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Original article

The effect of kiwifruit (*Actinidia deliciosa* A Chev) and yellow flowered broom (*Cytisus scoparius* Link) pollen on the ovary development of worker honey bees (*Apis mellifera* L)

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Summary — The effect of feeding honey or honey–pollen mixtures (using pollen from yellow flowered broom, male kiwifruit flowers, female kiwifruit flowers) on the ovary development of worker honey bees was assessed after the bees had been caged without a queen for 14 d. There was no significant difference in ovary development between bees fed honey and those fed pollen from female kiwifruit flowers mixed with honey, nor between bees fed broom pollen and pollen from male kiwifruit flowers when mixed with honey. Each of the latter 2 diets resulted in ovary development that was significantly greater than that of bees fed either honey only or pollen from female kiwifruit flowers mixed with honey. It is suggested that the nutritional value of various pollens for worker honey bees may be determined by examining their ovary development after being fed selected pollen diets in cages without a queen for 14 d.

ovary development / pollen / nutritional value / *Actinidia deliciosa*

INTRODUCTION

Ovary development of worker honey bees is inhibited by the following: 1) mated adult queens (De Groot and Voogd, 1954; Butler, 1957; Velthuis, 1970a); 2) unsealed worker brood (Perepelova, 1929; Müssbichler, 1952; Milojevic and Filipovic-Moskovljevic, 1959; Jay 1970, 1972; Kropáčová and Haslbachová, 1971; Bai and Reddy, 1975); 3) sealed worker brood (Milojevic and Filipovic-Moskovljevic, 1959; Jay, 1970; Bai and Reddy, 1975); 4) laying worker bees (Velthuis *et al*, 1965; Velthuis, 1970b; Jay and Nelson, 1973), and laying worker brood (Jay and Nelson, 1973). Alternatively, pollen that is rich in proteins, fats, minerals and vitamins promote, among other things, ovary development in newly emerged worker bees that are caged without queens (De Groot, 1952; Maurizio, 1954; Knox *et al*, 1971).

While investigating the behaviour of honey bees on Chinese gooseberries (*ie* kiwifruit), *Actinidia deliciosa* (A Chev) in New Zealand, Jay and Jay (1984) observed that 96% of the bees carry pollen loads in their corbiculae; these loads usually consist of a mixture of pollen from flowers located on the male and female vines (note: kiwifruit is dioecious). Some bees, however, forage on either male or female flowers (Jay and Jay, 1984; Goodwin, 1987) at certain times and thus are of little value as kiwifruit *pollinators*. This selective foraging behaviour has been verified by examining pollen loads collected in pollen traps attached to honey bee colonies located in kiwifruit orchards (Jay and Jay, 1984; Clinch, 1986; Goodwin, 1987).

An attempt was made in this study to assess the relative nutritional value of pollen from male and female kiwifruit flowers for honey bees. This was done using a technique devised to measure ovary development of queenless worker bees in cages when exposed to various kinds of brood or comb (see Jay, 1968; Jay and Jay, 1976).

MATERIALS AND METHODS

Two trials each with 4 replicates were carried out using honey bees (*Apis mellifera* L) of a yellow strain. Young worker bees were obtained by inserting combs of sealed brood, 1 from each of 10 colonies, into a box (with a screened bottom and solid wooden lid) that was placed on top of a well-populated colony of bees for 10 h. This was undertaken at 2 different times using 2 different groups of 10 colonies each; these 2 groups provided the bees for the 2 trials. Plastic cages (10 x 7 x 8 cm) fitted with 2 feeders, 1 for water and 1 for honey or for a honey and freshly ground pollen mixture (1:10 vol) were used in the 2 trials.

When the trials began (see table I), 125 bees < 12 h old were placed in each cage. None of the cages contained a queen. Cages in treatment (a) contained feeders of honey; cages in treatment (b) contained feeders of a honey–pollen mixture (pollen from yellow flowered broom; *Cytisus scoparius* Link); cages in treatment (c) contained feeders of a honey–pollen mixture (pollen from male flowers of *Actinidia deliciosa*, cv Matua); cages in treatment (d) contained feeders of a honey–pollen mixture (pollen from female flowers of *Actinidia deliciosa*, cv Hayward). Honey and pollen mixtures were replaced daily. The trials were conducted in an incubator at 32 ± 1 °C and at 50–60% RH:

Pollen for the trials was collected in pollen traps attached to honey bee colonies, located in kiwifruit orchards and in areas where broom plants were growing and flowering in large numbers. Loads of male or female pollen from kiwifruit flowers were separated from the pollen trap collections using a low-power microscope. This was possible because female pollen loads are white while male pollen loads are off-white or creamy in colour (McKay, 1976; Jay and Jay, 1984). Broom pollen loads are deep orange in colour. Verification of pollen load composition was undertaken using high-power magnification coupled with reference slides and pollen keys. Broom pollen was used as a "control" in the trials as it is considered to be a valuable source of protein for rapid build-up of honey bee populations in New Zealand (Walsh, 1978).

Fourteen d after the start of each trial, 25 bees were removed from each cage and dissected. Their ovaries were classified as 0, undeveloped (score = 1); I, slightly developed (swelling and (or) constriction of ovarioles (score = 2); or II, well-developed ova usually present at various stages (score = 3). The few ovaries that were between categories and difficult to classify were assigned alternatively to the next higher or the next lower category. Analysis of variance was used for statistical comparisons.

RESULTS

The results have been summarized in table I; in both trials there was no significant difference in ovary development of worker bees that were fed honey and those that were fed honey mixed with pollen from female kiwifruit flowers, nor was there any

Table I. The effect of various treatments on the ovary development of worker honey bees, with no queen present, after 14 d.

Treatment diets	*Replicate I**			*Replicate II*			*Replicate III*			*Replicate IV*			*Ovary development*
	*0***	*I*	*II*	*0*	*I*	*II*	*0*	*I*	*II*	*0*	*I*	*II*	*index +*
Trial I													
(a) Honey	24	1	0	19	6	0	13	12	0	15	10	0	$32.3 \pm 2.4^{b++}$
(b) Honey + broom pollen	0	8	17	0	7	18	1	6	18	0	5	20	68.0 ± 0.7^{a}
(c) Honey + ♂ kiwifruit pollen	0	7	18	1	10	14	0	9	16	0	4	20	67.0 ± 1.7^{a}
(d) Honey + ♀ kiwifruit pollen	21	4	0	19	6	0	22	3	0	20	5	0	29.5 ± 0.7^{b}
Trial 2													
(a) Honey	23	2	0	21	4	0	25	0	0	22	3	0	27.3 ± 0.9^{b}
(b) Honey + broom pollen	1	6	18	0	8	17	1	9	15	1	12	12	64.8 ± 1.4^{b}
(c) Honey + ♂ kiwifruit pollen	1	12	12	0	9	16	3	10	12	1	6	18	63.3 ± 1.9^{a}
(d) Honey + ♀ kiwifruit pollen	21	4	0	20	5	0	21	4	0	19	6	0	29.8 ± 0.5^{b}

* Twenty-five bees dissected ; ** 0, undeveloped (score = 1) ; I, slightly developed (score = 2) ; II, well developed (score = 3) ; + the "ovary development index" is the mean of the various scores when multiplied by the number of bees whose ovaries fall within each ovary development category. Figures within a column followed by the same letter are not significantly different at the 1% level by analysis of variance; ++ mean ± SD.

significant difference in ovary development of worker bees when fed honey mixed with broom pollen and honey mixed with pollen from male kiwifruit flowers. However, there was a significant difference ($P < 0.01$) in ovary development of worker bees when fed either honey or honey mixed with pollen from female flowers and honey mixed with broom pollen or honey mixed with pollen from male kiwifruit flowers.

Small amounts of comb were built around the feeders in most of the cages but at no time were eggs observed in the comb. Of interest was that the wax scales produced by bees fed on broom pollen were light yellow in colour while wax scales from bees fed on the other diets were colourless.

DISCUSSION

Female flowers of kiwifruit do not produce viable pollen, the pollen being "shrivelled" and lacking nucleii (McKay, 1976; Schmidt, 1978). Male kiwifruit flowers, in contrast, produce pollen in the binucleate stage (Rizet, 1945; Schmidt, 1978) which is 95–100% viable (McKay, 1976). Our results using worker ovary development indices indicate that pollen collected from broom and from male kiwifruit flowers has high nutritional value for honey bees; however this does not appear to be true for pollen from female kiwifruit flowers.

This bioassay may be useful in assessing the nutritional value of other pollens as well and if so would augment, or verify, data collected through chemical analyses of such pollens. The bioassay is relatively easy to use and requires little specialized equipment or dissection skills.

Although minor ovary development occurred in the bees of some replicates in which the bees were fed honey or pollen from female kiwifruit flowers this may have resulted from the bees using proteins from within their own bodies. The reason for the wax scales of the bees fed on broom being yellow in colour is not known.

Colonies of honey bees are often moved into kiwifruit orchards to assist in the pollination process. In general, bee populations decrease while the colonies are in these orchards despite being fed sugar syrup (this is done because kiwifruit flowers produce no nectar). It is also possible that the large amounts of pollen that are collected by the bees from female flowers (*eg*, Donavan, 1983; Jay and Jay, 1984; Goodwin, 1987) contribute to population declines in the colonies because, according to this study, the pollen appears to be of low nutritional value.

Thus, it is suggested that any contract that involves the pollination of kiwifruit using honey bees should take into consideration the colony population decreases that occur due to nectar and, or protein deficiencies.

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Résumé — Influence du pollen de kiwi (*Actinidia deliciosa* A Chev) et du genêt à balai (*Cytisus scoparius* Link) sur le développement ovarien des ouvrières d'abeilles (*Apis mellifera* L). Les pollens, qui sont riches en protéines, lipides, minéraux et vitamines, favorisent, entre autres, le développement ovarien chez les ouvrières écloses en l'absence de reines. Dans cette étude la valeur nutritive relative du pollen de kiwi (fleurs mâles et femelles) vis-à-vis de l'abeille domestique a été étudiée à l'aide d'une technique qui mesure le

développement ovarien d'ouvrières orphelines maintenues en cagettes. Les abeilles encagées, âgées de moins de 12 h, étaient nourries avec a) soit du miel, soit un mélange de miel et de pollen. Le pollen provenait b) du genêt à balai (*Cytisus scoparius*, connu pour favoriser le développement rapide des populations d'abeilles), c) des fleurs mâles de kiwi (*Actinidia deliciosa* cv Matua), d) des fleurs femelles de kiwi (*Actinidia deliciosa* cv Hayward). Chaque cagette comportait en outre un abreuvoir. Les abeilles encagées ont été maintenues en étuve à 32 ± 1°C et 50–60% HR durant 14 j, puis 25 abeilles ont été prélevées dans chaque cagette. Elles ont été disséquées et leurs ovaires classés en 3 catégories: non développés, peu développés et bien développés. On n'a pas trouvé de différences significatives entre le développement ovarien des ouvrières du régime a) et celles du régime d), ni entre celui des ouvrières du régime b) et celles du régime c). Mais il y avait une différence significative ($P < 0,01$) entre les ouvrières de ces 2 groupes (a,d et b,c). Nos résultats, basés sur l'indice de développement ovarien, montrent que le pollen de genêt à balai possède une valeur nutritive élevée et que ce n'est pas le cas pour le pollen de fleurs femelles de kiwi. Ce test biologique pourrait être utile pour déterminer la valeur nutritive d'autres pollens et augmenter ainsi, ou vérifier, les données obtenues sur ces pollens par analyse chimique. Le test est relativement facile et ne nécessite pas d'équipement spécialisé ni de compétences particulières pour la dissection.

développement ovarien / pollen / valeur nutritive / *Actinidia deliciosa*

Zussammenfassung — Der Einfluß des Pollens der "Kiwifrucht (*Actinidia deliciosa* A Chev) und des Gelben Ginsters (*Cytisus scoparius* Link) auf die Ovarentwicklung von Arbeiterinnen der Honigbiene (*Apis mellifera* L). Pollen, reich an Proteinen, Fett, Mineralen und Vitaminen, fördern unter anderem die Entwicklung der Ovarien von weisellosen, frisch geschlüpften Arbeitsbienen. In dieser Studie wurde der relative Futterwert des Pollens der männlichen und weiblichen Kiwifrucht-Blüte mit einer Technik untersucht, bei der die Ovarentwicklung weiselloser gekäfigter Arbeitsbienen gemessen wurde. Gekäfigte Arbeiterinnen, unter 12 h alt, wurden mit Honig oder einer Honig-Pollenmischung gefüttert. Der Pollen stammte vom Gelben Ginster, *Cytisus scoparius*, bekannt als wertvolle Pollenquelle zum raschen Aufbau der Bienenvölker, von männlichen Blüten von *Actinidia deliciosa*, Sorte Matua, und von weiblichen Blüten derselben Pflanze, Sorte Hayward. Zu dieser Diät kam in jeden Käfig noch ein Futtergefäß mit Wasser. Die gekäfigten Bienen wurden 14 Tage lang im Brutschrank bei einer Temperatur von 32 ± 1°C und einer relativen Feuchtigkeit von 50–60% gehalten; anschließend wurden jedem Käfig 25 Bienen entnommen, präpariert und die Ovarien nach den Klassen unentwickelt, leicht entwickelt und gut entwickelt eingeteilt.

Es bestand kein signifikanter Unterschied in der Ovarentwicklung von Bienen, die mit Honig allein und von solchen, die mit einem Honiggemisch mit Pollen der weibliche Kiwifrucht gefüttert worden waren. Ebenso bestand kein signifikanter Unterschied in der Ovarentwicklung von Arbeiterinnen, die ein Gemisch mit Ginsterpollen oder denen, die Pollen von männlicher Kiwifrucht erhalten hatten. Es bestand jedoch ein signifikanter Unterschied ($P < 0.01$) zwischen diesen beiden Gruppen, also zwischen Bienen nach Fütterung mit Honig allein oder mit einem Gemisch von weiblicher Kiwifrucht, und solchen, die entweder Ginsterpollen oder Pollen von männlicher Kiwifrucht erhalten hatten.

Unsere Versuche, die auf Indizes der Ovarentwicklung von Arbeitsbienen aufbauen, bestätigen den hohen Nährwert des Ginsterpollens; dies scheint jedoch nicht für den Pollen der weiblichen Kiwifrucht zuzutreffen. Es wird vorgeschlagen, diesen Biotest zur Bestimmung des Nährwertes anderer Pollenarten zu verwenden; dadurch könnten die Daten aus chemischen Analysen dieses Pollens bestätigt oder vermehrt werden. Dieser Biotest ist relativ einfach anzuwenden, er verlangt kaum spezielle Einrichtungen oder besonderes Präparationsgeschick.

Ovarentwicklung / Pollen Futterwert / Kiwifrucht

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