N O T E

Effect of Yellow Flowers on Abundance of *Bemisia tabaci* (Hemiptera: Aleyrodidae) on Plants[1]

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The B-biotype sweetpotato whitefly, *Bemisia tabaci* (Gennadius), is a serious agricultural pest in field and greenhouse productions on a global scale. There have been several compilations of host plants for *B. tabaci* and, collectively, over 1000 host plants have been recorded for this pest (Abd-Rabou and Simmons 2010, Entomol. News 121: 456 - 465). The problem from feeding by this pest is amplified because it transmits over 100 plant diseases (Jones 2002, European J. Plant Path. 109: 197 - 221). Many factors are known to affect the population dynamics of whiteflies (Gerling 1984, Phytoparasitica 12: 109 - 118; Simmons and Mahroof 2011, Ann. Entomol. Soc. Am. 104: 928 - 934). Understanding the population ecology of this insect is important for its management.

Whiteflies have been known to be attracted to yellow color since their orientation to this color was demonstrated nearly a hundred years ago (Lloyd 1921, Bull. Entomol. Res. 12: 355 - 359). Subsequently, yellow sticky traps have been devised and are widely used in greenhouses and fields to monitor for the presence of whiteflies or to reduce their numbers (Gerling and Horowitz 1984, Ann. Entomol. Soc. Am. 77: 753 - 759; Bi et al. 2002, J. Econ. Entomol. 95: 1179 - 1184; Slosser et al. 2002, J. Econ. Entomol. 95: 299 - 306). In addition to *B. tabaci* (Mound 1962, Ent. Exp. Appl. 5: 99 - 104), several natural enemies of *B. tabaci* are also attracted to yellow; namely, parasitoids in the genera *Encarsia* and *Eretmocerus* (Hoelmer and Simmons 2008, Environ. Entomol. 37: 391 - 399) and a coccinelid predator, *Delphastus catalinae* (LeConte) (Simmons 2003, J. Entomol. Sci. 38: 481 - 484). Moreover, aphids (Fereres et al. 1999, Ann. Entomol. Soc. Am.) and several other insects (Adams and Loss 1986, Environ. Entomol. 15: 867 - 873; Udayagiri et al. 1997, Environ. Entomol. 26: 983 - 988) are known to be attracted to the color yellow. We are not aware of any report concerning what impact that the color of flowers may have on the population of whiteflies on plants. Because

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of variations in population dynamics of *B. tabaci*, knowledge of the ecology and the host plants of this pest may aid in whitefly management and the management of associated viruses. The objective of this study was to determine if infestation levels of *B. tabaci* can be affected by the presence of yellow flowers during the growth of certain crops.

A laboratory experiment was established using flowering and deflowered plants of yellow Belgian mums (*Chrysanthemum indicum* L.; 'Dendranthema'). Five pairs of flowering and deflowered plants were arranged about 50 cm apart in an otherwise empty room (3.4 × 1.8 × 2.1 m high) maintained at 24 ± 4°C. Afterward, 500 adult *B. tabaci* were released in the room. On each of the next 3 consecutive days, the number of adult whiteflies on the upper and lower leaf surfaces of each plant was counted. The experiment was repeated 5 times. This same experimental design was conducted using flowering and deflowered sunflower plants (*Helianthus annuus* L.; 'Grey Stripe') which was repeated 4 times.

A related experiment was conducted in the greenhouse to assay the impact of yellow flowers on the infestation of *B. tabaci* on some vegetable plants. One month before and during the experiment, the whiteflies in an uncaged greenhouse colony were maintained on several species of vegetable crops. 'Straightneck' summer squash (*Cucurbita pepo* L.) plants were established from seedlings in 15.24-cm diam black pots in a whitefly-free greenhouse. Only 1 plant was in a pot. The plants were grown to the flowering stage. Two plants of similar size were placed on an empty table in an open colony of *B. tabaci* in a greenhouse. The pots were placed 50 cm apart. All flowers on 1 plant were detached. Eight pairs of plants (with and without flowers) were arranged in a randomized design on the table. Two leaves, position 3 and 4 from the apex, were marked with a green twist tie. On 1, 2, and 3 days after exposure to the whiteflies, the numbers of adults on the marked leaves were counted and recorded. For the count, the leaves were gently turned to facilitate observation, and the counts were made during early morning (about 1 - 2 h after sunrise). Following the last adult count on day 3, the marked leaves were detached and transported to the laboratory for egg counts with the aid of a microscope. Leaf areas of the detached leaves were determined using a leaf area meter (model 3,000, LI-COR, Lincoln, NE). Any new flowers on the deflowered treatment were detached on each of the next 2 days after the exposure period. The experiment was repeated 6 times. Also, floral color was determined using a CR-21- Minolta chroma meter according to CIELB color space (McGuire 1992, HortScience 27: 1254 - 1255). The inside and outside surfaces of petals of flowers were measured. Ten flowers were measured from plants of 3 trials. A similar experiment investigating the impact of yellow flowers was conducted using 'Poinsett' cucumber (*Cucumis sativus* L.). Six pairs of flowering and deflowered cucumber plants per trial were used in this experiment. Vines of the plants were trained vertically on trellises. The experiment was repeated 6 times.

An additional experiment was conducted in the field using plots of cucumber and squash. Both crops were planted in separate plots. The first flowers were detached 1 wk before the first whitefly counts were made, and flowers were detached in the deflowered treatment every 2 - 3 days. Adult counts were made on 2 random leaves per sampled plants on 4 consecutive days during 6 wks for cucumber and 2 wks for squash. Each week, 18 pairs of plants were sampled for whiteflies in squash trials, and 8 - 18 were sampled per week in cucumber.

The data were analyzed using procedures of SAS (SAS Institute 2010, Cary, NC). Type of flower treatment was considered as fixed effect and time (block) was considered

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as random effect. Data for each crop were analyzed separately and were subjected to analysis of variance (ANOVA) by using the MIXED procedure of SAS. Percentages of eggs deposited and number of adult whiteflies present on day 3 post exposure were analyzed with the SAS PROC GLM routine. Percentages of adults counted on each day were transformed using arcsine transformation before the analysis. Least squares means were used for separating treatment means at $P = 0.05$. Actual means and standard errors are presented in the text and figures.

Percentages of adult whiteflies found on flowering plants of Belgian mums (96%) and sunflower (80%) were significantly ($P < 0.0002$) higher than percentages found on deflowered plants in the laboratory room experiment (Fig. 1). In the greenhouse, although there was a trend for an increase in numbers of adults and eggs in the flower treatment, few significant differences were observed in either squash or cucumber. The only significant treatment effect in the greenhouse ($F = 5.65$; df = 1, 84; $P < 0.0197$) was observed for squash on the second day of exposure. No block effect was observed among the trials for either crop in the greenhouse. A significant interaction by block effect was observed during the first 2 days ($F = 10.75$; df = 5, 58; $P < 0.0001$; $F = 3.07$; df = 5, 58; $P < 0.0160$, respectively) for cucumber and the second day ($F = 2.46$; df = 5, 84; $P < 0.0395$) for squash. Adult whitefly counts per 2 leaves ranged from 2 - 1228 on squash and 0 - 178 on cucumber during the greenhouse trials. In the field, the only significant treatment effect ($F = 10.30$; df = 1, 66; $P < 0.0021$) observed was for squash on the first day of count. Adult whitefly counts per 2 leaves ranged from 0 - 292 on squash and 0 - 109 on cucumber during the field trials. In the greenhouse and field experiments, because treatments were adjacent flowering and deflowered plants, local movement between treatments may have made it difficult to detect any significant differences. *Bemisia tabaci* is known to constantly make trivial flights between crops and weed hosts (Byrne et al. 1990, Environ. Entomol. 15: 300 - 304). Additional observations were made on sunflower in the field in which flower and deflowered treatments were on

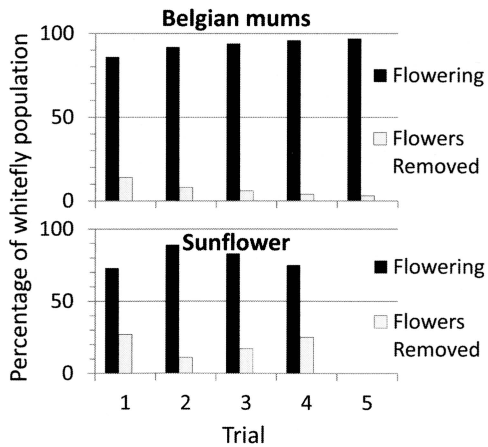

Fig. 1. Percentages of adult whiteflies on paired flowering and deflowered plants of Belgian mums, and percentages of adult whiteflies on paired flowering and deflowered sunflower plants in a laboratory room (each trial represents three consecutive days of counts).

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separate rows. The ratio of *B. tabaci* eggs/cm^2 leaf was 1.6: 1 for flowering and deflowered sunflower plants, respectively (n = 9; range 1 - 152 eggs; mean = 0.14 eggs/cm^2 for flower treatment and 0.09 eggs/cm^2 for deflowered plants).

The specific color and size of flowers are possible factors that may impact the level of whitefly infestation. Internal floral petals had higher values of color characteristics than external petals. Color values for the internal petal of the Belgian mums was generally higher (hue angle = 100.3, chroma = 55.9 and lightness =76.9) as compared with the internal petal of the cucumber (hue angle = 90.6, chroma = 74.3 and lightness =75.1), squash (hue angle = 85.6, chroma = 65.7 and lightness = 74.3) and sunflower (hue angle = 92.3, chroma = 78.4 and lightness =65.1). Ornamental and nursery plants in greenhouses commonly have a wide array of yellow flowers, and *B. tabaci* is a host on many of these plants. Results of this study support that such plants may become more of a target for whiteflies when they are flowering. Knowledge of the population ecology of whiteflies and other pests whose attraction to plants are enhanced because of yellow flowers may aid in their management and possibly in the management of associated viruses.

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