Plant Phenology-Related Shifts in Color Preferences of Epicometis (Tropinota) Hirta (Coleoptera: Scarabaeidae: Cetoniinae) Adults - Key to Effective Population Monitoring and Suppression

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PLANT PHENOLOGY-RELATED SHIFTS IN COLOR PREFERENCES OF *EPICOMETIS* (*TROPINOTA*) *HIRTA* (COLEOPTERA: SCARABAEIDAE: CETONIINAE) ADULTS - KEY TO EFFECTIVE POPULATION MONITORING AND SUPPRESSION

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ABSTRACT

The study was conducted to elucidate the possibility that a shift in color preferences of adults of the apple blossom beetle, *Epicometis hirta,* occurs sometime after the end of overwintering and the onset blooming of *Prunus* spp. trees and between the termination of blooming and the death of the adults. Such information is needed to choose the best color of the traps used for the detection, monitoring and suppression of this major pest. In a randomized complete block experiment with 9 replicates at 3 different cherry orchard sites in Turkey, blocks of 11 differently colored traps each ere operated and serviced daily in cherry orchards from the end of hibernation of *E. hirta* the adults disappeared at the end of the season. The numbers of adult beetles captured in each of the 11 differently colored traps in each block were recorded daily. According to ANOVA and the Tukey's test ($P < 0.01$), significantly the largest numbers of *E. hirta* were sampled by floral white-colored traps in both the prebloom (experiment I-749 individuals, $n = 38$) and post-bloom (experiment III-263 individuals, $n = 12$) periods. However during the bloom period significantly the largest numbers of *E. hirta* were sampled by the light sky-blue-colored traps (experiment II-715 individuals, $n = 30$). The effect of the color and block on population of *E. hirta* was tested by univariate analysis of variance; and only color effect variation was found statistically significant. Likewise the results of cluster analysis showed that floral white-colored traps were more attractive for *E. hirta* than traps of any other color during the pre-bloom and post-bloom periods; whereas, light sky-blue colored traps were the most attractive for *E. hirta*during the bloom period. These data clearly demonstrate the color preference of *E. hirta* shifted from floral white before the cherry trees bloomed to light sky-blue during the bloom period and back to floral white during the postbloom period. These shifts may be an adaptation to the different host plant species that are predominant during different periods of the growing season. Currently some growers in Turkey control *E. hirta* during the cherry bloom period by intensive trapping with light sky-blue traps. However these data suggest that the control effort should be shifted to the prebloom period with intensive trapping by floral white traps.

Key Words: apple blossom beetle; pest management, physical methods, trapping, color preference

RESUMEN

El estudio se realizó para elucidar la posible ocurrencia de cambios en las preferencias de colores en los adultos del escarabajo de la flor del manzano, *Epicometis hirta*, al terminar el período invernal y justo antes de la floración de *Prunus* spp., asi como también, al terminar el período de floración y muerte de los adultos. Esta información es necesaria para seleccionar el mejor color para las trampas utilizadas en la detección, control y supresión de esta importante plaga. El experimento fue de bloques completos al azar con 9 repeticiones en 3 huertos de cerezos de Turquía. Bloques de 11 trampas de diferentes colores, cada una llena de agua hasta la mitad, fueron revisadas y reacondicionadas diariamente desde el final del período de hibernación de *E. hirta* en la primavera hasta la desaparición de los adultos al final de la temporada del cultivo. El número de escarabajos adultos capturados en cada una de las trampas de 11 colores diferentes, en cada bloque, se registró diariamente. De acuerdo al análisis de varianza y la prueba de Tukey ($P < 0.01$), un número significativamente mayor de *E. hirta* fue capturado por trampas de color blanco en los períodos de pre-floración (experimento I-749 individuos, $n = 38$) y pos-floración (experimento III-263 individuos, $n = 12$). Sin embargo, durante el período de floración el número de capturas de *E. hirta* fue significativamente mayor en trampas de color de azul del cielo (experimento II-715 individuos, $n = 30$). El efecto del color y el bloque sobre la población de *E. hirta* fue determinado mediante análisis univariado; sólo la variación debida al color fue estadísticamente significativa. Similarmente, los resultados de análisis conjunto mostraron que las trampas de color blanco fueron las más atractivas para *E. hirta* durante los períodos de pre-floración y pos- floración, mientras que las trampas del color de azul cielo fueron más atractivas durante el período de floración. Estos resultados demuestran que los adultos de *E. hirta* cambiaron su preferencia de colores del blanco en el período de pre-floración al azul cielo durante la floración, y nuevamente blanco durante la post-floración. Estos cambios pueden ser una adaptación a las diferentes especies de plantas hospederas que predominan durante las temporadas de cultivo. Actualmente algunos productores de cereza en Turquía controlan a *E. hirta* utilizando trampas el color azul cielo intensivamente durante el período de floración. Sin embargo, nuestros resultados sugieren que los esfuerzos de control deberían realizarse durante el período de pre-floración y con trampas de color blanco.

Cherry (*Prunus avium* (L.) L.)is attractive to many pests (Özbek et al. 1996; Ulusoy et al. 1999; Tezcan & Pehlivan 2001; Tezcan & Önder 2003; Çınar et al. 2004). *Epicometis* (*Tropinota*) *hirta* (Poda 1761) is one of pests seen feeding on cherry flowers and maybe the pest most well-known by farmers in Turkey (Ertop & Özpınar 2011; Perez & Traveset 2011). *E. hirta* individuals overwinter either as larvae and/or adults beneath fallen leaves or other plant matter on the ground, among other places. This species can be seen from Apr to Sep; and it is distributed across the Palaearctic region (Naturewonders 2009). While adults feed on various flowers, larvae feed on dead wood. The polyphagous adult is a pest of cherry, apple (*Malus domestica* Borkh.), pear (*Pyrus communis* L.) quince (*Cydonia oblonga* Mill.), plum (Prunus domestica L.), canola (*Brassica napis* L.), rye (*Secale cereale* L.), raspberry (*Rubus idaeus* L.), blackberry (*Rubus allegheniensis* Porter), wheat (*Triticum aestivum* L.), dandelion (*Taxacum officinale* F. H. Wigg.), coltsfoot(*Tussilago farfara* L.), barley (*Hordeum vulgare* L.), lupine (*Lupinus* spp.), blackcurrant (*Ribes nigrum* L.), tulip (*Tulipa* spp.), narcissus (*Narcissus* spp.), broomrape (*Orobanche* spp.),etc. (DAFF & PHA, 2011).

Epicometis hirta adults feed on stamens and pistils of the flowers (Milenkovic & Stanisavljevic 2003; Çetin et al. 2006; Ertop & Özpınar 2011; Perez & Traveset 2011). During the blooming of crops, *E. hirta* is a very dangerous pest, and may damage 70% of the blossoms on young cherry trees (Kutinkova &Andreev 2004; Razov et al. 2009). *E. hirta*, similar to many other day-active flower-feeding insects, uses both chemical and visual cues to locate host plants (Vuts et al. 2010). It has a strong preference for the color blue (Schmera et al. 2004). *E. hirta* can be removed from flowers by hand or by shaking branches over a plastic sheet (Kutinkova &Andreev 2004).

When *E. hirta* adults emerge from hibernation most of the above plant species are not in bloom and, thus, initially, they must be able to locate other acceptable hosts. At this time such host plants exist mostly in non-agricultural habitats such as meadows, and these tend to be close to fruit orchards. Schmera et al. (2004) observed *E. hirta* adults feeding on *Crataegus* and *Sambucus* bushes in meadows. Likewise after the above mentioned hosts have ceased to bloom, *E. hirta* adults must again locate other acceptable hosts. This suggests that *E. hirta* adults may undergo shifts in color preferences that enable it to locate hosts as changes occur in the phenology of the plant community during the growing season. However, a review of the literature failed to find any documents that indicate that possible shifts in color preference have been investigated.

Because the acceptable pest level of mentioned species is low with an economic threshold of 3-5 beetles per 100 rosettes, or 5% racemes damaged, farmers prefer to use pesticides instead of preventive cultural practices, monitoring, mechanical and/or biological controls (Kutinkova &Andreev 2004). Synthetic pesticides are generally used not as required, and often they are used not only at recommended times but also before and even after pest is present. Also pesticide use in cherry and apple orchards can destroy populations of pollinating insects most of which are honey bees, *Apis mellifera* L. Moreover, in east European countries floral and/or chemical attractant-baited traps have very often been used to trap *E. hirta*, and other scarabaeids such as the rose chafer, (*Cetonia aurata* (L.)), flower chafer (*Potosia cuprea*F.) or Trauer-Rosenkäfer (*Oxythyrea funesta* Poda) (Tóth, et al. 2004; Schmera et al. 2004; Vuts et al. 2009). Some studies have shown that the control of *E. hirta* should start when this species is first detected in fruit orchards (Anonymous 2010a, 2010b, 2010c; Ertop & Özpınar 2011). All attempts to control the pest with synthetic insecticides have failed to assure high fruit yields thus far. Therefore, the further development of improved physical methods for managing this pest is currently recommended.

The study was conducted to elucidate the possibility that shifts in color preferences of adults of the apple blossom beetle, *E. hirta,* occur during the growing season. Such information is needed to choose the best trap color for detection, monitoring and suppression of this major pest.

Materials and Methods

The study was conducted between 14 Mar and 1 Jun 2011 at 3cherry orchards in Turkey: Atabey (Location I), Pembeli (Location II), and Egirdir (Location III) all in Isparta Province. Eleven different colors (hex code inside brackets), brown (#A52A2A), chartreuse (#7FFF00), coral (#FF7F50), dodger blue (#1E90FF), floral white

(#FFFAF0), golden rod (#DAA520), hot pink (#FF69B4), light sea green (#20B2AA), light sky blue (#87CEFA), medium orchid (#BA55D3), and transparent azure (#F0FFFF), were tested for determination of response of *T. hirta*. To measure the responses of the adult beetles to these colors, plastic bowls 30-cm in diameter and about 15 cm deep with these colors were procured (Altinsoy Firm, Isparta province) to serve as trapping devices (Fig. 1). Blocks containing 11 traps with the above colors, were replicated 9 times, in the cherry orchard at each of the 3 locations. Thus the total number of traps was 297. Within each block the colors were distributed randomly. The distance between adjacent colors was one meter within a block and each block were set up 50 m distant from the next. Based on the results of numerous previous studies, traps were set up on the soil surface in sunny places within the cherry orchards (Fig. 1). Almost 1 liter of water was placed into each trap, which made it almost The pre-bloom, bloom and post-bloom periods of cherry were determined as 14 Mar to 20 Apr (experiment I); 21 Apr to 20 May (experiment II) and 21 May to 1 Jun (experiment III), respectively.

Statistical analyses were calculated separately for each experiment. The effect of the color, block, and color × block on population of *E. hirta* was tested by the univariate analysis of variance (UNIANOVA, SPSS Inc., Chicago, version 10.1). The numbers of *E. hirta* adults trapped with the different colors were set as dependent variables. An ANOVA (Tukey's test) was calculated to test the differences of numbers of individual adults trapped among the different colors. The numbers of individuals trapped with the different colors were subjected to cluster analysis. Similarity analyses were done with the Multi-Variate Statistical Package (MVSP) 3.11c (Kovach 1999). Similarity coefficients were compared with Euclidean distances. The average linkage between 2 groups is considered as the average distance between all pairs of cases and one number from each group. Euclidean distance (x,y) = $\{\sum_i (x_i - y_i)^2\}$

Dendrograms were produced according to the unweighted pair-group mean arithmetic method (UPGMA) using MVSP software.

Results and Discussions

The effect of trap color and block on trap catch of *E. hirta* was tested by the univariate analysis of variance (Table 1). While the color effect variation was found to be statistically significant for the totals of individual *E. hirta* adults trapped, the block effect variation had a *P* value higher than 0.01% (Table 1).

Comparison of the numbers of *E. hirta* adults sampled with differently colored traps using ANOVA during the pre-bloom (n = 38), bloom (n = 30) and post-bloom (n = 12) periods in 3 locations is displayed in Table 2. According to the Tukey's test (P < 0.01) significantly the largest numbers of *E. hirta* adults were sampled by floral white traps in the pre-bloom and post-bloom periods at all three locations (marked by an "a" in Table 2). However during the bloom period, the light sky blue colored traps captured the significantly the most *E. hirta* adults at locations I, II and III; (marked "a" in Table 2). During the pre-bloom period at the locations I and II, the light sky blue color traps, although less effective than floral

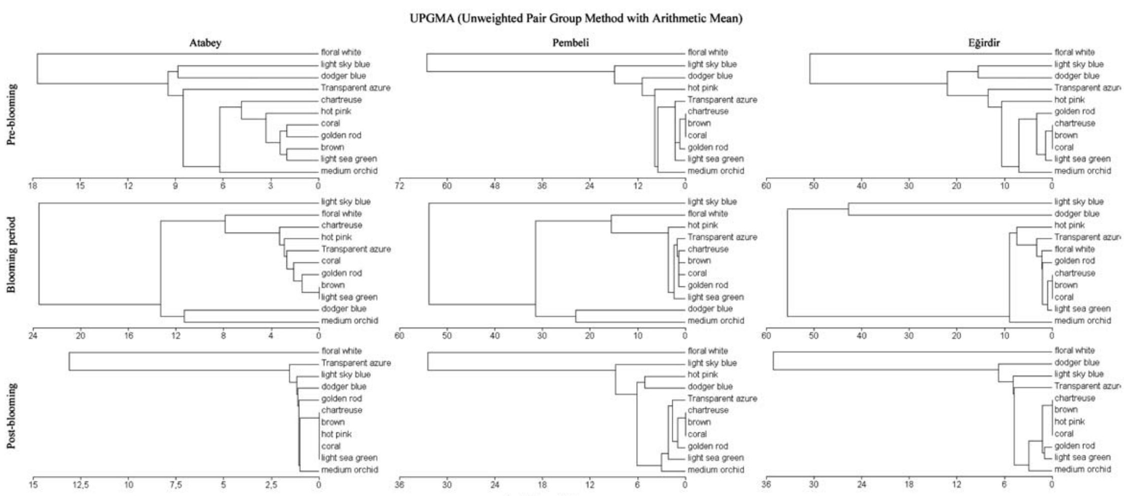

Fig 1. Cluster analysis dendrograms (UPGMA method, squared Euclidean distance) showing similarities between 11 different colors where *E. hirta* sampled during pre-bloom, bloom and post-bloom periods at 3 locations (Location I: Atabey; Location II: Pembeli; Location III: Egirdir).

TABLE 1. UNIVARIATE ANALYSIS OF VARIANCE (UNIANOVA, SPSS 10.1) ON THE EFFECTS OF COLOR AND BLOCK ON THE INDIVIDUAL NUMBERS OF *E. HIRTA*.

	Source			
Dependent variable	Color	Block	Color × Block	Error
Epicometis hirta				
df	10	2	20	99
MS	60.508	9.159	5.226	7.371
F	11.579	1.753	0.709	
P	<0.001	0.199	0.808	

white traps, was found significantly more effective than all remaining colors except chartreuse, dark blue traps, medium orchid, and azure at Location I, and dark blue and hot pink at Location II (marked "bc" in Table 2).

The light sky blue color traps was found significantly more effective than all remaining colors during the pre-bloom period at Location III. Tukey's test showed that the light sky blue color traps during the bloom period were significantly more attractive for the beetle than any traps with other colors, and they caught the highest number of *E. hirta* adults at all locations I, II and III with 122, 277, and 316, respectively. Also in the bloom period, the attraction of dark blue color traps was found statistically to be the second in importance after light sky blue color traps for the species at locations I and II; but dark blue color traps were not significantly more attractive than medium orchid color traps, and the latter were not significantly more attractive than floral white traps at location III (Table 2).

During the pre-bloom period, floral white color traps caught the highest numbers of beetles, i.e., 93, 382, and 274 at locations I, II and III, respectively ($n = 38$). During the bloom period, light sky blue color traps caught the highest numbers of *E. hirta*, i.e., 122, 277, and 316 at the location I, II and III, respectively ($n = 20$).

During the post bloom period, white color traps—as in the pre-bloom period—caught the highest numbers of *E. hirta* adults, i.e.,40, 104 and 119 individuals at location I, II, and III, respectively ($n = 12$).

Light blue color was recommended by Schmera et al. (2004), however they could not find significant differences between the responses of *E. hirta* to yellow, white or light blue colors in a field test; but the highest numbers of *E. hirta* adults sampled were 416, 204 and 251 individuals for light blue, yellow and white traps, respectively. Color attractancy was also reported for the closely related species, *Tropinota squalida* (Scop) (Coleoptera: Scarabaeidae, Cetoniinae), adults of which were sampled in the following numbers: white traps (229 individuals), light blue traps (189), and pink traps (108) (Ortu et al. 2001), while a recent study has found that there was no significant difference in the mean numbers of *T. squalid* caught with the floral bait in white or blue traps (Tóth, et al. 2009).Our study clarified that floral white and light sky blue colors are more attractive than any other colors for *E. hirta*; however *E. hirta* is differentially attracted by these colors in different periods of the growing season. The previous studies were performed approximately between end of the Apr and middle of the May (Ortu et al. 2001; Schmera et al.; 2004). Our study was started shortly after the overwintering season of *E. hirta* and maintained during the pre-bloom, bloom and post-bloom periods, i.e., 14 Mar through 1 Jun 2011. Hence we could determine significant seasonal differences in attractancy by different colors. The results of the present study showed that the floral white color was the most attractive of all tested colors for the pest during the cherry pre-bloom and post-bloom periods, while light sky blue color was the most attractive of all tested colors during the cherry bloom period.

Likewise the results of cluster analysis Euclidean distance measurements (Fig. 1) for all locations showed that floral white color traps were more attractive for *E. hirta* adults than any other color during the pre-bloom and post-bloom periods. However light sky blue color traps were the most attractive during the bloom period (Fig. 1). The floral white color measurements were found to be the most dissimilar during the pre and post bloom periods, because this color was then exceptionally attractive to the beetle. Comparable results were found during the bloom period for the light sky blue color traps (Fig. 1). The Euclidean distances of the floral white color trap samples during the pre-bloom period were calculated to be 17.70, 65.15, and 50.91 at Locations I, II, and III, respectively. The dissimilarity index also showed a similar result for the floral white color trap samples during the post-bloom period at Locations I, II and III with values of 13.11, 32.43, and 35.15, respectively.

During the bloom period, *E. hirta* adults were found to be more attracted to light sky blue color traps than to the other colors, and the dissimilar-

TABLE 2. COMPARISON OF THE NUMBERS OF *EPICOMETIS HIRTA* ADULTS SAMPLED BY DIFFERENTLY COLORED TRAPS USING ANOVA DURING THE PRE-BLOOM, BLOOM AND POST-BLOOM PERIODS IN THREE LOCATIONS IN TURKEY.

	Location I			Location II			Location III		
Colors	Pre bloom* Mean ± SE	Bloom Mean ± SE	Post bloom Mean ± SE	Pre bloom Mean ± SE	Bloom Mean ± SE	Post bloom Mean ± SE	Pre bloom Mean ± SE	ÇD Bloom Mean ± SE	Post bloom Mean ± SE
brown	0.08 ± 0.04 c**	0.00 ± 0.00 e	0.00 ± 0.00 b	0.00 ± 0.00 c	0.03 ± 0.03 c	0.00 ± 0.00 b	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 b
chartreuse	0.21 ± 0.12 bc	0.13 ± 0.09 de	0.00 ± 0.00 b	0.00 ± 0.00 c	0.03 ± 0.03 c	0.00 ± 0.00 b	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 b
coral	0.05 ± 0.04 c	0.07 ± 0.07 de	0.00 ± 0.00 b	0.00 ± 0.00 c	0.03 ± 0.03 c	0.00 ± 0.00 b	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 b
D.blue	0.68 ± 0.21 bc	2.20 ± 0.33 b	0.08 ± 0.08 b	0.87 ± 0.25 bc	3.33 ± 0.53 b	1.17 ± 0.42 b	1.13 ± 0.39 c	6.57 ± 0.91 c	1.00 ± 0.51 b
F. white	**2.45 ± 0.26 a**	1.07 ± 0.19 cd	**3.33 ± 0.57 a**	**10.11 ± 0.74 a**	2.53 ± 0.26 c	**8.67 ± 1.38 a**	**7.21 ± 0.72 a**	0.07 ± 0.07 c	**9.92 ± 0.96 a**
goldenrod	0.05 ± 0.04 c	0.07 ± 0.05 de	0.08 ± 0.08 b	0.05 ± 0.04 c	0.03 ± 0.03 c	0.08 ± 0.08 b	0.16 ± 0.08 c	0.07 ± 0.07 d	0.17 ± 0.11 b
hotpink	0.18 ± 0.07 c	0.17 ± 0.08 de	0.00 ± 0.00 b	0.45 ± 0.18 bc	0.23 ± 0.10 c	1.00 ± 0.41 b	0.66 ± 0.26 c	0.57 ± 0.22 d	0.00 ± 0.00 b
L.seagreen	0.08 ± 0.06 c	0.00 ± 0.00 e	0.00 ± 0.00 b	0.11 ± 0.06 c	0.17 ± 0.07 c	0.17 ± 0.17 b	0.05 ± 0.04 c	0.03 ± 0.03 d	0.08 ± 0.08 b
L.skyblue	1.00 ± 0.20 b	**4.07 ± 0.42 a**	0.08 ± 0.08 b	2.47 ± 0.28 b	**9.23 ± 1.09 a**	1.83 ± 0.59 b	2.32 ± 0.66 b	**10.53 ± 1.22 a**	0.67 ± 0.36 b
M.orchid	0.26 ± 0.15 bc	1.53 ± 0.26 bc	0.08 ± 0.08 b	0.42 ± 0.17 c	6.80 ± 0.63 c	0.50 ± 0.23 b	0.42 ± 0.17 c	0.77 ± 0.26 b	0.50 ± 0.23 b
T. azure	0.58 ± 0.19 bc	0.13 ± 0.08de	0.17 ± 0.11 b	0.11 ± 0.06 bc	0.07 ± 0.05 c	0.25 ± 0.13 b	0.87 ± 0.31 c	0.10 ± 0.10 d	0.75 ± 0.35 b

*Pre-bloom (n = 38), bloom (n = 30), post-bloom (n = 12).

**Means within a column followed by the same letter are not significantly different by Tukey's test at $P < 0.01$.

The 11 different colors (hex code inside brackets) are: brown (#A52A2A), chartreuse (#7FFF00), coral (#FF7F50), dodger blue (#1E90FF), floral white (#FFFAF0), golden rod (#DAA520), hot pink (#FF69B4), light sea green (#20B2AA), light sky blue (#87CEFA), medium orchid (#BA55D3), and transparent azure (#F0FFFF).

ity index values were found to be 23.55, 53.90, and 55.61, respectively (Fig. 1). After floral white, dodger blue and light sky blue color traps were found to be the other dissimilar traps during the pre and post bloom periods (Fig. 1). The trap colors with the most similar attractancies were found to be light sea green, brown, golden rod, coral, transparent azure, chartreuse, and hot pink, with which the lowest numbers of *E. hirta* were sampled during pre-bloom, bloom and post-bloom periods at all locations.

Conclusion

The color preferences of *E. hirta* were found to shift from floral white before the cherry trees bloomed to light sky-blue during the cherry bloom period and back to floral white during the cherry postbloom period. Insofar as we have been able to ascertain, this is the first study that demonstrates the main color preference of an insect species shifts during the growing season. The optimal trap color corresponding to the shifts in color preference must be selected in order that detection, monitoring and control efforts are the most successful.

Our data suggest that the control effort should be shifted to focus strongly on the pre-bloom period of cherry or other crops to be protected with intensive trapping by floral white traps. Indeed we believe that such trapping should begin at the beginning of Mar when it is likely that this species has completed overwintering. This hypothesis will be evaluated in future growing seasons.

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