

**FORAGING BEHAVIOUR OF *Apis mellifera* L. AND
Apis cerana F. AS DETERMINED BY THE ENERGETICS
OF NECTAR PRODUCTION IN DIFFERENT CULTIVARS
OF *Brassica campestris* var. *toria***

D h a r a m P a l A b r o l

Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology,
Faculty of Agriculture, Udheywalla, Jammu 180 002, Jammu & Kashmir, India.
E-mail: dharam_abrol@rediffmail.com

Received 22 February 2007; accepted 19 June 2007

S u m m a r y

Twenty-four cultivars of *Brassica campestris* var. *toria* were examined for their nectar secretion characteristics, nectar sugar concentration, amount of sugar and energy per flower per day in relation to their attractiveness to honeybees *Apis mellifera* L. and *Apis cerana* F. The volume of nectar produced ranged from a minimum of 0.052 μ l to a maximum of 0.120 μ l per flower per day. Nectar sugar concentration ranged between 36.0-43.8% and the amount of sugar ranged between 0.0198-0.0504 mg per flower per day. The energy reward varied from a minimum of 0.330 joules to a maximum of 0.845 joules per flower per day. The number of bees per 1 m² ranged between 4.0-12.0 and 2.6-10.2 in the case of *A. mellifera* and *A. cerana*, respectively in different cultivars of *Brassica*. These variations were found to be significantly and positively correlated with the foraging populations of honeybees, *Apis mellifera* L. and *Apis cerana* F. The results suggest that cultivars with higher caloric rewards had a competitive edge over others in attracting foraging populations and, consequently, in pollination.

Keywords: honeybee, *Apis mellifera*, *Apis cerana*, *Brassica campestris* var. *toria*, energy, pollination, nectar.

INTRODUCTION

Pollinator plant interaction depends upon the energy needs of the pollinators and the energy available from plants (Heinrich and Raven 1972; Heinrich 1975, 1983; Abrol 1986, 1992). Physical attributes of flowers such as colour, shape and odour are well known features that attract pollinators (Faegri and Vander Pijl 1966, Srinivasan 1994). One source of variation in foraging cues between genotypes is the nectar, which may provide a variety of stimuli. Nectar is the potential energy reward provided by the flowers to their visitors. It has been found to be a very significant parameter that decisively shapes the behaviour of pollinators in relation to their energy demands (Abrol 1986, 1992;

Heinrich and Raven 1972; Heinrich 1975). The following study was undertaken to assess whether different *Brassica* cultivars differ in production of caloric rewards and if foraging behaviour is influenced by such variation. *Brassica campestris* var. *toria* is highly self-incompatible and depends upon insects for cross-pollination to produce a crop (Sihag 1986, Free 1993, Abrol 1997). Honeybees *Apis mellifera* and *Apis cerana* have been widely recognized as the most efficient and potential pollinators of a wide variety of field and fruit crops (Free 1993, Abrol 1997). Among the various floral resources, Indian mustard is an important oilseed crop which constitutes approximately 80 percent of the total production of rapeseed and

mustard in India (Yadav et al 1985). The economically important crop plants selected for this study included *Brassica campestris* var. *toria*.

MATERIALS AND METHODS

The energy relationship of *A. mellifera* and *A. cerana* was studied in relation to their foraging upon *Brassica campestris* var. *toria*. The studies were conducted under the following sub-headings:

Sampling of pollinating insects

The relative abundance of pollinating honeybees visiting the *Brassica* group of crops was conducted following Abrol (1992). The abundance of bees visiting the *Brassica* group of crops was recorded right from the commencement of the flowering till their petal fall. For this purpose, 5 plots (each measuring 1 x 1 m) were selected randomly in the crop and the number of bees of each species visiting these plots was recorded by the visual counting method for 1 min. from each side of the plot. The mean of these 5 observations constituted a reading for each cultivar.

Determination of energetic reward

The data on the energetics of nectar production were obtained by measuring nectar volume and the percentage of dissolved solids in it. Inflorescences which may open in next 2-3 hours were bagged with synthetic nylon nettings to exclude all nectarivorous insects. The nectar from these flowers was sampled the next day between 10:00-13:00 hrs when the ambient temperature fluctuated between 18.0-22.5°C with the help of microcapillary pipettes. The volume of nectar was measured with the help of 5 λ pipettes and its sugar concentration was determined with a hand refractometer (Erma type, Japan Make).

Calculation of energy

Caloric reward/flower/day was calculated by assuming that 1 mg of sugar (irrespective of the type) yields 4 cal or 16.74

joules of energy (Henirich 1975) by the formula:

$$\frac{\text{Nectar volume } (\mu\text{l}) \times \text{Concentration of nectar } (\%) \times 16.74}{100}$$

Statistical analysis

The correlation coefficients for the relation between nectar volume, nectar sugar concentration, amount of sugar or energy and foraging populations of honeybees were calculated following Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Nectar production

The percentage of dissolved solids and amount of sugar vary from one plant species to another. Variations exist even among different cultivars of the same species. The data presented in table 1 show that different *Brassica* cultivars differed greatly in the pattern of nectar production characteristics and pollinator attractiveness. The volume of nectar produced ranged between 0.0520 μl and 0.1200 μl and the nectar sugar concentration ranged between 36.0-43.8%. Likewise, amount of sugar and energy per flower per day ranged between 0.0198 and 0.0504 mg and 0.330-0.845 joules, respectively. The present study corroborates the results obtained by Sihag and Kapil (1983). The differences observed between the data obtained in the present investigation and those reported previously may possibly be due to different geographic locations, climatic conditions, cultural practices, sampling methods and cultivars involved.

Relationship of nectar production with honeybee foraging activity

The foraging activity of honeybees differed on different cultivars of *Brassica*. The data in table 1 show that cultivars with more caloric rewards attracted a large number of bees and vice-versa.

Table 1

Population of *Apis mellifera* and *Apis cerana* in different cultivars of *Brassica campestris* var. *toria* in relation to nectar volume, sugar concentration and energy available.

Cultivars	Nectar volume (μ l)	Nectar sugar concentration (%)	Sugar content/flower/day (mg)	Energy /flower/day (joules)	Population/ m ² /minute <i>A. cerana</i> (Mean \pm S.D)	Population/ m ² /minute <i>A. mellifera</i> (Mean \pm S.D)
TCN-1	0.0734	38.0	0.0279	0.467	2.6 \pm 0.24	4.2 \pm 0.12
TCN-2	0.1016	43.8	0.0445	0.745	9.6 \pm 0.87	10.2 \pm 0.80
TCN-3	0.0820	42.0	0.0344	0.577	4.0 \pm 0.20	5.6 \pm 0.41
TCN-4	0.1005	41.5	0.0417	0.698	6.2 \pm 0.74	8.4 \pm 0.44
TCN-5	0.0920	40.0	0.0368	0.616	7.0 \pm 0.64	7.0 \pm 0.72
TCN-6	0.1020	38.6	0.0394	0.659	5.0 \pm 0.13	8.0 \pm 0.61
TCN-7	0.1060	43.0	0.0456	0.763	8.2 \pm 0.44	11.0 \pm 0.60
TCN-8	0.0980	40.0	0.0392	0.656	7.0 \pm 0.57	7.0 \pm 0.41
TCN-9	0.0890	41.0	0.0365	0.611	7.1 \pm 0.48	7.2 \pm 0.43
TCN-10	0.0680	38.0	0.0258	0.433	5.8 \pm 0.47	6.8 \pm 0.46
TCN-11	0.1100	42.0	0.0462	0.773	8.4 \pm 0.89	10.0 \pm 0.40
TCN-12	0.0980	41.5	0.0407	0.681	4.0 \pm 0.26	5.2 \pm 0.18
TCN-13	0.0920	40.0	0.0368	0.616	5.2 \pm 0.17	6.0 \pm 0.29
TCN-14	0.0620	38.0	0.0236	0.394	4.0 \pm 0.28	4.2 \pm 0.34
TCN-15	0.0880	42.0	0.0370	0.619	5.0 \pm 0.26	7.2 \pm 0.47
TCN-16	0.0870	40.0	0.0348	0.583	5.2 \pm 0.32	5.0 \pm 0.27
TCN-17	0.0890	41.5	0.0369	0.618	6.0 \pm 0.44	7.0 \pm 0.24
TCN-18	0.0990	36.0	0.0356	0.597	4.0 \pm 0.48	5.2 \pm 0.29
TCN-19	0.0810	38.0	0.0308	0.515	6.2 \pm 0.27	6.0 \pm 0.43
TCN-20	0.1020	41.0	0.0418	0.700	6.0 \pm 0.26	8.0 \pm 0.32
TCN-21	0.1200	42.0	0.0504	0.844	10.2 \pm 0.22	12.0 \pm 0.80
TCN-22	0.0520	38.0	0.0198	0.331	5.0 \pm 0.18	4.0 \pm 0.23
TCN-23	0.0900	38.0	0.0342	0.573	6.8 \pm 0.46	6.8 \pm 0.46
TCN-24	0.0960	42.5	0.0408	0.683	8.4 \pm 0.81	8.4 \pm 0.67

Nectar volume and bee activity

Foraging populations of both *A. mellifera* and *A. cerana* mostly preferred varieties with a higher volume of nectar (Table 1). The data in table 2 show that a highly significant and positive correlation existed between foraging populations and nectar volume in both of the bee species. Variations in nectar volume, which is an immediate source of energy, are expected to reflect the

spectrum of flower visitors. Similar results were obtained by Corbet (1978) who found that size of foraging populations is largely determined by the nectar quality and quantity. Sihag and Kapil (1983) also found that *Apis dorsata* with greater energy demands preferred more rewarding flowers than did *Apis florea* which relied on flowers providing low caloric rewards.

Table 2

Correlation coefficients and regression constants for relation between bee foraging activity, nectar volume, nectar sugar concentration, sugar content and energy content of different cultivars of *Brassica*.

Bee activity against	r	a	b
<i>A. mellifera</i>			
Nectar volume	0.781**	0.0508	0.0056
Nectar sugar concentration	0.671**	35.7430	0.6370
Sugar content	0.559*	0.0249	0.0182
Energy	0.840**	0.2703	0.0483
<i>A. cerana</i>			
Nectar volume	0.595**	0.0611	0.0048
Nectar sugar concentration	0.585**	36.4260	0.6273
Sugar content	0.542*	0.0256	0.0019
Energy	0.670**	0.3471	0.0435

** $P \leq 0.01$, * $P \leq 0.05$, d.f. = 22

Nectar sugar concentration and bee activity

The data in Table 1 and 2 show that nectar sugar concentration significantly influenced bee visitations. Cultivars with higher concentrations attracted a large number of bees in both the species. In general, honeybees were found to prefer nectars with higher sugar concentrations. For instance, Stephen (1958) found that pear orchards with plenty of *Brassica alba* and *Stellaria* sp. growing in them had poor crops because the bees preferred the latter two species with 48.0-54.0% and 51.0-58.0% nectar sugar concentration, respectively compared to the former species with 7-34% only.

Amount of nectar sugar per flower per day and bee activity

The data in Table 1 show that foraging populations of honeybee species, *A. mellifera* and *A. cerana* exhibited marked preference for some cultivars over others. Flowers providing a higher amount of sugar were highly attractive to bees. The foraging populations of *A. mellifera* and

A. cerana (Table 2) showed highly significant positive correlations with sugar content. Similar results have been reported by earlier investigators (Abrol 1995).

Energy per flower per day and honeybee foraging activity

The caloric rewards offered by the flowers determine, to a large extent, their discrimination by bees. The data presented in Table 1 show that foraging populations of both *A. mellifera* and *A. cerana* preferred flowers providing high caloric rewards. Energy/flower/day significantly and positively influenced the bee visitations (Table 2). Cultivars with higher energy/flower/day were highly attractive to honeybees providing low caloric rewards. Similar results were obtained by Heinrich and Raven (1972), who reported that honeybees tend to forage on those plants that give a greater caloric return for the energy expended in the search and extraction. The observed switching behaviour of honeybees seems to be an advantageous strategy to maximize net energy gains.

CONCLUSIONS

The study clearly reveals that such varieties should be developed which produce more caloric rewards and are highly attractive to bees for efficient pollination and significantly more seed fruit production with better quality. The studies establish that genetic improvement of the plants with better nectar rewards shall be highly useful for efficient pollination and qualitative and quantitative improvement of the crops.

ACKNOWLEDGEMENTS

This paper is affectionately dedicated to my supervisor, the late Professor Dr. R.P. Kapil, former Dean of Post-Graduate Studies at Haryana Agricultural University, Hisar and Director, Indian Lac Research Institute, Ranchi, Bihar, India. I acknowledge the generosity of the Department of Science & Technology of the Government of India, New Delhi for providing financial assistance for this research work under the Research Project Entitled 'Foraging ecology in relation to pollination – A study in bioenergetics' (DST No SP/SO/CO/1995).

REFERENCES

- Abrol D.P. (1986) – Time and energy budgets of alfalfa pollinating bees *Megachile nana* Bingh and *Megachile flavipes* Spinola (Hymenoptera: Megachilidae). *Proc. Indian Acad. Sci. (Anim. Sci.)*. 95: 579–586.
- Abrol D.P. (1992) – Bioenergetics in bee – flower interrelationship – an analysis of foraging behaviour. *Korean J. Apic.* 7: 39–66.
- Abrol D.P. (1995) – Energetics of nectar production in some almond cultivars as a predictor of floral choice by honeybees *Apis cerana indica* F. and *Apis mellifera* L. (Hymenoptera: Apidae). *Proc. Indian natn. Sci. Acad.* B61 (4): 285–290.
- Abrol D.P. (1997) – Bees and beekeeping in India. Kalyani Publishers, Ludhiana, India p. 450
- Corbet S.A. (1978) – A bee's view of nectar. *Bee World* 59:25–32.
- Faegri K., Vander Pijl L. (1966) – The Principles of Pollination Ecology. Pergamon Press; New York.
- Free J.B. (1993) – Insect pollination of crops. 2nd edition Academic Press London.
- Heinrich B. (1975) – Energetics of pollination. *Ann. Rev. Ecol. Syst.* 6: 137–171.
- Heinrich B. (1983) – Insect foraging energetics. In: Handbook of Experimental and Pollination Biology (ed.) C.E. Jones and R.J. Little (New York: Scientific and Academic Press) p. 187.
- Heinrich B., Raven P.H. (1972) – Energetics and pollination ecology. *Science*. 176:597–602.
- Snedecor G.W., Cochran W.G (1967) – Statistical Methods. (IOWA: The IOWA State University Press).
- Srinivasan M.V. (1994) – Pattern recognition in the honeybee: Recent progress. *J. Insect Physiol.* 40:183–194.
- Stephen W.P. (1958) – Pear pollination studies in Oregon. *Tech. Bull. Oregon Agric. Exp. Sta.* No. 43.
- Sihag R.C., Kapil R.P. (1983) – Foraging strategies of honeybees as determined by quality and quantity of nectar, Ed, J.N. Tasei. *Proc. 5th Int. Symp. Pollination* pp. 51–59 (Paris: INRA).
- Sihag R.C. (1986) – Insect pollination increases seed production in cruciferous and umbelliferous crops. *J. apic. Res.* 25: 121–126.
- Yadav T.P., Kumar P., Thakral S.K., Yadav A.K. (1985) – Genetic divergence, its relationship with heterosis and character association among seed yield and its component traits in Indian mustard. *J. Oilseed Res.* 2:163–171.

ZACHOWANIE PSZCZÓŁ MIODNYCH ZBIERACZEK *Apis mellifera* L. I *Apis cerana* F. POD WPŁYWEM ENERGETYKI PRODUKCJI NEKTARU PRZEZ RÓŻNE ODMIANY KAPUSTY POLNEJ *Brassica campestris* var. *toria*

Abrol D.P.

S t r e s z c z e n i e

Dwadzieścia cztery odmiany kapusty polnej *Brassica campestris* var. *toria* badano pod kątem obfitości nektarowania, zawartości cukru w nektarze, ilości cukru i energii uzyskanej z jednego kwiatu dziennie w odniesieniu do ich atrakcyjności dla pszczoł *Apis mellifera* L. i *Apis cerana* F. Objętość wyprodukowanego nektaru wynosiła od minimum 0,052 do maksimum 0,120 μ l/kwiat/dzień. Zawartość cukru w nektarze mieściła się pomiędzy 36,0% a 43,8%, a ilość cukru uzyskanego z jednego kwiatu dziennie wynosiła 0,0198 - 0,0504 mg. Wydajność energetyczna wahała się pomiędzy minimum 0,330, a maks. 0,845 dżuli/kwiat/dzień. Liczba pszczoł na 1 m² poszczególnych odmian *Brassica* wynosiła od 4,0 do 12,0 i od 2,6 do 10,2 odpowiednio w przypadku *A. mellifera* i *A. cerana*. Różnice te okazały się istotnie, pozytywnie skorelowane z populacjami pszczoł miodnych zbieraczek *A. mellifera* L. i *A. cerana* F. Uzyskane wyniki sugerują, że odmiany charakteryzujące się wyższą wydajnością kaloryczną miały przewagę nad innymi w przywabianiu populacji zbieraczek, a co za tym idzie w zapylaniu.

Słowa kluczowe: *Apis mellifera*, *Apis cerana*, *Brassica campestris* var. *toria*, energia, zapylanie, nektar.