Biology and Biotype of Two Strains of Pea Aphid *Acyrthosiphon pisum* (Homoptera: Aphididae) on Lentil

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Abstract

Four entries of lentil were used to study the life history parameters of two strains of *A. pisum* under laboratory condition. The entries and the strains were combined factorialy and arranged in CRD with 12 and 15 replications in trial one and two, respectively. Then the data were pooled after assessing the homogeneity of variance. The mean developmental period of the Debre Zeit (DZ) strain was 8.44 days, the pre-reproductive period was 1.26 days, the reproductive period was 15.91 days and the post reproductive period was 7.07 days. For the Goettingen (GOE) strain the mean values were 8.67, 1.58, 16.04 and 13.26 days, respectively. The peak reproductive rate per female per day and the intrinsic rate of increase (r_m) of the DZ strain were marginally greater than the corresponding values of the GOE strain. Moreover, the two strains varied in alate production and in realizing their potential fecundity. The r_m values on all of the tested entries were positive indicating that the entries were susceptible to both strains.

Introduction

Grains of lentil (*Lens culinaris*) contain a high amount of protein and serve as cheap source of protein for the Ethiopian highland population (Geletu et al. 1996). Moreover, this crop is part of the crop rotation systems established in the predominantly small cereal growing farming systems of the country (Seifu et al. 1991). Despite its importance, lentil productivity has remained low and uncertain partly due to its susceptibility to insect pests. Lentil is attacked by different insects, but only few of them are economically important. In Ethiopia, the major pest of lentil is the pea aphid (*Acyrthosiphon pisum*), which attacks lentil crops from the early seedling stage to crop maturity (Kemal & Tibebu 1994).

Estimations of the loss of potential grain yield of common lentil cultivars due to pea aphid damage ranged from 11-26% in 1984 and 1985 to total loss in 1995 in some lentil producing areas (DZARC 1996). Although these data underline the pest status of the pea aphid in Ethiopia, laboratory and field data on the biology of the pea aphid on lentil are lacking. The pea aphid is oligophagous, feeding on plants within the family Legumenaceae. However, because this aphid species is known to form several biotypes (Frazer 1972a), performance on different cultivars of host plants largely depends on the aphid strain under study. We, therefore, used two different strains, one from Ethiopia and one from Germany, to evaluate their performance on different accessions of lentil grown in Ethiopia. Therefore, this study was envisaged to generate base line information on the biology of pea aphid, *A. pisum* on lentil and to investigate varietal effect on its demography.

Materials and Methods

Two strains of *A. pisum* were used in all experiments. The Debre Zeit (DZ) strain was collected in October 1998 from lentil variety experiments at the Debre Zeit Agricultural Research Center (altitude 1900m) in Ethiopia. The Gottingen strain (GOE) descended from an *A. pisum* clone reared under laboratory conditions on faba bean (*Vicia fabae*) since 1984. This strain was given a one-year pre-adaptation period on lentil. A stock culture of each strain was established from single mother aphid kept in separate rearing cages on the lentil variety " Freudenberger" at a temperature of 21°C, a photoperiod of 16hr light to 8hr dark period and at a relative humidity of 50-70% (Frazer 1972b).

Variety Alemaya (AL) and Chalew (CH) and two accessions Flip-88-12L(FL) and ILL-8006(IL) were used in the study. Chalew was selected because of its known field tolerance to pea aphid (Kemal & Tibebu 1994). The others were selected based on their performance at the preliminary screening phase. Two seeds of each entry were sown in 11L pots filled with a mixture of standard medium (10% peat, 90% clay and nutrients) and sand in a ratio of 2:1 (W/W). Treatments were combined factorially and arranged in CRD with 12 (because of space limitation) and 15 replications in the first and second experiment, respectively. At the time of infestation plants were thinned to one plant per pot.

To obtain day old nymph, single adult aphid was placed on each plant when they were at 3-4 leaf stage and allowed to stay for 24hr. After 24hrs the mother aphid and her nymphs in excess of one were removed using water wet paint brush. When the aphid failed to deposit its nymph in 24hr time extra nymphs from the other replication were transferred to the plant. Infested plants were caged using a cylindrical, transparent cage of 30 cm high and 9.3 cm diameter, so that aphids were free to select their feeding site. To secure ventilation within the cages, the top and side windows (3-4 in numbers) of the cage were covered with nylon mesh cloth. The infested plants were kept under conditions similar with that of the stock culture.

Aphids were monitored daily until they died and newly born nymphs were counted and removed at each census date. Dead aphids were dissected and examined under a binocular microscope to check if they had completely delivered their embryos. Data on the developmental period, pre-reproductive period, reproductive period and post-reproductive periods were recorded.

The performance of the populations was assessed by constructing life tables for each strain at each entry following the calculation given by Gutierrez (1996). For each day interval from birth to death (x) age specific survival (l_x) and age specific fecundity (m_x) were recorded and $l_x m_x$ was calculated. The intrinsic rate of increase (r_m) of each strain under a given condition was calculated from the equation å $e^{-r_m x} l_x m_x = 1$ by iterative substitution of the values of r_m. Differences in r_m values between entries were compared using the Mann-Whitney U test (Zar 1974). The other data were subject to an analysis of variance and means were separated using LSD. However, when the data did not meet the assumption of normal distribution they were subjected to square root transformation; when they still did not attain normality after transformation they were tested using Mann-Whitney U test. Data on the developmental period, pre-reproductive period, and total number of progenies were pooled to one set. Before pooling data from each experiment, however, Bartlet's test was performed to ensure whether these attributes between the experiments were heterogeneous or not (Zar 1974).

RESULTS

Nymph development

The tested pea aphid strains performed differently on the lentil entries with regard to some life history parameters (Table 1). There was marginally significant ($P < 0.05$) difference between the two strains in developmental time required to reach adult stage. The DZ strain required only a mean of 8.44 days to reach adult stage, whereas the GOE strain required a mean of 8.67 days to reach the same stage. In the pre-reproductive and reproductive period, however, strains did not vary significantly ($P > 0.05$) from each other. Although non-significant, the longest mean pre-reproductive and reproductive periods were recorded from the GOE strain. In post-reproductive period and total longevity, however, the two strains did again differ significantly ($P < 0.05$) from each other. The GOE strain had a mean of 13.26 days of post-reproductive period as compared to the DZ strain, which had only a mean of 7.07 days. Similarly, the mean longevity of the GOE strain was 39.54 days with 50% and 100% mortality occurring 37 and 48 days after birth, respectively. On the contrary the mean longevity of the DZ strain was 32.67 days with 50% and 100% mortality occurring at 30 and 40 days after birth, respectively. These differences in life history traits of the two pea aphid strains tested could also be confirmed in the life expectancy at age zero calculated in the life table analysis (Table 2).

There were highly significant differences ($P < 0.01$) among the entries in affecting the developmental and reproductive periods required by both strains. However, the influence of the entries on pre-reproductive period was not statistically significant (Table 1). Even though statistically non-significant, the mean pre-reproductive period on Chalew and Flip-88-12L was relatively longer than either on Alemaya or ILL-8006. The mean developmental period of the strains was 8.34 on Flip-88-12L, 8.44 on Cahlew, 8.65 on ILL-8006, and 8.77 on Alemaya. Similarly, the mean reproductive period of the strains was 14.45 on Flip 88-12L, 15.42 on ILL-8006, 17.01 on Chalew and 17.02 on Alemaya.

Unlike that of the GOE strain the within variability in developmental period and reproductive period among individuals of DZ strain raised on each entry was significant and highly significant, respectively, and their relative ranking follows exactly the pattern of the overall means of both strains on each life history parameter. On the other hand, the within differences in pre-reproductive and reproductive periods among individuals of the GOE strain did significantly vary from each other.

Table 1. Bionomics of two strains of *Acyrthosipon pisum* on different lentil entries

Entries	Developmental period (days)**			Pre-reproductive period (days)*			Reproductive period (days)**			Post-reproductive Periods (days)°		Longevity (days)°	
	DZ	GOE	μ	DZ	GOE	μ	DZ	GOE	μ	DZ	GOE	DZ	GOE
Alemaya	8.76	8.78	8.77^{a}	1.22	1.54	1.38^{a}	17.18	16.86	17.02^{a}	5.50	12.35	32.26	39.53
Chalew	8.36	8.52	8.44^{bc}	1.29	1.84	1.57^{a}	17.26	16.75	17.01^{a}	8.08	12.92	34.99	40.03
Flip-88-12L	8.13	8.54	8.34^{c}	1.29	1.58	1.44^{a}	14.35	14.54	14.45^{b}	7.29	13.37	31.06	38.03
ILL-8006	8.50	8.81	8.65^{ab}	1.24	1.36	1.30^{a}	14.83	16.00	15.42^{b}	7.39	14.40	31.96	40.57
Mean*	8.44^{a}	8.67^{a}		1.26^{a}	1.58^{a}		15.91^{a}	16.04^{a}	-	7.07^{b}	13.26^{a}	32.67^{b}	39.54^{a}
CV(%)	7.3			19			16.8		-		-		

° = Mann-Whitney U-test , significant at $p < 0.05$
* = Means followed by the same letter within a column or row are not statistically different at $p = 0.05$
** = Means followed by the same letter within a column are not statistically different

Table 2. Some life table parameters of two strains of *A. pisum* on different lentil entries

Entries	Days to 50% mortality		Days to 100%mortality		Life expectancy at age zero (days)	
	DZ	GOE	DZ	GOE	DZ	GOE
Alemaya	31	37	41	48	29.42	31.23
Chalew	32	40	40	48	30.04	38.22
Flip-88-12L	30	36	38	46	28.54	32.81
ILL-8006	26	38	41	49	23.38	38.30
Mean	30	38	40	48	27.85	35.14

Reproduction

There was a significant ($P<0.05$) interaction between strains and entries in the total number of progenies produced per female (Table 3). In this experiment the DZ strain produced a maximum of 99.03 and 88.35 nymphs on Flip-88-12L and Chalew, respectively, whereas the GOE strain produced a maximum of 89.73 and 87.32 nymphs on ILL-8006 and Flip-88-12L, respectively. In contrast to this, the DZ strain raised on ILL-8006 and the GOE strain reared on Chalew produced the least number of nymphs.

Life table statistics

The net reproduction of each strain on Chalew and Flip-88-12L was closer to the total reproduction. The net reproduction of the GOE strain and the DZ strain was lower than the gross reproduction on Alemaya and ILL-8006, respectively. None of the differences in the intrinsic rate of increase (r_m) on the various entries were significant ($P>0.05$). The mean r_m of the DZ strain was 0.330 compared to 0.321 of the GOE strain (Table 3). Based on the age specific survivorship and reproduction curves the two strains experienced a high mortality during the post-reproductive period (Fig.1 a-d).

Table 3. Reproductive performance of two strains of *A. pisum* on lentil

Entries	No. of lymphs/female		Net reproduction/female		Intrinsic rate of increase $(r_m)_0$	
Alemaya	86.00b	84.81b	78.29	67.04	0.311	0.300
Chalew	88.35b	83.75b	84.19	83.89	0.328	0.320
Flip-88-12L	99.30a	87.32b	94.50	86.23	0.362	0.341
ILL-8006	85.76b	98.73b	69.12	86.76	0.319	0.324
Mean			**81.53**	**80.48**	**0.330a**	**0.321a**

** = Means followed by the same letter are not statistically different at p = 0.05*
° = Mann-Whitney U-test, means are not significantly different at p = 0.05

Table 4. Mean number of well-developed embryos detained by a dying aphid after post-reproductive period

Entries	Strains (trial 1)		Strains (trial 2)	
	DZ (n)	GOE (n)	DZ (n)	GOE (n)
Alemaya	5.73 (11)*	0.11(9)	4.82 (11)	2.08 (12)
Chalew	5.42 (12)	1.50 (12)	4.33 (12)	0.31 (13)
Flip-88-12L	4.90 (10)	2.00 (110	3.15 (13)	0.15 (13)
ILL-8006	11.88 (8)	0.55 (11)	4.92 (13)	0.21 (14)
Mean	6.98	1.04	4.31	1.19
N	41	43	49	52

* = means followed by different letter with in row (within trial) are significantly different at $p < 0.05$ (Mann-Whitney U-test)

Discussion

The overall variation of developmental time as well as the pre-reproductive time required by both strains on each of the four entries was not large (Table 1). The aphids grown on Alemaya and ILL-8006 required relatively longer developmental period than those aphids grown either on Chalew or Flip-88-12L. On the contrary, the pre-reproductive periods tended to be shorter on the former two entries than on the latter ones, indicating that the commencement of reproduction is unaffected by lentil varieties. In other words aphids are able to compensate for the delay in reproduction by shortening the pre-reproductive period or compensate pre-maturity by extending the pre-reproductive period. This high plasticity in adaptability is regarded as one prerequisite to colonize new host plants and to maintain populations even when environmental conditions are unfavorable (Lewontin 1965).

The longevity of the Debre Zeit strain was shorter than that of the Goettingen strain. However, the fertility range of the latter was within the fertility range of the former strain. Based on the relationships between fecundity and longevity, Southwood (1976) has categorized organisms capable of reproducing into organisms directing energy- towards self-survival and growth or towards offspring production or towards some partitioning between the two. Thus, it is perhaps the ability of partitioning energy between production of offspring and survival that enabled the Goettingen strain to achieve comparable number of nymphs without affecting its life span. On the contrary, the Debre Zeit strain seems to allocate more energy to nymph production than its energy requirement for survival. This was proved by the number of embryos detained in the mother aphids after cessation of reproduction (Table 4).

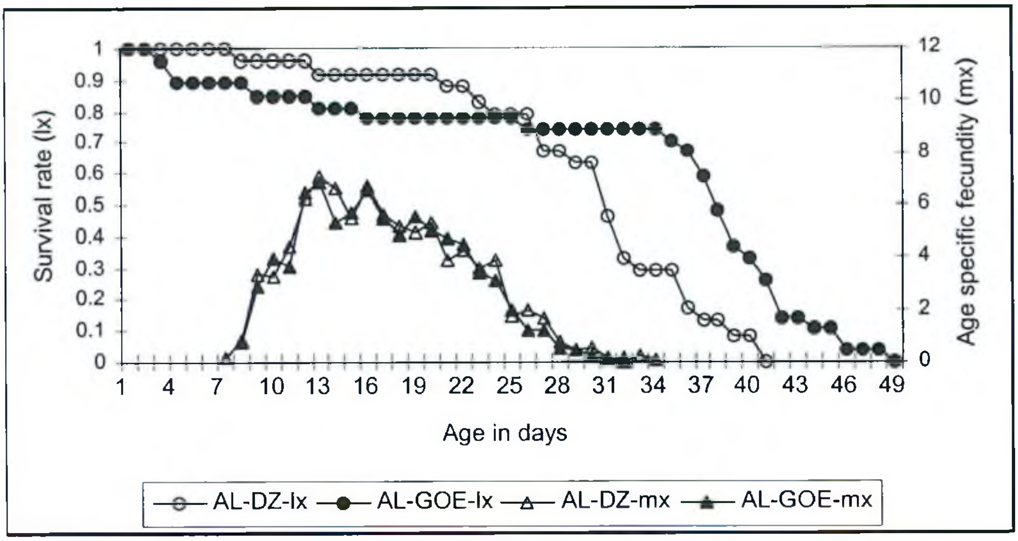
In this experiment dead aphids of the Debre Zeit strain contain significantly ($P<0.05$) more number of well developed embryos than the Goettingen strain. This suggests that the Debre Zeit strain terminated its reproduction before realizing its potential fecundity probably because of limitation of energy for survival. Frazer (1972b), however, had noted the inability of nymphs of *A .pisum* and *Aphis fabae* raised on broad bean to burst their embryonic membrane or still-birth glued in place that hinders succeeding births as the cause of engorgement of dead females with developed embryos.

The survivor curves for both strains (Fig.1a-d) on all but DZ strain on entry ILL-8006 exhibited a Type I pattern, in which mortality rate increases with age (Gutierrez 1996). This form of survivorship curves had also been observed in other life-table studies on *A. pisum* on susceptible hosts (Frazer 1972b, Mackay & Wellington 1975, Birch & Wratten 1984, Soroka & Mackay 1991). This suggests that the tested lentil entries are suitable or susceptible hosts to the strains tested. However, the survivor curve of DZ strain raised on ILL-8006 (Fig.1d) was closer to Type II in which mortality is distributed uniformly in the age structure of the aphid. But when the fertility distribution per reproductive period is considered, it was evident that both strains on all entries had normally distributed ($W < 0.01$) fertility. Webster et al (1992) have found a similar fecundity distribution of greenbug, *Schizaphis graminum* biotypes on susceptible barley, indicating that the mortality of the DZ strain reared on ILL-8006 was not associated with the resistance factor of the entry.

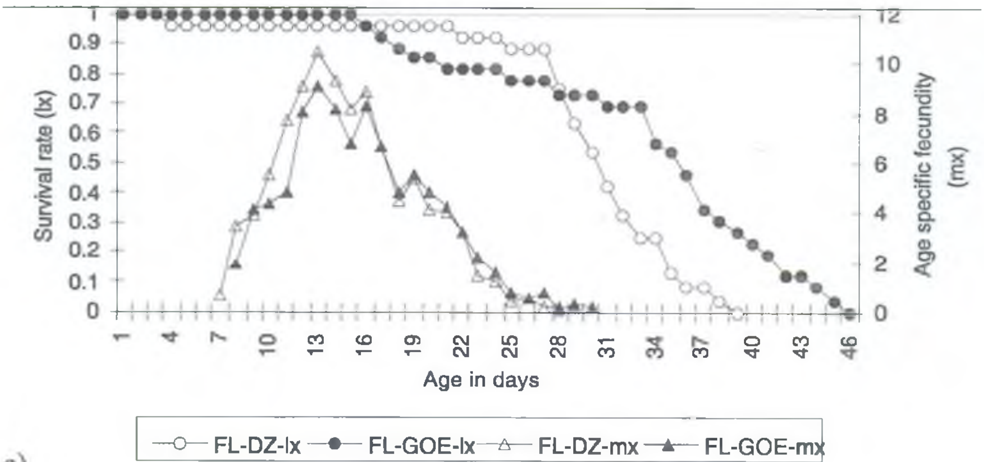
The intrinsic rate of increase, r_m values of both strains on all entries are positive indicating that the population is increasing. As compared to the Gottingen strain, however, the Debre Zeit strain had relatively greater r_m values on all entries except on ILL-8006 (Table 2). This greater r_m value of the Debre Zeit strains is attributed to the relatively shorter total pre-reproductive period (i.e. sum of developmental and pre-reproductive periods) elapsed before the beginning of reproduction. According to Lewontin (1965) r_m is particularly influenced by the time until first reproduction. Siddiqui et al (1973) have found an increase in r_m values because of shorter pre-reproductive period of *A. pisum* treated with increased amplitude of altering temperature. Although survival rate (l_x) is a component of r_m, it is not important in determining the rate of increase since very few aphids die during their reproductive periods (Frazer 1972b).

Figure 1. Age specific survivorship curves (circles) and fertility rates (mean number of nymphs per female per day; triangles) of two strains of the pea aphid (*Acyrtosiphon pisum*) on different lentil (*Lens culinaris*) entries, a: Alemaya (AL), b: Chalew (CH), c: Flip-88-12L (FL) and d: ILL-8006 (IL); strain : Debre zeit (DZ): open symbols; strain Goettingen (GOE): solid symbols.

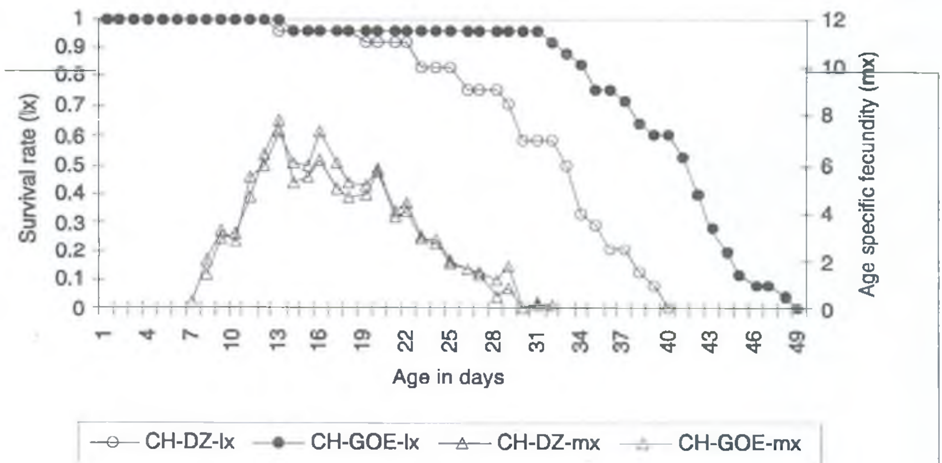
a).

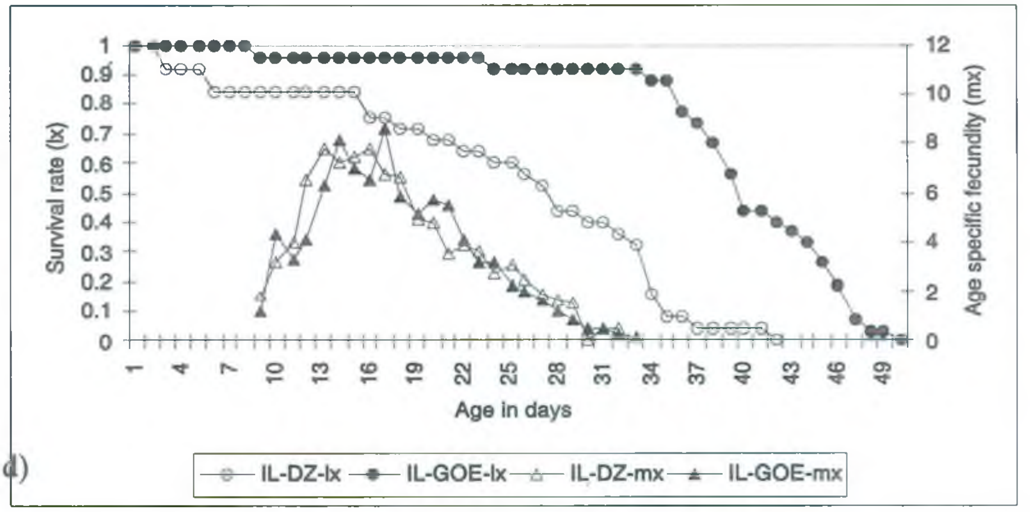


b)


Survival rate (lx)
Age specific fecundity (mx)
Age in days
FL-DZ-lx
FL-GOE-lx
FL-DZ-mx
FL-GOE-mx

c)


Survival rate (lx)
Age specific fecundity (mx)
Age in days
CH-DZ-lx
CH-GOE-lx
CH-DZ-mx
CH-GOE-mx



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