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STUDIES ON THE EFFECT OF THRESHOLD TEMPERATURES, DEGREE-DAY ESTIMATES ON CERTAIN POPULATION GROWTH PARAMETERS OF THE COTTON APHID, *APHIS GOSSYPII* (GLOVER) INFESTING WATERMELON IN UPPER EGYPT

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Abstract

Developmental rates and times, thermal constants and population growth parameters for cotton aphid, *Aphis gossypii* (Glover) infesting watermelon were estimated in relation to certain field conditions during winter, spring and summer.

Using both days and degree-days time scales, lower and higher temperature extremes in winter and late summer were found to delay development and shorten adult longevity as well as exhibiting a marked effect in natality and mortality schedules.

As a consequence, the gross reproductive rates (GRR), net reproductive rates (R_o) and finite rate of population increase (λ) were reduced, whereas the population doubling time (D) was lengthened as compared with the same parameters under the favourable conditions.

The biophysical model predictions based on the regression equations describing the relationship between temperature and developmental rates provided estimates of lower and upper temperature thresholds to be 6.9 and 33.5°C for the generation with degree-day accumulations of 96.3.

Population growth parameters varied among temperature regimes when times were expressed in days. The proportion of immatures decreased while that of adults increased with increasing temperature.

INTRODUCTION

The cotton aphid, *Aphis gossypii* (Glover), is probably the most economically important species in Egypt. It has a wide host range in both field and vegetable crops, especially watermelon, *Cucurbita melon* and other Cucurbitaceae. Watermelon crop injury is caused directly as a result of aphid feeding, but indirectly threaten by spread Cucurbita mosaic virus (CMV). The degree of crop injury depends on the extent of aphid infestation, its timing during the growing season and weather. The aphids are vectors of mosaic virus.

The biology of cotton aphid has been studied by many investigators (Nassar, 1960; Singh et al., 1977; Moursi et al., 1984). However, further investigations on certain ecological and biological aspects of this pest are needed.

The majority of phenology models of insect development are based on laboratory data (Uvarov, 1931). Recently, Ring and Harris (1983) estimated parmeters for a degree-day model, using field data.

Population growth parameters also, are used extensively to study population density changes in nature (Varley and Gradwell, 1971; Varley et al., 1974) and to make static assessments of the role of biotic and abiotic sources of mortality at points in time under particular sets of conditions (Harcourt, 1963),

In this study, several field experiments were done to estimate many important factors which affect the cotton aphid biology and population dynamics. In all these studies, natural enemies were excluded, but other factors remained uncontrolled. Our present analysis evaluates the ability to fit existing data and predictive performances of linear degree-day model using field - collected development data.

MATERIALS AND METHODS

The experiments were conducted during 1995 and 1996 watermelon growth seasons, in sandy soil at Sohag Governorate. The plant date was October 15th, 1994 and October 26th, 1995 and the method of cultivation was under ground rising cultivation (Brollosy method).

Survivorship and fecundity studies

Sets of single viviparous adults of *A.gossypii* were put in each of 50 watermelon leaf cages (Nylon mosquito netting) and allowed to produce youngs. Nymphs were computed and observed daily until death.

Adult survivorship and fecundity patterns were obtained from cohorts of 38, 43, 46, 41, 44 and 48 adults during winter, spring, summer and fall.

The following statistics described by Gross reproductive rate (R_o), generation time (Gt), intrinsic rate of natural increase (r_m), finite rate of natural increase (λ) and population doubling time (DT) were estimated.

Estimated parameters

$r_m = \log R_o/T$

$\lambda = e^{rm}$

R_o = lxMx

T = lxMx.x/lxMx

$Dt = \log e^2$ rm

Thermal requirements and developmental thresholds

Newly born nymphs of nearly equal ages (4 hrs.) were obtained by transplanting 80-100 nymphs for each treatment, from the stock to aphid free experimental cages, using a soft camel hair brush. Developmental times were determined by checking each cage twice daily for exuviae, until all nymphs had moulted to the adult stage and at the mid point of the time interval preceding an observed moult. In computing developmental time nymphs were considered to be 4hr. when they were transferred from plants to leaf plants inside the experimental conditions. A cohort of 80-100 nymphs were reared in each season.

Estimates of lower thresholds for immature development (t_o) and developmental times in days and degree-day were calculated using methods similar to those of Campbell et al. (1974). The upper thresholds were estimated, using linear regression equation, x - intercept where Y is the developmental time. The threshold in this equation is the value of X when Y = O (Park, 1988).

The accumulated heat units for different stages were determined using methods of Sevacherian et al. (1977).

For adult stage, the time of adult stage was recorded for each cohort and the calculation of lower and upper thresholds and thermal requirements were estimated using the same methods described for nymphal stage.

RESULTS AND DISCUSSION

Thermal thresholds (t_o)

A. Lower temperature thresholds (t_o)

Based on the linear regression of the rates of development on temperature, the lower thermal thresholds were estimated to be 6.5 and 7.0°C for nymphal and adult stage, Table, 1.

B. Upper thresholds (t_u)

Estimates of upper thresholds obtained using park methods (Park, 1988) were 33.5 and 33°C for nymphal and adult stage.

Under field conditons, developmental times in days were longer during winter and spring followed by mid summer. However, at summer, developmental times began to be somewhat longer, indicating a slower rate of development at temperatures beyond the upper thermal thresholds.

Our results are in agreement with those obtained by Steiner et al. (1974), Curry et al. (1978). They found that developmental rates for aphid reared at temperatures above the upper threshold were lower than those at more favourable temperatures.

Thermal requirements

The calculated number of degree days (DD) required for development of nymphal and adult stage is shown in Table 1.

Data in Table 1 also show the equation parameters for the relationship between temperature and developmental times. The values of r2 indicate the close linearity of temperature data vs. nymphal and adult development. Values of a (intercept) and b (slope) were used in the calculations of lower and upper thermal thresholds.

Table 1. Esimated of developmental thresholds and times (DD) of cotton aphid on watermelon..

				Developmental rates		
Stages	t_o	t_u	DD	a	B	r^2
Nymph	6.5	33.5	87	7.9	1.5	96.00
Adult	7.0	33.0	172	4.5	0.6	96.25

Age specific life table analysis

A. Survivorship (lx)

The pattern of aphid survival (lx) observed during the three seasons are summarized in Table 2. The survivorship rate (slope of the regression) for aphid in summer was higher than the same rate in winter, spring and fall populations.

Table 2. Age-specific survival (lx) and age-specific fecundity rates (Mx) of *Aphis*

Cohorts	IX	Mx	lx.Mx
Winter	5.22	30.4	10.9
Spring	6.57	36.5	27.2
Summer	4.02	40.3	34.8
Fall	5.08	47.8	41.0

B. Fecundity (Mx)

Table 3 shows the average daily fecundity (Mx) pattern observed for winter, spring, summer and fall cohorts. Average Mx values for aphid per day were: 30.4, 36.5, 40.3, and 47.8 during the 4 seasons, respectively.

Table 3. Regression of percent survivorship (lx) and fecundity rates (Mx) against D^{o} for 4 cohorts of *A.gossypii* on watermelon.

	lx			Mx		
Cohorts	a	b	r^2	a	b	r^2
Winter	2.75	0.015	0.96	-33.5	0.30	0.97
Spring	2.50	0.011	0.95	-30.0	0.32	0.95
Summer	2.70	0.015	0.94	-19.0	0.32	0.95
Fall	2.25	0.012	0.95	-25.0	0.45	0.94

High temperatures observed during mid and late summer appeared to have an adverse effect on adult longevity and fertility. Similar effect of high temperature on aphid fecundity have been demonstrated by Force and Messenger (1964) and Gutierrez (1968) for laboratory cohorts of aphid and by Nowierski et al. (1983) for field cohorts.

Regression statistics are given in Table 3, the birth rates (slope), indicate that fall, summer, spring were higher than winter rates.

Life table statistics

The intrinsic rate of increase (r_m), finite rate of population increase (λ), mean generation time (GT) and population doubling time (DT) were calculated for each cohort by using both Julian and physiological time scales, Table, 4. Life table parameters computed on daily basis cannot be realistcally compared, because the effective daily increments of time and thus aging varied (i.e. the daily temperatures were different) but the values are comparable in $D^{o}C$ basis.

The summer cohorts experienced high temperatures which delayed devlopment, shortened longevity and reduced fecundity, but these effects are not reflected in life table parameters, calculated on a daily basis. For example on a daily schedule, the summer populations had the highest r_m values (0.65), the shortest GT (4.5) and a shortest DT (1.2).

In summary, the calculated biological parameters, (R_o, GT, DT, r_m and λ) indicate that temperature range of 20 to 28 seems to be the favourable range of development and multiplication of *A.gossypii*, whereas the extremes in winter and late summer seem to be outside the favourable range.

Table 4. Summary of population growth parameters for winter, spring, summer and fall populations of *A.gossypii* on watermelon.

Time scale	Cohorts	R_o	GT	r_m	λ	DT
Days	Winter	10.5	25.5	0.092	1.09	7.50
	Spring	26.0	15.5	0.210	1.26	3.25
	Summer	18.5	4.5	0.650	1.90	1.20
	Fall	42.5	7.5	0.490	1.50	1.40
DD	Winter	11.0	125.0	0.020	1.01	33.5
	Spring	27.0	138.0	0.022	1.02	30.0
	Summer	18.5	116.0	0.024	1.02	28.0
	Fall	42.0	111.0	0.033	1.03	20.5

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الإحتياجات الحرارية ومقاييس نمو المجموع لحشرة من القطن على البطيخ بمنطقة مصر العليا

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فى هذا البحث تم حساب معدلات النمو وكذا فترات النمو والثوابت الحرارية ومقاييس نمو المجموع الحشرى لحشرة المن على البطيخ تحت ظروف الحقل خلال فترات الشتاء والربيع والصيف وذلك للوقوف على تأثير درجات الحرارة المختلفة على بعض القياسات البيولوجية للحشرة.

وقد أظهرت الدراسة باستخدام مقاييس النمو الزمنية والحرارية أن درجات الحرارة الدنيا (شديدة الإنخفاض) فى الشتاء والقصوى (عالية الإرتفاع) فى الصيف تؤدى الى بطئ معدلات النمو للحشرة وكذا طول فترة الحياة للحشرة الكاملة باللاضافة الى التأثير الواضح على معدلات التوالد والموت ، وكنتجية لذلك تتناقص قيم كل من معدل التوالد اليومى للأنثى (GRR) ومعدل التضاعف خلال الجيل الواحد (R_o) ومعدل الزيادة الطبيعى (r_m) وكذلك معدل الزيادة النهائى (λ) فى حين تتزايد قيم الزمن اللازم لتضاعف المجموع الحشرى (DT) وذلك مقارنة بنفس المقايس تحت درجات الحرارة المفضلة فى بداية الصيف .

وقد وجد أن قيمة المقاييس المختلفة سالفة الذكر تختلف بإختلاف درجات الحرارة عند استخدام المقياس اليومى للزمن ولكنها تكون متقاربة الى حد ما عند التعبير عن الزمن بالمقياس الحرارى (درجة – يوم) وأوضحت النتائج بالاضافة الى ذلك أن نسبة الأطوار غير الكاملة للآفة تتناقص كلما ارتفعت درجة الحرارة فى حين تتزايد نسبة الأطوار الكاملة.

وعند استخدام الموديل الرياضى لمعادلات الانحدار التى تمثل العلاقة بين درجات الحرارة ومعدلات النمو أمكن تقدير درجات الحرارة الحرجة الدنيا والقصوى للآفة فى حدود (٦,٩ ، ٣٣,٥°م) بينما بلغ عدد الوحدات الحرارية المتجمعة ٩٦,٣ (درجة – يوم) للجيل الكامل.