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THE FORAGING BEHAVIOUR OF HONEY BEES (*Apis mellifera* L.) ON SELECTED CULTIVARS OF *Brassica campestris* L. AND *Brassica napus* L.

A Thesis

Submitted to the Faculty

of

Graduate Studies

The University of Manitoba

by

Nina Angelika Bertholet

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

Department of Entomology

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THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read a Master's thesis entitled: The foraging behaviour of honey bees (Apis mellifera L.) on selected cultivars of Brassica campestris L. and Brassica napus L.

submitted by Nina A. Bertholet

in partial fulfillment of the requirements for the degree of Master of Science

The Thesis Examining Committee certifies that the thesis (and the oral examination, if required) is:

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THE FORAGING BEHAVIOUR OF HONEY BEES (*APIS MELLIFERA* L.) ON SELECTED CULTIVARS OF *BRASSICA CAMPESTRIS* L. AND *BRASSICA NAPUS* L.

BY

NINA ANGELIKA BERTHOLET

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

MASTER OF SCIENCE

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LIST OF ABBREVIATIONS

Abbreviation	Signification
RS	Random nectar sampling
CS	Cumulative nectar sampling
CoS	Continuous nectar sampling
TSW	Thousand seed weight
SC	Sugar concentration
RH	Relative humidity

ABSTRACT

Bertholet, Nina Angelika. M.Sc. The University of Manitoba, February 1985. The Foraging Behaviour of Honey Bees (Apis mellifera L.) on Selected Cultivars of Brassica campestris L. and Brassica napus L. Major Professor: S. Cameron Jay.

Studies of the foraging behaviour of honey bees on canola have become important, particularly because of the large acreage of canola that is being grown in Western Canada. However, past research on the foraging behaviour of honey bees on canola has provided conflicting results. Honey bees have been accepted as valuable pollinators of the self-sterile Brassica campestris L., but their value on the self-fertile B. napus L. has not been determined. There is a concern that new cultivars may be less attractive to honey bees, or may be producing less nectar. Conflicting results about honey bee nectar and pollen collecting behaviour also exist. This study examines the behaviour of honey bees on B. campestris (cv. Candle and Tobin) and B. napus (cv. Altex, Andor and Regent) in order to clarify some of these conflicts and concerns.

Plants of each cultivar were isolated from honey bees using pollination bags. At maturity, bagged plants were compared to open-pollinated control plants in order to determine the effect of honey bees on seed set and yield.

Nectar was gathered from 10 flowers of each cultivar at 2-hour intervals using capillary tubes. The amount of nectar that was collected was measured in μl and the percent sugar concentration determined from the sample where possible. Patterns of nectar production and percent sugar concentration were plotted. Pollen was also collected from pollen

traps at 2-hour intervals to ascertain if honey bees exhibit any foraging patterns in their pollen collection. Air temperature and relative humidity were also measured every 2 hours during the observation period.

Individual bees were followed and their foraging behaviour recorded. Bees were also observed and counted on each cultivar every 2 hours to determine their foraging patterns and to determine if they preferred certain cultivars.

Both B. campestris and B. napus show daily patterns of nectar secretion. Mean daily nectar production for B. campestris reached a maximum of 0.68 μl with a maximum mean sugar concentration of 65%. Mean daily nectar production for B. napus reached a maximum of 2.15 μl with a maximum mean sugar concentration of 62%. All cultivars produced ample amounts of nectar. Air temperature and relative humidity were closely correlated with nectar production and sugar concentration.

Honey bees "thieve" nectar from B. napus flowers. They will also collect pollen from both species of canola. Honey bees spend a maximum of 0.13 min./flower foraging on B. campestris and a maximum of 0.12 min./flower foraging on B. napus. Bees visit a maximum of 2.8 flowers/plant on B. campestris and 2.6 flowers/plant on B. napus.

Honey bees did not show consistent daily patterns in their foraging behaviour, nor did they show a preference for any one canola cultivar.

Honey bees increased seed yields of B. campestris cultivars up to 138% and B. napus cultivars up to 73%.

INTRODUCTION

Canola, or rapeseed, has been grown in Canada since 1942 (Anonymous 1971). Since then, canola has become the dominant oilseed crop grown in Canada and is also Canada's secondmost valuable field crop, next to wheat (Adophe 1980). Canada has also become the leading exporter of canola in the world (Adolphe 1980). Because of the value and importance of this crop, plant breeders are continually experimenting with new and improved varieties.

Since much of Canada's farmland is given over to this crop, it has also become the major honey crop in many areas. Canola produces ample amounts of a nectar which is attractive to honey bees and which results in a light amber coloured honey. This honey is most often used in a cream form becuase it crystallizes quickly.

Honey producers are concerned that canola breeders will produce a crop that is unattractive to bees, or one that produces little or no nectar. Because of the large acreage of canola grown, possible loss of such bee forage is of concern to commercial honey producers.

There are conflicting results in the literature as to the importance of honey bees for seed set and yield in canola. Such differing opinions are also expressed by canola producers.

Therefore, the purpose of this study was to investigate the foraging behaviour of honey bees on currently recommended cultivars of canola grown in Western Canada. By observing the behaviour of honey bees on

this crop an attempt was made to ascertain 1) the value of honey bees in the pollination and seed yield of canola, 2) if currently recommended canola cultivars are producing adequate amounts of nectar and finally, 4) if honey bees show any preference for one canola cultivar over another.

Chapter 1

LITERATURE REVIEW

Introduction

The association between insects and plants has existed for centuries. Hambleton (1944) states that certain species of plants are dependent on insects for their ultimate fruition and perpetuation through cross pollination and that the pollination of certain self-fertile species also benefits through insect visitation.

Canola (or rapeseed, Brassica spp., family Cruciferae) is a crop that often benefits through insect pollination. There are two commonly grown species of canola, Brassica campestris L. (also known as Polish or Turnip rape) which requires insect pollination to set seed, and B. napus L. (also known as Argentine or Swede rape) which is self-fertile. There is still some controversy as to whether B. napus can benefit through insect pollination or not. The term "rapeseed" or "rape" refers to the older varieties of the crop which were high in two anti-nutritional factors (i.e. glucosinolates and erucic acid) while "canola" is the name given to the newer varieties, which contain less than 5% erucic acid and less than 30 moles of glucosinolates per gram of oil free meal.

Canola flowers produce an abundance of nectar (Petkov 1963) and therefore are very attractive to honey bees. Increased acerage of canola has led to increased honey production in Western Canada. Because canola is a relatively new crop, little research about the foraging behaviour of honey bees has been done. Research to date has involved only European and Asian cultivars (Ewert 1929, Mohammad 1935, Hammer 1952, Louveaux 1952, Meyerhoff 1954, Belozerova 1960, Latif et al. 1960, Cedell 1966, 1977, Tasei 1978, Kubisova et al. 1980, Eisikowitch 1981, 1975,

Langridge and Goodman 1982, Free and Ferguson 1983. Thus, much pollination research remains to be done in North America with North American canola cultivars.

Plant Morphology

The two species of canola are quite different in their morphology. Young canola plants (2-4 leaf stage) of both B. campestris and B. napus are similar in appearance to young cabbage plants. They have basal leaves which are 10-30 cm long and 5-15 cm wide (McGregory 1976). The flowering racemes of B. campestris and B. napus reach a height of 0.5-1.0 m and 0.75-1.25 m respectively. Both species of canola are cool season crops, but are susceptible to frost (McGregor 1976).

The flowers of B. campestris and B. napus are similar in structure and grow on elongated terminal racemes. Flowers are hermaphroditic with each flower possessing a single stigma and six stamens (Free 1970). The four inner stamens have anthers which are approximately level with the stigma and dehisce outwards. As the flower fades, these stamens recurve so that automatic self-pollination can occur if the plant is self-compatible (McGregor 1976). The filaments of the outer two stamens are shorter and pollen is dehisced inwards. Each flower has four sepals, four petals and four nectaries. Two inner nectaries are located at the base of the shorter stamens while the other two are located outside the ring of stamens (Williams 1980). The inner nectaries secrete much more nectar than do the outer two nectaries (Hasler and Maurizio 1950). Frei (1955) found that the two inner nectaries have a well developed phloem supply, whereas the two outer nectaries lack vascularization. Because of this, Murrell and Nash (1981) stated that less

nectar is produced by the outer two nectaries, which may differ in composition and sugar concentration from the nectar produced by the inner pair.

The flowers of B. campestris are considerably smaller than those of B. napus and less nectar per flower is generally available from them. (Szabo 1982). Flowering extends for 22-45 days (Gerard and Cronan 1963, Radchenko 1964, Tayo and Morgan 1975). Flower buds can open at any time during the day and remain open as long as 3 days (Eisikowitch 1981). After pollination and fertilization of the flower, sepals, petals and stamens drop off in 2-3 days, and the young pod becomes visible a day or so after this (Tayo and Morgan 1975). The fruit is a slender silique or pod 5-10 cm long (McGregor 1976).

Pollen and Honey Bee Foraging Behaviour

General

Both B. campestris and B. napus produce copious amounts of an attractive pollen. Pollen grains of both species are normally 3 colpate, with B. campestris having smaller pollen grains (33-40 μ) than B. napus (41-47 μ) (Nair and Sharma 1976). Pollen grains of B. campestris were shown to be viable for 7 days after anthesis (Mohammad 1935).

For B. campestris, cross pollination usually results in higher seed yields (Sun 1937, Mohammad 1935,) and larger pods than does self-pollination (Mohammad 1935). Inbreeding has been shown to decrease yields up to 37% (based on small samples) (Sun 1937). A canola plant can achieve maximum carrying capacity only when pollination is adequate, i.e. when the maximum amount of compatible pollen reaches the maximum number of receptive stigmas on that plant (Dhaliwal and Malik 1980). Plants will compensate to some extent for inadequate pollination by producing more racemes, more

flowers and heavier seeds (Williams 1980). Sun (1935) also showed that plants grown from open pollinated seed yielded more seed than plants grown from inbred seed.

Both self- and cross-pollen can reach the stigma of any given flower. However, in plants such as B. campestris, which are highly self-sterile, the relatively few self-pollen tubes which may be present in the style are outnumbered by cross-pollen tubes (Ockendon and Currah 1978). Thus, if cross-pollen arrives on the stigma within an hour or two of the self-pollen it becomes unlikely that much self-seed will be set due to the self-incompatability reaction. Also, if no cross pollen arrives, there will be little, if any, seed set due to the self-incompatability. In plants such as B. napus (approximately 70% self-pollinating, Adolphe 1980) this self-incompatability reaction is not as evident.

Pollination Requirements of B. campestris and B. napus

B. campestris, in general, has a high degree of out-crossing or vicinism. Only about 20% selfing has been shown to occur in the closely related white mustard (Sinapsis alba L. = Brassica hirta L.) (Olsson 1960). Some differences in pollination requirements between cultivars of B. campestris may exist. For example, observations made on two Indian varieties sarson and toria, showed that one form of sarson favoured self-pollination while toria did not (Mohammad 1935). This difference was accounted for by the relative positions of the anthers over the stigma. However, as B. campestris is known to require cross-pollination (Adolphe 1980), most researchers believe that insects, especially honey bees, are exremely valuable in increasing cross-pollination and seed yields of B. campestris (Rao et al. 1980, Langridge and Goodman 1975). Yields of

white mustard (B. alba), and also to a lesser extent brown mustard (B. juncea L.), were shown to have increased through honey bee pollination (Free and Spencer-Booth 1963).

While the importance of insect pollinators for seed-set in B. campestris goes relatively unquestioned, the importance of insect pollinators on B. napus has not yet been determined with any certainty. It has been known since 1940 that B. napus does self-pollinate much better than does B. campestris (Olsson 1960, Williams 1978). Despite this, many researchers (i.e. Ewert 1929) consider that B. napus does benefit significantly from insect pollination, and that honey bees are among the most important and reliable insect pollinators (Zander 1951, Kaeser 1976, Mesquida and Renard 1979, Pawlikowski 1978). Zander (1951) found B. napus plants (cv. Janetztki, Lembke) in a bee free environment yielded very few seeds. Radchenko (1964) determined that approximately 5 insect visits per flower are required for good pollination of B. napus.

The importance of insect pollinators is usually determined through the use of cage trials. Cage trials generally employ 3 plots of equal size. One plot is covered by a cage in which there are no insect pollinators present, in order to determine the effect of the cage and the lack of pollinating agent(s). A second cage includes the desired insect pollinator. These two cage trials are then compared to an "open" plot in which no cage is present - an indication of the degree of pollination occuring under natural conditions (see Kaeser and Gunst 1974).

Another method used in pollination experiments involves "bag" trials. In this instance, individual plants, or flowering heads, are "bagged" with a material which allows as much light as possible to enter, yet prevents insect visitation.

As a result of cage trials with B. napus, Meyerhoff (1954) found that bees increase the number of seeds/pod by 12.6%, the 1000 seed weight by 11.7%, the number of pods by 53.2%, the pod length by 6.1%, and the germinability by 7.3% (cv. Lembke). Kubisova et al. (1980) reported that honey bees to increase the seed yield of B. napus by 59% (almost a doubling of seed yield/plant) and recommended that at least 4 hives/ha be used for optimum pollination. In another four year study, B. napus (var. napus) had an increased yield of 54.1% (Kamler 1983), which is very similar to the yield increase shown by Kubisova et al. (1980). However, Kamler (1983) found seed weights/ha decreased, probably because the main component of increased seed yield was due to an increase in the number of pods and not due to an increase in the number of seeds/pods-which only increased by 4.8%.

Benedek et al. (1972) showed that while pods/plants and the weight of the seeds/plant were somewhat greater on open plots than in cage plots, the results were not significant. However, seeds/pod, 1000 seed weight and the germinability of seed were significantly greater for uncaged plants (B. napus cv. Ferlodi).

Other researchers doubt that there are benefits from insect pollination for B. napus. According to Free and Nuttal (1968) the presence of bees makes little or no difference to the amount of seed produced even though 13% yield increases were recorded. Free and Nuttal's conclusions were later confirmed by Benedek et al. (1972) who also concluded that the presence of bees were of dubious benefit to the overall plant seed production. Although Free (1970) refers to B. napus as being self-fertile, Williams (1978) concluded that while this is so, it auto-pollinates poorly, and more seed is set when it is cross-pollinated. Olsson (1960) found canola to be frequented by insect visitors (especially honey and

bumble bees) and although they contributed to pollination, he stated that their importance to seed set, especially for B. napus "must not be over-rated". Olsson also conducted bag trials and attributed the poorer yield of B. napus under the bags to the effect of microclimate and not to the lack of insect pollinators. Langridge and Goodman (1982) also found that bees on B. napus (cv. Midas) had no demonstrable effects on seed yield.

There appears to be a difference of opinion regarding the importance of insect mediated pollination of B. napus and no attempt has been made as yet to determine why these differences exist. Perhaps those researchers who feel that B. napus sets seed well without insect pollinators live in areas where more aerial pollination is likely to occur or perhaps there are cultivar differences such that some may auto-pollinate better than others. Whatever the reason, more investigations are required to determine the importance of insect mediated pollination of B. napus.

Honey Bees as Pollinators of Canola

Honey bees are the primary pollinators of canola (Belozerova 1960, Radchenko 1964, Pawlikowski 1978) and show considerable constancy to this crop (Ieressel and Mommers 1954). All foraging bees collect nectar from canola, but Free and Ferguson (1983) found that none collect pollen only. Instead, they transfer the pollen collected incidently on their bodies to their corbiculae. Yet Langridge and Goodman (1982) found that while 95.6% of the honey bees were nectar collectors, some did actively collect pollen from B. napus at the same time. In their previous work in 1975 with B. campestris (cv. Arlo) they found 25.4% of bees gathering both nectar and pollen simultaneously, but classified these as nectar collectors because in all cases these bees were actively seeking nectar and only packing pollen that had been collected incidently into their

corbiculae.

The proportion of bees with pollen loads from canola were found to be highest at 0900 and 1000 hours (Free and Ferguson 1983). Murrell and Nash (1981) found anthesis to occur before 0830 hours in India (B. campestris, var. sarson and toria) the flowers producing copious amounts of pollen which dried up during the course of the day with little being available in the afternoon. Benedek et al. (1972) found that bees which were collecting both nectar and pollen, collected pollen near the end of a foraging trip. A pollen load adds considerable weight to the load a bee carries and perhaps it becomes more economical or energy efficient to decrease the amount of time spent flying with a heavy load.

A honey bee can gather approximately 10,000 pollen grains of canola on her body (Williams 1980). Because of this large pollen carrying capacity both pollen and nectar collectors are able to pollinate a canola flower when their bodies come in contact with the stigma. Pollen collectors are more likely to pollinate since they have more pollen on their bodies (Free and Williams 1972). The head of the bee carries the greatest amount of pollen (Free and Williams 1972) and I have observed that the heads of foragers are often completely coated with canola pollen. There is no correlation between the size of a bee's corbicular pollen load and the amount of pollen on her body (Free and Williams 1972). Bees can also transfer pollen from one to another within the hive through body contact. The pollen they transfer can remain viable for up to 24 hours (Free and Williams 1972). This enhances the possibilty of further cross-pollination.

Bees prefer one species of pollen over another (Levin and Bohart 1955). The odour of pollen may be one of the most important factors relating to the attractiveness of various pollens. Little research has

been done with regard to the attractiveness of canola pollen. Levin and Bohart (1955) showed that foraging honey bees prefer the closely related mustard pollen to that of clover and alfalfa. Boch (1982) observed that bees foraging in a flight room had a relatively high preference for Brassica pollen, and believed that this preference was due to its dense yellow pigment.

Aerial Pollination of Canola

Aerial pollination of canola has also been known to occur (Jenkinson and Glynne-Jones 1953), but its importance in seed set was considered to be small (Louveaux 1952). Certain cultivars of B. napus, such as Maris Haplona, do not usually auto-pollinate nor can the pollen grains be transferred by wind alone (Eisikowitch 1981). Wind velocities of 0-5 m/sec. (18 kph) do not dislodge pollen grians from anthers, even though small clodus of pollen grains can be seen to burst from the anthers when they are gently flicked with a brush or needle. Eiskowitch (1981) suggested that all visiting insects, including honey bees, assist in the pollination of canola and therefore beehives should be placed in fields of canola to increase pollination.

Not all researchers consider wind pollination to be insignificant. Langridge and Goodman (1975) stated that wind pollination could produce a crop of B. campestris though they acknowledge the beneficial effects of honey bees and other pollinators. Jenkinson and Glynne-Jones (1953) consider that the effects of wind pollination should not be overlooked. Mesquida and Renard (1982) found canola pollen grains blown up to 32 m from the original plant, with 23-29% seed set occurring within 6 m (3-12% seed yield). Others (Zander 1951, Olsson 1960, Mesquida and Renard 1982) have also stated that the effect of wind dispersal and pollination

are of some significance.

Nectar and Honey Bee Foraging Behaviour

General

Canola produces ample amounts of nectar. Honey bees are known to work the blossoms heavily, although they will pass over a canola field and work something else (i.e. basswood, Gerard and Cronan 1963). Nectar sugar concentrations are often low in early mornings at which time bees visit flowers primarily for pollen. However, as the day progresses nectar collection becomes increasingly important (Vansell 1934).

The attractiveness of a nectar source is dependent on the amount available per flower and its sugar concentration (Vansell 1934). Wykes (1952) found that the constituent sugars can also play a part in determining the relative attractiveness of different nectars to bees. The constituent sugars in canola nectar are glucose, fructose and ribose, and because of a very high glucose content, glucose monohydrate crystallizes out rapidly, turning the honey into "sugar" (Williams 1978).

Szabo (1982) found that a bee foraging for nectar on canola returns to the hive with an average load of 58.6 mg of nectar and/or pollen, which agrees with Wells' et al.(1981) statement that 60 µl represents a full load for a bee. The final volume of the load is positively correlated with the unladen weight of the bee and the capacity of the honey stomach is the determining factor in how much any given bee can carry (Wells and Giacchino 1968). The loads bees carry may weigh up to 90% or more of their own weight (Wells and Giacchino 1968). Interestingly enough, Wells and Giacchino (1968) found no evidence that the load of sugar solution carried by a foraging bee depends on sugar concentration (0.5-2.5M), scent (clove vs. no scent), or more importantly, the type of

sugar (fructose vs. sucrose).

The energy used by a bee while flying is believed to be negligible (Beutler 1950), but the time spent flying is important (Ribbands 1952). Earlier experiments by Ribbands (1951) demonstrated that the economical distance for nectar collecting is often not more then 0.40 km. Hammer (1952) found canola (B. napus var. oleifera) to be so attractive as to attract bees from fruit orchards 3.5-4.0 km away. Even on cold windy days (15°C.) bees were seen on the crop, each returning to the hive with 30-50 mg nectar (45-60% sugar concentration). Nectar collecting habits of bees may vary considerably from day to day and each day must therefore be considered separately when analyzing their behaviour (Vansell 1934).

Nectar Production and Sugar Concentration

Both B. campestris and B. napus provide ample amounts of nectar, with B. napus producing more nectar possibly because it has a larger flower then B. campestris (Szabo 198). Kubisova et al. (1980) found that B. napus (var. napus) blooms secrete nectar for 2 days, with a single blossom producing 2.28-2.55 mg of nectar with an average sugar concentration of 33-34%. Petkov (1963) reported that a single flower of B. napus produces 0.58 mg nectar with an average sugar concentration of 32.7%. Overall, results for canola vary somewhat from place to place and from researcher to researcher, e.g. Maksymiuk (1958) reports 0.90 mg nectar/flower at 32.3% sugar from one trial, with another trial resulting in 1.17 mg nectar/flower at 38.7% sugar. When nectar was removed 3 times a day using a microcapillary tube, 98.5% more nectar was collected. Maksymiuk concluded her study by stating that bees probably bring in a great deal more nectar than the amounts estimated experimentally.

Canola produces varying amounts of nectar and sugar per flower

depending on the species and the cultivar, as well as on the external conditions. Murrell and Nash (1981) found that the amount of nectar secreted by B. campestris (var. toria) was high in the morning and decreased at a fairly steady rate during the remainder of the day. This is probably due to the high relative humidity that occurs in the mornings. They also found the percent sugar concentration to be low in the morning (16% at 0900 hours) but increasing as the day progressed to reach an average maximum of 40%. (This confirms Hammer's (1952) observations on B. napus var. Oleifera of 45-60% sugar). In the afternoon, Apis cerena foragers only probed one inner nectary for nectar. If the nectary had not refilled (i.e. was empty) the bees would fly to other flowers. Few bees visited the outer nectaries confirming both Meyerhoff's (1958) and Free and Nuttall's (1968) observations that these nectaries do not produce any significant amount of nectar.

Honey bees often produce large amounts of canola honey. Honey yields as high as 15 kg/colony/day have been reported (Palmer 1959). Bishop (1974) stated that 200-300+ lbs (90-135+ kg) of canola honey could be produced by a colony annually. Szabo (1982) reported bees bringing in a minimum of 13 kg/honey/day during full bloom, with an average of 45.9 kg in 1976 and 127.0 kg in 1977.

Petkov (1963) determined that 1 ha of canola could produce 42.3 kg honey while Maksymiuk (1958) reported that 1 ha of canola could produce between 40.0 and 115.1 kg honey.

Honey yields are obviously extremely variable since they depend heavily on the strength of the colony, the number of flowers available (e.g. early bloom, peak bloom), and the weather conditions (McGregor 1976).

Honey Bee Nectar Collecting Behaviour

Honey bees are quite efficient at collecting nectar from canola. Kubisova et al. (1980) reported bees visiting 7-10 flowers/min.

(including flying time between blossoms) on B. napus (var. napus), Belozerova (1960) an average of 9.7 flowers/min., Petkov (1963) 12 flowers/min., and Radchenko (1964) 10 flowers/min. Free (1970) found bees spend 4.1-4.9 seconds working a flower (10-14 flowers/min.), Langridge and Goodman (1982) an average of 4.8 seconds/flower (13 flowers/min.), and Benedek and Prenner (1972) 6 seconds/flower (10 flowers/min.). The results for canola appear to be fairly consistent. There is little difference in the time spent by bees foraging on either B. campestris or B. napus (personal observation).

There are two terms which refer to the removal of nectar from flowers without pollination (Inouye 1980); "robbing" and "thieving". Robbers are bees that actually mutilate the flower in order to obtain nectar, e.g. by cutting a hole in the base of the corolla. Thieves remove nectar from the side of the flower without actually damaging it in any way. Therefore it is recommended that the term "thieving" be used in describing the removal of nectar from canola flowers.

Free and Ferguson (1983) found that certain bees on B. napus inserted their tongues in between the bases of the petals and the sepals and "thieved" the flowers of their nectar without pollinating the flower. Darwin had observed this phenomenum occurring on other plant species and realized that when this happens pollination does not take place (Brian and Crane 1959). Free and Ferguson (1983) stated that while thieving may increase the efficiency of nectar collecting and therefore honey production, these bees do not pollinate and if plant breeders produce cultivars for commercial use which do not readily self-pollinate it is important that flower structure and its effect on bee behaviour and pollinating efficiency be considered. Free and Ferguson (1983) found the mean percentage of bees thieving nectar from canola flowers was between

17% and 23.8% on two separate days.

Environmental Effects on Honey Bee Foraging Activity

The environmental factors affecting nectar and pollen secretion along with foraging behaviour, are numerous (Percival 1950, Eckert 1955, Shuel 1955, 1957, Wratt 1968). It is well known that a positive correlation exists between temperature and honey bee foraging speed (Petkov 1963, Radchenko 1964, Wratt 1968, Benedek and Prenner 1972). Temperature also effects honey bee flight range (Eckert 1955), and bees will not forage in temperatures under 10^{o} C. Light intensity also plays an important role in effecting foraging behaviour of honey bees (Nelson and Jay 1967, Heinrich and Raven 1972). Wind speeds affect foraging as well, since honey bees will cease to forage when wind speeds exceed 24-34 kph (Heinrich and Raven 1972).

Crop Improvement Possibilities

As early as 1944, Hambleton realized that much could be done to increase the productivity of canola by selecting and breeding plants that have nectar of a high sugar content that is easily available to foraging honey bees. He stated that thought should be given to the ability of plants to secrete nectar and produce pollen since this is important to both the plant producer and the bee-keeper.

There is a concern that plant breeders may "breed" the attractiveness out of a given canola cultivar. In a study conducted on brussel sprouts (*Brassica oleracea* L.), bees were shown to prefer certain cultivars over others, with the bees also showing considerable constancy to the preferred cultivars (Free and Williams 1973). Tasei (1978) also found that one cultivar of canola, Rafale (*B. napus*) could be more attractive to honey bees than Jet Neuf. However, testing with new

canola cultivars has shown that all varieties and breeder's lines of B. campestris and B. napus produce nectar with B. napus producing significantly more nectar than B. campestris (Szabo 1982); none appear to be more attractive to bees than others. Many of the breeder lines produce greater amounts of nectar than commonly grown varieties and are potential sources of good nectar producing varieties. Variety selection in the past has been aimed primarily at oil quality and quantity and also at reducing anti-nutritional factors such as glucosinolates and eruic acids in oil and residual meal.

Pollination through honey bees has been shown to increase the oil content of sunflower (Mahmood and Furgala 1983), and it has also been shown to affect the oil content of canola (i.e. Fries and Stark 1983), although relatively little research has been done in this area.

Finally, Szabo (1982) demonstrated the possibility of selecting for high nectar and sugar producing varieties as an additional plant breeding objective thus encouraging greater utilizaiton of canola as a honey crop as well as an oil seed crop.

Chapter 2

MATERIALS AND METHODS

Field Sites

In 1982 all field trials were conducted on plots set up in the Arboretum on the University of Manitoba campus. In 1983, general canola species comparison observations were made at plots set up at the Glenlea Research Station. Seed data were also collected from these plots as well. All other trials, in 1983, were conducted in the Arboretum.

Expermental Design

The foraging behaviour of honey bees was observed on two species, involving five cultivars, of canola. These were: Brassica campestris; cultivars Candle and Tobin and B. napus; cultivars Altex, Andor and Regent.

Cultivars were arranged in a randomized complete block designs with 4 blocks in both 1982 and 1983 (Fig. 1). Each plot contained four rows 3 m long in 1982 and four rows 6 m long in 1983. Standard row spacing was used (15 cm). In 1983 larger plots were used to facilitate ease of planting. These were spaced about 1.2 m apart from each other to allow the observer to move easily between them and to prevent the possible lodging of plants between plots as well. Data were collected at 2 hourly intervals (each period constituting a "reading") from 0800 hrs. to 1800 or 2000 hrs.

Plant Data

Seed Yields

In order to determine the effect of honey bees on plant seed yield, an individual plant "bagging" system was used as follows:

In 1982, small tulle bags, each approximately 0.25m x 0.45m, were placed over main branch flower racemes at the start of bloom. These bags were secured to the main branch stalk with wire "twist-ties". However, it was observed that these bags were too small and despite being pulled up as the plant grew, growth was restricted. Restriction of growth resulted in stunted and deformed main racemes.

In 1983, larger tulle bags, each approximately 0.5m x 1.2m were placed over entire canola plants at the beginning of bloom. These nets were supported by two bent 1.8m pieces of aluminum fencing wire secured at the top with pieces of copper wire. The nets were also secured by pinning the bottom of the net to the soil with 4 aluminum wire pins. These nets were large enough to allow for unrestricted plant growth throughout the field season. The mesh of the tulle is small enough to prevent honey bees and other potential pollinating insects from alighting on the plant but large enough to allow a large amount of sunlight and wind to pass through. No obvious stunting or deformation occurred in any of the plants grown under these larger tulle bags.

Two plants were randomly chosen and bagged from each plot for a total of 8 plants/cultivar. Main branch seed yields from these two plants were then compared to the yields of the same number of randomly selected control plants; these latter plants were open to all insect pollinators.

In 1982, main branch seed yield components were determined by randomly selec-

ting 4 pods/main branch. The number of seeds/pod were counted and weighed. The 1000 seed weight was then estimated from these figures. However, 4 pods/main branch were considered too low to give accurate estimates of plant seed yield, so in 1983 the seeds from 10 pods/main branch were counted

flowers, number of aborted flowers, number of pods, number of fully filled pods, and the number of partially filled pods (all per main branch) were also counted for each bagged and control plant.

These plants were hand harvested at the end of the growing season.

Plant Nectar and Sugar Concentration Collections

Nectar and sugar concentration data were collected from each of the five cultivars of canola. Readings were taken from the two inner nectaries of 10 flowers of each cultivar every 2 hours. Nectar was collected using either 1 or 2 lambda "Drummond Microcaps®" which are disposable micro-pipettes. The amount of nectar in the micropipette was determined by placing the pipette on a scale which measured the amount of nectar in the pipette to the nearest 0.5 μl.

Nectar was collected using 3 different methods at each reading. The first method involved random sampling (RS). In this case 10 flowers/cultivar were randomly selected from each cultivar and the nectar collected from them.

The second method involved cumulative sampling (CS). Here a number of flower racemes (5 or 6) were randomly selected from each cultivar and

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® (made by Drummond Scientific Co.)

bagged before 0800 hours using small tulle bags. These bags prevented any insects from removing nectar. At each reading 10 flowers were sampled from one of the bagged flower racemes. The method measures the total amount of nectar produced in the flowers progressively throughout the day.

The third method involved continuous sampling (CoS). This method measures nectar from the same two groups of 5 flowers (i.e. 10 flowers) over the course of the observation period in order to determine the total amount of nectar a flower can produce when nectar is being removed on a regular basis (flowers were sampled every 2 hours during the observation period). These three nectar sampling methods will be compared in Chapter 4.

After the nectar samples were measured, percent sugar concentrations (percent SC) were taken directly from the samples using a hand held refractometer, and measured to the nearest 0.5%.

Pollen Collections

Four strong bee hives (each consisting of 2 brood chambers) were placed at the midpoint of each side of the overall plot (Figure 2). Two of these hives were fitted with standard pollen traps. These traps were emptied every 2 hours, and canola pollen pellets were separated from other foreign pollen pellets. Separation was done by colour, canola pollen having a distinct bright yellow hue. In addition, periodic microscopic checks were made of the assumed canola pollen pellets with those of known canola pollen to ensure that no errors were being made. These samples were then weighed.

In 1982 only the fresh weight of the pollen samples, canola vs.

foreign pollens, were recorded using a torsion balance to the nearest 0.1 g. In 1983 both fresh and dry weights were recorded. For the latter weight samples were dried for 72 hours in a Bluem gravity oven and allowed to cool before being weighed.

Bee Behaviour

The foraging behaviour of individual honey bees on each of the five cultivars were recorded. At each 2 hourly reading on the field plots, a maximum of 12 bees/cultivar were observed, each for as long as they remained within sight up to a maximum of 3 minutes. Using a stop-watch and a simple code (see Figure 3) all actions of the individual honey bees were recorded. Observations were made in order to determine: when bees collected nectar and/or pollen, how much time it took to collect nectar and/or pollen, how often they changed plants, how often the stigma of the flower was crossed (giving an indication of the percent pollination taking place), and also any other behavioural phenomena associated with honey bees foraging on canola.

Bee Counts and Insects Surveys

The number of bees/cultivar were counted at each reading by slowly walking past each plot at a rate of 5m/min. The total number of bees present on a plot at each 2 hourly interval indicates at what time of the day bees are most active, and also indicates any preference bees might have for one cultivar over another.

A general insect survey was also conducted in the same manner; these insects were identified to Family where possible. The purpose of this survey was to determine what other insects are present on canola in addition to honey bees.

Weather Information

Temperature and relative humidity were recorded every 2 hours (0800-1800 or 2000 hrs), using a hand held, battery operated psychrometer.

Statistical Analysis

Analysis of variance was used to test all data and Duncan's multiple test was included to test the significance (α=0.05) of all differences. Correlation coefficients were also determined for weather and plant data to determine the relationship of weather with plant nectar production and percent SC.

CHAPTER 3

RESULTS

Plant Production

General

The significance of the experimental replicate, canola cultivar, treatment (bagged vs control), and cultivar within treatment for plant flower, pod and seed production ($\alpha = 0.05$), varied between species and cultivars in 1982 and 1983. These differences are summarized for the experimental variables in Appendix 1 and 2. The effect of replicate and cultivar by treatment were generally insignificant for both B. campestris and B. napus in both 1982 and 1983. Main differences were found among cultivars and between treatments.

Seed Yields

In 1982 and 1983 canola plants of each cultivar produced significantly more seed when open pollinated (control)than when they were isolated (bagged) from pollinating insects (according to Duncan's multiple range test, $\alpha = 0.05$) (Figure 4). Percentage yield increases of control plants over bagged plants are given in Table 1, and are higher for all cultivars in 1982 than in 1983. B. campestris cv. Candle and Tobin did not differ significantly in total seed yields during 1982 or 1983. However, B. napus cv. varied somewhat with Altex producing significantly more seed ($\alpha = 0.05$) than did Andor in 1982. Regent produced significantly more seed ($\alpha = 0.05$) than did Andor in 1983.

The mean number of seeds/pod (seeds per pod) was also significantly greater ($\alpha = 0.05$) for control plants compared to bagged plants for all canola cultivars in 1982 and 1983 (Figure 5). Candle and Tobin both

had similar numbers of seeds/pod ($\alpha = 0.05$) in 1982 and 1983. Andor produced significantly fewer seeds/pod ($\alpha = 0.05$) than did Altex and Regent in both 1982 and 1983 ($\alpha = 0.05$). The estimated 1000 seed weight (TSW) was higher for all canola cultivar control plants in 1982, but significantly higher ($\alpha = 0.05$) for B. napus only (Figure 6). Seed weights were lower for all cultivar control plants in 1983, but significantly lower ($\alpha = 0.05$) for B. campestris only. No significant differences ($\alpha = 0.05$) occurred between species cultivars in either 1982 or 1983.

Flower and Pod Production

The mean number of flowers/main branch varied significantly ($\alpha = 0.05$) between treatments for all cultivars in 1982 and 1983, with control plants having more flowers than bagged plants (Figure 7). However, there were no significant differences ($\alpha = 0.05$) between cultivars, with the exception of Regent which produced significantly more flowers ($\alpha = 0.05$) than did Altex and Andor in 1983.

The mean number of aborted flowers/main branch was higher for bagged plants of all cultivars in 1982, but varied in 1983 (Figure 8). There were no significant differences ($\alpha = 0.05$) between cultivars within species in 1982 or 1983.

The mean number of pods produced/main branch was significantly higher ($\alpha = 0.05$) for all control plants of all cultivars (Figure 9). However, no significant differences ($\alpha = 0.05$) existed among canola cultivars in 1982 or 1983.

The mean number of fully filled pods/main branch was significantly higher ($\alpha = 0.05$) for control plants of all cultivars in 1982 and 1983

(Figure 10). However, no significant (α= 0.05) differences existed among cultivars in either year.

The mean number of partially filled pods/main branch was generally higher for bagged plants in 1982 and 1983 (Figure 11). However, these differences were not significant (α= 0.05) for B. campestris cultivars in 1982 or 1983. Significant differences (α= 0.05) in treatment effect did exist for B. napus cultivars in 1982 and 1983.

Nectar Production and Sugar Concentrations

Random Nectar Sampling Technique

An analysis of variance

tar sampling (R S) data (1983 data only) to determine the significance of species, cultivar within species, date within species, species by time of day, time of day and cultivar by time of day within species. The analysis shows that species, date within species and time of day are all significant to nectar production (Table 2). The analysis of variance on the corresponding percent sugar concentrations (S C) (Table 3) confirm the significance of the same variables that affect nectar production.

Broad comparisons made between the two species, B. campestris and B. napus, indicate that significant differences in both nectar production (Table 4) and percent S C (Table 5) exist. In this case, species differences are not significant, while date within species and time of day (Table 5 only) are significant (α= 0.05).

The relationship between mean nectar production and mean percent S C for the five cultivars are given in Figures 12 and 13. For each cultivar, the amount of nectar sampled decreased as the day progressed

while the percent S C in the samples increased. Nectar samples do not vary significantly between species ($\alpha = 0.05$). However, Regent was shown to produce significantly more nectar than Candle ($\alpha = 0.05$). Percent S C on the other hand, was significantly different ($\alpha = 0.05$) between species, with B. napus cultivars having a higher percent S C than B. campestris cultivars. There were no significant differences in nectar production among the cultivars of each species.

Species comparisons (Figures 14 and 15) do not show the same pattern of nectar production and percent SC. However, the differences among means for both variables are not significant ($\alpha = 0.05$).

In all cases, the amount of nectar sampled and the corresponding percent S C differ mainly between 0800-100 hours; at this time nectar production is generally higher and percent S C lower than it is for the remainder of the day (Figures 9, 10, 11, 12).

Cumulative Nectar Sampling Technique

An analysis of variance was also performed on the cumulative nectar sampling (CS) data to determine to significance of species, cultivar within species, date within species, species by time of day, time of day, and cultivar by time of day within species. Analysis of the 1982 CS data show that species, cultivar within species and date within species are all significant ($\alpha = 0.05$) (Table 6). During this field season the time of day was not significant. The analysis of the SC data shows that species, cultivar within species, date within species, species by time of day and time of day are all significant ($\alpha = 0.05$) (Table 7).

Duncan's multiple range test on the nectar means however, indicates

that species differences exist, with B. napus cultivars producing significantly more ($\alpha = 0.05$) nectar than the B. campestris cultivars (Figures 16 and 17). At the same time no significant differences exist between cultivars of the same species.

Duncan's multiple range test on the S C also reveals differences between species with B. campestris having a significantly higher percent S C than B. napus ($\alpha = 0.05$). There are no differences between Candle and Tobin, but Andor had a significantly lower percent SC than did Altex or Regent (Figures 16 and 17).

The significance ($\alpha = 0.05$) of the time of day varied considerably for both nectar production and percent SC.

Results of the 1983 C S data analysis are similar to those of the 1983 R S data (Table 8 and 9). The only major difference in analysis is shown in Table 8 where species effects are now not considered to be significant.

The 1983 C S and R S data differ more so. Table 10 indicates that nectar production between species, the date within species and the time of day are significant ($\alpha = 0.05$) whereas analysis of the 1983 R S shows that only the date within species was significant. Analysis of the S C indicates that date within species is not significant ($\alpha = 0.05$) (Table 11).

The results of Duncan's multiple range test on the 1983 C S data are similar to those of the 1983 R S data. Nectar production (Figures 18 and 19) between species is not significant, but Altex is shown to produce significantly more nectar than Candle or Tobin.

Percent S C does differ between species and Altex and Andor had

significantly higher ($\alpha = 0.05$) concentrations than Candle or Tobin. No significant differences existed among cultivars within the same species.

Significantly higher ($\alpha = 0.05$) nectar samples with lower corresponding percent S C were also obtained between 0800 and 1000 hours than during the remaining times of the day.

Figures 20 and 21 show similar patterns of nectar production and percent SC as seen in Figures 14 and 15. However, Duncan's multiple range test shows that B. napus produces significantly more nectar than B. campestris in this case. Flowers are again seen to produce the most nectar of the lowest concentration between 0800 and 1000 hours.

Continuous Nectar Sampling Technique

Continuous nectar samples (CoS) were not analyzed. Instead, the means of the samples from each cultivar were added together over the course of the day to determine how much nectar a flower can produce in a day when the nectar is removed at regular intervals.

In 1982, Candle and Tobin each produced very little nectar (Table 12). The crop had very delicate flowers for unknown reasons which were hard to sample and accurate results were difficult to obtain. B. napus flowers were easier to sample and total production for 5 flowers ranged from 2.0 3 μl for Andor to 2.26 μl and 2.27 μl for Altex and Regent (Table 12). The percent S C is also given, where available, for the nectar sampled at each time period. The mean percent SC sugar concentration for CoS appears to be much lower, around 45%.

The 1983 CoS gives a more complete representation of total nectar

produced by Candle and Tobin as well as by Altex, Andor and Regent (Table 13). In general, B. napus cultivars, appear to produce more nectar than B. campestris cultivars, but some overlap in nectar production occurs between Tobin (2.94 µl) and Altex (2.73 µl). However, for the most part, B. napus can be said to produce more nectar than B. campestris. Mean percent S C remains around 45-46%.

Species comparisons show B. napus producing approximately 4 times the total amount of nectar compared to B. campestris (Table 14). In this experiment the mean percent S C is also considerably higher for B. campestris than for B. napus (see Chapter 4 for discussion of the significance of this data). This difference did not show up in the cultivar comparisons (Table 13).

Weather Correlations

Environmental factors affect plant performance (i.e. nectar production) and the extent to which they do so was examined for the five canola cultivars. Considerable variation occurred between sampling dates in the course of this study. However since fluctuation among daily environmental factors such as temperature, relative humidity, sunshine and wind speed and directions are a part of all field experiments, correlations will not be made between environmental factors and plant performance on a daily basis. The days when sampling was done were warm and sunny and therefore condusive to bee flight (See Appendices 3, 4 and 5 for daily air temperatures and percent relative humidities). Correlations were made between the nectar sampled and the percent S C with the temperature and relative humidity for the five canola cultivars over the entire observa-

vation period in 1982 and 1983.

The 1983 R S correlations show that nectar production and percent S C are significantly ($\alpha = 0.05$) and negatively correlated. Nectar production and temperature correlations are mainly non-significant but are all negatively correlated. Nectar production and percent R H together with percent S C and temperature are both significantly ($\alpha = 0.05$) and positively correlated for all cultivars. Percent S C. and percent R.H. are significantly ($\alpha = 0.05$) and negatively correlated for all cultivars.

In 1982, the correlations between nectar production and percent S C are generally negative and not significant ($\alpha = 0.05$) (Table 16). The correlations between nectar production and temperature and nectar production and percent R.H. are mostly positively correlated, but again these correlations are not strong and are non-significant ($\alpha = 0.05$). Percent S C and temperature are positively correlated, and the correlations for the cultivars are mostly significant with only Candle and Altex showing non-significant correlations with temperature ($\alpha = 0.05$). The relationship between percent S C of the various cultivars and percent R.H. was the most strongly negatively correlated relationship in 1982 (with the exception of Candle).

The 1983 C S correlations are similar to the 1983 R S correlations (Table 17) and will not be further discussed.

Correlations made for the species comparisons using both the 1983 R S and 1983 C S techniques show that nectar production for B. campestris and percent S C are not significantly correlated (Tables 18 and 19). However, the relationship between nectar production and percent S C is still negative

(Tables 18 and 19). Nectar production and temperature are positively correlated and insignificant ($\alpha = 0.05$). Nectar production and percent R H along with percent S C and temperature are positively related and are still insignificant. The relationship between percent S C and percent R H is significantly and negatively correlated ($\alpha = 0.05$).

The 1983 R S and the 1983 C S correlations for B. napus differ in regards to significance compared to those of B. campestris (Tables 18 and 19). The relationship between nectar production and percent S C is seen to be strongly significant in Table 18 and non-significant in Table 19. Similarly with percent R H. While the correlations between nectar production and temperature are significant ($\alpha = 0.05$) for B. campestris they are seen to be insignificant and negatively correlated for B. napus.

Pollen Collections

Pollen collection data shows that daily patterns of pollen collection by honey bees exist. These data also reveals the variation that can occur from day to day.

Preliminary pollen collection data (1982), despite small numerical values, indicates that honey bees collect more canola pollen before noon than in the afternoons (Table 20).

The 1983 pollen collection data basically confirms these results but also shows that if honey bees are collecting canola pollen, they do so primarily at 1000 and 1200 hrs., after which more pollen is collected from other plant sources (Table 21).

Pollen collection by honey bees also appears to vary considerably

from day to day. On the 28th of June 1983, for example, honey bees collected an average of 96% canola pollen compared to the 20th July 1983, when honey bees collected no canola pollen at all.

Honey Bee Behaviour

Cultivar Comparisons

Number of Canola Plants and Flowers Visited by Honey Bees in 1982.

In 1982, relatively few bees were observed foraging on canola. However, these preliminary results appear to be fairly representative of honey bee behaviour on canola. In 1982, a total of 17 and 16 bees were observed on Candle and Tobin respectively. These bees visited a total of 122 plants, 117 of which were visited solely for nectar collecting purposes (Table 22). Most of the flowers on these plants were visisted for nectar as well, only 4 being visited for pollen, and none being visited for both. A small number of flowers (15) had nectar removed by thieving (see Chapter 4). Honey bees visited a mean of 2.9 flowers/plant on Candle and 2.6 flowers/plant on Tobin. There does not appear to be any cultivar differences in foraging behavior, nor any daily patterns in foraging behaviour.

More honey bees were observed foraging on *B. napus* cultivars than on *B. campestris* cultivars in 1982 (Table 22). They visited more plants and subsequently more flowers. However, no plants or flowers were visited for pollen. Nearly half of the flowers visited for nectar had their contents thieved. Honey bees visited a mean of 2.6 flowers per plant on Altex, and 2.2 flowers per plant on Andor and Regent. These figures are slightly lower than those given for Candle and Tobin.

Time Spent Foraging by Honey Bees in 1982. Bees spent a mean of 0.36 min./plant and 0.30 min./plant on Candle and Tobin respectively (Table 24). Bees also spent a mean of 0.13 and 0.12 min./flower on Candle and Tobin respectively.

Bees on B. napus cultivars spent less time visiting plants; spending only 0.23-0.24 min./plant, and also took less time visiting each flower; spending 0.09-0.11 min./flower (Table 24).

No daily patterns of foraging time(s) were observed on any canola cultivar.

Number of Stigmas Crossed by Honey Bees while Foraging in 1982. Very few honey bees were observed carrying pollen during 1982 (Table 24). Most of the stigmas that were crossed by the bees occurred in the course of nectar collection. Only 2 stigmas were crossed during pollen collection (=2 flowers) on both Candle and Tobin, and no bees crossed stigmas on B. napus cultivars (Table 25).

No daily patterns of stigma crossing were observed for any canola cultivar. Total percent stigmas crossed for these cultivars ranged from 22-40% in 1982 (Table 24).

Number of Canola Plants and Flowers Visited by Honey Bees in 1983. In 1983, more honey bees were observed foraging on canola (Table 26). Most B. campestris plants were visited for nectar. Candle only had 13 plants visited for pollen while Tobin had 25. Very few flowers were visited for pollen. Candle had a total of 35/2007 (2%) flowers visited for pollen, and Tobin 94/2570 (4%). No flowers had the nectar thieved. Honey bees visited a mean of 2.7 flowers/plant on Candle and 2.5 flowers/

plant on Tobin. These figures are similar to those calculated in 1982.

Bees foraging on Altex, Andor and Regent in 1983 were found, for the first time, to visit a considerable number of plants for pollen and for pollen and nectar in addition to being visited for nectar only (Table 27). A number of flowers were also visited for pollen (47%), and several flowers were visited for both pollen and nectar (0.4%).

Honey bees visited a mean of 2.6 flowers/plant on Altex, 2.5 flowers/plant on Andor and 2.7 flowers/plant on Regent. These figures are slightly higher than those obtained in the 1982 data (Table 22) but are similar to those obtained for Candle and Tobin in 1983 (Table 26).

Time Spent Foraging by Honey Bees in 1983

Bees on Candle and Tobin visited a mean of 0.22 and 0.20 plants/min. respectively and a mean of 0.08 flower/min. each (Table 28). These figures are a little lower than those given for Candle and Tobin in 1982.

Bees on B. napus cultivars visited slightly more plants/min. (i.e. 0.26-0.31) and spent less time per flower (0.11-0.12 min./flower) than bees on B. campestris (Table 28). This is in direct contrast to the 1982 data.

No obvious differences in time spent foraging between species cultivars were observed. Also, no daily foraging patterns of bees were observed on any canola cultivars.

Numbers of Stigmas Crossed by Honey Bees while Foraging in 1983.

More honey bees were observed carrying canola pollen in 1983 than in 1982 (Table 29). Most of the stigmas that were crossed by bees on B. campestris cultivars still occurred during nectar collection (Table

28). However most of the stigmas crossed on Altex, Andor and Regent flowers occurred during pollen collection in 1983 (Table 28). Up to 54% of the stigmas crossed (on Andor) occurred during pollen collection and only 4-5% occurred during nectar collection (compared to 22-28% in 1982 (Table 24)).

No daily patterns of stigma crossing were observed for any canola cultivars. Total percent stigmas crossed for Candle and Tobin were 57 and 60% respectively (Table 29). Total percent stigmas crossed for Altex, Andor and Regent were 47, 58 and 50% respectively (Table 29). Andor had 8-11% more stigmas crossed than did Altex and Regent.

Species Comparisons 1983

Number of Canola Plants and Flowers Visited by Honey Bees

Results of this experiment are more similar to the 1982 cultivar comparison results than the 1983 cultivar comparisons than to the 1983 cultivar comparisons. Table 30 shows that no plants or flowers were visited by bees for pollen. Only B. napus flowers were observed being thieved by bees (16%).

No daily patterns of foraging habits were observed.

Time Spent Foraging by Honey Bees.

Bees foraging on B. campestris spent a mean of 0.24 min./plant and 0.10 min/flowers (Table 31). Bees foraging on B. napus spent a mean of 0.22 min/plant and 0.12 min/flower (Table 32). These results are between those found in the 1982 and 1983 cultivar comparisons. Bees spent more time foraging on B. napus flowers than on B. campestris

flowers and spend less time per B. napus plant.

No daily foraging patterns were observed.

Number of Stigmas Crossed by Honey Bees While Foraging

Table 32 indicates that all stigmas that were crossed were crossed during nectar collection while none were crossed during pollen collection. However, the total number of stigmas crossed (81%) was considerably higher for B. campestris than for B. napus (24%).

No daily patterns of stigmas crossings were observed.

Miscellaneous Observations

The flowers of B. campestris are considerably smaller and are clustered more tightly together than those of B. napus. Honey bees visiting B. campestris inflorescences are often able to walk from flower to flower without having to fly. However, B. napus flowers are larger and are spaced further apart on the terminal raceme and therefore bees have to fly from flower to flower while foraging.

Honey bees were rarely seen actively collecting pollen from canola cultivars. However, canola often produces copious amounts of pollen and it was common to see bees "coated" in pollen. Many bees were observed hovering over the canola plots "discarding" or brushing the pollen from their bodies with their 1st and 2nd pairs of legs.

While foraging for nectar, honey bees were seen probing the two inner nectaries with their proboscides. If one nectary provided nectar, bees would probe the second one. If the first inner nectary was dry,

bees would often fly to another flower without checking the remaining inner nectary for nectar. Bees were never observed probing the outer nectaries for nectar.

Should a bee visit 2 or 3 flowers containing no nectar it would often fly some distance away from that plant and continue probing new flowers for nectar. This behaviour was most commonly observed in the late afternoon when daily temperatures were "peaking" and the maximum number of honey bees were foraging.

Bee Counts and Insect Survey

Bee Counts

The number of honey bees counted on the plots were low for both 1982 and 1983.

In 1982, no bees were found on Candle, a total of 5 on Tobin, and 38 each for both Altex and Andor, with Regent having the highest number of bees at 46 (Table 33). These are the total number of bees found on the crop during the entire observation period.

In 1983, bee counts were somewhat higher (Table 34). *B. napus* appeared to attract more bees than did *B. campestris*, but the numbers were too small to consider the differences significant.

Species comparisons (1983) however, showed that more bees were counted on *B. campestris* than on *B. napus* (Table 35).

No obvious or consistent cultivar preferences by bees were observed.

Insect Survey

A large number of insects, in addition to honey bees, were observed on canola. Bombids and megachilids were observed collecting pollen

from canola throughout the course of the study.

The Syrphids were the most populous family of insects found on the crop, with a minimum of 4 species (unidentified) present throughout the observation period. Other Diptera included members of the Calliphoridae as well as numerous, small, unidentified species.

In addition, a number of Hemiptera, Homoptera and Lepidoptera (i.e. F. Peridae) were also present.

Finally, several Coleoptera were also found on the crop. These beetles were mostly injurious to the crop and included members of the Family Meloidae and Subfamily Alticinae.

Table 1. Percent main branch seed yield increases for canola cultivars (1982 and 1983).

	B. campestris		*B. napus*		
Year	Candle	Tobin	Altex	Andor	Regent
1982	336	196	689	591	371
1983	139	81	73	39	58

Table 2. Analysis of variance of nectar volumes obtained by random sampling canola cultivars (1983).

Source	df	ms	F	Significance[a]
Species	1	1.0389	10.81	*
Cultivar (Species	3	.0962		
[b]Cultivar (Species)	3	.0962	0.81	ns
Date (Species)	7	.9402	7.94	**
Date x Cultivar (Species)	11	.1184		
Species x Time	6	.2054	2.37	ns
Cultivar x Time (Species)	18	.0867		
Time	6	1.0192	6.01	**
[c]Cultivar x Time (Species)	18	.867	0.51	ns
Error	98	.1696		

a Significance level indicated by: ns = $P \geq 0.05$; * $P < 0.05$, ** $P < 0.01$

b. This term is repeated in the table. It is used as an error term for species, but the differences among cultivars within species are also of interest. For simplicity in reading the table it has been broken up into sections with the bottom line in each section being the appropriate error term to use for testing.

c. Similar to b.

Table 3. Analysis of variance of nectar sugar concentrations obtained by random sampling canola cultivars (1983).

Source	df	ms	F	Significance[a]
Species	1	445.5940	24.80	*
Cultivar (Species)	3	17.9650		
[b]Cultivar (Species)	3	17.9650	0.49	ns
Date (Species)	7	365.2204	9.87	**
Date x Cultivar (Species)	11	36.9885		
Species x Time	6	49.5688	1.04	ns
Cultivar x Time (Species)	18	47.4975		
Time	6	26167.9817	24.84	**
[c]Cultivar x Time (Species)	18	47.4975	0.54	ns
Error	95	87.2667		

a Significance level indicated by: ns = $P \geq 0.05$; * $P < 0.05$, ** $P < 0.01$

b This term is repeated in the Table. It is used as an error term for species, but the differences among cultivars within species are also of interest. For simplicity in reading the table it has been broken up into sections with the bottom line in each section being the appropriate error term to use for testing.

c Similar to b.

Table 4. Analysis of variance of nectar volumes obtained by random sampling canola species (1983).

Source	df	ms	F	Significance[a]
Species	1	2.9914	5.52	ns
[b]Date (Species)	3	0.5416	6.31	**
Time	5	0.1427	1.66	ns
Species x Time	5	0.1364	1.59	ns
Error	14	0.0858		

a Significance level is indicated by: ns = $P \geq 0.05$; *$P < 0.05$, **$P < 0.01$

b Error term for species

Table 5. Analysis of variance of nectar sugar concentrations obtained by random sampling canola species (1983).

Source	df	ms	F	Significance[a]
Species	1	72.2427	0.76	ns
[b]Date (Species)	3	94.8698	3.71	*
Time	5	213.3220	8.35	**
Species x Time	5	26.4834	1.04	ns
Error	14	25.5565		

a Significance level is indicated by: ns = $P \geq 0.05$; * $P < 0.05$, **$P < 0.01$

b Error term for species.

Table 6. Analysis of variance of nectar volumes obtained by cumulative sampling canola cultivars (1982).

Source	df	ms	F	Significance[a]
Species	1	38.3598	68.62	**
Cultivar (Species)	3	0.5588		
[b]Cultivar (Species)	3	0.5588	33.05	**
Date (Species)	3	4.1418	244.99	**
Date x Cultivar (Species)	4	0.0169		
Species x Time	4	0.2556	1.30	ns
Cultivar x Time (Species)	13	0.1960		
Time	5	0.5770	1.05	ns
[c]Cultivar x Time (Species)	13	0.1960	0.36	ns
Error	24	0.5473		

a Significance level is indicated by: ns = $P \geq 0.05$; * $P < 0.05$; ** $P < 0.01$

b This term is repeated in the Table. It is used as an error term for species, but the differences among cultivars within species are also of interest. For simplicity in reading the Table it has been broken up into sections with the bottom line in each section being the appropriate error term to use for testing.

c Similar to b.

Table 7. Analysis of variance of nectar sugar concentrations obtained by cumulative sampling canola cultivars (1982).

Source	df	ms	F	Significance[a]
Species	1	5572.8300	124.08	**
Cultivar (Species)	3	44.9130		
[b]Cultivar (Species)	3	44.9130	8.17	*
Date (Species)	3	879.5444	159.92	**
Date x Cultivar (Species)	4	5.5000		
Species x Time	4	183.9458	9.60	**
Cultivar x Time (Species)	12	19.1583		
Time	5	397.5388	27.22	**
[c]Cultivar x Time (Species)	12	19.1583	1.13	ns
Error	24	14.6056		

a Significance level is indicated by: ns = $P \geq 0.05$; * $P < 0.05$; ** $P < 0.01$

b This term is repeated in the Table. It is used as an error term for species, but the differences among cultivars within species are also of interest. For simplicity in reading the Table it has been broken up into sections with the bottom line in each section being the appropriate error term to use for testing.

c Similar to b.

Table 8. Analysis of variance of nectar volumes obtained by cumulative sampling canola cultivars (1983).

Source	df	ms	F	Significance[a]
Species	1	1.8700	4.95	ns
Cultivar (Species)	3	0.3778		
[b]Cultivar (Species)	3	0.3778	2.70	ns
Date (Species)	7	1.2056	8.61	**
Date x Cultivar (Species)	11	0.1400		
Species x Time	6	0.1182	2.06	ns
Cultivar x Time (Species)	18	.0575		
Time	6	1.1297	4.51	**
[c]Cultivar x Time (Species)	18	.0575	0.23	ns
Error	99	.2503		

a Significance level indicated by: ns = $P \geq 0.05$; * $P < 0.05$; ** $P < 0.01$.

b This term is repeated in the Table. It is used as an error term for species, but the differences among cultivars within species are also of interest. For simplicity in reading the table it has been broken up into sections with the bottom line in each section being the appropriate error term to use for testing.

c Similar to b.

Table 9. Analysis of variance of nectar sugar concentrations obtained by cumulative sampling canola cultivars (1983).

Source	df	ms	F	Significance[a]
Species	1	522.4399	47.60	**
Cultivar (Species)	3	10.9572		
[b]Cultivar (Species)	3	10.9572	0.70	ns
Date (Species)	7	484.3134	31.02	**
Date x Cultivar (Species)	11	15.6145		
Species x Time	6	39.1085	2.56	ns
Cultivar x Time (Species)	18	15.2868		
Time	6	2106.7345	41.96	**
[c]Cultivar x Time (Species	18	15.2868	0.30	ns
Error	98	50.2022		

a Significance level indicated by: ns = $P \geq 0.05$; * $P < 0.05$; ** $P < 0.01$.

b This term is repeated in the Table. It is used as an error term for species, but the differences among cultivar within species are also of interest. For simplicity in reading the table it has been broken up into sections with the bottom line in each section being the appropriate error term to use for testing.

c Similar to b.

Table 10. Analysis of variance of nectar volumes obtained by cumulative sampling canola species (1983).

Source	df	ms	F	Significance[a]
Species	1	3.3274	8.96	*
[b]Date (Species)	4	0.3715	6.61	**
Time	5	0.1985	3.53	*
Species x Time	5	0.1212	2.16	ns
Error	19	0.0562		

a Significance level is indicated by: ns = $P \geq 0.05$; *$P < 0.05$, ** $P < 0.01$.

b Error term for Species.

Table 11. Analysis of variance of nectar sugar concentrations obtained by cumulative sampling canola species (1983).

Source	df	ms	F	Significance[a]
Species	1	234.3538	2.55	ns
[b]Date (Species)	4	91.8218	2.01	ns
Time	5	227.3430	4.98	**
Species x Time	5	36.8664	0.81	ns
Error	19	45.6610		

a Significance level is indicated by: ns = $P \geq 0.05$; *$P < 0.05$; ** $P < 0.01$.

b Error term for Species.

Table 12. Continuous nectar samples and percent sugar concentrations for canola cultivars (1982). Nectar data presented in the table are additive over time for 5 flowers.

Cultivar		Time of day (hrs.)[a]						Mean of nectar production (µl) + S.E.	Mean % Sugar concentration + S.E.
		0800	1000	1200	1400	1600	1800		
Candle	nectar (µl)	0	0.25	0.35	0.40	0.45	0	0.11 ± 0.06	-
	% sugar	-	-	-	-	-	-		
Tobin	nectar (µl)	0.13	0.43	0.98	1.28	1.38		0.28 ± 0.06	50.0 ± 1.4
	% sugar	-	-	52.0	48.0	-	-		
Altex	nectar (µl)	-	1.16	1.49	1.81	2.11	2.26	0.45 ± 0.10	45.5 ± 4.9
	% sugar	-	25.3	-	50.3	57.0	-		
Andor	nectar (µl)	-	0.63	1.26	2.09	2.80	3.02	0.61 ± 0.09	41.7 ± 3.8
	% sugar	-	29.0	47.3	52.8	55.4	26.0		
Regent	nectar (µl)	-	0.44	0.79	1.52	2.02	2.27	0.46 ± 0.08	43.6 ± 5.3
	% sugar	-	26.3	50.5	50.5	51.7	56.0		

a Data are the means of nectar volumes and sugar concentrations over the observation period (s). Candle and Tobin were sampled on 21,26 July 1983 and Altex, Andor and Regent on 30 July and 2 August 1982.

Table 13. Continuous nectar samples and sugar concentrations for canola cultivars (1983). Nectar data presented in the table are additive over time for 5 flowers.

Cultivar		Time of day (hrs.)[a]							Mean nectar production (µl) + S.E.	Mean % Sugar concentration + S.E.
		0800	1000	1200	1400	1600	1800	2000		
Candle	nectar (µl)	0.63	1.15	1.60	1.97	2.26	2.56	2.56	0.41 ± 0.06	46.5 ± 3.00
	% sugar	37.3	42.20	60.5	49.4	41.0	70.0	-		
Tobin	nectar (µl)	0.70	1.53	2.16	2.68	2.94	2.94	2.94	0.54 ± 0.07	39.8 ± 3.76
	% sugar	28.8	36.00	37.6	51.0	63.3	-	-		
Altex	nectar (µl)	0.56	1.02	1.54	1.87	2.37	2.67	2.73	0.42 ± 0.05	50.9 ± 1.58
	% sugar	43.0	53.9	52.7	56.8	46.2	47.8	-		
Andor	nectar (µl)	0.42	0.96	1.65	2.26	2.85	3.30	3.52	0.54 ± 0.06	46.9 ± 1.57
	% sugar	39.0	46.6	52.6	47.8	43.9	48.1	36.3		
Regent	nectar (µl)	0.69	1.32	2.01	2.73	3.40	4.01	4.58	0.65 ± 0.05	48.4 ± 1.34
	% sugar	36.3	49.1	54.1	50.5	49.6	49.9	43.8		

a Data are the means of nectar volumes and sugar concentrations over the observation period (s). Candle and Tobin were on 18, 20, 21 and 22 July 1983 and Altex, Andor and Regent on 24, 25, 26, 27 and 28 July 1983.

Table 14. Continuous nectar samples and sugar concentration for canola species. (1983). Nectar data presented in the table are additive over time for 5 flowers.

Species		Time of Day (hrs.)[a] 0800	1000	1200	1400	1600	1800	mean nectar production (µl) + S.E.	mean % sugar concentration + S.E.
B. campestris	nectar (µl)	0.13	0.35	0.63	0.83	1.09	1.15	0.20 ± 0.03	55.1 ± 2.2
	% sugar	8.00	53.0	55.2	59.1	60.5	55.0		
B. napus	nectar (µl)	0.63	1.80	2.76	3.41	4.05	4.52	0.74 ± 0.05	46.0 ± 1.4
	% sugar	41.07	41.59	47.07	53.91	53.57	51.36		

a Data are the means of nectar production and sugar concentration over the observation period (s). B. campestris was sampled on 28 June, 5, 6 July 1983 and B. napus on 10, 12, 13 July 1983.

Table 15. Weather and nectar correlations in randomly sampled canola cultivars (1983).

Cultivar	Nectar (µl) sugar (%)	Nectar (µl) Temp. (°C)	Nectar (µl) R.H. (%)	Sugar (%) Temp. (°C)	Sugar (%) R.H. (%)
Candle	-0.8236**[a]	-0.3655[ns]	0.5551**	0.6482**	-0.6542**
n =	25	26	26	25	25
Tobin	-0.8625**	-0.4187*	0.5500**	0.6980**	-0.7132**
n =	25	26	26	25	25
Altex	-0.3652*	-0.3054[ns]	0.4710**	0.3263[ns]	-0.4287**
n =	33	33	33	33	33
Andor	-0.3839*	-0.0707[ns]	0.3589*	0.6876**	-0.7759**
n =	32	33	33	32	32
Regent	-0.7296**	-0.3284[ns]	0.4881**	0.7208**	-0.7528**
n =	33	33	33	33	33

a Significance level indicated by: ns = $P \geq 0.05$; * $P < 0.05$; ** $P < 0.01$.

Table 16. Weather and nectar correlations in cumulatively sampled canola cultivars (1982).

Cultivar	Nectar (µl) Sugar (%)	Nectar (µl) Temp. (°C)	Nectar (µl) R.H. (%)	Sugar (%) Temp. (°C)	Sugar (%) R.H. (%)
Candle	0.0801[ns a]	0.5143[ns]	0.0033[ns]	0.4174[ns]	-0.5436[ns]
n =	13	14	14	13	13
Tobin	-0.1272[ns]	0.2950[ns]	0.4704[ns]	0.5438*	-0.6066*
n =	14	14	14	14	14
Altex	-0.4603[ns]	0.1530[ns]	0.1754[ns]	0.6754[ns]	-0.8306**
n =	10	10	10	10	10
Andor	-0.3372[ns]	-0.1143[ns]	0.1794[ns]	0.7520*	-0.8191**
n =	10	10	10	10	10
Regent	-0.1296[ns]	0.4357[ns]	-0.0500[ns]	0.7267*	-0.8037**
n =	10	10	10	10	10

a Significance level indicated by: ns = $P \geq 0.05$; *$P < 0.05$; **$P < 0.01$.

Table 17. Weather and nectar correlations in cumulatively sampled canola cultivars (1983).

Cultivar	Nectar (µl) Sugar (%)	Nectar (µl) Temp. (°C)	Nectar (µl) R.H. (%)	Sugar (%) Temp (°C)	Sugar (%) R.H. (%)
Candle	-0.7984**[a]	-0.3382[ns]	0.4900**	0.7413**	-0.6985**
n =	26	27	27	26	26
Tobin	-0.7908**	-0.2395[ns]	0.4993**	0.6092**	-0.7094**
n =	26	26	26	26	26
Altex	-0.6878**	-0.2825[ns]	0.1966**	0.6754**	-0.7947**
n =	33	33	33	33	33
Andor	-0.8032**	-0.3494*	0.5494**	0.6376**	-0.773**
n =	33	33	33	33	33
Regent	-0.8077**	-0.4981**	0.7306**	0.7217**	-0.7967**
n =	33	33	33	33	33

a Significance level indicated by: ns = $P \geq 0.05$; * $P < 0.05$; ** = $P < 0.01$

Table 18. Weather and nectar correlations in randomly sampled canola species (1983).

Species	Nectar (µl) Sugar (%)	Nectar (µl) Temp (°C)	Nectar (µl) R.H. (%)	Sugar (%) Temp (°C)	Sugar (%) R.H. (%)
B. campestris	-0.5279^{ns}[a]	0.6043*	0.2317^{ns}	0.0135^{ns}	-0.6391*
n =	12	12	12	12	12
B. napus	-0.7385**	-0.3731^{ns}	0.7851**	0.7297**	-0.7705**
n =	17	17	17	17	17

a Significance level indicated by: ns = $P \geq 0.05$; * = $P < 0.05$; ** = $P < 0.01$.

Table 19. Weather and nectar correlations in cumulatively sampled canola species (1983).

Species	Nectar (µl) Sugar (%)	Nectar (µl) Temp (°C)	Nectar (µl) R.H. (%)	Sugar (%) Temp (°C)	Sugar (%) R.H. (%)
B. campestris	-0.3123^{ns}[a]	0.5393*	0.2003^{ns}	0.0141^{ns}	-0.5268*
n =	17	17	17	17	17
B. napus	-0.4664^{ns}	-0.3027^{ns}	0.7210**	0.5809*	-0.4634^{ns}
n =	18	18	17	18	17

a Significance level indicated by: ns = $P \geq 0.05$; *=$P < 0.05$; **= $P < 0.01$.

Table 20. Wet weights of pollen samples (1982).

Date	Time of Day (hrs)	Total Weight (g)	Canola Pollen Weight (g)	Other Pollen Weight (g)		% Canola Pollen Collected	% Canola Pollen of Total Canola Pollen Collected
21 July							
	1000	0[a]	0	0		0	0
	1200	0.375	0.225	0.150		60	54
	1400	1.525	0.110	1.415		7	26
	1600	3.000	0.060	2.940		2	14
	1800	2.675	0.025	2.650		1	6
	TOTAL	7.575	0.420	7.155	$\bar{X}$	17.50	100
28 July							
	1000	0	0	0		0	0
	1200	2.775	0.060	2.715		2	55
	1400	4.000	0.030	3.970		0.75	28
	1600	2.900	0.019	2.881		0.66	17
	1800	0	0	0		0	0
	TOTAL	9.675	0.109	9.566	$\bar{X}$	1.14	100
30 July							
	1000	0	0	0		0	0
	1200	2.200	0.175	2.025		8	39
	1400	6.850	0.210	6.640		3	47
	1600	4.900	0.050	4.850		1	11
	1800	1.901	0.015	1.886		0.76	3
	TOTAL	15.851	0.450	15.401	$\bar{X}$	3.19	100
2 Aug.							
	1000	0	0	0		0	0
	1200	1.900	0.235	1.665		12	76
	1400	5.450	0.060	5.390		1	19
	1600	4.825	0.015	4.810		0.30	5
	1800	2.000	0	2.000		0	0
	TOTAL	14.175	0.310	13.865	$\bar{X}$	3.33	100

a values presented are the means of two hives

Table 21. Dry weights of pollen samples (1983).

Date	Time of Day (hrs)	Total Weight (g)	Canola Pollen Weight (g)	Other Pollen Weight (g)		% Canola Pollen Collected	% Canola Pollen of Total Canola Pollen Collected
28 June	1000	11.7665[a]	11.5261	0.2403		98	22
	1200	14.5928	14.3304	0.3624		98	27
	1400	14.5928	13.7798	0.4186		97	26
	1600	8.9212	8.4936	0.4276		95	16
	1800	5.5060	4.9411	0.5649		90	9
	TOTAL	54.9848	53.0710	1.9138	$\bar{X}$	96	100
5 July	1000	0.9044	0.8931	0.0113		99	3
	1200	13.4545	12.7432	0.7113		95	38
	1400	11.9875	8.9008	3.0867		74	27
	1600	13.3632	6.4907	6.8725		49	20
	1800	16.3480	4.1108	12.2372		25	12
	TOTAL	56.0576	33.1386	22.9190	$\bar{X}$	68	100
6 July	1000	6.9381	6.5941	0.3440		90	25
	1200	5.8348	4.0252	1.8096		63	15
	1400	15.3943	8.0206	7.3737		50	31
	1600	15.6071	4.3525	11.2546		25	17
	1800	22.8074	3.1093	19.6981		12	12
	TOTAL	66.5817	26.1017	40.4800	$\bar{X}$	48	100
10 July	1000	1.8345	0	1.8345		0	0
	1200	11.7514	2.7171	9.0343		23	50
	1400	13.2398	2.1814	11.0584		16	40
	1600	3.5544	0.2578	3.2966		7	5
	1800	5.0742	0.3185	4.7557		6	6
	TOTAL	35.4543	5.4748	29.9795	$\bar{X}$	8	101
12 July	1000	2.0890	1.6845	0.4045		81	12
	1200	11.8382	4.5150	7.3232		38	33
	1400	18.3082	4.1800	14.1282		22	31
	1600	10.7675	1.5335	9.2340		14	11
	1800	14.8627	1.5905	13.2722		11	12
	TOTAL	57.8656	13.5035	44.3621	$\bar{X}$	33	99

a values presented are the means of two hives.

Table 21. Continued

Date	Time of Day (hrs)	Total Weight (g)	Canola Pollen Weight (g)	Other Pollen Weight (g)		% Canola Pollen Collected	% Canola Pollen of Total Canola Pollen Collected
13 July	1000	0.9189	0.7242	0.1947		79	6
	1200	5.1985	2.9032	2.2953		56	25
	1400	11.7206	3.7429	7.9777		32	32
	1600	7.5252	2.3525	5.1727		31	20
	1800	8.5364	2.0466	6.4898		24	17
	TOTAL	33.8996	11.7694	22.1302	$\bar{X}$	37	100
20 July	1000	0.2950	0	0.2950		0	0
	1200	7.7956	0	7.7956		0	0
	1400	7.8592	0	7.8592		0	0
	1600	3.1671	0	3.1671		0	0
	1800	3.1393	0	3.1393		0	0
	2000	3.6683	0	3.6683		0	0
	TOTAL	25.9245	0	25.9245	$\bar{X}$	0	0
21 July	1000	0.1215	0	0.1215		0	0
	1200	6.2464	0.1749	6.0715		3	55
	1400	6.1518	0.1006	6.0512		2	31
	1600	3.3486	0.0445	3.3041		1	14
	1800	3.9481	0	3.9481		0	0
	2000	5.6446	0	5.6446		0	0
	TOTAL	25.4610	0.3200	25.6446	$\bar{X}$	0	100
22 July	1000	0.2220	0.0440	0.1780		20	13
	1200	1.65 85	0.1277	1.5308		8	38
	1400	0.9249	0.0937	0.8312		10	28
	1600	0.2533	0.0688	0.1845		27	21
	1800	0	0	0		0	0
	2000	0	0	0		0	0
	TOTAL	3.0587	0.3342	2.7245	$\bar{X}$	0	100
26 July	1000	0.8930	0.8930	0		100	43
	1200	0.7245	0.6744	0.0501		93	32
	1400	0.1819	0.1819	0		100	9
	1600	0.0808	0.0808	0		100	4
	1800	0.2026	0.1167	0.0859		58	6
	2000	0.1885	0.1435	0.0450		76	7
	TOTAL	2.2713	2.0903	0.1810	$\bar{X}$	88	101

Table 21. Continued

Date	Time of Day (hrs)	Total Weight (g)	Canola Pollen Weight (g)	Other Pollen Weight (g)		% Canola Pollen Collected	% Canola Pollen of Total Canola Pollen Collected
27 July	1000	1.0640	0.8523	0.2117		80	25
	1200	1.3757	1.0065	0.3692		73	29
	1400	0.9255	0.6803	0.2452		74	20
	1600	0.5571	0.3377	0.2194		61	10
	1800	0.7139	0.3141	0.3998		44	9
	2000	0.5426	0.2617	0.2809		48	8
	TOTAL	5.1788	3.4526	1.7262	$\bar{X}$	64	101
28 July	1000	0.2969	0.2969	0		100	13
	1200	0.8487	0.7081	0.1406		83	32
	1400	0.4649	0.3668	0.0981		79	17
	1600	0.3728	0.3316	0.0412		89	15
	1800	0.3837	0.2791	0.1046		71	13
	2000	0.3390	0.2124	0.1266		63	10
	TOTAL	2.7060	2.1949	0.5111	$\bar{X}$	81	100

Table 22. Numbers of B. campestris plants and flowers visited by honey bees for nectar, pollen or both (1982).

CULTIVAR	TIME OF DAY (hrs)	NO. BEES OBSERVED[a]	TOTAL NO. PLANTS VISITED	NO. PLANTS VISITED FOR: NECTAR ONLY	POLLEN ONLY	BOTH	TOTAL NO. FLOWERS VISITED	NO. FLOWERS VISITED FOR NECTAR ONLY TRADITIONAL	THIEVED[b]	POLLEN ONLY	BOTH	MEAN NO. FLOWERS VISITED/PLANT
Candle	0800	1	1	1	0	0	2	2	0	0	0	2.0
	1000	4	13	13	0	0	56	56	0	0	0	4.3
	1200	2	2	2	0	0	5	5	0	0	0	2.5
	1400	4	15	13	2	0	40	38	0	2	0	2.7
	1600	4	15	15	0	0	47	37	10	0	0	3.1
	1800	2	9	8	0	1	23	21	2	0	0	2.6
	TOTAL	17	55	52	2	1	173	159	12	2	0	$\bar{X}$ 2.9
Tobin	0800	3	13	11	0	2	31	27	2	2	0	2.4
	1000	4	17	17	0	0	34	33	1	0	0	2.0
	1200	4	13	13	0	0	37	37	0	0	0	2.8
	1400	3	13	13	0	0	46	46	0	0	0	3.5
	1600	0	0	0	0	0	0	0	0	0	0	0
	1800	2	11	11	0	0	26	26	0	0	0	2.4
	TOTAL	16	67	65	0	2	154	169	3	2	0	$\bar{X}$ 2.6

a Observations were taken on the 21, 26 July 1982.

Table 23. Numbers of B. napus plants visited by honey bees for nectar, pollen or both (1982).

CULTIVAR	TIME OF DAY (hrs)	NO. BEES OBSERVED[a]	TOTAL NO. PLANTS VISITED	NO. PLANTS VISITED FOR: NECTAR ONLY	POLLEN ONLY	BOTH	TOTAL NO. FLOWERS VISITED	NO. FLOWERS VISITED FOR NECTAR ONLY TRADITIONAL	THIEVED[b]	POLLEN ONLY	BOTH	MEAN NO. FLOWERS VISITED/PLANT
Altex	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	6	27	27	0	0	78	65	13	0	0	2.9
	1200	16	27	27	0	0	110	63	47	0	0	2.3
	1400	10	30	30	0	0	87	61	26	0	0	2.9
	1600	13	54	54	0	0	141	91	50	0	0	2.6
	1800	4	15	15	0	0	32	0	32	0	0	2.1
	TOTAL	49	173	173	0	0	448	280	168	0	0	2.6
Andor	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	12	47	47	0	0	105	62	43	0	0	2.2
	1200	15	68	68	0	0	157	90	67	0	0	2.3
	1400	12	42	42	0	0	103	16	87	0	0	2.5
	1600	6	27	27	0	0	51	42	9	0	0	1.9
	1800	13	49	49	0	0	107	51	56	0	0	2.2
	TOTAL	58	233	233	0	0	523	261	262	0	0	2.2
Regent	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	11	48	48	0	0	99	51	48	0	0	2.1
	1200	14	52	52	0	0	111	45	66	0	0	2.1
	1400	11	42	42	0	0	88	32	56	0	0	2.1
	1600	13	44	44	0	0	79	14	65	0	0	1.8
	1800	11	29	29	0	0	82	62	20	0	0	2.8
	TOTAL	60	215	215	0	0	459	204	255	0	0	2.2

a Observations were taken on the 30 July and 2. Aug. 1983.

Table 24. Time spent by honey bees foraging on B. campestris and B. napus (1982).

Cultivar	Time of Day (hrs)	No. Bees Observed[a]	Total Time Observed (sec.)	Mean No. Plants Visited/Min.	Mean Time (Min.) Spent /Flower
Candle	0800	1	25	0.42	0.21
	1000	4	294	0.38	0.09
	1200	2	30	0.25	0.10
	1400	4	231	0.26	0.10
	1600	4	360	0.40	0.13
	1800	2	230	0.43	0.17
	TOTAL	17	1170	$\bar{X}$ 0.36	$\bar{X}$ 0.13
Tobin	0800	3	283	0.36	0.15
	1000	4	300	0.29	0.15
	1200	4	185	0.24	0.08
	1400	3	200	0.27	0.07
	1600	0	0	0	0
	1800	2	230	0.35	0.15
	TOTAL	16	1198	$\bar{X}$ 0.30	$\bar{X}$ 0.12
Altex	0800	0	0	0	0
	1000	6	453	0.28	0.10
	1200	16	623	0.22	0.10
	1400	10	427	0.24	0.08
	1600	13	787	0.24	0.09
	1800	4	182	0.20	0.09
	TOTAL	49	2472	$\bar{X}$ 0.24	$\bar{X}$ 0.09
Andor	0800	0	0	0	0
	1000	12	660	0.23	0.10
	1200	15	898	0.72	0.10
	1400	12	627	0.25	0.10
	1600	6	290	0.18	0.09
	1800	13	748	0.25	0.12
	TOTAL	58	3223	$\bar{X}$ 0.23	$\bar{X}$ 0.10
Regent	0800	0	0	0	0
	1000	11	621	0.22	0.10
	1200	14	641	0.21	0.10
	1400	11	586	0.23	0.11
	1600	13	701	0.27	0.15
	1800	11	481	0.28	0.10
	TOTAL	60	3030	$\bar{X}$ 0.24	$\bar{X}$ 0.11

a Observations for B. campestris were taken on the 21, 26 July 1982 and on the 30 July, 2 August 1982.

Table 25. Numbers and percentages of stigmas crossed by honey bees during nectar and pollen collection (1982).

Cultivar	Time of Day (hrs)	No. Bees Observed[a]	No. Bees Carrying Pollen	Total No. Flowers Visited	No. and % Stigmas Crossed During: Pollen Collection	Nectar Collection	Total No. and % Stigmas Crossed
Candle	0800	1	0	2	0	1(50)	1(50)
	1000	4	0	56	0	25(45)	25(45)
	1200	2	0	5	0	2(40)	2(40)
	1400	4	1	40	2 (5)	6(15)	8(20)
	1600	4	0	47	0	5(11)	5(11)
	1800	2	1	23	0	7(30)	7(30)
	TOTAL +/or $\bar{X}$	17	2	173	2 (0.71)	46(27)	48(28)
Tobin	0800	3	1	31	2 (6)	17(55)	19(61)
	1000	4	0	34	0	12(35)	12(35)
	1200	4	0	37	0	16(16)	16(16)
	1400	3	0	46	0	4(9)	4(9)
	1600	0	0	0	0	0(0)	0(0)
	1800	2	0	26	0	9(35)	9(35)
	TOTAL +/or $\bar{X}$	16	0	154	2 (1)	58(38)	60(40)
Altex	0800	0	0	0	0	0(0)	0(0)
	1000	6	0	78	0	7(9)	7(9)
	1200	16	1	110	0	20(18)	20(18)
	1400	10	1	87	0	42(48)	42(48)
	1600	13	1	141	0	51(36)	51(36)
	1800	4	0	32	0	0	0(0)
	TOTAL +/or $\bar{X}$	49	3	448	0	120(22)	120(22)
Andor	0800	0	0	0	0	0(0)	0(0)
	1000	12	1	105	0	14(14)	15(14)
	1200	15	0	157	0	32(20)	32(20)
	1400	12	0	103	0	9(9)	9(9)
	1600	6	0	51	0	35(67)	35(67)
	1800	13	1	107	0	30(28)	30(28)
	TOTAL +/or $\bar{X}$	58	2	523	0	121(28)	121(28)
Regent	0800	0	0	0	0	0(0)	0(0)
	1000	11	2	99	0	10(10)	10(10)
	1200	14	0	111	0	24(22)	24(22)
	1400	11	1	88	0	20(23)	20(23)
	1600	13	0	79	0	31(39)	31(39)
	1800	11	1	82	0	30(37)	30(37)
	TOTAL +/or $\bar{X}$	60	4	459	0	115(26)	115(26)

a Observations for B. campestris were taken on the 21, 26 July 1983, and for B. napus on the 30 July, 2 August 1983.

Table 26. Numbers of B. campestris plants and flowers visited by honey bees for nectar, pollen, or both (1983).

CULTIVAR	TIME OF DAY(hrs.)	NO. BEES OBSERVED	TOTAL NO. PLANTS VISITED	NO.PLANTS VISITED FOR: NECTAR ONLY	POLLEN ONLY	BOTH	TOTAL NO. FLOWERS VISITED	NO. FLOWERS VISITED FOR : NECTAR ONLY TRADITIONAL	THIEVED[b]	POLLEN ONLY	BOTH	MEAN NO. FLOWERS VISITED/PLANT
Candle	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	18	89	76	13	0	253	218	0	35	0	2.8
	1200	18	134	134	0	0	305	305	0	0	0	2.3
	1400	21	115	115	0	0	361	361	0	0	0	3.1
	1600	28	188	188	0	0	548	548	0	0	0	2.9
	1800	27	166	166	0	0	473	473	0	0	0	2.8
	2000	5	30	30	0	0	67	67	0	0	0	2.2
	TOTAL	117	722	709	0	0	2007	1972	0	35	0	$\bar{X}$ 2.7
Tobin	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	19	168	157	11	0	373	338	0	35	0	2.2
	1200	27	177	170	3	4	486	463	0	23	0	2.7
	1400	27	169	163	6	0	476	458	0	18	0	2.8
	1600	35	203	201	2	0	560	550	0	10	0	2.7
	1800	30	223	218	3	2	640	632	0	8	0	2.9
	2000	4	18	18	0	0	35	35	0	0	0	1.9
	TOTAL	142	958	927	25	6	2570	2476	0	94	0	$\bar{X}$ 2.5

[a] Observations were taken on 18,20, 21 and 22 July 1983.

[b] Thieving refers to nectar collected from between the petals and sepals of the flower.

Table 27. Numbers of B. napus plants and flowers visited by honey bees for nectar, pollen or both (1983).

CULTIVAR	TIME OF DAY (hrs)	NO. BEES OBSERVED[a]	TOTAL NO. PLANTS VISITED	NO. PLANTS VISITED FOR: NECTAR ONLY	POLLEN ONLY	BOTH	TOTAL NO. FLOWERS VISITED	NO. FLOWERS VISITED FOR NECTAR ONLY TRADITIONAL	THIEVED[b]	POLLEN ONLY	BOTH	MEAN NO. FLOWERS VISITED/PLANT
Altex	0800	12	43	21	22	0	112	30	27	55	0	2.6
	1000	33	147	67	79	1	448	91	87	269	1	3.0
	1200	27	152	52	98	2	412	35	89	288	0	2.7
	1400	22	95	59	29	6	225	62	75	80	8	2.4
	1600	31	137	115	19	4	343	58	229	49	7	2.5
	1800	33	142	80	59	3	366	62	181	133	0	2.6
	2000	29	155	103	49	3	344	65	177	101	1	2.2
	TOTAL	187	871	497	355	19	2250	393	865	975	17	$\bar{X}$ 2.6
Andor	0800	12	65	20	42	3	165	17	28	110	1	2.5
	1000	34	174	38	32	4	446	35	66	343	2	2.6
	1200	27	149	56	88	5	420	46	86	288	0	2.8
	1400	24	131	49	81	1	335	36	98	200	1	2.6
	1600	33	162	109	50	3	388	144	107	136	0	2.4
	1800	35	160	102	54	4	411	59	189	163	1	2.6
	2000	27	166	135	31	0	360	125	157	78	0	2.2
	TOTAL	192	1007	509	478	20	2525	462	731	1327	5	$\bar{X}$ 2.5
Regent	0800	12	41	16	25	0	114	5	51	58	0	2.8
	1000	33	144	82	61	1	372	62	113	197	0	2.6
	1200	27	138	50	86	2	360	23	96	241	0	2.6
	1400	30	125	85	37	3	328	50	156	119	3	2.6
	1600	32	100	67	30	3	306	85	123	98	0	3.1
	1800	35	134	76	58	0	354	86	113	155	0	2.6
	2000	31	157	99	50	8	380	94	139	145	2	2.4
	TOTAL	200	839	475	347	17	2214	405	1013	1013	5	$\bar{X}$ 2.7

a Observations were taken on 25, 26, 27, 28 July.

b Thieving refers to nectar collected from between the petals and sepals of the flowers.

Table 28. Time spent by honey bees foraging on B. campestris and B. napus (1983).

Cultivar	Time of Day (hrs.)	No. Bees Observed[a]	Total Time Observed (Sec.)	Mean No. Plants Visited/Min.	Mean No. Flowers Visited/Min.
Candle	0800	0	0	0	0
	1000	18	1522	0.29	0.10
	1200	18	1354	0.17	0.07
	1400	21	1606	0.23	0.07
	1600	28	2471	0.22	0.08
	1800	27	1906	0.19	0.07
	2000	25	343	0.19	0.09
	TOTAL	117	9202	$\bar{X}$ 0.22	$\bar{X}$ 0.08
Tobin	0800	0	0	0	0
	1000	19	1973	0.20	0.09
	1200	27	2326	0.22	0.08
	1400	27	2046	0.20	0.07
	1600	35	2517	0.21	0.07
	1800	30	2705	0.20	0.07
	2000	4	170	0.16	0.08
	TOTAL	142	11737	$\bar{X}$ 0.20	$\bar{X}$ 0.08
Altex	0800	12	802	0.31	0.12
	1000	33	2723	0.31	0.10
	1200	27	2415	0.26	0.10
	1400	22	1566	0.27	0.12
	1600	31	2420	0.29	0.12
	1800	33	2639	0.31	0.12
	2000	29	2524	0.27	0.12
	TOTAL	187	12565	$\bar{X}$ 0.29	$\bar{X}$ 0.11
Andor	0800	12	950	0.24	0.10
	1000	34	2435	0.23	0.09
	1200	27	2372	0.27	0.09
	1400	24	2153	0.27	0.11
	1600	33	2525	0.26	0.11
	1800	35	3029	0.32	0.12
	2000	27	2527	0.25	0.12
	TOTAL	192	15991	$\bar{X}$ 0.26	$\bar{X}$ 0.11
Regent	0800	12	892	0.36	0.13
	1000	33	2318	0.27	0.10
	1200	27	2187	0.26	0.10
	1400	30	2366	0.32	0.12
	1600	32	2104	0.35	0.11
	1800	35	2687	0.33	0.13
	2000	31	2702	0.29	0.12
	TOTAL	200	15316	$\bar{X}$ 0.31	$\bar{X}$ 0.12

a Observations on B. campestris were taken on 18, 20, 21, 22 July 1983, and on B. napus on 25, 26, 27, 28 July 1983.

Table 29. Numbers and percentages of stigmas crossed by honey bees during nectar and pollen collection (1983).

Cultivar	Time of Day (hrs.)	No. Bees Observed[a]	No. Bees Carrying Pollen	Total No. Flowers Visited	No. + Percent Stigmas Crossed During: Pollen Collection	Nectar Collection	Total No. + Percent Stigmas Crossed
Candle	0800	0	0	0	0(0)	0(0)	0(0)
	1000	18	8	253	35(14)	158(62)	193(76)
	1200	18	1	305	0(0)	193(63)	193(63)
	1400	21	5	361	0(0)	220(61)	220(61)
	1600	28	3	548	0(0)	311(57)	311(57)
	1800	27	2	473	0(0)	136(29)	136(29)
	2000	5	4	67	0(0)	0(0)	0(0)
	TOTAL	117	23	2007	35(2)	1018(54)	1053(57)
Tobin	0800		0	0	0(0)	0(0)	0(0)
	1000	19	7	373	35(9)	217(58)	252(67)
	1200	27	14	486	23(5)	307(63)	330(68)
	1400	27	11	476	18(4)	254(53)	272(57)
	1600	35	7	560	10(2)	337(60)	347(62)
	1800	30	4	640	8(1)	296(46)	204(47)
	2000	4	0	35	0(0)	21(60)	21(60)
	TOTAL	142	43	2570	94(4)	1432(57)	1526(60)
Altex	0800	12	8	112	55(49)	13(12)	68(61)
	1000	83	20	448	269(60)	6(1)	275(61)
	1200	27	17	412	288(70)	9(2)	297(72)
	1400	22	12	225	80(36)	25(11)	105(47)
	1600	31	8	343	49(14)	3(1)	52(15)
	1800	33	13	366	133(36)	15(4)	148(40)
	2000	29	12	344	101(29)	23(7)	124(36)
	TOTAL	187	90	2250	975(42)	94(5)	1069(47)
Andor	0800	12	9	165	119(72)	13(8)	132(80)
	1000	34	28	446	343(77)	19(4)	362(81)
	1200	27	17	420	288(69)	14(3)	302(72)
	1400	24	15	335	200(60)	3(1)	203(61)
	1600	33	15	388	136(35)	15(4)	152(39)
	1800	35	14	411	163(40)	23(6)	186(46)
	2000	27	10	360	78(22)	44(5)	122(27)
	TOTAL	192	108	2525	1327(54)	132(4)	1459(58)
Regent	0800	12	8	114	58(51)	2(2)	60(53)
	1000	33	22	372	197(53)	10(3)	207(56)
	1200	27	19	360	241(67)	2(1)	243(68)
	1400	30	17	328	119(36)	6(2)	125(38)
	1600	32	9	306	98(32)	9(3)	107(35)
	1800	35	17	354	155(44)	35(10)	190(54)
	2000	31	15	380	145(38)	38(10)	183(48)
	TOTAL	200	109	2214	1013(46)	102(4)	115(50)

[a] Observations on B. campestris were taken on 18,20,21,22 July 1983, and on 25,26,27, 28, July 1983 for B. napus.

Table 30. Numbers of Canola plants and flowers visited by honey bees for nectar, pollen or both (1983).

SPECIES	TIME OF DAY (hrs)	NO. BEES OBSERVED[a]	TOTAL NO. PLANTS VISITED	NO. PLANTS VISITED FOR: NECTAR ONLY	POLLEN ONLY	BOTH	TOTAL NO. FLOWERS VISITED	NO. FLOWERS VISITED FOR NECTAR ONLY TRADITIONAL	THIEVED[b]	POLLEN ONLY	BOTH	MEAN NO. FLOWERS VISITED/PLANT
B. campestris	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	61	311	311	0	0	739	739	0	0	0	2.4
	1200	61	294	294	0	0	751	751	0	0	0	2.6
	1400	60	327	327	0	0	814	814	0	0	0	2.5
	1600	60	333	333	0	0	727	727	0	0	0	2.2
	1800	51	253	253	0	0	560	560	0	0	0	2.2
	TOTAL	293	1518	1518	0	0	3591	2591	0	0	0	$\bar{X}$ 2.4
B. napus	0800	0	0	0	0	0	0	0	0	0	0	0
	1000	40	200	200	0	0	401	333	68	0	0	2.0
	1200	54	333	333	0	0	637	560	77	0	0	1.9
	1400	28	137	137	0	0	246	174	72	0	0	1.8
	1600	27	282	282	0	0	573	453	120	0	0	2.0
	1800	92	480	480	0	0	904	796	108	0	0	1.9
	TOTAL	271	1432	1432	0	0	2761	2316	445	0	0	$\bar{X}$ 1.9

a Observations for B. campestris were taken on the 28 June, 5, 6 July 1983, and for B. napus on 10, 12, 13 July 1983.

b Thieving refers to the nectar collected from between the petals and sepals of the flower.

Table 31. Time spent by honey bees foraging on canola (1983).

SPECIES	TIME OF DAY (hrs.)	NO. BEES OBSERVED[a]	TOTAL TIME OBSERVED (SEC.)	MEAN NO. PLANTS VISITED/MIN.	MEAN NO. FLOWERS VISITED/MIN.
B. campestris	0800	0	0	0	0
	1000	61	4395	0.24	0.10
	1200	61	4618	0.26	0.10
	1400	60	4674	0.24	0.10
	1600	60	4197	0.21	0.10
	1800	51	3450	0.23	0.10
	TOTAL	293	21334	$\bar{X}$ 0.24	$\bar{X}$ 0.10
B. napus	0800	0	0	0	0
	1000	40	2923	0.24	0.12
	1200	54	4570	0.23	0.12
	1400	28	1788	0.22	0.12
	1600	27	3729	0.22	0.11
	1800	92	5941	0.21	0.11
	TOTAL	271	19001	$\bar{X}$ 0.22	$\bar{X}$ 0.12

a Observation for B. campestris were taken on the 28 June, 5, 6 July 1983, and for B. napus on 10, 12, 13 July 1983.

Table 32. Numbers and percentages of stigmas crossed by honey bees during nectar and pollen collection (1983).

SPECIES	TIME OF DAY (hrs.)	NO. BEES OBSERVED[a]	NO. BEES CARRYING POLLEN	TOTAL NO. FLOWERS VISITED	NO. + PERCENT STIGMAS CROSSED DURING: POLLEN COLLECTION	NECTAR COLLECTION	TOTAL NO. + % STIGMAS CROSSED
B. campestris							
	0800	0	0	0	0	0	0
	1000	61	22	739	0	572 (77)	572 (77)
	1200	61	32	751	0	603 (80)	603 (80)
	1400	60	21	814	0	673 (83)	673 (83)
	1600	60	23	727	0	560 (77)	560 (77)
	1800	51	9	560	0	484 (86)	484 (86)
	TOTAL	293	107	3591	0	2892 (81)	2892 (81)
B. napus							
	0800	0	0	0	0	0	0
	1000	40	3	401	0	137 (34)	137 (34)
	1200	54	8	637	0	224 (35)	224 (35)
	1400	28	0	246	0	26 (11)	26 (11)
	1600	27	2	573	0	98 (17)	98 (17)
	1800	92	5	904	0	167 (18)	167 (18)
	TOTAL	271	18	2761	0	652 (24)	652 (24)

a Observations on B. campestris were taken on 28 June, 5, 6, July 1983, and on B. napus on 10, 12, 13, July 1983.

Table 33. Total numbers of honey bees present on canola cultivars (1982).

	TIME OF DAY (hrs.)						
CULTIVAR	0800	1000	1200	1400	1600	1800	TOTAL[a]
CANDLE	0	0	0	0	0	0	0
TOBIN	0	2	0	2	2	1	5
ALTEX	0	0	13	12	8	5	38
ANDOR	0	2	4	17	8	7	38
REGENT	0	2	9	15	13	7	46

a Bee counts on B. campestris were taken 21, 26 July 82 and for B. napus on 30 July, 2 August 1982.

Table 34. Total numbers of honey bees present on canola cultivars (1983).

	TIME OF DAY (hrs.)							
CULTIVAR	0800	1000	1200	1400	1600	1800	2000	TOTAL[a]
CANDLE	0	4	1	2	4	5	1	17
TOBIN	0	2	2	2	8	13	3	30
ALTEX	9	11	8	7	19	15	24	93
ANDOR	5	18	25	13	21	28	25	135
REGENT	5	15	13	11	21	23	24	112

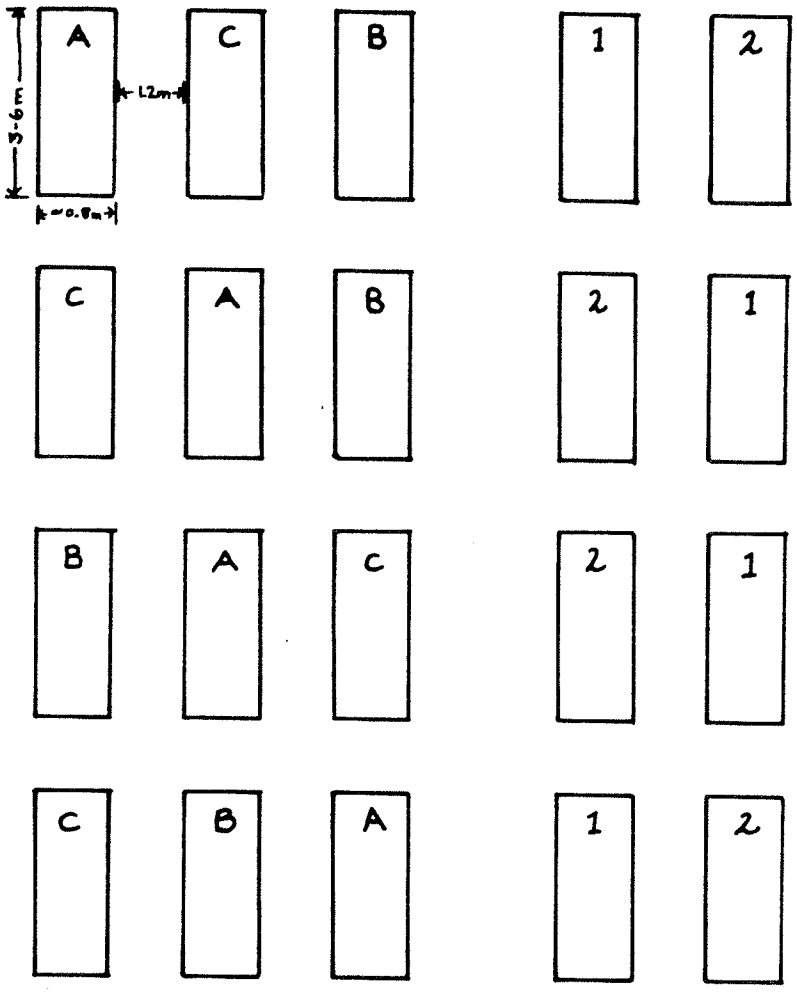
a Bee counts for B. campestris were taken on 18, 20, 21, 22 and on 25, 26, 27, 28 July for B. napus.

Table 35. Total numbers of honey bees present on canola species (1983).

	TIME OF DAY (hrs.)						
SPECIES	0800	1000	1200	1400	1600	1800	TOTAL[a]
B. campestris	0	24	43	35	16	11	129
B. napus	0	2	16	13	19	22	72

a Bee counts for B. campestris were taken on 28 June, 5, 6 July on 10, 12, 13 July 1983 for B. napus.

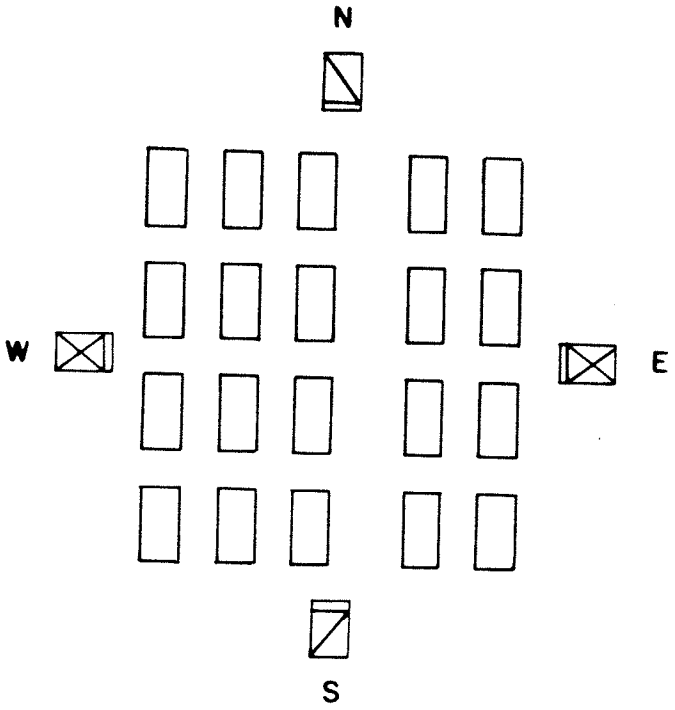
Figure 1. Completely randomized plot design for canola cultivars.



NUMBERS 1 and 2 CORRESPOND TO cv. CANDLE AND TOBIN

LETTERS A,B and C CORRESPOND TO cv. ALTEX, ANDOR and REGENT

Figure 2. Arrangement of hives around canola plot.



= HIVE WITH POLLEN TRAP

= HIVE WITHOUT POLLEN TRAP

Figure 3. Code for recording honey bee foraging behaviour.

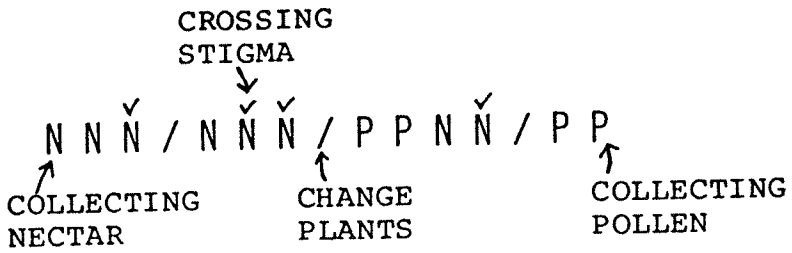
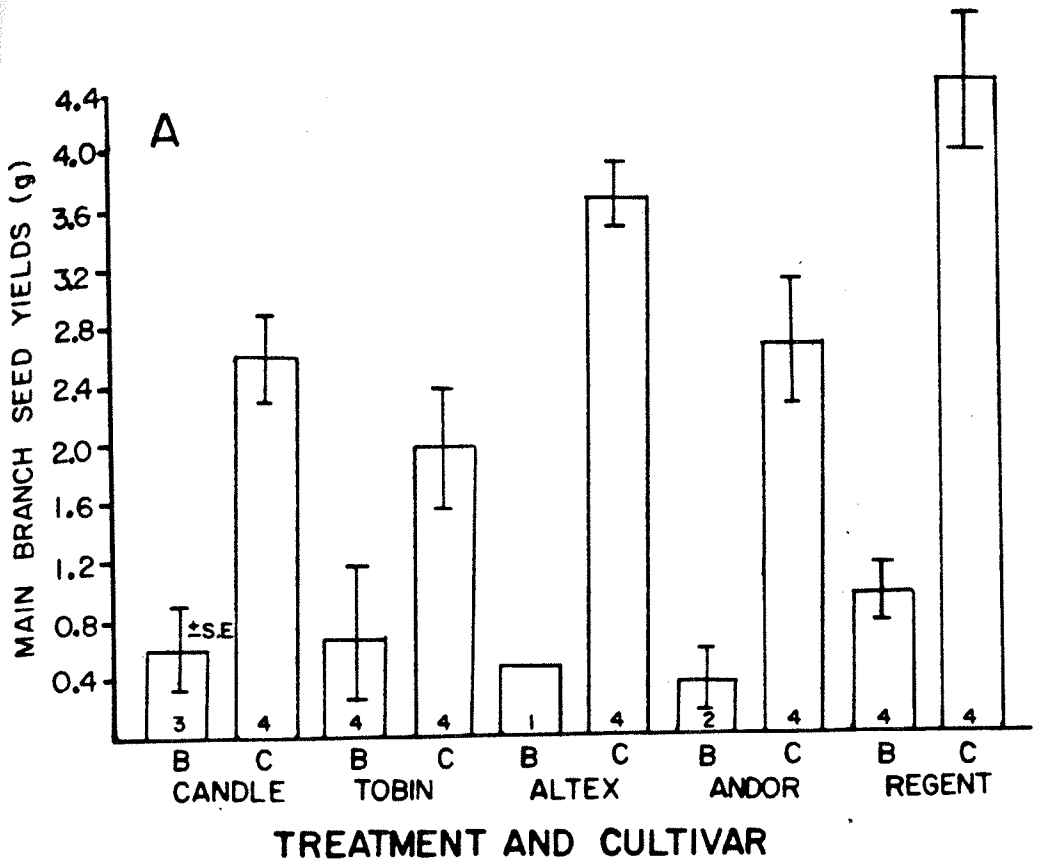

CROSSING
STIGMA
N N Ň / N Ň Ň / P P N Ň / P P
COLLECTING
NECTAR
CHANGE
PLANTS
COLLECTING
POLLEN

Figure 4. Mean main branch seeds yields of canola cultivars in (A) 1982 and (B) 1983

B = bagged C = Control
(The values within the bars represent the number of plants sampled).


A
MAIN BRANCH SEED YIELDS (g)
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
±S.E
3
4
4
4
1
4
2
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

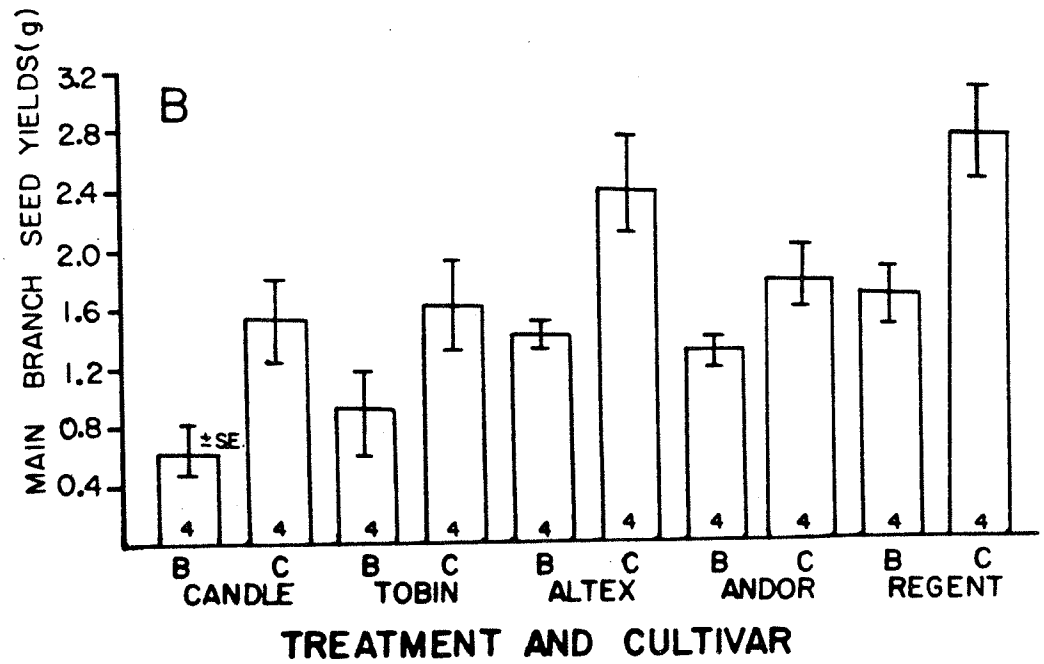
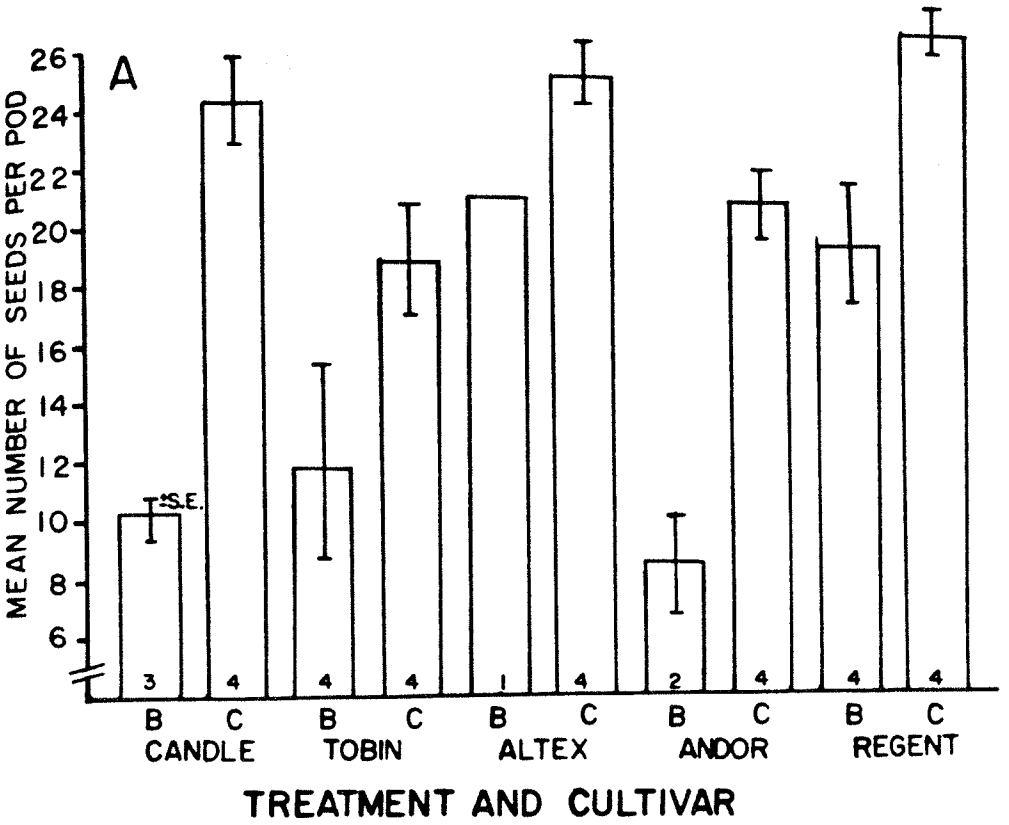

B
MAIN BRANCH SEED YIELDS(g)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
±SE
4
4
4
4
4
4
4
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

Figure 5. Mean number of seeds/pod of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged plants C = Control plants
(The values within the bars represent the number of plants sampled).


A
MEAN NUMBER OF SEEDS PER POD
26
24
22
20
18
16
14
12
10
8
6
±S.E.
3
4
4
4
1
4
2
4
4
4
B C B C B C B C B C
CANDLE
TOBIN
ALTEX
ANDOR
REGENT
TREATMENT AND CULTIVAR

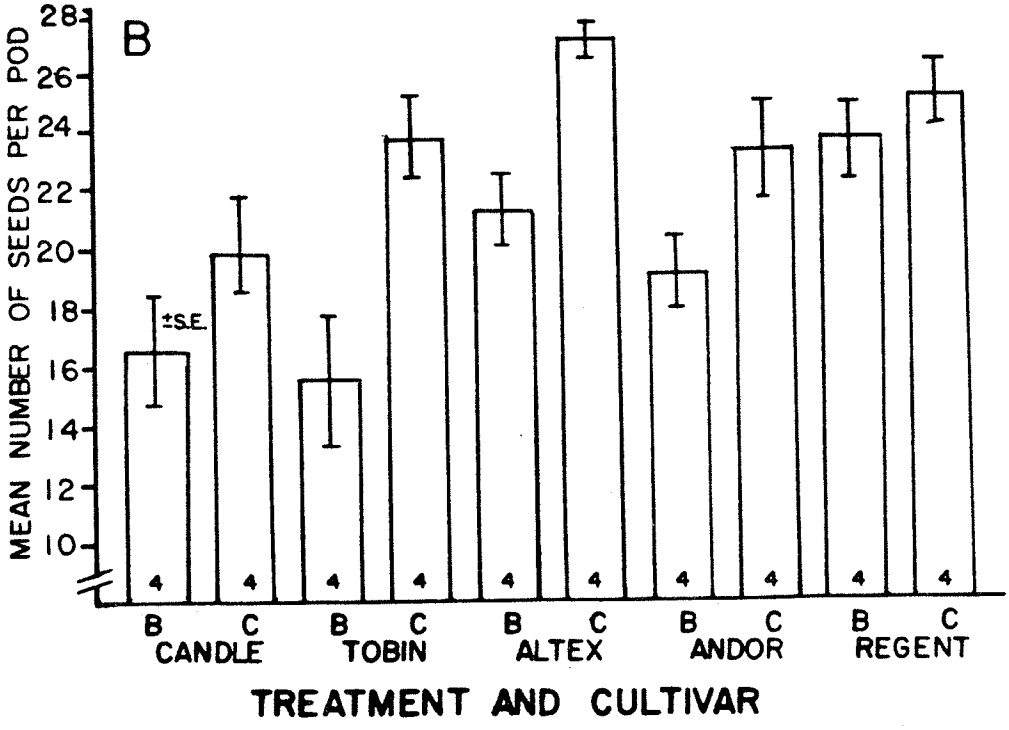
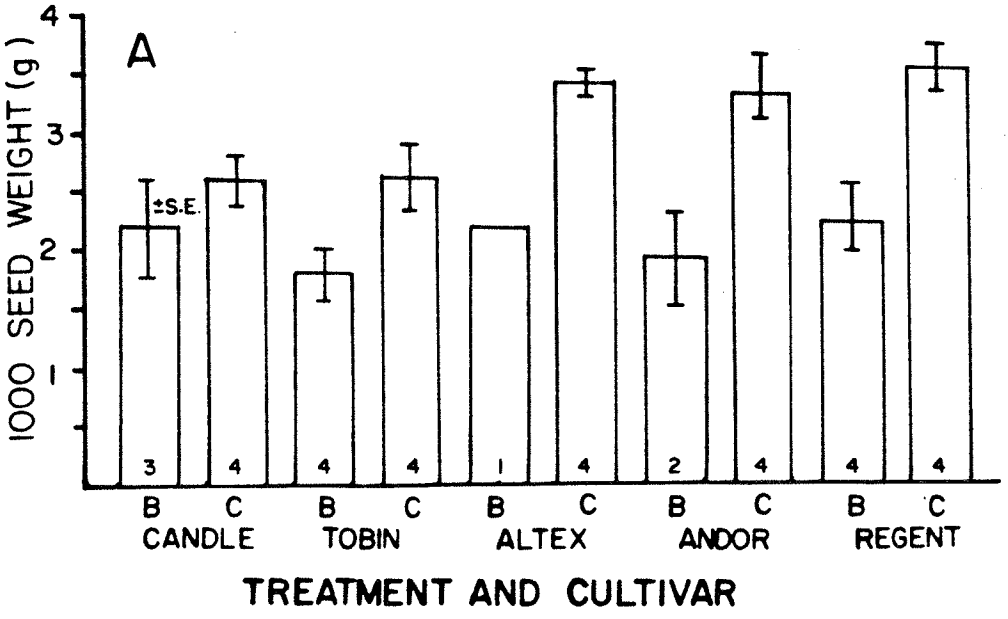

B
MEAN NUMBER OF SEEDS PER POD
28
26
24
22
20
18
16
14
12
10
±S.E.
4
4
4
4
4
4
4
4
4
4
B C B C B C B C B C
CANDLE
TOBIN
ALTEX
ANDOR
REGENT
TREATMENT AND CULTIVAR

Figure 6. Estimated 1000 seed weight of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged, C = Control
(The values within the bars represent the number of plants sampled).


A
1000 SEED WEIGHT (g)
4
3
2
1
±S.E.
3
4
4
4
1
4
2
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

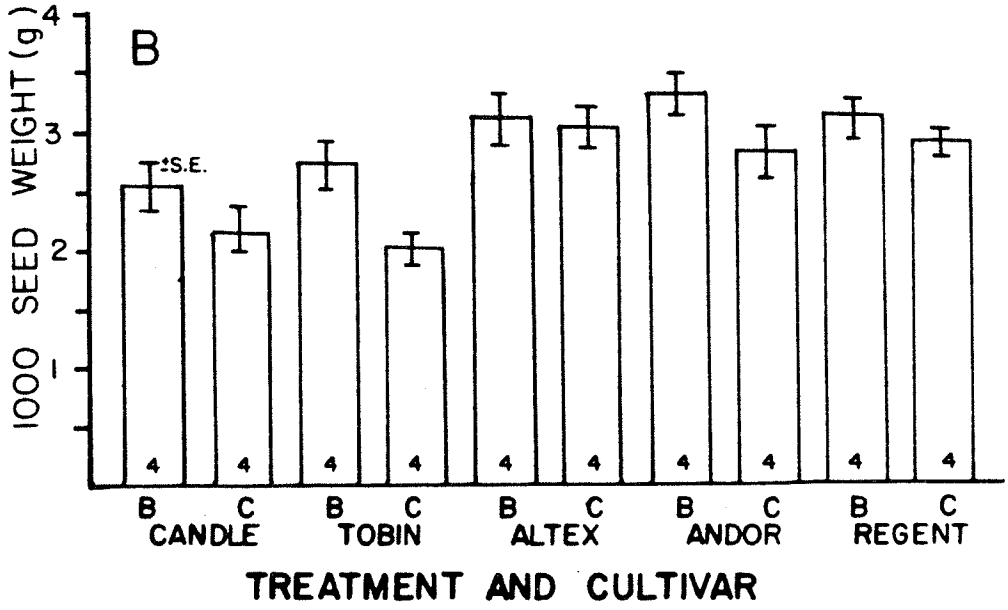
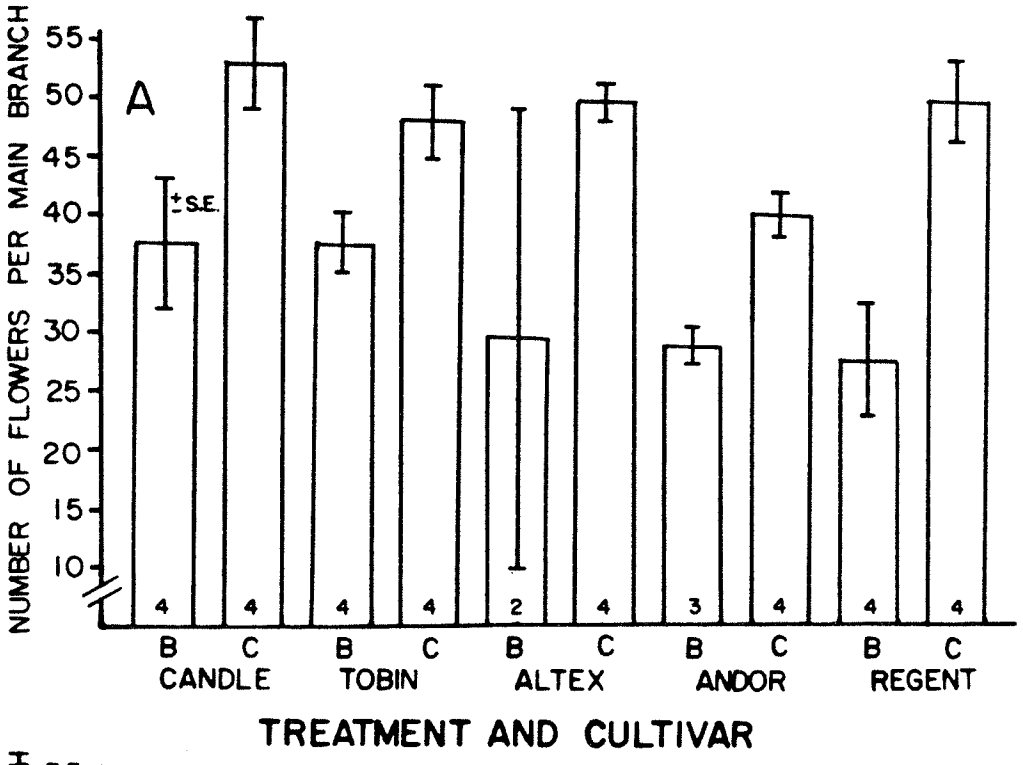

B
1000 SEED WEIGHT (g)
4
3
2
1
±S.E.
4
4
4
4
4
4
4
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

Figure 7. Mean number of flowers per main branch of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged C = Control
(The values within the bars represent the number of plants sampled).


A
NUMBER OF FLOWERS PER MAIN BRANCH
55
50
45
40
35
30
25
20
15
10
±S.E.
4 4 4 4 2 4 3 4 4 4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

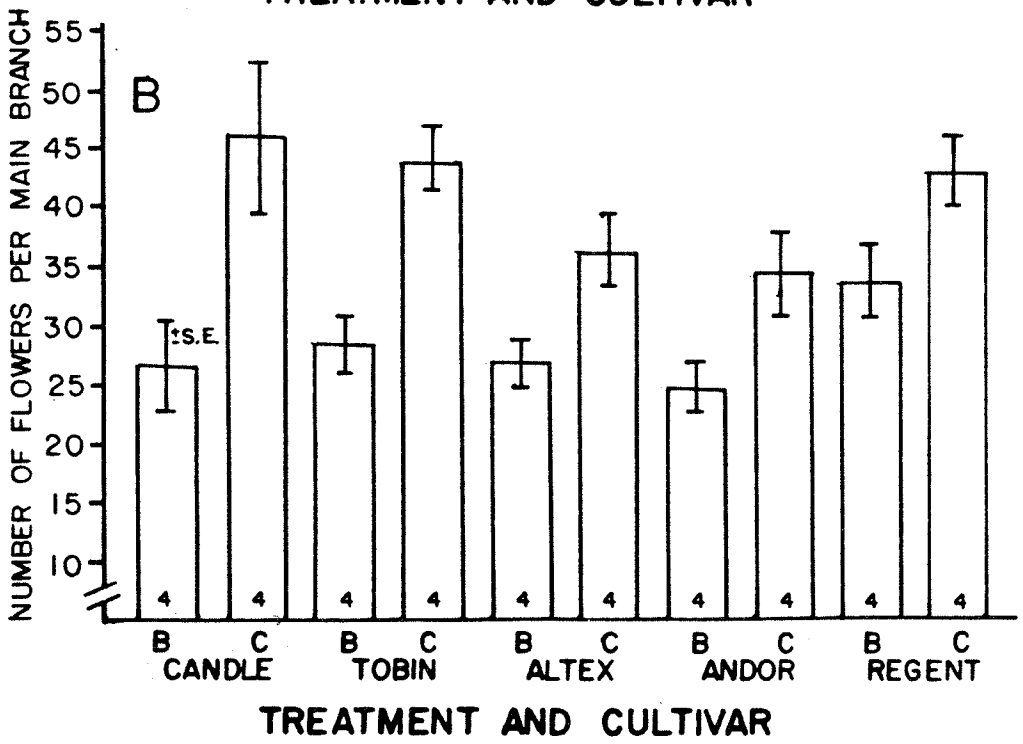
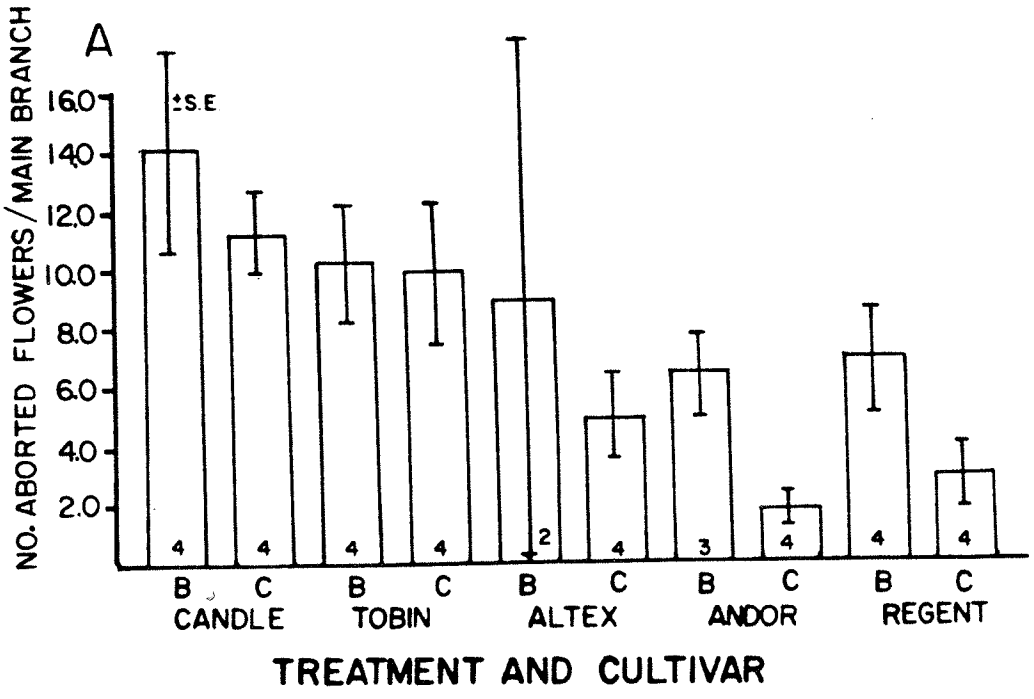

B
NUMBER OF FLOWERS PER MAIN BRANCH
55
50
45
40
35
30
25
20
15
10
±S.E.
4 4 4 4 4 4 4 4 4 4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

Figure 8. Mean number of aborted flowers per main branch of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged C = Control
(The values within the bars represent the number of plants sampled).


A
NO. ABORTED FLOWERS/MAIN BRANCH
±S.E.
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
4
4
4
4
2
4
3
4
4
4
B
C
CANDLE
TOBIN
ALTEX
ANDOR
REGENT
TREATMENT AND CULTIVAR

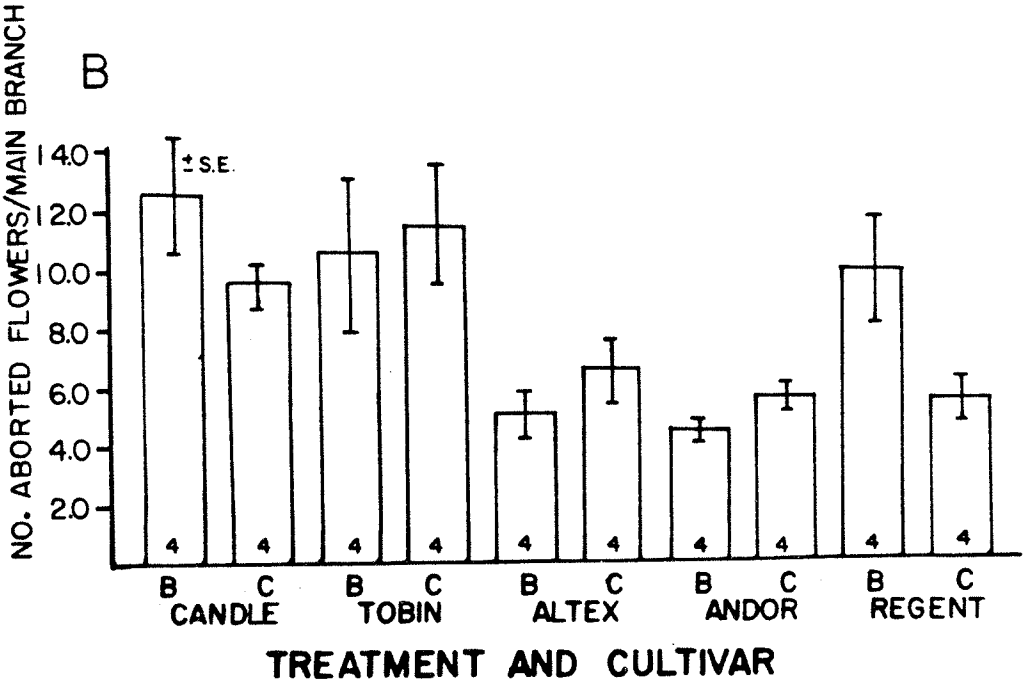
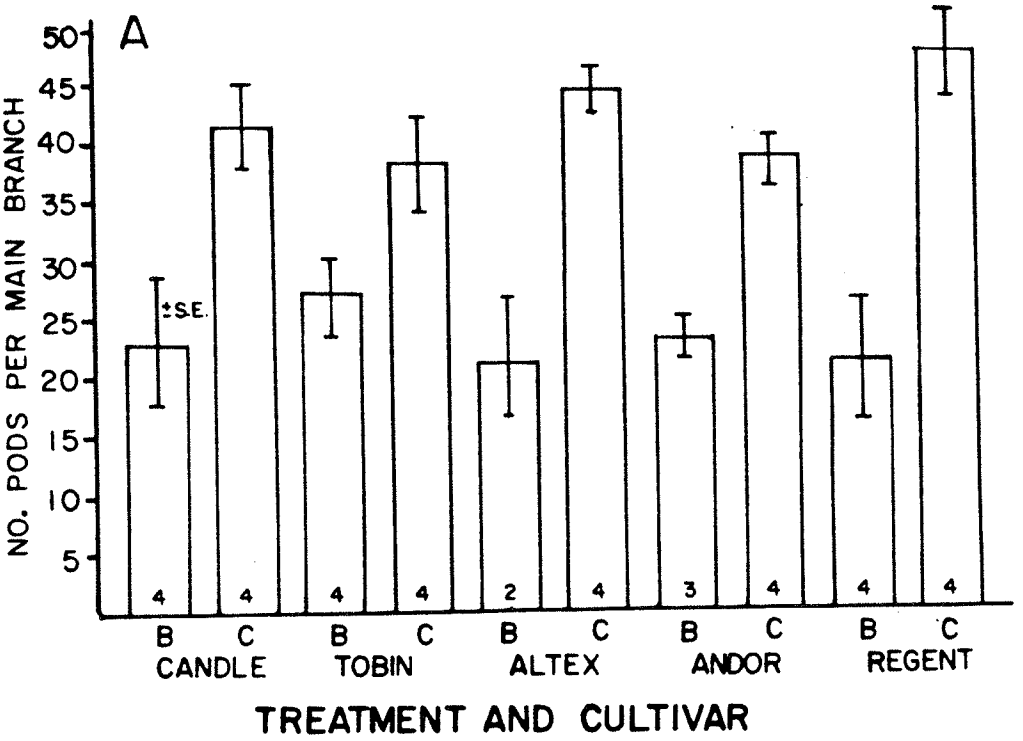

B
NO. ABORTED FLOWERS/MAIN BRANCH
±S.E.
14.0
12.0
10.0
8.0
6.0
4.0
2.0
4
4
4
4
4
4
4
4
4
4
B
C
CANDLE
TOBIN
ALTEX
ANDOR
REGENT
TREATMENT AND CULTIVAR

Figure 9. Mean number of pods per main branch of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged C = Control
(The values within the bars represent the number of plants sampled).


A
NO. PODS PER MAIN BRANCH
50
45
40
35
30
25
20
15
10
5
±S.E.
4 4 4 4 2 4 3 4 4 4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

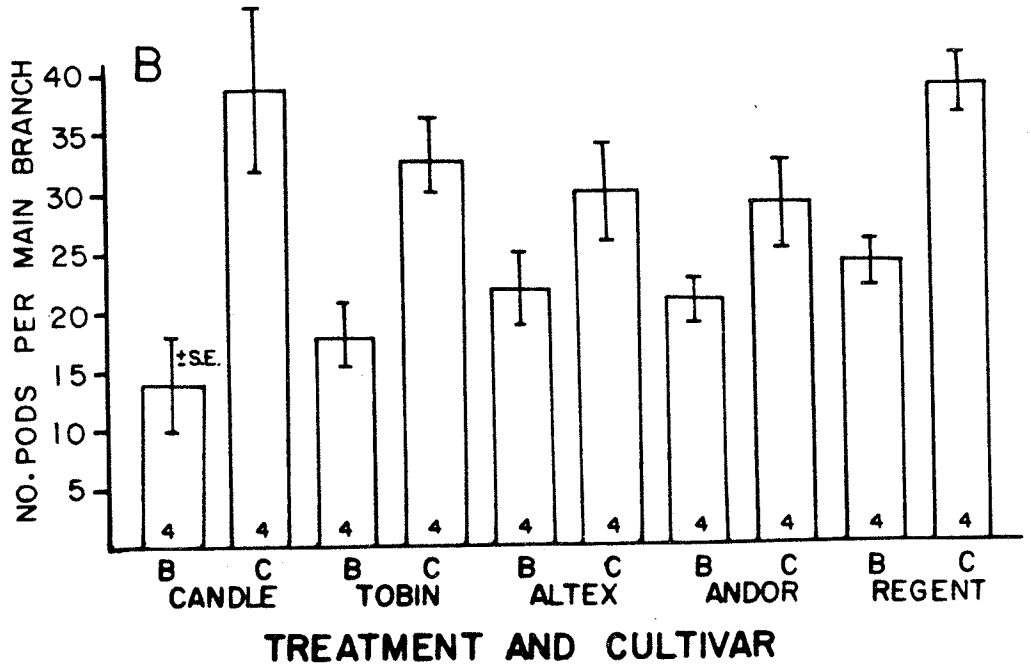
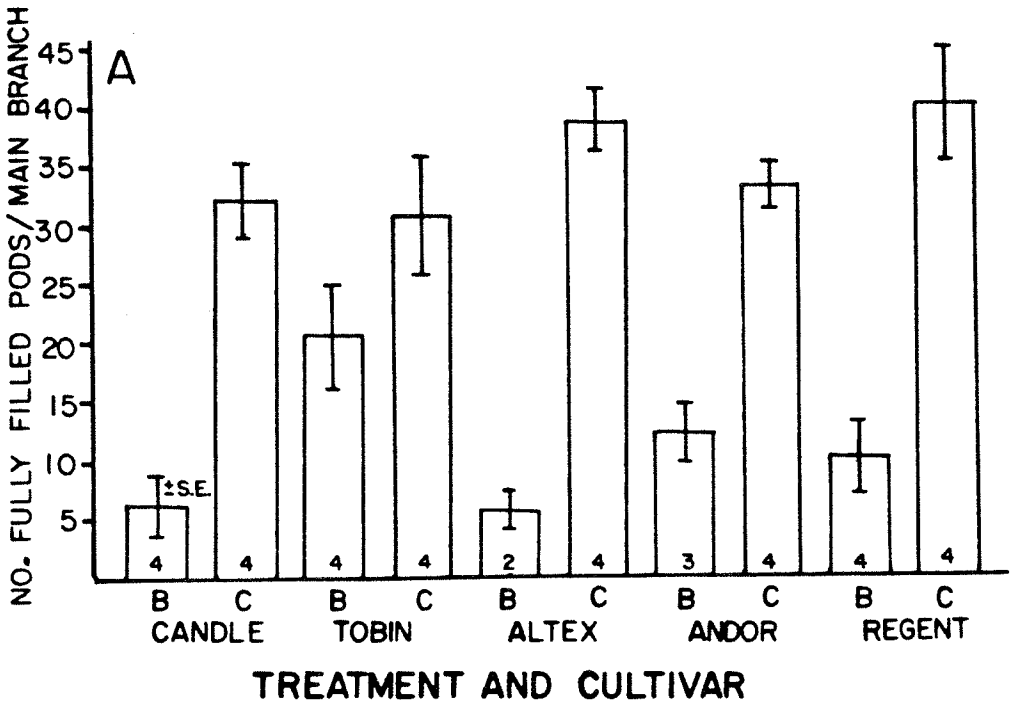

B
NO. PODS PER MAIN BRANCH
40
35
30
25
20
15
10
5
±S.E.
4 4 4 4 4 4 4 4 4 4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

Figure 10. Mean number of fully filled pods per main branch of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged, C = Control
(The values within the bars represent the number of plants sampled).


A
NO. FULLY FILLED PODS/ MAIN BRANCH
45
40
35
30
25
20
15
10
5
±S.E.
4
4
4
4
2
4
3
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

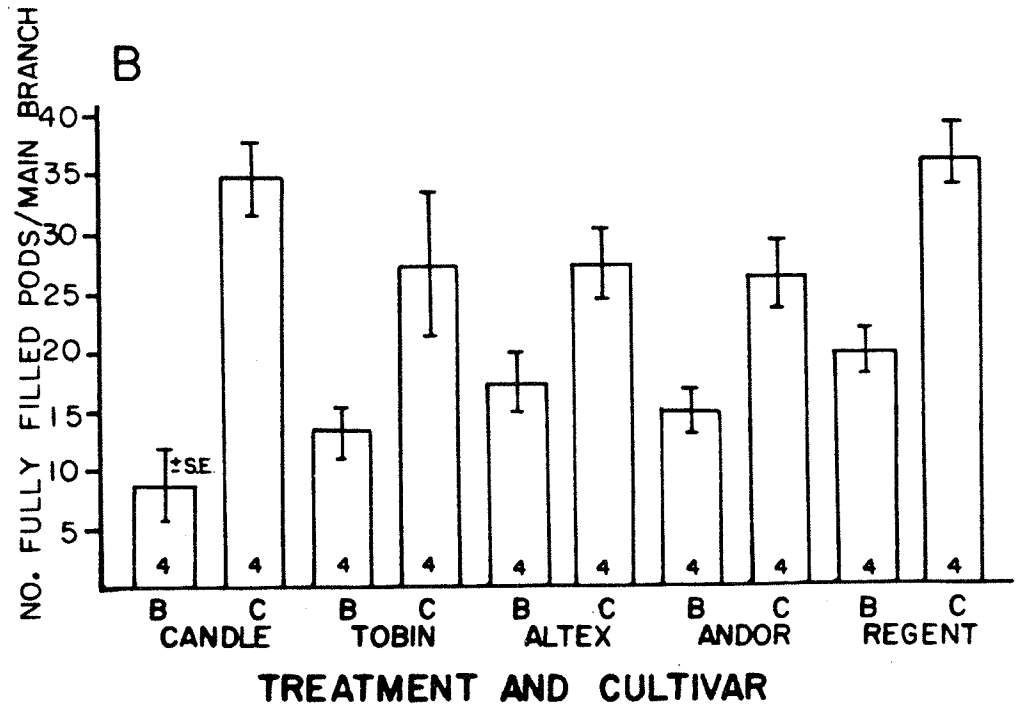
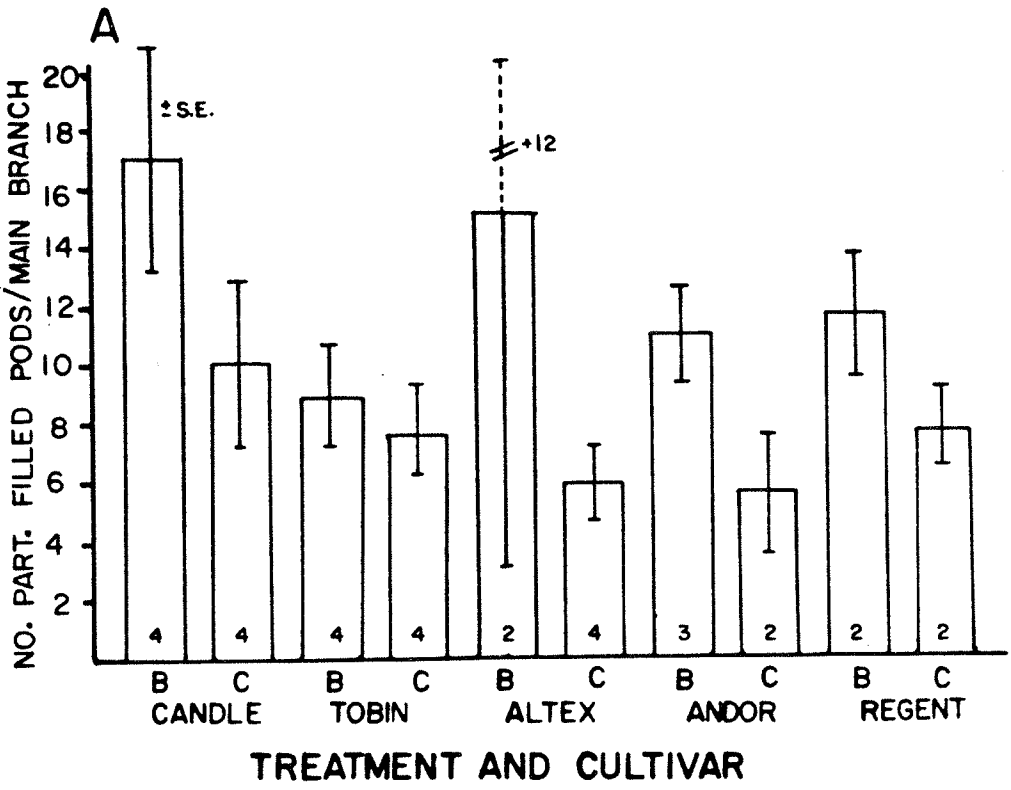

B
NO. FULLY FILLED PODS/MAIN BRANCH
40
35
30
25
20
15
10
5
±SE
4
4
4
4
4
4
4
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

Figure 11. Mean number of partially filled pods per main branch of canola cultivars in (A) 1982 and (B) 1983.

B = Bagged, C = Control
(The values within the bars represent the number of plants sampled).


A
NO. PART. FILLED PODS/MAIN BRANCH
20
18
16
14
12
10
8
6
4
2
± S.E.
+12
4
4
4
4
2
4
3
2
2
2
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

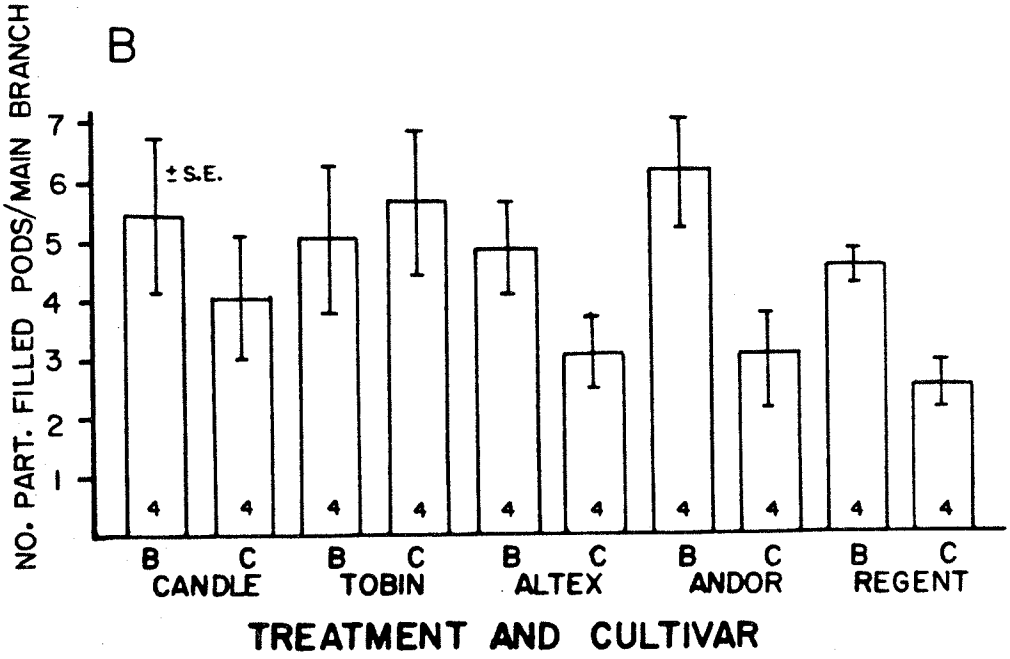
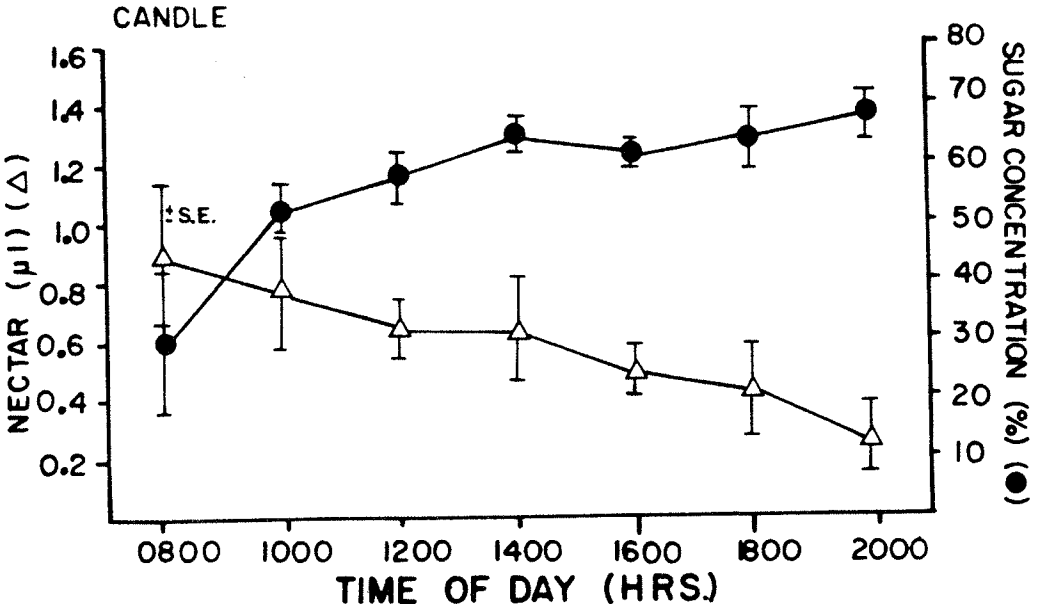

B
NO. PART. FILLED PODS/MAIN BRANCH
7
6
5
4
3
2
1
± S.E.
4
4
4
4
4
4
4
4
4
4
B C B C B C B C B C
CANDLE TOBIN ALTEX ANDOR REGENT
TREATMENT AND CULTIVAR

Figure 12. Mean nectar and sugar concentration values for B. campestris cultivars using the random sampling technique.

(Samples were taken on 18, 20 , 21, 22 July, 1983).
(See Appendix 6 for n values).


CANDLE
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
±S.E.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
2000
TIME OF DAY (HRS.)

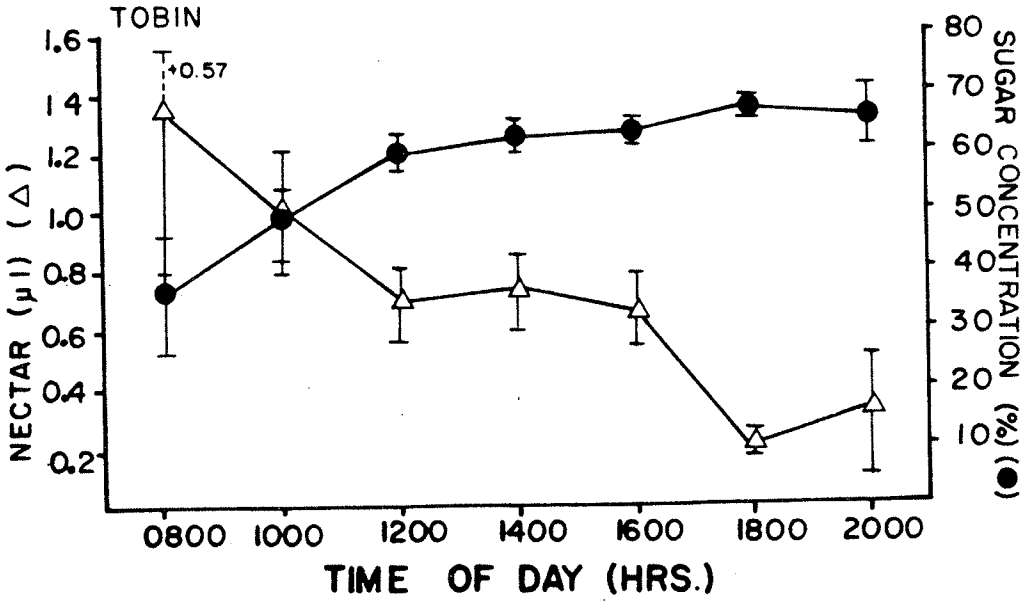

TOBIN
±0.57
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
2000
TIME OF DAY (HRS.)

Figure 13. Mean nectar and sugar concentration values for B. napus cultivars using the random sampling technique (1983).

Samples were taken on the 24, 25, 26, 27, 28 July.
(See Appendix 6 for n values).

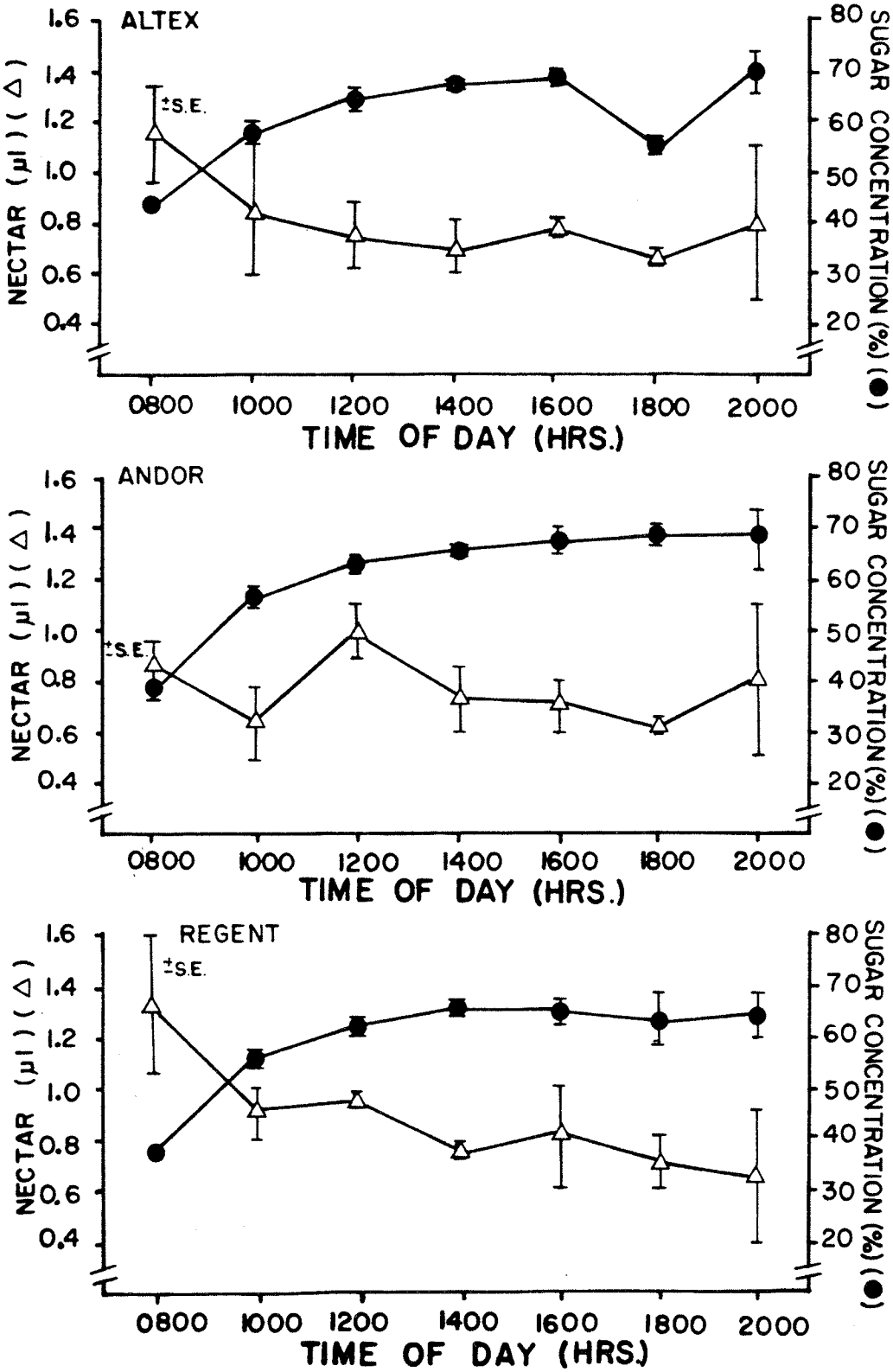
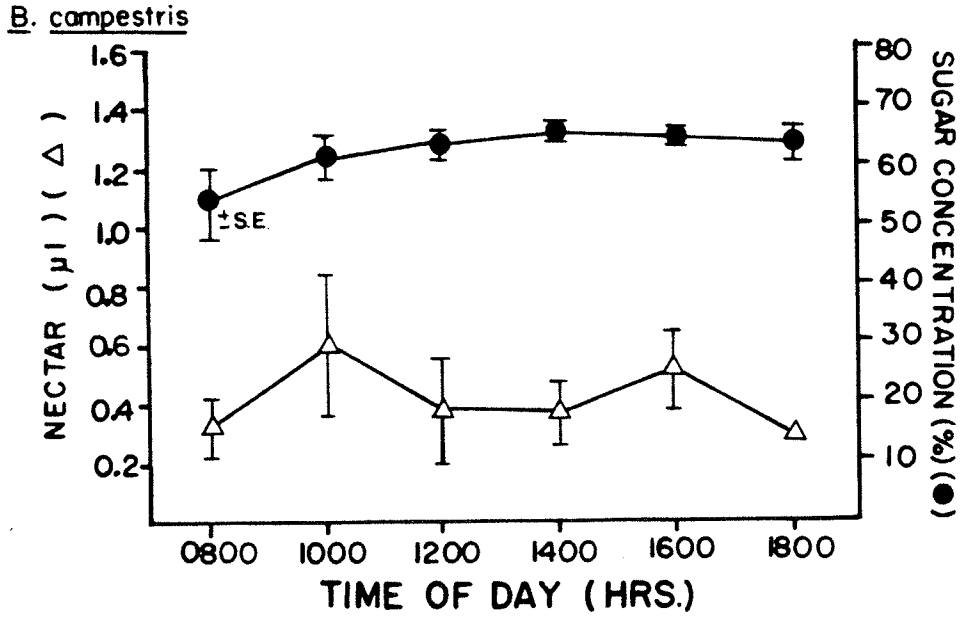

ALTEX
±S.E.
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
80
70
60
50
40
30
20
0800
1000
1200
1400
1600
1800
2000
TIME OF DAY (HRS.)
ANDOR
±S.E.
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
TIME OF DAY (HRS.)
REGENT
±S.E.
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
TIME OF DAY (HRS)

Figure 14. Mean nectar and sugar concentration values for *B. campestris* species using the random sampling technique.

Samples were taken on 28 June, 5, 6 July, 1983. (See Appendix 6 for n values).

Figure 15. Mean nectar and sugar concentration values for *B. napus* species using the random sampling technique.

Samples were taken on 10, 12, 13 July, 1983. (See Appendix 6 for n values).


B. compestris
NECTAR (µl) (Δ)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
±S.E.
SUGAR CONCENTRATION (%) (●)
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
TIME OF DAY (HRS.)

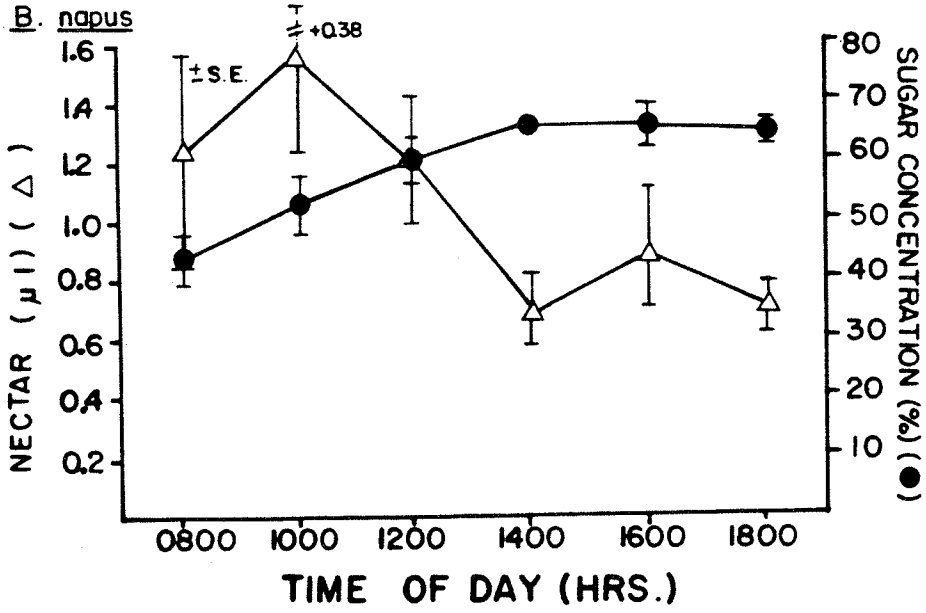
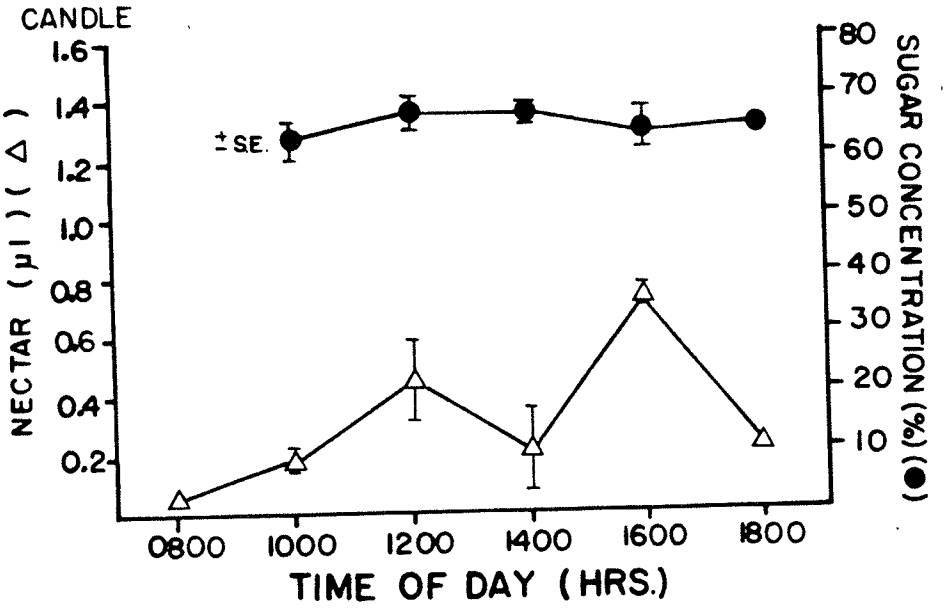

B. napus
+0.38
±S.E.
NECTAR (µl) (Δ)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
SUGAR CONCENTRATION (%) (●)
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
TIME OF DAY (HRS.)

Figure 16. Mean nectar and sugar concentration values for B. campestris cultivars using the cumulative sampling technique.

Samples were taken on 21 July, 26 July, 1982.
(See Appendix 6 for n values).


CANDLE
NECTAR (μl) (Δ)
SUGAR CONCENTRATION (%) (●)
±SE.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
TIME OF DAY (HRS.)

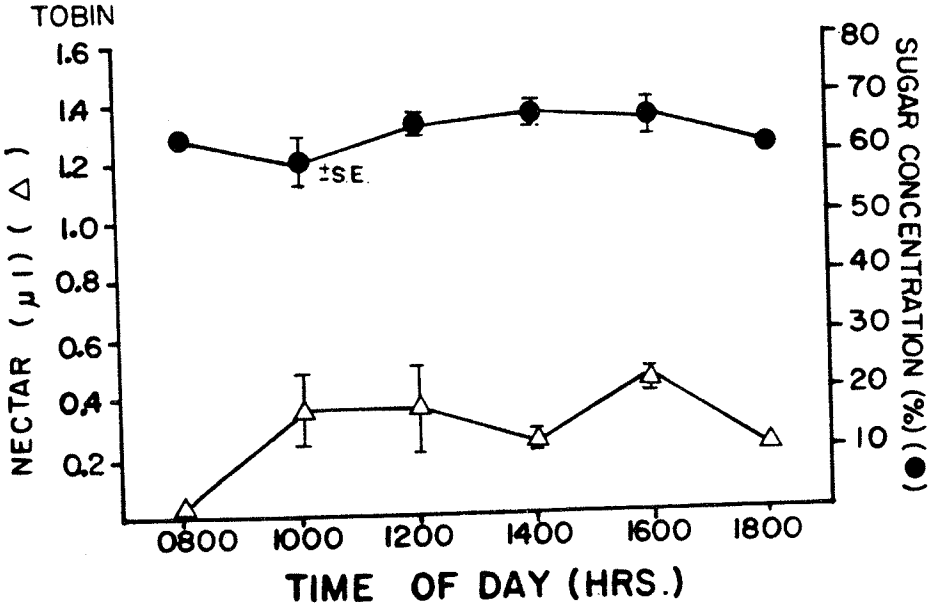

TOBIN
NECTAR (μl) (Δ)
SUGAR CONCENTRATION (%) (●)
±S.E.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
TIME OF DAY (HRS.)

Figure 17. Mean nectar and sugar concentration values for B. napus cultivars using the cumulative sampling technique.

Samples were taken on 30 July, 2 August (1983)
(See Appendix 6 for n values).

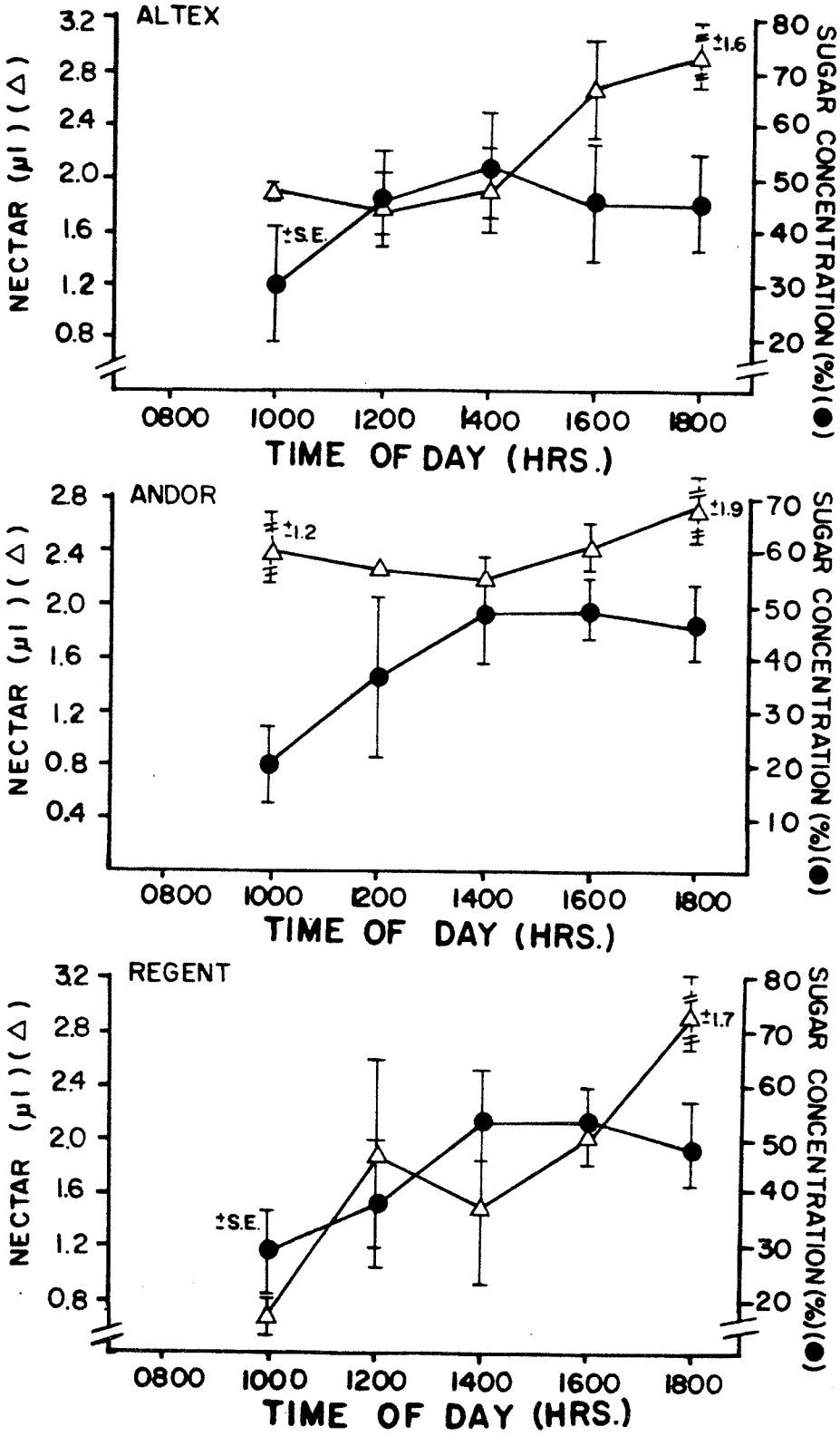
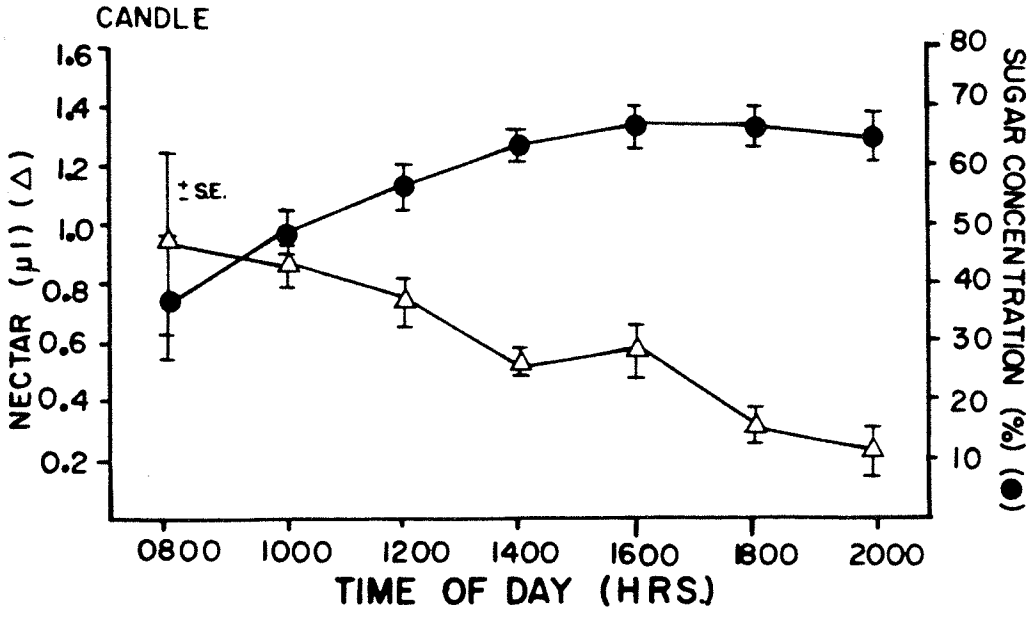

ALTEX
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
±S.E.
±1.6
TIME OF DAY (HRS.)
ANDOR
±1.2
±1.9
REGENT
±1.7
0800
1000
1200
1400
1600
1800

Figure 18. Mean nectar and sugar concentration values for B. campestris cultivars using the cumulative sampling technique.

Samples were taken on 18, 201, 21, 22 July, 1983.
(See Appendix 6 for n values).


CANDLE
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
± SE.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
2000
TIME OF DAY (HRS.)

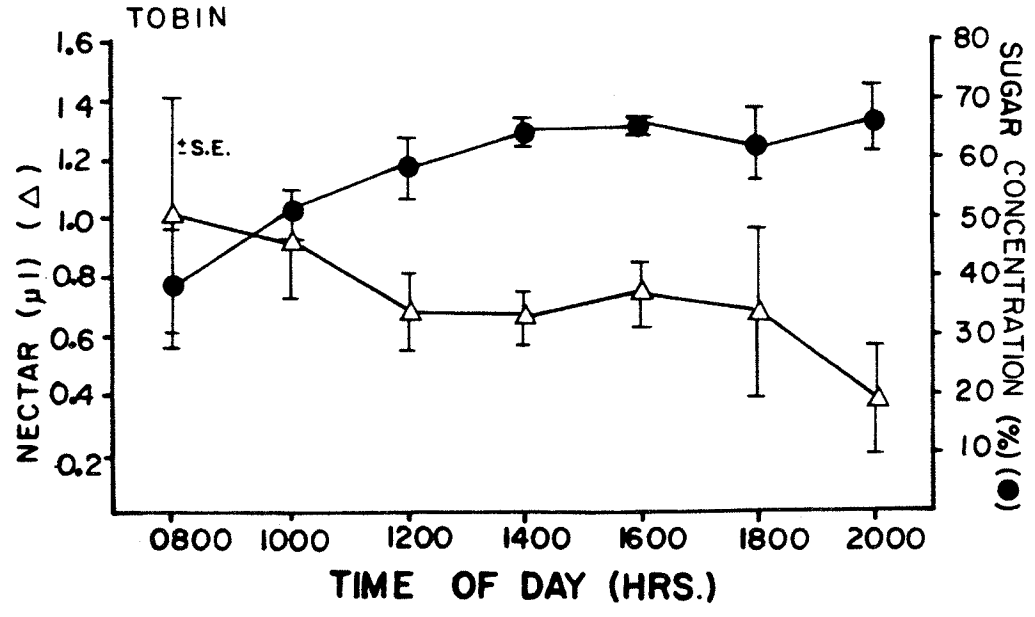

TOBIN
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
± S.E.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
2000
TIME OF DAY (HRS.)

Figure 19. Mean nectar and sugar concentration values for *B. napus* cultivars time using the cumulative sampling technique.

Samples were taken on the 24, 25, 26, 27, 28 July 1983.
(See Appendix 6 for n values).

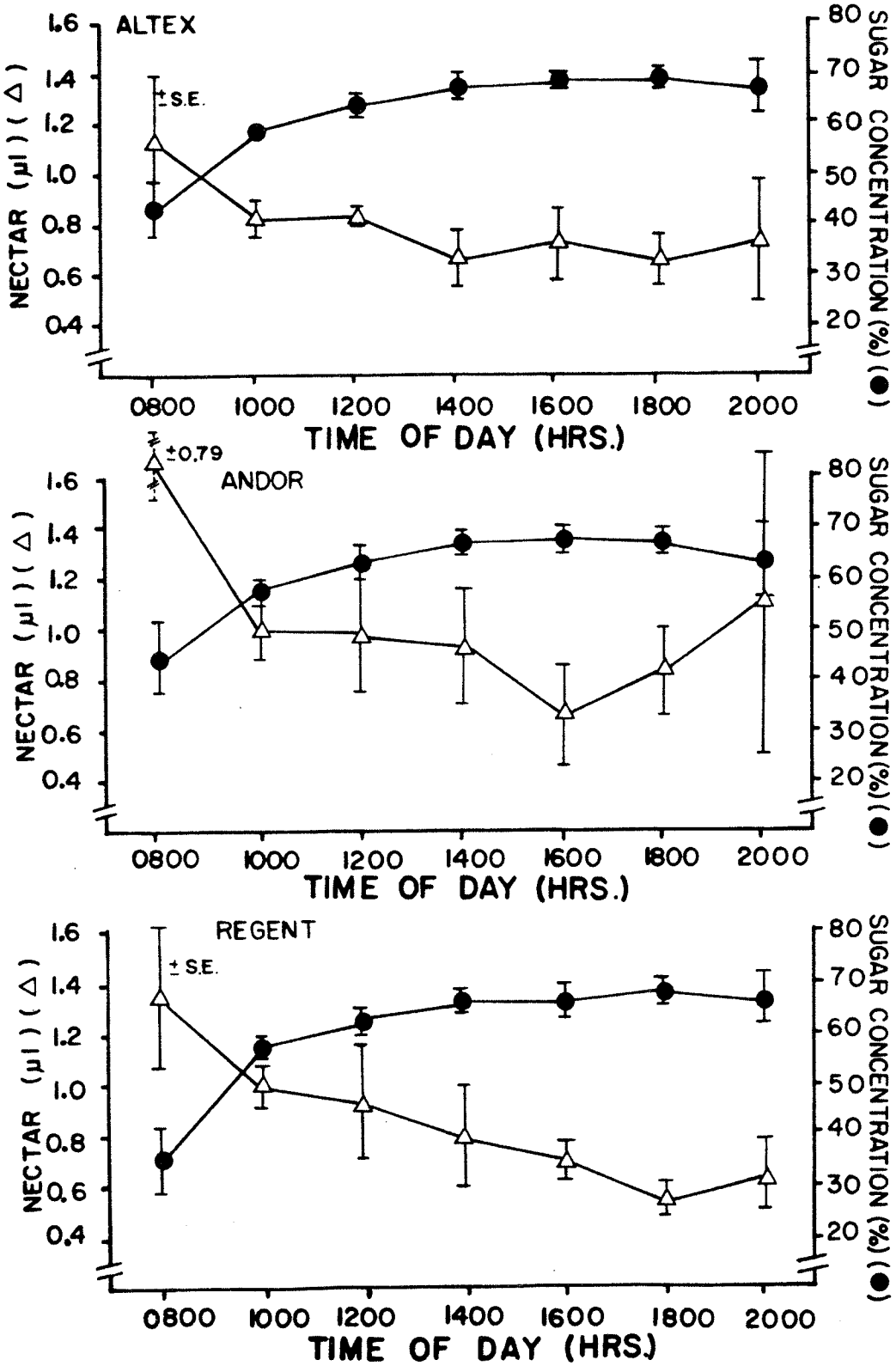
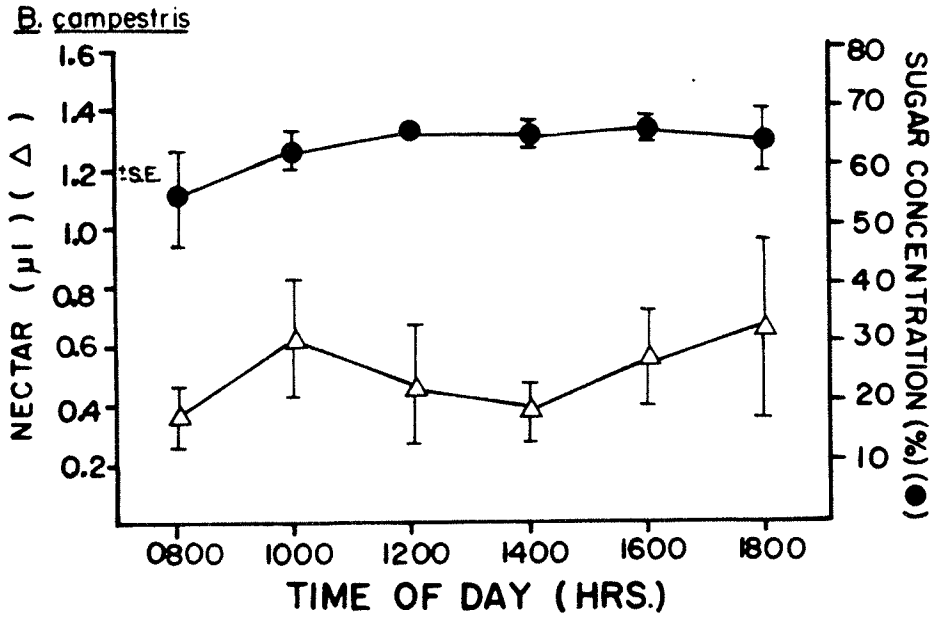

ALTEX
± S.E.
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
80
70
60
50
40
30
20
0800
1000
1200
1400
1600
1800
2000
TIME OF DAY (HRS.)
±0.79
ANDOR
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
TIME OF DAY (HRS.)
REGENT
± S.E.
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
TIME OF DAY (HRS.)

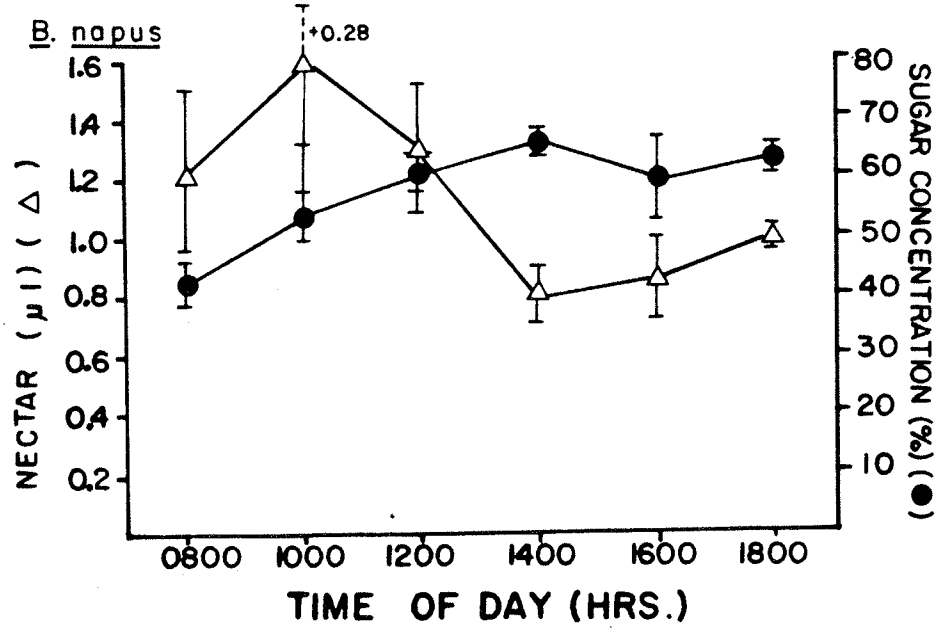
Figure 20. Mean nectar and sugar concentration values for B. campestris species using the cumulative nectar sampling technique.

Samples were taken on 28 June, 5, 6 July 1983.
(See Appendix 6 for n values).

Figure 21. Mean nectar and sugar concentration values for B. napus species using the cumulative nectar sampling technique.

Samples were taken on 10, 12, 13 July, 1983.
(See Appendix 6 for n values).


B. campestris
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
±S.E.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
TIME OF DAY (HRS.)


B. napus
+0.28
NECTAR (µl) (Δ)
SUGAR CONCENTRATION (%) (●)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
80
70
60
50
40
30
20
10
0800
1000
1200
1400
1600
1800
TIME OF DAY (HRS.)

CHAPTER 4

DISCUSSION

The Effect of Honey Bees on Canola Yield

It has been established that honey bees increase the seed yield of the cross-pollinating B. campestris canola species (Mohammad 1935, Langridge & Goodman 1975, Williams 1980, Rao et al. 1980). Langridge and Goodman (1975) reported that mean seed yields of B. campestris cv. Arlo, were significantly greater (60%) on open pollinated plots to which bees and other larger insects had access than on plots from which these insects were excluded. Rahman (1940) used Apis indica to pollinate fields on B. campestris var. toria and found yield increases of 10-25%. Latif et al. (1960) found yield increases of up to 259% on open plots compared with caged plots of var. sarson that had no pollinators enclosed.

While the role of the honey bees as an important factor in increasing seed yields on B. campestris has been established, their effect on seed yields of B. napus remains unclear. Olsson (1960) and Free (1970) conclude that wind is the main pollinating agent of B. napus. Research conducted by Free and Nuttall (1968) showed that while bees may increase seeds yields of B. napus by approximately 13%, these results are not significant. Langridge and Goodman (1982) also conclude that bees have no demonstrable beneficial effects on the seed yield of this species. Yet other authors (i.e. Ewert 1929, Zander 1951, Jenkinson and Glynne - Jones 1953, Belozerova 1960, Eisikowitch 1981) consider bees to be valuable pollinators and recommend that they be placed on fields of B. napus in order to maximize seed production. In 1929 Ewert reported

that honey bees increase seed yields of B. napus 27%. Zander (1951) reported 55% yield increases and Kamler (1983) reported increases ranging from 26.4 - 85.1%.

Other researchers, while not finding significant yield increases still report that B. napus fields supplied with bees set seed earlier and more uniformly (i.e. Williams 1978). The number of pods produced per plant, the TSW, the number of seeds per pod and the germinability of open pollinated seed are all greater on B. napus plants pollinated by honey bees (Benedek et al. 1972, Kubisova et al. 1980, Kamler 1983). Ewert (1929) and Zander (1951) found earlier petal fall in fields lacking bees. Williams (1980) states that inadequate pollination may limit yield.

In 1982, the seed yield increases for both B. campestris and B. napus in my study were extremely high (ie. 336% for Candle, and 689% for Altex - see Table 1). The bags used on the bagged plants were too small and narrow to allow for adequate plant growth. This was seen in the total number of flowers produced (Figure 7A) and in the number of aborted flowers (figure 8A). The number of aborted flowers on the bagged plants were greater than on the control plants and resulted in decreased pod production (Figure 9A). There were more partially filled pods (Figure 11A), less seeds/pod (Figure 5A), and a lower TSW (Figure 6A). Generally, plants under bags produce fewer seeds which weigh more than in unbagged trials (see Latif et al. 1960). This did not occur in 1982 (Figure 6A). Because of the bagging effect, further discussion of the 1982 seed yield data is not warranted.

In 1983, some bagging effect was also evident in the total number of flowers produced (Figure 78). The total number of flowers produced by control plants were significantly greater than the numbers produced by bagged plants for all cultivars. However, the total number of flowers produced by bagged Candle and Tobin plants was actually lower than in 1982, while the number of flowers produced by bagged Altex, Andor and Regent plants was higher. The number of aborted flowers should also give an indication of the restrictive nature of the bagging method used (Figure 8B). The number of aborted flowers in 1983 do not differ significantly between bagged and control plants. In fact, the number of aborted flowers are slightly higher for the controls of Tobin, Altex and Andor (Figure 8B). The larger tulle bags, therefore, appear to reduce the bagging effect, to what I believe is, a minimum and are recommended for use in small-scale seed production trials.

The 1983 seed yield increases are significant for both B. campestris and B. napus. Candle had a 139% (2X) increase and Tobin 81% (2X) (Table 1). These results are within the range (10-259% yield increases) established by other researchers for B. campestris cultivars. The 1983 yield increases for B. napus cultivars ranged from a high of 73% (2X) for Altex and 58% (2X) for Regent to a low of 39% (1X) for Andor (Table 1). While a 73% increase is high compared to those found by other authors for B. napus cultivars, 58% and 39% are well within the yield increases that have already been determined.

The numbers of pods produced by control plants were significantly greater than those produced by bagged plants (Figure 9B), as were the number of

fully filled pods (Figure 10B) and number of partially filled pods (Figure 11B). Control plants always had significantly more seeds per pod, but the TSW was almost the same for both bagged and control plants.

Thus, my plant production results confirm that both B. campestris and B. napus benefit from the use of honey bees as pollinators.

Nectar Data Sampling Results

General

Canola is known to produce ample amounts of nectar. B. campestris varieties sarson and toria produce nectar with an average sugar concentration of 49% and 45% respectively (Sharma 1958, as cited by Williams 1980). Murrell and Nash (1981) found the nectar volume per floret of toria to peak early in the morning and then decline throughout the late morning and afternoon. The nectar sugar concentration was low in the mornings (16% at 0900 hrs), but increased as the day progressed to an average of over 40%. (In all cases nectar production refers to the nectar volume produced in μl).

B. napus has larger flowers and generally produces more nectar than B. campestris (Szabo 1982). The amount of nectar produced has been reported to increase towards the end of the day (Radchenko 1964), and to be high in the early morning and late afternoon, but lower at noon (Meyerhoff 1954). Relatively high average nectar sugar concentrations (26-76%) have been reported for different cultivars (Hammer 1952, Maksymiuk 1958, Petkov 1963, Radchenko 1964). Sugar concentrations are also reported to increase towards the end of the day (Radchenko 1964).

Evaluation of Technique

In my studies nectar was sampled from canola flowers in three different ways; 1) Random nectar sampling (RS), 2) Cumulative nectar sampling (CS) and 3) Continuous nectar sampling (CoS). These three techniques were evaluated to determine their relative merit and feasibility in different situations. The results from all three techniques are discussed.

Random Nectar Sampling

In this technique, samples of nectar were taken from 10 unbagged flowers per cultivar at 2 hr. intervals and the nectar sugar concentration (percent SC) was determined directly from the cumulative sample where possible. Murrell and Nash (1981) bagged heads an hour before sampling to prevent nectar removal by insects. In areas where bees are abundant this becomes necessary to ensure a sizeable sample. In 1982 and 1983, relatively few bees were present on the test plots (Tables 33, 34, 35) and RS without bagging was possible. Table 2 reveals that species differences occur, with *B. campestris* producing significantly less nectar than *B. napus*. These findings agree with those of Szabo (1982) who reported *B. napus* cv. Andor, Regent and Tower producing more nectar than *B. campestris* cv. Torch and Candle. However, no significant differences in nectar production between cultivars of the same species exist.

The differences in nectar production and percent SC between sampling dates were significantly different, but separate days will not be discussed since variation between sampling days is an unavoidable part

of all field experiments. All of the sampling days were condusive to bee flight (see Appendices 3, 4 and 5 for temperature and relative humidity of sampling days). Time of day was considered to be significant (α = 0.05) in nectar production, but no significant differences occurred between species or cultivars in regards to time of day. The results of the analysis on percent SC were identical (Table 3). Mean results for all five cultivars are graphed on Figures 12 and 13. These graphs illustrate the decline in nectar production and increase in percent SC as the day progresses. These results correspond to those found for toria by Murrell and Nash (1981). Radchenko (1964) reported nectar of B. napus cultivars to be high in the mornings and afternoons, and low at noon; my findings are similar to these. Radchenko (1964) also mentions that percent SC increases towards the end of the day. FIgures 12 and 13 indicate that percent SC levels off during the afternoon and does not really peak. Average daily nectar production for B. campestris cultivars was 0.67 μl at 57% SC and 0.82 μl at 60% S C for B. napus cultivars.

The species comparisons were included to see if any variations in nectar production existed. Table 4 shows that time of day is not significant as to nectar production. Figures 14 and 15 show that the patterns of nectar production and sugar concentration are different for B. campestris and B. napus compared to Figures 12 and 13 for individual cultivars. Environmental factors may be responsible for these differences (Appendix 5). Air temperature and R H were lower on species sampling dates. The lower RH at 0800 and 1000 hrs may affect the nectar samples as to the total amount of nectar collected and the corresponding percent S C , ie the more dilute the nectar sample the lower the corresponding percent

SC. Thus, in this case, the nectar was more concentrated. Time of day however, still significantly affected percent SC (Table 5).

In general, the nectar production results and percent SC results are similar to those found by other workers. The average nectar production (n = 10) and percent SC for B. campestris was 0.44μl and 63%, and 1.09 μl and 59% for B. napus respectively. In this case, B. napus had a 4% lower SC than B. campestris, but this difference is not significant.

Cumulative Nectar Sampling

The CS technique involves bagging a series of heads before the initial samples are taken each day. Enough floral heads must be bagged to insure a sampling supply for each time period. At each sampling period the flowers will not have been visited by insects for nectar. For example, at 2000 hours, the nectar that is removed from the 10 florets will be the only nectar that has been removed from those flowers on that day.

The analysis of variance for the 1982 CS data varies somewhat from the 1983 RS data and shows that cultivar variations exist and that time of day is not a significant factor for nectar production (Table 6). The analysis on the percent SC indicates that all variables (species, cultivar (species) date (species), species x time and time), with the exception of cultivar x time (species) are significant. Figures 16 and 17 show that different patterns of nectar production and percent SC do not exist among B. campestris or B. napus cultivars. In 1982, there were only 2 sampling dates for each cultivar. B. campestris cultivars were

sampled on rather dry days (Appendix 3) and this may be reflected in Figure 16. The average nectar production and percent SC for B. campestris cultivars was 0.33 µl at 65%. For B. napus cultivars, average daily nectar production was 2.15 µl at 42.7%. It would appear that B. campestris was producing less than half the amount of nectar that B. napus was producing. However, it should be noted that B. campestris had a higher percent SC. Although temperature and relative humidity play an important role in affecting plant production, they do not appear to account for the magnitude of the difference seen here. However, it appears that the higher nectar production (of B. napus) is associated with a lower percent R H.

In 1983 the CS and RS results were similar.

Table 8 shows that species differences were not significant although the CS nectar production means remained similar to the RS nectar production means. Table 9 shows that percent SC results were different for species. Table 9 is very similar to the 1983 RS percent SC (Table 3). Figures 18 and 19 are also very similar to FIgures 12 and 13. Mean daily nectar production for B. campestris cultivars was 0.68 µl at 57% SC and 0.90 µl at 62% for B. napus cultivars.

The 1983 CS species comparisons (Figures 20 and 21) were also very similar to the 1983 RS species comparisons FIgures 14 and 15. Mean daily nectar production for B. campestris was 0.50 µl at 63%. B. napus had a mean nectar production of 1.12 µl at 58%. This technique however, allows one to sample flowers that have not had the nectar removed.

Since the 1983 CS results are practically identical to the 1983 RS results, they will not be discussed further.

One would expect the amount of nectar sampled to increase over the course of the day, but this did not appear to happen. Instead the results were almost identical to those of the RS results. In this case resorption or more likely, evaporation of nectar may be occurring in the flower. This would keep nectar at a more or less constant level. If this were the case the percent SC would be expected to increase, but this did not occur. Perhaps flowers require a stimulus to produce more sugar in their nectar or perhaps flowers attempt to keep nectar and sugar values constant to attract foragers. Much more research is needed in this area before any theories can be proposed.

Continuous Nectar Sampling

Continuous nectar sampling allows one to determine how much nectar a flower can produce over the course of a day or a particular sampling period. Szabo (1982) showed that B. napus cv. Andor, Altex and Regent produced 0.40, 0.29 and 0.39 μl/nectar/flower/24 hrs respectively. Candle produced 0.13 μl/nectar/flower/24 hrs. He also determined the percent SC of Regent (B. napus) to be 38.7% (=0.177 mg sugar/flower/24 hours) and the percent SC of Candle (B. campestris) to be 41.8% (=0.064 mg/sugar/flower/24 hrs). Kamler (1980) found B. napus flowers to produce 10.2 mg sugar each day. Again, flowers which produce the most nectar appear to have a lower percent SC.

In 1982, my results were limited due to various difficulties (including low RH) encountered while sampling. However, my results showed that B. napus cultivars produce more nectar per day and have a higher

overall nectar production than does B. campestris (Table 12). Since percent SC was not determined for Candle, generalizations between species in regards to sugar production will not be made. The differences in nectar production between cultivars was not significant.

In 1983, B. campestris flowers produced less nectar than did B. napus flowers (Table 13). However, since Tobin produced more nectar than Altex, one cannot conclude that all B. campestris cultivars produce less nectar than do B. napus cultivars. Since temperature and RH (Appendix 4) were similar on all sampling dates, they probably did not affect nectar production. CoS percent SC also appears to be lower than CS or RS percent SC.

Species comparisons (Table 14) show that B. napus produced significantly more nectar than did B. campestris with B. campestris nectar having a higher percent SC (approximately 10%).

When nectar is removed from canola flowers on a regular basis, the flower produces more nectar than if nectar is removed only once. Maksymiuk (1958) reported that 98.5% more nectar was recovered from B. napus flowers (n=10) when the nectar was removed 3 times a day (=26.7 mg) rather than once a day (=9.3-11.7 mg). Maksymiuk (1958) stated that it is also possible that honey bees can collect more nectar from the flowers than is possible using a capillary tube.

If a canola flower only produced nectar once early during the day, it would probably evaporate by the end of the day; thus, a flower produces nectar continuously. How much a flower will actually produce may be determined by the number of times that nectar is removed, i.e. by a foraging insect. If nectar is not removed often, it might

evaporate so that the result would be less nectar of a higher percent SC. On the other hand, the flower could resorbe nectar, especially if already pollinated (Jablonski and Szklanowska 1979). If the nectar is removed regularly, the sugar is also removed and therefore lager samples would have a comparatively lower percent SC. This might explain why CS and RS results in lower nectar production and higher sugar concentration compared to the CoS results.

Considering the above, care must be taken when interpreting the results of various sampling techniques. These technique comparisons may explain some of the variation found in the literature.

Kamler (1980) reported that considerable variation in nectar production can occur among B. napus cultivars; significant variations can also occur between plants of the same cultivar. These variations, along with technique must also be considered.

Szabo (1982) found that all 28 varieties of canola currently in use and those being tested, produce nectar. Kamler (1981) stated that it is also possible to select lines and cultivars which have high nectar production and are attractive to bees. His studies also indicate that all currently grown cultivars are equally attractive to bees. Therefore, the concern that new canola varieties are unattractive to honey bees appears to be unfounded.

Finally, it should be understood that each technique that I tested measures nectar in a slightly different way. The RS technique is useful when the foraging population of bees is low to medium since plants are selected at random by the researcher at each sampling period. In this study flower heads were not bagged because the total number of foraging

bees is low. However, to guarantee that nectar samples can be obtained when foraging populations of bees are higher, flower heads should be bagged at least an hour prior to sampling (see Murrell and Nash 1981).

The CS technique measures the total amount of nectar present in a flower for a given day at each sampling period and consequently can be used to obtain total nectar production per sampling period. Also, since all the flower heads are bagged before the sampling period begins these plants are not exposed to foraging insects before being sampled for nectar. Thus, this technique is useful when the foraging population is high since it guarantees that nectar has not been removed.

Finally, the CoS technique samples the same flowers repeatedly which sometimes damages the flowers. Therefore, it should be used for determining maximum nectar production.

Weather Correlations

Environmental conditions are known to affect plant production (i.e. seed production, flower production, etc.) and consequently honey bee foraging behaviour, (see Percival 1950, Eckert 1955, Nelson and Jay 1967, Wratt 1968, Heinrich and Raven 1962).

Air temperature and relative humidity were correlated with nectar production and the corresponding percent sugar concentration (over time) in order to see if significant correlations existed and to determine the degree of significance. Correlations were made with both the RS and CS data.

The 1983 RS data (Table 15) show that nectar production and per cent sugar concentration are significantly negatively correlated, i.e. as nectar production increases percent sugar concentration decreases, or becomes more dilute. Nectar production and temperature are also negatively correlated,

(although not significantly), which can probably be attributed to nectar evaporation as the temperature rises. To further support this statement, the correlation between nectar and R H is strongly positively correlated. Therefore while R H is high, the nectar does not evaporate. Percent S C concentration is generally significantly positively correlated with temperature. As the water in the nectar evaporates the sugar solutes remain and thereby reslt in higher concentrations. Finally, percent sugar concentration and R H are strongly inversely correlated, probably because the nectar becomes more dilute as R H rises.

The 1982 CS correlations (Table 16) are very different from the 1983 RS correlations. However, with the exception of the nectar production and temperature correlations, the basic relationships remain the same. The sample size was smaller in 1982 and the flowers were difficult to sample, because of the environmental conditions. These difficulties likely account for the variations seen in Table 16.

The 1983 CS correlations (Table 17) are similar to the 1983 RS correlations and will not be discussed.

Tables 18 and 19 show the correlations for the species comparisons The B. campestris correlations for CS and RS are similar to each other. However nectar production and temperature are significantly positively correlated in this case, compared to the inverse relationship generally found in Tables 15, 16 and 17. The slightly cooler morning temperatures encountered during the observation period may account for this difference.

The correlations for B. napus (Tables 18 and 19) are similar to those found in the other Tables (15, 16 and 17), but the CS and RS samples differ a little in terms of significance. In this case it is possible that the two different sampling techniques are responsible for the differences.

Since the 1983 RS and CS cultivar data have high n values, these data appear to be fairly "representative". However, the variations between the data in the tables indicate that care must be taken when interpreting correlations made between environment with nectar production and percent SC. Sampling technique and general weather conditions must also be taken into consideration before generalizations can be made regarding correlations and degrees of significance for nectar production and percent SC with the environment.

Pollen Collections

All pollen samples were separated into "canola pollen" and "foreign pollen". No attempt was made to distinguish between the pollen of various canola cultivars.

Tables 20 and 21 show an interesting trend with regard to canola pollen collections. If bees are collecting canola pollen at all on a given day, (ex. on July 20, 1983 (Table 21) no canola pollen was collected), they appear to prefer to collect it in the late mornings around 1000 and 12000 hours. The amount of canola pollen collected declines after 1200 hours. Murrell and Nash (1981) observed anthesis occurring before 0830 hours on B. campestris var. toria, with newly opened florets producing copious amounts of pollen in the morning. The florets appeared to dry and shrivel by mid-afternoon resulting in little pollen being available for collection.

Free and Nuttall (1968) also reported that bees collected more canola pollen in the mornings (0900 and 1000 hours). However, Free and Nuttall (1968) found no obvious connection between the percent of canola pollen collected and the total weight of pollen trapped. However they did notice variations in percent canola pollen collected on different days.

I observed flowers opening at all times of the day, but did not observe when they were producing pollen. That bees collect more canola pollen in the morning may be due to: anthesis, environmental conditions, nectar availability and sugar concentration, competition from other floral sources and internal hive factors such as brood production. These factors must be considered when drawing conclusions about pollen collection.

Bee Counts and Insect Survey

Bee Counts

The total number of honey bees counted on the plots of the various canola cultivars was quite low in both 1982 and 1983 (Tables 33 and 34). Other researchers (Langridge and Goodman 1975) have also reported low counts but attributed this to poor weather and low numbers of available bees. Weather for bee activity was generally poor in 1982, but was still condusive to flight on the days that observations were made. In 1983, conditions were very good. In both years, plots were supplied with 4 strong colonies, therefore there was no shortage of available bees. Competition from other crops, such as dandelion, clover(s) and fababeans may have accounted for the small number of bees present on the canola plots in both 1982 and 1983.

The counts do not show that the bees had a preference for any of the cultivars tested. Tasei (1978) has shown that bees prefer certain cultivars, but this was not the case in my work with Candle or Tobin, or with Altex, Andor or Regent.

The data was also examined to see if any foraging patterns developed during the day. However, Table 33 and 34 do not show any such patterns or trends of bee visitation on any of the cultivars.

Species comparisons (Table 35) show that more bees were present on B. campestris than on B. napus. However I do not consider this difference to be significant since the total number of bees present on B. napus was greater in 1982 and 1983 (Tables 33 and 34).

Insect Survey

Other common beneficial insects on canola have included syrphids, bumblebees (Free and Ferguson 1980), Calliphoridae and a few species of Hemiptera, Lepidoptera and Coleoptera (Langridge and Goodman 1982).

The insect surveys conducted in 1982 and 1983 show that the following groups of insects were found in high numbers: at least 4 spp. (unidentified) of syrphids, calliphorids, muscids, megachilids, bombids and to a lesser degree several members of Hemiptera, Lepidoptera and Coleoptera.

I believe that megachilids, bombids and syrphids may contribute to the pollination of canola. However, honey bees remain the major pollinating agent for canola.

Bee Behaviour

General

Honey bees forage on canola cultivars for nectar, for pollen, or for both simultaneously. In the latter category, honey bees will often collect pollen incidently, i.e. they will pack their corbiculae with pollen which has accumulated on their bodies while they were foraging for nectar. Honey bees have also been seen actively collecting both nectar and pollen from the same canola plant and also from the same flower. This is a rather rare occurrance. Instead, most bees collect either nectar or pollen.

Number of Plants and Flowers Visited by Honey Bees

In 1982, the flowers on B. campestris plants were visited by honey bees mainly for nectar, with only 2 plants (2%) visited solely for pollen and 3 plants (2%) visited for pollen and nectar (Table 22). Similarly, most B. campestris flowers were individually visited for nectar, only 4 flowers (1%) were visited solely for pollen and no flowers were visited for both pollen and nectar.

All B. napus plants and flowers were visited for nectar only (Table 23). Based on these data one can conclude that bees rarely, if ever, collect pollen only from canola plants.

Again, in 1983, flowers on B. campestris plants were being visited mainly for nectar. However, a few bees collected only pollen or both nectar and pollen (Table 26).

B. napus flowers were often visited for pollen, as well as for nectar and pollen in 1983 (Table 27).

Species comparisons for B. campestris and B. napus made in 1983

(Table 30) show that no flowers on plants nor individual flowers were visited for pollen only. From these data it appears that canola is mainly foraged for nectar. However, I have observed honey bees actively collecting pollen from the crop. Certain flowers from plants and individual flowers were visited for both nectar and pollen. This is a relatively rare occurance. Bees collecting both nectar and pollen may be in a "transitional" stage or more likely they are young bees which have just begun to forage. No apparent cultivar differences were observed. More research is needed in this area before any conclusions can be made.

Time Spent Foraging

Honey bees appear to be fairly consistent as to the time they spend foraging on flowers of plants and on individual flowers. In 1982 honey bees visited a mean of 2.8 flowers/plant of B. campestris and 2.3 flower/plant of B. napus (Tables 22 and 23). Langridge and Goodman (1975) noted that bees tend to move from cluster to cluster on B. campestris rather than visit all the flowers of a cluster. They also cross over frequently from plant to plant. I found that honey bees visisted 2.4-2.8 flowers/cluster, visiting 1 or 2 clusters before moving on to the flowers of another plant, this increases the chance of cross-pollination. On B. napus bees visited a mean of 2.0 flowers/head (Langridge and Goodman 1982). Table 24 shows the time that bees spent foraging on plants and flowers in 1982. The bees spent a mean of 0.33 min./plant (=19.7 sec/plant) and 0.13 min/flower (=7.2 sec./flower) on Candle and Tobin respectively. On Altex, Andor and Regent bees spent

a mean of 0.23 min./plant (=14.0 sec./plant) and 0.10 min./flower (=6.1 sec/flower) respectively.

Langridge and Goodman (1982) report that bees spend an average of 4.8 sec/flower on B. napus cv. Midas. Free (1970) reported that bees spend 4.1-5.9 sec./flower. These figures are close to those I recorded in 1982. Petkov (1963) found that bees visit an average of 12 flowers/min. (=5 sec/flower), Tasei (1978) 9 flowers/min., Belozerova (1960) 9.7 flowers/min., Radchenko (1964) 10 flowers/min., Free and Nuttal (1968) 14 flowers/min., Kubisova et al. (1980) 7-10 flowers/min. and Benedek and Prenner (1972) 10 flowers/min. (=6 sec/flower). The flower visiting speed of honey bees was found to be dependent on temperature (i.e. floral visiting speed increases as temperature increases) by Benedek and Prenner (1972). However, Benedek and Prenner (1972) found the number of flowers visited per plant drops as the temperature increases. This temperature dependent relationship probably explains most of the variations in the floral visiting speed discussed above.

In 1983, bees visisted an average of 2.6 flowers/plant on B. campestris and 2.6 flowers/plant on B. napus. Bees spent a mean of 0.21 min./plant (=12.5 sec./plant) and a mean of 0.08 min./flower (=4.6 sec./flower) on B. campestris (Table 28). Bees spent a mean of 0.29 min./plant (=16 sec/plant) and a mean of 0.12 min./flower (-6.3 sec/flower) on B. napus (Table 28). These results appear to be more realistic than the 1982 results, because B. campestris flowers are smaller than B. napus flowers and bees spend less time per flower and consequently, less time per plant. These means are also similar to those recorded by other workers.

Species comparisons (Table 32) show that bees visit an average of 2.4 flowers/plant on B. campestris and 1.9 flowers/plant on B. napus. Bees also spend a mean of 0.24 min./plant (=14 sec/plant) and 0.10 min./flower (=59 sec/flower) for B. campestris and a mean of 0.22 min./plant (=13 sec/plant) and 0.12 min./flower (=6.9 sec/flower) for B. napus.

Honey bees may spend the same amount of time foraging on B. campestris as on B. napus, but on average, bees probably take more time on B. napus due to the larger flower size and greater nectar production.

Nectar Collecting Behaviour

Honey bees were never observed probing more than the two inner nectaries for nectar; this verifies observations made by Meyerhoff (1958). This observation relates to Frei's (1955) (as cited by Murrell and Nash 1981) statement that the two outer nectaries produce little if any attractive nectar.

Bees probed only one nectary of a flower if it was empty. If the next flower visited on the same plant did not contain nectar, the bee would then fly some distance to another plant. If one nectary is full of nectar the bee probes the other one. This behaviour correlates well with Meyerhoff's (1958) observations that while in flight, bees cannot distinguish between empty and full nectaries, and soon learn to fly to another plant if the nectaries of one or two flowers on one plant are empty.

Thieving Behaviour

Flowers visited by bees for nectar are divided into two categories; "traditional" and "thieved". Traditional refers to flowers having the

nectar removed (by bees) from the anterior or top. In this case, a bees inserts its proboscis into the corolla of the flower while standing on the top of the petals.

When bees visit the flowers for nectar in this manner they usually cross over the stigmas or at least contact them. Since honey bees are often heavily coated with pollen, regardless of whether they are pollen or nectar gatherers, it is likely that they also pollinate a great many flowers without actually crossing the stigma.

Thieving refers to flowers from which the nectar is removed from between the petals making up the corolla. In this manner, bees gain more direct access to the nectaries of certain flowers than they would through traditional means (Inouye 1980). Kapil et al.(1971) observed that nectar collectors of Apis florea and A. dorsata had a tendency to approach B. campestris and mustard flowers from the side or below the petals, thereby collecting nectar through the gap between them. In doing so, they avoid contact with the anthers and the stigma.

Free and Ferguson (1983) refer to honey bees 'robbing' nectar from B. napus cv. Primor. They describe the process as the bees pushing "their tongues between the bases of the petals and sepals." Although Free and Ferguson refer to this process as robbing, it should be more correctly referred to as thieving. Robbing involves the mutilation of the flower, usually by cutting a hole through the base of the corolla (Inouye 1980). Neither Apis mellifera nor A. florea and A. dorsata mutilate the flowers.

However, my observations are the second report of thieving behaviour of A. mellifera on oil seed canola. Free and Ferguson (1983) indicate that thieving may be associated with flower size and structure.

Free and Williams (1973) have shown that the tendency of honey bees to 'rob' Brussels Sprout cultivars increases as the size of the flower increases. Free and Ferguson (1983) reported that 17%-23.8% of flowers robbed of nectar on B. napus (cv. Primor).

In 1982, I found that only 5% of B. campestris flowers visited for nectar were thieved, while at the same time 48% of B. napus flowers had their nectar thieved. The bees have also been observed attempting to probe the nectaries at the bottom of the relatively long corolla. B. campestris has smaller flowers than B. napus which are clustered tightly together. Therefore bees can walk from flower to flower and have no difficulty in removing nectar from the bottom of the corolla in the traditional way. B. napus has larger flowers and bees must fly from flower to flower. In 1983 I observed that no bees thieved nectar from B. campestris but a higher percentage of bees were thieving nectar from B. napus than I observed in 1982 (Table 27).

Pollen Collecting Behaviour

Honey bees have been reported actively and incidently collecting pollen from canola, or not collecting pollen at all (see Free and Nuttall 1968, Eisikowitch 1981, Free and Ferguson 1983). Bees have also been seen discarding pollen (see also Free and Nuttall 1968); they hover over the flowers and by using all three pairs of legs, brush the pollen from their bodies and discard it. Why bees actively collect pollen one time and discard it the next is not known. Perhaps competition from more attractive pollen sources plays a major role in determining how much pollen is to be collected and/or discarded. Alternatively, perhaps the amount of brood present in the colony partly determines how much pollen

is retained. However, I feel that a combination of floral competition, brood time of day, and the individuality of the foraging bee, all play a role in determining how pollen is collected.

In 1982 very few bees were either actively or incidently collecting pollen from either B. campestris or B. napus (Table 25). Benedek and Prenner (1972) stated that each bee they observed gathered both nectar and pollen from B. napus while individuals gathering either nectar or pollen were never observed. Langridge and Goodman (1975) observed that 25.4% of the bees collected nectar and pollen on B. campestris but classified them as nectar collectors since in nearly every case, only incidentally collected pollen was packed into the corbiculae. Langridge and Goodman (1982) found that 95.6% of bees foraging on B. napus collected nectar.

Free and Ferguson (1983) stated that "although all foragers collected nectar, and none collected pollen only, most became dusted with pollen while visiting a flower." However, Eisikowitch (1981) stated that "in some cases they were seen loaded with pollen grains during nectar collections, in others they were exclusively pollen collectors, but in both cases they touched the stigma." All flowers visited for pollen presumably result in pollination as the pollen laden bees touch the anthers and stigma. However, when the bees are collecting nectar the stigma is not necessarily crossed or touched.

In 1982, few bees collected pollen (Table 25). Thus, the few stigmas that were crossed occurred while bees collected nectar. Williams (1980) reported that bees touched 76% of stigmas while foraging. However I observed that only 32.5% of the stigmas were actually crossed

on B. campestris and 25.3% on B. napus (due to increased thieving). These figures however - include only flowers visited by bees for pollen and flowers visited for nectar where the bee actually crossed over the stigma. More flowers could have been pollinated by the bees as they brushed against the anthers and stigma without actually crossing the stigma.

In 1983 more bees collected pollen on B. campestris (Table 29), see Candle and Tobin). However, the majority of stigmas were crossed during nectar collection (58.5). No significant cultivar differences exist as to the number of stigmas crossed while foraging.

In 1983 Table 29 (Altex, Andor and Regent) includes some very interesting data regarding the number of stigmas crossed on canola flowers. Although the majority of flowers were visited by bees for nectar, most of the stigmas were only crossed while bees collected pollen from the flowers. A mean of 47.3% of the stigmas were crossed for B. napus during pollen collection, with only a mean of 4.3% during nectar collection. This is likely due to the high number of flower that had nectar thieved (Table 27). Why the bees began to collect canola pollen to this extent is not known. The overall mean percent of stigmas crossed on B. napus was 51.7% which is similar to the 1982 figure.

The 1983 species comparison data (Table 31) show that there were no pollen collectors; 81% of the stigmas of B. campestris were crossed while only 24% were crossed for B. napus.

Although these results vary considerably from 1982 to 1983, and even within 1983, they have important implications. B. campestris is usually pollinated by bees whether or not the bees are actively collect-

ing pollen from the flowers since the flowers grow in a tight cluster which allows bees to walk from one flower to another. In doing so they increase the chance of pollinating the flowers in that cluster. The bees also collect a great deal of pollen on their bodies while walking on the cluster which would likely increase the chance of cross-pollination occurring on the next cluster of flowers they visit. However, if bees did not actively collect pollen on B. napus in 1983, only 4.3% of stigmas would have been crossed due to increased thieving (Altex, Andor and Regent, Table 29). Since bees must also fly from flower to flower on B. napus their chances of contacting stigmas as they forage is decreased. It appears that the greater the percentage of honey bees that thieve, the lower the chance of cross pollination occurring. If honey bees only thieved nectar and did not actively collect pollen, they would be relatively useless as a pollinating agent on B. napus.

Thieving behaviour on B. napus appears to be learned. Young foragers were observed collecting nectar in a traditional manner by probing the inner nectaries with their tongues. On occasion they would "accidentally" fall to the side while still probing. If the tongue slipped between the petals and sepals and located nectar, it was quickly drawn up. As they visited other flowers they began to enter the side of the flower immediately after landing, without a traditional start. It appears that each bee starts foraging in the traditional way but may or may not learn to become a nectar "thief". The B. napus flower is of an intermediate size, i.e. it is not small enough to make traditional foraging easy, yet it is not large enough to illicit automatic thieving behaviour in bees. Therefore, as long as canola breeders produce cul-

tivars with intermediate to small flowers, extreme thieving by bees should not become a serious problem.

CHAPTER 5

SUMMARY AND CONCLUSIONS

1. In bagging trials honey bees increase the seed yield of B. campestris cultivars Candle and Tobin 139 and 81% respectively.
2. In bagging trials honey bees increase the seed yield of B. napus cultivars Altex, Andor and Regent 73, 39 and 58% respectively. Therefore the use of honey bees as a pollinating agent on B. napus is recommended.
3. The open-pollinated control plants had more flowers, more pods and more fully filled pods (per main branch) than plants which were bagged.
4. B. napus cultivars generally produce more nectar with a lower percent sugar concentration than B. campestris cultivars.
5. Canola flowers that had the nectar continuously removed throughout the sampling period (CoS) produce more nectar with a lower percent sugar concentration than flowers that had the nectar removed only once during the sampling period (RS and CS).
6. Canola nectar production is highest at 800-1000 hours. Nectar production then decreases as the day progresses.
7. Mean daily nectar production for B. campestris ranges from 0.68 μl - 0.33 μl, and from 2.15 - 0.82 μl from B. napus (RS and CS techniques only) (n = 10).
8. Canola percent sugar concentration is lowest at 0800-1000 hrs. Percent sugar concentration levels off as the day progresses.
9. Mean percent sugar concentration for B. campestris ranges from 57-65% and from 43-62% for B. napus (RS and CS techniques only).

10. Nectar production and percent sugar concentration are closely associated with air temperature and percent relative humidity.
11. Honey bees collect more canola pollen in the mornings than in the afternoons.
12. On B. campestris honey bees visit 2.4-2.8 flowers/plant, spend 0.22-0.33 min./plant and 0.08-0.13 min./flower.
13. On B. napus honey bees visit 1.9-2.6 flowers/plant, spend 0.22-0.29 min./plant and 0.10-0.12 min./flower.
14. Honey bees will collect both nectar and pollen from the same canola flower and/or flowers on the same plant.
15. Honey bees will either "purposefully" collect canola pollen or "actively" discard it.
16. Honey bees are likely to be more efficient pollinators of B. campestris due to the smaller, clustered flower heads of this species than of B. napus where flowers are larger and spaced further apart.
17. Honey bees learn to thieve nectar from B. napus where flowers are larger and spaced further apart.
18. Thieving can lead to a decreased percentage of stigmas that are crossed during nectar collection.
19. Honey bees do not show any obvious preferences for any of the canola cultivars tested.
20. Other pollinators on canola may include members of the Megachilidae, Bombidae and Syrphidae.

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Appendix 1. Significance of certain plant factors for B. campestris (1982, 1983).

Source	No. of flowers	No. of pods	No. fully filled pods	No. partially filled pods	No. aborted flowers	No. seeds/ pod	Thousand seed weight (g)	Main branch yield (g)
1982								
Replicate	ns[a]	ns	ns	ns	ns	ns	ns	ns
Cultivar	ns	ns	ns	ns	ns	ns	ns	ns
Treatment	**	*	**	ns	ns	**	ns	**
Cultivar & Treatment	ns	ns	ns	ns	ns	ns	ns	ns
1983								
Replicate	ns	ns	ns	ns	ns	ns	ns	ns
Cultivar	ns	ns	ns	ns	ns	ns	ns	ns
Treatment	*	**	**	ns	ns	*	**	*
Cultivar & Treatment	ns	ns	ns	ns	ns	ns	ns	ns

a Significance was determined using the analysis of variance procedure ($\alpha = 0.05$)
ns = $p \geq 0.05$; * $p < 0.05$; ** $p < 0.01$.

Appendix 2. Significance of certain plant factors for B. napus (1982, 1983).

Source	No. of flowers	No. of pods	No. fully filled pods	No. partially filled pods	No. aborted flowers	No. seeds/ pod	Thousand seed weight(g)	Main branch yield (g)
1982								
Replicate	ns[a]	ns	ns	ns	ns	ns	*	ns
Cultivar	ns	ns	ns	ns	ns	**	ns	ns
Treatment	**	**	**	*	*	**	**	**
Cultivar * Treatment	ns	ns	ns	ns	ns	ns	ns	ns
1983								
Replicate	ns	ns	ns	ns	ns	ns	ns	ns
Cultivar	*	ns	*	ns	ns	**	ns	*
Treatment	**	**	**	**	ns	**	ns	**
Cultivar * Treatment	ns	ns	ns	ns	ns	ns	ns	ns

a Significance was determined using the analysis of variance procedure ($\alpha = 0.05$)
ns = $p \geq 0.05$; * $p < 0.05$; ** $p < 0.01$.

Appendix 3. Air temperatures and relative humidity in 1982.

	Date							
	21 July		26 July		30 July		2 Aug.	
Time of day (hrs)	Temp. (°C)	% RH	Temp. (°C)	% RH	Temp. (°C)	% RH	Temp. (°C)	% RH
0800	19.5	53	20.0	70	16.0	86	18.0	90
1000	22.5	53	21.5	60	22.0	74	20.0	81
1200	23.5	48	25.0	52	24.0	62	24.0	68
1400	24.0	45	26.0	50	25.0	56	25.0	68
1600	25.0	46	27.0	46	25.5	50	24.5	68
1800	25.5	44	-	-	24.0	68	24.5	68

Appendix 4. Air temperatures and relative humidities in 1983.

Time of Day (hrs)	Date: 19 July Temp. (°C)	19 July % RH	20 July Temp. (°C)	20 July % RH	21 July Temp. (°C)	21 July % RH	22 July Temp. (°C)	22 July % RH
0800	23.5	60	21.5	90	22.5	88	22.0	82
1000	21.5	86	25.0	88	26.5	73	23.0	78
1200	26.0	68	29.5	65	30.0	60	28.0	46
1400	29.0	53	31.0	58	32.0	53	30.5	36
1600	28.0	64	31.5	46	32.5	51	31.5	30
1800	34.5	84	31.0	41	31.5	50	30.0	36
2000	-	-	30.0	51	29.5	72	26.5	50

	25 July		26 July		27 July		28 July	
0800	20.0	73	22.0	78	24.5	82	20.0	86
1000	23.5	75	23.0	74	24.0	72	23.5	71
1200	29.5	48	26.0	62	27.0	71	28.5	44
1400	30.5	52	29.5	60	30.0	60	30.0	26
1600	28.5	52	30.0	54	30.0	55	33.0	32
1800	29.0	42	29.5	54	30.5	52	31.5	57
2000	-	-	27.5	64	26.5	73	29.5	35

Appendix 5. Air temperatures and relative humidity in 1983.

Time of day (hrs.)	Date: 28 June Temp. (°C)	28 June % RH	5 July Temp. (°C)	5 July % RH	6 July Temp. (°C)	6 July % RH
0800	16.0	64	12.0	73	17.0	80
1000	21.0	51	14.5	66	22.0	71
1200	24.5	37	16.5	44	25.0	68
1400	25.0	38	18.5	49	27.5	64
1600	26.5	29	20.0	57	29.5	63
1800	26.5	26	22.0	53	29.5	69

Time of day (hrs.)	10 July Temp. (°C)	10 July % RH	12 July Temp. (°C)	12 July % RH	13 July Temp. (°C)	13 July % RH
0800	24.5	79	20.0	-	24.0	68
1000	26.5	76	24.5	64	22.0	86
1200	29.5	66	27.0	60	27.5	74
1400	32.0	59	20.5	52	31.0	65
1600	34.0	53	31.5	42	29.5	66
1800	33.5	60	31.5	48	32.0	50

Appendix 6. N values for the means of nectar volumes and sugar concentrations related to figures 12-21.

FIGURE	CULTIVAR OR SPECIES	VARIABLE	TIME OF DAY (hrs.) 0800	1000	1200	1400	1600	1800	2000
12	CANDLE	NECTAR	4	4	4	4	4	4	4
		SC[a]	3	4	4	4	4	3	3
	TOBIN	NECTAR	4	4	4	4	4	3	3
		SC	4	4	4	4	4	3	2
13	ALTEX	NECTAR	5	5	5	5	5	5	3
		SC	5	5	5	5	5	5	3
	ANDOR	NECTAR	5	5	5	5	5	5	3
		SC	5	4	5	5	5	5	3
	REGENT	NECTAR	5	5	5	5	5	5	3
		SC	5	5	5	5	5	5	3
14	B. CAMPESTRIS	NECTAR	3	3	3	3	3	2	-
		SC	3	3	3	3	3	2	-
15	B. NAPUS	NECTAR	3	3	3	3	3	3	-
		SC	3	3	3	3	3	3	-
16	CANDLE	NECTAR	1	3	3	3	3	1	-
		SC	-	3	3	3	3	1	-
	TOBIN	NECTAR	1	3	3	3	3	1	-
		SC	1	3	3	3	3	1	-
17	ALTEX	NECTAR	2	2	2	2	2	2	-
		SC	2	2	2	2	2	2	-
	ANDOR	NECTAR	2	2	2	2	2	2	-
		SC	2	2	2	2	2	2	-
	REGENT	NECTAR	2	2	2	2	2	2	-
		SC	2	2	2	2	2	2	-

a SC = Sugar Concentration

Appendix 6. continued.

FIGURE	CULTIVAR OR SPECIES	VARIABLE	TIME OF DAY (hrs.)						
			0800	1000	1200	1400	1600	1800	2000
18	CANDLE	NECTAR	4	4	4	4	4	3	3
		SC	4	4	4	4	4	3	2
	TOBIN	NECTAR	4	4	4	4	4	3	3
		SC	4	4	4	4	4	3	3
19	ALTEX	NECTAR	5	5	5	5	5	5	3
		SC	5	5	5	5	5	5	3
	ANDOR	NECTAR	5	5	5	5	5	5	3
		SC	5	5	5	5	5	5	3
	REGENT	NECTAR	5	5	5	5	5	5	3
		SC	5	5	5	5	5	5	3
20	*B. CAMPESTRIS*	NECTAR	3	3	3	3	3	2	-
		SC	3	3	3	3	3	-	-
	B. NAPUS	NECTAR	3	3	3	3	3	3	-
		SC	3	3	3	3	3	3	-