Host Susceptibility of 'French Prune' *Prunus domestica* to *Drosophila suzukii* (*Diptera*: *Drosophilidae*)

H.E. Wilson, K.A. Hamby and F.G. Zalom
Department of Entomology and Nematology
University of California
Davis, CA, 95616
USA

Keywords: spotted wing drosophila, fruit susceptibility, no-choice, trapping, plum

Abstract

Spotted wing drosophila, *Drosophila suzukii* Matsumura, invaded North America in 2008. In contrast to other *Drosophila* species, *D. suzukii* preferentially infests ripe fruits with its serrated ovipositor which can create commercially unmarketable fruit. As *D. suzukii* is reported to infest a variety of hosts, especially stone fruits and berries, growers are encouraged to monitor for *D. suzukii* to help prevent crop damage. We specifically tested the host susceptibility of *Prunus domestica* 'French prune' to *D. suzukii* in a no-choice host experiment and observed its presence in a mixed cultivar plum block. Few flies completed development within 'French prune' in a no choice experiment, demonstrating that it may not be a suitable host. *D. suzukii* adult captures were greatest at the beginning and end of plum season, with minimal captures throughout late summer, early fall, and winter. Therefore, while *D. suzukii* trapping may indicate presence of flies within the area, it may not correlate with fruit infestation.

INTRODUCTION

Drosophila suzukii Matsumura (*Diptera*: *Drosophilidae*) was first observed in California in 2008, infesting strawberries and caneberries in Santa Cruz County (Bolda et al., 2010). By the following year, additional infestations were detected in cherry orchards along California's central coast and central valley, western Oregon, and western Washington (Bolda et al., 2010; Walsh et al., 2011). *D. suzukii* has now spread to several provinces of Canada, the Southeastern U.S., and the upper Midwest (Hauser, 2011). When *D. suzukii* was first found in Japan, it was initially described as a pest of cultivated cherry, and it was observed to oviposit on cherries, peaches, plums, persimmons, strawberries, and grapes (Kanzawa, 1939). Kanzawa (1939) also considered *D. suzukii* an opportunistic pest as it fed on spoiled or dropped fruits and oak tree sap. Additionally, Mitsui et al. (2010) found that *D. suzukii* bred on Stylax flowers and emerged from fruits of many Japanese ornamental plants. Since its arrival in North America, *D. suzukii* adults have been captured in traps in many types of fruit including apricots, blackberries, blueberries, cherries, figs, grapes, hardy kiwis, nectarines, peaches, pears, persimmons, plums, pluots, raspberries, and strawberries, with reports of apple and orange culls being infested as well (Lee et al., 2011; Walsh et al., 2011). Such host associations are worrisome for commercial and private fruit growers as *D. suzukii* is capable of infesting ripe fruit before harvest with its serrated ovipositor (Dreves et al., 2009). Commercial strawberry, caneberry, and cherry production in California, Oregon, and Washington is a $2.6 billion dollar a year industry (Walsh et al., 2011). A 2009 estimate of yield loss ranged from negligible to 80% (depending on crop type and location) and noted that it is difficult to predict the economic threat to other soft fruit crops (Walsh et al., 2011).

California is the largest 'French prune' (*Prunus domestica*) producer worldwide, and plantings are predominantly located in California's central valley (Norton and Krueger, 2007), an area where *D. suzukii* has been observed (Dalton et al., 2011). In contrast to other plums, the 'French prune' has tougher skin and lacks lenticels (Sterling, 1953), potentially providing fewer sites for *D. suzukii* oviposition. During a preliminary trapping study at the USDA Wolfskill Germplasm Repository in Winters, CA, we trapped

D. suzukii adults in a mixed cultivar plum block that contained 'French prune.' These data, together with *D. suzukii*'s reported ability to infest other stone fruits, raised fear of crop damage among local prune growers. This paper describes a no-choice laboratory experiment utilizing field-collected 'French prune' fruit intended to determine whether *D. suzukii* could develop in 'French prune' plums, as well as an associated population monitoring study in the Wolfskill mixed plum block to assess the seasonal dynamics of *D. suzukii* adults.

MATERIAL AND METHODS

Trapping Studies

Our initial trapping study was conducted at the USDA Wolfskill Germplasm Repository during July and August 2010. This site was selected because that plum block consisted of multiple cultivars of plums (including 'French prune'). Within the mixed plum block, 5 traps were hung in randomly chosen trees. Glass, wide-mouth pint jars (Ball, Broomfield, CO) filled with 100 ml of apple cider vinegar (Western Family Foods, Inc., Tigard, OR) served as the baited traps. The traps were monitored for total number of *D. suzukii* adults, and the apple cider vinegar was replaced weekly.

We expanded our preliminary trapping work into a year-long (May 2011-May 2012) trapping study in the same mixed plum block. However, instead of the glass jars, three spotted wing drosophila traps (Contech, Victoria, BC, Canada) containing 50 ml of apple cider vinegar (Safeway, Inc., Phoenix, AZ) were used. Unscented Ultra Pure + Clear dishsoap (Colgate-Palmolive Co., New York, NY) (4 ml soap per 3.78 L vinegar) was added to break the surface tension of the vinegar and reduce post-capture escapes (Landolt et al., 2011; Lee et al., 2012). Three spotted wing drosophila traps filled with 50 ml of the apple cider vinegar lure were hung in randomly selected trees located toward the center of the mixed plum block. Traps were collected and the bait was replaced weekly. Trapping continued until the end of May, 2012. Each week the number of female and male *D. suzukii* captured in each trap was recorded.

No-Choice Prune Host Experiment

A no-choice laboratory experiment was designed to assess the viability of 'French prune' as a host for *D. suzukii*. Ripe 'French prune' plums were collected from untreated trees in Winters, CA, on four dates (30 Aug. 2010, 7 Sept. 2010, 12 Sept. 2010, 24 Sept. 2010). Brix and surface pressure were measured on the plums collected on each sampling date as proxies for fruit ripeness. Plum treatments included: a single plum without stem; without stem and with a puncture wound (made with a dissecting needle); and without stem and without wax bloom. On the last fruit collection date (24 Sept. 2010) an additional plum treatment, plum with stem intact, was added. Ten mated female *D. suzukii* from a colony maintained in the Zalom Lab at UC Davis were introduced to each plum treatment in a Falcon Specimen Container (110 ml) (Becton Dickinson Labware, Franklin Lakes, NJ). The negative control was a plum without a stem and no female *D. suzukii*, and the positive control introduced 10 mated females to laboratory drosophila media (corn meal, unsulfured molasses, nutritional yeast, agar, propionic acid, phosphoric acid, Tegosept) in a 25 x 95 mm drosophila vial (Biologix, LLC., Lenexa, KS). Each treatment and control was replicated five times and incubated in a growth chamber at 23±1°C with 12 h of light and 12 h of dark. Following the removal of females (after 72 h), each treatment was checked weekly for 1 month for *D. suzukii* eggs, larvae, pupae, and emerged adults. After the month-long experiment, all plums were destructively sampled to determine presence of additional larvae and pupae.

RESULTS

The traps placed in 2010 caught the greatest number of *D. suzukii* in the first week, and fewer adult flies were captured in each successive week (Fig. 1). The variance of *D. suzukii* adults per trap was also greatest during the first week. In 2011, trap captures

were greatest in late June and again in early November (Fig. 1). Between these two peaks, the traps caught on average fewer than 11 flies per week. The early November peak was preceded by increased *D. suzukii* captures beginning in early October. In 2012, another peak was observed in early May (Fig. 1). Adult flies were caught in the plum block until June 2012. Capture variance increased with greater fly captures.

The results from the no-choice laboratory experiment revealed little difference in *D. suzukii* development among treatments. Adult *D. suzukii* emerged from all of the treatments; however, very few adults emerged from any of the four treatments with plums, and none emerged from the field-collected plums that were not exposed to mated female *D. suzukii* (negative control). An average of 18.1 flies emerged from the drosophila diet vials (positive control) (Table 1). Females were indeed capable of laying eggs as they oviposited on both the prune and the cup in these 4 treatments (Table 1). The fewest eggs were laid in the stem intact treatment (Table 1). The average °Brix and surface pressures of the fruit from the four sample dates were 25.60±2.65° and 27.85±3.72 kPa, respectively. There was virtually no difference in these measures among sample dates.

DISCUSSION

Trap capture variance was greatest when trap captures were also high. This variability is likely due to fly aggregation since *D. suzukii* may favor one tree over another or have competitive factors leading to an aggregated distribution in the mixed plum block (Mitsui and Kimura, 2000; Takahashi, 2006). Another possible explanation for variability is a potential for increased attractiveness due to emission of an aggregation pheromone. Male *Drosophila melanogaster* flies release aggregation pheromones that attract other males and females to attractive sites (Wertheim et al., 2002; Takahashi, 2006; Lebreton et al., 2012); therefore, a trap that has already caught many *D. suzukii* might have an increased amount of aggregation pheromone that could increase the trap's attractiveness. Trap captures also varied seasonally. Although plums were ripe throughout summer and fall in the mixed plum block, few adult *D. suzukii* were captured in late summer and early fall, and captures increased again in late fall and spring. Adult flies were captured at low levels throughout the winter season in most weeks, indicating that some individuals were active. This finding was unexpected as other *D. suzukii* trapping studies have had extended periods of no captures throughout winter (Dalton et al., 2011). Although field captures of *D. suzukii* in traps indicate their presence, trapping does not appear to be a predictor of infestation.

'French prune' appears to be an unfavorable host for *D. suzukii*. Less than one adult fly emerged on average from each plum for all treatments in our no-choice laboratory experiment. In comparison, *D. suzukii* emergence from a favorable host (cherry) can reach as high as 62 flies per fruit and averages around 20 flies per fruit in laboratory conditions (Kanzawa, 1939). Kanzawa (1939) observed that *D. suzukii* only oviposited on damaged parts of fruit that had a thicker exocarp, therefore we had anticipated that damaged plums would be more likely to become infested and would exhibit higher adult emergence. Even when our experimental fruit were intentionally damaged or had stems removed, adult emergence did not significantly increase. More eggs were laid on the damaged plums, but the successful development of these eggs into adults did not improve over other treatments. The plums that were used in this experiment were similar in ripeness and at the optimal ripeness for harvest. According to Norton and Krueger (2007), 'French prune' plum harvest should start when plums are between 20.68 and 27.58 kPa. Post-harvest prune processing occurs soon after harvest when plums are sorted for damage and then rapidly dried in a gas dehydrator (Norton and Krueger, 2007). Temperatures are maintained between 60 and 85°C, and airflow is high within these gas dehydrators (Sabarez and Price, 1999). These dry and hot conditions are inhospitable for *D. suzukii* which greatly reduces the likelihood that *D. suzukii* would complete reproduction in processed prunes. Unprocessed 'French prune' fruit that are intended for the fresh market are recommended to be stored near 0°C to prevent rot and mold

(Mitcham et al., 2012). Plums in our study were held at 23°C and had severe mold formation occur after about 2 weeks. Cold temperatures and presence of mold are both unfavorable environmental conditions for *D. suzukii* development and reproduction (Kanzawa, 1939). We conclude that while it is possible for *D. suzukii* to complete a generation on 'French prune', it is not a favorable host and that post-harvest processing or cold temperatures would limit *D. suzukii* development.

ACKNOWLEDGEMENTS

The authors would like to thank Carolyn DeBuse for providing the plums used in this study, Sarah Bradley and Theodore DeJong for BRIX measurements, and Doris Yu for her assistance in trap processing.

Literature Cited

Bolda, M.P., Goodhue, R.E. and Zalom, F.G. 2010. Spotted wing drosophila: potential economic impact of a newly established pest. Giannini Agri. Res. 13:5-8.

Dalton, D.T., Walton, V.M., Shearer, P.W., Walsh, D.B., Caprile, J. and Isaacs, R. 2011. Laboratory survival of *Drosophila suzukii* under simulated winter conditions of the Pacific Northwest and seasonal field trapping in five primary regions of small and stone fruit production in the United States. Pest Mgt. Sci. 67:1368-1374.

Dreves, A.J., Walton, V. and Fisher, G. 2009. A new pest attacking healthy ripening fruit in Oregon. Oregon State University Extension Service, EM 8991.

Hauser, M. 2011. A historic account of the invasion of *Drosophila suzukii* (Matsumura) (*Diptera*:*Drosophilidae*) in the continental United States, with remarks on their identification. Pest Mgt. Sci. 67:1352-1357.

Kanzawa, T. 1939. Studies on *Drosophila suzukii* Mats. Kofu, Yamanashi Agricultural Experimental Station. p.49. In: Rev. App. Entomol. 29:622.

Landolt, P.J., Adams, T. and Rogg, H. 2011. Trapping spotted wing drosophila, *Drosophila suzukii* (Matsumura) (*Diptera*:*Drosophilidae*), with combinations of vinegar and wine, and acetic acid and ethanol. J. App. Entomol. 136:148-154.

Lebreton, S., Becher, P.G. and Witzgall, P. 2012. Attraction of *Drosophila melanogaster* males to food-related and fly odours. J. Insect Physiol. 58:125-129.

Lee, J.C., Bruck, D.J., Curry, H., Edwards, D., Haviland, D.R., Van Steenwyk, R.A. and Yorgey, B.M. 2011. The susceptibility of small fruits and cherries to the spotted-wing drosophila, *Drosophila suzukii*. Pest Mgt. Sci. 67:1358-1367.

Lee, J.C., Burrack, H.J., Barrantes, L.D., Beers, E.H., Dreves, A.J., Hamby, K.A., Haviland, D.R., Isaacs, R., Richardson, T., Shearer, P., Stanley, C.A., Walsh, D.B., Walton, V.M., Zalom, F.G. and Bruck, D.J. 2012. Evaluation of monitoring traps for *Drosophila suzukii* (*Diptera*: *Drosophilidae*) in North America. J. Econ. Entomol. (in press).

Mitcham, E.J., Crisoto, C.H. and Kader, A.A. 2012. Plum: recommendations for maintaining postharvest quality. UC Davis Postharvest Technology Center Produce Facts (http://www.postharvest.ucdavis.edu/PFfruits/Plum).

Mitsui, H. and Kimura, M.T. 2000. Coexistence of drosophilid flies: Aggregation, patch size diversity and parasitism. Ecological Res. 15:93-100.

Mitsui, H., Beppu, K. and Kimura, M.T. 2010. Seasonal life cycles and resource uses of flower- and fruit-feeding drosophilid flies (*Diptera*: *Drosophilidae*) in central Japan. Entomol. Sci. 13:60-67.

Norton, M.V. and Krueger, W.H. 2007. Growing prunes (dried plums) in California: An overview. 2007. Univ. Calif. Agric. Nat. Res. Publ. 8264. Oakland, CA. p.6.

Sabarez, H.T. and Price, W.E. 1999. A diffusion model for prune dehydration. J. Food Eng. 42:167-172.

Sterling, C. 1953. Developmental Anatomy of the Fruit of *Prunus domestica*. L. J. Torrey Bot. Soc. 80:457-477.

Takahashi, K.H. Spatial Aggregation and Association in Different Resource-Patch Distributions: Experimental Analysis with *Drosophila*. J. Animal Ecol. 75:266-273.

Walsh, D.B., Bolda, M.P., Goodhue, R.E., Dreves, A.J., Lee, J., Bruck, D.J., Walton, V.M., O'Neal, S.D. and Zalom, F.G. 2011. *Drosophila suzukii* (*Diptera*: *Drosophilidae*): Invasive pest of ripening soft fruit expanding its geographic range and damage potential. J. Int. Pest Mgt. 2:1-7.
Wertheim, B., Marcel, D. and Vet, L.E.M. 2002. Behavioural plasticity in support of a benefit for aggregation pheromone use in *Drosophila melanogaster*. Entomol. Exp. App. 103:61-71.

Tables

Table 1. Mean (±SE) *Drosophila suzukii* eggs, larvae, pupae, and adults recorded per 'French prune' in each experimental treatment held at 23°C for 4 weeks (n=5).

Treatment	Eggs on plum	Eggs on cup	Larvae	Pupae	Adults
No wax bloom	2.4±0.5	3.7±0.6	0.4±0.2	0.4±0.2	0.2±0.1
No stem	3.4±1.0	8.9±3.4	0.4±0.2	0.8±0.3	0.1±0.1
No stem with hole	2.4±0.5	3.7±1.0	0.8±0.2	0.5±0.2	0.1±0.1
Stem intact	0.2±0.2	2.2±0.4	0.2±0.2	0.2±0.2	0.2±0.2
Control (no flies)	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
Control (diet vial)	-	-	-	-	18.1±13.5

Figures

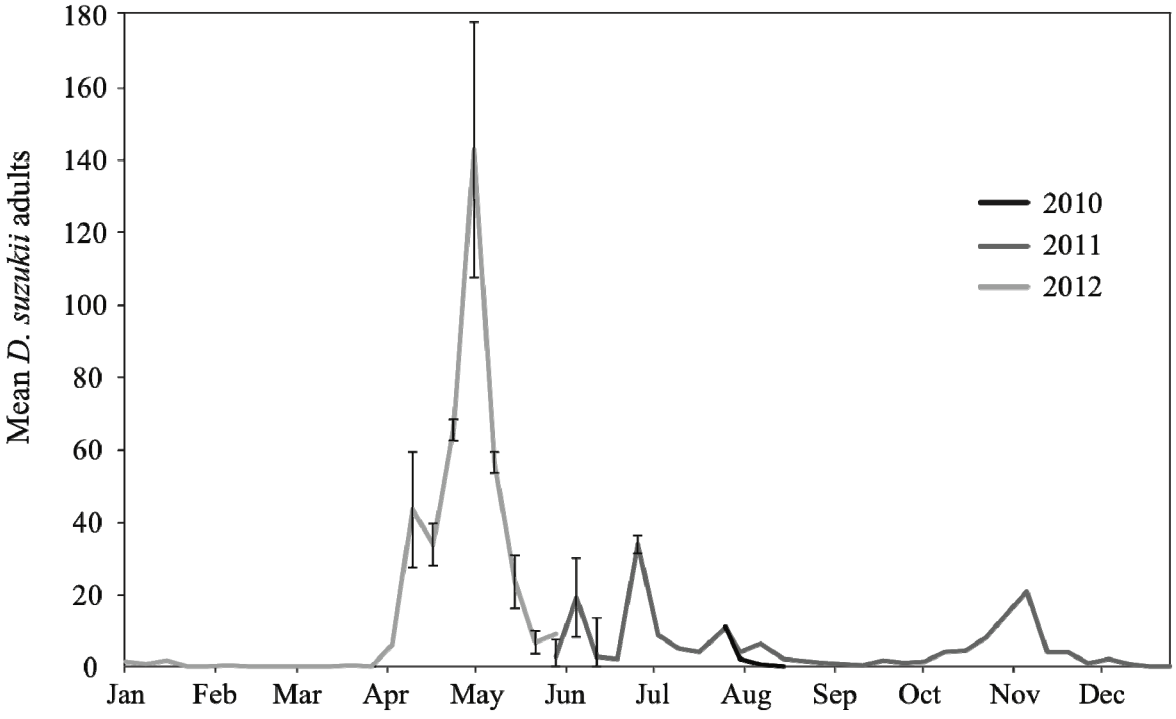

Fig. 1. Mean (±SE) *Drosophila suzukii* captured in apple cider vinegar-baited traps in a mixed cultivar plum block in Winters, CA. Trapping occurred for 5 weeks in 2010 and then weekly from May 2011 through May 2012.