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Research Article

Determination of Thermal Constant and Development Threshold of Cotton mealybug, *Phenacoccus solenopsis* (Tinsley)

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Abstract

Effect of constant temperatures viz, 18±1, 21±1, 27±1, 30±1 and 33±1 °C on egg, nymphal and male pre-pupal and pupal stage development of *Phenacoccus solenopsis* revealed that the development rate of egg, nymphs and pupal stages gradually increased with increase in temperature, while total development period decreased. The development threshold was determined to be 12.7, 15.8, 9.05, 8.87 and 7.1 °C for egg, nymphs (I to III instar) and male pre-pupal and pupal stage, respectively with corresponding thermal constant being 24.4, 52.63, 58.82, 62.5 and 142.85 DD. Total thermal constant requirement to complete a generation was thus 341.2 DD.

Keywords: Degree day, *Phenacoccus solenopsis*, Thermal constant, Threshold of development

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Introduction

Okra (*Abelmoschus esculentus*) belongs to family Malvaceae and is an important vegetable crop grown throughout the year. Besides India, it is grown in many tropical and subtropical parts of the world. Due to their tender and supple nature and their cultivation under high moisture & input regimes, okra is more prone to insect pest attack. The crop is attacked by number of pests of which cotton mealybug causes serious substantial reduction in crop growth and yield. It has been described as a serious and invasive polyphagous pest with a vast host range. It causes significant economic damage on cotton, brinjal, okra, tomato, sesame, sunflower and China rose [1-3]. The sucking of sap by the pest results in the yellowing of leaves which lead to loss of plant vigour, foliage and fruit drop [4, 5].

Temperature is one of the major environmental factors influencing insects. Development, survival, adult longevity and fecundity data are vital for understanding the population dynamics of any insect species on a particular host [6]. Understanding phenology of an insect species at different temperatures is crucial for predicting its seasonal occurrence and planning for integrated management. Many mathematical models describe insect developmental rate as a function of temperature [7-10]. Linear model [11] is widely used to explain the straight line relationship between the developmental rate and temperature in the limited range and calculate lower developmental thresholds and thermal constants required to complete development of life stages. Keeping this in view, the present studies were undertaken.

Experimental

Nymphs and adults of the cotton mealybug were collected from the experimental field of Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh and were mass reared on okra cuttings (tender shoots and leaves) in laboratory at 27 ± 1 °C and 70-80% relative humidity. The cuttings were replaced every three days by new ones and the mealybug population was transferred to the new cuttings using a camel hair brush. From this stock culture, further experiment was conducted. 15 gravid females were collected from the laboratory culture and kept on okra shoots in petriplates provided with filter paper. Moist absorbent cotton was put under filter paper to maintain the humidity and fresh shoots of okra were provided as food daily and incubated until oviposition. Eggs laid on the same day were placed in small vials and put in incubators at 15 ± 1, 18 ± 1, 21 ± 1, 24 ± 1, 27 ± 1, 30 ± 1 and 33 ± 1 °C with 65-70% relative humidity. The mealybug cohorts were examined daily and development was recorded.

Development rate (R) for egg, nymphal stages and prepupal and pupal stages of male of cotton mealybug was computed as reciprocal of the mean number of days to complete development. Development threshold (To) and thermal constant (K) were then determined by regressing development rate on temperature [12] according to the rule of the constant sum of effective temperature as under:

Thermal constant = (Temperature – development threshold) X development duration

The K was estimated as reciprocal of regression coefficient (b) between development rate and temperature.

$$K = 1/b$$

To was determined by the ratio of regression intercept (a) and (b)

$$To = - a/b$$

Result and Discussion

The present study revealed that the development duration of *P. solenopsis* decreased with increase in temperature from 15 ± 1 to 33 ± 1 °C (**Table 1**). The temperature increase from 15 ± 1 to 33 ± 1 °C reduced the incubation period from 5.15 to 1.15 days, 1st instar nymphal period from 22.3 to 2.4 days, 2nd instar nymphal period from 7.3 to 2.0, 3rd instar female from 6.85 to 2.2, and male (pre-pupal and pupal) period from 13.45 to 4.25days, respectively. The total life cycle duration of *P. solenopsis* was also observed at each temperature and it decreased from 48.2 to 9.8 days for males and 41.6 to 7.7 days for females with temperature increase. The total development period in male and female differedand was noted to be dependent upon variations in temperature. Interestingly at lower temperatures (upto 21 °C) the duration was greater (6.6, 6.5, 5.0 days) than at higher temperature upto 33 °C where the difference was of only 2.1 days.

Table 1 Determination of threshold temperatures and thermal constant for different developmental stages of cotton mealybug, *P. solenopsis*

P. solenopsis development stages	Regression equation	Thermal constant (K)	Temperature threshold (To)	R^2
Egg	y =0.041x - 0.521	24.40	12.70	0.92
1st instar	y = 0.019x - 0.301	52.63	15.80	0.88
2nd instar	y = 0.017x - 0.154	58.82	9.05	0.84
3rd instar (Female)	y = 0.016x - 0.142	62.50	8.87	0.91
Male (Pre-pupal and pupal stage	y = 0.007x - 0.054	142.85	7.71	0.96

Regression equations between development rate and temperature were found to be y=0.041x - 0.521 (R^2 = 0.92) for egg; y = 0.019x - 0.301 (R^2 = 0.88) for 1st instar nymph; y = 0.017x - 0.154 (R^2 = 0.84) for 2nd instar nymph; y = 0.016x - 0.142 (R^2 = 0.91) for 3rd instar female nymph y = 0.007x - 0.054(R^2= 0.96) for male pre-pupal and pupal stage, respectively (**Figures 1-3**). Development threshold was determined to be 12.70, 15.80, 9.05, 8.87 and 7.10 °C for egg, nymphs (I to III instar) and male pre-pupal and pupal stage, respectively with corresponding thermal constant being 24.40, 52.63, 58.82, 62.5 and 142.85 DD. Total thermal constant requirement to complete a generation was thus 341.2 DD. It may also be noted that temperature threshold decreased after 1st instar stage.

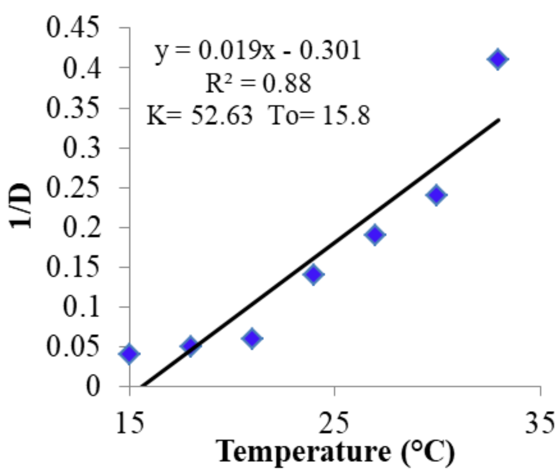

Figure 1 Regression between different temperatures and mean duration of *P.solenopsis* (I instar nymphs, female)

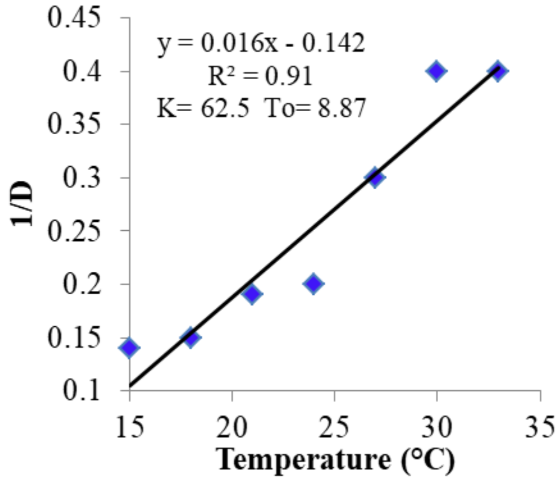

Figure 2 Regression between different temperatures and mean duration of *P.solenopsis* (male pre-pupal stage)

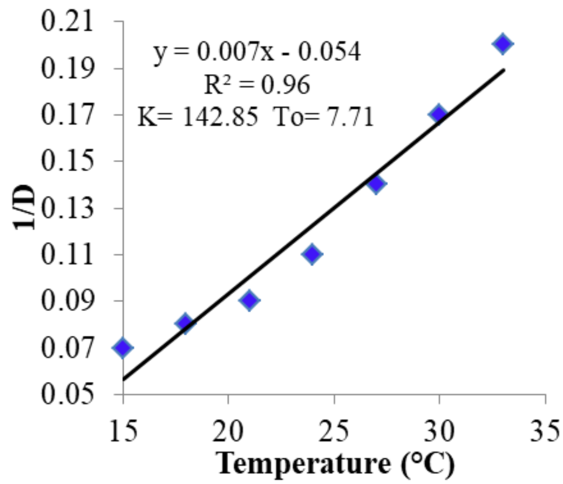

Figure 3 Regression between different temperatures and mean duration of *P.solenopsis* (pupal stage of male)

Conclusion

A linear approximation of relationship between developmental rate and temperature gives the most appropriate fit within the quasi-linear range of temperatures [13]. Entomologists have strong interest on this kind of relationships, since they are prerequisite to predicting timing and phenology of insect life cycle events and to initiating management actions [14, 15], while application of temperature driven models are also essential in epidemiology modeling, development of effective vector control programmes [16] and prediction of biological invasions [17]. From an agronomical standpoint, empirical models are often used to predict specific population events and provide means for precisely applied control methods, reducing costs as well as insecticide use [18, 19]. Furthermore, the determination of insect-specific vital thermal requirements provides evidence to infer on observed geographical distributions and predict future dynamics [20].

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References

[1] Sharma SS (2007) Aenasius sp. nov. Effective parasitoid of mealy bug (Phenacoccus solenopsis) on okra. Haryana J. Hort. Sci. 36: 412.
[2] Arif MI, Muhammad R, Abdul G (2009) Host plants of cotton mealybug (Phenacoccus solenopsis): a new menace to cotton agroecosystem of Punjab, Pakistan. Int. J. Agric. Biol. 11: 163-167.

[3] Jagadish KS, Shankaramurthy M, Kalleshwaraswamy CM, Viraktamath CA, Shadakshari YG (2009) Ecology of the mealy bug, Phenacoccus solenopsis Tinsley (Hymenoptera: Pseudococcidae) infesting sunflower and its parasitization by Aenasius sp. (Hymenoptera: Encyrtidae). Insect Environ. 15: 27-28.
[4] Dhawan AK, Singh K, Anand A, Sarika S (2009) Distribution of mealybug, Phenacoccus solenopsis Tinsley in cotton with relation to weather factors in South-Western districts of Punjab. J. Entomol. Res. 33: 59-63.
[5] Khuhro SN, Kalroo AM, Mahmood R (2011) Present status of mealybug Phenacoccus solenopsis (Tinsley) on cotton and other plants in Sindh (Pakistan). World Cotton Research Conference - 5, Mumbai, India, 7-11 November. pp 268-271.
[6] Carey JR (1984) Host specific demographic studies of the Mediterranean fruit fly Ceratitis capitata. Ecol Entomol 9: 261-270.
[7] Serrano MS, Lapointe SL (2002) Evaluation of host plants and a meridic diet for rearing Maconellicoccus hirsutus (Hemiptera: Pseudococcidae) and its parasitoid Anagyrus kamali (Hymenoptera: Encyrtidae). Florida Entomol 85: 417-425.
[8] Wagner TL, Wu HI, Sharpe PJH, Schoolfield RM, Coulson RN (1984) Modeling insect developmental rate: literature review and application of a biophysical model. Ann Entomol 77: 208-225.
[9] Kontodimas DC, Eliopoulos PA, Stathas GJ, Economou LP (2004) Comparative temperature-dependent development of Nephus includens (Kirsch) and Nephusbisignatus (Boheman) (Coleoptera: Coccinellidae), preying on Planococcus citri (Risso) (Homoptera: Pseudococcidae): evaluation of a linear and various nonlinear models using specific criteria. Environ Entomol 33: 1-11.
[10] Zahiri B, Fathipour Y, Khanjani M, Moharramipour S, Zalucki MP (2010) Preimaginal development response to constant temperatures in Hypera postica (Coleoptera: Curculionidae): Picking the best model. Environ Entomol 39: 177-189.
[11] Tran LT, Worner SP, Hale RJ, Teulon DAJ (2012) Estimating development rate and thermal requirements of Bactericera cockerelli (Hemiptera: Triozidae) reared on potato and tomato by using linear and nonlinear models. Environ Entomol 42: 1190-1198.
[12] Kipyatkov VE and Lopatina EB (2010) Intraspecific variation of thermal reaction norms for development in insects: New approaches and prospects. Entomol.Rev 90: 163-84
[13] Estay, SA, Lima, M, Labra FA (2009) Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modelling. J. Appl.Entomol. 133:491–499.
[14] Feng H, Goult F, Huang Y, Jiang Y, Wu K (2010) Modeling the population dynamics of cotton bollworm Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) over a wide area in northern China. Ecol. Modeling, 221: 1819–1830
[15] Pruess KP (1983) Day-degree methods for pest management," Environ. Entomol. 12:. 613–619
[16] Oshaghi MA, Ravasan, NM, Javadian, E (2009) Application of predictive degree day model for field development of sandfly vectors of visceral leishmaniasis in northwest of Iran. J. Vector Borne Dis. 46: 247–254
[17] Porter JH, Parry ML,. Carter, TR (1991) The potential effects of climatic change on agricultural insect pests. Agric Forest Meteorol, 57: 221–240
[18] Damos PT, Savopoulou-Soultani M (2010) Development and statistical evaluation of models in forecasting moth phenology of major lepidopterous peach pest complex for Integrated Pest Management programs. Crop Protec. 29: 1190–1199
[19] Damos P, Savopoulou-Soultani M (2011) Microlepidoptera of economic significance in fruit production: challenges, constrains and future perspectives for integrated pest management, in Moths: Types, Ecological Significance and Control Methods, Nova Science
[20] Davis MB, Zabinski C (1992) Changes in geographical range resulting from greenhouse warming: effects on biodiversity in forests in Global Warming and Biological Diversity, R. L. Peters and T. E. Lovejoy, Eds., pp. 297–308, Yale University Press, New Haven, Conn, USA.

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