Apidologie (1990) 21, 11-16

Original article

Pattern of nectar secretion in wild cherry, *Prunus puddum* Roxb, and the associated foraging behaviour of *Apis cerana indica* F and *Apis mellifera* L

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(Received 1 July 1988; accepted 26 June 1989)

Summary — Nectar sugar production per flower of *Prunus puddum* (during 8 h of flower opening) was 4•15 mg, when the nectar was removed at short intervals, compared to 1•89 mg/flower in flowers of the same age where nectar was allowed to accumulate. Similarly, nectar removal every 24 h after flower opening resulted in more nectar sugar production. Flowers where nectar was allowed to accumulate resorbed nectar. Analysis of nectar revealed the presence of glucose, fructose, sucrose and 1 unidentified sugar. Honeybees (*Apis cerana indica* and *A mellifera*) foraged both for nectar and pollen on the flowers. The activity of pollen gatherers peaked during early morning hours (8–9 h) and that of nectar gatherers at 11 h. *A mellifera* spent more time per flower than *Ac indica,* whether foraging for nectar or pollen. Honeybees preferred 24- and 48-h old flowers to freshly opened flowers or those older than 48 h.

***Apis mellifera* / *Apis cerana indica* / foraging behaviour / *Prunus puddum* / nectar secretion**

INTRODUCTION

Numerous wild plants are among the many valuable natural resources of the Himalayas and their presence is of utmost importance for beekeeping in Himachal Pradesh, India. Wild cherry, *Prunus puddum* Roxb (Family: Rosaceae), which flowers during the autumn, provides a good food bas for honeybees in the hills (1000–3000 m above sea level). In certain areas plantations are large and bees gather surplus honey from this source at a time when their other nectar resources are restricted.

The present paper reports the pattern of nectar secretion in *P puddum* and associated foraging behaviour of *Apis cerana indica* F and *A mellifera* L. Observations are also made on the effect of nectar removal on nectar secretion in this plant. Some workers have reported an increase in nectar production if nectar is periodically removed from a flower (Maksymink, 1958; Kurennoi *et al,* 1967), whereas Pleasants (1983) found that total nectar production was the same whether nectar was removed or not.

MATERIALS AND METHODS

The present studies were carried out during November–December 1984, at Solan (Himachal Pradesh), India, situated at 1300 m altitude. Nectar production in the flowers at different time periods was measured by caging the floral buds

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(nylon net, 16 mesh size; 25 x 15 cm) and the flowers were marked on their opening (the flowers which had opened by 0900 h). To measure the amount of sugar in flowers, the flowers were plucked and rinsed in 5 ml of distilled water which was then analysed for total sugar as per the method of Roberts (1979). Ten replicates (each consisting of 1 flower) were maintained for each sampling hour. To determine the effect of nectar removal on nectar secretion, in 1 experiment nectar was removed from the flowers using 4–5 filter paper strips (4.7 x 0.4 cm) at 2-h intervals during a 1-day period (900 to 1700 h) of flower opening. In a second experiment, nectar was removed at 24-h intervals after flower opening until the flowers started withering (*ie* up to 96 h of flower opening). The filter paper strips which were used to remove the nectar were rinsed in water, and dry sugar in the resulting solution was determined. Following the nectar removal experiments, the flowers were plucked and washed to determine the residual amount of sugar. Dry nectar sugar content in the flowers from which nectar was removed was compared with that of the flowers in which the nectar was allowed to accumulate.

Foraging activity of honeybees *A c indica* and *A mellifera* collecting nectar and pollen was recorded at hourly intervals, from 0700 to 1700 h during the day (per m^2 blooming branch/15 min). Foraging rates of pollen and nectar gatherers of the 2 honeybee species were recorded (from 0830–1700 h) for individuals by noting the time between alighting on a flower and departure. Ten foragers of each bee species were thus observed whether they collected nectar (the bees which extended their proboscis for nectar) or pollen (bees working on anthers). All the observations on foraging behaviour were continued for 3 sunny days and their means represented the foraging activity and foraging rate during a particular hour.

Observations were also recorded on the preference of honeybees to flowers of different ages (freshly opened, 24, 48, 72 and 96-h old flowers). Flowers of different ages were differentiated on the basis of colour changes in petals and stamen filaments, which were as follows: i), Freshly opened flowers – white petals, greenish white stamens; ii), 24 h – white petals, base of the stamen filament pinkish; iii), 48 h – light pinkish petals, medium pink coloured stamens; iv), 72 h – bright pink petals with pink stamens; v), 96 h – petals shrivelled.

The number of bees (of both species) visiting flowers of different ages was counted in a defined area. These counts were continued for 10 min at the beginning of each hourly count.

All the data were statistically analyzed using factorial randomized design and Student's *t*-test.

RESULTS AND DISCUSSION

In the flowers where nectar was removed at short intervals during the day, the maximum amount of sugar was present in flowers at 0900 h (2.97 mg/flower) and thereafter amounts varied non-significantly between 0.18 to 0.40 mg/flower (1 100–1 700 h) (table I). This indicated that nectar

Table I. Daily production of nectar sugar by *Prunus puddum* flowers following periodic nectar removal. Nectar secreted during 8 h if : i) Nectar removed periodically : 4.15a*; ii) Nectar allowed to accumulate : 1.89b. * Values significantly different in Student's *t*-test ($P = 0.05$).

Time of nectar removal	*Nectar sugar (mg)/flower*
0900	2.97
1100	0.18
1300	0.40
1500	0.28
1700	0.21
Flower left out nectar	0.11
$^{CD}(0.05)$	0.271

was never replenished completely after its initial removal at 0900 h. This pattern of secretion contrasts to that observed in rape by Meyerhoff (1954) where nectar was replenished within 30 min of being removed. The total amount of dry sugar produced by a flower (from which nectar was removed) of *P puddum* during the 8 h of the experiment was 4.15 mg as compared to 1.89 in flowers of the same age where nectar was allowed to accumulate, thus revealing ≈ 120% more nectar secretion in the former as compared with the latter. The response of flowers to nectar extraction varies among different species. In apple flowers, nectar removal 5 times a day stimulated nectar production by 12.4–29.3% (Kurennoi *et al,* 1967), whereas in winter rape, nectar secretion increased by ≈ 128% if the nectar was removed 3 times a day (Maksymink, 1958). However, Pleasants (1983) did not find any increase in the total sugar production in *Ipomopsis aggregata* (Polemoniaceae), even if nectar was removed periodically. It seems that influence of nectar removal on nectar production varies from plant to plant and that no generalization can be made. These studies are important since in most studies, 24-h sugar value is used to compare the nectar production in flowers and if repeated nectar removal increased the total nectar yield, as found in *P puddum,* the 24-h value might be an underestimate in such cases, *eg,* the 24-h sugar value for *P puddum* was 4.12 mg/flower (fig 1), whereas an almost equal amount (4.15 mg) of sugar was produced in 8 h if the nectar was repeatedly removed.

In the flowers where nectar was removed every 24 h, the initial extraction of nectar from freshly opened flowers did not affect the total nectar production during the 24 h of flower opening (fig 1), but the second extraction (after 24 h) resulted in a significant increase in the amount of sugar in the flowers visited by honeybees than in control flowers. The third extraction (from 48-h old flowers) did not affect the nectar production significantly. However, after the fourth extraction (from 72-h old flowers), nectar secretion was higher than in flowers in which nectar continued to accumulate. These control flowers showed a sudden drop of 3.34 mg sugar/flower. Continued secretion is attributed to the stimulatory effect of nectar removal, whereas in the control flowers, the drop in total amount of sugar seems to be due to resorption of nectar by the nectaries. Such resorption has been reported by various workers in a variety of flowers (Lüttge and Schnepf, 1976; Corbet, 1978).

The quantitative analysis of the nectar of *P puddum* revealed the presence of glucose, fructose, sucrose and 1 unidentified sugar in the ratio of 40.7 : 39.5 : 12.3 : 7.48, respectively. Thus the nectar was hexose-rich, and the fructose glucose ratio was 1.03. Fred (1976) found the fructose/glucose ratio to be 1.0 or more in 26 Phillippine nectars. Battaglini and Battaglini (1974) also found nectars of different fruit

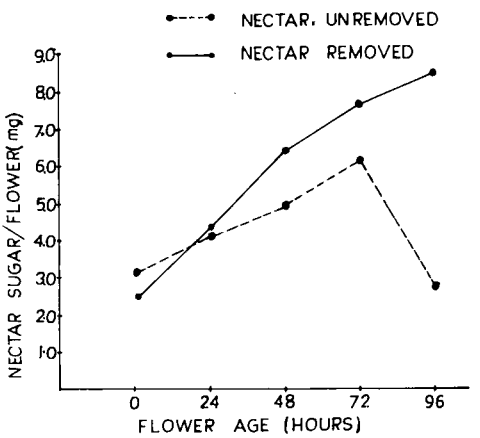

Fig 1. Effect of nectar removal on nectar sugar production in the flowers of *P puddum.*

trees to be rich in hexoses and poor in sucrose.

The honeybees, *Apis mellifera* and *A c indica* were the principal foragers on the blooms, representing about 70% of the insect visitors. The honeybees gathered both nectar and pollen from the flowers throughout the day (fig 2), but the activity of pollen gatherers of both bee species was maximum during early morning hours (0800 and 0900 h). This is probably related to peak of pollen presentation by the flowers. Percival (1955) found a peak of pollen presentation in cherry flowers during 0800–1200 h. The proportion of pollen foragers in the 2 bee species did not vary significantly from one another during the course of a day. Similarily the nectar–gathering activity of both the bees was maximum at 1100 h, and declined significantly during evening hours.

In general, pollen gatherers of either bee species spent less time/flower than nectar gatherers (table II). Time spent per flower by *A c indica* nectar or pollen forager was less (3.25 and 7.32 s, respectively) than by *A mellifera* (3.82 and 10.38 s, respectively). Time spent by nectar and pollen foragers of *A c indica* and pollen foragers of *A mellifera* was relatively constant throughout the day. However, nectar gatherers of *A mellifera* spent significantly more time per flower at 1030 and 1230 h (11.30 and 11.10 s, respectively) than at other times. Similar variation in time spent by *A mellifera* per flower at different times was also reported by Gupta *et al* (1984) in flowers of *Plectranthus rugosus*. The rate at which bees visit fruit flowers depends on the amount of nectar, type of flower and climatic conditions as well as on the number of foraging insects (Free, 1970).

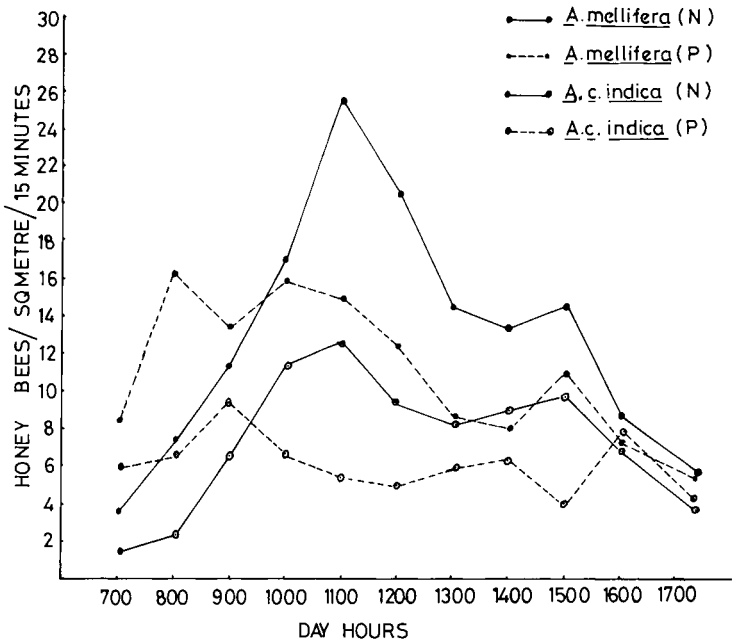

Fig 2. Foraging activity of nectar and pollen gatherers of *A c indica* and *A mellifera* on the flowers of *P puddum*.

Table II. Time (in s) spent per flower by pollen and nectar foraging honeybees on *Prunus puddum* flowers. $^{CD}(0.05)$; i) Pollen and nectar gatherers of the *A c indica* and *A mellifera* = 0.529; ii) For any combination pair = 1.18.

Time of Observation	A c indica		A mellifera	
	Pollen	*Nectar*	*Pollen*	*Nectar*
0830	3.40	7.14	3.70	9.70
1030	3.74	7.40	4.44	11.30
1230	3.00	7.60	4.10	11.10
1430	2.74	7.20	3.40	9.70
1630	3.40	7.30	3.50	10.10
Mean	3.25	7.32	3.82	10.38

Honeybees preferred 24 and 48-h-old flowers as compared to freshly opened flowers and those older than 48 h. This preference might be related to better nectar rewards (Reddy and Gupta, 1987).

Résumé — Sécrétion nectarifère du cerisier sauvage *Prunus puddum* Roxb et comportement de butinage d'*Apis cerana indica* F et *A mellifica* L. Le travail a été réalisé à Nauni, Solan (Inde) à 1 300 m d'altitude en novembre et décembre 1984. Le but était de déterminer les modalités de la sécrétion nectarifère de *Prunus puddum* et le comportement de butinage des deux espèces d'abeilles.

Les résultats montrent qu'une fleur, qui reste éclose durant 8 h, produit 4,15 mg de sucre de nectar si celui-ci est prélevé à intervalles rapprochés et 1,89 mg si on le laisse s'accumuler (tableau I). Le prélèvement du nectar toutes les 24 h entraine également une production de sucre par fleur plus élevée (fig 1). Il y a résorption du nectar dans les fleurs lorsqu'on le laisse s'accumuler, ce que montre bien l'effondrement de la teneur en sucres des fleurs âgées de 96 h. L'analyse du nectar a montré la présence de glucose, de fructose, de saccharose et d'un sucre non identifié, dans les rapports respectifs de 40,7 : 39,5 : 12,3 : 7,48. Le nectar est donc riche en hexoses.

Les 2 espèces d'abeilles (*Apis cerana indica* et *A mellifica*) récoltent nectar et pollen sur les fleurs durant toute la journée (fig 2). L'activité des butineuses de pollen des 2 espèces est maximale entre 8 et 9 h, tandis que le pic d'activité des butineuses de nectar se situe à 11 h. Le temps que passe une butineuse de pollen par fleur est moindre que celui passé par une butineuse de nectar (tableau II). Les ouvrières d'*A mellifica* passent moins de temps par fleur que celles d'*A c cerana,* que ce soit pour le pollen ou le nectar. Les abeilles préfèrent les fleurs de 24 et 48 h aux fleurs récemment écloses ou à celles qui ont plus de 48 h.

***Apis mellifica* / *Apis cerana indica* / comportement de butinage / *Prunus puddum* / sécrétion nectarifère**

Zusammenfassung — Nektarsekretion bei der Wildkirsche, *Prunus puddum*

Roxb, und das Trachtverhalten von *Apis cerana indica* F und *Apis mellifera* L. Die vorliegende Untersuchung wurde in den Monaten November-Dezember 1984 in Nauni, Solan (Indien) in einer Seehöhe von 1300 m unternommen. Es sollten das Muster der Nektarabscheidung von *Prunus puddum* und das Trachtverhalten der beiden Bienenarten festgestellt werden.

Als Ergebnis zeigte sich, daß eine Blüte während 8 h ihrer Öffnungszeit 4.15 mg Nektarzucker produzierte, soferne der Nektar in kurzen Intervallen entfernt wurde; dagegen waren es nur 1.89 mg, wenn sich der Nektar in der Blüte ansammelte (Tabelle I). Auch wenn der Nektar in Intervallen von 24 h entnommen wurde, zeigte sich eine höhere Zuckerproduktion per Blüte (Abb 1). In Blüten, in denen sich der Nektar ansammeln konnte, kommt es zu einer Nektarresorption, was sich aus dem Abfall des Zuckergehaltes in 96 h alten Blüten ergibt. Die qualitative Analyse des Nektars zeigte das Vorkommen von Glukose, Fruktose, Saccharose und einem unbestimmten Zucker im Verhältnis von 40,7: 39,5: 12,3: 7,48. Der Nektar ist demnach reich an Hexosen.

Beide Bienenarten, *Apis cerana indica* und *Apis mellifera,* sammelten den ganzen Tag über sowohl Nektar wie Pollen (Abb 2). Die Aktivität der Pollensammler erreichte bei beiden Arten zwischen 8.00–9.00 h ihren Höhepunkt, bei den Nektarsammlern um 11.00 h. Die Zeit, die eine Pollensammlerin an einer Blüte verbrachte, war kürzer wie die einer Nektarsammlerin (Tabelle II). Sowohl beim Pollen- wie beim Nektarsammeln verbrachten *mellifera*- Bienen mehr Zeit in der Blüte als *cerana*-Bienen. Die Bienen bevorzugten 24 und 48 h alte Blüten im Vergleich mit frisch geöffneten und solchen, die über 48 h alt waren.

***Apis mellifera* / *Apis cerana indica* / Trachtverhalten / *Prunus puddum* / Nektarsekretion**

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