Fertilizer-Mediated Ditrophic Interactions between *Aphis gossypii* and Cucumber

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ABSTRACT

The effects of different fertilizers including 'Cow manure', 'Vermicompost', 'NPK' (20-20-20 NPK), 'NPKBN' (NPK+*Azotobacter vinelandii*), 'NPKBP' (NPK+*Pantoea agglomerans*+*Pseudomonas putida*), and 'NPKBNBP' (NPK+*Azotobacter vinelandii*+*Pantoea agglomerans*+*Pseudomonas putida*) were compared with the control treatment. Comparisons included not only the nutrient and chlorophyll content of cucumber leaves, but also the demographic parameters and body size of *Aphis gossypii* Glover. The highest nitrogen content (2.45%) was observed in 'NPKBN' and the highest phosphorus, along with potassium content (0.58 and 12.17%, respectively) was observed in 'cow manure' treatment. The highest chlorophyll content (37.51 SPAD units) was measured in 'NPKBNBP' treatment. Results showed that the intrinsic rate of increase (r) varied from 0.409 (in 'Cow manure') to 0.480 d^{-1} (in 'NPKBP') under application of different fertilizers. Net Reproductive rate (R_0) varied from 71.65 to 79.25 nymphs/individual in 'Vermicompost' and 'NPKBP' treatments, respectively. The largest (1.28 mm) and smallest (1.00 mm) body length of the aphids was measured on 'Vermicompost' and 'Control', respectively. Results revealed that 'NPKBP' was the most suitable fertilizer for population growth of *A. gossypii*, compared with the other treatments, and the aphid's longevity and fecundity was relatively low under 'Vermicompost' application.

Keywords: Aphid performance, Cow manure, Fecundity, Life table, Vermicompost.

INTRODUCTION

The *Aphis gossypii* Glover (Hemiptera: Aphididae) is a cosmopolitan, polyphagous pest and widely distributed in tropical, subtropical, and temperate regions of the world (Kersting *et al*., 1999). The populations of this pest on cotton and cucurbits can be large and damaging (van Emden and Harrington, 2007). Fertilizers are among the largest inputs in agroecosystems and can affect the nutritional quality and nutrient levels of the treated plants that result in the modified sensitivity and susceptibility of such plants to insect pests (Altieri and Nicholls, 2003;

Garratt *et al*., 2010). Furthermore, the type of fertilizers, crop cultivar, and insects-species, as well as their interactions can have different effects on pest population (Yardım and Edwards, 2003). Some studies demonstrated that organic fertilizers including composted or un-composted organic matters can suppress the attacks of insect pests or decrease its population (Culliney and Pimentel, 1986; Phelan *et al*.,1995; Yardım and Edwards, 2003). Using the substitution rates of 20% and 40% of Vermicompost in a soil-less plant growth medium suppressed the populations of *Myzus persicae* Sulzer and *Pseudococcus* spp. on peppers (Arancon *et*

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al., 2005). However, barley plant grown with organic fertilizers was more attractive to cereal aphids, compared with plants getting conventional chemical fertilizer (Garratt *et al.*, 2010). Nitrogenous fertilizers application has influenced survivorship, fecundity, intrinsic rate of increase, and many other life history attributes of different insect pests (Jahn *et al.*, 2005). Study on *A. gossypii* showed that adult and nymph densities as well as intrinsic rate of increase of the pest were positively correlated with nitrogen fertilization levels of cotton plants resulting in bigger and darker aphids (Nevo and Coll, 2001). Some of the Plant Growth Promoting Rhizobacteria (PGPR) has gained worldwide attention and their benefits have been accepted for agricultural application (Figueiredo *et al.*, 2011). One of PGPR modes of action is being a biofertilizer as they can promote growth of plants by bioprotectants and biostimulants (Ramjegathesh *et al.*, 2013). Herman *et al.* (2008) found that, although there were higher populations of *M. persicae* on control and *Bacillus* spp. PGPR-treated pepper plants, fruit yield in the *Bacillus* PGPR treatment and insecticide-treated plant was similar.

As there are various effects reported from different studies, it seems that understanding of different fertilizers' effects on insect pest could present a good view on the issue at the first glance. Therefore, more studies are needed to investigate the effect of different fertilizers on the nutritional quality of plants and their linked insect pests to get a better understanding of the interactions among different types of fertilizers, plants and pests. Accordingly, the present study aimed to investigate the potential effects of organic, conventional chemical fertilizer and PGPR biofertilizers on the leaf nutrient and chlorophyll content of cucumber plants. Furthermore, the effects of these possible changes on life table parameters and body size of *A. gossypii* was assessed under laboratory conditions.

MATERIALS AND METHODS

Substrate Preparation

Substrates were prepared from soil, sand, perlite and water-coco peat and the proportion was 1:2:2:3, respectively. Substrates and cylindrical pots (16 cm diameter and 14 cm deep) were sterilized at 121ºC, 15 psi for 2 hours and 20 minutes, respectively.

Fertilizer Treatments

The fertilizer treatments were as follows: (I) 'Control': Untreated, (II) 'Cow manure': 100 g and 50 g traditional cow manure compost was added before seed planting and at maturity stage, respectively, (III) 'Vermicompost': 100 g Vermicompost was added to substrate before seed planting and 50 g was added at maturity stage, (IV) 'NPK': 200 mg conventional chemical 20-20-20 NPK was applied every two weeks to achieve a total of 800 mg per container, (V) 'NPKBN': 50 mL of nitrogen-fixing bacteria (*Azotobacter vinelandii*) was added at 5×10^5 CFU (colony-forming unit) per mL to the substrate surface of pots, (VI) 'NPKBP': 50 mL of phosphorus solubilizing bacteria (*Pantoeaagglomerans* and *Pseudomonas putida*) at 5×10^5 CFU per mL was added to each container, (VII) 'NPKBNBP': Simultaneously 50 mL nitrogen-fixing bacteria and 50 mL phosphorus solubilizing bacteria (at 5×10^5 CFU per mL for each solution) were added on each substrate. In the treatments 'NPKBN', 'NPKBP' and 'NPKBNBP', planting the seed and biofertilizer applications were simultaneous. In addition to the specific biofertilizer in the mentioned treatments, 20-20-20 NPK fertilizer was applied to their substrates as 'NPK' treatment.

Plant Cultivation

Cucumber plants, *Cucumis sativus* L. (BEITH ALPHA OP), were planted in pots

and kept in growth chamber at 27±1°C, 60±5% *RH*, and a photoperiod of 16:8 (L: D) hours. As the cucumber plants reached the maturity stage, they were used in the experiments.

Insect Rearing

The initial population of *A. gossypii* was obtained from the Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran. These aphids were reared on leaves of cucumber plants in growth chamber (WTB Binder, Germany) at 25±1°C, 60±5% *RH*, and a photoperiod of 16:8 (L: D) hours. Then, aphids were reared separately on the leaves of treated cucumber plants for two generations before the experiments.

Leaf Chemical Analysis and Chlorophyll Measurement

Fully grown leaves of the eight-week old plants were removed and analyzed for nitrogen (N), phosphorous (P), and potassium (K) content. Kjeldal method (Jones, 1991), Olsen colorimetric method and flame photometry (Motsara and Roy, 2008) were used for determining NPK content, respectively. In addition, the chlorophyll content was measured in leaves using SPAD-502 chlorophyll meter (Minolta Camera Co. Ltd., Japan).

Leaf Disc

The leaves of each treatment were cut into 2.80 cm diameter leaf discs, which were later placed upside down on water soaked cotton in the Petri dishes (9 cm diameter and 1 cm height) with a net-covered hole in its center (3 cm). In order to maintain the leaves fresh, adequate water was added to each Petri dish daily. The leaf discs were replaced continuously. Transferring aphids from old to new leaf discs was done using a soft hair brush.

Demographic Parameters

Experiments were conducted in the growth chamber at 25±1°C, 60±5% *RH*, and a photoperiod of 16:8 (L: D) hours. Apterous adults were randomly selected from the stock colony and were placed separately on leaves of experimental plants. They were allowed to produce nymphs for 24 hours. The newborn nymphs were individually transferred to leaf disc with up to 60 replicates per treatment. The developmental stage, survival, and fecundity were recorded daily. Observations were continued until the death of all individual.

Age-Stage Life Table

The life history raw data of *A. gossypii* were analyzed according to the age-stage, two-sex life table theory (Chi, 1988; Chi and Liu, 1985). The age-stage Specific survival rate (s_{xj}) (where, x= Age in days and j= Stage); the age-stage specific fecundity (f_{xj}), the age-specific survival rate (l_x), the age-specific fecundity (m_x) and the population growth parameters [the intrinsic rate of increase (r), the finite rate of increase (λ), the net Reproductive rate (R_0) and the mean generation Time (T)] are calculated accordingly (Khanamani *et al.* 2013; Safuraie-Parizi *et al.* 2014; Nikooei *et al.*, 2015). In the age-stage, two-sex life table (Chi and Liu, 1985), the age-specific survival rate and the age-specific fecundity are calculated as follows:

$$l_x = \sum_{j=1}^{k} s_{xj} \tag{1}$$

and

$$m_x = \frac{\sum_{j=1}^{k} s_{xj} f_{xj}}{\sum_{j=1}^{k} s_{xj}} \tag{2}$$

Where, k is the number of insect stages.

The intrinsic rate of increase was estimated using iterative bisection method from the following equation:

$$\sum_{x=0}^{\omega} e^{-r(x+1)} l_x m_x = 1 \tag{3}$$

With age indexed from 0 to ω (last age) (Goodman, 1982).

The mean generation time is the time length that a population needs to increase to R_0-times of its size as the stable age distribution and the stable increase rate are reached, *i.e.*, $e^{rT}= R_0$ or $\lambda^T= R_0$. Thus, the mean generation time was calculated as $T= \ln R_0/r$. The net Reproductive rate (R_0) was estimated using:

$$R_0 = \sum_{x=0}^{\omega} \sum_{j=1}^{k} s_{xj} f_{xj} \qquad (4)$$

Data analysis and population growth parameters (r, λ, R_0 and T) were calculated using the TWOSEX-MSChart program (Chi, 2015). The means and standard errors of the population parameters were estimated by Bootstrap procedure (Efron and Tibshirani, 1994). In the bootstrap procedure, we randomly took a sample of n individuals from the cohort with replacement and the $r_{i\text{-boot}}$ for this bootstrap sample was calculated as:

$$\sum_{x=0}^{\omega} e^{-r_{i-boot}(x+1)} l_x m_x = 1 \qquad (5)$$

Where, the subscript *i-boot* represents the *i*th bootstrap and l_x and m_x are calculated from the n individuals selected randomly with replacement. Generally, the data on the same individual is repeatedly selected. This procedure was repeated m times (m= 10,000) and the mean of these m bootstraps was computed as follows:

$$r_B = \frac{\sum_{i=1}^{m} r_{i-boot}}{m} \qquad (6)$$

The Variance ($VARr_B$) and Standard Errors (SE r_B) of these m bootstraps were calculated as:

$$VARr_B = \frac{\sum_{i=1}^{m} (r_{i-boot} - r_B)^2}{m-1} \qquad (7)$$

$$SEr_B = \sqrt{VARr_B} \qquad (8)$$

The same methods are used for the corresponding estimates of the finite rate of increase, net reproductive rate, and mean generation time. The age-stage life table bootstrap-values of *A. gossypii* on different fertilizer treatments were compared using paired-bootstrap procedure (Khanamani *et al*., 2013; Akköprü *et al*., 2015).

Age-Specific Life Table

In the age-specific life table, the number of female progeny, survival rate of immature

and female adult stages, and daily fecundity were used for estimating different life table parameters (Carey, 1993; Fathipour and Maleknia, 2016).

Body Size

Aphids were separately reared on the leaves of different treatments for five generations before the measurements. For the body size parameters, body length (front of head to cauda) and head width (between lateral borders of eyes) were measured (Nevo and Coll, 2001) using an Olympus SZH10 stereo microscope with graticule (Olympus, Japan).

Statistical Analysis

The data of leaf nutrients, chlorophyll content, as well as the body size parameters were analyzed by one-way ANOVA. Correlation among these data and life table parameter of aphids was done using Pearson's correlation coefficient. The means comparison was performed by Tukey's Honestly Significant Difference (HSD) test using SPSS 21.0 (IBM Corp., 2012).

RESULTS

Leaf Nutrient and Chlorophyll Content

The nutrient contents of the experimental cucumber plants were different significantly (Table 1). The nitrogen content was greater in all fertilizer treatments compared to the control (F= 9.77; df = 6,14; *P*< 0.05) (Table 1). Although the phosphorus content of leaves was highest on 'Cow manure' (F= 55.39; df= 6,14; P< 0.05), there was not any significant difference among other treatments. Furthermore, the potassium on 'Cow manure' was highest while the lowest potassium content was measured in 'Vermicompost' treatment (F= 283.69; df= 6,14; P< 0.05). In addition, significant

Table 1. Effect of different fertilizer treatments on the content of nitrogen, phosphorus, potassium, and chlorophyll of the cucumber plants.[a]

Treatment	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Total chlorophyll (SPAD units)
Control	1.327±0.161b	0.253±0.003b	4.223±0.270b	18.388±1.310c
Cow manure	2.050±0.060a	0.580±0.012a	12.170±0.156a	16.206±1.750c
Vermicompost	2.047±0.116a	0.310±0.012b	1.780±0.215d	27.300±0.764b
NPK	2.123±0.129a	0.257±0.019b	3.123±0.162c	35.613±1.290a
NPKBN	2.453±0.133a	0.277±0.020b	3.587±0.295bc	35.313±2.880ab
NPKBP	2.393±0.053a	0.293±0.017b	3.520±0.132bc	35.406±0.690a
NPKBNBP	2.143±0.130a	0.270±0.020b	2.717±0.164cd	37.513±2.420a

[a] Data (Mean±SE.) in each column followed by the same letters is not significantly different (Tukey's HSD test, $P< 0.05$).

effects of different fertilizer treatments were observed for the leaves chlorophyll concentration (F= 25.548; df= 6,21; P<0. 05) (Table 1). There was a positive correlation between nitrogen and chlorophyll content (r= 0.69, P= 0.04), and a negative correlation between potassium and chlorophyll content (r= -0.68, P= 0.04). Also, no correlation was found between phosphorus and chlorophyll content in leaves (r= -0.62, P= 0.67).

Developmental Time and Survival Rate

The developmental time of *A. gossypii* was significantly different among treatments and ranged from 4.26 days in 'NPKBP', to 5.44 days in 'Cow manure' treatments (F= 7.46; df = 6,227; P< 0.05); while adult longevity values were not different among different

treatments (F= 2.54; df= 6,227; P> 0.05). Total pre-oviposition period (TPOP) of *A. gossypii* was significantly different among different fertilizer treatments (F= 6.35; df= 6,227; P< 0. 05) (Table 2).

The age-stage Specific survival rates (s_{xj}) of *A. gossypii* show the probability that a newborn will survive to age *x* and develop to stage *j* (Figure 1). These curves showed that the newborn nymphs could successfully survive and develop to females in different fertilizer treatments.

Fecundity

The age-specific fecundity (m_x) and age-stage specific fecundity (f_{xj}) of *A. gossypii* under different fertilizer treatments are shown in Figure 2. The highest age-specific fecundity (that is equal to age-stage specific

Table 2. Mean (±SE) developmental time, adult longevity, total pre-oviposition period and fecundity of *Aphis gossypii* under different fertilizer treatments.[a]

Treatment	Development time (Day)	Adult longevity (Day)	TPOP (Day)	Fecundity (Nymphs)
Control	5.33±0.17a	28.46 ±0.64a	5.52±0.11a	71.97±2.52a
Cow manure	5.44±0.16a	27.15±0.59a	5.68±0.15a	77.15±1.73a
Vermicompost	5.34±0.18a	26.25±0.61a	5.59±0.19a	71.66±1.60a
NPK	4.8±0.13ab	27.06±0.82a	5.06±0.16ab	74.40±1.59a
NPKBN	5.24±0.18a	29.18±0.91a	5.59±0.22a	76.47±1.95a
NPKBP	4.26±0.09b	28.82±0.65a	4.53±0.11b	79.24±2.03a
NPKBNBP	4.94±0.16a	26.78±0.77a	5.25±0.19a	74.06±2.40a

[a] Values in each column followed by the same letters are not significantly different (Tukey's HSD test, $P< 0.05$).
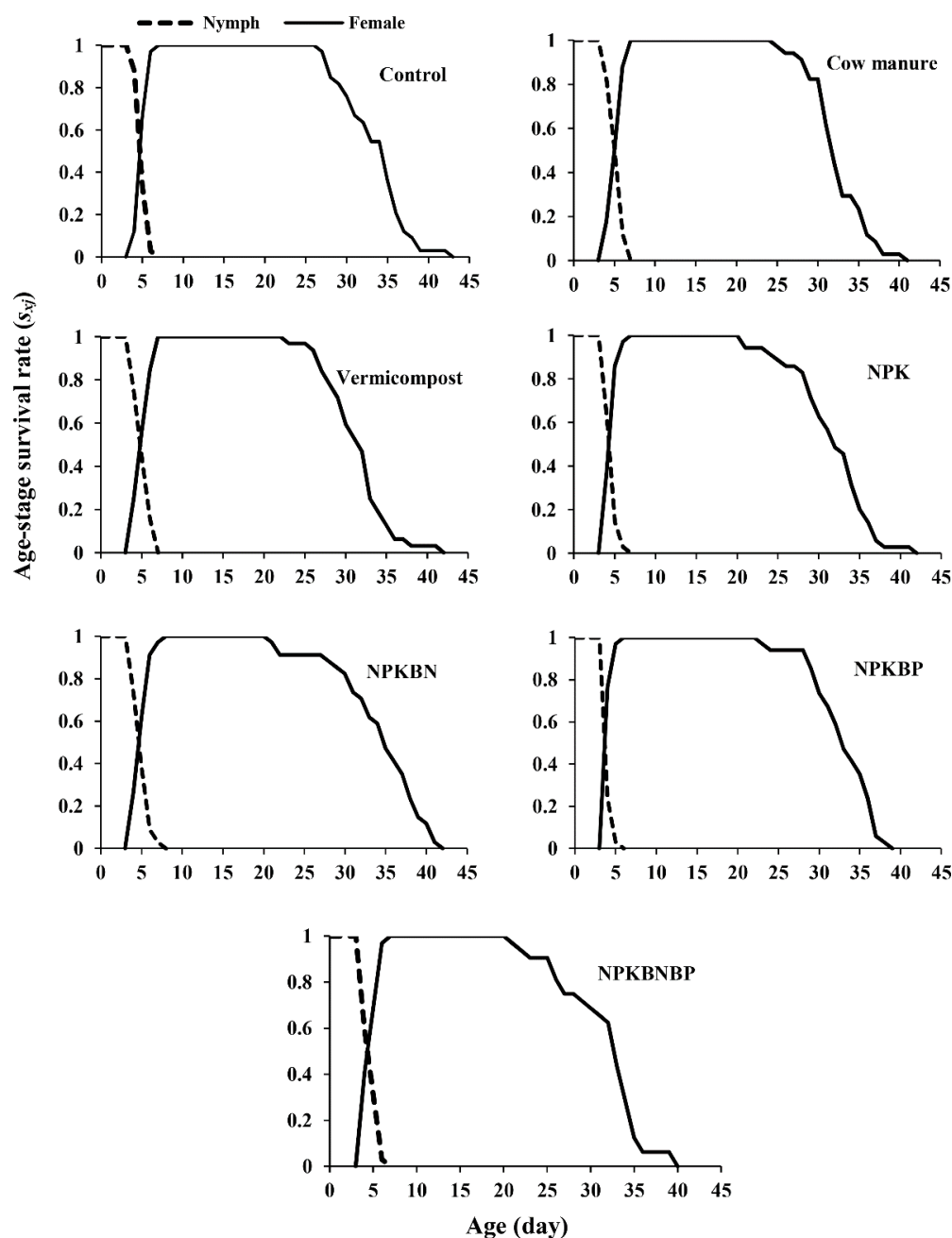
Figure 1. Age-stage Survival rate (s_{xj}) of *Aphis gossypii* under different fertilizer treatments of cucumber.

fecundity) of *A. gossypii* was 7.73, 7.32, 7.53, 7.43, 7.44, 8.35 and 7.93 (individual/individual/day) on 'Control', 'Cow manure', 'Vermicompost', 'NPK', 'NPKBN', 'NPKBP' and 'NPKBNBP', respectively (Figure 2). Also, the mean of total number of nymphs per female was not significantly different (F= 1.93; df = 6,227; P> 0.05) (Table 2).

Population Growth Parameters

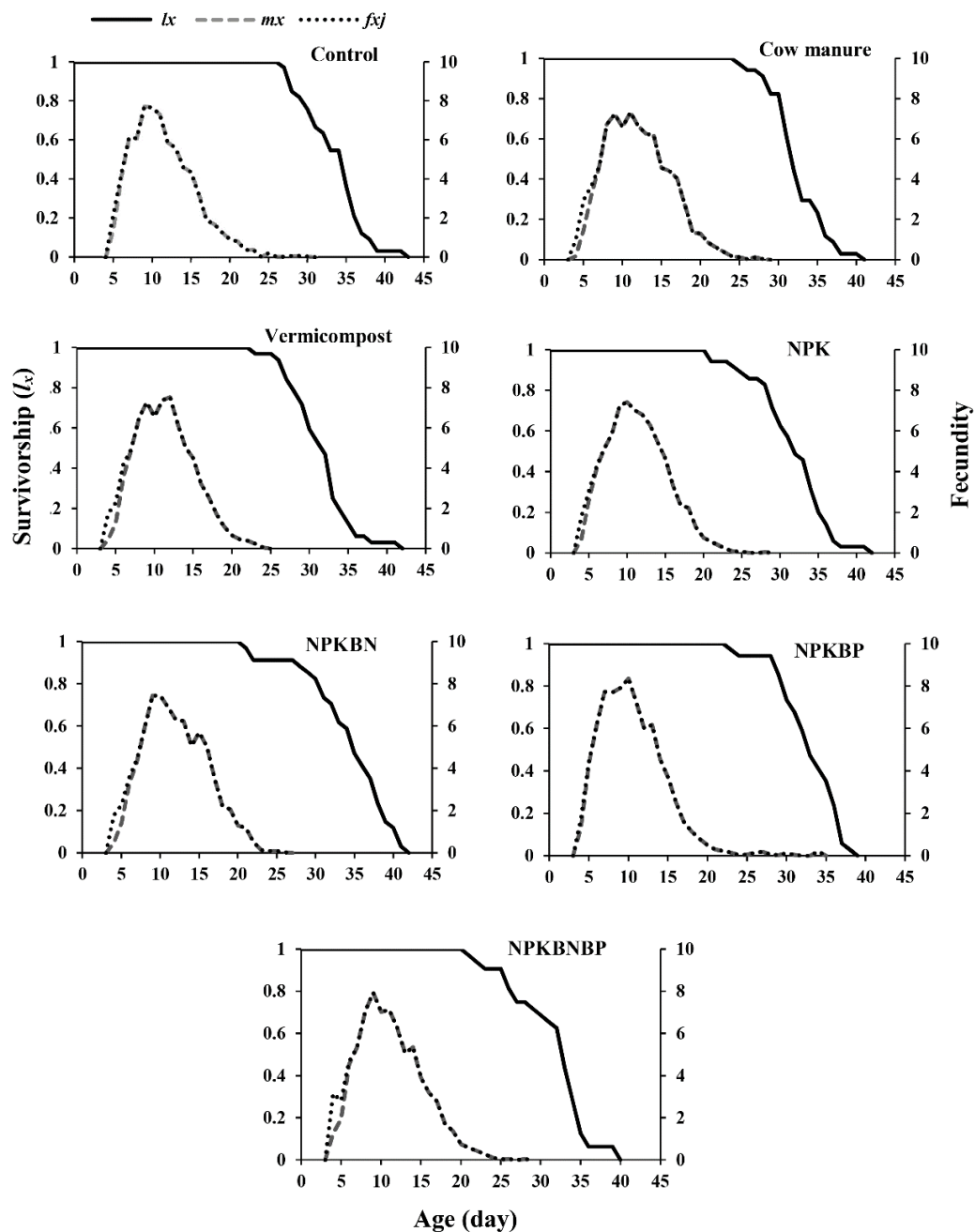The age-stage life table parameters of *A. gossypii* estimated by the bootstrap

Figure 2. Age-specific survivorship (l_x), age-stage specific fecundity (f_{xj}) and age-specific fecundity (m_x) of *Aphis gossypii* reared under different fertilizer treatments of cucumber.

procedure, as well as its age-specific life table parameters, are shown in Table 3. Net Reproductive rate (R_0) values of *A. gossypii* were significantly different among different fertilizer treatments. The intrinsic rate of increase (r) and finite rate of increase (λ) showed significant differences among different fertilizer treatments; the lowest

values of these parameters were in 'Cow manure' (0.4099 and 1.5067 d^{-1}, respectively) and the highest in 'NPKBP' treatment (0.4809 and 1.6176 d^{-1}, respectively). In addition, there were significant differences in the mean generation Time (T) of *A. gossypii* among different fertilizer treatments. There was a

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positive correlation between nitrogen content of leaves and R_0 of *A. gossypii*, but there was no significant correlation between leaf nutrient and chlorophyll content with other population parameter of the aphids (Table 4).

Body Size

The body length (F= 25.53; df = 6,236; P< 0.05) and head width (F= 9.15; df= 6,236; P< 0. 05) of *A. gossypii* were significantly different under different fertilizer treatments (Table 5). The highest body length was in 'Vermicompost', 'NPK'and 'NPKBP'; while the highest head width was obtained in 'Vermicompost', 'NPK' and 'Cow manure. On the other hand, although the 'Control' had the lowest body length, the lowest head width was observed in 'NPKBN' (Table 5). Also, the aphids body lengths were positively correlated with their head widths (r= 0.733, P= 0.030), but the *A. gossypii* body length and head width were not significantly correlated with fecundity (r= -0.07, P= 0.441 and r= 0.-37, P= 0.206, respectively).

DISCUSSION

Fertilizers could have several effects on plant quality that positively or negatively affect the performance of aphids (Awmack and Leather, 2002; Altieri and Nicholls, 2003). In the current study, the fertilizer treatments affected the development time and TPOP of aphids, but did not have a significant effect on *A. gossypii* fecundity and longevity. Bethke *et al.* (1998) reported that the fecundity, longevity, and survivorship of *A. gossypii* were not affected by fertilizer level. On the other hand, in some studies, increase of nitrogen fertilization enhances the fecundity of *A. gossypii* (Petitt *et al*., 1994; Nevo and Coll, 2001; Chau *et al*., 2005; Rostami *et al*., 2012), which could be due to the type and amount of fertilizer used.

The results of the life table parameters of *A. gossypii* calculated by using the age-stage life table was similar to the results of age-specific life table. This could be due to parthenogenesis and longevity of aphids.

The net reproductive rate value is a key factor that summarizes the physiological ability of an arthropod relative to its

Table 3. Life table parameters (means ±SE) of *Aphis gossypii* under different fertilizer treatments of cucumber.

Treatment	R_0 (Nymphs/Individual)	r (d^{-1})	λ (d^{-1})	T (Day)
Control	71.97±2.484b	0.4181±0.007cd	1.5191±0.010cd	10.23±0.156abcd
	71.97	0.4181	1.5191	11.48
Cow manure	77.16±1.714ab	0.4099±0.008d	1.5067±0.013d	10.61±0.214a
	77.15	0.4100	1.5068	12.09
Vermicompost	71.65±1.569b	0.4147±0.009d	1.5140±0.013d	10.30 ± 0.207abc
	71.66	0.4148	1.5141	11.49
NPK	74.41±1.560ab	0.4338±0.008bc	1.5431±0.012bc	9.94±0.167cde
	74.40	0.4337	1.5430	11.39
NPKBN	76.47±1.928ab	0.4111±0.008d	1.5085±0.013d	10.55±0.203ab
	76.47	0.4112	1.5086	12.07
NPKBP	79.25±2.005a	0.4809±0.006a	1.6176±0.010a	9.09±0.113f
	79.24	0.4809	1.6175	10.53
NPKBNBP	74.06±2.372ab	0.4418±0.010b	1.5556±0.016b	9.75±0.227e
	74.06	0.4420	1.5558	11.24

[a] Data in the first row for each parameter is related to age-stage specific life table and data in the second row related to the age-specific life table. Means in the same column followed by the same letters are not significantly different (Paired-bootstrap, P< 0.05).

Table 4. Pearson correlation coefficients for relation between leaf nutrient and chlorophyll content with population parameters and body size of *Aphis gossypii.*[a]

	Population parameters				Body size	
	r	λ	R_0	T	Body length	Head width
Nitrogen content	$r= 0.35$, $P= 0.22$	$r= 0.36$, $P= 0.22$	$r= 0.67^*$, $P= 0.05$	$r= -0.25$, $P= 0.29$	$r= 0.46$, $P= 0.15$	$r= 0.06$, $P= 0.45$
Phosphorus content	$r= -0.32$, $P= 0.24$	$r= -0.31$, $P= 0.25$	$r= 0.36$, $P= 0.21$	$r= 0.42$, $P= 0.17$	$r= -0.29$, $P= 0.26$	$r= 0.14$, $P= 0.39$
Potassium content	$r= -0.32$, $P= 0.25$	$r= -0.31$, $P= 0.25$	$r= 0.40$, $P= 0.19$	$r= 0.42$, $P= 0.17$	$r= -0.55$, $P= 0.10$	$r= -0.10$, $P= 0.41$
Total chlorophyll	$r= 0.55$, $P= 0.10$	$r= 0.54$, $P= 0.11$	$r= 0.23$, $P =0.31$	$r= -0.56$, $P= 0.10$	$r= 0.53$, $P= 0.11$	$r= 0.04$, $P =0.47$

[a] Correlation is significant at $P< 0.05$ level.

Table 5. Effect of different fertilizer treatments on body size of *Aphis gossypii.*[a]

Treatment	No. of aphids (5th generation)	Body length (mm)	Head width (mm)
Control	41	1.001±0.019d	0.276±0.004c
Cow manure	36	1.044±0.021cd	0.290±0.004abc
Vermicompost	36	1.284±0.016a	0.306±0.003a
NPK	30	1.227±0.024a	0.302±0.005ab
NPKBN	32	1.084±0.023cd	0.274±0.005c
NPKBP	34	1.202±0.020ab	0.281±0.005c
NPKBNBP	34	1.123±0.024bc	0.287±0.003bc

[a] Data are the mean±SE. Values in each column followed by the same letters are not significantly different (Tukey's HSD test, P< 0.05).

reproductive capacity (Liu *et al.*, 2004). Our results showed that net reproductive rate was highest in 'NPKBP' and lowest in 'Vermicompost' treatments. Also, the obtained R_0 values were equal to the fecundity of *A. gossypii* that related to the relationship between F and R_0 in the two-sex life table which can be written as $R_0= F$ (N_f/N), where (N_f/N) is the proportion of Nymphs (N) which develop into females (N_f) (Chi, 1988). Since in the current study the ratio of $(N_f/N)= 1$, the net reproductive rate and fecundity values were equal.

We found that the intrinsic rate of increase calculated was lowest in 'cow manure'; where the phosphorus and potassium concentrations were highest and chlorophyll concentration was lowest as predicted. Many factors such as fecundity, survival, and, specifically, mean generation time affect r value. Thus, this parameter adequately summarizes the physiological qualities of an insect in relation to its capacity to increase, so, it would be the most appropriate index to evaluate the performance of an insect on different host plants (Soufbaf *et al.*, 2010a, b). The higher r value of *A. gossypii* in 'NPKBP' could be related to the considerably higher survival rate and shorter developmental time in this treatment. Furthermore, the shortest TPOP on 'NPKPB' which resulted in sooner oviposition in this treatment, could be considered as one of the factors enhancing the rate of increase under this treatment. Therefore, the 'NPKBP' was the most suitable fertilizer treatment for population growth of *A. gossypii* in comparison with other treatments. Myers and Gratton (2006) found that the intrinsic rate of increase and net reproductive rate of soybean aphid, *Aphis glycines* Matsumura, fed on soybean

with low potassium content were greater than those fed on plants with medium and high potassium. On the other hand, the potato leafhopper, *Empoasca fabae* Harris, populations increased up to 43% on alfalfa under low-fertility treatments (Shaw *et al.*,1986), which indicated different effects of fertilizers on plants and pests.

This study illustrates the significant effects of fertilizers on body size of *A. gossypii*. The bigger aphids were measured in 'Vermicompost' treatment and smaller in 'Control', even thought it was not effective on life table parameter and fecundity of *A. gossypii*. In contrast, Nevo and Coll (2001) found that the aphids developed on 100% nitrogen fertilizer were significantly bigger compared with aphids fed on nitrogen-deprived plants, and in their study, the body size were positively correlated with fecundity of aphids.

The information obtained from this research revealed that the organic, biological, and synthetic conventional fertilizers could affect the populations of *A. gossypii,* and by scrutiny of these information, especially the intrinsic rate of increase, it seems that the most appropriate treatments for agricultural applications are 'Vermicompost' amongst organic as well as 'NPKBN' amongst bio-chemical fertilizers. However, decision-making on the application of fertilizers should be dependent on economic and agronomic considerations such as the crop yield and quality of the harvested product. Our results may provide a relatively reliable result regarding interactions between cucumber and aphids under application of different soil fertilizers at microcosm scale. However, to achieve more practical results, semi-field and field experiments should be conducted in future research programs.

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اثر کود در برهمکنش غذایی دو سطحی بین شته *Aphis gossypii* وگیاه خیار

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چکیده

اثر تیمارهای کودی مختلف (شامل 'Cow manure'، 'Vermicompost'، 'NPK' (۲۰–۲۰–۲۰) 'NPKBN'،(NPK× *Azotobacter vinelandii*) 'NPKBP' (*Pantoea* × NPK و 'NPKBNBP' (*agglomerans × Pseudomonas putida* NPK × *Azotobacter vinelandii × Pantoea agglomerans × Pseudomonas putida*) در مقایسه با تیمار شاهد) نه تنها بر سطح مواد غذایی و میزان کلروفیل برگ گیاه خیار، بلکه بر پارامترهای دموگرافیک و اندازه بدن شته *Aphis gossypii* Glover مورد بررسی قرار گرفت. بیشترین میزان نیتروژن برگ (۲/۴۵ درصد) در تیمار 'NPKBN' و بیشترین میزان فسفر و پتاسیم در تیمار 'Cow manure' (به ترتیب ۰/۵۸ و ۱۲/۱۷درصد) مشاهده شد. بیشترین میزان کلروفیل (۵۱/ ۳۷ واحد SPAD) در تیمار 'NPKBNBP' اندازه گیری شد. نتایج نشان داد که نرخ ذاتی افزایش جمعیت (r) از ۰/۴۰۹ بر روز (در تیمار 'Cow manure' تا ۰/۴۸۰ بر روز (در تیمار 'NPKBP') متغیر بود. مقادیر نرخ خالص تولید مثل (R_0) از ۷۱/۶۵ تا ۷۹/۲۵ پوره به ازای هر فرد ماده به ترتیب در تیمارهای 'Vermicompost' و 'NPKBP' متغیربود. بیشترین (۱/۲۸ میلی‌متر) و کمترین (۱/۰۰ میلی‌متر) طول بدن شته در تیمار 'Vermicompost' و شاهد (به ترتیب ۱/۲۸ و ۱/۰۰ میلی متر) اندازه گیری شد. نتایج به دست آمده نشان دهنده افزایش بیشتر جمعیت شته *A. gossypii* در تیمار 'NPKBP' در مقایسه با تیمارهای دیگر می‌باشد. همچنین شته‌های پرورش یافته روی تیمار 'Vermicompost' به طور نسبی دارای باروری و طول عمر کمتری بودند.