Effects of Five Host Plant Species on the Life History and Population Growth Parameters of *Myzus persicae* (Hemiptera: Aphididae)

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Received 13 June 2019; Editorial decision 19 August 2019

Abstract

The green peach aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae), is an important agricultural pest with a wide range of host plants. To study effects of host species on the life history traits of *M. persicae*, aphids were individually reared on five host plants: *Brassica campestris* L. (Brassicaceae), *Capsicum annuum* L. (Tubiflorae: Solanaceae), *Nicotiana tabacum* L. (Tubiflorae: Solanaceae), *Raphanus sativus* L. (Brassicaceae), and *Vicia faba* L. (Rosales: Leguminosae). TWOSEX-MSchart software was used for the statistical analysis according to the age-stage, two-sex life table theory. The results showed that the shortest preadult stage and adult/total prereproductive period of *M. persicae* were 6.48, 0.19, and 6.67 d on *V. faba*, respectively. While the adult and total longevity of *M. persicae* on *R. sativus* (25.00 and 31.62 d) and *N. tabacum* (24.40 and 30.56 d) were significantly longer than that on the other three hosts, as was the reproductive period. The fecundity of *M. persicae* on *R. sativus* (80.83 nymphs per female), *N. tabacum* (71.72 nymphs per female), and *V. faba* (70.39 nymphs per female) was also greater than that on *B. campestris* and *C. annuum*. It was demonstrated that *V. faba*, *R. sativus*, and *N. tabacum* were more suitable plants for the growth of *M. persicae* exhibiting a shorter preadult stage, longer longevity, and greater fecundity than the remaining two species, as confirmed by the higher intrinsic rate of increase and net reproductive rate.

Key words: *Myzus persicae*, host species, life table, population characteristics

Ecological patterns may often be determined by the physiological constraints of interacting organisms (Singer 2001). One of the most important factors affecting the fitness of insect herbivores is the quality of the host plant. Compounds from host plants, such as carbon, nitrogen, and defense metabolites, directly affect the potential and achieved herbivore fecundity, and the responses of insect herbivores to changes in host plant quality vary within and between feeding guilds (Awmack and Leather 2002, Hosseini et al. 2019). Polyphagous herbivores are particularly challenged, as feeding on different plant species can result in differences in life history traits (Ojala et al. 2005). It is estimated that 15% of crop yield worldwide is lost to herbivore pests in spite of plant breeding and pest control efforts (Van Der Meijden 2013). However, plant diversity also promotes herbivore suppression through movement patterns, host associations, and predation promises a potential alternative to pesticide-intensive monoculture crop production (Letourneau et al. 2011). The fitness of a pest population is represented by its damage capacity to the host plant. That fitness can be properly evaluated using a life table, as it provides an integrated and comprehensive description of the survival, development, and reproduction of a population (Tuan et al. 2016).

The life table is a powerful and necessary tool for analyzing and understanding the effect of external factors and host plants on the growth, survival, reproduction, and intrinsic rate of increase of insect populations (Chi and Su 2006). A life table study is fundamental for population ecology research and provides a complete description of the survivorship, development, stage differentiation, and reproduction of a population as well as basic population growth parameters (Hu et al. 2010, Yousaf et al. 2018). Using a life table, population projections can be made by means of computer simulations (Chi 1990). Life tables have been used in a variety of studies related to population ecology, such as the effect of temperature on population growth of *Hyalopterus pruni* Geoffroy (Hemiptera: Aphididae) (Atlihan and Chi 2008), climate change/global warming studies (Kanle Satishchandra et al. 2019), host plant resistance on *Lipaphis erysimi* Kaltenbach (Hemiptera: Aphididae) (Qayyum et al. 2018), and harvesting theory (Yu et al. 2018).

As an economically important pest, the green peach aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae), attacks over 400 species in...
Materials and Methods

Aphid and Host Plant Culture

Adult *M. persicae* samples were collected from *Nicotiana tabacum* L. (Tubiflorae: Solanaceae) plants in Chongqing, China, and then maintained on the same host species in a climate incubator at 23 ± 1°C, 50 ± 5% RH, and a photoperiod of 16:8 (L:D) h. Five host plants commonly found in Chongqing were used for this study, including rapeseed (*Brassica campestris* L. (Brassicaceae)), pepper (*Capsicum annuum* L. (Tubiflorae: Solanaceae)), tobacco (*N. tabacum*), radish (*Raphanus sativus* L. (Brassicaceae)), and fava bean (*Vicia faba* L. (Rosales: Leguminosae)). All tested plants were grown in growth chambers with Pindstrup substrate as media and were watered as required.

Life Table Construction

For the life table study, more than 100 *M. persicae* adults were transferred onto tobacco leaves. After 12 h, newborn nymphs were individually transferred to the leaf discs (2 cm of diameter) of five host plants. The leaf disc was placed upside down on a water-saturated sponge pad in a plastic dish (8.5 cm of diameter, and 1.5 cm of height). A piece of filter paper with a hole (2 cm of diameter at the center) was placed onto the leaf disc to form a water fence. The molting and reproduction of *M. persicae* were observed and recorded every 12 h until all aphids were dead. All studies were carried out in climate incubators (MLR-351H, Panasonic, Matsuyama, Japan) at 23 ± 1°C, 70 ± 5% RH, and a photoperiod of 16:8 (L:D) h (Tang et al. 2017).

Statistical Analysis

TWOSEX-MSchart software was used for analysis of the life history based on the age-stage, two-sex life table theory (Chi and Liu 1985).

### Table 1. Effect of host plants on the development of *Myzus persicae*

| Statistics                  | Host species                   |
|-----------------------------|--------------------------------|
|                             | *Vicia faba*                    | *Capsicum annuum*                | *Raphanus sativus*                        | *Nicotiana tabacum*                       | *Brassica campestris*                     |
|                             | Mean ± SE                       | Mean ± SE                       | Mean ± SE                                 | Mean ± SE                                 | Mean ± SE                                 |
| Preadult duration (d)       | 116 ± 0.04c                     | 118 ± 0.06c                     | 120 ± 0.05b                               | 117 ± 0.08b                               | 116 ± 0.11a                               |
| First instar (d)            | 120 ± 0.03c                     | 120 ± 0.03b                     | 120 ± 0.05b                               | 120 ± 0.03b                               | 120 ± 0.05b                               |
| Second instar (d)           | 120 ± 0.02d                     | 120 ± 0.03bc                    | 120 ± 0.03b                               | 120 ± 0.03b                               | 120 ± 0.02a                               |
| Third instar (d)            | 120 ± 0.02a                     | 120 ± 0.02bc                    | 120 ± 0.02a                               | 119 ± 0.03a                               | 116 ± 0.03a                               |
| Fourth instar (d)           | 118 ± 0.03b                     | 118 ± 0.03b                     | 118 ± 0.02a                               | 117 ± 0.05a                               | 116 ± 0.03a                               |
| Adult longevity (d)         | 116 ± 0.26b                     | 118 ± 0.28c                     | 120 ± 0.56a                               | 117 ± 0.8a                                | 116 ± 0.71a                               |
| Total longevity (d)         | 120 ± 0.68bc                    | 120 ± 0.83c                     | 120 ± 0.56a                               | 120 ± 0.85a                               | 120 ± 0.75b                               |

Means in the same row followed by different letters are significantly different (*P* < 0.05) using bootstrap test.
The means and standard errors of the developmental time, longevity, fecundity, and population parameters were estimated using the bootstrap technique. To reduce the variability of the results, we used 200,000 bootstrap replications in this study. The differences among the five host treatments were analyzed by the paired bootstrap test with a $P$ value of less than 0.05.

### Results

**Effect of Host Species on the Development of *M. persicae***

The durations of the four nymph stages for the aphids fed with five plant species all differed significantly from each other (Table 1). The preadult durations for *M. persicae* reared on *B. campestris,*...
C. annuum, N. tabacum, R. sativus, and V. faba were 7.54 ± 0.11, 6.44 ± 0.06, 6.77 ± 0.08, 6.62 ± 0.05, and 6.48 ± 0.04 d, respectively. The shortest preadult durations were observed on C. annuum and V. faba, and the curves of the age-stage-specific survival rate ($s_{ij}$) showed that the survival rates of mature aphids on C. annuum and B. campestris were lower than those on N. tabacum and R. sativus (Fig. 1; Supp Fig. 1 [online only]). The adult longevity and total longevity of the aphids reared on C. annuum and B. campestris were also significantly shorter than those reared on N. tabacum and R. sativus. The age-stage life expectancy ($e_{ij}$) showed the same trend (Fig. 2; Supp Fig. 2 [online only]). The life expectancy of the new born nymph at age = 0 and stage = 1 ($e_{01}$ value) was exactly the mean longevity of 21.55 ± 0.83 d on C. annuum, 23.51 ± 0.68 d on V. faba, 24.69 ± 0.75 d on B. campestris, 30.56 ± 0.85 d on N. tabacum, and 31.62 ± 0.56 d on R. sativus, respectively (Table 1).

**Effect of Host Species on the Fecundity of M. persicae**

Means of TPRP and APRP of M. persicae reared on different host plants also differed significantly (Table 2). Mature aphids and

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**Fig. 2.** The age-stage-specific life expectancy ($e_{ij}$) of Myzus persicae on five different host plants. N1, first instar nymph, purple curve; N2, second instar nymph, blue curve; N3, third instar nymph, green curve; N4, fourth instar nymph, yellow curve; A, adult aphid, red curve. Each panel represents Vicia faba (a), Capsicum annuum (b), Raphanus sativus (c), Nicotiana tabacum (d), Brassica campestris (e), respectively.
newborn aphids on V. faba both took the least time to produce offspring (APRP = 0.19 ± 0.03 d and TPRP = 6.67 ± 0.05 d), whereas the greatest APRP and TPRP were, respectively, observed in newborn aphids on C. annuum (APRP = 0.61 ± 0.04 d) and mature aphids on B. campestris (TPRP = 7.99 ± 0.13 d). Conversely, the reproductive period of M. persicae on C. annuum and B. campestris was shortest. Upon comparison of aphids' fecundity on different host species, we found that the mean nymph-laying per female on C. annuum and B. campestris was also significantly lower than on the other three host plants. There were no significant differences among the \( \nu \) of the M. persicae females reared on various host species, but the curves for aphids on C. annuum and B. campestris showed lower peaks than the others (Fig. 3; Supp Fig. 3 [online only]), which further supported the weak fecundities of the two host populations.

### Discussion

The parameter \( r \) (intrinsic rate of increase) is regarded as a useful concept in demographic analyses of insect populations (Birch 1948). This parameter \( r \) summarizes the physiological qualities of an animal relative to its capacity of increase and is often used to compare the fitness of populations across diverse climatic and food-related conditions (Tsai and Wang 2001, Saeed et al. 2010). The \( r \) values for M. persicae were reported as 0.160–0.236 d\(^{-1}\) a decade ago on solanaceous and cruciferous vegetables and crops (Boughton et al. 2006, Chi and Su 2006, Davis et al. 2006, Ribeiro et al. 2006), which is significantly lower than in the present study. This might be attributed to the enhanced adaptability of M. persicae to a complex environment. Life history theory is based on the assumption that evolution is constrained by trade-offs among different traits that contribute to fitness, and life history costs play a central role in explaining the evolution of resistance (Carriere et al. 1994). Fitness costs include reduced survival, increased developmental time, and reduced fecundity (Sayed et al. 2008). Therefore, the stronger the adaptability, the lower the fitness cost, and the higher the \( r \) value.

The age at first nymph-laying is critical for \( r \) value calculation. If fecundity remains the same, early reproduction will be associated with a higher \( r \) value (Huang and Chi 2012). Both the APRP and TPRP of M. persicae on V. faba were shortest, resulting in the highest \( r \) value of increase, which is consistent with the aforementioned theory. Conversely, the two statistics, APRP and TPRP do not represent the actual beginning of reproduction, and thus their effects on the \( r \) value should not be overemphasized (Jha et al. 2012). Barlow (1962) found that offspring produced after peak fecundity have little influence on the \( r \) value of the population when the fecundity rate is more or less sharply defined in time. Therefore, the number of offspring produced by aphids on the five host species before peak fecundity was analyzed and indicated the same \( r \) value order. It does not necessarily follow that the higher the \( r \) value is, the more successful the species will be.

Most species exist in saturated environments and abundance fluctuates in response to changes in the conditions of survival and growth as a result of changes in factors such as weather (Cole 1954). One can examine the potential importance of life history parameters in adapting to perturbations by determining the effect of change in the life history parameters on the net reproductive rate \( R_0 \). In our study, aphids reared on R. sativus exhibited a higher \( R_0 \) than that on the other plant species, while the aphids on C. annuum and B. campestris performed poorly. To determine the effective factors, correlation analyses were carried out with a correlation coefficient equal to 0.05 between \( R_0 \) and the means of each developmental period, reproductive period, female fecundity, age-stage-specific survival rate \( s_0 \), and the female age-stage-specific fecundity \( f_{s,k,\text{female}} \). With the exception of reproductive period, \( s_0 \) and female fecundity, the remainder of the indices showed no significant correlation with \( R_0 \) value. Female fecundities showed a similar tendency as the \( R_0 \) value, as preadult survival rates of the M. persicae females on the five host plants were quite similar in terms of the equation \( R_0 = s_0F \), where \( s_0 \) represents the preadult survival rate and \( F \) is the mean female fecundity. However, the female age-stage-specific fecundity \( f_{s,k,\text{female}} \) was not found to be closely related to the \( R_0 \) value, which indicated that the net reproductive rate of a population is associated with the adult number and the total offspring but not the adult age or the daily

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**Table 2. Effect of host plants on the fecundity (nymphs per female) of Myzus persicae**

| Statistics                  | Vicia faba | Capsicum annum | Raphanus sativus | Nicotiana tabacum | Brassica campestris |
|-----------------------------|------------|----------------|-----------------|-------------------|-------------------|
| APRP (d)\(^a\)              | 114        | 0.19 ± 0.03c   | 116             | 0.61 ± 0.04a      | 120               | 0.41 ± 0.03b       |
| TPRP (d)\(^b\)              | 114        | 6.67 ± 0.05d   | 116             | 7.04 ± 0.08c      | 120               | 7.03 ± 0.06c       |
| Reproductive period (d)     | 114        | 12.96 ± 0.36c  | 116             | 11.05 ± 0.59d     | 120               | 18.30 ± 0.43d      |
| Fecundity (nymphs per female) | 114   | 70.39 ± 2.26b  | 116             | 47.05 ± 2.54d     | 120               | 80.83 ± 2.09a      |

Means in the same row followed by different letters are significantly different (\( p < 0.05 \)) using bootstrap test.

\(^{a}\)APRP = adult prereproductive period.

\(^{b}\)TPRP = total prereproductive period.
fecundity. Though the reproductive period and $s_\text{a}$ of the aphids on $V.\text{faba}$ were both lower than those on $N.\text{tabacum}$, the $R_0$ value for $M.\text{persicae}$ on $V.\text{faba}$ was similar to that on $N.\text{tabacum}$. Nitrogen application rates are known to affect the individual size, survival, and $r$ value of several species of rice pest (Jahn et al. 2005). It was concluded that the nitrogen-rich legumes improved the fertility of the parasitic aphid and further affected the population development.

In conclusion, $V.\text{faba}$, $R.\text{sativus}$, and $N.\text{tabacum}$ constituted more suitable host plants for $M.\text{persicae}$ and were associated with a shorter preadult stage, longer longevity, and stronger fecundity in comparison to the remaining species. Furthermore, the intrinsic rate $r$ of the aphids was also significantly higher on $V.\text{faba}$, which depended on their ages at first nymph-laying and the number of offspring produced before peak fecundity. Another important life history parameter, $R_0$ was found to be higher in aphids reared on $R.\text{sativus}$ than that on the other plant species, proving that the adult number was more meaningful to the population growth of $M.\text{persicae}$ than the adult age. Laboratory colonies of $M.\text{persicae}$ are necessary for experimental study of its biology, behavior, and insect–virus interactions. In our study, $R.\text{sativus}$ was proved to be the

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**Fig. 3.** The age-stage-specific reproductive value ($v_{xj}$) of *Myzus persicae* on five different host plants. N1, first instar nymph, purple curve; N2, second instar nymph, blue curve; N3, third instar nymph, green curve; N4, fourth instar nymph, yellow curve; A, adult aphid, red curve. Each panel represents *Vicia faba* (a), *Capsicum annum* (b), *Raphanus sativus* (c), *Nicotiana tabacum* (d), *Brassica campestris* (e), respectively.
most favorable cultivar for the green peach aphid in lab which exhibited the longest longevity and strongest fecundity. If mass-rearing of this species, V. faba will be the best choice because of the short prereproductive period and the strong fecundity.

**Supplementary Data**

Supplementary data are available at *Journal of Insect Science* online.

**Figure S1.** The age-specific survival rate ($s_x$) of adult *Myzus persicae* on five different host plants. Purple curve, *Vicia faba*; blue curve, *Capsicum annuum*; green curve, *Raphanus sativus*; yellow curve, *Nicotiana tabacum*; red curve, *Brassica campestris*.

**Figure S2.** The age-specific life expectancy ($e_x$) of adult *Myzus persicae* on five different host plants. Purple curve, *Vicia faba*; blue curve, *Capsicum annuum*; green curve, *Raphanus sativus*; yellow curve, *Nicotiana tabacum*; red curve, *Brassica campestris*.

**Figure S3.** The age-specific reproductive value ($v_x$) of adult *Myzus persicae* on five different host plants. Purple curve, *Vicia faba*; blue curve, *Capsicum annuum*; green curve, *Raphanus sativus*; yellow curve, *Nicotiana tabacum*; red curve, *Brassica campestris*.

**Acknowledgments**

We thank Dr. Hsin Chi (National Chung Hsing University, China) for technical assistance. This research was funded by the National Key Research and Development Project (2018YFD0200300) and the Ph.D. Research Funding of Southwest University (SWU1181110).

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