Original Research Article

EFFECT OF TEMPERATURE ON THE MORPHOLOGY OF GREEN PEACH APHID, *MYZUS PERSICAE* (SULZER) (HOMOPTERA : APHIDIDAE)

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ABSTRACT: Morphological variation of insect population in response to the temperature is an important phenomenon. In this study, we describe the morphological variations of *Myzus persicae* (Sulzer) (Homoptera: Aphididae) individuals reared at five different range of temperatures (15°C, 20°C, 25°C, 30°C, 35°C, ±1°C), with 70±5% RH and 16:8 L:D photoperiod. The samples of aphids were used as to compare the temperature response of single genotype, and thus to distinguish genotypic and environmental contributions to the phenotypic response. In this study the analysis was based on a large data set obtained by measuring sixteen morphological characters of 50 wingless viviparous adult female *Myzus persicae* clones. In each clones of *Myzus persicae,* the result displayed a linear correlation in shortening the body size and other jointed appendages with increasing temperatures. The optimum temperature for better growth is 25°C±1°C. The clones was attained much larger length of body and other appendages when at lower temperature ranges (15°C±1°C, 20°C±1°C) to optimum and was much less at higher range of temperatures 30°C±1°C, 35°C±1°C) beyond optimum. In the present study the clones of aphids revealed a significant difference in eleven characters namely, length of body, length of a.s. III, IV, V and VI base, length of siphunculi, length of cauda, length of forefemur, midtibia, hindfemur and hindtibia. Results demonstrated that the morphology of *Myzus persicae* was affected by temperature.

KEYWORDS: *Myzus persicae*, morphological variation, temperature.

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1. INTRODUCTION

Most organisms live in environments that vary within and across generations. Many theoretical and empirical studies have investigated the evolution of plasticity and acclimation in response to such environmental variability [1], [2], [3]. These studies, however, focus on the relationship between phenotype and the mean value of an environmental variable, i.e., the familiar form of a norm of reaction. Less well appreciated and less frequently addressed is the relationship between environmental variability and phenotype, such as a norm of reaction for trait value across two environments with the same mean but different variance for a given environmental factor. If present, the phenotypic effects of environmental variance may be an important component of local adaptation [4]. It is well known fact that the temperature is an important environmental factor. Like other environmental variables, temperature affects the morphology of aphids like other insects [5]. Many insects including aphids are smaller when they develop at higher temperatures [6], [7], [8]. Aphids, like many other insects are smaller when they develop at higher temperature [9], [10]. High degree of phenotypic plasticity due to variation in temperature both within and between the morphs of *Sitobion avenae* Fabricius had been reported earlier [11]. Similarly, the spring and summer migrants of *Rhopalosiphum padi* (Linn.) are morphologically different [12]. The pea aphid, *Acyrthosiphon pisum* Harris, when reared at a range of temperatures on good quality food resulted in an increase in embryonic growth rate and relative growth rate, and a decline in developmental time [13]. The prediction that aphids are larger at birth and in adult stage at lower temperature than at higher temperatures is true when reared on good quality food. This has been shown for a number of species such as *Lipaphis pseudobrassicae* Davis [14], *Toxoptera aurantii* (Boyer de Fonsc.) [15] and *Ceratovacuna silvestrii* (Takahashi) [16]. In *Aphis gossypii* Glover, body length is negatively correlated with temperature [17]. As temperature increases, body length for this species decreases to less than 1 mm where normal apterae length is between 0.9 and 1.8 mm [18]. *Myzus persicae* (Sulzer) is also affected by high temperature, and reduction in aphid size is directly linked to adverse effects on aphid symbionts [7]. The cabbage aphid, *Brevicoryne brassicae* (Linn.) reared at 30 ºC were significantly smaller in length and width than aphids reared at 15 ºC, particularly later instars [19]. Measurements of general body size, however, describe only one limited aspect of the pattern of morphological change that results from different temperatures. Instead of body size, the jointed appendages of insects and other arthropods are seem the same effect when develop at higher temperatures. Earlier studies on *Acyrthosiphon pisum* [13] indicated a relative shortening of legs and antennae, respectively at higher temperatures, but the statistical analysis did not differentiate between general size variation in the data and the specific effect of temperature. In temperate climates, the successive generations of multivoltine insects are exposed to different temperatures. Considering only one quantitative traits, such as the length of antennal segments, the extent of its variation over a range of temperature normally experienced will depend on the phenotypic plasticity

of the genotype [20]. The particular mean value for only one character expressed at one temperature within the range may be expected to tend towards an optimum, as a result of stablising selection [21], [22], it implies that one might expect to find a shifting pattern of temperature-dependent allometric growth, resulting the shape changes that continually adjust the phenotype to the contemporary environment [5]. The morphology of insects is also affected by many other environmental variables besides temperature such as food plants [23]. In nature the genotype-environment interactions is extremely complex. However, a study of temperature effect on phenotypic effects seems to be a good starting point from which to test the evolution of phenotypic plasticity. Aphids are ideal insects to examine the effect of temperature on the morphology and the findings may help to solve taxonomical problems regarding aphids. The variations in morphology of aphids sometimes create problems in their identification particularly at species level. The aphid, *Myzus persicae* (Sulzer) (Homoptera : Aphididae) is commonly known as green peach aphid or peach potato aphid is a widely distributed and highly polyphagous and infests over 1600 plant species worldwide belonging to 64 different plant families [24]. In India it infests about 300 plant species [25]. It is a notorious pest on several crops, e.g. potato, chilli, tobacco, brinjal, cabbage, cauliflower, mustard, radish, sugarbeet, wheat, coriander, sunflower, etc. belonging to different families such as Solanaceae, Brassicacae, Poaceae, Asteraceae, Rosaceae etc. [25], [26]. It causes direct damage, resulting from searching for food, which may induce plant deformation [27]. Colonies of aphids can severely reduce the vigour and yield potential of potato crop especially if it is being grown for seed production. *Myzus persicae* is a vector of 182 viral diseases in a large range of plants [28], [29], [30]. Some of the particularly damaging diseases transmitted by it include potato leafroll virus and potato virus Y to Solanaceae, beet western yellows and beet yellows viruses to Chenopodiaceae, lettuce mosaic virus to Asteraceae, cauliflower mosaic and turnip mosaic viruses to Brassicaceae, and cucumber mosaic and watermelon mosaic viruses to Cucurbitaceae. A discoloration in potato tubers, called net necrosis, occurs in some potato varieties following transmission of potato leafroll [31], [32]. The main objective of this study is to determine the effects of temperature on the possible variation in adult morphology of apterous viviparous female *Myzus persicae* (16 morphological traits)*,* when other environmental variables were kept constant. The main purpose of this study was to obtain a general picture of the phenotypic response of the aphid against variation in temperature.

2. MATERIALS AND METHODS

2.1. Aphid collection, preservation and Mounting

A clone of *Myzus persicae* was obtained from and reared on the rapeseed mustard, *Brassica rapa campestris* grown in fields/claypots. The aphids were reared on the same host plant seedlings for 2 generations to acclimatize the laboratory conditions. The test aphids were randomly selected from the new-born nymphs, and were put on the leaves of the host plant grown in small pots which then

were placed in Yarco Plant Growth Chambers at five constant temperatures (15±1°C, 20±1°C, 25±1°C, 30±1°C, 35±1°C), with 70±5% RH and 12:12 L:D photoperiod. After attaining adulthood, the apterous adults were picked off from the leaves kept at different temperatures. The collected adults were preserved in 70% ethanol and glycerol mixture (5:1) ratio for morphometrical studies. The aphids were mounted in Berlese medium. After mounting the specimens, the slides were properly labeled and left in the trays in horizontal position, and then placed in an incubator at 50-60 °C for slow drying. The dried slides were stored in slide cabinets for morphometric measurements.

2.2. Morphometric measurements and analysis

To determine the morphological variations between samples, sixteen characters were measured that had been reported to be useful in other studies of aphid's morphometrics [33], [34]. The following measurements were taken by ocular micrometer corroborated with stage micrometer and have expressed in mm:

Character I, Body length (Bl): Distance from middle of frons to tip of cauda.

Character II, Length of first and second antennal segment (a.s. I-II): Length from base of antennal segment I to tip of antennal segment II.

Character III, Length of third antennal segment (a.s. III): Length from base antennal segment III to tip of antennal segment III.

Character IV, Length of forth antennal segment (a.s. IV): Distance from base to tip of antennal segment IV.

Character V, Length of fifth antennal segment (a.s. V): Distance from base to tip of antennal segment V.

Character VI, Length of the base of sixth antennal segment (a.s. VI base): Length of base of antennal segment VI from basal articulation to distal end of primary rhinaria.

Character VII, Length of processus terminalis of sixth antennal segment (pt): Length of processus terminalis from apical end of primary rhinarium and tip of the antennal segment.

Character VIII, Length of the ultimate rostral segment (URS): Length of the portion of rostrum between basal articulations of segment IV to tip of the rostrum.

Character IX, Length of siphunculus (Sl): Length from its base to apex.

Character X, Length of cauda (Cl): Length from middle of its very base to apex.

Character XI, Length of forefemur (Ffm): Length of forefemur from base to tip.

Character XII, Length of foretibia (Ftb): Length of segment from base to tip.

Character XIII, Length of midfemur (Mfm): Length of midfemur from base to tip.

Character XIV, Length of midtibia (Mtb): Length from base to tip of midtibia.

Character XV, Length of hindfemur (Hfm): Length of hindfemur from its base to tip.

Character XVI, Length of hindtibia (Htb): Length from base to tip of hindtibia.

2.3. Statistical analysis

The parameters recorded for different individuals of *Myzus persicae* reared at different temperature ranges were subjected to one factor analysis of variance (ANOVA) and means were separated by Duncan mean range test (DMRT) at the 5% or 1% level of significance.

3. RESULTS AND DISCUSSION

The mean values and standard errors for the sixteen morphological characters of *Myzus persicae* population reared at five different temperatures are given in Table 1. Results demonstrated significant morphological differences in 11 out of 16 characters studied, viz. length of body, a.s. III, a.s. V, a.s. V, a.s. VI base, siphunculus, cauda, forefemur, midtibea, hindfemur and hindtibea.

3.1. Variation in character I (length of body, Bl)

The data revealed a significant difference in length of body of clones of apterous *Myzus persicae* reared at five temperatures (F=22.93, df=4, P=0.01) (Table 1). The clones reared at temperature 15°C were bigger in body size (2.330 ± 0.035 mm) than those reared at progressively higher temperatures, i.e. 20°C (2.170 ± 0.031 mm), 25°C (2.133 ± 0.037 mm), 30°C (2.048 ± 0.024 mm) and 35°C (1.918 ± 0.031 mm) (Table 1, Fig. 1). However, significant difference was only observed between clones reared at lower temperatures (15-20°C) and higher temperatures (30-35 ºC). As earlier reported that the optimum temperature for population growth of *Myzus persicae* is about 25 ºC (Davis *et al.,* 2006; Bebi, 2014), the adults reared at below this temperature are larger than those reared at above this temperature (Table 1, Fig. 1).

3.2. Variation in character II (length of a.s. I-II)

The statistical analysis displayed no significant difference in the length of a.s. I-II of the clones of apterous *Myzus persicae* reared at five different temperatures. However, as the body length is larger at lower temperature, the length of a.s. I-II of the clones were little larger in size (0.183 ± 0.005 mm) than those reared at 20°C (0.179 ± 0.004 mm), 25°C (0.178 ± 0.003 mm), 30°C (0.177 ± 0.004 mm) and 35°C (0.175 ± 0.003 mm) (Table 1, Fig. 2).

3.3. Variation in character III (length of a.s. III)

The data revealed a significant difference in length of a.s. III of clones of apterous *Myzus persicae* reared at five temperatures (F=6.11, df=4, P=0.01) (Table 1). In the clones reared at temperature 15°C, the length of a.s. III was longer (0.458 ± 0.012 mm) than those reared at progressively higher temperatures, i.e. at 20°C (0.448 ± 0.013 mm), 25°C (0.427 ± 0.009 mm), 30°C (0.405 ± 0.008 mm) and 35°C (0.396 ± 0.011 mm) (Table 1, Fig. 2). However, significant difference in this trait was only noticed between clones reared at two extremes, i.e., at lower temperature (15°C) and at higher temperatures (30-35 ºC) (Table 1, Fig. 2).

Table 1: Length (mm, mean±SE) of 16 morphological characters of 50 *Myzus persicae* reared at different temperatures.

| Character No.	Temperature					F. value ($n_1 = 4$, $n_2 = 45$)	Level of Signifi - cance
	15°C ± 1°C	20°C ± 1°C	25°C ± 1°C	30°C ± 1°C	35°C ± 1°C		
	Mean± SE	Mean± SE	Mean± SE	Mean± SE	Mean± SE		
I (Bl)	2.33±0.04b	2.17±0.03b	2.13±0.04ab	2.05±0.02a	1.92±0.03a	22.93	0.01
II (a.s. I - II)	0.18±0.01a	0.18±0.00a	0.18±0.00a	0.18±0.00a	0.18±0.00a	0.61	NS
III (a.s. III)	0.46±0.01b	0.45±0.01ab	0.43±0.01ab	0.41±0.01a	0.40±0.01a	6.11	0.01
IV (a.s. IV)	0.38±0.01b	0.37±0.01b	0.33±0.01a	0.33±0.01a	0.32±0.01a	5.83	0.01
V (a.s. V)	0.31±0.01b	0.29±0.01ab	0.29±0.01ab	0.27±0.01a	0.27±0.01a	3.56	0.05
VI (a.s. VI base)	0.12±0.00b	0.12±0.00ab	0.12±0.00ab	0.11±0.00ab	0.11±0.00a	4.90	0.01
VII (pt.)	0.50±0.01a	0.50±0.01a	0.50±0.02a	0.49±0.01a	0.49±0.02a	0.12	NS
VIII (URS)	0.12±0.00a	0.11±0.00a	0.11±0.00a	0.11±0.00a	0.11±0.00a	1.38	NS
IX (Sl)	0.57±0.02b	0.56±0.01b	0.53±0.02ab	0.50±0.01a	0.50±0.01a	4.32	0.01
X (Cl)	0.29±0.01b	0.27±0.01b	0.24±0.01ab	0.23±0.01a	0.23±0.01a	10.80	0.01
XI (Ffm)	0.52±0.01b	0.51±0.01ab	0.50±0.01ab	0.47±0.02ab	0.47±0.02a	2.51	0.05
XII (Ftb)	0.84±0.02a	0.83±0.02a	0.82±0.02a	0.78±0.03a	0.76±0.02a	2.40	NS
XIII (Mfm)	0.53±0.01a	0.52±0.01a	0.52±0.01a	0.49±0.02a	0.49±0.02a	1.77	NS
XIV (Mtb)	0.98±0.02b	0.95±0.02ab	0.92±0.02a	0.91±0.03a	0.87±0.03a	2.59	0.05
XV (Hfm)	0.70±0.03b	0.69±0.02b	0.66±0.02b	0.62±0.01a	0.62±0.01a	4.73	0.01
XVI (Htb)	1.20±0.04b	1.16±0.03b	1.11±0.02b	1.06±0.03a	1.06±0.03a	4.67	0.01
Mean values followed by different letters are significantly different from each other at P < 0.05, Duncan's Multiple range test.							
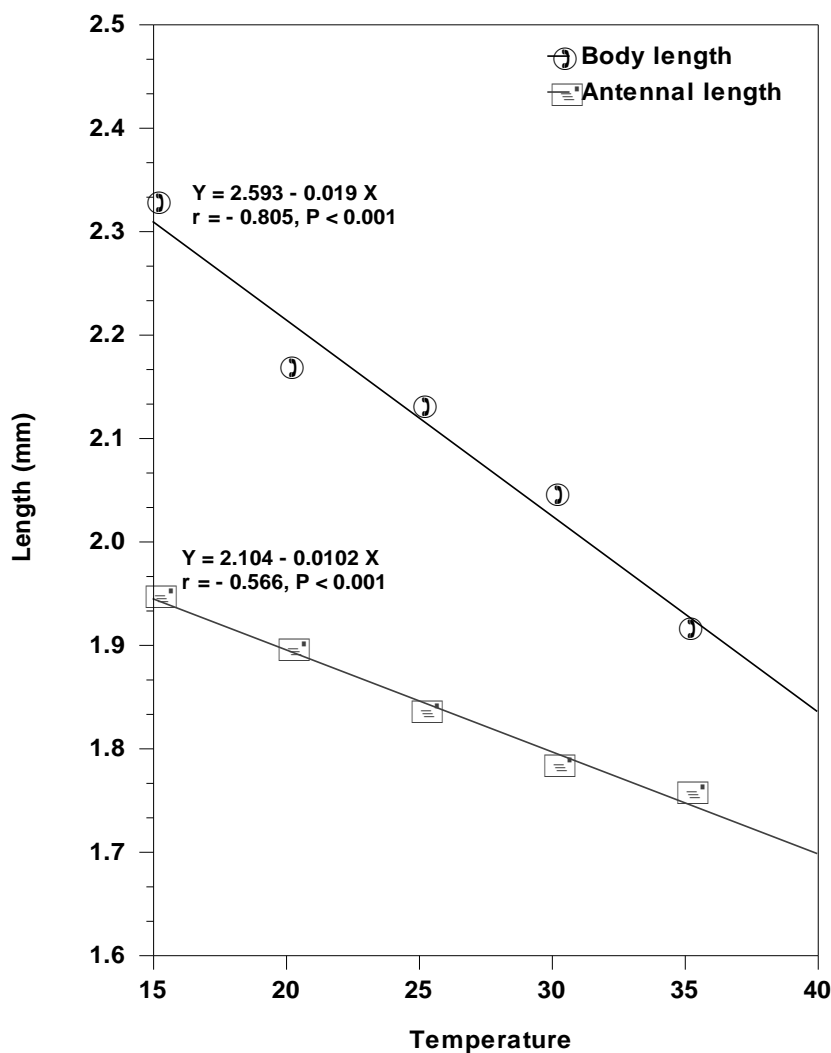
Fig. 1. Mean length (in mm) of body and antennae of *Myzus persicae* reared at 5 constant temperature.

3.4. Variation in character IV (length of a.s. IV)

The result displayed in Table 1 demonstrated a significant difference in the length of a.s. IV of the clones of apterous *Myzus persicae* reared at different temperatures (F=5.83, df=4, P=0.001). The length of a.s. IV of clones reared at 15°C were longer (0.375 ± 0.009 mm) than those reared at 20°C (0.366 ± 0.012 mm), 25°C (0.334 ± 0.011mm), 30°C (0.327 ± 0.010 mm) and 35°C (0.319 ± 0.010 mm). However, no significant difference in this trait was observed between clones reared between 15°C to 20°C and between 25°C to 35°C, but a significant difference in the length of a.s. IV was observed between clones reared at these two ranges, i.e., between 15-20°C and 25-35ºC (Table 1, Fig. 2).

3.5. Variation in character V (length of a.s. V)

The data revealed a significant difference in the length of a.s. V, of the clones of apterous *Myzus persicae* reared at different temperatures (F=3.56, df=4, P=0.005, Table 1, Fig. 2). In the clones reared at temperature 15°C the length of a.s. V were longer (0.308 ± 0.008 mm) than those reared at successively higher temperatures 20°C (0.287 ± 0.008 mm), 25°C (0.287 ± 0.008 mm), 30°C

(0.274 ± 0.007 mm) and 35°C (0.270 ± 0.009 mm). However, significant difference was only observed in this trait between two extremes, i.e., at lower temperature 15°C and at higher temperatures (30-35 ºC) (Table 1, Fig. 2).
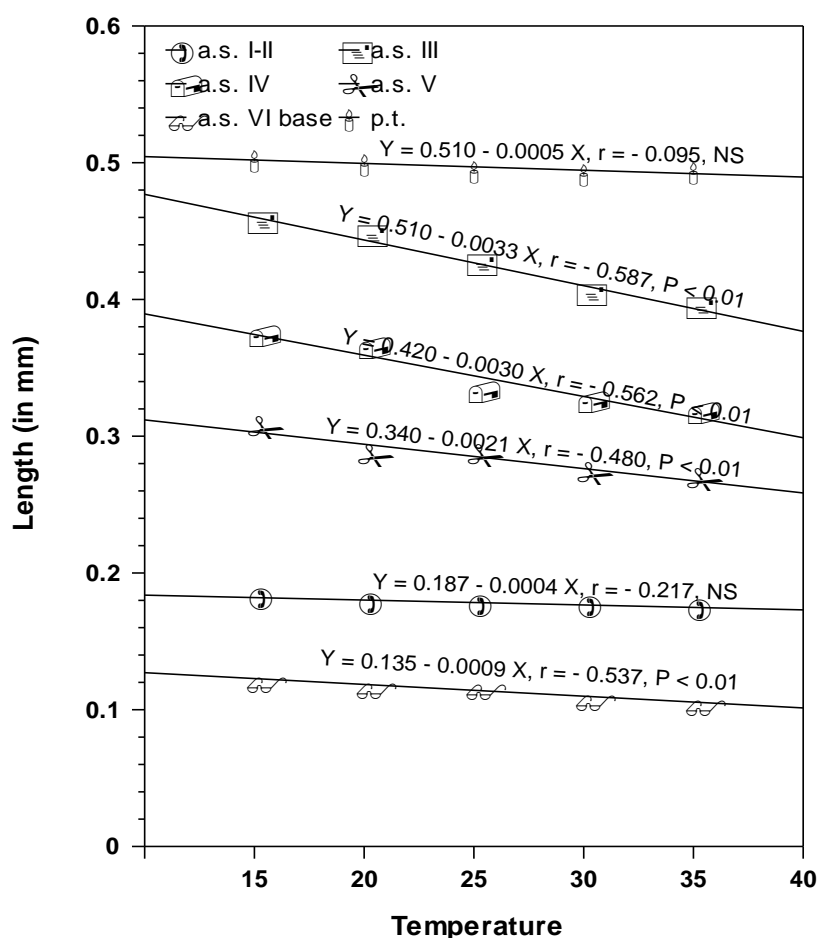

Fig. 2. Mean length (in mm) of antennal segment I - II (a.s. I - II), III (a.s. III), IV (a.s. IV), V (a.s. V), base of VI (a.s. VI base) and terminal processes (p.t.) of *Myzus persicae* reared at 5 constant temperature

3.6. Variation in character VI (length of a.s. VI base)

The statistical analysis displayed a significant difference in the length of a.s. VI base of clones of apterous *Myzus persicae* reared at five temperatures (F=4.90, df=4, P=0.001, Table 1, Fig. 2). The length of a.s. VI base of the clones reared at 15°C were longer (0.122 ± 0.003 mm) than those reared at 20°C (0.118 ± 0.004 mm), 25°C (0.117 ± 0.003 mm), 30°C (0.109 ± 0.003 mm) and 35°C (0.105 ± 0.002 mm). Significant difference in the length of a.s. VI base was observed when the aphids were reared at two extreme temperatures, i.e., at 15°C and at 35°C (Table 1, Fig. 2).

3.7. Variation in character VII (length of processus terminalis, pt)

The statistical analysis displayed no significant difference in the length of pt. of the clones of apterous *Myzus persicae* reared at five temperatures. Moreover, the length of pt of the clones reared at 15°C were little longer (0.503 ± 0.011 mm) than those reared at 20°C (0.500 ± 0.012 mm), 25°C

(0.495 ± 0.015 mm), 35°C (0.494 ± 0.015 mm) and 30°C (0.493 ± 0.007 mm) (Table 1, Fig. 2).

3.8. Variation in character VIII (length of u.r.s.)

The statistical analysis displayed in Table 1 demonstrated no significant difference in the length of u.r.s. of the clones of apterous *Myzus persicae* reared at different temperatures. Similar to length of pt, the length of u.r.s. of the clones reared at 15°C were slightly longer (0.115 ± 0.003 mm) than those reared at 20°C (0.113 ± 0.003 mm), 25°C (0.112 ± 0.002 mm), 30°C (0.109 ± 0.002 mm) and 35°C (0.107 ± 0.003 mm) (Table 1, Fig. 3).
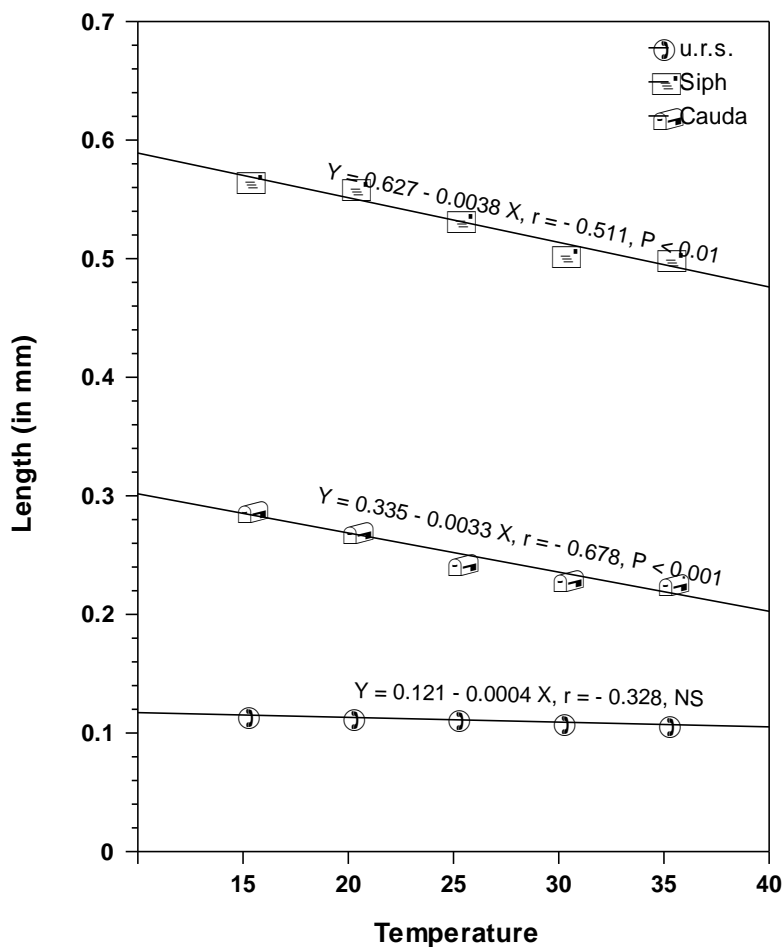

Fig. 3. Mean length (in mm) of ultimate rostral segment (u.r.s.), siphunculus (Siph) and cauda (Cauda) of *Myzus persicae* reared at 5 constant temperature

3.9. Variation in character IX (length of siphunculus, Siph)

The data displayed in Table 1 demonstrated a significant difference in the length of siphunculus of apterous *Myzus persicae* clones reared at different temperatures (F=4.32, df=4, P=0.001). In the clones reared at 15°C the length of Siph were longer (0.566 ± 0.015 mm) than those reared at 20°C (0.560 ± 0.014 mm), 25°C (0.533 ± 0.019 mm), 30°C (0.504 ± 0.013 mm) and 35°C (0.500 ± 0.011 mm). However, significant difference in this trait was noticed only between clones reared at 15-20°C and at 30-35°C (Table 1, Fig. 3).

3.10. Variation in character X (length of cauda)

The statistical analysis revealed a significant difference in the length of cauda of apterous *Myzus persicae* clones reared at different temperatures (F=10.80, df=4, P=0.001) (Table 1). The length of cauda of the clones reared at 15°C were longer (0.289 ± 0.008 mm) than those reared at progressively higher temperatures, e.g. at 20°C (0.271 ± 0.008 mm), 25°C (0.244 ± 0.009 mm), 30°C (0.230 ± 0.008 mm) and 35°C (0.277 ± 0.007 mm). Like other characters, the length of cauda was significantly shorter at 30-35°C as compared to 15-20°C (Table 1, Fig. 3).

3.11. Variation in character XI (length of forefemur, Ffm)

The data in Table 1 displayed a significant difference in the length of Ffm of apterous *Myzus persicae* reared at five temperatures (F-2.51, df= 4, P=0.005). The length of Ffm of apterous *Myzus persicae* reared at 15°C were generally longer (0.518 ± 0.012 mm) than those reared at gradually higher temperatures 20°C (0.512 ± 0.011 mm), 25°C (0.500 ± 0.013 mm), 30°C (0.472 ± 0.019 mm) and 35°C (0.468 ± 0.016 mm). However, significant difference in this trait was only observed between clones reared at two extreme temperatures i.e., 15°C and at 35°C (Table 1, Fig. 4).

3.12. Variation in character XI (length of foretibia, Ftb)

The statistical analysis displayed no significant difference in the length of Ftb of the clones of apterous *Myzus persicae* reared at different temperatures. However, as the previous characters Ftb, the length of Ftb of the clones were little longer when reared at 15°C (0.838 ± 0.021 mm) than those reared at 20°C (0.829 ± 0.016 mm), 25°C (0.820 ± 0.024 mm), 30°C (0.775 ± 0.028 mm) and 35°C (0.758 ± 0.023 mm) (Table 1, Fig. 4).

3.13. Variation in character XII (length of midfemur, Mfm)

The result of statistical analysis displayed in Table 1 demonstrated no significant difference in the length of Mfm of the clones of apterous *Myzus persicae* reared at different temperatures. However, as the length of other characters the length of Mfm of the clones were little longer at 15°C (0.532 ± 0.013 mm) than those reared at gradually higher temperatures 20°C (0.519 ± 0.012 mm), 25°C (0.517 ± 0.014 mm), 30°C (0.491 ± 0.015 mm) and 35°C (0.490 ± 0.015 mm) (Table 1, Fig. 4).

3.14. Variation in character XI (length of midtibia, Mtb)

The data displayed in Table 1 demonstrated a significant difference in the length of Mtb of apterous *Myzus persicae* reared at different temperatures (F-2.59, df= 4, P=0.005). In the clones reared at 15°C, the length of Mtb were little longer (0.983 ± 0.020 mm) than those reared at 20°C (0.954 ± 0.022 mm), 25°C (0.917 ± 0.023 mm), 30°C (0.914 ± 0.029 mm) and 35°C (0.873 ± 0.034 mm). A significant difference was noticed in this character between clones reared at 15°C and at 25-35°C (Table 1, Fig. 4).
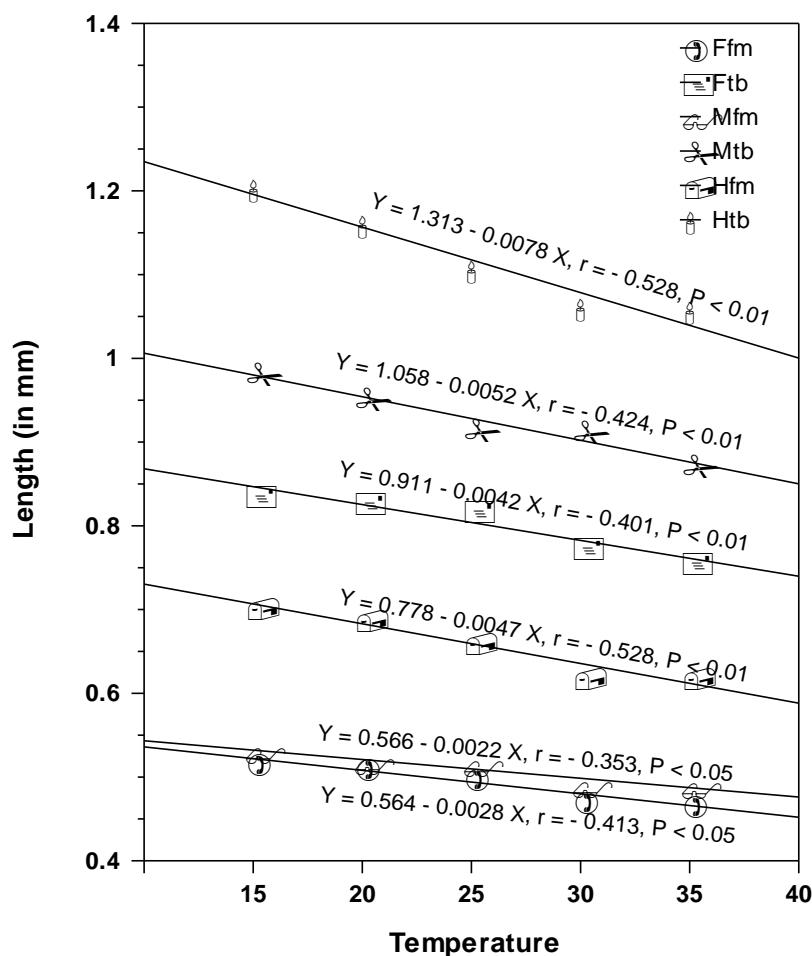
Fig. 4. Mean length (in mm) of forefemur (Ffm), foretibia (Ftb), midfemur (Mfm), midtibia (Mtb), hindfemur (Hfm) and hindtibia (Htb) of *Myzus persicae* reared at 5 constant temperature.

3.15. Variation in character XV (length of hindfemur, Hfm)

The statistical analysis displayed a significant difference in the length of Hfm of apterous *Myzus persicae re*ared at different temperatures (F-4.73, df= 4, P=0.001) (Table 1, Fig. 4). The length of Hfm of clones reared at 15°C were longer (0.704 ± 0.026 mm) than those reared at gradually higher temperatures 20°C (0.690 ± 0.017 mm), 25°C (0.662 ± 0.015 mm), 30°C (0.621 ± 0.014 mm) and 35°C (0.620 ± 0.013 mm). However, as earlier reported that the optimum temperature for population growth of *Myzus persicae* is about 25 ºC the clones reared at this temperature have significantly shorter Hfm than those reared at lower temperature while have significantly longer Hfm when reared at higher temperature (Table 1, Fig. 4).

3.16. Variation in character XV (length of hindtibia, Htb)

The data of statistical analysis raveled a significant difference in the length of Htb of apterous *Myzus persicae* reared at different temperatures (F-24.67, df= 4, P=0.001) (Table 1, Fig. 4). The length of Htb of clones reared at 15°C were longer (1.203 ± 0.041 mm) than those reared at gradually higher temperatures 20°C (1.160 ± 0.027 mm), 25°C (1.107 ± 0.023 mm), 30°C (1.061 ± 0.027 mm) and 35°C (1.057 ± 0.025 mm). A significant difference was observed in the length of Htb of clones

reared at extreme temperature ranges i.e., 15-25°C and at (30-35°C) (Table 1, Fig. 4).

DISCUSSION

Aphids under high temperature spend more energy on catabolic processes and less energy on development [7]. Aphids reared at 30 ºC were smaller in length and width than aphids reared at 20 ºC. In the present study, the length of the aphid in general as well as the length of its appendages seemed to vary between the temperatures. Herewith, sixteen morphological characters of clones of *Myzus persicae* were examined when reared at 5 constant temperatures: 15, 20, 25, 30 and 35°C±1°C. The previous studies have shown that morphological characteristics have linear correlation with changing temperature [5]. The aphids like other insects are smaller in body length and length of other appendages when developed at higher temperature [6]. In this study the result displayed the orderly decreasing in body length and other appendages with increasing per 5°C of temperature. However, the development, mortality, adult size and weight, feeding behaviour and local adaptation are also affected by temperature [35]. Morphological plasticity, i.e. strong interaction between environmental and genetic components of variation has been well demonstrated, for example in a completely asexual aphid species *Myzus antirrhinii* (Macchiati) [36], [37]. In earlier studies, the taxonomist used canonical variate analysis (CVA) as a powerful tool for resolving taxonomic problems among closely-related aphid taxa. The CVA applied to separates environmental from genetic components of variance and can thus distinguish even between different genotypes to aphid lineages reared under controlled conditions [5]. It can also be usefully applied to samples from field populations [38], [39]. Use of multivariate analyses was used to describe taxonomic relationships within an insect species group is that the environmental component of variation may be large and as a consequence the morphological differences may not have a genetic basis [40]. Temperature can affect both isometric and allometric growth in aphids and its interaction with genotype is complex [5]. Besides, temperature along with many other ecological factors creates morphological discrimination in insect and aphid too like. The host plant species and its physiological condition may also affect aphid morphology [7], [40], [41], [42]. It had been demonstrated that *Aphis gossypii* is also a phenotypically very plastic species [43]. Aphid size varies greatly between the temperatures. Results must be interpreted carefully because statistical analysis was not appropriate; size differences could be due to a chamber effect and not only temperature [44], [45], [46]. However, there seems to be a trend between higher temperature and aphid size. Aphids under high temperature spend more energy on catabolic processes and less energy on development [7]. Aphids reared at 30-35 ºC were smaller in length and width than aphids reared at 15 ºC. Similar trend was observed in almost all morphological traits studied herein. It has been reported that the aphids are smaller in size when they develop at higher temperature [7]. High degree of phenotypic plasticity to effects of temperature both within and between the morphs of *Sitobion avenae* have earlier been reported [11]. Similarly, the spring and summer migrants of *Rhopalosiphum padi* are

morphologically different [12]. The pea aphid, *Acyrthosiphon pisum*, when reared at a range of temperatures on good quality food resulted in an increase in embryonic growth rate and relative growth rate, and a decline in developmental time. The prediction that aphids are larger at birth and in adult stage at lower temperature than at higher temperatures is true when reared on good quality food. This has been shown for a number of species such as *Lipaphis pseudobrassicae* [14], *Toxoptera aurantii* [15], *Ceratovacuna silvestrii* [16], and *Aphis gossypii* [17], [18]. Temperature also affects the aphid morphology by altering the physiology of the host plant, i.e., the quality of the food of the aphid that influences indirectly the growth pattern of their nymphs. No genotype-environment interactions was reported while studying two species of *Myzus* (*Myzus persicae* and *Myzus anirrhinii*) in the temperature response [5]. If it is true, then they suggested the possibility of construction of a general model of the phenotypic response to temperature that could play for perhaps to more than one species. Such a model might help in the interpretation of temperature-related variation in filled collected specimens, by enabling morphological discriminates to be "corrected" for hot or cold conditions. The results of the current studies showed the body length was always significantly much smaller at higher temperature. The result presented here provides the information about the speed, extent and direction of change of the morphology of the aphids *Myzus pesicae* with temperature. Many of the sixteen characters used in this analysis are highly correlated with changing temperature at higher temperature many characters are much shorter than at lower temperature. The results presented herein agree with Bergmann's Rule [47] but not the Allen's Rule [48] which are applied to field data for a wide range of organisms. Bergmann's Rule deals that individual body size tends to be less in the warmer parts of a species' range, while Allen's Rule, states that 'protruding body parts' are relatively shorter in cooler climates and these changes do not necessarily involve genetic differences between populations. The results presented herein demonstrated that the body size as well as size of the appendages such as antennae, u.r.s., legs (femur and tibia), siphunculi, cauda etc. gradually decreases with increase of temperature with significant difference between 15 and above 25º C, i.e., it follows Bergmann's Rule. It seems possible that the phenotypic response of *Myzus persicae* to temperatures, perhaps reflecting different metabolic pathways by which temperature affect the pattern of growth [5]. However, the variation in the length of protruding appendages such as antennae, legs and their parts, siphunculi, cauda in response to temperature do not follow Allen's Rule as the length of these parts are longer in cooler temperature (15ºC). Indeed, Allen's Rule mostly applies in homoeothermic animals. Decrease in body size that reflects in the size of other morphological units at high temperature may also be caused by inadequate nutrition than to a direct effect of high temperature. The midsummer 'dwarfs' of many aphid species reported at high temperature and the relatively short appendages typical of the fundatrix morph are probably an adaptation to a sedentary life in a relatively exposed habitat, rather than the result of early-season development at low temperature. Temperature effect on the

morphology of fundatrices of *Drepanosiphum platanoidis* was reported [49]. If the phenotypic response to temperature can be suppressed in certain morphs such as the fundatrix, this is a further indication that it is an adaptive phenomenon rather than an obligatory outcome of the interaction of temperature and metabolic processes [5]. It is an established fact in case of aphids that small individuals develop when they are reared at crowded conditions, on mature plants or at high temperatures and large individuals develop when they are reared in isolation on young or senescent plants or at low temperatures [6]. Well fed animals grow generally large than poorly fed ones; therefore, the effect of food quality on size is not surprising. The inverse relationship observed between size and temperature is more puzzling, but is a widespread phenomenon in insects. Long back, it was postulated that size in aphids is a consequence of the balance between catabolism and anabolism [50]. At high temperatures catabolism consumes most of the available energy and little is left for growth (anabolism). Small size in *Myzus persicae* at high temperatures has been accredited to an adverse effect on the aphid's symbionts and resultant deterioration in the quality of food available to the aphid, which would reduce anabolism. By treating development and growth as separate processes showed that although aphids reared at high temperatures are small, they nevertheless have higher growth rate than those reared at low temperatures [51]. Size is a consequence of the relative effect of food quality and temperature on the growth and developmental rates. Both an increase in food quality and temperature result in an increase in the growth rate measured as their intrinsic rate of increase [52]. However, increase in temperature disproportionally decrease the development time as a consequence aphids are small when reared at high temperatures [52].

4. CONCLUSION

In the present study the clones of *Myzus persicae* demonstrated that temperature do affect the morphometry of different body parts as an adaptation.

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CONFLICT OF INTEREST

The authors have declared that they have no conflict of interest.

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