



## EFFECTS OF TEMPERATURE ON DEVELOPMENT OF *MYZUS PERSICAE* (SULZER)

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### ABSTRACT

The effects of temperature on development of *Myzus persicae* (Sulzer) was investigated at five constant temperature 17, 20, 23, 26 and 29± 1 °C, 65± 5 % RH, and a photoperiod of 16:8 (L:D) hr fed on cabbage (*Brassica oleracea* var. capitata) under laboratory condition using the age-stage, two-sex lifetable approach. The intrinsic rate of increase ( $r$ ) of this aphid was highest at 29°C (0.3212 d<sup>-1</sup>) and lowest at 17°C (0.02157 d<sup>-1</sup>). The developmental rate of nymphs at different temperatures fit the linear equation,  $y = 0.005x - 0.001$  with a coefficient of determination ( $R^2$ ) of 0.98. The thermal summation of the pre-adult, the female, and the total life stages (from birth to death) was 194.6, 241.8 and 430.2 DD, respectively. The developmental threshold of the pre-adult, the female, and the total life stage was 0.29, 10.6, and 5.29°C, respectively. The mean generation time was 18 d at 17°C, which declined to 10.2 d at 29°C. The net reproduction rate ( $R_0$ ) was 26.6 offspring/ individual at 29°C, and it was considerably lower than the rates obtained at other temperatures. The highest net reproductive rate was obtained at 20°C ( $R_0 = 54.2$  offspring/ individual). In the absence of other limiting factors, populations of *M. persicae* would be expected to increase faster if introduced into environments having temperature ranging between 23 and 26°C.

**Key words:** *Myzus persicae*, lifetable, threshold, thermal summation, reproductive rate, rate of increase, pre-adult, female, total life stages, developmental threshold, rate, photoperiod

The green peach aphid *Myzus persicae* (Sulzer) (Aphididae: Hemiptera) is a polyphagous insect which has been reported to feed on more than 500 species of host plants from at least 40 plant families which include several economically important agricultural crops (van Emden and Harrington, 2007). It is also one of the most important insect pests of greenhouse crops (Kim et al., 2018) and is characterized of rapid population development due to a high reproductive capacity. It is an efficient vector of large number of plant viruses (Bhat and Rao, 2020; van Emden et al., 1969) and resistant to most classes of insecticide including organophosphates, carbamates, pyrethroids, cyclodienes and neonicotinoids (Margaritopoulos et al., 2021). Its feeding on host plants may cause indirect damage through cell sap depletion and retardation of photosynthesis due to sooty mould on foliage occurred of aphid secretion of honeydew. Insects are ectothermic (poikilothermic) organisms, in which atmospheric temperature plays a critical role in their developmental rate, survival, and reproduction (Davis et al., 2006; Wang et al., 2020). As population dynamics of arthropods are temperature-dependent (Logan et al., 1976) and temperature affects biological processes (Dixon, 1998; Bale et al., 2007), lifetables for insects subjected to a wide range of temperatures are appropriate tools for describing these dynamics (Hutchison and

Hogg, 1984; Ramalho et al., 2011). Lifetable studies, on the other hand, are far more inclusive, and capable not only of predicting development but also survival and reproduction rates, and are, thus, far more informative than studying temperature-dependent development alone. This paper presents the age-stage, two-sex lifetable (Chi, 1988) of *M. persicae* at five constant temperatures to evaluate the effect of temperature on the development, survival, and reproduction and correctly describe the stage differentiation.

### MATERIALS AND METHODS

In this study, cabbage (*B. oleracea* L. var. capitata) was selected as host plant as it is one of the most preferred hosts of *M. persicae* and being one of the most popular and commercial vegetables in the world which is grown in Nepal for long time. To prevent aphid infestation, cabbage seedlings were grown inside a net house at Vegetable Development Center Khumaltar, Lalitpur, Nepal in 24-well-plastic tray filled with coco pit-compost nursery mixed in 3:1 ratio. Such seedlings were grown in batches of 15 to 20 days interval to maintain a regular supply of tender leaves for insect rearing. Before starting experiment the colony of *M. persicae* was established inside a net cage in the Central Agricultural Laboratory with the help of apterous adults collected from pesticide

uncontaminated cabbage field and was periodically supplemented with nymphs collected from such fields to maintain its genetic heterogeneity. Before starting experiment, insects were reared for 2-3 generations to maintain healthy stock. Experiments were carried in two-chambered incubator (Optic Technology, Delhi) available at the Central Agricultural Laboratory, Harihar Bhawan, Nepal maintaining desired temperature, keeping a constant  $65 \pm 5\%$  relative humidity and photoperiod 16:8 hr light: dark for all experiments.

Before starting temperature dependent lifetable study, adults from stock colony were reared on cabbage for one generation to acclimatize at a similar laboratory condition maintained in the incubator. Fifty females from acclimatized stock were randomly picked and placed in plastic cups (each 0.5 l capacity with 10 cm at base and 11.5 cm at top diameter and 6.5 cm depth) separately. 1 to 2 nymphs born within 24 hr from each female were individually transferred to leaves placed in similar plastic cups by using a fine camel hair brush separately. Such cups were labeled and kept in the same chamber in the similar condition. A total of 50 to 60 nymphs were used for temperature dependent life table studies. The individuals were observed daily for their molting and survival till adult stage. The leaves were replaced in every alternate day. Once reached to adult stage, females were checked daily for the birth of nymphs and such nymphs were removed from rearing cups after counting. Survival and fecundity were recorded for each individual from birth to death. Altogether five experiments were completed in five different temperatures 17, 20, 23, 26, and 29°C. When rearing at 32°C, no individual could survive to the female stage, so the lifetable data at 32 °C is not included.

Raw data were analyzed based on the theory of the age-stage, two-sex lifetable (Chi and Liu, 1985; Chi, 1988) using TWOSEX-MSChart which is available at <http://140.120.197.173/Ecology/prod02.htm> (Chi, 2020). The mean of the development periods for each development stage, longevity and fecundity of *M. persicae* were calculated. The age-stage specific survival rate ( $s_{xj}$ ) (where  $x$  is the age and  $j$  is the stage), the age-stage specific fecundity ( $f_{xj}$ ), the age-specific survival rate ( $l_x$ ), and the age-specific fecundity ( $m_x$ ) were calculated from the daily records of the survival and fecundity of all individuals in the cohort. The linear degree day model was used to estimate thermal constant of *M. persicae* which is a product of time and the degrees of temperature above the threshold temperature. It is represented by following fundamental equation:

$$K = D(T - T_0) \quad \dots(1)$$

Where  $K$  is thermal constant of the ectothermic organism,  $D$  is development time (days),  $T$  is temperature, and  $T_0$  is the lower developmental threshold temperature. These parameters were estimated by calculating the rate of development  $y = 1/D$  for the day variable and linearizing transformation of eq. 1. The lower development temperature threshold (i.e., base temperature) is derived from the linear function as  $T_0 = a/b$  and thermal constant  $K$  is simply the inverse of slope ( $b$ ) which is the average duration in degree days.

## RESULTS AND DISCUSSION

The present results show that *M. persicae* is sensitive to changes in temperature. Temperature affected its developmental time, survival, and fecundity. The total developmental time in pre-adult stages (nymph to female) ranged from 5.5 d at 29°C to 11.1 d at 17°C. Like most ectothermic organisms, the developmental time of *M. persicae* decreased at higher temperatures (Table 1), and the developmental rate increased as the temperature increased (Fig. 1). Shorter immature developmental time at higher temperature might be due to the increasing metabolism in *M. persicae*. Because the species is multivoltine, it would be capable of completing several generations in a year in Nepal. The developmental rates of nymphs at different temperatures fit the linear equation,  $y = 0.005x - 0.001$  with a coefficient of determination ( $R^2$ ) of 0.98. The linear regression equation for female was  $y = 0.004x - 0.043$ ,  $R^2 = 0.962$ . The thermal summation ( $K$  value) of the pre-adult stages, the female stage, and the total life stages (from birth to death) of *M. persicae* reared on cabbage were 194.6, 241.8 and 430.2 DD, respectively. The thermal constant provides a measure of the physiological time required for the completion of a developmental process.

These values are higher than those reported in literature as cold-adapted species tend to have greater DD requirements (Trudgill, 1995; Trudgill et al., 2005; Hoffmann and Blows, 1994). Cividanes and Souza (2003) reported  $K$  values of *M. persicae* reared on *B. oleracea* L. to be 165.6 DD whereas, Liu and Meng (1999) calculated  $K$  values on *B. campestris* ssp. *chinensis* to be 119.8 DD. Thermal constant and respective DD requirements are also based on the particular morphology and size of the species. Damos and Savopoulou-Soultani (2012) mentioned that size at maturity is a function of the rate and duration of growth, and large size at maturity implies a long generation time and a correspondingly higher DD requirement.

The developmental threshold of the pre-adult stages, the female stage, and the total life stage was 0.29, 10.6,

Table 1. Life history and mean population parameters of *M. persicae* reared on cabbage vs. temperatures

Stages specific duration day	Temperature									
	17± 1°C		20± 1°C		23± 1°C		26± 1°C		29± 1 °C	
	n	Mean± S.E.	n	Mean± S.E.	n	Mean± S.E.	n	Mean± S.E.	n	Mean± S.E.
N <sub>1</sub>	47	2.2± 0.1	48	2.1± 0.1	57	1.7± 0.1	47	1.5± 0.1	59	1.0± 0.0
N <sub>2</sub>	42	2.2± 0.1	48	2.4± 0.1	46	1.8± 0.1	44	1.8± 0.1	58	1.0± 0.0
N <sub>3</sub>	40	2.9± 0.1	48	2.7± 0.2	42	1.7± 0.1	42	1.6± 0.1	58	1.3± 0.1
N <sub>4,5</sub>	37	3.8± 0.2	47	3.7± 0.2	41	2.7± 0.1	41	2.7± 0.1	56	2.2± 0.1
Female	37	37.6± 2.5	47	23.7± 1.6	41	19.1± 0.9	41	15.3± 0.8	56	13.2± 2.4
Pre-adult	37	11.1± 0.2	47	10.7± 0.2	41	7.9± 0.2	41	7.7± 0.2	56	5.5± 0.1
Longevity	50	37.7± 3.2	50	32.8± 1.8	64	21.2± 1.5	48	20.3± 1.2	59	19.0± 0.6
Fecundity	37	65.5± 2.9	47	57.7± 3.8	41	72.4± 3.5	41	50.2± 3.2	56	28.0± 1.1
Oviposition day	37	19.9± 1.0	47	20.0± 1.1	41	17.0± 0.9	41	14.1± 0.8	56	9.6± 0.3
The intrinsic rate of increase, <i>r</i>		0.2157± 0.0064		0.2160± 0.0039		0.2894± 0.0100		0.2911± 0.0090		0.3212± 0.0058
The finite rate of increase, $\lambda$		1.2408± 0.0079		1.2412± 0.0049		1.3357± 0.0133		1.3378± 0.0121		1.3788± 0.0079
The net reproductive rate, <i>R</i> <sub>0</sub>		48.5± 4.6		54.2± 4.0		46.4± 4.9		42.9± 3.8		26.6± 1.3
The mean generation time, <i>T</i>		18.0± 0.2		18.5± 0.3		13.3± 0.3		12.9± 0.3		10.2± 0.1
The gross reproductive rate, <i>GRR</i>		70.7± 1.5		76.5± 3.2		85.3± 3.3		61.0± 2.0		29.2± 1.0

N<sub>1</sub>= First nymphal instar, N<sub>2</sub>= Second nymphal instar, N<sub>3</sub>= Third nymphal instar, N<sub>4,5</sub>= Fourth and Fifth nymphal instar

and 5.29°C, respectively. The developmental time of the total life stages can be described by a quadratic equation  $y=0.14x^2-8.078x+135.1$  ( $R^2=0.974$ ) (Fig. 1). For many aphids, optimal fecundity and developmental rates occur between 20.0 and 30.0°C (Barlow, 1962; Dean, 1974; Tsitsipisand Mittler, 1976). Chitra and Gupta (2014) reported decrease in fecundity of *M. persicae* at extreme high temperature of 30°C compared to 25°C. *M. persicae* is reported to have capacities for increase between 4.0 and 30.0°C, and optimal survival and development of *M. persicae* occurs in between 20 to 25°C (Barlow, 1962; Whalon and Smilowitz, 1979; Liu and Meng, 1999). *M. persicae* was found not to reproduce above 30°C and to have a thermal death point of 38.5°C (Broadbent and Hollings, 1951).

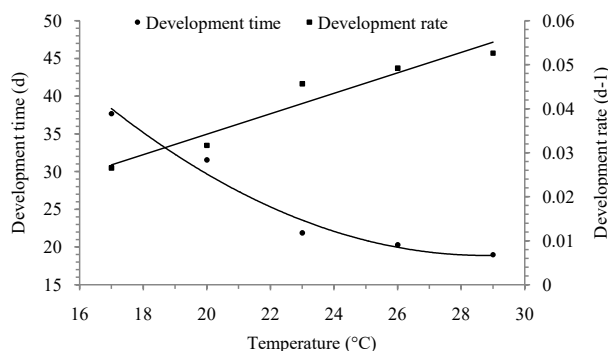


Fig. 1. Development time and rate of *M. persicae* vs temperature

Davis et al. (2006) reported the lower and upper developmental thresholds of *M. persicae* as 6.5 and 37.3°C, respectively.

These results are consistent with these finding. The lower development threshold is found to be 5.6°C and not a single individual reached to female stage when reared at 32°C in laboratory. Normal insect growth occurs under optimal temperature ranges, but when an insect is exposed to extreme low or high temperatures, development rates are reduced, reproduction fails, and if exposed sufficiently long enough, death occurs (Andrewartha and Birch, 1954). An increase in temperature will affect insect pest abundance by shortening generation time, disrupting predator/prey temporal synchrony (Lawton, 1995), and shifting pest distributions (Porter, 1995).

The age-stage specific survival rate ( $s_{xj}$ ) of *M. persicae* gives the probability that a newborn will survive to age *x* and stage *j* (Fig. 2). The variable developmental rate among individuals results in overlapping among these curves. The mean number of offspring produced by individual *M. persicae* of age *x* and stage *j* per day is shown with the age-stage fecundity ( $f_{xj}$ ) in Fig. 3. Because only females produce offspring, there is only a single curve  $f_{x6}$  (i.e., the female is the sixth life stage). Age-specific maternity ( $l_x m_x$ ) reaches to its peak on 18<sup>th</sup> day at 17°C and gradually decreases to

8<sup>th</sup> day at 29°C. The highest peak of  $l_x m_x$  was observed at 26°C. Population parameters for *M. persicae* are presented in Table 1. The intrinsic rate of increase ( $r$ ) of this aphid was the highest at 29°C (0.3212 d<sup>-1</sup>) and the lowest at 17°C (0.0.2157 d<sup>-1</sup>). Because  $\lambda = e^r$ , the finite rate of increase showed a trend similar to  $r$ . Increasing temperature shortened the mean generation time ( $T$ ) of *M. persicae*. The mean generation time was 18 d at 17°C, and declined to 10.2 d at 29°C. The net reproduction rate ( $R_0$ ) was 26.6 offspring per individual at 29°C, and it was considerably lower than the rates obtained at other temperatures. The highest net reproductive rate was obtained at 20°C ( $R_0 = 54.2$  offspring). The GRR values obtained at 17, 20, 23 and 26°C were considerably higher than those obtained at 29°C. The intrinsic rate of increase and finite rate of increase at 29°C was higher than at lower temperatures due to the fast development and the earlier reproduction at this temperature.

The life expectancy gives the time that an individual of age  $x$  and stage  $j$  is expected to live. Under controlled laboratory conditions without the adverse effects of field conditions, our results show that the life expectancy monotonously decreases with aging. The age-stage reproductive value ( $v_{xj}$ ) of *M. persicae* (Fig. 5) describes the contribution of an individual of age  $x$  and stage  $j$  to the future population as defined by Fisher (1930). Lifetable study under controlled laboratory conditions reveals the biological potential of development and fecundity of insect populations. In natural environments, however, most populations are influenced by a variety of changing biotic and abiotic factors. In general, this study describes the effect of temperature on several biological parameters of the *M. persicae*. This information is useful in formulating management strategy against *M. persicae* in cabbage fields.

The age-stage specific life expectancy ( $e_{xj}$ ) of *M. persicae* at different temperatures is plotted in Fig. 4.

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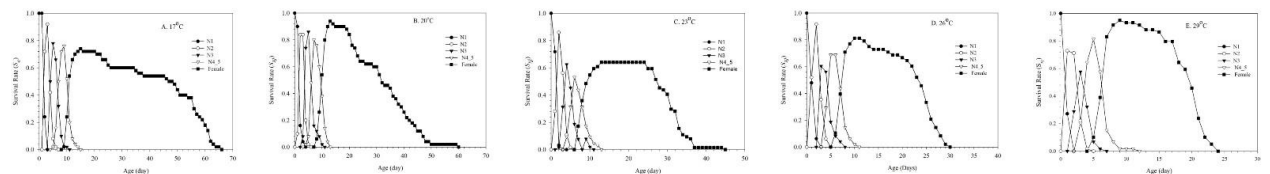


Fig. 2. Age-stage specific survival rate of *M. persicae* at different temperatures: A. 17 °C, B. 20°C, C. 23°C, D. 26°C, E. 29°C

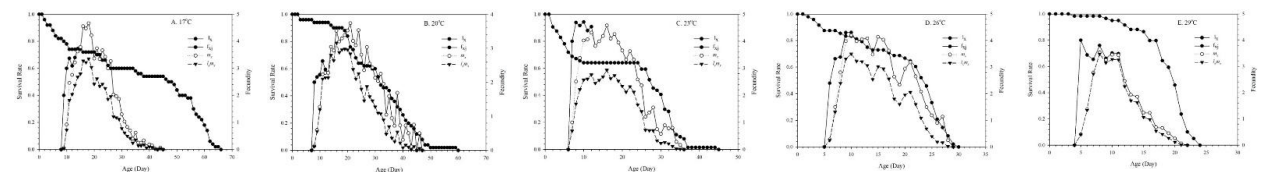


Fig. 3. Age specific survival rate ( $l_x$ ), female age-specific fecundity ( $f_{xj}$ ), age-specific fecundity ( $m_x$ ), age-specific maternity ( $l_x m_x$ ) of *M. persicae* at different temperatures: A. 17 °C, B. 20°C, C. 23°C, D. 26°C, E. 29°C

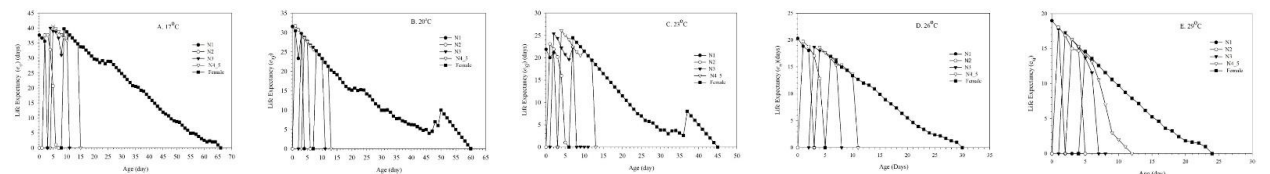


Fig. 4. Age-stage specific life expectancy ( $e_{xj}$ ) of *M. persicae* at different temperatures: A. 17 °C, B. 20°C, C. 23°C, D. 26°C, E. 29°C

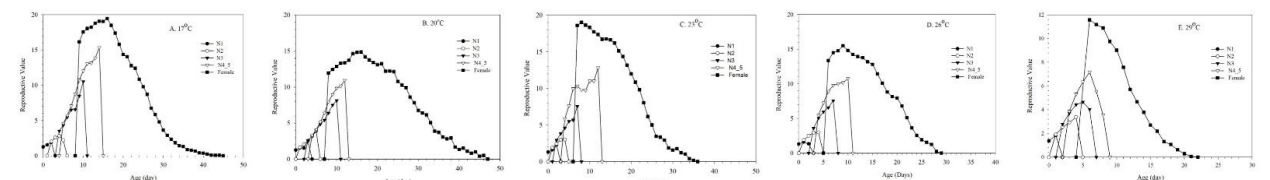


Fig. 5. Age-stage specific reproductive value ( $v_{xj}$ ) of *M. persicae* at different temperatures A. 17 °C, B. 20°C, C. 23°C, D. 26°C, E. 29°C

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#### REFERENCES

- Andrewartha H G, Birch L C. 1954. The distribution and abundance of animals. University of Chicago Press, Chicago, IL, USA. pp. 782.
- Bale J S, Ponder K L, Pritchard J. 2007. Cropping with stress. In Emden H. F. Van, Harrington R. (eds.), Aphids as crop pests. CAB International, Wallingford. pp. 287-309.
- Barlow C A. 1962. The influence of temperature on the growth of exoerimental population of *Myzus persicae* (sulzer) and *Macrosiphum euphorbiae* (Thomas) (Apididae). Canadian. Journal of Zoology 40(2): 145-156.
- Bhat A I, Rao G P. 2020. Transmission of Viruses by Aphids. In: Characterization of Plant Viruses. Springer Protocols Handbooks. Humana, New York, NY. [https://doi.org/10.1007/978-1-0716-0334-5\\_11](https://doi.org/10.1007/978-1-0716-0334-5_11)
- Broadbent L, Hollings M. 1951. The influence of heat on some aphids. Annals of Applied Biology 38(3): 577-581. <https://doi.org/10.1111/J.1744-7348.1951.tbo7829.x>
- Chi H. 1988. Life-table analysis incorporating both sexes and variable development rate among individuals. Environmental Entomology 17(1): 26-34.
- Chi H. 2020. TWSEX-MSChart: A computer program for the age-stage, two-sex life table analysis. Available at <http://140.120.197.173/Ecology/Download/Twosex-MSChart.zip>.
- Chi H, Liu H. 1985. Two new methods for the study of insect population ecology. Bulletin of the Institute of Zoology. Academia Sinica 24(2):225-240.
- Chitra C L, Gupta M K. 2014. Temperatures vs development and fecundity of *Myzus persicae* (Sulzer). Indian Journal of Entomology 76(3): 219-223.
- Cividanes F J, Souza E P. 2003. Thermal requirements and age-specific life tables of *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) in laboratory. Neotropical Entomology (online). 32(3): 413-419. <https://doi.org/10.1590/S1519-566X2003000300005>.
- Davis J A, Radcliffe E B, Ragsdale D W. 2006. Effects of high and fluctuating temperatures on *Myzus persicae* (Hemiptera: Aphididae). Environmental Entomology 35(6): 1461-1468
- Damos P, Savopoulou-Soultani M. 2012. Temperature-driven models for insect development and vital thermal requirements. Psyche. A Journal of Entomology. doi:10.1155/2012/123405
- Dean G J. 1974. Effect of temperature on the cereal aphids *Metopolophium dirhodum* (Wilk.), *Rhopalosiphumpadi* (L.), and *Macrosiphum avenue* (F.) (Hem., Aphididae). Bulletin of Entomological Research 63: 401-409.
- Dixon AF G. 1998. Aphid ecology, an optimization approach. Chapman and Hall, London.
- Fisher R A. 1930. The genetical theory of natural selection. Clarendon Press, Oxford, United Kingdom.
- Hoffmann A A, Blows M W. 1994. "Species borders: ecological and evolutionary perspectives", Trends in Ecology and Evolution. 9(6): 223-227.
- Hutchison W D, Hogg D B. 1984. Demographic statistics for the pea aphid (Homoptera: Aphididae) in Wisconsin and a comparison with other populations. Environmental Entomology 13: 1173-1181.
- Kim S, Lee J K, Song Y J, Kang S C, Kim B, Choi I J, Lee S H. 2018. Evaluating natural compounds as potential insecticides against three economically important pests, *Bemisia tabaci* (Hemiptera: Aleyrodidae), *Frankliniella occidentalis* (Thysanoptera: Thripidae), and *Myzus persicae* (Hemiptera: Aphididae), on greenhouse sweet peppers. Applied Biological Chememistry 61: 313-323. <https://doi.org/10.1007/s13765-018-0362-8>
- Lawton J H. 1995. The response of insects to environmental change. In. Harrington R. Stork N.E. Insects in a Changing Environment. Academic Press San Diego, CA. pp. 3-26.
- Liu S, Meng X. 1999. Modeling development time of *Myzus persicae* (Hemiptera: Aphididae) at constant and natural temperatures. Bulletin of Entomological Research 89(1): 53-63.
- Logan J A, Wollkind D J, Hoyt S C, Tanigoshi L K. 1976. An analytic model for description of temperature dependent rate phenomena in arthropods. Environmental Entomology 5: 1133-1140.
- Margaritopoulos J, Kati A, Voudouris C, Skouras P, Tsitsipis J. 2021. Long-term studies on the evolution of resistance of *Myzus persicae* (Hemiptera: Aphididae) to insecticides in Greece. Bulletin of Entomological Research 111(1): 1-16. doi:10.1017/S0007485320000334
- Porter J. 1995. The effects of climate change on the agricultural environment for crop insect pests with particular reference to the European corn borer and grain maize. In. Harrington R. Stork N.E. Insects in a Changing Environment. Academic Press, San Diego, CA. pp. 94-113.
- Ramalho F S, Wanderley P A, Malaquias J B, Fernandes F S, Nascimento A R B, Zanuncio J C. 2011. Effect of temperature on the reproduction of *Bracon vulgaris* Ashmead (Hymenoptera: Braconidae), a parasitoid of the cotton boll weevil. Annals of the Brazilian Academy of Sciences 83(3): 1021-1030.
- Trudgill D L, Honek A, Li D, van Straalen N M. 2005. "Thermal time-concepts and utility," Annals of Applied Biology 146(1): 1-14. <https://doi.org/10.1111/j.1744-7348.2005.04088.x>
- Trudgill D L. 1995. "Why do tropical poikilothermic organisms tend to have higher threshold temperatures for development than temperate ones?" Functional Ecology 9(1): 136-137.
- Tsitsipis J A, Mittler T E. 1976. Development, growth, reproduction, and survival of apterous virginoparae of *Aphis fabae* at different temperatures. Entomologia. Experimentalis. Applicata. 19: 1-10.
- van Emden H F, Harrington R. 2007. Aphids as crop pests. CABI North American Office, Cambridge, Massachusetts. pp. 699.
- van Emden H F, Eastop V F, Hughes R D, Way M J. 1969. The ecology of *Myzus persicae*. Annual Review of Entomology 14: 197-270.
- Wang Y S, Wang B L, Yan G L, Liu Y H, Zhang D Y, Liu T X. 2020. Temperature-Dependent Demographic Characteristics and Control Potential of *Aphelinus asychis* Reared from *Sitobion avenae* as a Biological Control Agent for *Myzus persicae* on Chili Peppers. Insects 11: 475. doi: 10.3390/insects11080475
- Whalon M E, Smilowitz Z. 1979. Temperature-dependent model for predicting field populations of green peach aphid, *Myzus persicae* (Homoptera: Aphididae). Canadian. Entomologist 111(9): 1025-1032. <https://doi.org/10.4339/Ent1111025-9>.

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