	T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	0.93	1.11	1.37	2.45	1.58	1.01	2.81	2.08	0,41	0.89	0.43	1.07	1.58	0.74	1.42	1.11
1000-1200	1.04	1.77	0.82	2.34	0.51	0.73	1.50	6.30	0.51	0.73	0.57	0.46	0.32	0.98	0.38	0.29
1200-1400	0.79	1.91	0.63	1.41	0.38	0.74	0.93	1.85	0.63	0.57	0.60	0.62	1.45	0.38	1.31	1.07
1400-1600	0.54	1.01	1.07	0.69	0.33	0.30	0.32	3.76	0.58	0.84	0.49	0.58	1.04	0.44	0.63	1.26
1600-1800	0.96	1.08	1.17	0.57	0.70	0.62	1.26	2.13	1.33	0.44	1.33	0.29	1.20	0.54	0.73	1.36
1800-2000	0.88	0.87	1.36	0.87	0.62	0.64	1.01	1.07	1.48	0.67	1.11	0.76	1.10	0.47	1.07	1.71
2000-2200	0.85	0.95	0.82	1.64	1.14	0.66	1.99	0.62	0.85	0.27	0.76	0.79	0.25	0.55	0.32	0.48
Total Mean	0.86	1.24	1.04	1.42	0.75	0.67	1.40	2.54	0.83	0.63	0.75	0.65	0.99	0.59	0.84	1.04
S.E.	0.09	0.12	0.14	0.17	0.11	0.06	0.02	0.39	0.11	0.08	0.13	0.09	0.13	0.08	0.16	0.15

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extra-floral nectary (microlitre/5 stipules)

APPENDIX TABLE V

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, GLENLEA SITE, 1977)

Time of The Day	Date: 7 July (53 Days After Seeding)								21 July (67 Days After Seeding)							
	Cultivar								Cultivar							
	A		D		E		H		A		D		E		H	
	T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	3.14	2.40	1.23	2.24	1.61	1.20	1.10	2.34	0.60	1.17	0.51	1.82	0.69	0.58	0.60	1.01
1000-1200	1.20	1.67	1.61	1.83	0.47	0.66	0.44	1.96	0.82	0.68	1.20	0.47	0.51	0.73	0.69	1.36
1200-1400	1.04	1.80	1.44	0.95	1.04	1.42	1.33	1.99	1.49	0.68	0.99	0.47	0.82	0.47	0.88	0.73
1400-1600	0.85	1.26	1.07	1.93	0.88	1.10	2.10	0.88	0.62	1.09	0.88	0.63	1.04	0.55	0.68	0.41
1600-1800	0.69	1.01	1.15	1.52	1.26	0.88	1.99	0.89	0.85	0.68	0.88	0.76	0.91	0.62	0.98	0.72
1800-2000	1.36	0.40	1.20	1.20	0.94	0.24	0.76	1.83	1.17	0.88	0.70	0.93	1.04	0.88	1.32	0.71
2000-2200	0.63	0.40	1.10	0.69	0.98	0.85	2.05	1.36	1.23	0.30	0.79	0.88	0.74	0.88	1.07	0.49
Total Mean	1.27	1.28	1.26	1.48	1.03	0.91	1.40	1.60	0.97	0.78	0.85	0.85	0.82	0.67	0.89	0.78
S.E.	0.21	0.20	0.13	0.15	0.11	0.08	0.18	0.14	0.12	0.08	0.07	0.13	0.08	0.06	0.08	0.10

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectary (microlitre/5 stipules)

APPENDIX TABLE VI

AMOUNT OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, GLENLEA SITE, 1977)

Time of The Day	Date: 7 July (53 Days After Seeding)								Date: 21 July (67 Days After Seeding)							
	Cultivar								Cultivar							
	A		D		E		H		A		D		E		H	
	T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	1.47	2.27	1.64	2.30	0.73	1.62	2.54	1.39	1.07	2.81	0.87	1.41	0.50	0.46	0.29	2.35
1000-1200	1.30	2.15	1.83	2.11	0.95	0.46	1.95	3.35	0.85	0.54	1.23	0.60	0.30	0.25	0.41	0.71
1200-1400	0.60	1.35	0.95	1.35	0.63	1.04	0.64	1.36	0.57	0.66	1.23	0.65	0.96	0.29	0.56	0.29
1400-1600	1.45	1.67	1.93	0.97	0.83	0.66	1.86	1.02	0.70	0.69	0.70	0.55	0.70	0.54	0.88	0.54
1600-1800	1.01	1.16	1.52	1.16	0.75	0.70	0.82	1.30	0.50	1.17	0.53	0.57	0.36	0.58	1.01	0.52
1800-2000	0.93	1.39	1.20	1.02	1.15	0.82	0.84	1.01	1.52	0.38	1.00	0.79	0.65	0.82	0.73	0.73
2000-2200	0.55	1.03	0.69	1.67	1.11	1.45	2.08	1.74	0.66	0.70	0.82	1.22	1.10	1.16	0.98	1.42
Total Mean	1.05	1.58	1.39	1.51	0.88	0.97	1.53	1.59	0.84	0.99	0.91	0.82	0.65	0.59	0.69	0.94
S.E.	0.14	0.19	0.12	0.22	0.12	0.13	0.19	0.20	0.09	0.20	0.09	0.09	0.08	0.06	0.08	0.20

A Ackerperle, D Diana, E Erfordia, H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (microlitre/flower)
E.N. Extrafloral nectar (microlitre/5 stipules)

APPENDIX TABLE VII

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, U. OF M. SITE, 1977)

Time of The Day	Date: 23 June, 1977 (69 Days After Seeding)								9 July, 1977 (85 Days After Seeding							
	Cultivar								Cultivar							
	A		D		E		H		A		D		E		H	
	T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.*	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	37.00	6.00	27.00	6.50	43.00	10.50	23.00	11.00	20.00	10.00	32.00	15.00	22.00	19.00	26.00	12.50
1000-1200	38.00	7.50	22.00	7.00	51.00	13.00	31.00	13.00	26.00	22.50	23.00	22.50	25.50	20.00	30.00	34.00
1200-1400	27.50	10.00	28.00	9.50	38.00	12.00	40.00	11.00	20.00	32.00	37.00	27.00	30.00	35.00	30.00	18.00
1400-1600	40.00	12.00	40.00	17.00	55.00	15.00	39.00	33.00	35.00	38.00	31.00	30.00	43.00	40.00	55.00	19.00
1600-1800	67.00	18.00	45.00	31.00	70.00	20.00	65.00	25.00	23.00	33.00	28.00	30.00	27.00	30.00	35.00	21.00
1800-2000	44.00	18.00	39.00	15.00	57.00	16.00	35.00	13.00	31.00	27.00	37.00	29.00	36.00	37.00	29.00	21.00
2000-2200	58.00	30.00	41.00	17.00	41.00	42.00	41.00	14.00	25.00	58.00	31.00	21.00	37.00	31.00	60.00	27.00
Total Mean	44.50	14.50	34.57	14.71	50.71	18.36	39.14	17.14	25.71	31.50	31.29	24.93	31.50	30.29	37.86	21.79
S.E.	5.09	3.09	3.27	3.15	4.19	4.09	4.98	3.15	2.14	5.59	1.75	1.95	2.76	3.02	5.20	2.54

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

APPENDIX TABLE VIII

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS

AT DIFFERENT TIMES THROUGHOUT THE DAY (OPEN PLOTS, GLENLEA SITE, 1977)

Time of The Day	Date: 7 July, 1977 (53 Days After Seeding)								21 July, 1977 (67 Days After Seeding)							
	Cultivar								Cultivar							
	A		D		E		H		A		D		E		H	
	T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	16.00	5.00	33.00	5.00	23.00	11.00	34.00	5.00	16.50	7.50	19.00	7.50	20.00	22.00	14.00	17.00
1000-1200	35.00	9.00	27.00	8.00	39.00	25.00	39.00	11.50	20.00	18.00	13.00	22.00	45.00	19.00	34.00	19.00
1200-1400	27.00	14.50	33.00	13.00	28.50	30.50	23.50	20.00	25.00	26.50	23.00	21.50	26.00	27.00	22.00	22.00
1400-1600	30.50	23.00	39.00	22.00	47.00	27.50	25.00	27.00	21.00	18.00	27.00	21.00	30.00	23.00	25.00	27.00
1600-1800	63.00	25.00	46.50	23.00	58.00	27.50	36.00	28.00	26.00	26.00	26.00	21.00	30.00	27.00	19.00	29.50
1800-2000	60.00	36.00	52.00	20.00	60.00	65.00	58.00	36.00	28.00	18.50	20.00	11.00	35.00	16.00	33.00	16.00
2000-2200	54.00	41.00	57.00	17.00	51.00	18.00	25.00	18.00	27.00	21.00	23.50	13.50	30.50	10.50	28.00	15.00
Total Mean	40.79	21.93	41.14	15.43	43.79	29.21	34.36	20.79	23.36	19.36	21.64	16.79	30.93	20.64	25.00	20.79
S.E.	6.85	5.13	4.14	2.69	5.35	6.50	4.58	4.00	1.75	2.23	1.75	2.14	2.96	2.05	2.76	2.14

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extrafloral nectary (% sugar concentration collected from 25 stipules)

APPENDIX TABLE IX

SUGAR CONCENTRATION OF NECTAR FROM FOUR CULTIVARS OF FABABEANS

AT DIFFERENT TIMES THROUGHOUT THE DAY (CAGED PLOTS, GLENLEA SITE 1977)

	Date															
	7 July, 1977 (53 Days After Seeding)								21 July, 1977 (67 Days After Seeding)							
	Cultivar								Cultivar							
	A		D		E		H		A		D		E		H	
	T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.		T.N.	
	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.	F.N.	E.N.
0800-1000	31.00	21.00	33.50	10.00	41.00	13.50	40.50	19.00	9.00	16.50	12.00	16.00	19.50	54.00	13.00	17.00
1000-1200	37.00	18.00	36.00	14.50	46.00	47.00	35.00	13.00	15.00	35.00	16.50	24.00	25.00	55.00	33.00	15.00
1200-1400	49.00	35.00	50.00	26.00	36.00	43.00	32.00	32.00	15.00	28.50	24.00	34.00	24.50	62.00	21.00	58.00
1400-1600	49.00	47.00	45.00	50.00	61.00	50.00	58.00	47.00	16.00	59.00	17.00	27.00	23.00	68.00	18.00	46.00
1600-1800	48.00	50.00	50.00	43.00	64.00	57.50	51.00	52.00	27.00	50.50	18.00	49.00	25.00	39.00	17.00	58.00
1800-2000	71.00	56.00	57.00	54.00	76.00	56.00	69.00	55.50	26.50	57.00	18.00	36.00	24.00	28.00	25.00	35.00
2000-2200	69.00	64.00	59.00	48.00	53.00	57.00	53.00	49.00	28.50	26.00	15.00	14.00	21.00	15.00	22.00	21.00
Total Mean	50.57	41.57	47.21	35.07	53.86	46.29	48.36	38.21	19.57	38.93	17.21	28.57	23.14	45.86	21.29	35.71
S.E.	5.64	6.61	3.68	6.80	5.33	5.85	5.01	6.41	3.67	3.55	3.18	3.09	3.89	3.73	3.35	3.77

A Ackerperle
D Diana
E Erfordia
H Herz Freya
T.N. Type of nectary
F.N. Floral nectary (% sugar concentration collected from 5 flowers)
E.N. Extra-floral nectary (% sugar concentration collected from 25 stipules)