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# Foraging Ecology of The Cyprus Honey Bee (*Apis mellifera cypria*) and its Implications for Agriculture

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## ABSTRACT

*The forager responses of Apis mellifera cypria were tested using artificial flower patches consisting of blue, white, and yellow flowers. A.m. cypria foragers frequenting blue and white flowers responded to quality and quantity differences between blue and white flowers by favoring the flower color which offered the higher molar or greater quantity reward. Cyprus bees favoring yellow flowers responded when the smaller reward quantity was presented in yellow flowers by increasing visitation to the blue and white color morphs. The results presented here for the Cyprus honey bee when compared to work we have published on Italian and Caucasian bees suggest that the wasp predation pressure is responsible for evolution of differences in foraging behavior.*

***Key Words****: Apis mellifera cypria, predation, foraging, pollination, artificial flowers.*

## ÖZET

**Kıbrıs Arısının (*Apis mellifera cypria*) Yayılma Ekolojisi ve Tarımdaki Etkileri**

*Apis mellifera cypria (Kıbrıs arısı) arılarının ödül kalitesi, miktarına bağlı olarak çiçek rengi tercihleri, mavi, beyaz ve sarı yapay çiçek modelleri*

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*üzerinde test edilmiştir. A.m. cypria yayılmacıları mavi ve beyaz çiçeklerde nektar kalite ve miktarını dikkate alarak daha yüksek konsantrasyonlu, daha fazla miktarda nektar bulunduran çiçek renklerini tercih etmişlerdir. Sarı rengi tercih eden bir bölüm Kıbrıs arıları aynı zamanda düşük nektar miktarı bulunduran sarı renkli çiçekleri bırakıp daha iyi ödül bulunduran mavi ve beyaz çiçeklere yönelmişlerdir. Sonuç olarak Kıbrıs arısının ödül değişkenliğine bağlı olan çiçek rengi tercihleri avcı arıların bal arıları ile avlanmalarından kaynaklanabilir.*

***Anahtar Sözcükler**: Apis mellifera cypria, avlanma, yayılma, tozlaşma, yapay çiçekler.*

## INTRODUCTION

One ecological factor which might act to modify honey bee forager behavior is predation. Predation has been reported to affect foraging behavior in a wide range of prey taxa (Gilliam and Fraser 1987; Kotler and Holt 1989; Lima and Dill 1990; Brown 1992). *A. mellifera* races from regions where predators are abundant thus may have different flower fidelities than races from regions where predators are relatively rare.

The flower choices of bees may prolong the time foraging and increase the number of flights among flowers; both factors increase forager exposure to predators. That will in turn increase forager mortality rate. Thus, flower choices of many Mid-East and African *A. mellifera* races should include behaviors which minimize exposure, whereas races from regions where predators are rare should be risk-indifferent foragers (model predictions of: Gilliam and Fraser 1987; Brown 1992).

*A.m. cypria* is a race restricted to Cyprus (Ruttner 1988). Wasp predators specializing on honey bee foragers are prevalent on the island (Adam 1983). We frequently observed *Vespa orientalis* attacking honey bees in front of the hive, and they often captured honey bee foragers visiting flowers (natural and artificial). Correlated to predator abundance, the Cyprus bee has an energetic hive defense (Awetisyan 1978; Adam 1983, Ruttner 1988).

Even though there are over twenty *Apis mellifera* races, only *A.m. ligustica* (the Italian bee) has been extensively studied. The variation among European honey bee races with respect to the flower fidelity of foragers has not been reported. Based on morphological variation, colony size, and behavioral differences associated with hive defense, we suspect that forager flower fidelity differences also exist among *A. mellifera* races.

This study presents data on the flower fidelity of *A.m. cypria* foraging on artificial flower patches, and compares flower choices of the Cyprus bee to those reported for the Italian and Caucasian races under similar, strictly controlled, conditions (Italian bee forager behavior: Çakmak and Wells 1995; Caucasian bee: Çakmak and Wells 1996). The choice of *A.m.cypria* as the focus of our study was based only in part on the abundance of wasp predators on Cyprus compared to the native habitats of the Italian and Caucasian bees. We were also interested in *A.m. cypria* because it is well suited for widespread agricultural use, based upon the Cyprus bee's reported ability to survive in diverse climates (Adam 1983) -- even though its natural distribution is subtropical.

## MATERIALS and METHODS

*A.m. cypria* was studied in Girne, Cyprus (subtropical climate). Identification of the *A. mellifera* races used in the study was based on morphological analysis and Cyprus beekeeper conformation of *A.m. cypria* distribution on the island.

Bees, in each case, were trained to visit a watch glass provisioned with 10 µl/L clove-scented 1M sucrose solution located 150m from the hive. The watch glass was replaced with an artificial flower patch and bees were allowed to freely choose which flowers to visit. Studied bees were individually marked. All other foragers were removed and caged. Artificial flower patches contained 12 blue, 12 white, and 12 yellow pedicellate flowers randomly arranged as to color. Flowers within a patch were rearranged between and periodically within experimental treatments. The color of every flower visited by each marked bee was recorded (for further detail, and reflectance spectra of the colors used: Wells and Wells 1983, 1986). Two experiments were performed. A different set of bees were used in each experiment. Experiment I varied reward quality among flower colors while Experiment II varied reward quantity among flower colors. Each experiment consisted of four treatments performed sequentially and without interruption in a repeated measures experimental design (Sall and Lehman 1996). Corresponding to the repeated measures design, each bee was exposed to all four treatments.

**Experiment I.** Treatment 1: all flowers contained 5*u*l unscented 1M sucrose reward. Treatments 2: Blue flowers contained 5*u*l 2M sucrose while white and yellow flowers contained 5*u*l 1M sucrose reward. Treatment 3: White flowers contained 5*u*l 2M sucrose while blue and yellow flowers contained 5*u*l 1M sucrose reward. Treatment 4: Yellow flowers contained 5*u*l 2M sucrose while blue and white flowers contained 5*u*l 1M sucrose reward.

**Experiment II.** Treatment 1: all flowers contained 5*u*l unscented 1M sucrose reward. Treatments 2: Blue flowers contained 2.5*u*l 1M sucrose while white and yellow flowers contained 20*u*l 1M sucrose reward. Treatments 3: White flowers contained 2.5*u*l 1M sucrose while blue and yellow flowers contained 20*u*l 1M sucrose reward. Treatments 4: Yellow flowers contained 2.5*u*l 1M sucrose while blue and white flowers contained 20*u*l 1M sucrose reward.

Data from each experiment were analyzed using a repeated measures MANOVA (Sall and Lehman 1996). Analysis was based on arcsine square-root transformed visitation frequency to white flowers using a group by treatment statistical design.

## RESULTS and DISCUSSION

**Experiment I.** Observations were made on 3107 flower choices by 13 Cyprus honey bee foragers presented reward quality differences (2M versus 1M) among flower colors (Table 1). *A.m. cypria*, exhibited a significant forager-type effect ($F=32.5$; $df=1,11$; $P<0.0001$), and treatment effect ($F=5.94$; $df=3,9$; $P=0.016$), but not a significant interaction between treatment and forager-type ($F=3.37$; $df=3,9$; $P<0.068$).

**Table: 1**

***Apis mellifera cypria*** **forager response to differences in reward quality (sucrose molarity: 2M *vs* 1M) associated with flower color morphs (blue, white, and yellow). Percent visitation (mean among bees) to each flower color (Blue, White, Yellow) by experimental treatment (1 to 4) is given for bees first selecting a yellow flower (Yellow Group Bees) and for bees first selecting either a blue or white flower (Blue-White Group Bees). Reward quality does not differ among flower color morphs in Treatment 1. Blue flowers offered the higher molar reward in Treatment 2, white flowers in Treatment 3, and yellow flowers in Treatment 4**

| **Yellow Group Bees** | **TREATMENT** | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| **% Yellow Flowers Visited** | 76 | 72 | 55 | 90 |
| **% White Flowers Visited** | 16 | 17 | 37 | 6 |
| **% Blue Flowers Visited** | 8 | 11 | 8 | 4 |
| **TOTAL** | 100 | 100 | 100 | 100 |
| **Blue-White Group Bees** | **TREATMENT** | | | |
| | **1** | **2** | **3** | **4** |
| **% Yellow Flowers Visited** | 1 | 2 | 2 | 2 |
| **% White Flowers Visited** | 48 | 23 | 63 | 53 |
| **% Blue Flowers Visited** | 51 | 75 | 35 | 45 |
| **TOTAL** | 100 | 100 | 100 | 100 |

**Experiment II.** Observations were made on 3174 flower choices by 13 Cyprus foragers responding to reward quantity differences (2μl versus 20μl) among flower colors (Table 2). *A.m. cypria*, exhibited a significant forager-type effect ($F=67.1$; $df=1,11$; $P<0.0001$), treatment effect ($F=19.9$; $df=3,9$; $P=0.0003$), and interaction between treatment and forager-type ($F=10.6$; $df=3,9$; $P<0.003$).

**Table: 2**

***Apis mellifera cypria*** **forager response to differences in reward quantity (2*ul* *vs* 20*ul*) associated with flower color morphs (blue, white, and yellow). Percent visitation (mean among bees) to each flower color (Blue, White, Yellow) by experimental treatment (1 to 4) is given for bees first selecting a yellow flower (Yellow Group Bees) and for bees first selecting either a blue or white flower (Blue-White Group Bees). Reward quantity does not differ among flower color morphs in Treatment 1. Blue flowers offered the smaller quantity reward in Treatment 2, white flowers in Treatment 3, and yellow flowers in Treatment 4**

| **Yellow Group Bees** | **TREATMENT** | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| **% Yellow Flowers Visited** | 90 | 95 | 84 | 68 |
| **% White Flowers Visited** | 8 | 3 | 11 | 20 |
| **% Blue Flowers Visited** | 2 | 2 | 5 | 12 |
| **TOTAL** | 100 | 100 | 100 | 100 |

| **Blue-White Group Bees** | **TREATMENT** | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| **% Yellow Flowers Visited** | 2 | 5 | 5 | 0 |
| **% White Flowers Visited** | 47 | 67 | 34 | 52 |
| **% Blue Flowers Visited** | 51 | 28 | 61 | 48 |
| **TOTAL** | 100 | 100 | 100 | 100 |

Forager response of *A.m. cypria* had similarities to and distinct differences from reported forager behavior of *A.m. ligustica* and *A.m. caucasica*. When presented a reward quality difference, some bees frequented yellow flowers while others favored blue and white flowers (Table 1). That division of labor was reminiscent of Italian and Caucasian bee behavior. The Cyprus bee also showed behavior like that of the Italian and Caucasian bees in that foragers favoring blue and white flowers readily changed fidelity to the flower color morph (blue or white) containing the higher molar reward (Table 1). Unlike either Italian or Caucasian bees (Wells and Wells 1983, 1986; Çakmak and Wells 1995, 1996; Hill *et al.*

1997), Cyprus bees frequenting yellow flowers decreased visitation to yellow when yellow offered 1M reward (85% to 63%:Treatment 3) and increased visitation to yellow when yellow offered 2M reward (64% to 94%:Treatment 4).

When reward quantity differed among flower colors some *A.m. cypria* foragers favored yellow flowers while others showed a distinct preference for blue and white flowers (Table 2). Blue-white group bees avoided blue when blue contained less reward than white flowers (Treatment 2), and avoided white when white contained less reward than blue flowers (Treatment 3). Blue-white group bees showed neither a preference for blue nor for white flowers when rewards did not differ among flower color morphs (Treatment 1). Bees preferring yellow flowers increased visitation to blue and white flowers (from 4% to 20%) when yellow contained the smaller reward (Treatment 4). In contrast, Italian and Caucasian bees do not respond to the quantity differences presented; blue-white group Italian and Caucasian bees do not even respond when quantity differs between blue and white flowers (Wells and Wells 1983, 1986; Çakmak and Wells 1995, 1996).

Those results agree with expectations of forager predator avoidance models (Gilliam and Fraser 1987; Brown 1992). Cyprus bee behavior would minimize exposure to predatory wasps. Visiting the flower color providing the larger reward quantity decreases the number of flowers that a forager must visit to obtain a full load. In turn, that decreases time foraging and movement between flowers (cues for visually hunting predators).

**Alternative Honey Bee Pollen Vectors?**

The diversity of plants and their different pollination requirements results in diverse types of agricultural pollination tasks (Erickson 1983; Parker *et al.* 1987; Torchio 1990; Osborne *et al.* 1991), ranging from hybrid seed production (Kime and Tilley 1947; Oendeba *et al.* 1993; Williams 1995) to inter-cropping to reduce pesticide use (Hussein and Samad 1993; Theunissen 1994; Kennedy *et al.* 1994). Honey bees have failed to achieve the desired pollination goal in many instances (Boren *et al.* 1962; Hanson *et al.* 1964; Faulkner 1970, 1974; Free and Williams 1973, 1983; Vaissere *et al.* 1984; Davis *et al.* 1988; Free *et al.* 1992). Thus, alternative pollen vectors, such as leaf cutter and alkali bees, are managed in some areas for crop pollination (Jay 1986; Curie *et al.* 1990; Kevan *et al.* 1990; Torchio 1991; Richards 1996). However, economics favors using *A. mellifera* when possible (Parker et al.1987; Robinson et al. 1989; Southwick and Southwick 1992).

We have demonstrated here that diversity in pollinator flower fidelity exists among *A. mellifera* races, but the full extent is yet to be determined. That suggests that some races which are largely unexploited for agricultural use may have particular value for certain types of pollination tasks. Of course, much more work is needed to understand the diversity of subspecies related forager behaviors, to fully determine what effect different behaviors have on pollination of crops, and to develop honey bee lineages through breeding and selection that are best suited for alternative agricultural purposes.

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