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IMPACT OF ECOLOGICAL ZONES ON MORPHOLOGY OF *PTEROCHLOROIDES PERSICAE* CHOLODKOVSKY (HEMIPTERA, APHIDIDAE)

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A B S T R A C T

Morphometric studies are often carried out on different aphid taxa in order to analyze population variation in relation with different factors, such as host plant, temperature and geography, which have a significant effect on aphid morphology. The brown peach aphid *Pterochloroides persicae* Cholodkovsky (Hemiptera, Aphididae), is a widespread pest on cultivated prunuceous trees throughout the world. In the present study, 15 morphological characters in six populations of *P. persicae* from Tunisia, Spain, Serbia, Iran and Italy were investigated and morphometric data were assessed through a one-way analysis of variance (ANOVA) at 5% significance level. The results showed significant morphological differences among the populations of *P. persicae* in body length, hind femur length, hind tibia length, all antennal segment length, cauda and siphunculi length. It could be concluded that geographic sites and climatic conditions are among the most important factors which contribute to the differentiation between populations. Other complementary studies, such as impact of host plant on morphology of *P. persicae*, host adaptation and performance with regard to environmental conditions will provide a better understanding of the evolutionary implications of the population's structure.

Keywords: *Pterochloroides persicae*, population variation, aphid morphology, morphometry, geographic sites.

INTRODUCTION

Aphids (Hemiptera: Aphididae) comprise a large group of economically important phytophagous insects distributed worldwide (Alyokhin, 2011). They are a truly interesting group of insects that can affect plant directly and indirectly by feeding on its sap (Blackman and Eastop, 2000). Among aphids, the brown peach aphid, *Pterochloroides persicae* Cholodkovsky (Hemiptera, Aphididae) is a serious pest of several host belonging to three families (Rosaceae, Rutaceae, Salicaceae) (Kairo and Poswal, 1995).It's geographical distribution, life cycle, host specificity, harmfulness and morphology have been the subject of intensive studies (Talhouk, 1977; El Trigui and El Shérif, 1987; Kairo and Poswal, 1995). For the geographical distribution, it is a serious pest of *Prunus* spp. trees in Asia, Europe, Africa and America (Talhouk, 1977; El Trigui and El Shérif, 1987; Kairo and Poswal, 1995; Cabello, 1995; Stoetzel and Miller, 1998; Ahmeid Al-Nagar and Nieto Nafria, 1998; Blackman and Eastop, 2006; Mdellel *et al*., 2011; Hidalgo *et al*., 2012). In several countries of these continents, *P. persicae* has assumed a pest status on several plants, causing severe damage by sucking the sap from the bark and branches (Kairo and Poswal, 1995; El Trigui *et al*., 1989; Rakhshani *et al.,* 2005; Darwich *et al.,* 1989; Khan *et al*., 1998; Blackman and Eastop, 2000). As a result, trees become weak and drop fruits prematurely. The large amount of honeydew accumulating on the trees gives them a smothered appearance because of sooty moulds, which grow on the honeydew (Talhouk, 1977; Cross and Poswal, 1996). Several studies demonstrated that host plant, temperature and geographical distribution have a significant impact on the aphid biology (Talhouk, 1977; Darwich *et al*., 1989; Khan *et al*., 1998; Mdellel *et al*., 2011). Indeed, it is described as a holocyclic and anholocyclic species depending on the environmental conditions. Thus, in countries where winter temperatures fall below freezing such as Turkey, Central Asia, India and Syria, *P. persicae* usually has a holocyclic

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life cycle (Darwich *et al.*, 1989; Kairo and Poswal, 1995). while in warmers areas, it remains anholocyclic. The study of the impact of host plant and temperature on the biology and population of *P. persiace* has revealed that 20°C is the best temperature for the reproductive potential of this aphid and peach is the best host in terms of mass rearing (Mdellel *et al*., 2011). The morphological criteria for aphid species may be affected by environmental factors, such as climatic conditions, geography and physiological status of the host plant and in order to adapt different geographical sites and host plant species, aphids undergo morphological and physiological changes (Murdie, 1969;Wool, 1977; Sokat *et al*., 1980; Riska, 1985; Blackman and Spence, 1994; Wool and Hales, 1997; Dixon, 1998; Margaritopoulos *et al*., 2000; Madjdzabeh and Mehrparvar, 2009;Lozier *et al*.,2007; Hazell *etal*.,2010; Fabre *et al*., 2005).Concerning the morphology, the apteral of *P. persicae* are large, shiny, oval, dark brown to black with a between 2.7 to 4.2 mm(Blackman and Eastop, 1984;Kairo and Poswal, 1995; Khan *et al*., 1998) and the alate have characteristic pigmented areas on the forewings. However, the morphology of *P. persicae* like many other aphids may change functions of host plant and environmental factors of geographical sites. Furthermore, morphometric approach can provide useful information at the subspecies level for investing the geographical structure of insect population (Blackman and Brown, 1991; Via and Shaw, 1996). Several studies suggest a correlation among the morphological variations of *P. persicae* and environmental factors. However, so far, little is known about the morphological variations in *P. persicae* despite its wide range of host plants and geographical distribution. In the present study, morphological characters were examined in the populations of *P. persicae* collected from several geographical locations. Thus, the aim of this study was to investigate the morphological variations among the geographical populations of *P. persicae* in Tunisia, Iran, Spain, Serbia and Italy. The knowledge generated here will provide a firm basis to establish a biological control strategy against *P. persicae*.

MATERIAL AND METHODS

Sampling area: In order to analyze the morphological characters of the specimens of *P. persicae* population samples were mostly collected from *Prunu s*trees from six locations of five countries (Tunisia, Italy, Spain, Iran and Serbia) between 1998 and 2010 (Figure 1, Table 1).

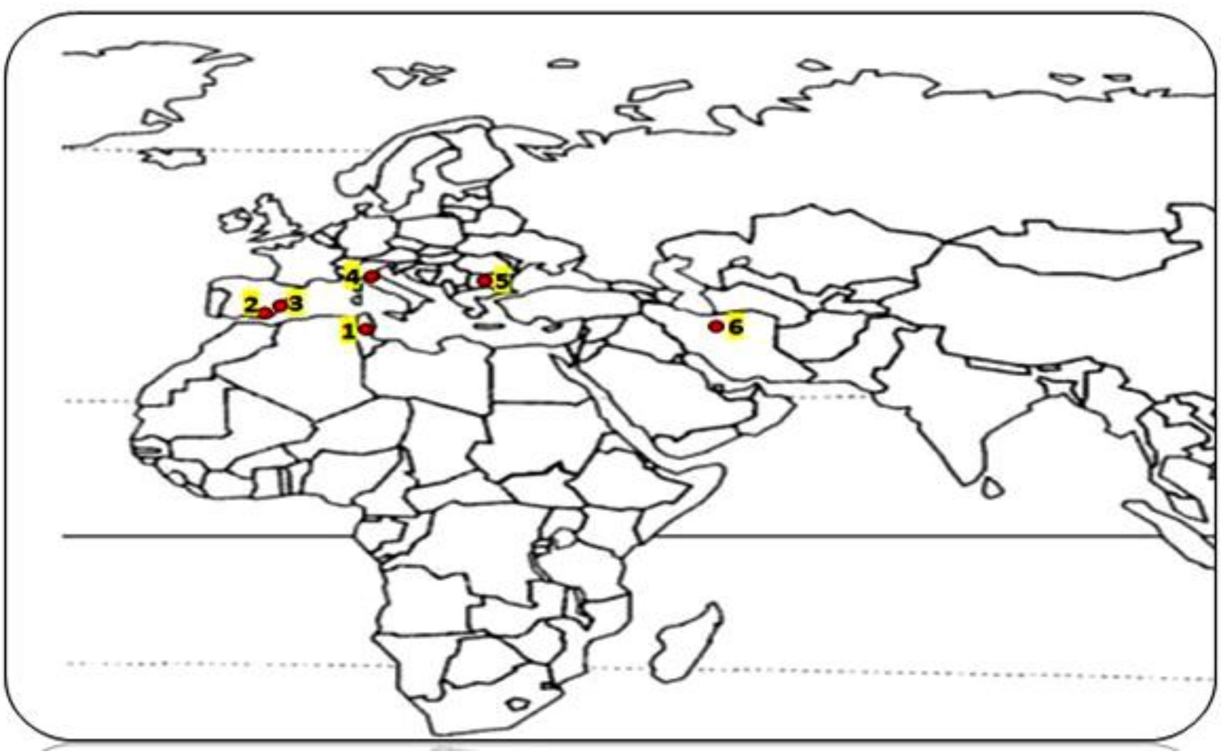

Figure 1. Geographical map representing samples sites.
[1: Tunisia, 2: Spain (Murcia), 3: Spain (Valencia), 4: Italy (Vicenza), 5: Serby (Jagodian), 6: Iran (Taftan)].

Tables 1. Information on *P. persiace* samples collected from different geographic sites.

Country	Host	Locality	Feeding site	Date	Collector	Individual number
Tusania	Almond	Tunisia	Trunk	March 2009	ML	30
Iran	Almond	Taftan	Trunk	May 2008	ER	30
Spain	Almond	Valencia	Trunk	August 2010	DMT	30
Spain	Almond	Murcia	Trunk	March 2009	ALP	30
Italy	Almond	Vicenza	Trunk	September 2010	PC	26
Serbia	Almond	Jagodian	Trunk	August 1998	OPO	18

ML, MdellelLassaad; ER, Ehsan Rhaksheni; GR, George Remaudière; OPO, Olivera Petrovic Obradovic; DMT: David Martinez Torres; ALP, Alfredo Lacasa Plasencia; PC, Piero Cravedi.

Sampling and slide-mounting: Samples of *P. persicae* were manually collected from infested *Prunus* spp. and preserved in 95% ethanol until mounting. To reduce the potential impacts hosts could have on the morphological plasticity of the aphid, samplings were taken only from almond trees. The wingless viviparous females from each location were slide-mounted using Blackman and Eastop's (2000) maceration procedure, opting for a permanent Euparal technique.

Morphometric measurements: The characters (variables) measured in this study have been shown in other morphometric studies were used for aphid identification (Lykouressis, 1983, Agarwala *et al*., 2009). Fifteen continuous characters were selected as follows: body length (LC), hind femur length (HFL), hind tibia length (HLT), antennal segment 1 length (A_1L), antennal segment 2 length (A_2L), antennal segment 2 length (A_3L), antennal segment 4 length (A_4L), antennal segment 5 length (A_5L), antennal base segment 6 length (Ab_6L), antennal processusterminalis segment 6 length (Apt_6L), siphuncular length (SL) and cauda length (CL). The number of setae on cauda and rhinaria on antennal segment 3 and 4 were also included in this study. Fifteen slides from each location were chosen while the others were rejected due to the artifacts when mounting the specimens. The permanent slides were studied under a stereoscopic binocular microscope (Olympus CX 21). All morphological characters were measured in millimeters with the help of an ocular micrometer. The permanent slides were deposited in the entomological collection at the department of plant protection, Higher *Agronomic Institute of Chott Mariem,* Tunisia.

Statistical analysis: To determine the morphological differences in specimens from the ecological zones studied, morphometric data were assessed through a one-way analysis of variance (ANOVA) at 5% significance level (SPSS: version 17).

RESULTS

A total of 164 individuals were collected from 6 ecological sites from 5 countries (30 from Tunisia, 30 from Spain, 26 from Italy, 18 from Serbia and 30 from Iran). Unfortunately, only 90 individuals were measured. All the 15 characters proposed in this study were used. A statistical summary of characters measurements are given in Table 2. The results of the present study demonstrated that from all the characters measured, the greatest variation was observed in the body length, hind femur length, hind tibia length, all antennal segment length, cauda and siphunculi length. However, there were significant differences in 12 of 15 characters collected from six ecological sites i.e., body length (F=5.07; df=5; P=0.0012), hind femur length (F=121.02; df=5; P=0.000), hind tibia length (F=159.78; df=5; P= 0.0021), antennal segment 1 length (F=49.20; df=5;P=0.002), Antennal segment 2 length (F=11.48; df=5; P=0.000), Antennal segment 3 length (F=8.7; df=5; P=0.001), Antennal segment 4 length (F=16.38; df=5; P=0.004), Antennal segment 5 length (F=9.4; df=5; P=0.001), Antennal base segment 6 length (F=13.2; df=5; P=0.001), Antennal processus terminalis segment 6 length (F=52.3; df=5; P=0.002), Siphuncular length (F=11.6; df=5; P=0.000), Cauda length (F=17.4; df=5; P=0.003). Results also demonstrated a morphometric difference between samples collected from Valencia and Murcia from the same country (Spain) in 9 characters: body length hind femur length, hind tibia length, antennal segment 1 length, Antennal segment 2 length, Antennal segment 3 length, Antennal segment 4 length, Antennal segment 5 length, Siphuncular length, Cauda length. However, no significant difference was observed for the rest of the parameters measured.

Table 2. Statistical summary of the morphological traits measured (mm) in *Pterochloroides persicae* collected in several localities (n=90).

Characters: Mean±SD (Range)	Chott Mariem (Tunisia) (n=15)	Taftan (Iran) (n=15)	Valencia (Spain) (n=15)	Murcia (Spain) (n=15)	Jagodina (Serbia) (n=15)	Vicenza (Italy) (n=15)
1. Body length (LC):	4.56 ± 0.02^{c} 4.42-4.55	4.51 ± 0.55^{c} 4.045-4.709	4.93 ± 0.04^{a} 4.04-5.908	4.52 ± 0.53^{c} 4.22-4.90	4.71 ± 0.92^{b} 3.48-5.89	5.03 ± 0.40^{a} 3.48-5.81
2. Length of hind femur (HFL):	0.82 ± 0.02^{b} 0.789-0.856	0.71 ± 0.003^{e} 0.687-0.728	0.86 ± 0.012^{a} 0.834-0.896	0.74 ± 0.01^{d} 0.712-0.768	0.83 ± 0.01^{b} 0.814-0.846	0.76 ± 0.04^{c} 0.736-0.784
3. Length hind tibia (HLT):	1.91 ± 0.01^{c} 1.867-2.042	1.89 ± 0.02^{d} 1.863-1.954	1.74 ± 0.01^{f} 1.734-1.758	2.01 ± 0.03^{a} 1.984-2.123	1.98 ± 0.02^{b} 1.923-2.016	1.84 ± 0.02^{e} 1.836-1.854
4. Antennal segment 1 length (A_1L)	0.136 ± 0.034^{d} 0.112-0.146	0.166 ± 0.034^{ab} 0.126-0.183	0.163 ± 0.034^{b} 0.152-0.178	0.167 ± 0.032^{a} 0.165-0.184	0.126 ± 0.005^{c} 0.112-0.153	0.133 ± 0.015^{c} 0.128-0.162
5. Antennal segment 2 length (A_2L)	0.145 ± 0.01^{c} 0.136-0.158	0.161 ± 0.043^{a} 0.149-0.173	0.155 ± 0.016^{b} 0.127-1.74	0.147 ± 0.01^{c} 0.142-0.154	0.141 ± 0.01^{c} 0.135-0.148	0.141 ± 0.012^{c} 0.136-0.146
6. Antennal segment 3 length (A_3L)	0.613 ± 0.02^{a} 0.593-0.634	0.590 ± 0.067^{a} 0.562-0.613	0.595 ± 0.06^{a} 0.564-0.614	0.563 ± 0.06^{b} 0.538-0.584	0.496 ± 0.039^{c} 0.476-0.523	0.610 ± 0.023^{a} 0.579-0.637
7. Antennal segment 4 length (A_4L)	0.264 ± 0.014^{c} 0.242-0.273	0.283 ± 0.046^{c} 0.264-0.296	0.339 ± 0.06^{a} 0.298-0.369	0.317 ± 0.01^{b} 0.302-0.334	0.246 ± 0.08^{d} 0.221-0.259	0.303 ± 0.04^{b} 0.291-0.336
8. Antennal segment 5 length (A_5L)	0.264 ± 0.006^{b} 0.234-0.296	0.265 ± 0.067^{b} 0.248-0.276	0.233 ± 0.035^{d} 0.217-0.254	0.245 ± 0.01^{c} 0.236-0..258	0.283 ± 0.015^{a} 0.271-0.302	0.268 ± 0.02^{b} 0.257-0.284
9. Antennal base segment 6 length (Ab_6L)	0.153 ± 0.008^{a} 0.146-0.162	0.113 ± 0.018^{c} 0.108-0.127	0.121 ± 0.014^{b} 0.119-0.136	0.124 ± 0.015^{b} 0.108-0.134	0.128 ± 0.015^{b} 0.123-0.138	0.119 ± 0.002^{c} 0.114-0.126
10. Antennal processus terminalis segment 6 length (Apt_6L)	0.058 ± 0.008^{d} 0.045-0.063	0.088 ± 0.018^{a} 0.076-0.092	0.076 ± 0.07^{b} 0.072-0.083	0.076 ± 0.06^{b} 0.072-0.087	0.069 ± 0.04^{c} 0.062-0.074	0.076 ± 0.01^{b} 0.072-0.086
11. Siphuncular length (SL)	0.148 ± 0.01^{a} 0.126-0.159	0.152 ± 0.03^{a} 0.148-0.159	0.149 ± 0.02^{a} 0.146-0.154	0.138 ± 0.015^{b} 0.134-0.146	0.142 ± 0.003^{b} 0.137-0.148	0.154 ± 0.01^{a} 0.148-0.159
12. Cauda length (CL)	0.174 ± 0.01^{c} 0.162-0.184	0.183 ± 0.024^{a} 0.174-0.196	0.173 ± 0.002^{c} 0.169-0.184	0.167 ± 0.003^{d} 0.164-0.172	0.172 ± 0.024^{c} 0.159-0.182	0.178 ± 0.02^{b} 0.164-0.194
13. Number of setae on cauda (SC)	15±5.08 12-20	16±2.18 13-21	15.3±3.12 7-20	13.22±4.05 6-19	15.12±3.31 11-18	15.3±3.12 8-17
14. Number of rhinaria on antennal segment 3 (RA_3)	3.56±2.90 0-4	3.37±3.29 2-11	4.27±2.25 2-11	3.11±1.66 2-9	3.48±2.64 1-8	3.25±0.88 2-5
15. Number of rhinaria on antennal segment 4 (RA_4)	2.93±0.68 0-5	2.67±0.88 2-5	3.18±1.02 2-5	3.18±1.02 2-5	2 .72±1.26 2-4	3.37±0.74 2-4

Different letters with mean values in a row indicate significant differences between the treatments (Duncan test at P>0.05).

DISCUSSION

There are no studies concerning analysis of morphological characters in *P. persicae* associated with ecological zones. The results of the morphometric analysis reveal the size variation in various morphological characters such as body length, length of hind femur, tibia, antennal segment 1, 2, 3, 4 and 5, antennal base segment 6, antennal processus terminalis segement 6, siphuncular and cauda among the geographical populations of *P. persicae*. The results of the present study also demonstrate that there were significant differences among the six populations (Tunisia, Valencia (Spain), Murcia (Spain), Jagodina (Serbia) and Vicenza (Italy) in the body length, length of hind femur and length of hind tibia. Several factors can explain this morphological variation of *P. persicae* population from different ecological zone such as temperature (Blackman and Spence, 1994), host plant conditions (Wool and Hales, 1997; Dixon, 1998; Margaritopoulos *et al*., 2000) and geography (Wool, 1977; Sokat *et al*., 1980; Riska, 1985; Madjdzabeh and Mehrparvar, 2009). As for the geographical factors, several studies demonstrated morphological variation between populations of many species of aphids collected from divers' geographical zones on divers' hosts' crops. Certainly, Madjdzabeh and Mehrparvar (2009) demonstrated the discrimination between populations after investigation of 21 characters of 11 populations of *Macrosiphoniella sanborni* Richard (Hemiptera: Aphididae) collected from several geographic locations in Iran on cultivated *Chrysanthemum* and indicated the presence of morphologically distinct groups. Margaritopoulos *et al.*, (2006) also demonstrated a clear morphomoetric separation of *Aphis gossypii* Glover (Hemiptera: Aphididae) population originating from Compositae and Cucurbitaceae and Malvaceae, regardless of the geographical origin of the aphid and the host plant which they were reared on. There are several reasons to explain the differentiation of aphids' population in relation to geographical sites. Among these reasons, we noted firstly the variation of temperature among different geographical sites. Moreover, several entomological studies suggest that the variation of temperature among several regions can affect the size of aphids (Simmons and Yeargan, 1988; Blackman and Spence, 1994). Similarly, Blackman and Spence (1994) demonstrated that the temperature affects the size of aphids, reducing the aphid size when develop at high temperature. Our results are in agreement with Murdie (1969) and Blackman and Spence (1994) results. In the present study, body size of *P. persicae* population collected from Tunisia and Taftan Iran is smaller than those collected from Vicenza (Italy), Valencia (spain) and Jagodina (Serbia). This is because the climate of Vicenza is fairly dries in summer with cooler autumns and springs and snow in winter. The climate of Valencia is subtropical Mediterranean and semi-arid while Jagodina's between continental in the north with cold winters and humid summers with well distributed rainfall patterns and a more Adriatic climate in the south with hot dry summers as compared to the hot and dry summer and mild with moderate rainfall of Tunsia and Taftan. In this connection, Murdie (1969) demonstrated that *Acyrthosiphum pisum Harris*s howsa relative shortening of legs and antennae at higher temperatures. In contrast, Dixon (1974) revealed that the temperature does not affect the morphology of fundatrices of *Drepanosiphum platanoidis* Schrank. Likewise, several studies suggest that the difference in latitude between the sites of population samples is among the important factors, affecting morphological characters of insects (Haas and Tolley, 1998). These studies indicate that the increasing latitude has a positive correlation with increasing body size and fecundity. Our results are also in accordance with this hypothesis in Vicenza (45°N) where higher body size of *P. persicae* was recorded. Nevertheless, the smaller individuals were also recorded from population collected from Taftan (28.6°N). In conclusion, it can be deduced that the morphological differentiation between *P. persicae* individuals collected from mentioned geographic sites may be due to the climatic and environmental factors. Some studies also confirmed this by genetic investigations, using molecular genetic markers for identification of the populations of *P. periscae* from distinct geographic origins and clustered them into a single consistent group with little variations (Mdellel *et al*., 2012; Kharrat *et al*., 2014). Nevertheless, further studies on the impact of host plant on the morphology of *P. persicae*, host adaptation and performance with regards to environmental conditions are needed to clarify these populations as cryptic species. This will lead to a better understanding of the evolutionary implications of the population structure and its geographical, environmental and historical determinant.

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