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The Influence of Host Fruit and Temperature on the Body Size of Adult *Ceratitis capitata* (Diptera: Tephritidae) under Laboratory and Field conditions.

~~**The Influence of Host Fruit and Temperature on the Body Size of Adult *Ceratitis capitata* (Diptera: Tephritidae) in Laboratory and field Populations**~~

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Abstract

The adult body size of the medfly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), varies in natural conditions. ~~Both temperature during larvae development and host fruit quality have been cited as possible causes for this variation.~~ Body size is an important fitness indicator in medfly; larger individuals are more competitive at mating and have a greater dispersion, fecundity and fertility. Both temperature during larvae development and host fruit quality have been cited as possible causes for this variation. We studied the influence of host fruit and temperature during larvae development on adult body size (wing area) in the laboratory, and determined body size variation in field populations of medfly in eastern Spain. Field flies measured had two origins. Firstly, flies periodically collected throughout the year in field traps from 32 citrus groves, during the period 2003-2007. Secondly, flies evolved from different fruit species collected between June and December in 2003 and 2004. In the lab, wing area of male and female adults varied significantly with temperature during larva~~l~~e development, being larger at the lowest temperature. Adult size was also significantly different depending on the host fruit in which larvae developed. The size of the flies captured at the field, either from traps or from fruits, varied seasonally showing a gradual pattern of change along the year. The largest individuals were obtained during winter and early spring and the smallest during late summer. In field conditions, the size of adult medflies seems apparently more related with air temperature than with host fruit. The implications of this adult size pattern on the biology of *C. capitata* and on the application of the sterile insect technique are discussed.

Key words: medfly, body size, host, temperature, Sterile Insect Technique.

The Mediterranean Fruit Fly *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) is one of the most serious pests affecting cultivated plants in the world (Christenson and Foote 1960). It is highly polyphagous, attacking more than 300 plant species, and presents high reproductive potential and dispersal capacity (Fletcher 1989a, Liquido et al. 1991). Body size is an important fitness component for *C. capitata*. Larger individuals are more competitive at mating and have a greater dispersion capacity and fertility (Sharp et al 1983, Krainacker et al 1989). Especially for males, larger size is associated with higher mating success; larger individuals have larger wing areas which confer them greater flight ability and also enables them to produce a louder, more attractive sound for the females (Churchill-Stanland et al. 1986). Therefore, the final size that adult *C. capitata* attains influences various life-history traits that in turn have serious consequences for their potential as pests.

The most common factors related with body size variation in insects are temperature and food resources. Environmental temperature during larvae development affects adult body size (Sankarperumal and Pandian 1991, Atkinson and Sibly 1997, Angilletta and Dunham 2003). In ectotherm organisms, decreasing temperature causes reduced growth and development rates but a larger final body size. This relation follows the evolutionary Bergmann's rule, where the size of organisms increases with latitude (Hoffmann et al. 2007). More than 80% of ectothermic species studied to date follow this temperature-size rule (Atkinson 1994, Diamond and Kingsolver 2010). In Diptera, the relation between temperature and adult body size was first proved by Ray (1960) using *Drosophila* spp. No such information is available for *C.capitata*.

Furthermore, insects generally grow to smaller sizes on lower quality diets (Danthanarayana 1976, Chapman 1998). There are numerous studies demonstrating the influence of host plant species on the insect final size (Krainacker et al. 1987, Diamond and Kingsolver 2010). In *C. capitata*, protein-enriched larval diets increase individual size while on the other hand decrease development time (Kaspi et al. 2002). The different fruits used as hosts ~~plants~~ by medfly and other fruit flies vary greatly in their quality for larvae development, and this results in different adult size. For instance, Inglesfield (1982) demonstrated that flies obtained from oranges were significantly larger than those obtained from prickly pears in the same conditions. Krainacker et al. (1987) also found that medfly pupae reared on 24 different host fruit species varied in their size and other life history parameters. Diet quality can interact with temperature and can alter thermal reaction norms for body size (Stamp 1990, Kingsolver et al. 2006). A reduction in host plant quality can change the sign of the thermal reaction norm for size, reversing the temperature-size rule (Diamond and Kingsolver 2010). Moreover, adult body size in *C. capitata* can be affected also by the intra-specific larval competition or by the different stages of fruit maturation (Bodenheimer 1951, Debouzie 1977, Inglesfield 1982, Sigurjonsdottir 1984, Fletcher 1989a).

The variability in the population peaks observed in field populations of *C. capitata* is related with the presence of different species of host fruits (Israely et al. 1997, Martínez-Ferrer et al. 2006, Martínez-Ferrer et al. 2010). Larvae develop only inside mature fruits~~-~~. *Ceratitis capitata* life strategy to exploit resources which are unpredictable in time and space includes long duration of adult life and changes of host sequentially during their annual cycle ~~and long duration of adult life~~ (Gómez Clemente and Planes 1952, Fletcher 1989a). Therefore, adult flies encountered simultaneously in the field could originate from different host fruits and additionally could have developed as larvae in different times of the year. Thus, their body size variation could be related, among others, with the species of host fruit and with the air temperature during their larva~~l~~e development.

Determination of *C. capitata* body size variation with respect to environmental temperature and fruit host would help us to better understand the ecology of the pest. Moreover, important implications may derive for the SIT technique given that sterile flies for releases have to be at least as large as or even larger than males from the target field population (Calkins 1984). Thus, the objectives of this study are: i) to study in laboratory the influence of temperature and different species of host fruits during larval development in adult body size of *C. capitata*, (ii) to determine overall patterns of change in adult body size along the year in field populations of *C. capitata*, and (iii) to compare the relative importance of air temperature and host fruit as factors influencing these changes.

Material and methods

Adult flies of *C. capitata* were obtained by three procedures: reared in laboratory, collected in field traps, and collected from infested fruits in the field.

Laboratory trials. Eggs used in the laboratory trials were obtained from a *C. capitata* laboratory colony, reared with artificial diet at 25 ± 5°C, 65 ± 10% RH, and a photoperiod of 16:8 (L:D) h. The artificial diet was composed by 550 ml water, 250 g whole wheat, 4 g benzoic acid, 75 g sucrose, 36 g yeast, 2g methyl paraben and 2 g propyl paraben (Santaballa et al. 2001).

To determine the influence of temperature on adult *C. capitata* size, a 0.25 cm^3 solution of water and eggs (containing approximately 250 eggs) was placed on a tray containing 500 g of artificial diet. The tray was kept inside a climatic chamber at constant temperature with a temperature control of ± 0.5°C, 65% RH, and a photoperiod of 16:8 (L:D) h until the pupae emerged (see below for pupae treatment). The influence of temperature on adult *C. capitata* size ~~–~~was tested fo~~t~~r five temperatures:, 14°C, 18°C, 22°C, 26°C and 30°C.

To determine the influence of host fruit on adult size, 20 fruits of each fruit species (~~,–~~apricot, peach, plum and orange), were artificially injected with *C. capitata* eggs. The fruits selected were fully mature. The injection of eggs was done with a syringe of 5 cm^3 following Santaballa et al. (2001). We prepared a water suspension of eggs, 0.25% agar jelly and 1% disinfectant (benzylalkyldimethylammonium chloride) with a known number of eggs per unit of volume. We injected 0.02 cm^3 of the suspension (containing 8-10 eggs) under the fruit skin with a syringe to imitate a natural infestation. Three injections were practiced on each fruit.

The inoculated fruits were maintained inside plastic rearing cages at 26°C and 70% RH and a photoperiod of 16:8 (L:D) h. Emerging pupae of both laboratory trials were ~~collected and~~ placed inside Petri dishes and maintained inside rearing cages in the same climatic conditions until adulthood. Freshly emerged adults (1-2 days old) were killed by freezing and measured (Wing area, see below). Moreover, the number of days from injection to adulthood was recorded for each fly.

Traps. Flies were captured in traps in two citrus growing areas in eastern Spain, Tarragona (40°23´ N, 0°34´ E) and Valencia (39°14´ N, 0°28´ W) (see Martínez-Ferrer et al (2010) for description of the two areas). In the Tarragona area, 25 groves were selected in 2003 and 2004, and five in 2005 to 2007. In the Valencia area, seven groves were selected from 2003 to 2005. The area of each grove ranged from 0.5 to 2 ha. All the groves were commercial mature citrus plantations representative of the area and were of one of the two most common citrus species cultivated in eastern Spain, sweet orange (*Citrus sinensis* (L.) Osbeck) or clementine tangerine (*Citrus reticulata* Blanco).

The flies were captured using two types of traps, a Tephri trap baited with the parapheromone Trimedlure as attractant and a Tephri trap baited with the food attractant Tripack. During the warmer months (from May to October) one trap of each type was placed on each orchard and adults of *C. capitata* were removed from the traps every week. During the colder months (from November to April), 10-20 traps of each type were placed in each orchard and insects were removed fortnightly. Their size was measured (Wing area, see below). Temperature data were obtained from by 3-5 meteorological stations for each growing area.

Infested fruits. Samples of different fruit species naturally infested by *C. capitata* were collected from the field in the Valencia area from July until November of 2003 and from June until December of 2004. The fruits were apricot (*Prunus armeniaca* L.), fig (*Ficus carica* L.), jujube (*Ziziphus jujuba* Mill.), loquat (*Eriobotrya japonica* (Thunb.) Lindl.), orange (*Citrus sinensis* (L.) Osbeck), peach (*Prunus persica* (L.) Batsch), pear (*Pyrus communis* L.), persimmon (*Diospyros kaki* L.), plum (*Prunus domestica* L.), prickly pear (*Opuntia ficus-indica* L.) and tangerine (*Citrus reticulata* Blanco and *Citrus unshiu* Marc.). In total, 78 samples, corresponding to the 12 fruits species, were collected. Fruits were selected for showing symptoms of advanced infestation meaning that larval development was apparently in their final stages. The collected fruits were maintained inside rearing cages in an open greenhouse without temperature regulation, so that ambient temperature was similar ~~or slightly higher~~ than the exterior. The rearing cages were plastic containers (55 cm long by 40 cm wide by 18 cm high) with several layers of filter paper at the bottom. Fruits were placed on a metallic mesh screen 5 cm above the filter paper. Emerging pupae were collected at the bottom of the cage,~~ and~~ placed inside Petri dishes and maintained in the same rearing cages until adulthood. Freshly emerged adults (1-2 days old) were killed by freezing and measured (Wing area, see below).

To assure that most larval development took place under field conditions prior to collection, only adults developing from larvae which pupated in the initial two or three days after being placed inside the rearing cages were selected for size measuring.

Wing size measurements. We used wing area as an estimator of adult body size. Wing size has often been used in numerous studies as an estimate of adults size in morphological studies on *C. capitata* and other flies; wing area and general body size are highly correlated characters (Churchil-Stanland 1986, Yuval et al. 1993, Kaspi et al. 2000, Gilchrist and Partridge 2001).

Wing area was estimated by measuring wing length and width. From every adult, both wings were removed and mounted on a glass microscope slide following the methodology described by Gilchrist and Crisafulli (2006). A photograph of each wing was made using a camera connected to a binocular microscope and distances were measured using the software Image Tool. Wing length was estimated by the distance from the intersection of the humeral vein and the costal vein to the end of the radial vein and width was measured as the distance from the intersection of the subcostal vein with the costal vein to the most outstanding point situated between the anal vein and cubital vein. Each value of wing area determined was based on a minimum of 20 adult flies (either in ~~each ~~field traps, naturally infested fruit samples, ~~or ~~constant temperatures in the laboratory or type of fruit in the laboratory). Sometimes, especially during certain periods of the year in field traps, the number of flies available was lower, but never inferior to 15.

The area of each wing was determined from its length and width based on a multiple linear regression, previously established in 250 wings (125 males and 125 females), between wing area and the independent variables length and width. The 250 wings were selected from different fruits and sampling dates to be representative of the whole range of flies sampled. At each photograph, coordinates of 10 wing landmarks were recorded and the wing area subsequently obtained with the image program. The regressions were obtained separately for males and females as the wing shape of *C. capitata* adults ~~is different~~differs between sexes. Females have a wing more elongated and narrower than males (Bodenheimer 1951, Churchil-Stanland et al. 1986). The regression models for females (equation 1) with $r^2 = 0.97$ and males (equation 2) with $r^2 = 0.95$ were (measures in mm):

$$area = -5.461 + 1.686 \times length + 2.699 \times width \quad (1)$$

$$area = -4.865 + 1.823 \times length + 2.195 \times width \quad (2)$$

Statistical analysis. Pairwise t-tests were used to ~~Pairwise c~~compare~~isons of~~ wing length, width~~measurements~~ and ~~wing~~ area between sexes~~ were subjected to the t-test~~, using data obtained from the laboratory~~ data~~. ~~We report results using significance criteria at 0.05 levels.~~ Four separate one-way ANOVAs were used to analyze the influence of temperature and host fruit on adult size and time of development. Means were compared using Fisher’s LSD test. We report results using significance criteria at 0.05 levels.

All statistical analyses were performed using Statgraphics 5.1 program (Statgraphics 1994).

Results

The wing shape of the females was different from the males in *C. capitata*. The average size of all female wings measured in our laboratory experiments were 3.44 ± 0.01 mm (mean ± SE) in length and 2.10 ± 0.01 mm in width, significantly different from male wings which measured 3.33 ± 0.01 mm in length and 2.22 ± 0.01 mm in width ($t = 11.28$; df = 329; $P < 0.0001$, and $t = -17.69$; df = 329; $P < 0.0001$, for length and width, respectively). The overall wing area was slightly lower for females (6.00 ± 0.04 mm^2) than for males (6.09 ± 0.03 mm^2) (t = -2~~,~~.76; df = 329; P < 0.0~~1~~5). C~~C~~onsequently, we have analyzed separately males and females when comparing wing areas.

Size of laboratory reared adults. The temperature during larval development significantly influenced the size (wing area) of adult *C. capitata* (Fig. 1A). Adults of both sexes were larger at the lowest temperature of 14°C (females: 6.89 ± 0.05 mm^2; males: 6.88 ± 0.05 mm^2) and their size decreased progressively as temperature increased, reaching a minimum at 26°C [(females: 5.20 ± 0.11 mm^2, $F = 114.06$; df = 4, 209; $P < 0.001$) (males: 5.40 ± 0.06 mm^2, $F = 107.89$; df = 4, 209; P < 0.001)]. At 30°C, there was a slight increase in size of females (5.33 ± 0.06 mm^2) and males (5.59 ± 0.05 mm^2). The time of development from egg to adult showed a similar pattern of change with temperature, being maximum at 14°C and minimum at 26°C (females: $F = 6828.03$; df = 4, 205; $P < 0.001$; males: $F = 50269.69$; df = 4, 209; $P < 0.001$) (Fig. 1B).

Adult sizes were also significantly different depending on the host fruit in which larvae developed (Fig. 2A). Apricot gave the biggest females (6.34 ± 0.04 mm^2), followed by peach (6.05 ± 0.30 mm^2), plum (5.86 ± 0.91 mm^2) and finally by orange

(5.61 ± 0.13 mm^2) ($F = 11.23$; df = 3, 127; $P < 0.001$). Similarly, males were bigger in apricot and peach (6.27 ± 0.05 mm^2 and 6.21 ± 0.05 mm^2, respectively) than in plum and orange (5.83 ± 0.1 mm^2 and 5.93 ± 0.11 mm^2, respectively; $F = 7.84$; df = 3, 131; $P < 0.001$). The time of development from egg to adult in different host fruits showed a trend opposite to the adult size for both sexes, being minimum in apricots and maximum in oranges [(females: $F = 56.31$; df = 3, 63; $P < 0.001$) (males: $F = 42.06$; df = 3, 65; $P < 0.001$)] (Fig. 2B).

Size of adults captured in field traps. The size of flies captured in traps at the field varied seasonally showing a similar gradual pattern of change along the year for both sexes and in the two areas of study (Fig. 3). The largest individuals were obtained during winter and early spring (from January to May). Adult size decreased in early summer (June and July), being smallest during late summer (August and September). Individuals captured in Tarragona were smaller than in Valencia, especially during the spring months. The size of females ranged from a minimum of 5.91 ± 0.05 mm^2 (in Valencia on September~~May~~) to a maximum of 7.31 ± 0.06 mm^2 (in Valencia on May ~~September~~). Similarly, male size ranged from 6.14 ± 0.03 mm^2 (in Valencia on July) to 7.28 ± 0.16 mm^2 (in Tarragona on March).

The size pattern observed follows apparently a very close inverse relationship with the average air temperature in the area, which is also shown in Fig.3, though with a delay related apparently with the fact that adults captured developed as larvae approximately one month (in summer) to four months (in winter) earlier.

Size of adults from fruits naturally infested in the field. Adult males and females of *C. capitata* obtained from 55 samples corresponding to 11 different fruits species showed great variability in their size. However, when representing the average size of all samples (irrespective of the fruit species) collected during each month, we obtained a seasonal pattern of change which follows the average monthly temperature in the study area (Fig. 4). The smallest individuals were obtained in August and September, and the biggest in November and December (F = ; P = ; df =). When comparing fruit species, flies that emerged from oranges (with 6.58 ± 0.21 mm^2 and 6.45± 0.20 mm^2 of average~~,~~ wing area~~size~~ for~~of~~ females and males, respectively) and from tangerines ~~were bigger~~ (6.57 ± 0.12 and 6.47 ± 0.10~~ for female and male~~) were bigger than flies emerged from peach (5.78 ± 0.123 and 5.88 ± 0.10) and plum (5.44 ± 0.10 and 5.55 ± 0.06) (F = ; P = ; df =).~~.~~

Discussion

Body size in ectotherms is affected by temperature, nutrient quality, nutrient quantity and genotype (Nijhout et al. 2006, Edgar 2006). Our study, conducted under laboratory and field conditions, has focused in the effect of two of these factors, temperature and nutrient quality.

Individuals of *C. capitata* reached bigger sizes when reared at low temperatures, following the temperature-size rule proved in other insects (Sankarperumal and Pandian 1991, Atkinson and Sibly 1997, Angilletta and Dunham 2003). Th~~is~~e increase in size at low temperatures was accompanied with an increase in developmental time. These results are in agreement with Albajes (1980). Interestingly, at the field, the variation pattern in the size of adult *C. capitata* followed the temperature pattern in both areas, though with a lag of several weeks. This lag results from adult body size being determined by the temperature during larvae phase, which occurs several weeks before the adult captures. A similar trend in body size has been reported for another tephritid, *Batrocera oleae* (Torres-Vila et al. 2006).

Medfly body size also varied among~~according to~~ the four host fruits tested, indicating that these fruits are ~~probably~~ of different nutritional quality. Variation in ~~several~~ life history parameters in *C. capitata* according to host fruit has been reported by several authors (Carey 1984, Zucoloto 1987, Krainacker et al. 1987, Kaspi et al. 2002). Inglesfield (1982) and Krainacker et al. (1987) demonstrated that flies obtained from different host fruit species varied in size. Similarly, Joaquim-Bravo et al. (2010) also found a smaller size in medflies obtained from oranges than from other fruits. Furthermore, our results show that ~~and in agreement with Kaspi et al. (2002),~~ insects ~~which~~ fed in higher quality hosts needed less time to complete development. Other authors have reported similar results in *C. capitata* (Back and Pemberton 1918, Rivnay 1950, Carey 1984, Krainacker et al. 1987, Kaspi et al 2002). According to Rivnay (1950) the rate of development is closely related to the physical texture of the food tissue and also with the concentration of sugar.

Our results show that the two factors that give bigger adult body sizes, low temperature and high nutritional quality, exert a different effect on development time. Whereas low temperature increases development time, high nutritional quality decreases it. That is because there are different components of the physiological mechanism that control body size. The final size an insect attains is considered to be the result of the growth rate during the larval phases and the duration of this growth period (~~Edgar 2006, Davidowitz et al. 2004,~~ Davidowitz and Nijhout 2004, Davidowitz et al. 2004, Edgar 2006). The duration of the growth period is controlled by the timing of the cessation of juvenile hormone secretion, the time required for the larva to attain the critical weight, and by the timing of ecdysteroid secretion leading to pupation (the interval to cessation of growth [ICG] after reaching the critical weight). Interestingly, critical weight (CW) only change~~d~~s in response to diet quality, whereas the ICG depends only on temperature (Davidowitz et al. 2004). The final size of the larva is a result of a balance between these sensitivities and their responses. Body size is bigger at lower temperatures because the lower growth rate increases the ICG, thereby increasing the amount of mass that larvae can accumulate. Development time is longer at lower temperatures because the lower growth rate increases the time required to attain the ~~critical weight (~~CW~~)~~ and, independently, increases the duration of the ICG (Davidowitz and Nijhout 2004). Body size is bigger for high nutrient quality because high nutrient quality increases the CW. Development time is shorter when nutrient quality is high because the higher growth rate decreases the time required to attain the CW without influencing the ICG.

~~In the field, the body size of adult *C. capitata* apparently varies mostly due to the effect of environmental temperature. This is further supported by the fact that although orange is the less favorable host at the laboratory (given that the flies emerged are the smallest and need longer time to develop), flies emerged from oranges at field are the biggest.~~ From our field data it is not possible to separate the effect of the host fruit from the effect of temperature as species of fruits mature in different times of the year (oranges and tangerines mature during October and November whereas peaches and plums mature during July and August). Nevertheless, given that seasonal variation in adult medfly size showed a pattern of variation closely related with temperature, it is likely that size is more influenced by the air temperature during the period of larval development than by the host fruit in which larvae develop. This is further supported by the fact that although orange is the less favorable host at the laboratory (given that the flies emerged are the smallest and need longer time to develop), flies emerged from oranges ~~at field~~ are the biggest. Thus, i~~I~~n the field, the body size of adult *C. capitata* ~~apparently~~ varies mostly due to the effect of environmental temperature.

However, there is a considerable amount of variation in adult size that cannot be explained by the effect of seasonal air temperature alone. Adults obtained from the same species of fruit collected in the same date showed also differences in their wing areas. ~~The different fruit hosts, l~~Larval competition and other ~~unknown~~ factors could be related with this variation (Hasson and Rossler, 2002). ~~Even t~~The same fruit species very often possesses different degrees of suitability depending on~~in~~ its ~~different~~ stages of maturation (Bodenheimer, 1951). Interestingly, the differences in the *C. capitata* size observed between the two areas sampled (Valencia and Tarragona) from April until June are probably related with ~~the~~ differences in the availability of mature fruits in these areas, since their climatic conditions were very similar. Martinez-Ferrer et al. (2010) demonstrated that the annual trend in medfly abundance is different between Valencia and Tarragona, and these differences were related with differences in the availability ~~in~~ of host fruits between~~in~~ the two areas.

The adult size pattern observed under field conditions may provide useful information about the origin and the generations of the medfly. Changes in the adult medfly size probably indicate different developmental moments along the year, making possible the detection of the generational change. Though adult medfly ~~at laboratory~~ can surviv~~al~~e for long periods in the laboratory (Fletcher 1989b) our results suggest that adult survival is low in the field ~~flies live for short periods~~ because average size of adults follows closely temperature changes~~, suggesting that flies come from fruits that have matured in recent times~~.

Finally, *Ceratitis capitata* has a complex lek-based mating system (Prokopy and Hendrichs 1979, Eberhard 2000, Sivinski et al. 2000, Papadopulos et al. 2009) and male mating success has been found to be ~~in~~ influenced by its~~their~~ body size. Larger males of *C. capitata* were more successful in obtaining copulations (Calkins 1984, Churchill-Stanland et al. 1986, Blay and Yuval 1997, Kaspi et al. 2000). Size of medflies could be important in those aggregations because females of *C. capitata* compare males and select the male that has~~d~~ the highest copulation score (Arita and Kaneshiro 1985, Whittier 1994). According to this, seasonal changes in male size in the field could have important consequences for the success of the SIT since the outcome of the sterile insect technique depends entirely on the success or failure of courtships of~~by~~ sterile males with wild~~s~~ females (Calkins 1984).

In conclusion, the results obtained in the present study demonstrate that under laboratory conditions *C. capitata* adult size varies significantly influenced by the effect of temperature and nutrient quality. Therefore, at the field, biggest sizes would be expected for individuals ~~which have~~ developed as larvae during ~~the~~ cold periods and/or with high quality food ~~(apricot and peach)~~. On the other hand, the smallest individuals ~~it~~ would develope under the influence of high temperatures and/or ~~developed with~~ poor quality food ~~(orange)~~. Nevertheless, ~~at the field,~~ it seems that the effect of ~~development during winter with low~~ temperatures is major than the effect of host ~~fruit~~ quality. These observations could improve our current background on the behavior and adult survival of *C. capitata* in the field and be used to assess the size status of wild males in comparison with released sterile males. Further experiments should be conducted to determine~~study~~ if this seasonal size pattern influences the success of the SIT.

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Figure legends

Fig. 1. Wing area (in mm^2; mean ± SE) (A) and development time (days; mean ± SE) (B) of *Ceratitis capitata* males and females reared at different temperatures. Bars with different letters indicate significant differences at $P < 0.05$ (Fisher protected LSD).

Fig. 2. . Wing area (in mm^2; mean ± SE) (A) and development time (days; mean ± SE) (B) of *Ceratitis capitata* males and females obtained from different hosts. Bars with different letters indicate significant differences at $P < 0.05$ (Fisher protected LSD).

Fig. 3. Wing area (in mm^2; mean ± SE) of females (A) and males (B) of *Ceratitis capitata* obtained at field of two citrus growing areas: Valencia and Tarragona. In the inverted scale, fortnight means of the temperatures for each area are represented.

Fig. 4. Wing area (in mm^2; mean ± SE) of females (A) and males (B) of *Ceratitis capitata* obtained from 11 different species of host fruits collected in the field. The average wing size (± SE) in each month is also represented. Monthly means of the temperatures where fruits were collected are represented in the inverted scale.

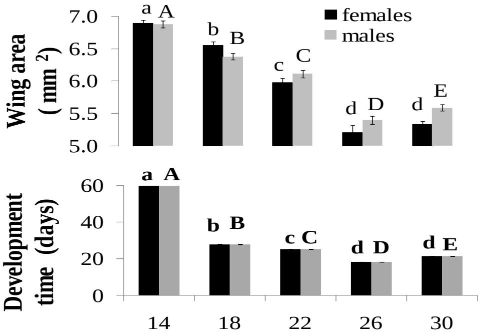
Wing area (mm 2)
7.0
6.5
6.0
5.5
5.0
a A
b B
c C
d D
d E
females
males
Development time (days)
60
40
20
0
a A
b B
c C
d D
d E
14
18
22
26
30
Temperature (ºC)

Fig. 1

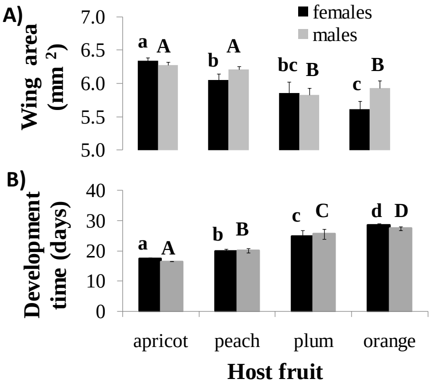
A)
B)
Wing area (mm 2)
7.0
6.5
6.0
5.5
5.0
■ females
■ males
a A
b A
bc B
c B
Development time (days)
40
30
20
10
0
a A
b B
c C
d D
apricot
peach
plum
orange
Host fruit

Fig. 2

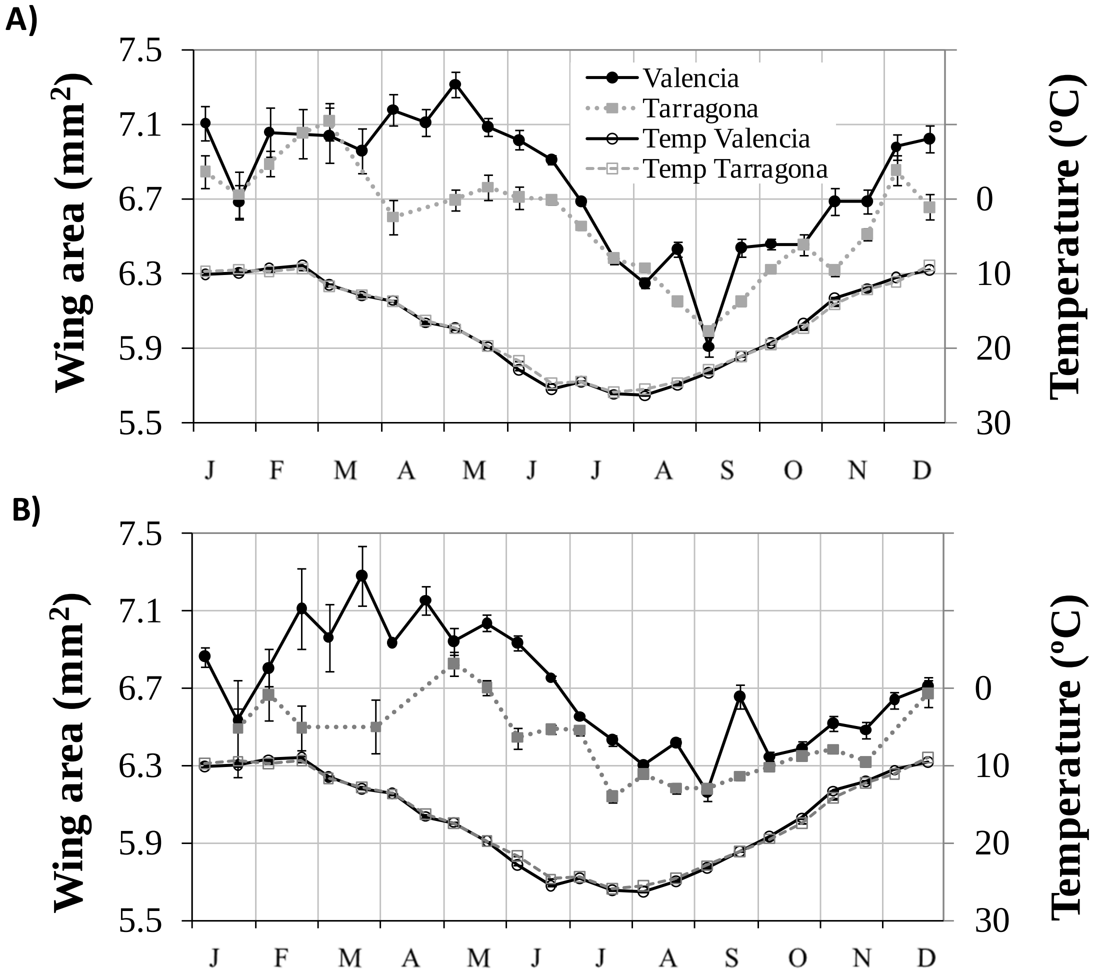
A)
Wing area (mm^2)
Temperature (ºC)
7.5
7.1
6.7
6.3
5.9
5.5
0
10
20
30
Valencia
Tarragona
Temp Valencia
Temp Tarragona
J F M A M J J A S O N D
B)
Wing area (mm^2)
Temperature (ºC)
7.5
7.1
6.7
6.3
5.9
5.5
0
10
20
30
J F M A M J J A S O N D

Fig. 3

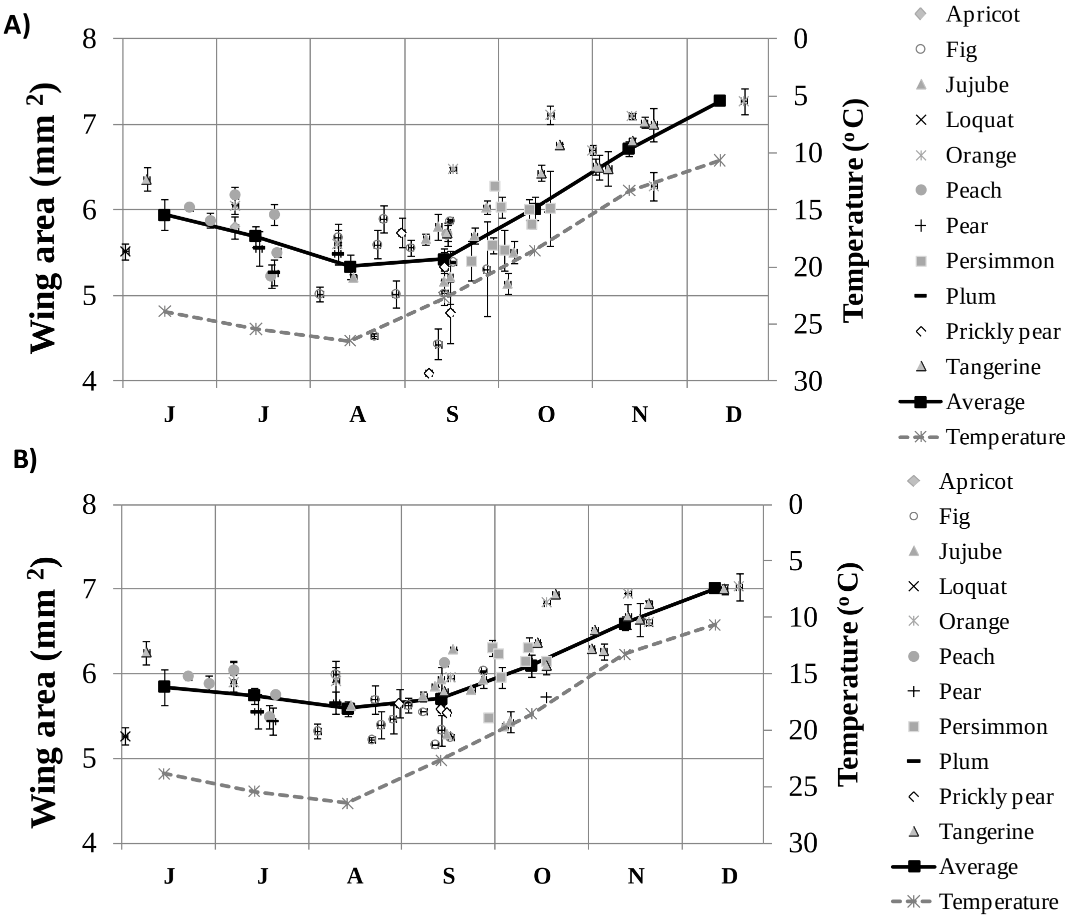
A)
8
7
6
5
4
Wing area (mm ^{2})
0
5
10
15
20
25
30
Temperature (ºC)
J
J
A
S
O
N
D
Apricot
Fig
Jujube
Loquat
Orange
Peach
Pear
Persimmon
Plum
Prickly pear
Tangerine
Average
Temperature
B)
8
7
6
5
4
Wing area (mm ^{2})
0
5
10
15
20
25
30
Temperature (ºC)
J
J
A
S
O
N
D
Apricot
Fig
Jujube
Loquat
Orange
Peach
Pear
Persimmon
Plum
Prickly pear
Tangerine
Average
Temperature

Fig. 4