FIELD ESTIMATES FOR POPULATION GROWTH PARAMETERS OF COTTON APHID

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Abstract

Age-specific life table techniques were applied to field-collected data to examine the effect of favorable and unfavorable temperature conditions on life table parameters. 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 on natality and mortality schedules. As a consequence the gross reproductive rate (GRR), net reproductive rate (Ro), intrinsic rate of natural increase (r_m) and finite rate of population increase (λ) were reduced whereas the population doubling time (D) lengthened as compared with the samee demographic statistics under more favorable temperature conditions in early summer, mid-summer and fall. Values of the latter life table parameters varied among temperature regimes when times were expressed in days, but converged somewhat, when times were expressed in degree-days (DD). The proportion of immatures decreased and the proportion of adults increased with increasing temperature.

Introduction

Cotton, a crop of greatest importance in Middle Egypt is subject to yield and quality losses by arthropod pests, especially the cotton aphid *Aphis gossypii* (Glover), (Salman, 1988).

Basic information on the biology and physical ecology of this pest in Middle Egypt are still lacking. Therefore, the present studies were conducted to obtain better knowledge about some age-specific parameters, population growth and demographic statistics, using the field collected data.

Constructing a life table is the most common method of measuring these parameters. However, the age-specific life tables generally follow the fate of cohort of individuals from birth to death are used to measure intrinsic attributes of species, such as fecundity, longevity and rate of increase under nonlimiting conditions (Anderwartha* and Birch, 1954; Southwood, 1966, Siddiqui *et al*., 1973 and Poole, 1974). In contrast, field age-specific life tables are used extensively to study population density changes in nature (Varley and Gradwell, 1971 and 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, field experiments, were devised to estimate many important factors which affect the green peach aphid biology and population dynamics. In all these studies natural enemies were excluded, but physical factors remained uncontrolled. Our present analysis uses age-specific life table analysis commonly used for laboratory, other extensive sets of field data used to develop a simulation model for the green path aphid.

Materials and Methods

Survivorship and Fecundity Studies

Sets of single adult vivipara of *A. gossypii* were put in each of 50 cotton leaf cage (nylon mosquito netting) during each of cotton plantations, allowed to produce youngs and nymphs were computed and observed daily until death. Adult survivorship and fecundity patterns were obtained from cohorts of 36, 41, 45, 44 and 46 adult during fall.

The following statistics described by Birch were derived from these data: gross reproductive rate (GRR), net reproductive rate (Ro), generation time (r), generation doubling time (DT), intrinsic rate of natural increase (r_m), finite rate of population increase (λ), stable age distribution (Px) and percentage contribution of each age class to the value of (r_m).

Parameters

r_m=log
Ro/T
$\lambda=e^{rm}$
$Ro=ImT=I_x{}^x m_x{}^x \cdot x/I_x m_x$
$DT=\log^2/^{rm}$

Temperature Regimes

Temperature regimes for the six cohorts under field conditions, using a thermograph were:

Cohorts	**Avg. temp. ºC**
Winter	12.66
Spring	16.5
Early Summer	22.5
Mid-Summer	27.8
Late Summer	30.66
Fall	19.25

Heat unit accumulations were calculated for different developmental stages using Sevacherian *et al*. methods (1977).

Results and Discussion

Age-Specific Life Table Analysis

Survivorship (Ix). The patterns of aphid survival (Ix) observed during winter, spring, summer (early, mid and late) and fall are summarized in Tables (1 and 2) and graphically illustrated in Fig. (1) and includes results of both nymphal and adult stages. The survivorship rates (slope of the regression) for mid-summer and late summer on DD basis were nearly similar (Table 3), and were on average about 40, 31, 27 and 32% higher than that of the winter, spring, early summer and fall populations, respectively. An examination of the survivorship data and the weather records during the winter, spring, summer and fall indicates that sharp increase in mortality in cohorts were preceded by periods of low winter and high summer temperature extremes.

Fecundity (m_x). Tables (1 and 2) show the average daily fecundity (m_x) pattern observed for winter, spring, summer and fall cohorts. Average m_x values per aphid per day were: 1.52, 3.32, 6.7, 5.92, 2.22 and 6.82 for winter, spring, early summer, mid-summer, late summer and fall populations, respectively, whereas the corresponding mean total fecundity per female (GRR) were: 30.42, 36.56, 40.25, 23.7. 8.9 amd 47.8 (Table 4). The duration of the reproductive periods were almost similar in the early summer and fall populations.

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

Cumulative plots for average daily m_x on Dº for the six cohorts are shown in Fig. (1) and the regression statistics are given in Table (3), the birth rates

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(slopes), indicate that fall, early summer, spring and mid-summer rates were higher than late summer and winter rates.

Results also show that number of progeny produced per female did not only depend on temperature but also on the age of female. As shown in Fig. (1), high reproductive rates were observed in the early life of insect followed by a decline.

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 a daily basis cannot be realistically compared, because the effective daily increments of time and this aging varied (*i.e.*, the daily temperature were different) but the values are comparable on D° basis.

The summer cohort experienced high temperature which delayed development, 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 (0.492, 0.650 and 0.324), the shortest FT 7.22, 4.48 and 5.29 days and a shortest DT reaching 1.408, 1.066 and 2.139 days. In contrast, life table parameters computed on a physiological time basis, more realistically reflected the consequences of temperature stress as the late summer cohort showed the lowest r_m (0.013) and λ (0.013), a relatively long mean generation time (129.1 D°) and the longest DT (53.319 D°). The net reproductive rate (Ro=5.56) computed for late summer cohort was only about 51, 21, 16, 30 and 13% of the same rates for winter, spring, early summer, mid-summer, and fall populations, respectively.

(Ro). The calculated data in Table (4) indicate that the green peach aphid can increase ca. 10.91, 27.18, 34.82, 18.46, 5.56 and 42.83 times after a single generation in winter, spring, early summer, mid-summer, late summer and fall, respectively.

GT and DT. As shown in Table (4) the generation time of *A. gossypii* was shorter in mid-summer and late summer cohorts as compared with other cohorts. The population of *A. gossypii* also, had the capacity to double every 7.453, 3.269, 1.406, 1.066, 2.139 and 1.397 days or 35.36, 29.12, 19.47, 28.29, 53.32 and 20.51 DD in winter, spring, early summer, mid-summer, late summer and fall, respectively. These results are in agreement with those of Deloach (1974).

r_m and λ. The highest values of r_m and λ were recorded in fall, mid-summer and early summer on the basis of days and degree-days time scale (Table 4).

In summary, the calculated biological parameters (Ro, FT, DT, r_m and λ) indicate that temperature range of 19 to 28 seem to fall in the favorable range of development and multiplication of *A. gossypii* whereas the extremes in winter and late summer seems to be outside the favorable range.

Stable Age Distribution

The stable age distribution gives the proportion of individuals in each age class in population with a stable age structure (Birch, 1948). Stable instar distribution were derived for each of the six cohorts by combining appropriate age classes according to DD requirements necessary to complete each developmental stages. The adult stage was further subdivided into pre-reproductive, young reproductive, old reproductive and post reproductive stages. Data in Table (5) show that higher percentages of adult stage and young reproductive adults were recorded in summer cohorts; meanwhile, the lowest percentages of adult stage with the highest percentages of old reproductive adults were recorded in the other cohorts.

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Table 1. Age specific survival rates (I_x) and age specific fecundity rates (m_x) of A. gossypii during winter and spring.

	Winter				Spring		
Days	I_x	m_x	I_xm_x	Days	I_x	m_x	I_xm_x
23	1.0	2.4	2.40	13	1.0	5.60	5.60
24	0.95	2.3	2.18	14	1.0	5.25	5.25
25	0.80	2.25	1.80	15	0.95	4.52	4.29
26	0.70	2.10	1.47	16	0.90	4.33	3.90
27	0.50	2.0	1.0	17	0.75	3.66	2.75
28	0.30	1.8	0.54	18	0.60	3.50	2.10
29	0.26	1.75	0.45	19	0.50	2.90	1.45
30	0.20	1.60	0.35	20	0.45	2.40	1.08
31	0.20	1.50	0.30	21	0.30	2.0	0.6
32	0.1	1.50	0.15	22	0.10	1.4	0.14
33	0.05	1.40	0.07	23	0.02	1.0	0.02
34	0.038	1.30	0.05				
35	0.033	1.20	0.04				
36	0.017	1.15	0.02				
37	0.018	1.10	0.02				
38	0.019	1.05	0.02				
39	0.01	1.02	0.01				
40	0.01	1.0	0.01				
41	0.01	1.0	0.01				
42	0.01	1.0	0.01				

Table 2. Age specific survival rates (I_x) and age specific fecundity rates (m_x) of *A. gossypii* under field conditions, during summer and fall.

	Early Summer			Mid-Summer			Late Summer			Fall		
D	I_x	m_x	i_xm	I_x	m_x	i_xm	I_x	m_x	I_xm	I_x	m_x	i_xm
4				1.0	11.0	11.2						
5				0.7	7.5	5.6	1.0	4.2	4.2			
6	1.0	12.5	12.0	0.4	4.0	1.6	0.4	2.6	1.1			
7	0.9	10.0	9.5	0.0	1.0	0.0	0.1	1.1	0.1	1.0	12.0	12.0
8	0.9	7.5	6.7				0.0	1.0	0.0	1.0	10.0	10.6
9	0.7	6.2	4.6							1.1	8.4	10.0
10	0.4	3.0	1.3							0.7	7.2	5.4
11	0.0	1.0	0.0							0.6	5.0	3.3
12										0.4	3.5	1.4
13										0.02	1.0	0.02

Table 3. Regression of percent survivorship (Ix) against Dº for 6 cohorts of *A. gossypii*.

	Survivorship rate (I_x)			Fecundity rate (m_x)		
Cohorts	a	b	r^2	a	b	R^2
Winter	2.753	-0.016	0.970	-34.69	0.29	0.97
Spring	2.47	-0.011	0.965	-29.95	0.34	0.96
Early Summer	2.21	-0.012	0.943	-14.81	0.38	0.95
Mid-Summer	2.68	-0.015	0.95	-19.39	0.32	0.95
Late Summer	3.097	-0.017	0.94	-5.761	0.084	0.94
Fall	2.267	-0.012	0.973	-25.50	0.046	0.94

Table 4. Summary of age-specific life table statistics for winter, spring, summer and fall populations of *A. gossypii*.

Time scale	Cohorts	GRR	Ro	GT	rm	λ	Dt
Days	Winter	30.42	10.91	25.64	0.093	1.097	7.453
	Spring	36.56	27.18	15.56	0.212	1.263	3.269
	Early S.	40.25	34.82	7.22	0.492	1.635	1.408
	Mid. S.	23.70	18.46	4.48	0.650	1.915	1.066
	Late S.	8.90	5.56	5.29	0.324	1.382	2.139
	Fall	47.80	42.83	7.57	0.496	1.462	1.397
Degree-	Winter		10.91	121.7	0.020	1.020	35.36
Days	Spring		27.18	138.6	0.024	1.024	29.12
(DD)	Early S.		34.82	99.56	0.026	1.036	19.47
	Mid. S.		18.46	118.9	0.025	1.025	28.29
	Late S.		5.56	129.1	0.013	1.013	53.32
	Fall		42.83	111.2	0.033	1.034	20.51

Table 5. Stable instar (stage) for *Aphis gossypii* under field conditions.

	Percentage in each instar or stage					
Instar or stage	Winter	Spring	Early S.	Mid S.	Late S.	Fall
Nymphal stage I	52.4	56.3	57.4	58.1	58.4	43.8
II	22.1	18.2	17.0	16.0	15.8	18.6
III	11.9	10.5	10.4	10.0	9.60	11.1
IV	7.0	5.4	5.5	5.2	5.0	6.0
Adult stage	6.6	9.6	9.7	10.7	11.3	9.55
Pre-reproduction	26.4	20.1	18.7	17.6	16.5	19.2
Young reproduction	65.3	69.4	73.8	71.9	79.5	70.3
Old reproduction	8.2	10.5	7.50	4.45	4.0	10.4
Post reproduction	0.1	<0.1	<0.1	<0.1	0.0	<0.1