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Effect of temperature on life history of predatory mite *Amblyseius californicus* (Acari: Phytoseiidae) associated with the scale *Aulacaspis tubercularis* (Hemiptera: Diaspididae) infesting mango

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Abstract:

Amblyseius californicus (McGregor) (Acari: Phytoseiidae) is a beneficial predatory mite endemic to the Eastern Mediterranean region. This species is considered a generalist predatorand readily consumes small soft-bodied pest species as well as pollen or plant exudates. *Amblyseius* has attracted substantial interest as a biological control agent of mites, thrips and whiteflies in greenhouse and nursery crops. The present studies were conducted to study the effect of temperatures on development and food consumption of *Amblyseius californicus* (McGregor) feed on the scale *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) under constant temperatures. The results showed that the developmental period increased with temperature decrease. Fecundity, longevity and lifespan were longer at 25°C and lower at 27°C. Feeding capacities were increased with increasing temperature from 22°C to 25°C and then decreased at 27°C. The highest means of total prey consumption of females were recorded during oviposition, when they devoured an average of 103.0, 189.3, 109.0 and 79.0 prey at 20, 25, 30, and 35°C, respectively. The highest values of the mean prey consumption by postoviposited females was observed at 25°C (108.42 preys) followed by 27°C (76.61 preys), respectively.

Introduction

Scale insect injures leaves and fruits affecting the commercial value of the fruits and their export potential. Colyn and Schaffer (1993) , Pena *et al.* (1998) and Joubert *et al*. (2000) mentioned that *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) injures the leaves and fruits of mango trees *Mangifera indica* L. (Anacardiaceae) affecting the commercial value of the fruits and their export potential. Mango trees considered as one of the most popular fruit in Egypt contains a high percent of sugar, protein, fats, salt and vitamins. It played an important role in food industrialization such as juices, which wanted with large amounts of export according to good reputation of

Egyptian varieties. Now , the Egyptian agricultural strategy is to increase the quality level of exported crops to certain European countries , for this reason many efforts has been done to increase the total cultivated areas of mango in Egypt , as a favorable fruits in many countries . Scale insects are usually considered as the most important pests which infesting mango trees in many countries of the world. Phytoseiid mites have been studied extensively with respect to their potential for the biological control of phytophagous mites in greenhouses, on strawberry and deciduous fruit (Helle and Sabelis, 1985). McMurtry and Croft (1997) listed phytoseiids now being used or with the potential of being used in control programs against agricultural and horticultural pests. One of these species being used in control programs is *Amblyseius californicus* (McGregor) (Acari: Phytoseiidae), also known as *Neoseiulus californicus*. This predatory mite originates from field of Egypt. It is used extensively in biological control programs against red spider mites (*Tetranychus urticae* Koch., Tetranychidae) on a global scale (Hart *et al*., 2002). *A. californicus* is widely used in the Mediterranean region, particularly southern France, Italy and Spain, where it is reported to occur naturally (Raworth *et al*., 1994 and Castagnoli and Simoni, 1999).

Biological events of the arthropods in relation to key environmental factors are necessary to determine the extent of their influence on the population dynamic of the predator and/or pests. Temperature has long been recognized as a primary environmental factor influencing the rate of development of arthropods (Høye and Cull, 2018).

The present investigation was oriented to study feeding capacity of *A. californicus* against *A. tubercularis* infesting mango under constant temperatures.

Materials and methods

1. Prey culture:

The scale *A. tubercularis* was found on leaves of naturally infested mango trees at Giza, Egypt. Samples were taken and transferred to laboratory and reared under laboratory conditions.

2. Predator culture:

A laboratory colony of *A. californicus* was collected from mango orchard at Giza Governorate. It was mass cultured in the laboratory on castor leaves infested with *T. urticae* as prey. The experiment was under the same conditions.

3. Experimental procedure:

The experiments were conducted at three constant temperatures (22, 25 and 27±1ºC) with relative humidity of 70±5%. Thirty gravid females of *A. californicus* were taken randomly and transferred to rearing substrates. Females were left 24 hours and their oviposited eggs were used to start biological aspects. Thereafter, when a sufficient number of eggs were laid, the adult females were removed and eggs from the same age were obtained to start the experiment. Observations were made at 6 hourly intervals to see if the eggs had hatched. After the eggs hatching to larvae, the larval individuals of larvae were transferred very carefully onto leaf disks of castor leaves (3 cm in diameter). Leaf discs were placed with the upper surface facing down on cotton layer in petridishes (6 cm in diameter). Water was added when needed to maintain the suitable moisture. The leaf margin was surrounded by a cotton strip to prevent the mites escaping. A few cotton threads were placed on the surface of leaves to serve as shelter and oviposition sites. Ten replicates were maintained for each temperature, so 40 petri dishes were maintained simultaneously. All the petri dishes were kept in incubators maintaining the desired temperature. Immature stages of *A. tubercular* is which was given as food for the predatory mite *A. californicus*. Duration of the developmental stages, pre-oviposition, oviposition, post-oviposition periods, longevity, fecundity, lifespan and food consumption were recorded by taking observations using the stereomicroscope.

4. Statistical analysis:

Data were subjected to statistical analysis using F-test and means were compared according to Duncan's multiple range test. Developmental thresholds (t_0) becalculated according to the method of (Weinberg and Lange 1980) and the thermal units (TU) needed for the developments of each stage were calculated according to Madubunyi and Koehler (1974).

K (TU) = T ($t-t_0$), where,

K (TU) = Thermal units (day-degree),
(T) = Duration (in days),
(t) = Exposure temperature (ºC),
(t_0) = temperature threshold (ºC).

Results and Discussion

The present investigations were carried out to study the effect of constant temperature regimes of 22, 25 and 27ºCon the development and feeding capacity of *A. californicus* against *A. tubercularis* infesting mango under constant temperatures to estimate temperature developmental threshold (t_0ºC) and thermal units (TU) (day-degrees) required for the development of the immature stages.

1. Effect of constant temperatures on the immature stages:

The results indicated that the pest developed successfully from egg to adult emergence over the temperatures ranged from 22 to 27ºC. The duration of the immature stages under the different constant temperature regimes are given in Table (1).

1.1.Egg stage:

The incubation periods at various constant temperatures are given in Table (1). As shown, the time required for completion of embryogenesis decreased gradually as temperature increased. The incubation periods lasted from 2.15±0.07, 1.11±0.12, to 1.01±0.08 days at the constant temperatures of 22, 25 and 27ºC, respectively. There were significant differences between the incubation periods at the tested temperatures. The longest incubation period (2.15 days) was recorded at 22ºC and the shortest (1.01 days) was revealed at 27ºC. This may suggest that the constant temperature of 27ºC was the most preferable tested temperature for the development of the egg stage.

1.2.Larval stage:

The larval durations tended to be shortened with an increasing of temperature. The results in Table (1) showed that the average duration of larval stage of *A.californicus*. Means of 1.13±0.05, 1.01±0.01 and 0.90±0.03 days were recorded at temperatures of 22, 25 and 27ºC, respectively. Statistical analysis showed that significant differences between values of mean durations of larval stage at the tested temperatures.

1.3. Protonymphal stage:

The duration of the protonymphal stage is shown in Table (1). Results show that the protonymphal stage lasted 1.65±0.04, 0.55±0.02 and 0.15±0.05 days at 22, 25 and 27ºC, respectively.

1.4. Deutonymphal stage:

The duration of the deutonymphal stage is shown in Table (1). Results showed that the deutonymphal stage lasted 1.21±0.08, 1.00±0.05 and 0.85±0.06 days at 22, 25 and 27ºC, respectively with significant differences.

1.5. From egg to adult emergence:

Data in Table (1) showed that the developmental times for the immature stages of *A. californicus* were inversely related to temperature. Total developmental time (egg to adult) ranged from 1.80 days at 22°C to 1.30 days at 27°C. As shown in Table (1), the total developmental time from egg to adult emergence was correlated significantly with the corresponding temperatures. This result seems to be logic, since the duration of any developmental stages or/and physiological process are negatively correlated with temperature within the tolerant zone of temperatures. The foregoing results concerning, the duration in relation to temperature clearly indicated that temperature of 27ºC was the most preferable temperature for development of *A. californicus*.

Development temperature relationship expressed as rate of development (100/y) is shown in Table (2). Data in Table (1) were used to calculate regression equations, which were used in estimation threshold of temperature. As shown in Table (2), it seems that the equation fit the observed rather well, as indicated by high values of coefficient of determination. Extrapolation of the regression line to the temperature axis resulted in a threshold temperature of 10.30 ºC. The calculated thermal units, using this threshold as a base temperature, were about 86.20 day degrees (Table, 2).

The observation that developmental period decreased with increasing temperature was also observed in *Amblyseius fallacis* (Garman) by Smith and Newsom (1970), *A.citrifolius* (Denmark and Muma) by Moraes and McMurtry (1982), *Amblyseius swirskii* Athias-Henriot by Yousef *et al*. (1982) and Onzo *et al*. (2012) and in *Amblyseius coccosocius* Ghai and Menon by Saha *et al*. (2001). Incubation period was a maximum at 20°C andminimum at 30°C and these findings are in agreement with the findings of Sharma and Sadana (1984).

Means for the total prey consumption by *A. californicus*on a diet of *A. tubercularis* immatures at constant temperatures are presented in Table (3). The larvae of this predator did not feed during the experiment and predation activity started just after. Data analysis revealed a significant effect of temperature on total food consumption by *Amblyseius californicus*except larval stage where there was no significant effect. The total number of prey consumed by the protonymphs increased with increasing temperature from 2.11 prey at 22°C to 4.15 prey at 25°C, and then decreased to 3.01 prey at 27◦C. Feeding capacities of deutonymphs followed a similar trend as protonymphs. It was ranged from 9.11 preys at 25°C to 6.04 preys at 25°C. The highest mean number of total preyconsumed by protonymphs and deutonymphs was 13.31 preys which were obtained at 25°C.

Adult of *A. californicus* started prey consumption after emergence at all temperatures tested. During the preoviposition period, predators devoured an average of 3.70, 13.71, and 6.20 preys at 22, 25 and 27◦C, respectively. The maximum means for total food consumption of the predator was recorded during the oviposition period; it consumes an average of 53.31, 89.30 and 67.11 preys at the same temperatures. The highest and lowest values for the mean prey consumption by postoviposited females were observed at 25˚C (89.30 preys) and 22 °C (53.31 preys). During adulthood, the highest number of prey consumed was at 25˚C (108.42 preys), which decreased to 76.61 and 58.11 individuals at 27 and 22˚C, respectively.

The present study showed that temperature affects the feeding capacity of all life stages of *A. californicus* except the larval stage where it developed to the protonymphal stage without feeding. Non feeding larval behavior may be a mechanism to avoid sibling cannibalism. Similar findings have been reported for otherphytoseiid species by (El-Banhawy *et al*., 2000; Kouhjani *et al*., 2009 and Fatemeh *et al*., 2011).

During immature stages of *A. californicus*, food consumption increased with increasing temperature from 22 to 25°C. Therefore, it could be concluded that theoptimal temperature for predation of this predator was about 25°C. A clear reduction was observed in the mean number of prey consumption from 25 to 27°C. The findings of Metwally *et al.,* (2005) and Fatemeh *et al*. (2011) support our results.

Although we observed the same trend in all experiments, the obtained values were different because of different prey and predator species were used in the experiments. Furthermore, several other factors, such as relative humidity, photoperiod, presence of pollen and the type of experimental arena may also affect apredator's feeding (Fernando and Hassell, 1980). The females during oviposition consumed a significantly higher number of preys, suggesting that females need extra food for egg production during this period. This new information is in agreement with other findings (Kouhjani *et al*., 2009). To the best of our knowledge, little previous study has been made concerning the predation of this species; therefore we could not compare the results with previous published studies. However, there are numerous investigations on other phytoseiid species, revealing the effect of temperature on these predators food consumption. The results from the current study would help us to gain a better insight into the efficiency and practical application techniques of a predator in biological control programs of spider mites. According to the findings, *A. californicus* could be a beneficial biocontrol agent in both greenhouses and field when temperature is above 22 °C, however, to optimize results, additional experiments should be performed. From an overall evaluation of results it appeared that 25°C was the most suitable temperature for the growth of *A. californicus*. At this temperature the total developmental period was moderated with a longer ovipositional period, higher fecundity and longer longevity.

Table (1): Development of the immature stages and preoviposition period (days) of the predator mite *Amblyseius californicus* reared on *Aulacaspis tubercularis* at constant temperatures.

Temp. (°C)	Developmental time (in days) ± SD					
	Egg	Larvae	Protonymph	Dutonymph	Total	Preoviposition
22	2.15±0.07a	1.13±0.05a	1.65±0.04a	1.21±0.08a	6.14±0.24a	1.80±0.16a
25	1.11±0.12b	1.01±0.01b	0.55±0.02b	1.00±0.05b	3.67±0.20b	1.60±0.13b
27	1.01±0.08c	0.90±0.03c	0.15±0.05c	0.85±0.06c	2.91±0.22c	1.30±0.09c
Total	4.27±0.27	3.04±0.09	2.71±0.11	3.36±0.19	12.72±0.66	4.70±0.23
Mean ± SD	1.42±0.09	1.01±0.03	0.90±0.04	1.12±0.06	4.24±0.22	1.57±0.08

Means followed by the same litters vertically are not significantly different at 0.05 level of probability.

Table (2): Regression equations, lower developmental thresholds (t_0) and thermal units (TU) of *Amblyseius californicus* reared on *Aulacaspis tubercularis* at constant temperatures.

Stage	Regression equations	R^2	Developmental thresholds (t_0)	Thermal units
Egg	Y = 0.52+0.04x	0.97	11.60	22.30
Larva	Y =1.48+0.13x	0.95	11.10	7.50
Protonymph	Y =0.71+0.06x	0.97	10.40	14.60
Deutonymph	Y =0.65+0.07x	0.98	9.90	15.20
Egg to adult	Y =0.18+0.02x	0.98	10.90	59.20
Preoviposition	Y =0.29+0.04x	0.95	8.20	27.50
Egg to adult oviposition	Y =0.12+0.01x	0.98	10.30	86.20

Table (3): Prey consumption of different stage of *Amblyseius californicus* reared on *Aulacaspis tubercularis* at constant temperatures.

Temp. (°C)	No. prey consumed / stage ± SD							
	Immature stage				Adult stage			
	Larva	Protonymph	Deutonymph	Total	Pre.	Oviposition	Post.	Total
22	0.01 ±0.01**c**	2.11 ±0.02**c**	7.30 ±0.06**c**	9.42 ±0.09**c**	3.70 ±0.02**c**	53.31 ±2.14**c**	1.10 ±0.21**c**	58.11 ±2.37**c**
25	0.05 ±0.00**a**	4.15 ±0.03a	9.11 ±0.05**a**	13.31 ±0.08**a**	13.71 ±0.01**a**	89.30 ±4.48**a**	5.41 ±0.27**a**	108.42 ±4.76**a**
27	0.02 ±0.01**b**	3.01 ±0.01**b**	6.04 ±0.11**b**	9.07 ±0.13**b**	6.20 ±0.12**b**	67.11 ±1.85**b**	3.30 ±0.21**b**	76.61 ±2.18**b**
Total	0.08 ±0.02	9.27 ±0.06	22.45 ±0.22	31.80 ±0.30	23.61 ±0.15	209.72 ±8.47	9.81 ±0.69	243.14 ±9.31
Mean ± SD	0.03 ±0.01	3.09 ±0.02	7.48 ±0.07	10.60 ±0.10	7.87 ±0.05	69.91 ±2.82	3.27 ±0.23	81.03 ±3.01

Means followed by the same litters vertically are not significantly different at 0.05 level of probability.

References

Castagnoli, M.; Liguori, M. and Simoni, S. (1999): Effect of two different host plants on biological features of *Neoseiulus californicus* (McGregor). Int. J. Acarol., 25: 145–150.

Colyn, J. and Schaffer, B. (1993): The South African mango industry. Fourth international mango symposium, Miami, Florida, U.S.A. Acta Horticulture, 341: 60-68.

El-Banhawy, E.M.; Hafez, S.M. and Saber, S.A. (2001): Response of *Amblyseius cydnodactylon* (Phytoseiidae) to increasing prey density of *Tetranychus urticae* (Tetranychidae) in absence or presence of nymphs of *Bemesia tabaci* (Homoptera) in Egypt. Int. J.AcaroL., 27: 241-244.

El-Banhawy, E.M.; Amer, S.A.A. and Saber, S.A. (2000): Development and reproduction of the predacious mite, *Amblyseius cydnodactylon* on different prey species, effect of plant leaf texture on the behaviour and reproduction of the predator. J. Plant Diseases and Protection, Vol. 107(2): 218-224.

Fatemeh, G.; Yaghoub, F. and Karim, K. (2011): Effect of temperature on prey consumption of *Typhlodromus bagdasarjani* (Acari: phytoseiidae) on *Tetranychus urticae* (Acari: Tetranychidae). Int. J. Acarol., 37 (6): 556–560.

Fernando, M. H. J. P. and Hassell, M. P. (1980): Predator-prey responses in an acarine system. Res. Popul. Ecol., 22: 301–322.

Hart, A.J.; Bale, J.S.; Tullett, A.G.; Worland, M.R. and Walters, W.F.A. (2002): Effects of temperature on the establishment potential of the predatory mite *Amblyseius californicus* McGregor (Acari: Phytoseiidae) in the UK. J. Insect Physiol., 48: 593–599.

Helle, W. and Sabelis, M. W. (1985): Spider mites. Their biology, natural enemies and control. Volume 1 of the Series: World Crop Pests. Elsevier, Amsterdam- New York. Part A: XVIII + 406 pp.

Høye, T.T. and Culler, L.E. (2018): Tundra arthropods provide key insights into ecological responses to environmental change. Polar Biol., 41: 1523-1529.

Joubert, P.H.; Daneel, M.S.; Grove, T. and Pichakum, A. (2000): Progress towards integrated pest management (IPM) on mangoes in South Africa. Acta Horticulturae, 509: 811-817.

Kouhjani, G. M.; Fathipour, Y. and Kamali, K. (2009): The effect of temperature on the functional response and prey consumption of *Phytoseius plumifer* (Acari: Phytoseiidae) on the two-spotted spider mite. Acarina, 17(2): 231–237.

Madubunyi, L.C. and Koehler, C.S. (1974): Effect of photoperiod and temperature in *Hypera brunneipennis*. Environ. Entomol., 3: 1017-1021.

McMurtry, J.A. and Croft, B. A. (1997): Life-styles of phytoseiid mites and their roles in biological control. Annu. Rev. Entomol., 42: 291–321.

Metwally, A.M.; Abou-Awad, B.A. and Al-Azzazy, M.M.A. (2005): Life table and prey consumption of the predatory mite *Neoseiulus cydnodactylon* Shehata and Zaher (Acari: Phytoseiidae) with three mite species as prey. Z. Pflanzenk. Pflanzen., 112:276–286.

Moraes, G.J. and McMurtry, J.A. (1982): Biology of *Amblyseius citrifolius* (Denmark and Muma) (Acarina – Phytoseiidae). Hilgardia, 49 (1): 1–29.

Onzo, A.; Houedokoho, A.F. and Hanna, R. (2012): Potential of the predatory mite, *Amblyseius swirskii* to suppress the broad mite, *Polyphagotarsonemus latus* on the gboma eggplant, *Solanum macrocarpon*. J. Insect Sci., 12(7): 1-11.

Pena, J.E.; Mohyuddin, A.I. and Wysoki, M. (1998): Areview of the pest management situation in mango agroecosystems. Phytoprasitica, 26(2): 1-20.

Raworth, D.A.; Fauvel, G. and Auger, P. (1994): Location, reproduction and movement of *Neoseiulus californicus* (Acari: Phytoseiidae) during the autumn, winter and spring in orchards in the south of France. Exp. Appl. Acarol., 18: 593–602.

Saha, K.; Somchoudhury, A.K.; Sarkar, P.K. and Gupta, S.K. (2001): Effect of temperature on the rate of development, fecundity, longevity, sex ratio and mortality of *Amblyseius coccosocius* Ghai and Menon (Acari: phytoseiidae), an important biocontrol agent against tea red spider mite in India. Acarology: Proc. 10th Intern. Congress, 470-472.

Sharma, K. N. and Sadana, G. L. (1984): Influence of temperature on the development of the predatory mite, *Amblyseius finlandicus* (Acari: Phytoseiidae). Indian J. Acarol., 9: 57–62.

Shih, C.I.T. and Shieh, J. N. (1979): Biology, life table, predation potential and intrinsic rate of increase of *Amblyseius longispinosus* (Evans). Plant Prot. Bull. Taiwan, 21: 175–183 (in Chinese).

Smith, J.C. and Newsom, L.D. (1970): The biology of *Amblyseius fallacies* (Acarina: Phytoseiidae) at various temperature and photoperiod regions. Ann. Entomol. Soc. America, 63: 460–462.

Weinberg, H.L. and Lange, W. H. (1980): Development rate and lower temperature threshold of the tomato pinworm. Environ. Entomol., 9:245-246.

Yousef, A.E.T.A.; El-Keifer, A.H. and Metawally, A.M. (1982): On the effect of temperature and photoperiod on the development, nutrition and oviposition of the predatory mite, *Amblyseius swirskii* Athias–Henriot (Acari: Gamasida: Phytoseiidae). Anzeiger fur Schadlingskunde Pflanzenschutz Umweltschutz, 55: 107–109.