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Original Contribution

Influence of Host Plants on Longevity, Fecundity and Y-tube Olfactometer Response of *Bemisia Tabaci* B (Hemiptera: Aleyrodidae)

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The whitefly, *Bemisia tabaci* B (Hemiptera: Aleyrodidae) is one of the serious sucking pest insects throughout the world on vegetables, fruits, ornamentals, and broad leaf agronomic crops. In this experiment, we observed fecundity and adult longevity of *B. tabaci* on four different host plants and compare its host plant attraction through a Y-tube olfactometer. Results showed that daily fecundity was different in the entire period of *B. tabaci* life and more number of total eggs laid on eggplant and medium on tomato and cucumber and lower on pepper. Female life longevity was higher than male life where both of them survive longer on eggplant, medium on tomato and cucumber, and lower on pepper. The Y-tube olfactometer results showed that comparison preferences between cucumber vs. eggplant and tomato vs. eggplant did not differ significantly. Host plant attraction between tomato vs. cucumber, eggplant vs. pepper, cucumber vs. pepper, and tomato vs. pepper differed significantly. The olfactometer results confirmed that eggplant, cucumber, and tomato are preferred hosts where pepper is the non-preferred host for *B. tabaci* B. These basic results will provide important information for a better understanding of *B. tabaci* biology as well as dispersal subject to the development of management strategies to successfully combat infestations of the whitefly in a cropping system with different crops.

INTRODUCTION

Among the notorious insect species of greenhouses and open field crops worldwide, *Bemisia tabaci* B Gennadius (Hemiptera: Aleyrodidae) is the significant one (Liu, 2007; Dinsdale *et al*., 2010; De Barro *et al*., 2011). *B. tabaci* is a complex species comprised of sibling species with more than 35 cryptic species bearing diverse genetic variation (De Barro *et al*., 2011; Hu *et al*., 2011; Wang *et al*., 2011; Xu *et al*., 2011; Liu *et al*., 2012; Ahmed *et al*., 2013; Bing *et al*., 2013). Plant species affect *B. tabaci* differently including its host choice, survivability, fecundity, volatile response (Perring, 2001; De Barro *et al*., 2005; Shah and Liu, 2013; Islam *et al*., 2017). *B. tabaci* B biotype is the important one among the complex species. It has ability to adapt easily into new territories due to its unique biological and behavioral characteristics with infesting on variety of crop species (Mayer, 2002; Xu *et al*., 2011; Shah *et al*., 2015). Apart Antarctica, it has been recorded throughout the world (Martin *et al*., 2000; De Barro *et al*., 2005), while it infests more than 600 plant species, including eggplant, tomato, cucumber, and pepper (Oliveira *et al*., 2001; Naranjo and Ellsworth, 2009). These plant species could modify the fitness, life longevity, egg laying capacity, developmental period of *B. tabaci* (Nava-Camberos *et al*., 2001, De Barro *et al*., 2006; De Barro and Bourne, 2010; Shah and Liu, 2013).

B. tabaci exhibited significant oviposition preference among plant hosts (Liu and Stansly, 1995) and leaf surfaces of the same host (Liu and Stansly, 1995; Gruenhagen and Perring, 2001). To maximize the performance of insects, females are liked to lay eggs on

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good quality hosts. Their oviposition preference is positively correlated with host quality for their offspring performance (Mayhew, 1997; Berdegué *et al*., 1998; Gripenberg *et al*., 2010).

Host plant repels or attracts herbivores through emission of volatiles (Unsicker *et al*., 2009; Dicke and Baldwin, 2010; Mumm and Dicke, 2010). The plant leaf features, defensive and nutritional chemistry, influence host preference and fitness of herbivores (Bernays and Chapman, 1994). It is possible that volatile chemicals emitted by host plants are assumed to mainly affect females (Finch, 1980), whereas pheromones stimulates higher responses from male insects than from female insects (Li and Maschwitz, 1985).

In this experimental study we hypothesized that host plant species will affect on the adult longevity, fecundity and plant volatile response of *B. tabaci* B. We tested our hypothesize using four host plants namely eggplant, tomato, cucumber and pepper for the adult longevity, daily fecundity and plant volatile response of *Bemisia tabaci* B.

MATERIALS AND METHODS

Whitefly culture

Bemisia tabaci biotype B was cultured on tomato plants (*Solanum lycopersicum var*. Florida lanai) in large screen cages (65 × 65 × 65 cm) inside an air conditioned insectaries with the environmental conditions as 25±2°C, RH 65±5%, and a photoperiod of 16L:8D h at a light intensity of 1400-1725 lux. Adult *B. tabaci* used in this study was identified by mitochondrial COI gene as B (Frohlich *et al*., 1999). Newly emerged adults, <4h were used for longevity and fecundity bioassays and tests were done into the same environmental condition.

Host Plants

Eggplant, *Solanum melongena* L. (Solanaceae) cv. Zichangqie; tomato, *Solanum lycopersicum* L. (Solanaceae) cv. Florida lanai; pepper, *Capsicum annuum* L. (Solanaceae) cv. Qiemen-Tianjiao, and cucumber, *Cucumis sativus* L. (Cucurbitaceae) cv. Jinchun were selected as host plants for this study. Plant seeds were germinated and seedlings were raised in a potting media (a mixer of peat moss, vermiculite, and perlite at 5:1:1 ratio by vol.) inside growth chamber at 25±1°C, RH 65±5%, and a photoperiod of 16L:8D h with 1400-1725 lux light intensity. Seedlings were transferred individually in 10 cm diameter plastic pots with the same potting media to examine the fecundity and adult longevity of *B. tabaci* biotype B. The plants used for the bioassay were grown up to five-six true leaves stage, where 2nd and 3rd from the top were used for observation. The plants were watered and fertilized when as necessary.

Adult longevity and fecundity assays

Adult longevity and Fecundity were tested using 10 pairs of newly emerged (<4 h) male and female adults on eggplant, cucumber, tomato and pepper. When the whitefly pupae were matured enough and few adults were started to emerge, leaves with pupae were softly cut at early morning and putted inside glass petridishes where the cut portion of petiole was covered with wet cotton to avoid withering the leaves. After 4h check the petridishes and the emerged adults were collected and transferred them onto new leaf of selected plants inside clip cages. At alternate day, both male and female adults were transferred onto new plants' leaves and cut the previous leaves for counting eggs. Eggs were identified as current dated or previous dated eggs through its color as current dated were light green where previous dated were light pink colored. These assays were continued until adult died and when one individual was remaining in a single clip cage, if there option tried to keeps it make couple with other individual.

Y-tube Olfactometer test

The responses of *B. tabaci* female adults to a dual choice of plant volatiles emitted by eggplant and cucumber or eggplant and tomato or eggplant and pepper or cucumber and tomato or cucumber and pepper or tomato and pepper were compared in a Y-tube olfactometer. Transparent glass made Y-tube olfactometer (stem 20 cm; two arms 20 cm each at a 75° angle; ID 4 cm) was used where each arm was connected with glass container holding the odor source of test plants. A pump was used to flow air through the olfactometer at a speed of 400 ml min^{-1}, controlled by a flow meter connected to each arm. The air was filtered through passing with charcoal before entering the odor source container. Experiments were conducted in a temperature controlled room maintained 25°C. One female adult was released each time in the opening of the Y-tube olfactometer stem and observed for five minutes. When adult moved more than 10 cm into one of the two arms and stayed there for more than 1 minute, it was recorded as her first choice to the odor of that arm. The connections of the odor sources to the olfactometer arms were exchanged after testing every ten adults to avoid any asymmetrical bias in the set-up. In total, 60 female adults were tested for each pair of host plants assays where maintained 6 groups with 10 females in each group.

Statistical analysis

All observed data were analyzed through IBM SPSS statistical software (SPSS Inc., Chicago, IL, USA). Adult longevity and fecundity data were analyzed through one-way analysis of variance (ANOVA); means were separated by the Tukey test. Paired sample t-tests were conducted for the comparison of the host plant choice of Y-tube olfactometer bioassay.

RESULTS

Adult longevity between male and female varied significantly (t_{35} = -5.687; $P \leq 0.001$) where female survived longer than the male adults. Both male ($F_{3,33}$ = 7.594; P = 0.001) and female ($F_{3,32}$ = 13.885; $P \leq 0.001$) adults' longevity differed on tested four host plants. Male adult survived longest on eggplant and cucumber, female adult survived longest on eggplant where both of that shortest on pepper.

Table 1: Adult longevity of *B. tabaci* male and female adults on different host plants

Sex	Adult longevity (Mean days ± SE)			
	Eggplant	Tomato	Cucumber	Pepper
Male	23.8 ± 1.5a	16.4 ± 2.5bc	23.2 ± 2.8ab	9.5 ± 2.6c
Female	46.2 ± 4.9a	30.4 ± 2.9b	33.1 ± 3.2b	13.0 ± 3.5c

Daily fecundity curves of *B. tabaci* B on the four host plants during entire period of life time displayed in figure 1 showed that the highest number of eggs laid on eggplant on 11th day (7.75 ± 1.39), on tomato on 9th day (6.88 ± 0.77) and on 11th day (6.88 ± 0.77), on cucumber on 5th (5.89 ± 0.75) and 6th (5.89 ± 0.84) day and on pepper on 2nd day (2.7 ± 0.67).

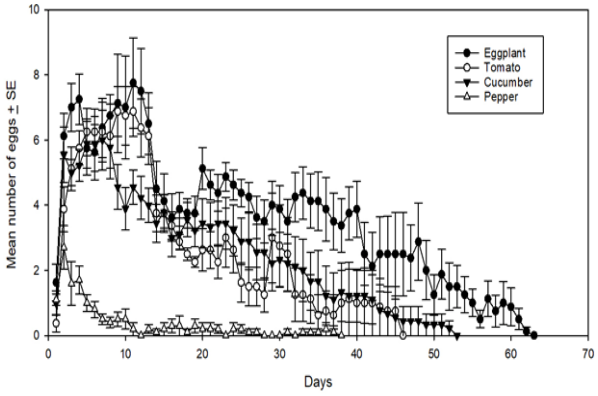

Figure 1: Daily mean fecundity of *B. tabaci* on different host plants

Significant differences were observed in most of days during their entire life period for daily fecundity (Appendix 1, page 15).

Total number of eggs laid *B. tabaci* female adults in their entire life period on different host plants varied significantly ($F_{3,31}$ = 23.118; $P \leq 0.001$). The highest number of eggs was laid on eggplant, medium number of eggs on tomato and cucumber, and the lowest of that on pepper (Figure 2).

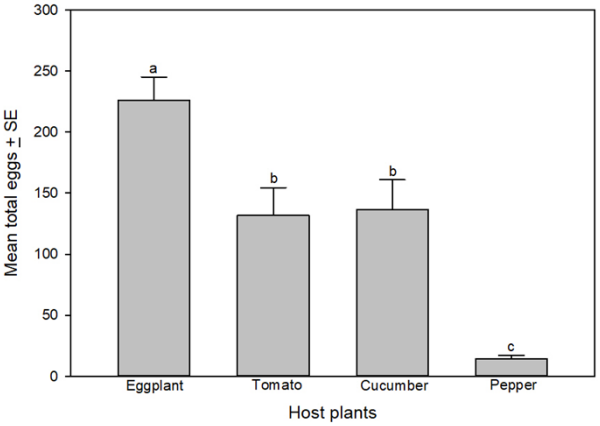

Figure 2: Mean lifetime fecundity of individual female on eggplant, tomato, cucumber and pepper plants

The Y-tube test showed that *B. tabaci* female adults had clear preferences to a specific host plant between two host plants when tested four host plants in a paired basis. The comparison preferences between cucumber vs. eggplant (t_{59} = 0.256; P = 0.799) and tomato vs. eggplant (t_{59} = -1.298; P = 0.199) did not differ significantly. Host preferences between tomato and cucumber (t_{59} = -2.416; P = 0.019), eggplant and pepper (t_{59} = 5.283; $P \leq 0.001$), cucumber and pepper (t_{59} = 6.870; $P \leq 0.001$), and tomato and pepper (t_{59} = 4.435; $P \leq 0.001$) differed significantly. The female adults chose cucumber compared to tomato and rejected pepper when compared individually with eggplant or cucumber or even with tomato (Figure 3).

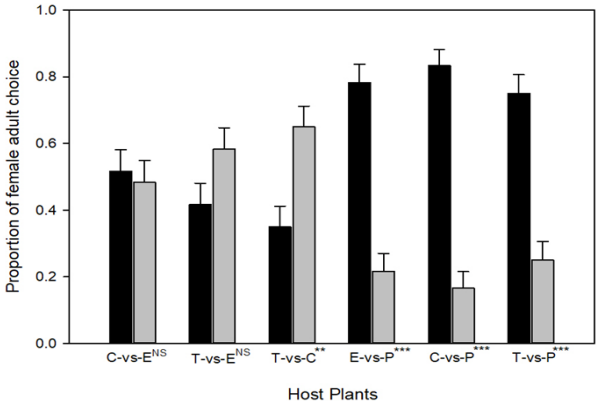

Figure 3: The Y-tube olfactometer test of *Bemisia tabaci* B documented the percentage of female adult attracted to the selected plant volatiles. C = Cucumber, E = Eggplant, T = Tomato, P = Pepper. Values are mean ± SE (paired

sample t-test), ** & *** indicate significant differences at $P < 0.05$ & $P < 0.01$ where NS = Non-significant.

DISCUSSION

The effect of host plants on the longevity of *B. tabaci* B adults was assessed for both male and female. The results showed that female adult survived longer than the male adult. Both female and male adult survived longest on eggplant, medium on tomato and cucumber and shortest on pepper plant. Al-Zyoud and Sengonca (2004) described the longevity of *B tabaci* adult where they found that *B tabaci* survived 19.25 days on cucumber, 8.55 days on pepper which satisfy with our findings where contrast result on tomato i.e. 5.65 days. This might be due to varietal characteristics we used in this study tomato variety "Lanai" but Al-Zyoud and Sengonca (2004) used variety "Roma". They also described that significant differences were observed in the mean longevity between different sexes within the same host plant that is consisted with our result. Powell and Bellows 1992 described the consisted result with our findings where they observed that longevity is greater for females than males, female longevity ranged from 43.5-13.0 days, mean total fertility ranged from 252-43 eggs/female. Gonzalez-Zamora and Gallardo, 1999 stated that female adults of *B. tabaci* survived 24.3 days at 20°C and 7.68 days at 30°C on sweet pepper where our results obtained 13.0 ± 3.5 days at 25°C. This variation might be due to temperature and varietal effect as well. Mansaray and Sundufu (2009) described consisted result that is the mean longevity differed in two host plants and females lived longer than male on *G. max* and *P. vulgaris*.

Daily mean fecundity of *B. tabaci* B differed on the basis of days and host plants. The highest daily fecundity was observed on 2nd to 11th days. In the case of total mean fecundity, the highest number of eggs was found on eggplant where medium on tomato and cucumber, and the lowest of that on pepper. The similar pattern of egg laying performance was reported in previous finding (Shah and Liu, 2013). Several findings support that pepper is a poor host for *B tabaci* B for oviposition (Nava-Camberos *et al*., 2001; Omondi *et al*., 2005; Tsueda and Tsuchida, 2011; Xu, *et al*., 2011; Shah and Liu, 2013).

Al-Zyoud and Sengonca (2004) described that B. tabaci laid higher number of eggs on cucumber and tobacco and lowest on sweet pepper that reflect with our results.
This study along with previous research findings (Powell and Bellow, 1992; Mansaray and Sundufu, 2009) showed that fecundity differed on various host plants. Mansaray and Sundufu, 2009 found that *B. tabaci* females laid an average of 163.50 ± 3.91 eggs over their lifetime on *G. max* and 105.35 ± 2.67 eggs on *P. vulgaris*.

A Y-tube olfactometer bearing two arms where one female can choose only one arm attempt to its preferred plant leaves volatiles. In this study, female adults had no influence when tested between cucumber vs eggplant or tomato vs eggplant where in other four cases female adults showed significant influences to specific host plants. In previous study (Shah and Liu, 2013) demonstrated that in choice test *B. tabaci* B chose cucumber and eggplant and opposed pepper plant. Saad *et al*. (2015) observed the similar trend of host plant preference of *B. tabaci* either in the free-choice or olfactometer assays. Latournerie-Moreno *et al*. (2015) explained that some plant defensive enzymes like chitinase, polyphenoloxidase, and peroxidase released from pepper plant that repelled *B tabaci* B from pepper plant.

Further study is needed to identify the volatile organic compounds and/or nutritional quality of the selected host plants for better clarification of *B. tabaci* B influences and performances. However, this finding can be used in IPM technology to manage *B. tabaci* in a cropping system using attractant or repellency characters of host plants.

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Appendix 1: ANOVA table of daily fecundity of *B. tabaci* B on four different host plants

Days	Sum of Squares	Degree of freedom	Mean Square	F statistic	Probability
D1	6.321	3	2.107	1.885	.153
	34.650	31	1.118		
D2	66.671	3	22.224	4.716	.008
	146.072	31	4.712		
D3	139.468	3	46.489	13.434	.000
	107.275	31	3.460		
D4	152.944	3	50.981	19.121	.000
	82.656	31	2.666		
D5	176.797	3	58.932	16.041	.000
	113.889	31	3.674		
D6	188.822	3	62.941	15.752	.000
	123.864	31	3.996		
D7	232.696	3	77.565	15.426	.000
	155.875	31	5.028		
D8	244.355	3	81.452	17.023	.000
	148.331	31	4.785		
D9	260.271	3	86.757	13.551	.000
	198.472	31	6.402		
D10	252.254	3	84.085	11.695	.000
	222.889	31	7.190		
D11	314.374	3	104.791	19.784	.000
	164.197	31	5.297		
D12	301.255	3	100.418	18.159	.000
	171.431	31	5.530		
D13	230.496	3	76.832	20.806	.000
	114.475	31	3.693		
D14	106.978	3	35.659	13.379	.000
	82.622	31	2.665		
D15	97.441	3	32.480	12.054	.000
	83.531	31	2.695		
D16	66.836	3	22.279	10.179	.000
	67.850	31	2.189		
D17	67.833	3	22.611	16.400	.000
	42.739	31	1.379		
D18	79.549	3	26.516	23.742	.000
	34.622	31	1.117		
D19	64.487	3	21.496	17.239	.000
	38.656	31	1.247		
D20	114.571	3	38.190	13.071	.000
	90.572	31	2.922		
D21	95.221	3	31.740	13.415	.000
	73.350	31	2.366		
D22	89.488	3	29.829	14.183	.000

	65.197	31	2.103		
D23	116.446	3	38.815	11.671	.000
	103.097	31	3.326		
D24	93.780	3	31.260	11.151	.000
	86.906	31	2.803		
D25	84.733	3	28.244	12.831	.000
	68.239	31	2.201		
D26	85.454	3	28.485	10.116	.000
	87.289	31	2.816		
D27	61.288	3	20.429	6.529	.001
	96.997	31	3.129		
D28	62.963	3	20.988	7.093	.001
	91.722	31	2.959		
D29	79.416	3	26.472	4.375	.011
	187.556	31	6.050		
D30	73.168	3	24.389	4.490	.010
	168.375	31	5.431		
D31	56.516	3	18.839	3.781	.020
	154.456	31	4.982		
D32	83.711	3	27.904	6.660	.001
	129.889	31	4.190		
D33	84.696	3	28.232	6.239	.002
	140.275	31	4.525		
D34	75.236	3	25.079	6.138	.002
	126.650	31	4.085		
D35	81.036	3	27.012	6.361	.002
	131.650	31	4.247		
D36	67.041	3	22.347	5.037	.006
	137.531	31	4.436		
D37	57.022	3	19.007	5.277	.005
	111.664	31	3.602		
D38	52.011	3	17.337	3.539	.026
	151.875	31	4.899		
D39	36.069	2	18.035	2.544	.101
	155.931	22	7.088		
D40	41.569	2	20.785	3.166	.062
	144.431	22	6.565		
D41	10.604	2	5.302	.731	.493
	159.556	22	7.253		
D42	6.236	2	3.118	.435	.653
	157.764	22	7.171		
D43	15.329	2	7.665	1.051	.366
	160.431	22	7.292		
D44	17.540	2	8.770	1.383	.272
	139.500	22	6.341		
D45	18.838	2	9.419	1.422	.263

	145.722	22	6.624		
D46	17.895	1	17.895	2.527	.133
	106.222	15	7.081		
D47	15.785	1	15.785	3.284	.090
	72.097	15	4.806		
D48	25.020	1	25.020	4.031	.063
	93.097	15	6.206		
D49	11.765	1	11.765	3.268	.091
	54.000	15	3.600		
D50	3.559	1	3.559	1.810	.199
	29.500	15	1.967		
D51	10.066	1	10.066	3.694	.074
	40.875	15	2.725		
D52	6.915	1	6.915	3.091	.099
	33.556	15	2.237		
D53	9.529	1	9.529	5.956	.028
	24.000	15	1.600		