

Article

Different Host Plants Distinctly Influence the Adaptability of *Myzus persicae* (Hemiptera: Aphididae)

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Abstract: Piercing–sucking insects are prominent phloem-feeding insect pests and understanding their feeding behavior and life characteristics plays a crucial role in studying insect host adaptability. The green peach aphid, *Myzus persicae* (Hemiptera: Aphididae), is one of the most prominent pests in tobacco-growing areas around the world. This study evaluated the adaptability of *M. persicae* to five host plants: tobacco, radish, Chinese cabbage, *Brassica oleracea*, and rape using the electropenetrography, age-stage, two-sex life table and population dynamics. The results demonstrated that the feeding behavior of *M. persicae* differed significantly according to the target hosts. *M. persicae* exhibited reduced pathway activities and increased phloem sap ingestion on radish, whereas the opposite was observed on Chinese cabbage. Additionally, the mechanical difficulties of *M. persicae* mouthparts in the probe pathway phase were significantly lower on tobacco and radish than on other host plants. Life table parameters indicated that for *M. persicae* reared on radish, preadult duration, longevity, and total preoviposition increased significantly and the fecundity was the highest. Furthermore, the net reproductive rate (R_0) increased significantly. The population number of *M. persicae* on radish after 15 days was significantly higher than that on other hosts, except for tobacco. Although *M. persicae* can successfully survive on the five plants, our results demonstrated that radish is the optimal host. These results provide significant information for understanding the population dynamics of *M. persicae* and on different host crops integrated management strategy.

Keywords: *Myzus persicae*; electropenetrography; feeding behavior; life table; population dynamics; host adaptability



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1. Introduction

In the natural ecosystem, phytophagous insects and plants may develop different host-specific types during long-term coevolution [1,2]. In this process, the two lifeforms interact with each other, mainly manifested in the host adaptability of insects and plant resistance to insects [3]. Phytophagous insects commonly feed on several host plants with different physical structure, chemical defenses, and trophic components. Insect populations feeding on dissimilar host plant species and cultivars are under selection pressure to adapt to these discrepancies, thus continuously improving their adaptive ability toward host plants. Some studies have reported that host-specific insect types mainly depend on host plant nutrition, and the nutritional quality of the host can influence the feeding behavior, growth, and fertility of insects [4–6]. Therefore, studying the performance of insects on different hosts can reveal their host adaptability.

The peach aphid, *Myzus persicae* (Sulzer), is a worldwide polyphagous pest; it can not only damage crops directly by feeding on the vascular bundles of plants but also transmit a variety of plant viruses [7]. Prior studies have shown that *M. persicae* has a wide host

range and can harm more than 400 plant species from 50 families, including Solanaceae, Cruciferae, Compositae, and Leguminosae, thus resulting in serious economic losses [8,9]. Hence, *M. persicae* is one of the main pests whose prevention and control should be focused on. Although *M. persicae* is a typical polyphagous insect, its adaptability to the host varies greatly depending on the host species. For example, the fecundity of *M. persicae* on Chinese cabbage and lily is higher than that on string bean and chrysanthemum [10]. The oviposition of *M. persicae* on *Brassica oleracea* and tobacco is lower than that on pakchoi [11]. Currently, published reports on host adaptabilities of *M. persicae* primarily focus on feeding behavior or life table, but there is no report on comprehensive evaluation of host adaptability of *M. persicae* by combining feeding behavior, life table, and population dynamics.

Studying the feeding behavior and life characteristics of aphids is essential to understand host adaptabilities, and may help exploring the possible host transfer pathways of *M. persicae* to provide information for the development of more effective control methods against this aphid [12]. In addition to directly damaging plant tissues and causing serious tissue distortion, aphid probing and feeding can also indirectly spread viruses to host plants [13,14]. Aphids, which are different from chewing insects, directly obtain nutrition and sap from the phloem and xylem via an intercellular pathway using their stylets, which are specialized mouthparts that cannot induce significant damage to plant tissues [15,16]. The feeding behavior of hemipterans is not directly observable but can be monitored using the electrical penetration graph (EPG) technique [17,18]. EPG signals reflect the stylet tip positions within plant tissues [19]. Nowadays, the EPG technique is a relatively precise and rigorous method widely used to assess aphid host specificity [20–22]. The life table is a major tool for studying and analyzing the dynamics of insect populations. Compared with the traditional life table, the age-stage two-sex life table can comprehensively count and analyze the growth, development, reproduction, and survival of all insect individuals to reveal the dynamic parameters of insect populations more accurately [23,24].

In this study, five host plants: tobacco, radish, Chinese cabbage, *B. oleracea*, and rape, were used as experimental materials. The EPG technique has been used to measure the feeding behavior of *M. persicae* on five different host plants. In addition, the feeding of *M. persicae* on these five host plants was considered for constructing life tables, and their development, longevity, and reproductive performance were analyzed to assess their life characteristics on target hosts. Furthermore, the growth trend of the *M. persicae* population was predicted. This is the first study to compare the adaptability of *M. persicae* in five different host plants by combining the methods of feeding behavior, life table, and population dynamics. Our study aimed to offer theoretical support for population monitoring and strategy management of *M. persicae*.

2. Materials and Methods

2.1. Test Materials

2.1.1. Insects

The *M. persicae* specimens utilized in this experiment were originally obtained from a tobacco (*Nicotiana tabacum* L.) field in Guiyang, China (latitude 26°24' N, longitude 106°41' E). These aphids were raised at the Institute of Entomology, Guizhou University, since August 2021. *M. persicae* were reared on tobacco plants (Yunyan 87) inside an insect-proof cage (50 × 50 × 50 cm), which was maintained in climate-controlled chambers. An adult apterous aphid from spare communities was transferred to the five different host plants. After rearing the aphids for three generations, adults were collected and used for the study. Before the experiments, insects were reared at 25 ± 1 °C and 60 ± 10% relative humidity (RH), with a 16L:8D photoperiod.

2.1.2. Plants

Yunyan 87 was sown on a float seedling tray in 160 holes, transplanted to a flowerpot when the tobacco seedling grew to the four true-leaf stage, and used at the seven true-leaf stage. Radish (*Raphanus sativus* L.), Chinese cabbage (*Brassica pekinensis* L. Rupr.), Brassica

oleracea (*B. oleracea* L. var. *acephala* DC), and rape (*Brassica napus* L.) were all uniformly grown in greenhouses. The seedlings were transplanted when effective true leaves reached four or more leaves. The plants of the same size and growth status were selected and transplanted into plastic pots (8 × 8 × 10 cm), such that there was one plant per pot. The plants were maintained in an artificial climate chamber [25 ± 1 °C, 60 ± 10% RH, 16L:8D photoperiod]. When the effective true leaves of all host plants grew to seven leaves, they were used for the experiments.

2.2. Test Methods

2.2.1. EPG Parameter Measure

A DC-EPG Giga-8 system (EPG Systems, Wageningen, The Netherlands) was used to monitor the probing and feeding activities of *M. persicae* on five host plants. A copper electrode connected to an electropenetrograph was inserted into the moist soil of the host plants, and another copper “insect” electrode was connected to the head stage amplifier. The insect electrode was a gold wire (length, 2 cm and diameter, 15 µm), and the terminal of the gold wire was attached to *M. persicae* via another thin gold wire. Wired aphids were fasted for 2 h during acclimatization to the pressure of the gold wire. Wired aphids were fasted for 2 h during acclimating to the pressure of the gold wire. The wired insect was connected to the amplifier using a copper nail inserted into the EPG probe and placed on the abaxial side of the youngest fully expanded leaf of the potted host plant. The feeding behavior of *M. persicae* on these five host plants was conversion into different waves. The experiments were conducted inside a Faraday cage to avoid electrical noises in the laboratory. EPGs were continuously recorded for 6 h with a fresh insect and a new host plant for each replicate; 15 effective repetitions were selected for statistical analysis. All experiments were performed at 25 ± 1 °C and 60 ± 10% RH. The EPG waveforms were recorded using Stylet+d software downloaded from the website <http://www.epgsystems.eu/> (accessed on 2 March 2021), and Stylet+a was used to analyze the waveform events [15,25–27]. Then, an Excel workbook was used for automatic EPG parameter calculation.

2.2.2. Life Table Parameter Measure

The development, survival, and reproduction of *M. persicae* fed on tobacco, radish, Chinese cabbage, *B. oleracea*, and rape were investigated and compared. During the experiment, the newly hatched (0–6 h) larvae of *M. persicae* were individually transferred onto leaf disks (diameter, 3.4 cm and depth, 1 cm) in a plastic dish with 2% water agar culture medium; the plate was covered with a mesh screen for aeration. The plates were kept in a climatic chamber at 25 ± 1 °C and 65 ± 5% RH under a 16L:8D photoperiod. The nymph development time of different stages, preadult duration, adult longevity, mean longevity, reproduction period, and the number of progeny produced per female were recorded from birth to death for each aphid. The fresh leaves of all treated host plants were renewed once daily. The exuviae and newborn nymphs were removed at every 12 h.

2.2.3. Life Table Analysis

The net reproductive rate (R_0) refers to the total number of offspring produced by an individual after one generation and is calculated using the following formula:

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

The intrinsic rate of increase (r) refers to the maximum growth rate of a population under ideal environmental conditions with stable biological and abiotic factors in which the influence of other species is completely excluded. It is calculated using the following formula [28]:

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

The finite rate of increase (λ) refers to the total growth rate within a certain period and is calculated as follows:

$$\lambda = e^r$$

The mean generation time T indicates the time required for the population to increase to R_0 times of its original size when the population age structure shows a stable distribution. It is calculated using the following formula:

$$T = \frac{\ln R_0}{r}$$

2.2.4. Population Development

For all host plants, the population dynamics of *M. persicae* was determined using a no-selection test. During the whole experiment, the five tested host plants were placed in a plastic salver (diameter, 18 cm), which was filled with water (depth, 2 cm) to hinder aphids from moving between plants. Ten newly exuviated (0–6 h) adult apterous aphids were transferred onto the leaf abaxial surface of the potted host plants from the same cultivar (10 host plants for each cultivar). The experiments were conducted under controlled conditions of 25 ± 1 °C temperature, $60 \pm 10\%$ relative humidity, and 14L:10D photoperiod. The total numbers of aphids, adults, and nymphs were counted on days 3, 6, 9, 12, and 15 of the experiment.

2.2.5. Data Analysis

Tukey's test ($p < 0.05$) was used to analyze all parameters of the host plants. Differences in the probing and feeding behavior parameters among different host plants of *M. persicae* were assessed using SPSS 26.0. In the absence of normal distribution, data regarding the feeding behavior and life table parameters of *M. persicae* were converted using $\ln(x + 1)$ or $\sqrt{x + 1}$ transformation. If the difference was significant, the mean parameter values of the aphids on various host plants were assessed using one-way analysis of variance with Fisher's least significant difference test at $\alpha = 0.05$. Raw data on the mean fecundity and three developmental periods (pre-reproductive, reproductive and post-reproductive) of *M. persicae* were compared using the TWO-SEX-MSChart program [29–31]. Parameters such as intrinsic rate of population growth (r), finite rate of population growth (λ), net rate of reproduction (R_0), and average period length of one generation (T) were obtained from the output of the software. We used the bootstrap technique with 100,000 resampling to obtain the standard errors of all life table parameters including r , λ , R_0 , T , adult longevity, and fecundity [32,33].

3. Results

3.1. Probing Behavior of *M. persicae* on Five Different Host Plants

M. persicae revealed seven distinct EPG waveforms on all five hosts: non-probing (np), pathway (C), potential drop (pd), derailed stylet mechanics (F), sieve element salivation (E1), passive phloem ingestion (E2), and xylem ingestion (G). *M. persicae* reached the xylem sieve elements on the five tested plants. C and E2 waveforms emerged in higher percentages for all EPG parameters, whereas waveform G appeared in lower percentages, i.e., between 4.8% and 8.9% (Figure 1). The vast majority of the EPG parameters showed significant discrepancies among the five host plants.

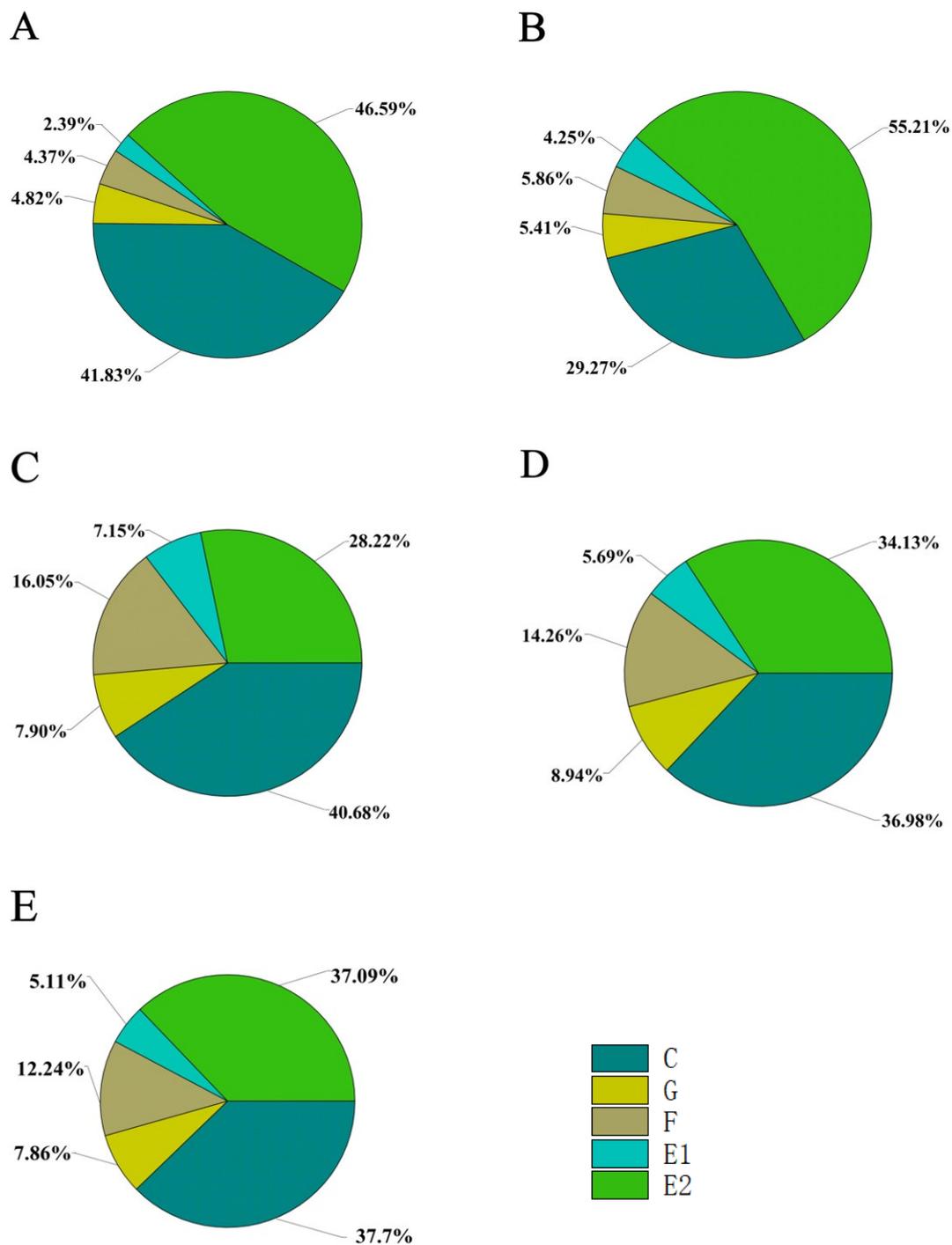


Figure 1. Average percentage of the total time required by *M. persicae* stylet for feeding on the tissues of five different host plants: tobacco (A), radish (B), Chinese cabbage (C), *B. oleracea* (D), and rape (E). The generated EPG waveforms mainly include the following five types: pathway waveforms (C), xylem ingestion (G), derailed stylet mechanics (F), sieve element salivation (E1), and passive phloem ingestion (E2).

3.2. Pathway Activities

The probe count on *Brassica oleracea* was significantly higher than that on radish. Moreover, the sum time of the np wave on tobacco was significantly lower than that on Chinese cabbage and *B. oleracea*. The aphids required a significantly longer time to the first probe on Chinese cabbage than on tobacco and radish. Nevertheless, no evident

discrepancies were observed in the duration of the G wave, mean duration of the pd wave, duration of the first probe, number of short probes, number of probes to the first E1 and number of G waves among the five host plants. The count of pd waves on *B. oleracea* was significantly higher than on other host plants, except for tobacco. The total duration of the C wave was significantly extended on tobacco compared with that on radish and *B. oleracea*. The number of F waves and duration of F waves on tobacco and radish were significantly lower than those on Chinese cabbage, *B. oleracea*, and rape (Table 1).

Table 1. EPG parameters of *M. persicae* feeding on the nonpenetration phase of five host plants.

EPG Parameter	Tobacco	Radish	Chinese	<i>Brassica oleracea</i>	Rape
			Cabbage		
Count probes	7.47 ± 0.72 ab	5.13 ± 1.30 b	6.87 ± 1.21 ab	10.13 ± 1.97 a	6.87 ± 0.94 ab
Sum time of np wave (min)	41.93 ± 6.80 b	62.29 ± 16.80 ab	106.16 ± 24.24 a	93.09 ± 13.61 a	74.06 ± 13.63 ab
Time to 1st probe (min)	3.69 ± 1.43 b	2.02 ± 1.08 b	10.87 ± 3.06 a	6.89 ± 2.62 ab	5.89 ± 3.55 ab
Duration of 1st probe (min)	42.02 ± 7.58	58.31 ± 10.75	46.16 ± 11.24	31.70 ± 7.40	54.28 ± 14.24
Number of probes to the 1st E1	5.53 ± 0.94	4.87 ± 0.89	6.00 ± 0.97	6.93 ± 0.96	5.8 ± 0.72
Number of pd	89.93 ± 8.34 ab	68.87 ± 15.08 b	81.67 ± 11.36 b	121.93 ± 15.87 a	71.4 ± 8.14 b
Mean duration of pd (s)	5.14 ± 0.30	5.64 ± 0.25	5.39 ± 0.27	5.74 ± 0.24	5.80 ± 0.23
Number of short probes C (<3 min)	3.93 ± 0.51	3.07 ± 0.59	2.87 ± 0.61	4.73 ± 1.08	3.67 ± 0.73
Total duration of C (min)	133.06 ± 12.73 a	87.12 ± 10.05 b	103.13 ± 16.07 ab	98.75 ± 8.84 b	107.78 ± 9.25 ab
Number of G	0.8 ± 0.17	0.93 ± 0.27	1.20 ± 0.30	1.00 ± 0.26	1.33 ± 0.30
Duration of G (min)	15.35 ± 2.86	16.12 ± 3.23	20.01 ± 3.44	23.87 ± 4.38	22.48 ± 3.20
Number of F	0.67 ± 0.19 b	0.6 ± 0.19 b	1.93 ± 0.38 a	2.00 ± 0.35 a	1.87 ± 0.32 a
Duration of F (min)	13.91 ± 4.09 b	17.46 ± 3.43 b	40.67 ± 7.51 a	38.08 ± 6.94 a	34.99 ± 5.50 a

Data are represented as the mean ± standard error (SE). Significant differences between different host plants within the same rows are indicated by a, b, and c ($p < 0.05$, Tukey's test).

3.3. Phloem and Xylem Activities

The number of E1 waves on Chinese cabbage was the highest and was significantly higher than that on tobacco. A similar result was observed for the total duration of the E1 wave. The time from the first probe to the first E2 (min) of *M. persicae* on Chinese cabbage was significantly longer than that on tobacco and radish. The total duration of the E2 wave on tobacco and radish was significantly higher than that on Chinese cabbage, *B. oleracea*, and rape (Table 2). Waveform E2 of *M. persicae* on radish (55.21%) was approximately two times higher than that on Chinese cabbage (28.22%; Figure 1). The feeding waveform of *M. persicae* in the phloem stage (E1 + E2 waves) of radish showed the largest proportion (59.46%), whereas that of Chinese cabbage showed the smallest proportion (35.37%). For waveform G (%), *B. oleracea* was significantly longer than that on tobacco (Figure 1). The total duration of the E2 wave on tobacco and radish was significantly higher than that on Chinese cabbage, *B. oleracea*, and rape (Table 2).

Table 2. EPG parameters of *M. persicae* feeding on phloem phase of five host plants.

EPG Parameter	Tobacco	Radish	Chinese Cabbage	<i>Brassica oleracea</i>	Rape
Number of E1	1.07 ± 0.27 b	1.33 ± 0.35 ab	2.40 ± 0.42 a	1.87 ± 0.42 ab	1.73 ± 0.57 ab
Total duration of E1	7.61 ± 1.68 b	12.64 ± 2.39 ab	18.11 ± 3.09 a	15.19 ± 3.33 ab	14.58 ± 2.85 ab
Number of E2	1.87 ± 0.29	1.53 ± 0.31	1.27 ± 0.25	1.47 ± 0.26	1.60 ± 0.43
Time from 1st probe to 1st E2 (min)	65.75 ± 8.84 b	71.04 ± 12.03 b	118.07 ± 14.75 a	85.34 ± 16.43 ab	96.43 ± 13.41 ab
Number of sustained E2 (>10 min)	1.27 ± 0.21	1.07 ± 0.21	0.8 ± 0.2	1.00 ± 0.17	1.07 ± 0.28
Total duration of E2 (min)	148.17 ± 11.49 a	164.39 ± 11.15 a	71.51 ± 12.68 b	91.10 ± 11.87 b	106.04 ± 15.24 b

Data are represented as the mean ± standard error (SE). Significant differences between different host plants within the same rows are indicated by a, b, and c ($p < 0.05$, Tukey's test).

3.4. Life History Statistics of *M. persicae* on Five different Host Plants

The development periods for each immature stage and adult longevity of *M. persicae* fed on five host plants are shown in Table 3. Each immature stage from the first to fourth instars developed significantly faster on tobacco than on radish, except for the fourth instar. Adult longevity was significantly higher on radish, *B. oleracea*, and rape than on tobacco and Chinese cabbage (all $p < 0.01$). The adult pre-reproductive period (APOP) of *M. persicae* reared on Chinese cabbage (1.20 day) was the longest and significantly greater than that of the other four host plants. In addition, the total pre-reproductive period (TPOP) of *M. persicae* reared on rape (8.05 days) was the longest, whereas the shortest TPOP was documented in tobacco (6.46 days). The fecundity was highest in rape (53.73), whereas the shortest fecundity was documented in Chinese cabbage (36.52).

Table 3. Preadult duration, adult longevity, mean longevity, reproduction period, and mean fecundity of *M. persicae* on five host plants.

Stage	Tobacco	Radish	Chinese Cabbage	<i>Brassica oleracea</i>	Rape
First instar (N1)	1.51 ± 0.11 bc	1.57 ± 0.05 abc	1.76 ± 0.07 a	1.74 ± 0.05 ab	1.48 ± 0.05 c
Second instar (N2)	1.57 ± 0.09 c	2.06 ± 0.05 b	1.65 ± 0.08 c	1.92 ± 0.06 bc	2.20 ± 0.05 a
Third instar (N3)	1.57 ± 0.08 b	2.17 ± 0.05 a	1.67 ± 0.07 b	2.01 ± 0.04 a	2.15 ± 0.04 a
Fourth instar (N4)	1.27 ± 0.07 bc	1.14 ± 0.06 bc	1.51 ± 0.08 a	1.10 ± 0.06 c	1.34 ± 0.09 ab
Preadult duration	5.85 ± 0.18 c	6.89 ± 0.08 ab	6.56 ± 0.14 b	6.77 ± 0.06 ab	7.18 ± 0.11 a
Adult longevity	14.52 ± 0.48 c	19.16 ± 0.37 a	17.58 ± 0.49 b	19.12 ± 0.36 a	19.22 ± 0.50 a
Mean longevity	20.34 ± 0.51 c	26.02 ± 0.40 a	24.07 ± 0.50 b	25.63 ± 0.41 a	26.21 ± 0.59 a
APOP	0.66 ± 0.05 b	0.68 ± 0.04 b	1.20 ± 0.13 a	0.76 ± 0.06 b	0.88 ± 0.08 b
TPOP	6.46 ± 0.17 c	7.57 ± 0.08 b	7.76 ± 0.16 ab	7.53 ± 0.10 b	8.05 ± 0.13 a
Reproduction period	11.90 ± 0.31 c	16.55 ± 0.45 a	14.91 ± 0.45 b	15.81 ± 0.50 ab	15.07 ± 0.35 b
Mean fecundity	40.67 ± 2.58 bc	53.73 ± 1.95 a	36.52 ± 2.74 c	47.24 ± 1.91 b	50.78 ± 2.53 a

Data are represented as the mean ± standard error (SE). Significant differences between different host plants within the same rows are indicated by a, b, and c ($p < 0.05$, Tukey's test).

3.5. Population Parameters of *M. persicae* Reared on Five Host Plants

The population parameters were calculated based on the data from the entire cohort [29]. The intrinsic rate of increase (r), finite rate of increase (λ), net reproductive rate (R_0), and mean generation time (T) of *M. persicae* on different hosts were estimated using the bootstrap method (Table 4). Statistical analyses showed that r and λ for *M. persicae* fed on tobacco were 0.3918 and 1.4797 per day, respectively; these values were significantly higher than those for feeding on other plants (all $p < 0.05$). R_0 and T showed no significant differences on radish (47.3000 and 12.04 days, respectively) and rape (44.7076 and 12.39 days, respectively), although both were significantly higher than on Chinese cabbage (35.1570 and 11.04 days, respectively).

Table 4. Population parameters of *M. persicae* on five host plants.

Parameter	Tobacco	Radish	Chinese Cabbage	<i>Brassica oleracea</i>	Rape
r (d^{-1})	0.3918 ± 0.0092 a	0.3203 ± 0.0065 b	0.3224 ± 0.0093 b	0.3191 ± 0.0059 b	0.3066 ± 0.0082 b
λ (d^{-1})	1.4797 ± 0.0136 a	1.3775 ± 0.0089 b	1.3805 ± 0.0129 b	1.3760 ± 0.0080 b	1.3589 ± 0.0111 b
R_0 (offspring/individual)	38.43 ± 2.71 bc	47.30 ± 3.17 a	35.16 ± 2.72 c	44.63 ± 2.54 ab	44.71 ± 3.37 ab
T (d)	9.31 ± 0.22 d	12.04 ± 0.09 ab	11.04 ± 0.21 c	11.90 ± 0.10 b	12.39 ± 0.17 a

Data are represented as the mean \pm standard error (SE). Significant differences between different host plants within the same rows are indicated by a, b, and c ($p < 0.05$, Tukey's test).

3.6. Population Dynamics

The population of *M. persicae* on the five different host plants increased with time, with tobacco and radish showing the fastest growth rate. For 3 days, the population of *M. persicae* on the five host plants did not differ significantly. However, for 15 days, the population number on tobacco (446.90) and radish (455.30) was 1.36 times that on Chinese cabbage (337.20) and *B. oleracea* (328.20), and the population number on tobacco and radish was significantly higher than that on Chinese cabbage, *B. oleracea*, and rape (Figure 2).

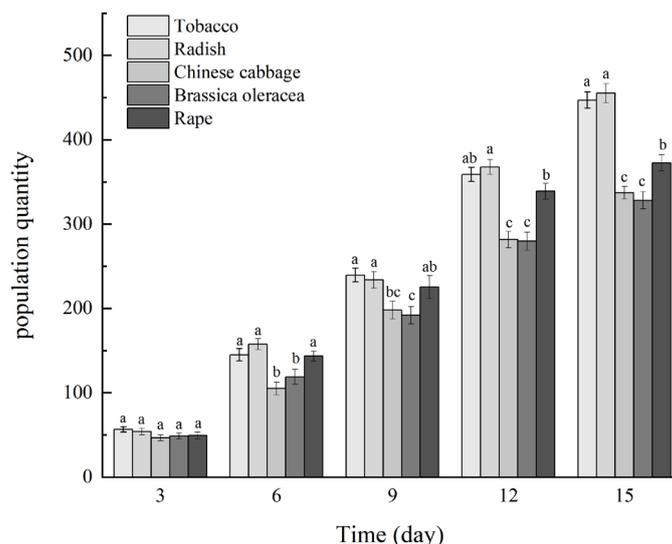


Figure 2. Population dynamics of *M. persicae* on the five host plants. Lowercase letters indicate significant differences ($p < 0.05$) among the five host plants, which were assessed using one-way analysis of variance with Fisher's least significant difference test at $\alpha = 0.05$.

4. Discussion

After long-term coevolution, insects and their host plants forge various forms and degrees of mutual adaptation. Host plants provide food and habitat for the insects, and a suitable host environment which is the basis for insect survival [34]. To survive and reproduce in a better way, insects must continuously improve their adaptive ability toward host plants. Study of the host adaptation mechanism can provide a reference for pest control and development of new insect-resistant crops. The current study evaluated the adaptabilities of *M. persicae* on five host plants by combining three methods of feeding behavior, life table parameters, and population development.

Feeding activities and efficiency are important indexes to evaluate the adaptability of insects to host plants [35]. In our studies, the probing and feeding behavior of *M. persicae* in five different host plants were evaluated using the EPG technique. We observed the following seven waveforms: non-probing (np), pathway (C), potential drop (pd), derailed stylet mechanics (F), sieve element salivation (E1), passive phloem ingestion (E2), and xylem ingestion (G). A similar result has been reported by Zeng et al. [36]. Various studies have

demonstrated that the plant accession or probing behavior of aphids could be affected by the characteristic surface properties of a plant, a possible resistance factor to aphids [37,38]. When aphids attach to a plant, they first evaluate the surface characteristics of the host plant and then determine its internal composition [39]. The count probes of *M. persicae* on *B. oleracea* increased significantly, whereas those on radish were lower than the ones on other hosts. More probing revealed that *M. persicae* exhibited resistance toward *B. oleracea* and constantly shifted its feeding sites. Thus, *M. persicae* appeared to easily needle probe, accepting and initiating feeding on radishes more often than on other hosts. The sum time of the np wave by *M. persicae* on *B. oleracea* was greater than that on other host plants, indicating that *M. persicae* finds it more difficult to penetrate the surface of *B. oleracea* than that of other host plants. This result may be related to the indicated color, leaf surface structures, and surface physical and chemical factors. In the aphid–plant interaction, the plant surface can play a vital function in host plant susceptibility. Wojcicka detected the exterior leaf surfaces (wax content) changes during plant development [40]. Insect action on the leaf's surface can be physically impeded by wax content. A slower increase in *M. persicae* population was observed on plants with higher epicuticular wax levels, as reported by Bjorkman et al. [41]. This study demonstrated that the physical structure or chemical composition of plant surface has a significant impact on the feeding behaviors of aphids. Zhao et al. revealed that the structural traits of leaf epidermis may affect the time to the first probe in the brown citrus aphid *Toxoptera citricida* (Kirkaldy) (Hemiptera: Aphididae) [42]. The aphid took the shortest time to the first probe on radish compared with that on other host plants. The reason for the faster probe may be due to less waxy content on radish leaves but this needs to be proved by further investigation.

Aphids mainly feed on the phloem sap of host plants, and their performance is determined by nutrients and defensive metabolites in their diet. Therefore, the index of phloem factors plays a key role in evaluating the suitability of host plants for aphids [35,43]. The E1 wave represents the process of an aphid stylet prick into the phloem sieve tube and secretion of saliva into tube; the aphid's saliva plays a pertinent role in overcoming phloem-related resistance [35]. In the present study, the number and total duration of E1 waves on tobacco and radish were less than those on other host plants, thereby indicating that the aphids had to mount a stronger defense response on other host plants. The time required for phloem sap feeding is an important parameter and is closely associated with the host plant suitability for aphids [44]. During the 6 h experiment, the total duration of E2 on tobacco and radish was longer than that on Chinese cabbage, *B. oleracea*, and rape, and the longest duration was found on radish, thus indicating the higher suitability of aphids on radish than on other host plants.

Host plant species and cultivars can significantly affect the life history-related parameters of herbivores [43]. The adaptability of phytophagous insects to different host plants is closely associated with the morphology, nutritional composition, and secondary metabolic compounds of the host [10,44]. Changes in host plant adaptability can affect the life table parameters of phytophagous insects. In the current study, we used the life table parameters of *M. persicae* in five different host plants to investigate the degree of host plant adaptability. The population parameters, i.e., the net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and mean generation time (T) can be used to determine the growth ability of a specific population under ideal environmental conditions [45]. These parameter values frequently alter with changes in the external environment and host plant species [46–48]. The intrinsic rate of increase (r) and net reproductive rate (R_0), which are important life table parameters for analyzing the growth, development, and reproduction of a specified population, are essential indicators for affecting the growth potential and fecundity of a population under specific food and environmental conditions. These parameters comprehensively evaluate the biological and physiological characteristics associated with population growth capacity and reproduction and are usually used to compare the adaptability of species under different climatic and food conditions [49]. In previous studies, *M. persicae* showed no significant difference in the intrinsic rate of increase

(r) on radish, Chinese cabbage, *B. oleracea*, and rape, indicating that its population growth potential is equally high on radish, Chinese cabbage, *B. oleracea*, and rape. The R_0 of *M. persicae* on radish reached the maximum among the five host plants, indicating that *M. persicae* was more suitable for reproduction on radish. The adult reproductive potential is determined based on the nutrition obtained during the preadult stage; therefore, the preadult duration is closely associated with adult fecundity [50]. In this study, the higher fecundity and shorter adult pre-reproductive period (APOP) of *M. persicae* reared on radish suggests that radish is more suitable as an alternative host plant for rearing *M. persicae* than Chinese cabbage, *B. oleracea*, and rape. The fecundity of *M. persicae* on radish was greater than that on other host plants. The statistical analyses of *M. persicae* population dynamics also revealed that the highest population of *M. persicae* was observed on radish. Moreover, Hon et al. reported similar results [51].

5. Conclusions

This study showed that feeding on radish by *M. persicae* could reduce the mechanical difficulties and increased the time of phloem sap ingestion, unlike Chinese cabbage. Additionally, the fecundity and the net reproductive rate of *M. persicae* reared on radish reached the maximum. The population number of *M. persicae* on tobacco and radish were significantly higher than that of other host plants after 15 days. According to the results, radish is the optimal host although the adaptability of *M. persicae* differed significantly according to the target hosts. Our results illuminate the adaptability of different hosts, and not only contribute a practical application for an integrated pest management (IPM) system but also elucidate the mechanism involved in making these host plants adaptive to *M. persicae*. Furthermore, this acquired knowledge will further our understanding of generating host plant specialization and improve the management strategies for *M. persicae*.

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