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Original Research Article

Influence of compost fertilization on the biology and morphology of green peach aphid (*Myzus persicae*) on pepper

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Aphids are important pests of pepper and their abundance may be influenced by fertilizers. To address the influence of compost fertilizers on the morphology and biology of *Myzus persicae* Sulzer, an experiment was carried out in 2014/15 on pepper plants cultivated in a greenhouse. Five treatments using four types of composts (C1, C2, C3, and C4), a combination of vegetables scraps and equine, poultry, cattle and sheep manures and one control were used with six replications. The population of *M. persicae* on pepper for the five treatments was counted weekly and thirteen morphometric characters were studied. The results showed that aphid morphology and biology were affected by treatments. Highest population (4283 aphids/plant), higher mean relative growth rate (0.068) and lowest population doubling time (10.14 days) were registered with C4, whereas, minimum population (2019 aphids/plant), minimum mean relative growth rate (0.046) and higher population doubling time (15 days) were registered with C1. These results showed that C1 can reduce the damage caused by aphid on pepper and this knowledge might be useful in making a more informed compost fertilizer application choice.

Key words: Compost, pepper, *Myzus persicae*, morphometry, population.

INTRODUCTION

The organic farming system aims at supporting and sustaining a healthy ecosystem, soil, farmers, food production, the community, and the economy. In recent times, to minimize the adverse effects of synthetic fertilizers and pesticides on human health and environmental components, organic agriculture has started gaining worldwide attention (Chowdhury, 2004). The current global concern firmly emphasizes on the adaptation of eco-friendly agricultural practices for sustainable food production, including organic fertilizers, since they are produced from organic materials. However, organic fertilizers are still out of the reach of small and marginal farmers due to high cost. Organic fertilizers provide nutritional requirements, increase the yield and quality of agricultural crops in ways similar to inorganic fertilizers and suppress plant pest populations (Bulluck et al., 2002). Indeed, recent studies have shown that plant resistance to insect and disease pest is linked to the optimal physical, chemical and biological properties of the soil (Altieri and Nicholls, 2003). Also, high organic matters and their biological activity increase soil fertility, thereby stimulating plant growth and the development of soil organisms. Ultimately, these will support plant health as they decompose organic matter, cycle nutrients, hold nutrients, degrade pollutants, improve soil structure, and control populations of crop pests (Chau and Heong, 2005). Magdoff and Harold (2000) found that farming practices that cause nutritional imbalances reduce plant pest resistance. Also, soil fertility practices can affect the resistance of plants to pests (Meyer, 2000). Biofertilizers such as chicken and hog

Table 1. Composition and nitrogen level content of soil and compost used in the experiment

Treatment	Composition	Nitrogen level content (g/kg)
Suitable soil	-	2.68
C1	60 % Equines manures, 20 % Poultry manures, 20 % Cattles manures.	3.52
C2	15 % Vegetable scraps, 30 % Sheep's manures, 55 % Cattles manures.	3.59
C3	20 % Equines manures, 20 % Poultry manures, 60 % Cattles manures.	3.68
C4	40 % Equines manures, 10 % Poultry manures, 40 % Cattles manures, 10 % Sheep's manures.	3.87

manure can affect insect abundance and cause subsequent levels of damage to herbivores (Chau and Heong, 2005). Among these herbivores, aphids are known as the most important pest of several crops. The green peach aphid *Myzus persicae* (Sulzer) (Hemiptera, Aphididae) is one of the most economically important pests, is polyphagous and has a worldwide distribution. It has been recorded in Tunisia on pepper crops and several other crops and it causes big problems for pepper production (Ben- Halima Kamel, 2011). A moderate or high density of this aphid causes direct damage by sucking plant sap thereby inducing the deformation of plant leaves and indirect damage caused either by honeydew production or by transmission of plant viral diseases (Satar et al., 2008; Mulot et al., 2018). This can drastically restrain plant growth rates and result in reduced yield. This aphid has a short generation period and high fecundity (Mdellel and Kamel, 2014). However, the reproductive potential of aphids on pepper and other plants (peach, potato) may be affected by several factors such as cultivar, temperature and soil fertility (Altieri and Nicolls, 2003; Mdellel and Kamel, 2014); Patriquin et al. (1995); Arancon and Edwards (2004) and Arancon et al. (2005) demonstrated that the application of various forms of organic matter to soils may decrease the populations of sap-sucking insects. However, the impact of biofertilizers on pest population such as aphids, is in relation to its nitrogen content. Indeed, in Tunisia, different types of composts were prepared with different proportions in basic materials and with different chemical characteristics. The nitrogen content of each compost can have an influence on the population of aphids. Thus, the present study was designed to provide data about the impact of four types of composts as biofertilizers on morphometrics, fecundity, mean relative growth rate, specific age and infestation rate of *M. persicae* on pepper plants in growth chamber.

MATERIALS AND METHODS

Aphids and plant culturing

The experimental pepper plants (Starter/cultivar) were grown in pots of two liter capacity containing soil amended with 200-g/pot of one of the four types of composts [Compost 1 ‟C1"(60% equine manures, 20% poultry manures, 20% cattle manures) , Compost 2 ‟C2" (15% Vegetable scraps, 30% sheep manures, 55% Cattle manures), Compost 3 ‟C3" (20% Equine manures, 20% Poultry manures, 60% Cattle manures), Compost 4 ‟C4" (40% Equine manures, 10% Poultry manures, 40% Cattle manures, 10% Sheep manures)]. The nitrogen level of each compost (Table 1) was demonstrated by analysis at the Soil Science Laboratory in Monastir referred to the Kjeldhal method (Lynch and Barbano, 1999).

Plants were irrigated as required and placed in a greenhouse for 4 weeks under the following conditions: day/night temperature ranging from 27 to 32°C, 50–80% Relative Humidity ‟RH" and ambient light. To execute the experiment, when plants reached the six-leaved stage, they were transferred to a growth chamber at 21±2°C, HR: 60-80% and under a long day photoperiod (Light ‟L": Dark‟D" - 14:10) (Troncoso et al., 2005).

Aphid infestation

Pepper plants were infested with five adult apterous aphids plant^{-1} on the lower leaf surface of the experimental plants at leaf-stage N° 8. Infestation of experimental plants was accomplished using aphids produced at the rearing greenhouse. The green peach aphids used in this research were clones of wild aphids collected from commercial pepper fields at Chott Mariem in Tunisia (36° 48' N, 10°11'E). The colonies were maintained on a pepper 'Starter' cultivar inside the environmental chambers at a research laboratory. For each treatment (C1, C2, C3 and C4), five plants were infested and each infestation was replicated six times.

Aphid population evolution

Five days after the initial aphid infestation at leaf-stage N° 8, pepper growth stage, whole plant aphid population was counted using a magnifying glass. The evolution of *M. persicae* population on pepper was studied by counting the total number of aphids/plant each five (5) days during the total period of the experiment (45 days). The total number of aphids/plant was obtained after counting the aphid number/infested leaf using a magnifying glass. Average aphid populations plant^{-1} was used to describe aphid population evolution and for statistical analyses.

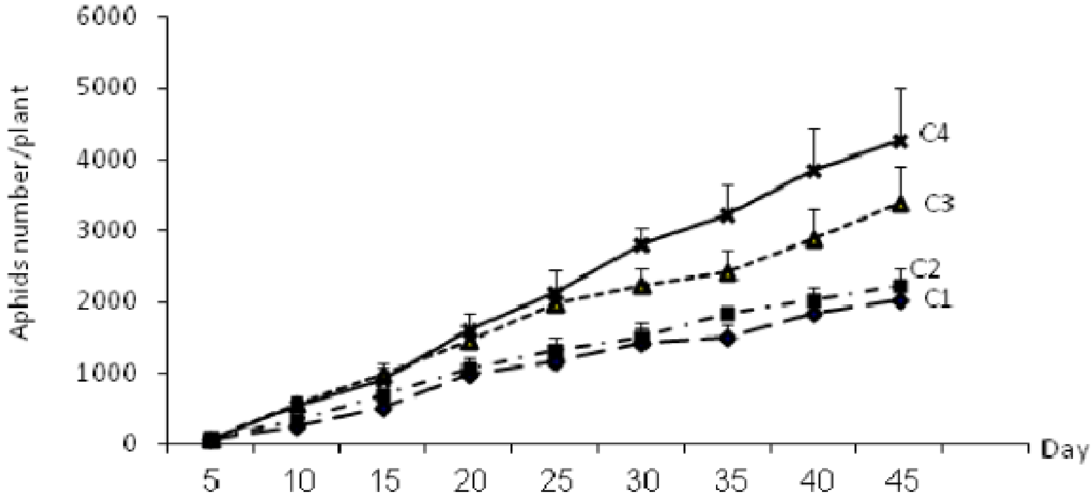

Figure 1: Evolution of mean number of *M. persicae*/plant in soil amended with different composts

Aphid biological parameters

The overall fecundity (total number of larvae produced after 45 days), infestation rates (number of infested leaves/total number of leaves) were determined and the mean relative growth rate (MRGR) was calculated according to Fisher (1920) and Radford (1967), in Leather and Dixon (1984) using the formula:

$$Rm = MRGR \frac{Ln\ N\ t_n - Ln\ N\ t_{n-1}}{\Delta t}$$

$N\ t_{n-1}$ = size of the population at the time t_{n-1}, $N\ t_n$ = size of the population at the time t_n, Δt = interval of time between the two evaluations of the population size = 5 days.

Also, we determined the specific age (T) according to Ramade (2003), using the equation $T = \frac{\log 2}{MRGR}$ and the infestation rate.

Morphometric measurement and analysis

For each treatment, 25 adult individuals (apterous viviparous females living on pepper plants) were kept in 70% ethanol for slide-mounting (Mdellel and Kamel 2015). Wingless *M. persicae* adults were cleared and individually mounted on slides using the techniques of Blackman and Eastop (1984). To determine the differences in size and shape between samples, thirteen (13) characters had been found useful in other studies of aphid's morphometrics (Lykouressis, 1983; Agarwala et al., 2009). Thirteen continuous characters were selected for analyses: Body length (Ch.1), Antennal length (Ch. 2), Antennal segment I length (Ch. 3), Antennal segment II length (Ch. 4), Antennal segment III length (Ch. 5), Antennal segment IV length (Ch. 6), Antennal segment V length (Ch.7), Basal part of antennal segment VI length (Ch. 8), *Processus terminalis* length (Ch.9), Caudal length (Ch.10), Siphunculus length (Ch. 11), Hind femora length (Ch. 12) and Hind tibia length (Ch. 13). Morphological measurements were examined and recorded.

Statistical analysis

The experimental results were statistically analyzed using the SPSS 17 program, a one way analysis of variance and a S-N-K test, with statistical significance set at ß=0.05. The population density, number of winged and wingless individuals and infestation rate on pepper plants with different treatments were compared.

RESULTS

Effect of compost types on aphid population

Figures 1 and 2 present a summary of the effect of different types of compost on the population of *M. persicae* on pepper. According to the data, compost types had an effect on aphid population evolution. Among the various types of compost, aphid population attained higher densities on plants which were fertilized with the compost (C4) and the highest population (4283.34±723.4 aphids plant^{-1}) was observed in the 45th day on pepper plants receiving (C4), followed by plants receiving (C3), (C2) and (C1), having 3396±522, 2125.74±212.6 and 2019.16±314.6 aphids plant^{-1}, respectively. A significant difference in population between these treatments was recorded (F= 28.5; df=3; ß=0.0002) (Figure 2). A significant impact compost types was observed at infestation rate (F= 166.98, df=5, ß=0.001). The highest infestation rate was recorded on plants receiving compost (4) (64.6±8%), followed by (C2), (C3)

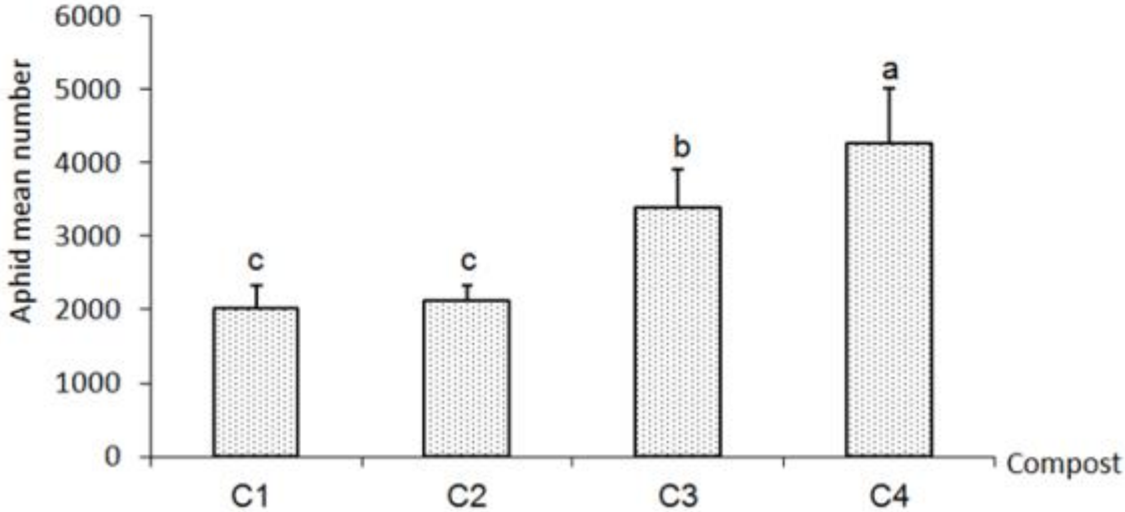

Figure 2: Mean number of *M. persicae* on pepper plants in soil amended with different composts. (Different letters at the tops of the columns indicate significant differences between treatments based on S-N-K test and ß= 0.05).

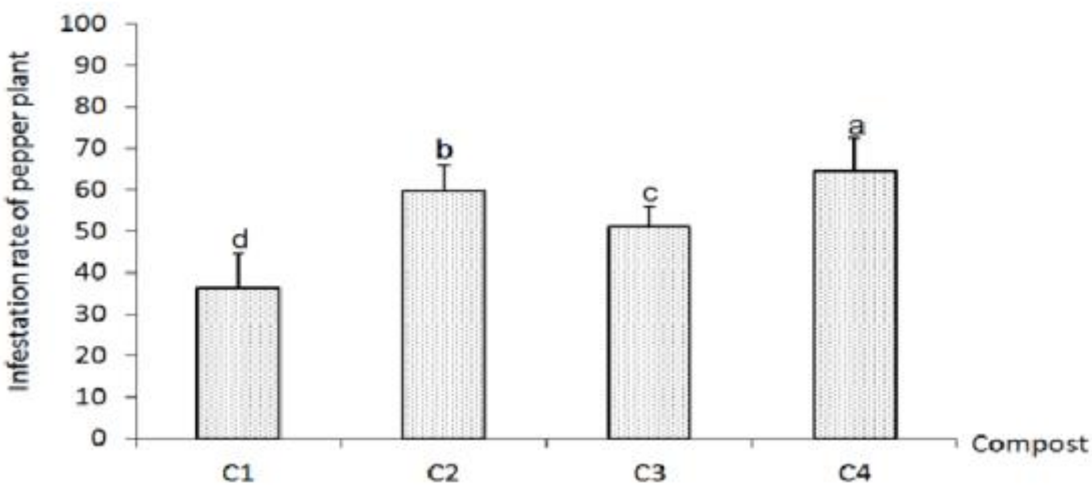

Figure 3: Infestation rate (%) of pepper plants by *M. persicae* in different treatments used in the experiment.
(Different letters at the tops of the columns indicate significant differences between treatments based on S-N-K test and ß= 0.05). C1: compost (1), C2: compost (2), C3: compost (3), C4: compost (4).

and (C1) with infestation rate of 59.7± 6.4%, 51.2±4.8 and 36.4±8.3% respectively) (Figure 3).

The mean relative growth rate Rm (F=3; df=31.09; ß=0.004) was significantly different depending on the type of compost (Table 2). The highest (Rm) was recorded on plants treated with (C4) (0.068±0.002), followed by plants treated with (C3), (C2) and (C1), having Rm of 0.064, 0.054 and 0.046, respectively. Furthermore, there was a significant increase in the population doubling time (T) on pepper receiving (C4) (F=3; df=7.15; ß=0.003). The highest doubling time was observed for the aphid population on pepper receiving (C1) (15 days) and the lowest was for those receiving (C4) (10.14 days).

Impact of compost types on aphid morphology

A summary of measurement considering the 13 morphological characters of the *M. persicae* population associated with six treatments are presented in Table 3. The results showed a morphological difference between wingless adult *M. persicae* collected from pepper plants receiving four different types of compost at 11 characters. Measurement of the body length of wingless *M. persicae* showed that samples collected from plants receiving (C4)

Table 2. Mean Relative Growth Rate (MRGR) and Population doubling time (T) of *M. persicae* on pepper receiving four types of compost

	C1	C2	C3	C4
Rm=MRGR	0.046±0.003c	0.054±0.009b	0.064±0.006a	0.068±0.004a
T (Day)	15±1.2a	12.77±4.3b	10.78±2.8c	10.14±1.6c

Different letters at the tops of the columns indicate significant differences between treatments based on S-N-K test and ß= 0.05)

Table 3. Range and mean of length of 13 morphological traits of 25 *M. persicae* on pepper receiving four types of compost (mm)

Character Range Mean ± SE	Compost (1) (n = 25)	Compost (2) (n = 25)	Compost (3) (n = 25)	Compost (4) (n = 25)
1	1.45 – 1.95	1.62 – 1.96	1.63 – 1.96	1.60 – 2.05
	1.80 ± 0.11c	2.00 ± 0.12a	1.91 ± 0.19 b	2.02 ± 0.08a
2	1.34 – 1.59	1.29 – 1.64	1.34 – 1.63	1.44 – 1.73
	1.45 ± 0.07b	1.50 ± 0.09b	1.50 ± 0.08b	1.75 ± 0.07a
3	0.06 – 0.16	0.06 – 0.13	0.06 – 0.13	0.05 – 0.16
	0.11 ± 0.02a	0.08 ± 0.01b	0.08 ± 0.018b	0.09 ± 0.02b
4	0.03 – 0.11	0.04 – 0.06	0.03 – 0.08	0.03 – 0.08
	0.07 ± 0.02a	0.05 ± 0.005b	0.05 ± 0.01b	0.05 ± 0.01b
5	0.17 – 0.35	0.23 – 0.6	0.12 – 0.45	0.16 – 0.36
	0.25 ± 0.051b	0.31 ± 0.07a	0.22 ± 0.08c	0.25 ± 0.05b
6	0.12 – 0.25	0.14 – 0.29	0.10 – 0.28	0.10 – 0.28
	0.17 ± 0.037b	0.22 ± 0.04a	0.18 ± 0.04b	0.17 ± 0.05b
7	0.07 – 0.2	0.11 – 0.24	0.09 – 0.22	0.06 – 0.18
	0.10 ± 0.027c	0.18 ± 0.033a	0.15 ± 0.037b	0.12 ± 0.03c
8	0.05 – 0.11	0.07 – 0.16	0.07 – 0.14	0.09 – 0.15
	0.07 ± 0.02c	0.12 ± 0.027a	0.10 ± 0.02b	0.11 ± 0.01b
9	0.22 – 0.37	0.09 – 0.38	0.14 – 0.32	0.10 – 0.34
	0.27 ± 0.036a	0.28 ± 0.07a	0.23 ± 0.05b	0.23 ± 0.06b
10	0.08 – 0.21	0.06 – 0.23	0.07 – 0.23	0.07 – 0.18
	0.12 ± 0.037a	0.12 ± 0.037a	0.12 ± 0.04a	0.12 ± 0.02a
11	0.09 – 0.42	0.18 – 0.42	0.18 – 0.44	0.21 – 0.45
	0.31 ± 0.08b	0.34 ± 0.06a	0.30 ± 0.06b	0.33 ± 0.06a
12	0.22 – 0.5	0.28 – 0.52	0.20 – 0.50	0.20 – 0.50
	0.33 ± 0.073c	0.39 ± 0.078a	0.32 ± 0.09c	0.36 ± 0.07b
13	0.45 – 0.9	0.45 – 0.98	0.43 – 0.88	0.42 – 0.98
	0.65 ± 0.13c	0.73 ± 0.14a	0.70 ± 0.13b	0.67 ± 0.16c

Different letters at the tops of the columns indicate significant differences between treatments based on S-N-K test and ß= 0.05). C1: compost (1), C2: compost (2), C3: compost (3), C4: compost (4), n: number of aphid.

and (C2) were bigger in size compared to those receiving (C3) and (1) and a significant difference was demonstrated (F=17.09, df=5, ß =0.010). A significant difference was also recorded in the antennal length (character number 2) of samples collected from plants receiving different treatments (F=4.95, df=5, P=0.0012). Furthermore, a significant difference in antennal segment I, II, III, IV and V length (character number 3, 4, 5, 6 and 7) between all samples was demonstrated (Table 3). The results also demonstrated a significant difference in the length of the basal part of the antennal segment VI and in the Processus terminalis length of the antenna of different aphid samples (F=19.03, df=5, ß =0.000; F=4.08, df=5, ß =0.001). However, no significant difference was observed for the remaining measurement parameters.

DISCUSSION

Soil fertility practices can impact the physiological susceptibility of crop plants to insect pests by either affecting the resistance of individual plants to attack or by altering plant acceptability to certain herbivores (Chau and Heong, 2005). Indeed, Dixon (1987); Dixon et al. (1993) proved that host plant quality and their nitrogen content are known to be important factors affecting aphid morphology, demography, survival, fecundity and life expectancy. Our study confirmed that compost as fertilizer and the nitrogen level on each type of compost affect aphid performance. Our results showed that *M. persicae* developed faster on pepper in soil amended with C4 (40% Equines manures, 10% Poultry manures, 40% cattle manures, 10% Sheep manures) and having a high level of nitrogen (3.87 g/kg) in comparison to those on pepper in soil amended with C1, C2 and C3 with nitrogen level of 3.52, 3.59 and 3.68, respectively. The lowest aphid population was observed on pepper receiving C1 (60% Equines manures, 20% Poultry manures, 20% Cattles manures) with nitrogen level of 3.52 (g/kg). The compost type and nitrogen level have an impact on the morphology of *M. persicae*. Our results also contributed to confirm that soil fertility management could have several effects on plant quality, which in turn, can affect the insect abundance and subsequent levels of damage to herbivores and this abundance. Indeed, in relation to soil fertility, several factors can influence *M. persicae* population growth, an example is mineral content. Throughout the experiment, the level of nitrogen varied from compost to others and aphid morpho-reproduction variation in our obtained data can be explained by nitrogen level variation. Varied nitrogen level have a direct effect on host plant quality which is known to be an important factor affecting aphid demography, survival, fecundity and life expectancy (Dixon, 1987). Several studies have revealed the impact of nitrogen on aphid population growth. In this context, Wang et al. (2006) reported that *Peregrinus maidis* Ashmead feeding on corn plant and receiving the highest fertilization treatment of nitrogen had the greatest mean relative growth rate. Similarly, Nevo & Coll (2001) showed that an increase of nitrogen fertilization level in cotton resulted in an increase of mean relative growth rate in *Aphis gossypii*. Also, Harrewijn (1983) and Petitt et al. (1994) showed that *M. persicae* is positively influenced by nitrogen fertilization. Van Emden and Bshford (1969) and Harrewijn (1983) showed that fertilization with a high N:K ratio is positive for *M. persicae* performance. In addition, our obtained data demonstrate that the morphometry of *M. persicae* varied with treatments and with manure composition.

According to Petitt et al. (1994), Nevo and Call (2001) and Chau et al. (2005), this variation may be related to the nitrogen level. Studies have shown that aphid's weight, size, color and fecundity are enhanced by its nitrogen level. Therefore, nitrogen level cannot be the single factor of *M. persicae* population decrease or morphometric variation. Indeed, according to Cole (1997), the concentration of important amino acids such as tyrosine, alanine, leucine and glutamic acid, accounted for 43% of the variation in intrinsic increase. They further stated that a higher concentration of tyrosine and glutamic acid improved aphid performance.

The green peach aphid, *M. persicae* has a very high population and is very injurious to pepper. On plants receiving (C4), five adult aphids plant^{-1} introduced at L8 reached a peak of 4283 aphids plant^{-1}, highest infestation rate (64.6%), highest mean relative growth rate and shorter doubling time. This injury is certainly due to the nitrogen content level of (C4) which can affect some important characters of aphids such as growth parameters and body size. Our findings appear to support the conclusion reached by Nevo and Coll (2001) and Chau et al. (2005) that nitrogen level can enhance the fecundity and size of aphids. The lowest population on pepper receiving (C1) indicated that the green peach aphids were less injurious to pepper when the nitrogen content was little. This can help us to consider that the application of the compost (C1) as a fertilizer, as model or management system for insect pests. The use of such models as well as other biochemical and physiological characteristics of compost were considered. Organic fertilizers could be effective factors in reducing the damage caused by aphids and it possibly reduces insecticides use and reduces worker exposure to pesticides. Finally, we suggest that future studies should evaluate the effectiveness of compost (C1) in fertilization, as a relatively simple and easily implemented tactic with other IPM strategies including biological control and cultural practices for *M. persicae* management on pepper and other crops.

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Conflict of interests

The authors declare that they have no conflicting interests.

REFERENCES

Agarwala BK, Das K, Raychoudhry P (2009). Morphological, ecological and biological variations in the mustard aphid, *Lipaphis pseudobrassicae* (Kaltenbach) (Hemiptera, Aphididae) from different host plants. J. Asia. Pac. Entomol. 12: 169-173.

Altieri MA, Nicholls CI (2003). Soil fertility management and insect pests: harmonizing soil and plant health in agroecosystems. Soil. Till. Res. J. 72: 203-211.

Arancon NQ, Edwards CA (2004). Vermicomposts can suppress plant pest and disease attacks. Biocycle. 53: 51-53.

Arancon NQ, Galvis PA, Edwards CA (2005). Suppression of insect pest population and damage to plants by vermicomposts. Bioresour. Technolol. 96: 1137-1142.

Blackman RL, Eastop VF (1984). Aphids on the world's crops, an identification guide. John Wiley and Sons, the Natural History. (pp 465). Museum, UK.

Bulluck LR, Brosius M, Evanylo GK, ristaino JB (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. Appl. Soil. Ecol. 19: 147-160.

Chau A, Heinz KM, Davis FT (2005). Influence of fertilization on *Aphis gossypii* and insecticide usage. J. App. Entomol. 29:89-97.

Chau LM, Heong KL (2005). Effects of organic fertilizers on insect pest and diseases of rice. Omonrice. 13: 26-33.

Chowdhury R (2004). Effects of chemical fertilizers on the surrounding environment and the alternative to the chemical fertilizers. IES. Envis. Newsletter. 7: 4-5.

Cole RA (1997). The relative importance of glucosinolates and amino acids to the development of two aphids pests *Brevicoryne brassicae* and *Myzus persicae* on wild and cultivated *Brassica species*. Entomol. Exp. Appl. 85:121-133.

Dixon AFG (1987). Parthenogenetic reproduction and the rate of increase in aphids. In: Minks AK, Harrewijn P, editors. Aphids: their biology, natural enemies and control. World crop pests, volume 2A (pp. 123-139). Amsterdam: Elsevier. The Netherlands.

Dixon AFG, Wellings PW, Carter C, Nichols JFA (1993). The role of food quality and competition in shaping the seasonal cycle in the reproductive activity of the sycamore aphid. Oecol. 95: 89-92.

Fisher RA (1920). Some remarks on the methods formulated *in a* recent article on the quantitative analysis of plant growth". Ann. Appl. Biol. 7: 367-372.

Harrewijn P (1983). The effect of fertilization on pest and diseases. Neth. J. Plant. Pathol. 98: 257-264.

Kamel MBH (2011). Effectiveness of *Lysiphlebus testaceïpes* Cresson as biocontrol agent of *Aphis gossypii* Glover infesting pepper plants. Eur. J. Environ. Sci. 1: 28-32.

Leather SR, Dixon AFG (1984). Aphid growth and reproductive rate. Entomol. Exp. Appl. 35:137-140.

Lykouressis DP (1983). Key for identification of the instars of the English grain aphid, *Sitobion avenae* (F.) (Hemipetra: Aphididae). Entomol. Hell. 1: 47-51.

Lynch MJ, Barbano MD (1999). Kjeldahl Nitrogen Analysis as a Reference Method for Protein Determination in Dairy Products. J. AOAC. INT. 82 (6): 1389.

Magdoff F, Harold V E. (2000). Building soils for better crops. Sustain. Agri. Res. Edu. (pp. 294), Washington DC.

Mdellel L, Kamel MBH (2014). Effects of different varieties of pepper on the biological parameters of the green peach aphid. Eur. J. Environ. Sci. 4: 102-105.

Mdellel L, Kamel MBH (2015). Effect of host plant on morphology of Pterochloroides persicae Cholodkovsky 1899 (Hemiptera, Aphididae). J. Entomol. Zool. Stud. 3: 324-327.

Meyer GA. (2000). Interactive effects of soil fertility and herbivory on *Brassica nigra*. Oikos. 22:433-441.

Mulot M, Monsion B, Boissinot S, Rastegar M, Meyer S, Bochet N, Brault V (2018). Transmission of Turnip yellows virus by *Myzus persicae* is reduced by feeding aphids on double-stranded RNA targeting the ephrin receptor protein. Front. Microbiol. 9: 457.

Nevo E, Coll M (2001). Effect of nitrogen fertilization on Aphis gossypii (Homoptera: Aphididae): variation in size, color and reproduction. J. Econ. Entomol. 94: 27-33.

Patriquin DG, Baines D, Abboud A (1995). Diseases, pests and soil fertility. In: Cook H.F., Lee H.C. (Eds.), Soil Management in Sustainable Agriculture. Wye College Press (pp. 161-174). UK.

Petitt FL, Loader CA, Schon MK (1994). Reduction of nitrogen concentration in the hydroponic solution on population growth rate of the aphids (Homoptera: Aphididae) *Aphis gossypii* on cucumber and *Myzus persicae* on pepper. Environ. Entomol. 23: 930-936.

Radford PJ (1967). Description of some new or little known species of *Aphis* of Japan with a key to species. T. Am. Entomol. Soc. 92: 519-556.

Ramade F (2003). Eléments d'Écologie, Ecologie fondamentale. (3rd Edition), (pp. 824), Paris, France.

Satar S, Kersting U, Uygun N (2008). Effect of temperature on population parameters of *Aphis gossypii* Glover and *Myzus persicae* (Sulzer) (Homoptera: Aphididae) on pepper. J. Plant. Dis. Protect. 115: 69-74.

Troncoso R, Espinoza C, Sánchez-Estrada A, Tiznado ME, García HS (2005). Analysis of the isothiocyanates present in cabbage leaves extract and their potential application to control alternaria rot in bell peppers. Food. Res. Int. 38:701–708.

Van Emden HF, Bashford MA (1969). A comparison of the reproduction of *Brevicoryne brassicae* and *Myzus persicae* in relation to soluble nitrogen concentration and leaf age (leaf position) in the Brussels sprout plant. Entomol. Exp. Appl. 12: 351-364.

Wang JJ, Tsang JH, Broschat TK (2006). Effect of nitrogen fertilization of corn on the development, survivorship, fecundity and body weight of *Peregrinus maidis* (Hom. Delphacidae). J. App. Entomol. 130: 20-25.