# Honey bee (Apis mellifera L) response to simulated onion nectars containing variable sugar and potassium concentrations

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**Original article**

# Honey bee (*Apis mellifera* L) response to simulated onion nectars containing variable sugar and potassium concentrations *

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**Summary** — Potassium concentrations in nectars of several common onion (*Allium cepa* L) cultivars were analyzed by atomic absorption spectrophotometry. Concentrations ranged from 5 347 to 6 914 ppm. Honey bee (*Apis mellifera* L) collection of artificial nectars containing potassium, glucose, fructose, and sucrose concentrations, similar to several common onion cultivars, was evaluated quantitatively. Bees ingested greater volumes of nectar containing low potassium content. When simulated nectars had approximately equal concentrations of potassium, bees preferred nectar with higher carbohydrate content.

***Apis mellifera* / nectar / attractiveness / chemical composition / potassium / *Allium cepa***

## INTRODUCTION

The most common insect pollinator in onion (*Allium cepa* L) seed fields is the honey bee, *Apis mellifera* L (Nye *et al*, 1973). Farmers often pay beekeepers to place their colonies by blooming onion fields to attain higher bee foraging populations. Honey bees are known to forage selectively among onion species and between cultivars (Lederhouse *et al*, 1972; Shasha'a *et al*, 1973; Carlson, 1974). The effect of visitation on pollination and seed set is well documented (McGregor, 1976).

Low bee activity in onion fields has had a deleterious effect on onion seed production in the United States, leading to reduced or differential seed yields among individual onion cultivars (Campbell *et al*, 1968; Carlson, 1974). In California, Gary *et al* (1972, 1977) found that the mean distances that bees travel to visit carrot (*Daucus carota* L) and safflower (*Carthamnus tinctoris* L) was greater than the mean distances bees travelled to visit the common onion. From this, Gary concluded that the onion flowers are decidedly less attractive to bees than carrot or safflower flowers.

Nectar is highly attractive to foraging bees. However, the optimal sugar composition of nectar for bee foraging has not been completely resolved. Neither the su-

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crose/hexose ratio, nor any other single aspect of nectar sugar composition appears to exclusively determine the foraging behavior of these pollinators. The 3 major sugars in nectars are sucrose, glucose, and fructose, all of which are acceptable to bees. Wykes (1952a,b) determined that bees prefer a balanced nectar, consisting of equal amounts of sucrose, glucose, and fructose. Percival (1961) stated that balanced nectars are uncommon in nature. Waller (1972) disputed Wykes' claim that bees prefer balanced nectar by showing that bees prefer a sucrose-rich diet. He conducted bioassays to evaluate bee responses to sugar solutions of various fructose, glucose, and sucrose ratios and found that mixtures containing equal concentrations of fructose and glucose were readily accepted by bees. Onion nectar is hexose dominant with 53–56% fructose, 40–43% glucose, and only 4% sucrose (Waller, 1974). Thus, although sugar ratios in onion nectar are not optimal for bees, the results of Waller suggest that these ratios should not inhibit the collection of onion nectar.

Barker and Lehner (1974a,b) showed that starved honey bees would fill their crops with sucrose, glucose, and fructose when each was offered singly, but that a mixture of sucrose with a hexose sugar caused even greater loading. The general conclusion, from these studies using artificial flowers, is that bees prefer a sucrose-rich nectar, but they will accept a variety of sugar types and concentrations.

Other substances may have a deterrent effect on potential insect visitors. For example, Waller *et al* (1972) found that bee foraging was inversely proportional to the potassium content. Waller determined that onion nectar is high in potassium content and concluded that these high potassium levels are the primary factor limiting successful bee pollination of onions.

This study was designed to determine the attractiveness to bees of the known concentrations of sucrose, glucose, and fructose (Hagler *et al,* 1990) in combination with known potassium concentrations found in 6 onion cultivars.

## MATERIALS AND METHODS

The sucrose, glucose, and fructose compositions of nectar from the onion cultivars used in this test were determined by gas chromatography analysis (Hagler *et al,* 1990). A summary of these cultivar sugar compositions is presented in table I.

Nectar samples from 5 blooming *A cepa* cultivars were collected in 2-µl micropipettes on 20 April 1986. All samples were immediately frozen and maintained in a freezer at –22 °C until analyzed for potassium. In March 1987, each 2-µl sample was diluted to 5 ml with 1 000 ppm sodium chloride (NaCl) solution. Potassium content was determined by atomic absorption spectrophotometry using a Perkin-Elmer® Model 5 000 double-beam atomic absorption spectrophotometer with a wavelenght of 266.5-nm. The absorbance was displayed as the mean of 3 readings with a 2.0 s integration time. The signal was recorded on a Model 056 strip-chart recorder at 2 mV full-scale.

Data were analyzed by analysis of variance (ANOVA) to determine differences between cultivars. A Tukey's multiple mean comparison determined significant differences among cultivars (Steel and Torrie, 1980).

Six different simulated onion "nectars" were formulated to mimic the fructose, glucose, sucrose, and potassium compositions of the 6 onion cultivars (Note: nectar from Delta Giant, the *Allium cepa* x (*A fistulosum* x *A cepa)* cross, was unavailable, so potassium concentration data obtained by Waller (1974) for an *A fistulosum* x *A cepa* cross were used (*ie* 1 269 ppm).

Foraging bioassays were conducted from 26–28 February 1988 in a 8.5 x 6.7 x 3.0 m plastic greenhouse (24 °C, 45% RH) at the Carl Hayden Bee Research Center, Tucson, Arizona. Prior to each test, bees from 2 colonies were trained to forage at artificial flower feeders (Waller, 1972). Six feeders similar to those de-

**Table I.** Mean carbohydrate composition of tested artificial onion nectars [a]. [a] The sugar levels presented here were determined from a previous experiment (Hagler *et al*, 1990).

| *Cultivar* | *Fructose* [a] *(µg/µl)* | *Glucose (µg/µl)* | *Sucrose (µg/µl)* | *Total Carbohydrate (µg/µl)* |
|---|---|---|---|---|
| TEG 502 prr | 206.5 | 188.8 | 23.7 | 418.9 |
| Creole | 205.8 | 168.4 | 15.6 | 389.7 |
| Delta Giant | 190.6 | 182.1 | 63.1 | 435.7 |
| Bermuda | 163.5 | 171.3 | 26.2 | 361.0 |
| Grano | 146.2 | 134.0 | 38.1 | 318.3 |
| TEG 1015Y | 141.8 | 128.8 | 31.7 | 302.4 |

scribed by Inouye and Waller (1984) were used in each test. A feeder consisted of seven 0.9 ml vials held together with a rubber band and covered by a 3 mm thick blue plastic disc (3.6 cm diameter) with 1 mm openings over each of the 6 peripheral vials. Test solutions (0.5 ml) were placed in each of the peripheral vials and bees were given simultaneous access to the solutions through sections of 20-µl disposable VWR® micropipets that extended from the bottom of each vial to 2 mm above the plastic top.

The 6 artificial onion nectars were placed randomly within each artificial flower. Each flower was evenly spaced around a circular table that was mechanically rotated at a rate of 2 revolutions/min to prevent the bees from using position as a foraging cue. Six artificial flowers were replicated in 5 trials. Bees were allowed to forage on an artificial flower until 1 of the 6 vials was empty. The foraging activity for the other vials was determined by measuring the remaining solution with a 1 $cm^3$ disposable syringe.

Bees were quickly recruited to the artificial flowers. Discrimination among the test solutions was less effective when the density of foragers exceeded 1 or 2 bees per artificial flower. To maintain an optimal forager density, individual artificial flowers were covered with galvanized wire cloth cone (3.2 mesh/cm) after 2 bees began foraging on individual flowers. Bees that had imbided to satiation could leave through the top of the cone, then the cones were raised to admit additional foragers.

Data were analyzed by ANOVA to determine bee preferences. Significant foraging differences between the nectars were determined by Tukey's multiple mean comparison test (Steel and Torrie, 1980).

## RESULTS

### *Potassium analysis*

Potassium concentrations from 5 common onion nectars ranged from 5 347 ppm (TEG 502 prr) to 6 914 ppm (TEG 1015Y) (table II). Only TEG 502 prr and TEG 1015Y contained significantly different potassium concentrations. Three of the cultivars, Creole, Grano and Bermuda, possessed similar potassium concentrations of 6 340, 5 929 and 5 927 ppm, respectively.

**Table II.** Onion nectar potassium concentration of 5 cultivars. [a] Means within columns followed by the same letter are not significantly different (Tukey's multiple mean comparison test, $P < 0.05$).

| *Cultivar* | n | *Potassium content (ppm)* [a] *mean (± SE)* | | |
|---|---|---|---|---|
| TEG 1015Y | 11 | 6914 | (428) | a |
| Creole | 11 | 6340 | (217) | ab |
| Grano | 11 | 5929 | (314) | ab |
| Bermuda | 11 | 5927 | (479) | ab |
| TEG 502 prr | 11 | 5347 | (203) | b |

### *Sugar and potassium bioassays*

Bioassay results are shown in table III. Formulated "nectar" based on Delta Giant, the *A cepa* x (*A fistulosum* x *A cepa*) cross, was clearly preferred over the 5 cultivars of the common onion. Bees consumed 2–4 times more Delta Giant "nectar" than any of the *A cepa* simulated nectars, as indicated by the preference ratios (*ie* the total amount consumed divided by the amount of Delta Giant consumed) (table III). Delta Giant nectar possessed the lowest potassium content (1 269 ppm), and the highest carbohydrate reward (435.7 μg/μl) of all the nectars tested. All the *A cepa* formulations were less attractive as indicated by the low bee preference ratios (less than 0.54). TEG 502 prr was the most attractive *A cepa* formulation

**Table III.** Honey bee collection rates of the artificial onion nectars (maximum possible was 0.5 ml). [a] Means within columns followed by the same letter are not significantly different (Tukey's multiple mean comparison test, $P < 0.05$). [b] Amount consumed / 0.39.

| *Simulated cultivar* | n | *Amt consumed (ml)* [a] *mean (± SE)* | | | *Preference ratio* [b] |
|---|---|---|---|---|---|
| Delta Giant | 30 | 0.39 | (0.04) | a | 1.00 |
| TEG 502 prr | 30 | 0.21 | (0.03) | b | 0.54 |
| Creole | 30 | 0.16 | (0.02) | bc | 0.41 |
| Bermuda | 30 | 0.13 | (0.02) | bc | 0.33 |
| TEG 1015Y | 30 | 0.10 | (0.01) | c | 0.26 |
| Grano | 30 | 0.09 | (0.01) | c | 0.23 |

(preference ratio 0.54), although only about half as attractive as Delta Giant. TEG 502 prr contained the lowest potassium content (5 347 ppm) and highest carbohydrate reward (418.9 µg/µl) of the *A cepa* artificial formulations that were tested. Grano and TEG 1015Y were clearly avoided by the foraging bees, as indicated by low preference ratios of 0.23 and 0.26, respectively. These cultivars contained high potassium concentrations coupled with low carbohydrate reward.

## DISCUSSION

The potassium concentration of nectars from 5 *A cepa* cultivars ranged from 5 347 to 6 914 ppm. These concentrations are similar to those found in the flowers of the common onion, but about 10 times greater than in most competing flora (Waller, 1972). The effects of potassium concentration on the bee foraging activity suggests that high nectar potassium concentrations inhibit foraging by bees. High potassium concentration is a very important factor in explaining the reduced bee foraging activity in blooming onion fields.

Sugar composition analysis of the onion cultivars revealed that all six cultivars in this study have variable but adequate sugar concentrations that should attract and maintain foraging activity by pollinators (Hagler *et al,* 1990). Sensitivity to variable carbohydrate rewards may be a plausible explanation for the intervarietal differences in bee attraction seen among these *A cepa* cultivars in actual field situations.

Admittedly, this bioassay oversimplified the honey bee foraging process, as it only considered the variables of potassium and sugar. Nectars contain may other substances such as amino acids, phenolics, lipids, etc, that may affect the foraging process (Baker and Baker, 1975, 1983). Environmental parameters such as the number of blooming plant species available in a given area, the caloric rewards of the species, the distribution and densities of the plants, and the morphologies of the flowers are not accounted for in this bioassay (Waddington, 1983). Furthermore, constraints imposed by the design of the artificial flowers does not account for honey bee foraging behaviors involving visual, tactile, and odor *(i e* marker pheromone) cues.

In summary, the results of this bioassay showed that bees were sensitive to both potassium and sugar concentrations present in nectar. High potassium concentrations had a repellent effect on bee foraging. However, when bees foraged on the potassium rich *A cepa* "nectars", they preferably selected artificial nectars of high carbohydrate reward. These data provide an explanation for the low bee visitation and pollen transport commonly seen in onion fields.

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**Résumé — Réponse de l'abeille à des nectars d'oignon simulés ayant des concentrations variables en sucres et en potassium.** Un test biologique, utilisant un dispositif de fleur artificielle comme nourrisseur, a permis d'étudier la réponse de l'abeille à des nectars possédant les concentrations connues en potassium, glucose, fructose et saccharose de divers nectars d'oignon communs. (La difficulté de pollinisation des cultures d'oignon à cause de la faible visite des butineuses constitue la raison de cette étude).

Les concentrations en glucose, fructose et saccharose avaient été déterminées pour chaque nectar des 6 cultivars d'oignon par chromatographie en phase gazeuse lors d'une expérience précédente (Hagler *et al*, 1989). Le tableau I en donne un résumé. Les concentrations en potassium du nectar de chaque cultivar d'oignon ont été déterminées par spectrophotométrie d'absorption atomique. Elles s'échelonnent de 5 347 ppm à 6 914 ppm (tableau II). Les résultats du test biologique avec les nectars simulés montrent que les abeilles butinent de préférence les nectars qui ont une faible teneur en potassium (tableau III). Les concentrations élevées en potassium, très courantes dans le nectar d'oignon, ont une action répulsive sur le butinage des abeilles. Lorsque les nectars simulés ont des concentrations en potassium à peu près équivalentes, les abeilles butinent préférentiellement ceux qui offrent une récompense en sucres plus élevée.

Ce test biologique confirme donc les observations faites en champ, selon lesquelles les fleurs d'oignon semblent moins attractives pour les abeilles que les fleurs de la plupart des plantes compétitives. Les analyses de sucres montrent que le nectar d'oignon a une récompense en sucre correcte qui devrait attirer les butineuses. Pourtant, dans ce test biologique, la faible consommation des nectars simulés d'oignon montrent que l'abeille discrimine très bien les nectars riches en potassium des autres.

***Apis mellifica* / nectar / attractivité / composition chimique / potassium / *Allium cepa***

**Zusammenfassung — Die Reaktionen der Honigbienen auf simulierten Zwiebel-Nektar mit verschiedenen Konzentrationen von Zucker und Kalium.** In dieser Arbeit wird ein Biotest beschrieben, in dem mittels eines künstlichen Blüten-Futtergerätes die Reaktion von Honigbienen auf Nektar mit den bekannten Kalium-, Glukose-, Fruktose- und Sucrose-Konzentrationen von mehreren häufigen Zwiebel-Nektaren geprüft wird. (Anlaß für die Untersuchung bildeten die Schwierigkeiten bei der Bestäubung von Zwiebelkulturen wegen des zu geringen Beflugs durch Honigbienen).

Die Konzentrationen von Glukose, Fruktose and Sucrose des Nektars jeder der sechs Zwiebelsorten wurden in einem früheren Versuch durch Gaschromatographie-Analyse bestimmt (Hagler *et al*, 1989). Eine Zusammenfassung wird in Tabelle I gegeben. Die Kalium-Konzentrationen jeder Zwiebelsorte wurden durch Atomabsorptions-Analyse bestimmt. Die Konzentrationen bewegten sich zwischen 5,347 und 6,914 ppm.

Die Ergebnisse des simulierten Zwiebelnektar-Biotests zeigten, daß die Bienen bevorzugt Kalium-armen Nektar sammelten (Tabelle III). Hohe Kalium-Konzentrationen, wie sie im Zwiebelnektar sehr häufig vorkommen, hatten auf die Sammelaktivität der Bienen einen Repellent-Effekt. Wenn simulierte Nektare etwa denselben Kalium-Gehalt hatten, so wurde derjenige mit der höchsten Belohnung an Zuckern vorgezogen.

Zusammenfassend kann gesagt werden, daß dieser Biotest die Feldbeobachtungen bestätigt, daß Zwiebelblüten für Honigbienen weniger anziehend sind als die Blüten von konkurrierenden Trachtpflanzen. Die Zuckeranalyse ergab, daß der Zwiebelnektar einen ausreichenden Zuckergehalt besitzt, um Trachtbienen

anzulocken. Die geringe Abnahme des simulierten Zwiebelnektars in diesem Versuch zeigt, daß sich die Bienen gegen Kalium-reiche Nektare entscheiden.

***Apis mellifera* / Nektar / Anziehung / chemische Zusammensetzung / Kalium / *Allium cepa***

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