Journal of Phytopathology and Pest Management 5(2): 129-142, 2018
pISSN:2356-8577 eISSN: 2356-6507
Journal homepage: http://ppmj.net/

Laboratory host selection and development of immature *Drosophila suzukii* (Diptera: Drosophilidae) on fruits and artificial diets

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Abstract

The spotted-wing drosophila (SWD), *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), is an important pest of thin-skinned fruits including blueberries, raspberries, strawberries, and cherry. In this study, six fruit hosts were chosen (raspberries, blackberries, strawberries, blueberries, green grapes and red grapes) and used as fruit and artificial diets to evaluate oviposition selection by *D. suzukii* females in free choice assays and no-choice assays. Also, development and performance of progeny until adult emergence was determined. Overall, *D. suzukii* females preferred to lay eggs on raspberries rather than green grapes in both tested fruit and artificial diet. Also, larvae that developed in raspberries developed 2-4 days faster than those in red grapes and green grapes, in both no-choice and choice assays for tested fruit and artificial diets. No significant differences were found among tested fruits in both free choice assays for pupal duration. Furthermore, adults complete of the development time 3 days earlier in raspberries rather than green grapes in both choice and no-choice assays for both tested fruit and artificial diets. Results also showed that strawberries, raspberries and blackberries had similar and high proportion of pupal survivorship than green grapes in choice and no-choice assays on tested fruits. Proportion of adults was greater in raspberries than green grapes in both fruits and artificial diets. No significant differences were found among fruits and among artificial diets in proportion of males and females in choice and no-choice assays. It could be concluded that raspberries were more favorable and comfortable host for *D. suzukii* oviposition and progeny development and performance.

Keywords: *Drosophila suzukii*, free choice assay, no-choice assay, artificial diet, oviposition selection.

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Introduction

The spotted -wing drosophila, *Drosophila suzukii* (Matsumura), is an invasive economic polyphagous pest from Asia that occurs in North America and Europe (Asplen et al., 2015; Cini et al., 2014) and recently in South America (Depra´ et al., 2014). This pest infests blackberries, blueberries, cherry, raspberries, strawberries, plums, peaches, grapes, figs, kiwi fruit, pears and sometimes wine grape (Ioriatti et al., 2015; Bellamy et al., 2013; Lee et al., 2011; Dreves et al., 2009). Damage is caused when adult female flies, using a serrated ovipositor and easily pierce the fruit skin lay eggs in ripe and partially ripe fruit before harvest. Developing larvae cause soft, unmarketable fruit, leading to increased risk of secondary rot infections (Walsh et al., 2011). Economic losses of 80% yield or 20–37% have been reported (Lee et al., 2011; Goodhue et al., 2011). Given its rapid life cycle (Tochen et al., 2014) and that 90–95 % of the population is estimated to be at immature life stages during blueberry harvest (Wiman et al., 2014), commonly used insecticides that target adult *D. suzukii* have limited impact on population trajectories. This situation necessitates repeated pesticide sprays to maintain pest control and fruit marketability. Insecticide dependency can be reduced by improved knowledge of fruit susceptibility to *D. suzukii* (Lee et al., 2015). Host preference studies examined behaviors associated with host selection e.g., host location, distribution, and abundance (Gripenberg & Roslin, 2005; Hassan et al., 2003; Kareiva, 1982) at individual and population levels (Cunningham & West, 2008; Apperson et al., 2004; Singer, 1982). Host suitability studies evaluated factors affecting the physiological development/ performance of the harbored organism and other features of host quality (Papaj, 2000; McSorley, 1999; McClure, 1980; Thompson, 1988). The objectives of the present work were to use, strawberries, blackberries, raspberries, blueberries, green grapes and red grapes fruit and artificial diets to determine: (1) oviposition host selection for egg laid by females; (2) performance of *D. suzukii* progeny that develop in each fruit and artificial diet; (3) preference of *D. suzukii* for various fruit and /artificial diets. No-choice tests were used to determine which fruit and artificial diet are most susceptible based on the physiological capabilities of *D. suzukii*, otherwise, choice tests were used to determine preferences of *D. suzukii* for the group of tested fruits and group of tested artificial diets. These controlled laboratory tests will provide a baseline for future studies on fruit preference and *D. suzukii* infestation potential in the field.

Materials and methods

This research was implemented in the laboratory of Entomology Department at North Carolina State University, NC, USA.

SWD culture: Spotted-wing drosophila (SWD) flies were obtained from SWD rearing colony maintained at Biological Resource Facilities (BRF). Insects used in experiments were from a laboratory colony established from flies reared from raspberries and blackberries at the Upper Mountain Research Station (Allegheny County, NC). Field collected flies reared from a variety of host fruit are periodically added to this colony to maintain genetic diversity. Flies were held at 20°C, 65% RH and 12:12 light: dark conditions, and maintained on a standard cornmeal *Drososphila* diet

(Standard Cornmeal Recipe Online, 2012). All flies used to infest different fruit hosts for experiments were reproductively mature between 7-14 days old.

Fruit source: Six different host fruits were evaluated in these experiments, where fruits were purchased at a local grocery store; red seedless table grapes (sweet California grown with a mild flavor profile), green seedless table grapes (California grown with a sweet flavor and firm texture), blueberries (Patagonia, product of Argentina), strawberries (San Diego, CA, USA), raspberries (Driscoll's, Watsonville, CA, USA) and blackberries (Los Angeles, CA, USA).

Diet substrates preparation: Two-hundred grams of each tested fruit type were weighted and blended to get puree, then added to 200 ml of boiled water and 4.0 g of agar. Propionic acid and Tegosept were added to the mixture (2.4 ml for each) as a preservation material against molding. The puree was poured to 60 mm petri dishes and left to cool at the room temperature, then kept in the fridge until use.

Laboratory assays: Fruit and artificial diet were presented to drosophila females to evaluate their host selection, performance and development of immature *D. suzukii* in both free choice and no-choice tests.

Free choice assays: Fifty flies (25 males and 25 females) were placed in $0.30m^3$ collapsible cages with fine mesh sides and one clear observation panel (Bioquip Products, Rancho Dominguez, CA) and exposed to 15 g of each tested fruit (2 grape fruit, 2-3 blackberries and raspberries, 1 strawberries fruit and 10-14 blueberries fruit) for 24 hrs. Each tested fruit was replicated 5 times. Number of eggs laid/ replicate/ host was counted using a stereomicroscope. Samples were stored in 266 mL plastic containers (up and up brand; Target, Raleigh, NC) vented on the bottom with thrips barrier mesh (Bioquip Products, Rancho Dominguez, CA) at 26^oC and checked daily for pupal emergence for 7 days to calculate the larval development time. Daily visible pupae were collected and held in 60 mm petri dishes with a moistened paper towel square until emergence (Burrack et al., 2013). Petri dishes with pupae were held at 22^oC+61%RH under growth chamber conditions and checked daily until adult emergence. Emerged adults were collected daily to determine the pupal duration, proportion of eggs that survived to the adult stage, and the sex ratio of emerged adults were calculated. For artificial diet free choice assay; the same previous steps were implemented, where one petri dish from each tested fruit was positioned in the collapsible cage and (20 males and 20 females) were released for four hours. Each diet type was replicated 5 times. Diets were removed from cages and numbers of laid eggs were counted for each replicate and each treatment using stereomicroscope. Petri dishes which recorded zero after infestation (females did not oviposit eggs), 10 eggs were transferred to measure the larval duration and some other biological aspects. Other infested petri dishes, a range of 5-20 eggs were kept inside each petri dish and held on the growth chamber at 22^oC+61%RH until the first appearance for pupae. Then the same previous steps were carried out for pupae as mentioned above.

No-choice assays: In no-choice assays, groups of (five males and five females) of *D. suzukii* were exposed to 15 g of each tested fruit (each host kept separately) held in a small plastic cup covered with mesh and tightly closed with rubber for 24 hrs. Five replicates were conducted for each tested fruit and number of eggs laid per replicate per treatment was counted using a stereomicroscope. Infested fruits were held in 266 mL plastic containers and treated with the same method as mentioned above. For artificial diet no-choice assays; each individual petri dish was confined with a group of (5 males and 5 females) for four hours. Each tested fruit type was replicated 5 times. Extra eggs than 20 eggs were removed from infested dishes, while zero ones, about 10 eggs were transferred to measure the same parameters as mentioned.

Statistical analysis: The experiment was conducted in a randomized complete block design. Data obtained in the present study was subjected to an analysis of variance (ANOVA) with the honestly significant difference value, calculated as LSD (Post Hoc Test) Multiple Comparison Test at 0.05 Probability (IBM SPSS Statistics version 9.0, 1998).

Results

Oviposition in host fruit (free choice and no-choice assays): The number of *D. suzukii* eggs laid was counted for both free choice and no-choice assays and presented in Figure (1). There were significant differences among host fruit in number of eggs for free choice assays ($F=17.85$, $P<0.01$). Raspberries showed greater number of eggs (101.2 eggs/ female) compared to strawberries, green grapes and red grapes with a range of 4.4-34.4 eggs, but not significantly differ from blackberries and blueberries. While, green grapes had the least number of eggs (4.4 eggs/ female) than all tested fruits except red grapes (14.22 eggs). In no-choice assays, no significant differences were found among tested host fruits in number of eggs laid ($F=1.82$, $P>0.05$). Number of eggs was slight similar for strawberries, blackberries, raspberries and blueberries (56.6, 60, 64 and 63.6 eggs, respectively). Otherwise, green grapes had the least number of eggs (25.4 eggs) than all fruits.

Oviposition in artificial diets (free choice and no-choice assays): Egg laid by females showed a significant difference among tested artificial diets for both free choice and no-choice assays ($F=3.09$, $P<0.01$ and $F=4.89$, $P<0.01$). In free choice assay, raspberries showed the greatest number of eggs (15.4 eggs). While, no eggs were deposited on strawberries which did not significantly differ with green grapes, red grapes and blackberries (0.2, 3.8 and 1.8 eggs) (Figure 2). In no-choice assay, highest number of eggs was recorded for raspberries (27.4 eggs), but not different with blueberries (16.2 eggs). Otherwise the least number of eggs was found in green grapes (1 egg), which was not significantly different with red grapes and strawberries (5.8 eggs and 6.6 eggs).

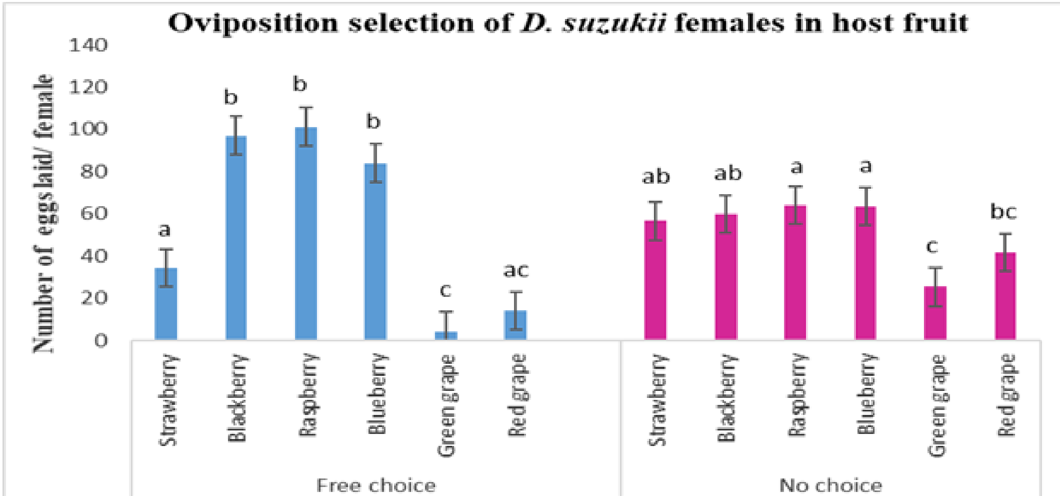

Figure 1: Number of *D. suzukii* eggs fruit/female (mean ± SE) in different host fruits in free choice and no-choice bioassays. Different letters indicate significant differences within each group of bars representing egg number for each tested host fruit and bioassay type, according to the LSD test (P < 0.05).

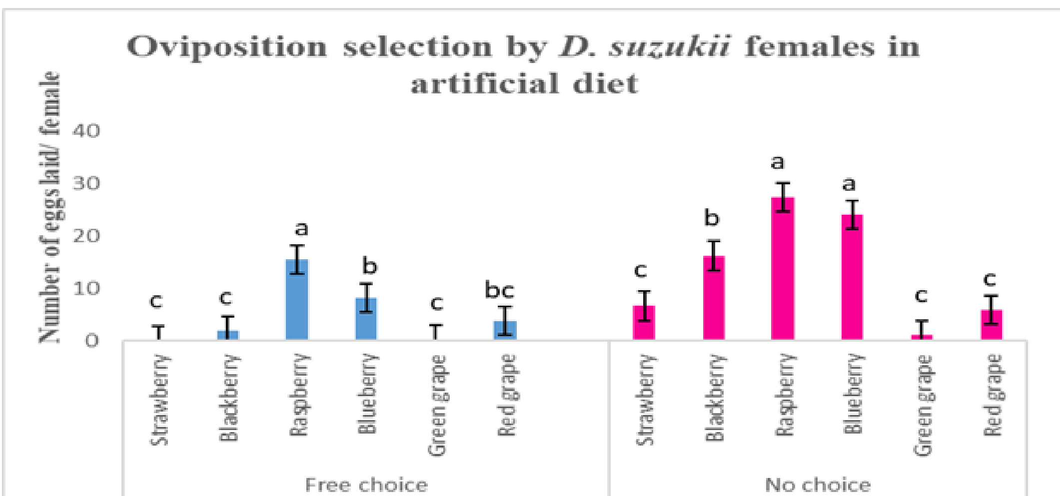

Figure 2: Number of *D. suzukii* eggs fruit/female (mean ± SE) in different artificial diets in free choice and no-choice bioassays. Different letters indicate significant differences within each group of bars representing egg number for each tested host fruit and bioassay type, according to the LSD test (P < 0.05).

Larval development time, pupal duration and adult development time in fruit: Larval development time (days from egg to pupation), pupal duration and adult development time were recorded for each tested fruit and presented in Figure (3).

Larval development time: *D. suzukii* larval development time showed significant differences among fruit in choice assay (F=35.62, P<0.01) and no-choice assay (F=50.47, P<0.01). In choice assay, raspberries had shorter larval development (5.8 days) than other tested fruits except blackberries and strawberries (6.2 days and 6.3 days). Otherwise, longer larval development time was observed on red grapes and green grapes (9.2 days and 9.1 days) than other tested fruits except blueberries (8.5 days). In no-choice assay, similar results were recorded for raspberries which had shorter larval development time (5.7 days) than other tested fruits but not different with strawberries and blackberries (6.3 days). While, red grapes showed longer larval development time (9.1 days) which not differ from blueberries and green grapes (8.5 days and 8.8 days).

Pupal duration: Pupal duration was recorded daily for each pupa/ tested fruit and presented in (Figure 3). No significant differences were found among tested fruits in both free choice assay (F=0.75, P>0.05) and no-choice assay (F=0.71, P>0.05). Where pupal duration ranged between 6.17-6.5 days on fruits in both assays.

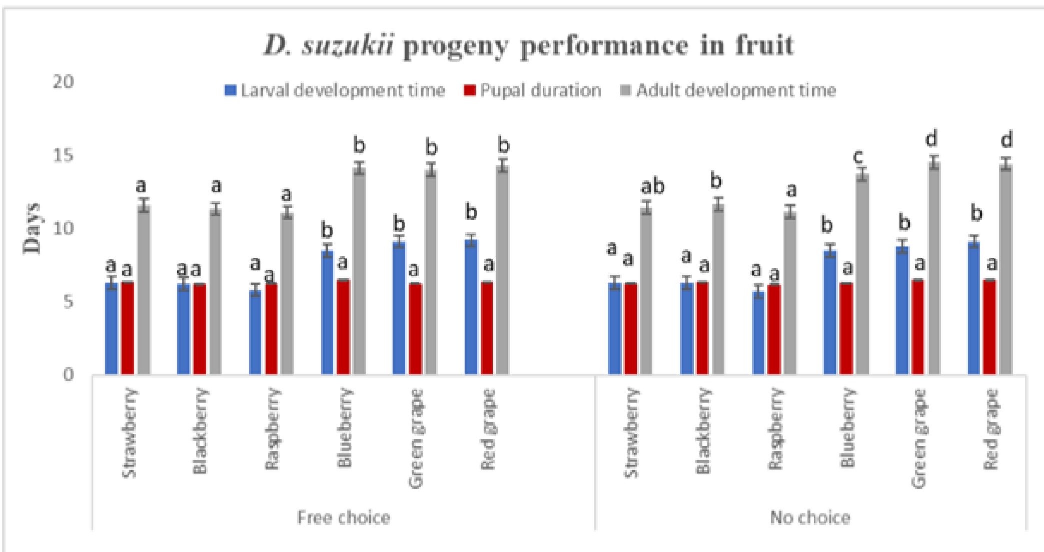

Figure 3: Larval development time, pupal duration and adult development time measured for *D. suzukii* in six host fruit. Different letters indicate significant differences within each group of the same colored bars separate for each parameter and each assay according to the LSD test (P < 0.05).

Adult development time: Adult development time was recorded daily for each pupa/ tested fruit and showed in (Figure 3). Significant differences were found among tested fruits in adult development time in free choice assay (F=57.6, P<0.01) and no-choice assay (F=99.5, P<0.01). In choice assay, adult development time took shorter time in raspberries fruit (11.08 days) than other tested fruits, but not significant different with blackberries and strawberries (11.31 and 11.57 days). On the other hand, adult development time elongated 3 days in green grapes, blueberries and red grapes (14, 14.10 and 14.29 days, respectively). In no-choice assay, similar shorter adult development was recorded for raspberries, strawberries and blackberries (11.13, 11.42 and 11.64 days, respectively) than the rest of tested fruits. While, longer adult development time was recorded for green grapes (14.5 days) as compared with all fruits except red grapes (14.38 days).

Larval development time in artificial diets: Significant differences were found among diets in larval development time in choice assay (F=8.97, P<0.01), and no-choice assay (F=4.12, P<0.01). For choice assay, in raspberries, the larval development time took 8.1 days which significantly was shorter than all diets except strawberries and red grapes (9.2 days and 9.4 days). Otherwise, the longest larval development time was recorded for green grapes 11.97 days as compared with all diets except blackberries (11.33 days). In no-choice assay, the shortest larval development time was recorded for raspberries (9.13 days as compared with all diets except red grapes (9.33 days). While, longer larval development time was in green grapes (10.9 days), but with no difference for strawberries, blackberries and blueberries (10.5, 10.7 and 10.7 days, respectively) (Figure 4).

Pupal duration in artificial diets: Significant differences were found among diets in pupal duration in choice assay (F=5.23, P<0.01) and no-choice assay (F=7.00, P<0.01). For choice assay, shorter pupal durations were similarly recorded on blackberries and red grapes (6.3 days), and strawberries (6.6 days) as compared to the rest of diets. Otherwise, the longest pupal duration was observed on green grapes as compared with the other tested diets (6.79 days). In no-choice assay, blackberries showed the shortest pupal duration (6.25 days) than all fruit. Green grapes had the longest pupal duration (7 days) followed by blueberries and strawberries (6.8 days and 6.8 days).

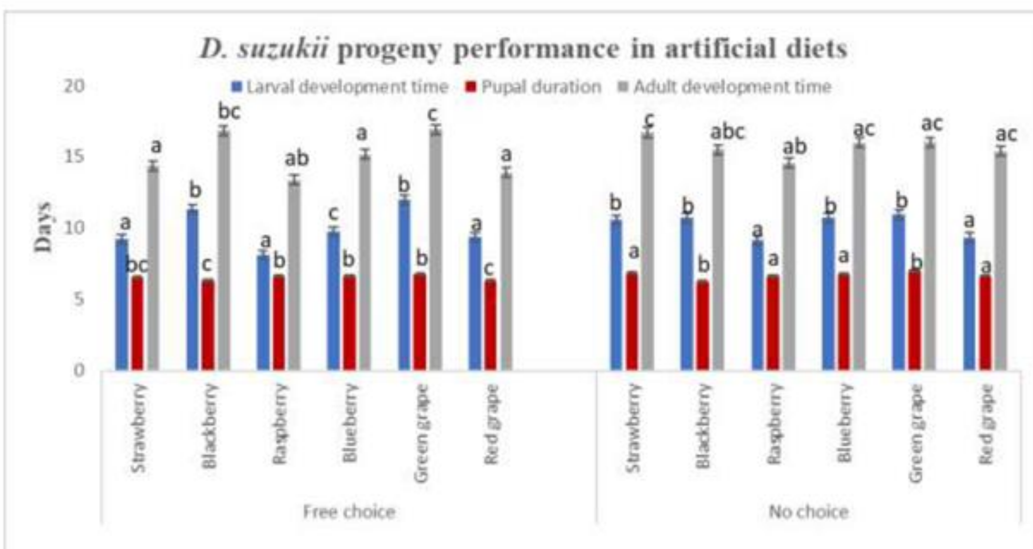

Figure 4: Larval development time, pupal duration and adult development time measured for *D. suzukii* in six artificial diets. Different letters indicate significant differences within each group of the same colored bars separate for each parameter and each assay according to the LSD test (P < 0.05).

Adult development time in artificial diets: A significant difference in adult development time were found among diets in choice assay (F=12.01, P<0.01), but not significant for no-choice assay (F=1.78, P>0.05). Adults had faster development time in raspberries in choice assay (13.4 days) than other tested diets except for red grapes and strawberries (13.9 days and 14.4 days). While longer adult development time was observed on green grapes and blackberries (16.9 days and 16.8 days). In no-choice assay, raspberries had significantly shorter adult development time (14.5 days) than strawberries (16.7 days), but not different with the rest of diets. While, strawberries had the longest adult development time than raspberries only.

Table 1: Proportion of pupal survivorship, adults, males and females for *D. suzukii* assayed for six host fruits in free choice and no-choice laboratory tests.

Fruit host	Proportion (Mean ± SE)							
	Free choice assay				No-choice assay			
	Pupal survivorship	Adults	Females	Males	Pupal survivorship	Adults	Females	Males
Strawberries	0.913± 0.03a	0.357±0.09ac	0.867±0.07abc	0.133±0.07abc	0.933±0.21a	0.438±0.02ac	0.768±0.08ab	0.232±0.08ab
Blackberries	0.961±0.01a	0.402±0.02a	0.781±0.04abc	0.219±0.04abc	0.950±0.01a	0.515±0.02ac	0.792±0.02ab	0.208±0.02ab
Raspberries	0.957±0.01a	0.619±0.07b	0.731±0.05b	0.269±0.05b	0.905±0.03ad	0.541±0.12c	0.703±0.02a	0.297±0.02a
Blueberries	0.579±0.02bc	0.275±0.05ac	0.850±0.02abc	0.150±0.02abc	0.659±0.08b	0.365±0.04a	0.787±0.02ab	0.213±0.02ab
Green grapes	0.633±0.19ac	0.167±0.11c	1.000±0.00c	0.000±0.00c	0.158±0.04c	0.046±0.03b	0.833±0.17ab	0.167±0.17ab
Red grapes	0.498±0.16bc	0.128±0.06c	0.783±0.16abc	0.217±0.16abc	0.716±0.16bd	0.114±0.04b	0.931±0.04b	0.069±0.04b

Means within columns followed by the same letters are non-significantly different at 0.05 probability.

Proportion of pupal survivorship in fruits: Results showed that there is a significant difference among fruit in proportion of pupal survivorship in choice assay (F=4.26, P<0.01) and no-choice assay (F=16.54, P<0.01). In choice assay, strawberries, raspberries and blackberries had similar and high proportion of pupal survivorship (0.913, 0.957 and 0.961). While, red grapes had significantly the least value for proportion of pupal survivorship (0.498) compared with the tested fruits except blueberries and green grapes (0.579 and 0.633). For no-choice assay, highly similar proportions of pupal survivorship were observed for raspberries, strawberries and blackberries with no significant difference (0.905, 0.933 and 0.950, respectively). Otherwise, green grapes showed the least proportion for pupal survivorship (0.158) (Table 1).

Proportion of adult in fruits: Proportion of adults showed a significant difference among fruit in choice assay (F=6.37, P<0.01) and no-choice assay (F=13.76, P<0.01). Raspberries had greatly the highest proportion of adults in choice assay (0.619) than all fruit. Otherwise, lower proportion of adults was detected on red grapes (0.128) compared to other tested fruits, except green grapes and blueberries (0.167 and 0.275, respectively). In no-choice assay, raspberries had significantly the highest proportion of adults (0.541) than all tested fruits except strawberries and blackberries (0.438 and 0.515). Lowest proportion of adults was occurred on green grapes (0.046), but no difference with red grapes (0.114).

Proportion of females in fruits: No significant difference was found among fruits in proportion of females in choice assay (F=1.44, P>0.05) and no-choice assay (F=1.75, P>0.05). Highest proportion of females was observed on green grapes (1.000) as compared with raspberries (0.731) which had the lowest proportion of females in choice assay. Results for no-choice assay showed that red grapes had significantly the highest proportion of females (0.931) as compared with the raspberries which had the lowest proportion of females (0.703).

Proportion of males in fruits: No significant difference was found among fruits in proportion of males in choice assay (F=1.44, P>0.05) and no-choice assay (F=1.75, P>0.05). High proportion of males was detected on raspberries (0.269) in choice assay, while no males were found in green grapes.. In no-choice assay, proportion of males was high on raspberries (0.297) than on red grapes, which had the lowest proportion of males (0.069).

Table 2: Proportion of pupal survivorship, adults, males and females for *D. suzukii* assayed for six fruit artificial diets in free choice and no-choice laboratory tests.

Fruit host	Proportion (Mean ± SE)							
	Free choice assay				No-choice assay			
	Pupal survivorship	Adults	Females	Males	Pupal survivorship	Adults	Females	Males
Strawberries	0.460±0.09a	0.380±0.09a	0.800±0.08ab	0.200±0.08ab	0.480±0.28a	0.426±0.25ab	0.849±0.08ab	0.151±0.08ab
Blackberries	0.340±0.14a	0.060±0.04c	1.000±0.00b	0.000±0.00b	0.540±0.19a	0.060±0.40a	0.750±0.14ab	0.250±0.14ab
Raspberries	0.840±0.10b	0.740±0.14b	0.706±0.06a	0.294±0.06a	0.703±0.04a	0.595±0.09b	0.776±0.07ab	0.224±0.07ab
Blueberries	0.800±0.09b	0.780±0.10b	0.779±0.07ab	0.221±0.07ab	0.540±0.29a	0.488±0.27ab	0.843±0.06ab	0.157±0.06ab
Green grapes	0.243±0.21b	0.243±0.09ac	0.854±0.09ab	0.146±0.09ab	0.186±2.83b	0.186±0.48ab	1.000±0.00a	0.000±0.00a
Red grapes	0.795±0.03b	0.795±0.09b	0.849±0.08ab	0.151±0.08ab	0.525±0.26a	0.500±0.23ab	0.704±0.04b	0.296±0.04b

Means within columns followed by the same letters are non-significantly different at 0.05 probability.

Proportion of pupal survivorship in artificial diets: Results for proportion of pupal survivorship showed that, there is a significant difference among tested diets in choice assay (F=3.92, P<0.01) and no-choice assay (F=4.93, P<0.01). In choice assay, raspberries, blueberries and red grapes had significantly higher proportion of pupal survivorship (0.840, 0.800 and 0.795, respectively) than blackberries and strawberries (0.340 and 0.460) (Table 2). While, blackberries had the lowest proportion of pupal survivorship as compared with all diets except strawberries. For no choice assay, significantly highest proportion of pupal survivorship was observed on raspberries (0.703) compared to the tested diets. Otherwise, greatly lowest proportion of pupal survivorship was recorded on green grapes (0.186) than all tested diets.

Proportion of adult in artificial diets: Proportion of adult revealed that, there is significant difference among tested diets in choice assay (F=11.22, P<0.01), but not significant in no-choice assay (F=0.94, P>0.05). In choice assay, red grapes had significantly higher proportion of adults (0.795) than other tested diets except raspberries and blueberries (0.740 and 0.780). While, significant low proportion of adults was occurred on blackberries (0.060) than all tested diets, except green grapes (0.243). For no choice assay, results showed that raspberries had significantly more proportion of adults (0.595) than blackberries, which had the lowest proportion of adults (0.060).

Proportion of females in artificial diets: No significant difference was found among diets in proportion of females in choice assay (F=1.70, P>0.05) and no-choice assay (F=1.22, P>0.05). Blackberries had higher proportion of females (1.000) than raspberries (0.706) in choice assay. While in no-choice assay, green grapes had significantly more proportion of females (1.000) than red grapes, which had the lowest proportion of females (0.704).

Proportion of males in artificial diets: No significant difference was found among diets in proportion of females in choice assay (F=1.70, P>0.05) and no-choice assay (F=1.22, P>0.05). Choice assay results showed that raspberries had higher proportion of males (0.294) than blackberries which showed no proportion of males. Red grapes had the highest proportion of males (0.296), while no proportion of males was recorded for green grapes in no choice assay.

Discussion

Ongoing research study the behavior oviposition host selection of *D. suzukii*, host preference and development and performance of spotted wing drosophila (SWD) progeny on six tested fruits and artificial diets. Overall, our results for choice and no-choice assays on fruit and artificial diets showed that raspberries fruit and artificial diet was the most preferred host for females oviposition, followed by blackberries, blueberries and strawberries, while green grapes showed the least preferred ones to SWD followed by red grapes. Where the mean numbers of eggs laid in raspberries fruit were (101.2 eggs in choice assay and 64 eggs in no-choice assay) and in artificial diets were (15.4 eggs in choice assay and 27.4 eggs in no-choice assay). While the mean number of eggs laid in green grapes fruit were (4.4 eggs in choice assay and 25.4 eggs in no-choice assay) and in artificial diets were (0.2 eggs and 1 egg in choice and in no-choice assays, respectively). Raspberries have the highest actual preference probability followed by blackberries, strawberries, peaches, cherries, blueberries and grapes (Bellamy et al., 2013). Previous observations have suggested that, despite higher egg and larval densities in raspberries than in other fruit, *D. suzukii* performed the best in raspberries (Burrack et al., 2013). This suggests that some attribute of raspberries may make them a better host than other commonly infested fruit. Revadi et al. (2012) showed recently that *D. suzukii* flies are attracted to odors from intact raspberry, blackberry, blueberry, cherry, and strawberry fruit, indicating that fruit volatiles are important in its host location. Also, Burrack et al. (2013) reported the highest *D. suzukii* oviposition in raspberry fruit and the lowest in blueberry fruit, and suggested that there is a positive relationship among adult *D. suzukii* attraction, female oviposition, and offspring performance, particularly for raspberries. Additionally, mentioned that raspberries had significantly lower average surface penetration force when compared with the blackberries, strawberries and blueberries. Also, when flies were given a choice between blackberries, blueberries, strawberries or raspberries, more eggs were always laid in raspberries. Larvae that developed in raspberries developed 2-4 days faster than those in red grapes and green grapes, in both no-choice and choice assays for tested fruits and artificial diets. Faster larval development time, adult development time and proportion of adults were observed on raspberries fruit and this suggests that raspberries are suitable host for *D. suzukii* larvae development. Other studies cleared that suitability for larval development and attraction can differ widely among fruit variety, cultivar and ripening stage. Also, the host suitability of different fruits, raspberries and blackberries turned out to be the most preferable (Bellamy et al., 2013; Burrack et al., 2013). Larvae developed faster in raspberry, suggesting that sufficient nutrients were acquired in raspberries diet, so as not to hinder pupal development time (Hardin et al., 2015). Grapes have skins too thick for *D. suzukii* females to oviposit (Sampson et al., 2016), also, Bellamy et al. (2013) mentioned that SWD larvae developed slowest on the grape-agar medium. Furthermore, *D. suzukii* will reject a host if it is too firm (highest brix and the highest penetration force) and has implications for determining field host susceptibility, particularly for firm fruit such as peaches, apples and grapes (Burrack et al., 2013). Lee et al. (2011) and Burrack et al. (2013) mentioned that both skin thickness and fruit firmness have been posited as a deterrent to successful oviposition in fruit crops. The susceptibility of cold hardy grapes to *D. suzukii* may depend on variety, the fruit’s chemical and physical characteristics. One important chemical characteristic, which has been posited as a determinant in *D. suzukii* preference in cane fruits, is sugar content (Lee et al., 2011; Burrack et al., 2013). Also, Ioriatti et al. (2015) found oviposition increased with sugar content in intact *Vitis vinifera* grape varieties. A weak relationship has also been noted between acid levels (pH) and infestation in blueberries and cherries (*Prunus spp.*) (Lee et al., 2011) and *V. vinifera* varieties (Ioriatti et al., 2015). Physical characteristics could also impact susceptibility, especially traits which impede oviposition in the flesh of the fruit. In two laboratory studies, damaged grapes had greater levels of oviposition in *V. vinifera* varieties (Atallah et al., 2014; Ioriatti et al., 2015). In other fruits, peaches with indumenta (peach fuzz) deter female oviposition, while damaged areas can have high rates of oviposition (Stewart et al., 2014) and cranberries are susceptible only if damaged (Steffan et al., 2013). *D. suzukii* larvae developed significantly slower on all grape varieties compared to raspberry. Our result showed that adult development time took 11 and 14 days in raspberries fruit and artificial diets, while in green grapes the adult development time reached to 14 days and 17 days in fruit and artificial diets. These results cleared that adults took 3 days longer to complete its development time in grapes rather than raspberries. In concur with our results; Emiljanowicz et al. (2014) observed that *D. suzukii* flies reared on raspberries took 12.9 days from egg to adult which is comparable to development time observed on artificial diet (12.8 days). Comparably, mean development time on grape ranged from 14.4 to 16.7 days. Despite grapes relatively higher sugar content (°Brix value of14.5–19.7), grapes have higher acid levels than raspberry which may make grapes suboptimal hosts (Pelton et al., 2017). However, the trends across the six fruit types suggests that differences in susceptibility between fruit types may be largely influenced by other factors such as color, odor, texture, firmness and size of fruit (Lee et al., 2011).

Acknowledgements

I am grateful for Professor Hannah Burrack Professor and extension specialist at Department of Entomology at North Carolina State University, USA for hosting me at her laboratory and offering space and materials in the laboratory. Also, special thanks for Aurora Toennisson a Research Associate and Specialty Crops Lab at Department of Entomology at North Carolina State University.

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