

## THE EFFECTS OF TEMPERATURE AND HOST QUALITY ON THE RATE OF INCREASE OF THE COWPEA APHID (*Aphis craccivora*) ON FABA BEAN

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### ABSTRACT

Under constant temperatures from 10 °C to 25 °C *Aphis craccivora* reared on young and mature leaves of faba bean *Vicia faba* L. (Giza 2 variety), developed faster, had a higher mean relative growth rate and a higher intrinsic rate of increase on young than on the mature leaves of faba bean. At temperatures above 25 °C there is a marked decline in the performance of the aphid. The intrinsic rate of increase is strongly correlated with the mean relative growth rate during development for both aphids reared on young and mature leaves from 10 °C to 25 °C.

### INTRODUCTION

The pest status of the cowpea aphid (*Aphis craccivora* Koch.) is in part a consequence of its ability to multiply rapidly on legumes during the winter and summer. Little investigations have been conducted into the factors that influence this rate of increase. Differences in its development and fecundity occur in response to changes in temperature (Noda, 1960; Gunther *et al.*, 1980; Wellings, 1981). However, similar effects may be produced by differences in the age of the host plant (Watt, 1979). Although *Aphis craccivora* preferentially infests the fresh host plants of legumes, especially clustered in the folded upper surfaces of young leaves in the growing head or even senescing parts of faba bean plants, which provide the most nutritious sites for aphid feeding (Low, 1967; Azza Emam, 1980 and El-Defrawi, 1994), the effects of temperature on the performance of this aphid species on the earlier developmental stages of faba bean has been little studied.

The object of this study is to quantify the effects of temperature on the rate of increase of *Aphis craccivora* on plants at developmental stages normally colonized by this aphid in the field, and to relate changes in the rate of increase to their mean relative growth rate during development.

### MATERIALS AND METHODS

The offspring of apterae from a black colony of *Aphis craccivora* were isolated in clip-cages on seedlings of faba bean (cv. Giza 2) in a constant temperature at 20 °C ± 2 °C and a 16 h daylength. When mature the apterous aphids were checked every 3 - 6 h between 09.00 - 20.00 h and their offspring removed and caged on faba bean at two developmental stages (seedling and vegetative growth). Nymphs were clip-caged individually on young (new expanded) and matured (senesced) leaves at a density of two clip-cages per plant using cages of the type described by Watson and Dixon (1984), at a density of one aphid per leaf, separated by a small plastic cones.

The experiment was conducted at constant temperatures of 10°C, 15°C, 20°C, 25°C and 30 °C,  $\pm$  2 °C, and a 16-h daylength at Giza, ARC, Aphid Screening Laboratory.

The nymphs were checked every 3 – 6 h from 09.00 - 20.00 h, and the time of the final moult recorded. They were then weighed and replaced singly on plants at the same developmental stage and temperature at which they had been reared. The time of the onset of reproduction was noted. Nymphs were counted and removed daily for a time equal to the pre-reproductive period. Plants were changed as necessary in order to maintain the specified developmental stages.

## RESULTS AND DISCUSSION

### Developmental and growth:

Aphid development rate, defined as  $1/D$  where  $D$  = time in days from birth to adult moult, increased with temperature up to 25 °C when further increase in temperature became detrimental (Fig. 1). Developmental rate was higher at all temperatures on the young than on the mature leaf, and the relationship with temperature over the range 10 °C – 25 °C was linear on both young and mature leaf.

**Fig 1: The developmental rate of apteros *A. Craccivora* on the young and mature leaf of faba bean in relation to temperature**

Mean relative growth rate (RGR), was defined according to (Van Emden, 1969) formulae as  $(\ln A - \ln B) / D$ ; where  $A$  = adult teneral weight,  $B$  = birth weight and  $D$  = developmental time, increased with temperature up to 25 °C on both young and mature leaf (Fig. 2). The relationship with temperature over the range 10 °C – 25 °C was linear on the young, but slightly concave on the mature leaf, and at all temperatures RGR was higher on the young than on the mature leaf.

**Fig 2: The mean relative growth rate of apteros *A. Craccivora* on the young and mature leaf of faba bean in relation to temperature**

**Fig 3: Adult weight of apteros *A. Craccivora* on the young and mature leaf of faba bean in relation to temperature**

The weight attained by aphids varied with temperature and feeding site (Fig. 3). Aphids were larger at a range of temperature (15 - 25 °C) than on low (10°C) or on high temperature (30 °C). On the young leaf aphids were largest at 20 °C, but on the mature leaf aphids were largest at 20 °C – 25 °C. At 20 °C aphids were significantly larger on the young than on the mature leaf, but the converse was true at 10 °C and 30 °C.

There was no trend in nymphal mortality with temperature or feeding site, until 30 °C when it increased dramatically (Table, 1).

**Table 1. Percentage nymphal mortality of *A. craccivora* on the young and mature leaf of faba bean at five different temperatures (°C).**

Food quality offered	Aphids reared at temperature of				
	10 °C	15 °C	20 °C	25 °C	30 °C
Young leaf	13.8 (25)	12.3 (53)	11.5 (43)	8.5 (50)	70.5 (45)
Matured leaf	14.1 (27)	12.6 (44)	14.5 (45)	12.1 (46)	77.8 (51)

\* Number of replicates in parentheses.

#### **Reproduction:**

The effective lifetime fecundity (Md) of an aphid is achieved in time 2d, from birth where d is the time from birth to first reproduction (Wyatt & White, 1977). There was no significant difference in Md achieved on the young or mature leaf ( $t = 0.064$ , N.S., as shown in Fig. 4). The maximum effective lifetime fecundity on the young occurred at 25 °C; meanwhile, on the mature leaf at 20 °C. Lower number of nymphs were born at 30 °C.

**Fig 4: The effective lifetime fecundity of apteros *A. Craccivora* on the young and mature leaf of faba bean in relation to temperature**

**The intrinsic rate of increase:**

The mean intrinsic rate of increase ( $r_m$ ) refers to the rate of daily population growth (Aphids/aphid/day) and was calculated from the formula  $(\ln M_d \div d)$  where  $d$  = time from birth to reproduction and  $M_d$  = number of nymphs born in time  $d$  from birth according to (Wyatt & White, 1977 and Shamsan, 1999),  $r_m$  was higher on the young than on the mature leaf (Fig. 5). It increases on the young up to 25 °C, but reached a maximum on the young leaf between 20 °C – 25 °C.

**Fig 5: The intrinsic rate of increase ( $r_m$ ) of apteros *A. Craccivora* on the young and mature leaf of faba bean in relation to temperature**

A high correlation existed between the intrinsic rate of increase and the mean relative growth rate for aphids reared on both the young and mature leaf over the range 10 °C – 25 °C ( $r = 0.9561$ , d.f. = 6,  $p < 0.001$ ) (Fig. 6)

Temperature affects the rates of development of aphids and host plant; in addition to, the impact of a natural enemy on an aphid population or of an aphid population on a host plant varies with temperature because of differing optimum temperatures for development and varying tolerances of the different insects and plants. For each species of aphid there is an optimum temperature for development and reproduction. *A. craccivora* has an optimum of about 20-30 °C. Development does not occur below about 5 °C and growth rate increase progressively until about 25 °C, after which it declines rapidly (El-Defrawi *et al.*, 1994). This helps to explain the absence or scarcity of *A. craccivora* during hot summer conditions for long time in upper Egypt conditions. Hodek (1973) demonstrated the differential effects of temperature on the reproductive capacity of *A. fabae* and the preying efficiency of *Coccinella septempunctata* adults on sugar beet in experimental field cages in Czechoslovakia.

Work on pasture legumes in S.E. Australia (Gutierrez *et al.*, 1971) has shown that the aphid is highly sensitive to temperature and possesses a highly potential for migration. Although not in conformity with results of Grylls (1972), who demonstrated ability to multiply locally during November to April, Gutierrez *et al.* (1971) inferred that *A. craccivora* may not survive mild winters or hot dry summers characteristic of this region, so hosts are colonized during autumn and spring each year from distant favorable regions.

**Fig 6: The relationship between the intrinsic rate of increase ( $r_m$ ) and the mean relative growth rate (RGR) of apteros *A. Craccivora* on the young and mature leaf of faba bean in relation to temperature**

Chambers (1979) considered growth and development as separate processes that together determine the size attained by an aphid. Teneral weight is greater at low temperatures in several aphid species (Wellings, 1981 and Dixon *et al.*, 1982) and increased nutrition has been shown to result in larger aphids (Watt, 1979 and Dixon *et al.*, 1982). This is due to the different influence of temperature and nutrition on growth and development (Chambers, 1979 and Shamsan, 1999). Although at high temperatures growth is more rapid this does not result in larger aphids because the development rate is accelerated disproportionately, causing growth to be truncated earlier. Between 15 °C – 25 °C the relative growth rate of *A. craccivora* on the young leaf increased from 0.312 – 0.684 (219.2 %); while the development rate increase from 0.098 – 0.147 (150 %), and consequently aphids were smaller at 20°C than at 15 °C. A peak in size results from a curvilinear relationship of growth or development, with temperature. Increased host plant quality will result in larger aphids if the developmental rate is increase less than the growth rate. In *A. craccivora* this occurred at 15 °C, when the growth rate was 0.312 on the young leaf and 0.101 on the

mature leaf (308.9 %), while the developmental rate was 0.098 on the young leaf and 0.074 on the mature leaf (132.4 %), which resulted in larger aphids on the young leaf.

At low temperatures the relationship between development and temperature may be curvilinear (Dixon et al., 1982). This was evident in the concave relationships of aphid growth and development with temperature on the young leaf.

Reproductive rate is positively correlated with both aphid size and temperature (Watt, 1979; Dixon and Dharma, 1980). Consequently the intrinsic rate of increase is also increased by improved nutrition and at higher temperatures. The intrinsic rate of increase has been used as a criterion of host plant resistance to aphid attack (Sotherton and Van Emden, 1982). The intrinsic rate of increase of *A. craccivora* was closely correlated with the mean relative growth rate during development over a wide range of nutritional and temperature conditions such as  $r_m = 0.279$  RGR.

## REFERENCES

- Azza Emam, K. (1980). Feeding sites of certain Hemipterous insects with special reference to Genus *Aphis* L. M. Sc. Thesis Fac. Agric. Ain Shams Univ.
- Chambers, R.J. (1979). Simulation modeling of a sycamore aphid population. Ph. D. Thesis, Univ. of East Anlia.
- Dixon, A.F.G.; Chambers, R.J. and Dharma, T.R. (1982). Factors affecting size in aphids with particular reference to the black bean aphid *Aphis fabae*. *Entomologia Experimentalis et Applicata* 32, 123-128.
- Dixon, A.F.G. and Dharma, T.R. (1980). Spreading the risk in developmental mortality; size, fecundity and reproductive rate in the black bean aphid *Aphis fabae*. *Entomologia Experimentalis et Applicata* 28, 301-312.
- El-Defrawi, G.M.; M. Abd-El-Azim; I.M. Marzouk and S.I. Bishara (1994). Seasonal fluctuation of five aphid species infesting faba bean plants in Beni-Suef Governorate, Egypt. *Egypt. J. Appl. Sci.*; 9 (10) 1994: 235-247.
- Grylls, N.E. (1972). Aphid infestation and virus infection of peas and beans on The Central Tablelands of New South Wales. *Aust. J. exp. Agric. Anim. Husb.* 12 :667-674.
- Gunther, Th.; B. Freier and Th. Wetzel (1980). Untersuchungen uber des Temperaturregims in einen Weizenbestand und sein Einfluss auf die Entwicklung der Getreidlaus (*Macrosiphum avenae* (Fabr.)). *Archiv fur Phytopathologia und Pflanzenschutz* 16, 209-216.
- Gutierrez, A.P., D.J. Morgan; D.E. Havenstein (1971). The ecology of *Aphis craccivora* Koch and subterranean clover stunt virus. I. The phonology of aphid populations and the epidemiology of virus in pastures in Southeast Australia. *J. appl. Ecol.* 8 : 699-721.
- Hodek, I. (1973). *Biology of Coccinellidae*, Academia, Prague. 260 pp.
- Low, H.J.G. (1967). Interspecific differences in the biology of aphids (Homoptera: Aphididae) on leaves of *Vicia faba*: 1. Feeding behavior. *Ent. Exp. Appl.*, 1 (10): 347-357.
- Noda, I. (1960). The emergence of winged viviparous female in aphid. VI. Difference in the rate of development between the winged and the unwinged forms. *Japanese J. of Ecolo.* 10, 97-102.

- Shamsan, A.D.A. (1999). Studies on some leafminer insects infesting fruit trees in Egypt. Ph. D. Thesis Fac. Agric. Ain-Shams Univ.
- Sotherton, N.W. AND Van Emden, H.F. (1982). Laboratory assessment of resistance to the aphids, *Sitobion avenae* and *Metopolophium dirhodum* in Three *Triticum* species and two modern wheat cultivars. Ann. of Appl. Bio. 101: 99-107.
- Van Emden, H.F. (1969). Plant resistance to *Myzus persicae* induced by a plant Regulator and measured by aphid relative growth rate. Entomologia Experimentalis et Applicata 12, 125-131.
- Watt, A. D. (1979). The effect of cereal growth stages on the reproductive activity of *S. avenae* and *M. dirhodum*. Ann. of Appl. Biol., 91, 147-157.
- Wellings, P.W. (1981). The effect of temperature on the growth and reproduction of two closely related aphid species on sycamore. Ecological Entomology, 6: 209-214.
- Watt, i.j. and P.F.White (1977). Simple estimation of intrinsic rate for aphids and tetranychid mites. J. of Appl. Ecol., 14: 757-766.

### تأثيرات درجات الحرارة ونوعية الجزء النباتي للعائل على الزيادة في معدل النمو لحشرة من اللوبيا *Aphis craccivora* Koch على الفول البلدي جودة محمد الدفراوي و إدريس سلام عبد الوهاب و سمير محمد توفيق معهد بحوث وقاية النباتات - مركز البحوث الزراعية

تهدف هذه الدراسة للحصول على بيانات أساسية تستخدم للتقدير الكمي للتأثيرات المختلفة لدرجات الحرارة ونوعية الغذاء المربى عليه على معدل الزيادة في النمو لحشرة من اللوبيا على نباتات الفول البلدي العائل الرئيسي وعلى فترات النمو النباتي المختلفة والتي عادة ماتصايبها الحشرة في الطبيعة وتحت الظروف الحقلية وأيضاً فإن الدراسة تحاول إيجاد ارتباط لهذه العوامل على معدل الزيادة النسبي في النمو. تم حساب معدلات النمو والزيادة في فترات النمو والكفاءة التناسلية ومعدل الزيادة في النمو الحقيقي لحشرة من اللوبيا تحت الظروف المعملية الثابتة من الحرارة وهي ١٠ م و ١٥ م و ٢٠ م و ٢٥ م و ٣٠ م في معمل غربلة أصناف الفول البلدي لحشرات المن بمركز البحوث الزراعية بالجيزة والتغذية على نوعين من الأجزاء النباتية المفضلة للحشرة تحت الظروف الطبيعية بالحقل وهي الأوراق الحديثة والأوراق المسنة لنبات الفول البلدي وذلك للوقوف على التأثير المشترك لدرجات الحرارة ونوعية الجزء النباتي للعائل على بعض القياسات البيولوجية للحشرة.

#### ويمكن تلخيص البيانات التي تم التوصل إليها كالتالي :-

- ١- أن درجات الحرارة مابين ١٠ م - ٢٥ م هي انسب مدى حراري لنمو والزيادة السريعة في أعداد الحشرة من اللوبيا خاصة على الأوراق الحديثة عنه على الأوراق المسنة لنبات الفول البلدي.
- ٢- درجات الحرارة أعلى من ٢٥ م كان لها تأثير معنوي سلبي على معدل النمو وزيادة الأعداد.
- ٣- أن معدل النمو الحقيقي يرتبط بشدة بكل من معدل النمو النسبي RGR خلال فترة النمو والتغذية على الأوراق النباتية الصغيرة والمسنة على السواء في المدى الحراري ما بين ١٠ م - ٢٥ م.
- ٤- وجد أن درجات الحرارة ما بين ١٠ م - ٢٥ م والتغذية على الأوراق الصغيرة هي انسب الظروف المثلى لنمو وتكاثر حشرة من اللوبيا.
- ٥- أظهرت الدراسة أيضاً ان درجات الحرارة المنخفضة والعالية تؤدي ألي بطئ معدلات النمو للحشرة وطول فترة الحياة ومعدلات التوالد والموت ونتيجة ذلك تتناقص قيم معدل الزيادة العددية والزيادة النهائية.
- ٦- معرفة أعداد حشرة من اللوبيا التي تضاف للمجموع الحشري تحت الظروف الحرارية المختلفة ومساهمة كل أنثى في زيادة أعداد أفراد المجموع الحشري على الأجزاء النباتية.
- ٧- يمكن استخدام البيانات التي تم التوصل إليها لهذا البحث في التنبؤ بالأعداد التقريبية لحشرة من اللوبيا على الفول البلدي وتحت الظروف النمو المختلفة للنباتات والتي تدخل أساساً ضمن إطار الإدارة المتكاملة لمكافحة حشرة من اللوبيا على الفول البلدي.