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Effect of Various Vermicompost-Tea Concentrations on Life Table Parameters of *Macrosiphum rosae* L. (Hemiptera: Aphididae) on Rose (*Rosa hybrida* L.) Flower

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Abstract

The life table parameters of *Macrosiphum rosae* L. (Hemiptera: Aphididae) on five vermicompost-tea (tea-compost) concentrations (20, 40, 60, 80 and 100%) and control treatment (0%) on *Rosa hybrida* L. were determined under laboratory conditions. There were significant differences among pre-imaginal period and adult longevity of the aphid on the five tea-compost concentrations. The highest mortality occurred at first nymphal instar on all treatments. The life expectancy (e_x) of one-day-old adults was estimated to be 30, 35, 37, 40, 42 and 20 days on various tea-compost concentrations and control treatment, respectively. The net reproductive rate (R_0) significantly differed on different treatments, which was the highest on control (29.12 ± 2.21 female offspring) and lowest on 100% of tea-compost concentration (15.47 ± 2.12 female offspring). The highest and lowest values of the intrinsic rate of increase (r_m) were 0.736 ± 0.171 day^{-1} (on control) and 0.105 ± 0.005 day^{-1} (on 100% treatment), respectively. The finite rate of increase (λ) varied from 1.101±0.143 day^{-1} (on 100% treatment) to 1.853 ± 0.001 day^{-1} (on control). Doubling time ranged from 1.806 ± 0.023 (on control) to 4.587 ± 0.161 days (on 100% treatment). The longest mean generation time (T) of the rose aphid was obtained on 100% treatment. The results showed that the 100% of tea-compost concentration had the highest antibiotic effect on population growth of *Macrosiphum rosae.*

Keywords: Life table, *Macrosiphum rosae*, Population growth parameters, Tea-compost.

INTRODUCTION

Vermicomposts, which are produced from organic wastes by interactions between earthworms and microorganisms in a mesophilic process, are finely divided, fully stabilized organic materials with large microbial populations and activity (Edwards and Arancon, 2004). Aqueous extract of vermicompost (vermicompost tea) as an extract or leachate can be derived from composted plant or animal waste. Such organic matter has been decomposed by soil micro-fauna such as bacteria, fungi, nematodes, and soil arthropods (Diver, 2002; Sheuerell and Mahaffee, 2006). Vermicompost tea applied as a foliar spray or soil drench has been demonstrated to improve plant health, yield, nutritive quality and protection against pests and pathogens by (a) enhancing beneficial microbial communities and their effects on agricultural soils and plants, (b) improving the mineral nutrient status of plants and (c) inducing the production of plant defence compounds that have beneficial bioactivities in humans (Carpenter, 2005; Diver, 2001; Hoitink *et al.*, 1997; Ingham, 2005; Scheuerell and Mahaffee, 2002; Weltzein, 1991). Although the chemistry and microbiology of vermicompost extract are complex, it is believed that soluble mineral nutrients extracted from vermicompost will have a positive effect on plant growth with foliar and soil applications of vermicompost extract (Ingham, 2005). It is also postulated that the action of living microorganisms and microbial metabolites will stimulate plant growth (Carpenter, 2005; Diver, 2001). Several studies have shown a positive effect of vermicompost tea on suppression of certain plant disease factors such as botrytis on green beans, strawberries, grapes and geraniums, leaf spot on tomatoes, bacterial speck in arabidopsis and powdery mildew on apples (Hoitink *et al*., 1997; Al-Dahmani *et al.*, 2003; Elad and Shtienberg, 1994; Haggag and Saber, 2007; Scheuerell and Mahaffee, 2004, 2006; Weltzein and Ketterer, 1986; Zhang *et al.*, 1998). Moreover, compost extracts have been shown to induce natural plant defenses against pathogens (Zhang *et al.*, 1998; Welke, 2005). Vermicomposts have also been shown to suppress populations of plant parasitic nematodes (Arancon *et al.*, 2002) and plant pathogens in laboratory (Chaoui *et al*., 2002). There are reports in the literature which indicate that various forms of organic matter applied to soils, may be able to decrease populations of arthropod pests and resultant crop damage (Patriquin *et al.,* 1995). In preliminary experiments in the laboratory, vermicomposts have been shown to suppress populations and damage by arthropod pests, such as aphids and cabbage white caterpillars (Arancon and Edwards, 2004; Arancon *et al*., 2005). Other researchers have reported that vermicomposts suppressed numbers of leafhopper, aphids and spider mites (Rao *et al*., 2001; Rao, 2002). The effect of fertilizers on the extent of pest infestations and plant damage were also studied, with the aim of identifying the effects of fertilization on arthropod pest suppression by vermicomposts (Scheuerell and Mahaffee, 2004, 2006; Weltzein and Ketterer, 1986; Patriquin *et al.*, 1995). Vermicompost tea may be extracted under aerated or non-aerated (passive) conditions. During aerated extraction, air is pumped through water containing vermicompost to maintain the oxygen level above 5 mg L^{-1} (Ingham, 2005). Sugar, grain, fish emulsion, kelp extract, humic acid and other products are often incorporated as additives during extraction of aerated tea to enhance microbial activity of the finished product, but little work regarding the impact of these additives on tea quality or plant response has been reported. For passive extraction, vermicompost is placed in a certain volume of water and allowed to sit for several days, with occasional stirring (Weltzein, 1991). Several investigators have reported that non-aerated compost tea has a consistent and significant positive effect on disease control and plant growth compared with aerated compost tea, while other works suggest that non-aerated compost teas can be inconsistent in quality, may cause phytotoxicity and are generally less preferable than aerated compost teas (Weltzein, 1991; Scheuerell and Mahaffee, 2004 , 2006; Cronin *et al.*, 1996; Tranker, 1992).

Life table is powerful tool for analyzing and understanding the impact that an external factor on the growth, survival, reproduction, and rate of increase of an insect population (Bellows *et al.,* 1992; van den Boom *et al.*, 2003; Musa and Ren, 2005; Greco *et al.*, 2006). The host plants have main effects on development, mortality, and fecundity rates of insects. Wittmeyer *et al*. (2001) showed that the nutritional quality of food consumed during both nymphal and adult stage of development influenced the fecundity and fertility of females Podisusma culiventris Say. Life table parameters, including net reproductive rate (R_0), mean generation time (T), doubling time (D_T), finite rate of increase (λ), and intrinsic rate of natural increase (r_m) have been used to evaluate the susceptibility or resistance of several host plants in relation to various pests (Tsai and Wang, 2001; Satar and Yokomi, 2002; Razmjou *et al.,* 2009). Among these parameters, the intrinsic rate of increase is commonly used to evaluate the level of plant resistance to insects (Razmjou *et al.,* 2006). The greenhouse experiments that are reported in this paper describe the effects of various concentrations of aqueous extracts produced from food waste-based vermicomposts (vermicompost tea), on life table parameters of rose aphid (*Macrosiphum rosae*) on rose plants (*Rosa hybrida*).

MATERIALS AND METHODS

Plant material: *Rosa hybrida* L. (cut-flower roses group) var. Dolce Vita, was selected as test crop for the experiments. This variety was prepared from Flowers and Ornamental Plants Research Institute of Mahallat - Iran (the entomology research laboratory, department of plant protection and research greenhouses). Greenhouse experiments were conducted during 2012-2013. Rose plants were grown under both organic (chicken manure vermicompost) and chemical (Biozar, 20:20:20 NPK, Fannavar-Nano products Company, Biozar, Khomein, Iran) fertilization at a rate of 25 kg N ha^{-1}. Plants were grown in plastic pots (20 cm diameter, 25 cm height). One rose cutting was sown in each pot. Plants were allowed to grow in the greenhouse on a bench fitted with overhead sprinklers that operated for 5 m in every 6 h.

Rose aphid colony: Adults of rose aphid (*Macrosiphum rosae*) were originally collected from common rose greenhouses of the Mahallat region, Iran in December 2011. These aphids were reared on rose (*Rosa hybrida* L. var. Dolce Vita) grown in plastic pots (20 cm diameter 25 cm height) in a growth chamber (27 ± 2^{o} C, 70 ± 5% RH and a photoperiod of 16:8 L:D) for at least 2 months (several generations) before conducting the experiments. All experiments were performed at the above mentioned conditions in growth chambers.

Preparation of vermicompost tea: The vermicompost used to prepare vermicompost tea, was obtained from a commercial vermicompost source (Gilda vermicompost, Gildakoud products Company, Tehran, Iran). Vermicompost tea was made based on Balfanz (2010) and Aracon *et al.* (2007) extraction methods.

Treatments and leaf samples: The treatments consisted of a range of five concentrations of aqueous vermicompost extract (vermicompost tea), namely 20%, 40%, 60%, 80% and 100%, and their effects were compared with those of a distilled water control. To perform the experiments, the leaf sample method was used (Pedigo and Buntin, 1994; Naher *et al.,* 2006). Each rose leaf with 5 leaflets was selected and was placed on a water-saturated cotton in plastic glass (4 cm diameter, 8 cm height). Thereafter, one fully expanded young leaf was randomly collected and used for the leaf sample preparation. Finally, each rose aphid was transferred on leaf sample in plastic glass (for each treatment of vermicompost tea) and the vermicompost tea effect on life table of rose aphid was studied.

Experiments: The life table parameters of *M. rosae* were determined on rose plants in laboratory conditions at 27±2^{o}C, 70±5% humidity and a photoperiod of 16:8 L:D h. The study was initiated with 60 nympha of the rose aphid (*M. rosae*) as cohort for each treatment. In this regards, 10 adult aphids of *M. rosae* (reared on each treatment), were transferred onto new leaf sample of the same treatment. The 12 h later, the new nympha were collected from these leaf samples and individually transferred with a fine camel hair brush onto new leaf sample. Thereafter, the mortality, development and number of offspring were recorded daily up to the death of last individual.

Data Analysis: The age-specific fecundity (m_x) and age-specific survival (l_x) of aphid on various concentrations of vermicompost tea were calculated according Brich (1948) and the life table parameters estimated based on suggested formula by Carey (1993). The life table parameters were included: net reproductive rate (R_0), intrinsic rate of natural increase (r_m), finite rate of increase (λ), mean generation time (T), doubling time (D_T) and life expectancy (e_x). Data on immature developmental period and adult longevity of rose aphid were analyzed with one-way analyses of variance (ANOVA). When the variation among treatments was significant, means comparison were done based on Duncan's multiple range test ($P<0.05$). The statistical differences of life table parameters among various treatments were detected using the jackknife procedure (Meyer *et al*., 1986; Maia *et al*., 2000). In this procedure, jackknife pseudo values of each life table parameter were calculated for n aphids by following equation:

$$A_{(j)} = n \times A_{(all)} - (n - 1) \times A_{(i)}$$

Where $A_{(j)}$ is the jackknife pseudo value, n is the number of aphids, $A_{(all)}$ is the calculated life table parameters for all aphids and $A_{(i)}$ is the calculated parameters for (n–1) aphids. All statistical analysis was carried out using the Minitab statistical software (MINITAB, 2000) and SPSS statistical packages (SPSS, 2004).

RESULTS

Development and fecundity

Developmental times of viviparous wingless aphids were significantly different among tea-compost concentrations (F=28.17; df =5,341; P<0.01) (Fig. 1A), indicating some patterns for the effect of tea-compost concentrations on the development of rose aphid nymphs. The shortest and longest developmental times were recorded on control (5.22±0.08 days) and 100% of tea-compost concentration (8.10 ± 0.18 days). The subsequent results showed a significant difference in longevity (F=94.83; df=5,341; P<0.01) (Fig. 1B) and total number of newly laid nymphs per female (F=78.15; df=5,341; P<0.01) (Fig. 1C). The longest and shortest adult longevity of rose aphid nymphs were observed on the 100% of tea-compost concentration (33.75 ± 1.04 days) and control (20.45 ± 1.12 days), respectively. Total number of nymphs ranged from 111 ± 1.47 nymphs/female

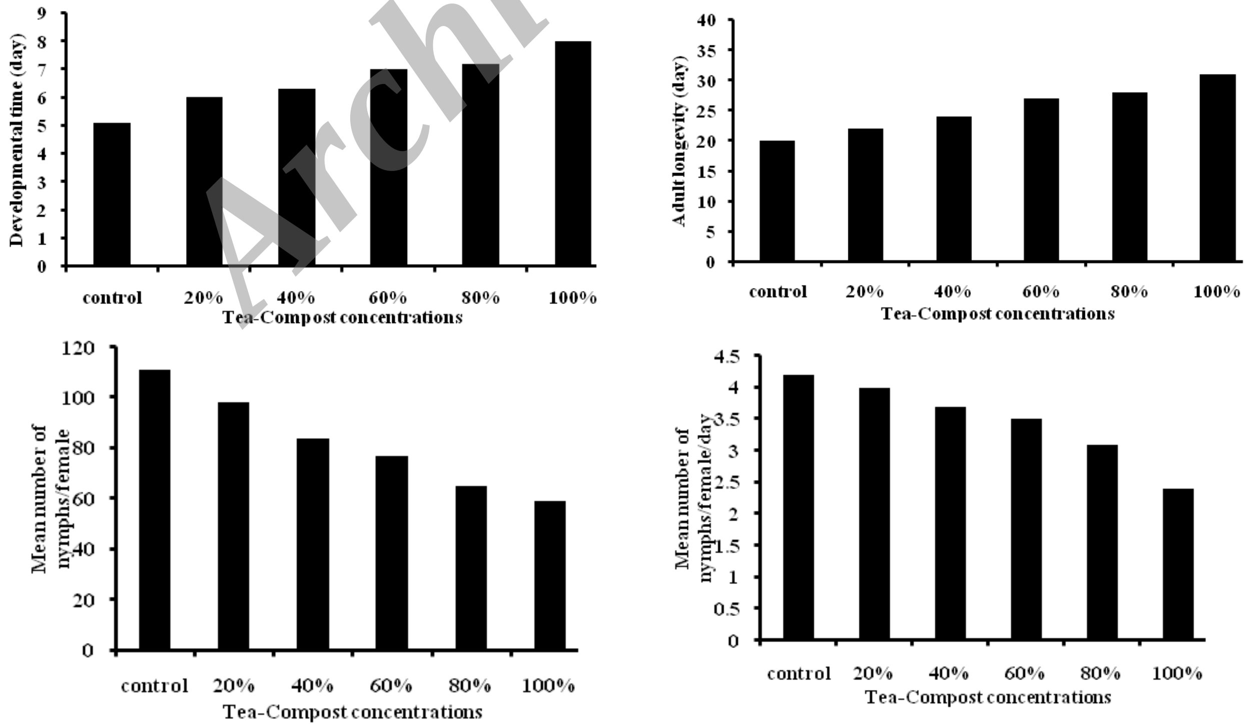

Fig. 1. Biological parameters of *M. rosae* on five concentrations of tea-compost: A. Developmental time, B. Adult longevity, C. Mean number of nymphs/female, D. Mean number of nymphs/female/day. Within columns, means indicated by different letters are significantly different (P<0.05, one-way ANOVA).

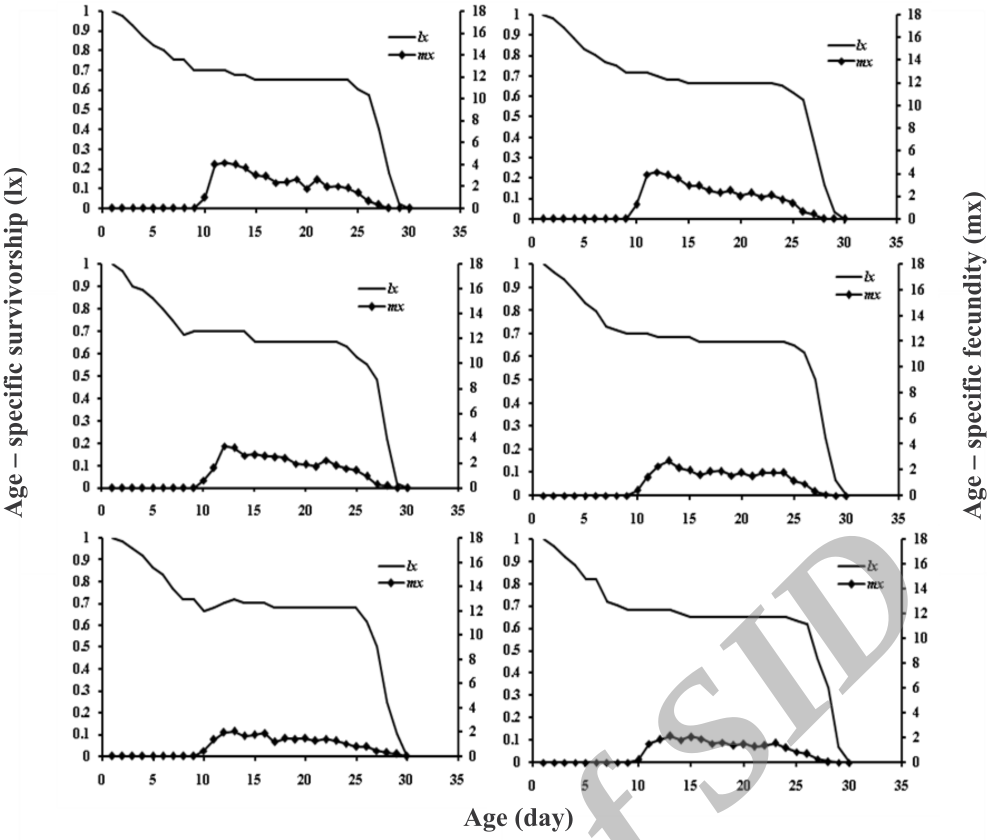

Fig. 2. Age-specific survivorship (l_x) (simple line) and age-specific fecundity (m_x) (solid diamonds) of *Macrosiphum rosae* on various tea-compost concentrations.

on control to 65 ± 1.24 nymphs/female on 100% of tea-compost concentration. The mean number of newly laid nymphs per female per day showed significant differences on various tea-tompost concentrations (F=28.63; df=5,341; P<0.01). This parameter was highest on control (4.2 ± 0.14 nymphs/female/day) and lowest on 100% of Tea-Compost concentration (2.4±0.05 nymphs/female/day) (Fig. 1D). The pre-imaginal mortalities were 63, 58, 47, 39, 21 and 14% on 100, 80, 60, 40 and 20% of Tea-Compost concentrations and control treatment, respectively.

Life table parameters

The life expectancy (e_x) at adult emergence time of *Macrosiphum rosae* was 30, 35, 37, 40, 42 and 20 days on various tea-compost concentrations (20, 40, 60, 80 and 100%) and control treatment, respectively. In the meantime, the highest and lowest life expectancies were found on 100% of tea-compost concentration and control, respectively. The deaths of all examined aphids were occurred in 27, 28, 29, 29, 29 and 30 days on various treatments (Fig. 2). Survival analysis showed that there was significant difference among life-span of *M. rosae* (Table 1). Similar patterns of m_x (female nymphs/female/ day) were observed on all Tea-Compost concentrations. The number of nymphs at the peak of nymphi position of females was determined to be 4, 4, 3.8, 2.5, 2 and 4.2 on various tea-compost concentrations and control treatment, respectively. The peak of oviposition occurred at age of 13, 12, 14, 16, 16 and 13 days after nymph deposition, respectively (Fig.2).

There were significant differences among the net reproductive rates (R_0) of *M. rosae* on different Tea-Compost concentrations (F=67.58; df=5,341; P<0.01). The highest and lowest R_0 were obtained on control (29.12±2.21 female offspring) and 100% of tea-compost concentration (15.47±2.12 female offspring), respectively (Table 2). The intrinsic rates of natural increase (r_m) were found to be significantly different among treatments (F=55.19; df=5,341; P<0.01). The r_m values ranged from 0.105 to 0.736 day^{-1} on 100% of tea-compost concentration and control, respectively (Table 2). Additionally, the mean generation time (*T*) of *M. rosae* showed significant

Table 1. Life-span of *M. rosae* on various Tea-Compost concentrations using the Kolmogorov-Smirnov test.

Tea-Compost concentrations	**Life span (day)**	
	(Mean±SEM)	**Range**
0 % (control)	27.96 ± 1.25^b	23-30
20 %	29.21 ± 1.02^b	27-31
40 %	30.12 ± 1.89^b	27-33
60 %	34.27 ± 1.33^a	32-35
80 %	38.52 ± 1.54^a	36-40
100 %	39.18 ± 1.14^a	37-41

Different letters in the column indicate significant differences within various cultivars (P<0.05).

differences (F=76.48; df=5,341; P<0.01) among treatments. DT values (Table 2) of *M. rosae* showed significant differences among the five Tea-Compost concentrations (F=84.13; df=5,341; P<0.01), as well as the finite rate of increase (λ) (F=62.74; df=5,341; P<0.01).

DISCUSSION

The results in this research revealed significant effects of tea-compost concentrations on the development and reproduction of *Macrosiphum rosae*. The *M. rosae* developed significantly faster on control than other treatments. Also, the adult longevity was highest and the mean number of newly laid nymphs/female/day was lowest on 100% of tea-compost concentration indicating that this treatment has the worst feeding quality for *M. rosae*. Among the life table parameters, the intrinsic rate of increase (r_m) is the best parameter for evaluating the host plant species or treatment effects, because it reflects the overall effects on both survivorship and fecundity (Soufbaf *et al*., 2010). A population with a higher intrinsic rate of increase (r_m) will grow faster than one with a lower rate of increase (Carey, 1993). Moreover, there were significant differences among *T* and D_T of *M. rosae* on different tea-compost concentrations. Total N, K, P, NO_3-N, NH_4-N and carotenoids concentration and microbial activity in vermicompost extraction (Tea-compost) is the most levels but total *N* concentration in tea-compost was lower than *P* and *K* concentration (Ingham, 2005; Archana *et al*., 2009). Vermicompost tea consistently enhanced plant growth and mineral nutrient concentration in plant tissue under, in accordance with the findings of previous studies (Sanwal *et al.,* 2006; Hargreaves *et al*., 2008). The effect of vermicompost tea was most pronounced under vermicompost fertilization. Soluble mineral nutrients and microbial by-products in vermicompost tea can enhance nutrientuptake from the soil and increase foliar up take of nutrients (Ingham, 2005; Xu *et al*., 2001). Nutrient analysis indicated that vermicompost tea supplied a considerable amount of soluble mineral nutrients to plants. The strong correlation between above-ground dry weight and nitrogen uptake by plant sex plains the yield response to vermicompost tea (Archana *et al*., 2009). Increased above-ground fresh and dry weights, leaf area and extract able mineral element concentration in plant tissue as a result of vermicompost tea treatment were observed in Archana *et al.* 2009 study.

It has previously been demonstrated that stress, particularly low *N*, can induce greater concentrations of phenolics in plant tissue (Brown *et al.,*1984; Estiarte *et al.*,1994). Nutrient stresses can reduce growth more than photosynthesis; the excess C relative to nutrients will be allocated to C-based defensive compounds, including phenolics (Tuomi *et al.*, 1988). An increased concentration of total phenolics was associated with lower plant growth and low mineral N concentration in plant tissue of control plants compared to vermicompost tea-treated plants (Archana *et al*., 2009). A higher level of total phenolics was observed in plants grown under vermicompost fertilization than in those grown under chemical fertilization. This could be due to a more rapid release of plant-

Table 2. Data mean comparison of IBA concentration on the measured traits.

Parameters	Tea-Compost concentrations					
	0% (control)	20%	40%	60%	80%	100%
r_m (day^{-1})	0.736 ± 0.17^a	0.601 ± 0.112^{ab}	0.543 ± 0.082^b	0.379 ± 0.043^b	0.171 ± 0.018^d	0.105 ± 0.005^e
R_0 (female offspring)	29.12 ± 2.21^a	28.07 ± 1.98^{ab}	26.06 ± 2.83^b	19.56 ± 2.01^b	16.06 ± 2.18^d	15.47 ± 2.12^e
T (day)	$14.77 \pm 0.147_c$	14.58 ± 0.119^c	16.81 ± 0.170^b	18.03 ± 0.164^a	18.40 ± 0.117^a	18.81 ± 0.179^a
λ (day^{-1})	1.85 ± 0.001^a	1.75 ± 0.014^{ab}	1.66 ± 0.010^b	1.46 ± 0.120^b	1.18 ± 0.018^{cd}	1.10 ± 0.143^d
D_T (day)	1.80 ± 0.023^d	2.56 ± 0.082^c	2.90 ± 0.113^c	$3.06 \pm 0.138_b$	3.67 ± 0.150^b	4.58 ± 0.161^a

Means followed by similar letters in rows are not significantly different (one-way ANOVA, α=0.05).

available nutrients from chemical fertilization compared to vermicompost. Asami *et al.* (2003) and Wang *et al*. (2002) also observed consistently higher levels of total phenolics in organically grown crops compared with those produced by conventional agricultural practices. Dixon *et al.* (1995) and Zhao *et al.* (2007) reported that a higher level of antioxidant capacity of leafy vegetables is associated with reduced pant growth, lower N concentration and accumulation of higher levels of phenolic compounds in plant tissue. There is a very sparse literature recording the suppression of pest that attack crop plants by sucking plant foliage treated by vermicomposts. For instance, there have been reports of vermicomposts suppressing attacks of sucking insects such as jassids, aphids, and spider mites very significantly on ground nuts in India (Rao, 2002, 2003). Biradar *et al*. (1998) reported a clear correlation between a mounts of vermicompost in a growing medium and decreased incidence of psyllids (*Heteropsylla cubana*) on a tropical leguminous tree (*Leucaena leucocephala*). Arancon and Edwards (2004) and Arancon *et al.* (2005) reported suppression of aphids (*Myzus persicae*) on cabbages by vermicomposts. Patriquin *et al*. (1995) reported more aphids, *Aphis fabae*, on plants grown with urea applications than on those in organically managed soils. Morales *et al*. (2001) recorded larger populations of aphids (*Rhopalosiphum maidis*) on corn grown with an inorganic fertilizer. It has been reported by several authors (e.g. Phelan, 2004) that plants grown with organic fertilizers are usually attacked by fewer arthropod pests, and can tolerate pest attacks more than plants that receive conventional fertilizers; however possible ecological mechanisms driving this phenomenon are poorly understood. Some workers have suggested that inorganic *N* fertilization may decrease plant resistance to insects, by improving the nutritional quality and palatability of the host plants, and inhibiting the buildup of secondary metabolites concentrations (Fragoyiannis *et al.,* 2001; Herms, 2002). It has also been suggested that *N* may stimulate the fecundity of insects, attract more individuals for oviposition on host plants grown with inorganic *N* (Bentz *et al*., 1995), and also increase insect population growth rates (Culliney and Pimentel, 1986, Jansson., and Smiowitz, 1986). Additionally, a slower rate of nutrient release from organic materials (Patriquin *et al*., 1995), an enhanced nutritional composition and decreased *N* levels in plants grown with organic fertilizers (Steffen *et al*., 1995) could all contribute to the resistance of these plants to arthropod pest attacks. Phelan *et al*. (1996) suggested that the acceptability of corn, to the European corn borer *Ostrinia nubilalis* (Hubner), could possibly be mediated by the plant's mineral balance and also by a biological buffering characteristic of organically managed soils (Phelan *et al.,* 1995, 2004).

Vermicomposts are known to provide a slow, balanced nutritional release pattern to plants, in particular release of plant available N, soluble K, exchangeable Ca, Mg and P (Edwards and

Fletcher, 1988; Edwards, 1998). Moreover, vermicomposts have a much greater microbial diversity and activity than conventional thermophilic composts, because organic wastes fragmented by earth worms have a greater surface area and therefore support much more microbial activity. Additionally, microbial activity tends to be largely suppressed by the high temperatures reached during thermophilic composting. In our experiments, the combination of slow release of nutrients and high microbial activity from vermicomposts seems to have indirectly enhanced the plant's capacity to suppress pest insect attacks. We also suggest that a component of the mechanisms inhibiting attack by arthropod pests by vermicomposts and similar organic materials, on the foliage and fruits of crop plants, may be due to feeding responses to different forms of N in the plant foliage. It is well known that phenolic substances are distasteful to secondary decomposers in soil systems and inhibit the breakdown of dead plant materials (Edwards and Heath,1963; Heath and Edwards, 1964). Simmonds (1998) reviewed the modification of insect feeding behavior by phenolics and non-protein amino acids and general inhibition of insect pest feeding. Asami *et al.* (2003) reported that total amounts of phenolic substances were much higher in strawberries and corn grown organically than in those grown with inorganic fertilizers. It has also been shown that sprays of phenols and phenolic acids extracted from gingko plants were effective in controlling attacks by cotton aphids, vegetable aphids, caterpillars and thrips. Stevenson *et al.* (1993) reported inhibition of development of *Spodoptera litura* (Fabricius) by a phenolic compound from the wild ground nut. Haukioja *et al.* (2002) stated that phenolics in plant tissues changed rates of consumption of tissues by a geometrid caterpillar *Epirrita autumnata* (Borkhausen).

We hypothesize that the decreased insect pest numbers and damage on plants grown with vermicomposts and Tea-Compost concentrations (vermicompost tea), in both our greenhouse and field experiments (Yardim *et al.*, 2006), could be attributed at least partially to changes in the form of N, a controlled slower release rates of mineral nutrients and particularly by the production of phenolics through the use of vermicomposts. Further research is needed to support this hypothesis and to further identify mechanisms by which vermicompost suppress arthropod pest feeding and reproduction.

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