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Original article

Nectar sugar production and honeybee foraging activity in 3 species of onion (*Allium* species)

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Summary — Nectar sugar content and solute concentration in the nectar of 3 *Allium* species were determined to assess their potential for honeybee foraging. The pattern of nectar secretion varied among the 3 onion species. In *A cepa* and *A cepa fistulosum* there was resorption of nectar sugars after 72 and 144 h of flower opening, whereas in *A fistulosum* even 144-h-old flowers contained 3.908 mg sugar/flower and there was no apparent resorption. The 3 onion species contained highly concentrated nectar and the solute contents were on average 68.96, 56.74 and 53.47% in *A cepa*, *A fistulosum* and *A cepa fistulosum*, respectively. The 24-h sugar value varied between 0.219 to 0.767 mg/flower, though significant amounts of sugar were produced after this period. Honeybees preferred the nectar of *A cepa*. Among honeybees, *Apis dorsata* dominated the blooms as compared to *A mellifera* and *A cerana indica*. The differential preference of *A cepa* by honeybees might be associated with the concentration of nectar solutes coupled with the amount of dry nectar sugars.

***Apis mellifera* / *Apis cerana indica* / *Apis dorsata* /foraging activity / *Allium cepa* / *Allium fistulosum* / *Allium cepa fistulosum* / nectar sugar production**

INTRODUCTION

Onion flowers are visited by honeybees mainly as a source of nectar and the proportion of nectar-gathering foragers has been found to be significantly higher than that of the pollen gatherers (Atkins and Anderson, 1970; Benedek and Gaal, 1972; Williams and Free, 1974; Kumar *et al*, 1985). These nectar-gathering bees have been reported to contribute significantly to onion pollination (Benedek and Gaal, 1972; Kumar *et al*, 1985). The most important factors influencing the attractiveness of nectar to honeybees are its volume and sugar concentration (Free, 1970). Concentration of sugars in onion *(A*

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cepa) nectar has been reported to vary from 52 to 65% (Hagler *et al,* 1990) and 70 to 75% (Akopyan, 1977). The present investigations were undertaken on *Allium cepa* L (common onion), *Allium fistulosum* L (Welsh onion) and *Allium cepa fistulosum* (amphidiploid) to determine their relative attractiveness to honeybees and the possible relationship to their amount and concentration of nectar sugars.

MATERIALS AND METHODS

Investigations were undertaken during April–May 1986 on 3 *Allium* species, *viz*: *A cepa*, *A fistulosum* and *A cepa fistulosum*, each grown in field plots of 15 x 5 m at the farm of the Department of Entomology and Apiculture, University of Horticulture and Forestry, Solan (1 100 m altitude). Nectar sugar production in the flowers during different periods of their opening was measured by caging the unopened umbels in nylon net cages (16-mesh size; 25 x 15 cm) in the evening to screen subsequent flowers from insect visitors. The flowers were marked with ink at the base of the pedicel on their opening (the flowers which had opened by 0900 h). Sampling of the flowers for dry nectar sugar production with age was started at 0900 h and continued at 24-h intervals until the flowers started drying up. For each sampling time, 12 replicates (1 flower per replicate) were maintained. The flowers were washed in 5 ml distilled water in a capped vial for 45 min and after removing out the flowers, the rinsings were analyzed for dry nectar sugar (total nectar sugar contents) (Roberts, 1979).

To determine sugar concentration, nectar was withdrawn using microcapillaries from 48-h-old flowers. Nectar was immediately placed on the prismatic surface of a hand refractometer (Erma, Japan) and sugar concentration was measured.

Frequency of honeybee visits over a 5-min period was recorded on each of 5 umbels of 3 *Allium* spp between 0700–0800, 0900–1000, 1100–1200 and 1400–1500 h over a period of 6 sunny days. An apiary consisting of 10 managed colonies each of *Apis mellifera* L and *Apis cerana indica* F was ≈ 200 m away from the experimental area. Feral populations of *A c indica* and migratory swarms of *A dorsata* were also present in the area. Data on the activity of honeybees were statistically analyzed *via* a factorial-completely randomized design (Panse and Sukhatme, 1978).

RESULTS AND DISCUSSION

The average amount of dry nectar sugar content secreted per flower in 3 *Allium* species was found to be significantly higher in *A fistulosum* (1.998 mg) followed by *A cepa* (1.400 mg) and *A cepa fistulosum* (1.139 mg). There was no significant difference between the species in the amount of total nectar sugars in freshly-opened flowers, but there was comparatively less nectar sugar production in 24-, 48- and 72-h-old flowers of *A cepa fistulosum.* During this period no significant differences were found in the sugar contents of *A cepa* and *A fistulosum.* However, in *A cepa* nectar secretion continued only up to 72 h after flower opening and then dropped to only 0.271 mg in 144-h-old flowers. In *A cepa fistulosum*, secretion of nectar continued until 120 h of flower opening and then dropped in 144-h-old flowers. This may

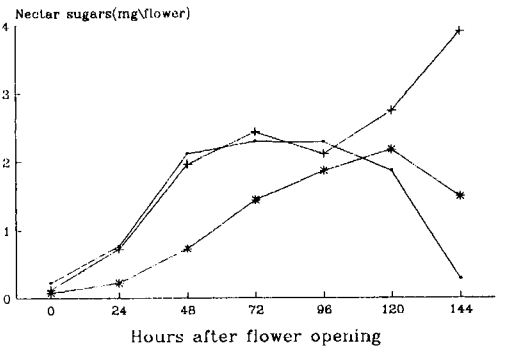

Fig 1. Average amount of dry nectar sugar content (mg/flower) secreted by 3 *Allium* species at different times after flower opening. —•— *Allium cepa*; —+— *A fistulosum*; —✳— *A cepa fistulosum.*

have been due to resorption of nectar. Such resorption of nectar has been reported in a variety of flowers (Luttage and Schnepf, 1976; Corbet, 1978; Corbet and Delfosse, 1984; Gupta *et al*, 1984, 1990). However, in *A fistulosum*, accumulation of nectar sugar was found to continue up to 144 h (3.908 mg/flower) and there was no apparent resorption of nectar sugars.

The 24-h value is generally used to show comparative attractiveness of bee flora. In onion flowers, significant nectar secretion was found even after 24 h. Therefore, in such flowers, the 24-h value may lead to an underestimation of potential bee flora.

Hagler *et al* (1990) while working on 6 onion cultivars, have reported that onion flowers bloom over a 6-d period. These results are corroborated by the present studies on the 3 *Allium* species. However, they also reported that onion flowers secrete nectar only during the last 3 d of bloom, which is contrary to the present findings. We found substantial nectar secretion in the flowers of the 3 species even after 1 d of flower opening, *ie* after 24 h, and secretion continued for varying periods in these onion species. These differences between studies might be related to the techniques adopted for determination of nectar contents. Hagler *et al* (1990) used micropipettes for removing nectar, whereas we rinsed the flower in water to remove any residual nectar. In the former case small amounts of the nectar present in the flowers might have been missed, because onion nectar is known to be highly concentrated.

The sugar concentration of nectar in 48-h-old flowers (n = 10) in 3 *Allium* species were found to vary from 52.8 to 82.6% (average; 68.96% in *A cepa*; 42.0 to 72.8% (average: 56.74%) in *A fistulosum* and 48.0 to 66.4% (average: 53.74%) in *A cepa fistulosum*. These results are in agreement with those of Akopyan (1977), Orlova *et al* (1981) and Hagler *et al* (1990) on *A cepa*. Differences in the 3 *Allium* species in the average sugar concentration are evidently species-specific.

Data on the activity of honeybees on the bloom of 3 *Allium* species (table I) showed that honeybees in general were significant-

Table I. Activity of honeybees on *Allium* species.

Allium *species*	*No of bees/5 min/umbel*			
	Apis dorsata	Apis cerana indica	Apis mellifera	*Average*
A cepa	3.26 (2.03)	0.70 (1.24)	0.36 (1.13)	1.44 (1.47)
A fistulosum	1.70 (1.63)	0.05 (1.02)	0.28 (1.12)	0.68 (1.26)
A cepa fistulosum	0.39 (1.16)	0.00 (1.00)	0.08 (1.04)	0.16 (1.07)
Average	1.78 (1.61)	0.25 (1.09)	0.24 (1.10)	

CD (P = 0.05) for *Allium* species = (0.15); *Apis* species = (0.15). Interaction (*Allium* spp x *Apis* spp) = significant; any pair of combinations = (0.23). Figures in the parentheses are $\sqrt{n} + 1$ transformed values.

ly more frequent on *A cepa* bloom (1.44 bees/umbel/5 min) followed by *A fistulosum* (0.68 bees/umbel/5 min) and *A cepa fistulosum* (0.16 bees/umbel/5 min). Honeybees are known to forage selectively on onion species and cultivars (Lederhouse *et al,* 1972; Carlson, 1974; Hagler *et al,* 1990). Among the honeybees, visits by *A dorsata* were more frequent (1.78 bees/umbel/5 min) than the other 2 species which were on a par with each other.

Results thus show that there are considerable differences in the amount and concentration of nectar sugars in 3 *Allium* species and their attractiveness to honeybees. This differential preference might be associated with the concentration of nectar solutes coupled with the amount of dry nectar sugars (Bohart *et al,* 1970; Lederhouse *et al,* 1972) and varying levels of potassium in the nectar. Waller *et al* (1972) have shown that high potassium levels reduce attractiveness of onion nectar to honeybees. However, Hagler *et al* (1990) have found that in simulated nectars which had an approximately equal concentration of potassium, bees *(A mellifera)* preferred nectar with a high carbohydrate content. In the present study also, *A cepa* was found to have the maximum sugar content for most of the blooming period. Thus *A cepa* flowers might have been preferred by honeybees to *A fistulosum* and *A cepa* might have been preferred by honeybees to *A fistulosum* and *A cepa fistulosum* on the basis of sugars alone, although there are a large number of other factors responsible for attractiveness to honeybees in addition to caloric rewards (Hagler *et al,* 1990).

Résumé — Composition en sucres du nectar et activité de butinage des abeilles (*Apis* sp) sur 3 espèces d'oignon (*Allium* sp). Les recherches, réalisées sur le campus de l'université de Solan (HP Inde) à 1 100 m d'altitude, ont porté sur 3 espèces d'*Allium* (*A cepa* L, *A fistulosum* L et *A cepa fistulosum*, forme amphidiploïde) afin de connaître le rôle des sucres du nectar, du point de vue quantitatif et qualitatif, vis-à-vis de l'attraction des abeilles. Afin de mesurer la production de sucres dans le nectar à différentes phase de l'ouverture de la fleur, on a enfermé le soir des ombelles non encore épanouies dans des sachets en nylon (maille de 16; 25 x 15 cm) pour empêcher les visites d'insectes. Les fleurs ouvertes le matin à 9 h ont été marquées à l'encre à la base du pédicelle. Le prélèvement des échantillons a eu lieu toutes les 24 h à partir de ce moment jusqu'au flétrissement de la fleur. Chaque fois, 12 fleurs ont été prélevées. Les fleurs ont été lavées dans 5 ml d'eau distillée durant 45 min dans des ballons fermés; l'eau de rinçage a été ensuite analysée selon la méthode de Roberts (1979) pour déterminer la teneur en sucres totaux. Pour connaître la concentration en sucres, le nectar a été prélevé à l'aide de microcapillaires dans des fleurs âgées de 48 h, puis placé sur la surface prismatique d'un réfractomètre manuel (Erma, Japan). La fréquence des visites sur 5 ombelles de chaque espèce d'oignon a été relevée pendant 5 min à 4 reprises (à 7, 9, 11 et 14 h) sur une période de 6 j ensoleillés. La quantité moyenne de sucres totaux secs du nectar sécrétée par fleur est significativement la plus élevée chez *A fistulosum*; viennent ensuite *A cepa* puis *A cepa* fistulosum (fig 1). Il n'y a pas de différence significative entre les 3 espèces d'*Allium* dans les quantités de sucres secs sécrétées par les fleurs fraîchement ouvertes. Par contre la quantité sécrétée par les fleurs âgées de 24, 48 et 72 h est légèrement plus faible chez *A cepa fistulosum.* Chez *A cepa* et *A cepa fistulosum*, la sécrétion nectarifère se poursuit respectivement jusqu'à 72 h et 120 h après l'ouverture de la fleur, et décline ensuite. La

résorption du nectar existe chez ces 2 espèces d'*Allium*. En revanche, chez *A fistulosum* on a trouvé une accumulation des sucres du nectar (3 908 mg/fleur) jusqu'à l'âge de 144 h, et aucune résorption du nectar n'a été observée. La concentration moyenne en sucres chez les fleurs âgées de 48 h est respectivement de 68,96, 56,74 et 53,74% chez *A cepa*, *A fistulosum* et *A cepa fistulosum*. Les abeilles ont préféré les fleurs de *A cepa* à celles de *A fistulosum* et de *A cepa fistulosum* (tableau I). Parmi les espèces d'abeilles (*mellifera*, *cerana indica* et *dorsata*) cette dernière prédominait. La préférence relative pour *A cepa* est peut-être due à la plus grande concentration du nectar liée à la quantité de sucres totaux secs.

Apis mellifera* / *Apis cerana indica* / *Apis dorsata* / nectar / concentration en sucres / butinage / *Allium

Zusammenfassung — Die Produktion von Nektarzucker und die Trachtaktivität von Honigbienen bei drei Zwiebelarten *(Allium)*. Diese Untersuchung wurde am Universitätscampus von Solan (1100 m üdM), HP, Indien, an drei *Allium*-Spezies (*A cepa* L, *A fistulosum* L und *A cepa fistulosum* (amphidiploide Form) ausgeführt, um die Rolle der Menge und der Konzentration der Nektarzucker bei der unterschiedlichen Attraktivität für Honigbienen herauszufinden.

Es wurde die Produktion von Nektarzuckern in den Blüten während der verschiedenen Phasen ihrer Öffnung in der Weise gemessen, daß die noch geschlossenen Blütenstände abends mit Nylonkäfigen (16 Maschen/Zoll; Größe 25 x 15 cm) umschlossen wurden, um Insektenbesuch zu verhindern. Die Blüten, die sich um 9 00 h geöffnet hatten, wurden an ihrem Stiel mit Tusche markiert. Die Probenentnahme zur Bestimmung der Produktion von Nektarzucker begann zu diesem Zeitpunkt und wurde in Intervallen von 24 Stunden bis zum Verwelken der Blüte fortgesetzt. Für jede Probenentnahme gab es 12 Wiederholungen (1 Blüte je Wiederholung). Die Blüten wurden in 5 ml destilliertem Wasser 45 min lang in geschlossenen Gläsern ausgewaschen; nach Entnahme der Blüte wurde das Spülwasser nach der Methode von Roberts (1979) für den Gehalt an Gesamtnektarzucker analysiert.

Zur Bestimmung der Nektarkonzentration wurde der Nektar mittels Mikrokapillaren aus 48 h alten Blüten entnommen und auf die prismatische Oberfläche eines Handrefraktometers getropft (Erma, Japan). Die Häufigkeit des Honigbienenbesuchs wurde während 5 min-Perioden bei allen drei *Allium*-Arten an je 5 Blütenständen an 6 sonnigen Tagen jeweils zu vier Tagesstunden (7, 9, 11 und 14 h) gezählt.

Die mittlere Menge von Gesamt-Trockennektarzucker pro Blüte war bei *Allium fistulosum* signifikant höher, gefolgt von *A cepa* und *A cepa fistulosum*. In frisch geöffneten Blüten bestand jedoch kein signifikanter Unterschied in der Menge des Trockennektarzucker zwischen den drei *Allium*-Arten. Bei *A cepa fistulosum* wurde in 24, 48 und 72 h alten Blüten im Vergleich eine geringere Menge von Nektarzuckern erzeugt. Bei *A cepa* und *A cepa fistulosum* hielt die Nektarproduktion bis zu 72 h, bzw. 120 h nach Blütenöffnung an, um dann abzusinken. Bei diesen beiden *Allium*- Arten wurde Nektarresorption festgestellt. Bei *A fistulosum* jedoch wurde eine Akkumulation von Nektarzucker (3.908 mg/Blüte) bis zu einem Alter von 144 h gefunden, und es gab keine Resorption von Zucker. Die mittlere Zuckerkonzentration des Nektars bei 48 h alten Blüten betrug 68.96, 56.74 und 53.74% bei *A cepa*, *A fistulosa* und *A cepa fistulosa*. Die Honigbienen bevorzugten die Blüten von *A cepa* gegenüber denen von *A fistulosa* und *A cepa fistulosa* (Tabelle I). Bei

den 3 Arten von Honigbienen (*Apis mellifera*, *Apis cerana indica* und *Apis dorsata*) war *Apis dorsata* vorherrschend. Die relative Bevorzugung von *Allium cepa* durch die Bienen könnte eine Folge der höheren Nektarkonzentration in Verbindung mit der Trockenzuckermasse sein.

***Apis mellifera* / *A cerana indica* / *A dorsata* / Sammelaktivität / *Allium* species / Nektarzuckerkonzentration**

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