Development and fecundity of pea aphid (Acyrthosiphon pisum Harris) as affected by constant temperatures and by pea varieties

Autor(en): **Bieri, M. / Baumgärtner, J. / Bianchi, G.**

Objekttyp: **Article**

Zeitschrift: **Mitteilungen der Schweizerischen Entomologischen Gesellschaft = Bulletin de la Société Entomologique Suisse = Journal of the Swiss Entomological Society**

Band (Jahr): **56 (1983)**

Heft 1-2

PDF erstellt am: **25.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-402070

MITTEILUNGEN DER SCHWEIZERISCHEN ENTOMOLOGISCHEN GESELLSCHAFT
BULLETIN DE LA SOCIÉTÉ ENTOMOLOGIQUE SUISSE
56, 163-171, 1983

Development and fecundity of pea aphid (Acyrthosiphon pisum Harris) as affected by constant temperatures and by pea varieties

M. Bieri, J. Baumgärtner, G. Bianchi, V. Delucchi & R. von Arx
Institut für Phytomedizin, ETH-Zentrum, CH-8092 Zürich

Pea aphid *(Acyrthosiphon pisum* Harris) development and fecundity were studied in relation to constant temperatures (10°, *15°, 20°, 25°, 30°C).* For immature stages developing to apterous virginoparae a temperature threshold of 5,7 °C was calculated using a linear model that describes the developmental rates between 10° and 20 °C. For the temperature range between the threshold and 30 °C the developmental rates were described by a new non-linear model. From 10° to 25 °C nymph survival did not appear to be affected by temperature. The total fecundity of apterous virginoparae, however, was highest at 15 °C. At this temperature both age specific survival and fecundity rates were described by regressions models.
The influence of 6 widely used pea varieties on the developmental rates and the fecundity of the pea aphid was compared on plants at different stages under laboratory and field conditions. None of the tested pea varieties proved to have inhibiting effects on aphid population parameters.

The pea aphid *(Acyrthosiphon pisum* Harris) is considered as an important pest of pea *(Pisum sativum)* in Switzerland (Meier, 1955; Suter, 1977). Following the approach of Gutierrez and coworkers in the analysis of California's alfalfa ecosystem (Gutierrez & Baumgärtner, in prep.) the aphid dynamics as observed in the field is simulated by a set of mathematical equations describing the aphid biology as effected by temperature, nutrition, and biotic/abiotic control mechanisms. In this work it is attempted to parametrize some of these relationships on an experimental basis that accounts for (1) differences between pea aphid strains feeding on the same plant species in different locations (Campbell *et al.,* 1974), (2) differences between aphid populations living on different plant species (Fröhlich, 1962) or (3) on different host plant varieties (Meier, 1956; Cartier, 1963; Harvey *et al.,* 1972). Canadian and US entomologists have investigated many aspects of the temperature dependent developmental biology (Harrison & Barlow, 1972, 1973; Sharma *et al.,* 1973, 1976; Siddiqui *et al.,* 1973; Lamb & Pointing, 1975; Roitberg & Myers, 1979). Less information on this subject appears to be available for the European strains of *A. pisum.* In Europe, aphid strain performances or host plant influences have been studied in detail (Fröhlich, 1962; Markkula, 1962; Müller, 1962; Markkula & Roukka, 1970, 1971) rather than the effect of temperature on aphid development and fecundity. This paper is intended to be a contribution to close this gap. Furthermore, varietal effects on pea aphid development may be considered as an indication for resistance (Delucchi *et al.,* 1981) that could be integrated in a pest management program.

MATERIAL AND METHODS

Rearing of aphids

Pea aphids were collected on pea plants near Finsterhennen (Ct. Berne) in the fall. A small stock culture was established on the pea variety «Mars» (no. 19)

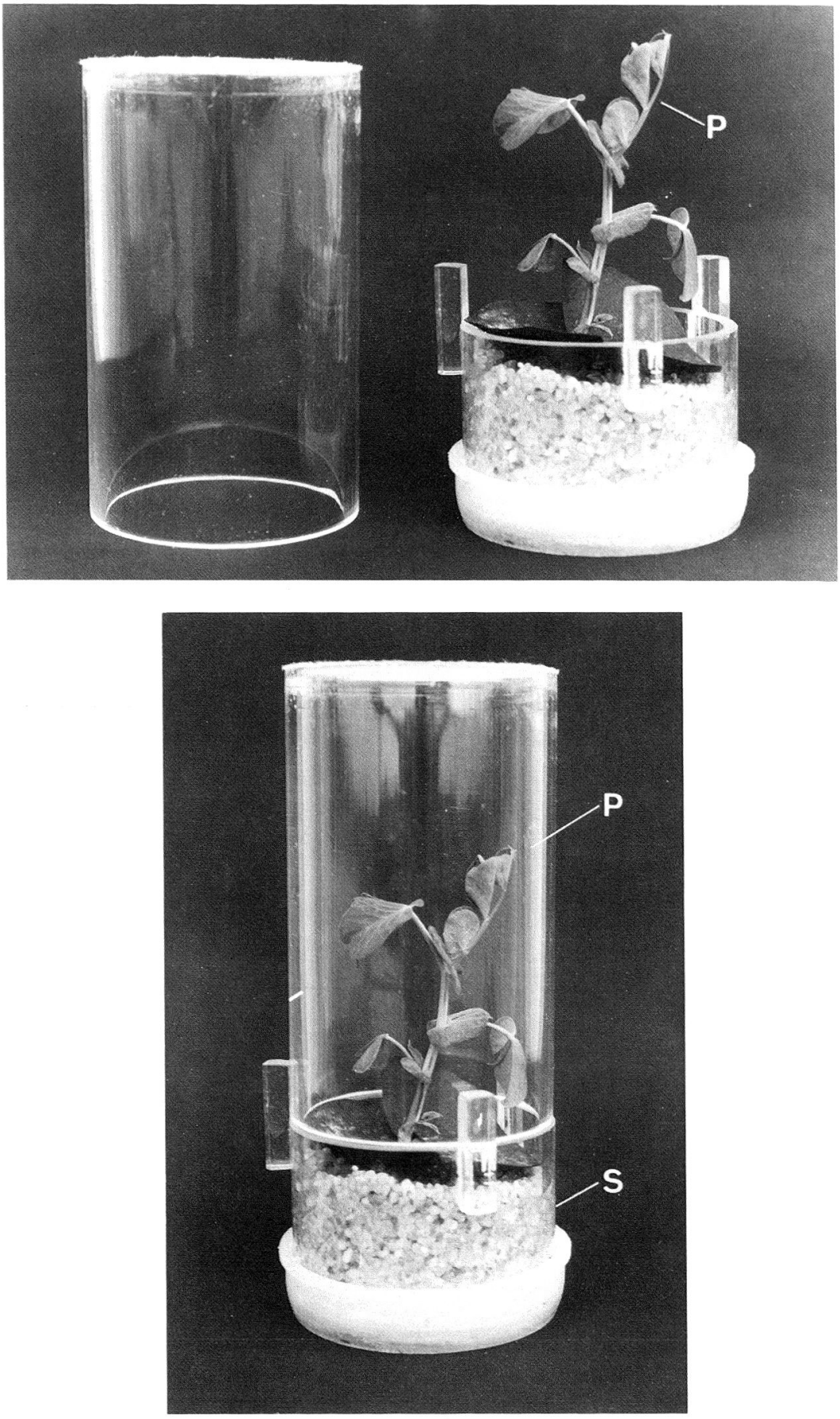

Fig. 1: Rearing unit (S = Nutrient solution in sand, P = pea plant).

under long day conditions (16/8) at 21 °C. From this rearing, newly born nymphs were each transferred to a plant in the 4 leaf stage, growing on a nutrient solution (1.7% N, 1.7% P, 3% K) and kept individually in a plexiglass cage (fig. 1). The quartz sand in the root zone was covered by black paper to reduce water evaporation and to facilitate the recover of the exuivae.

Developmental biology

Nymphs developed at long day conditions (16/8) and at different constant temperatures of 10°, 15°, 20°, 25° and 30 °C (± 1 °C). The nymph development was recorded daily. The relationship between developmental rate and temperature was tested for linearity with the method of SACHS (1978). For the temperature range between 10° and 20 °C the developmental threshold was calculated after CAMPBELL *et al.* (1974). For the range between the developmental threshold and 30 °C a new model was used to describe the non-linear developmental rate (DR) (fig. 2):

$$DR = P1 * (TEMP - DT) - P2 ** [(TEMP - DT) - P3] \quad [1]$$

where DT = developmental threshold
TEMP = temperature
P1, P2, P3 = constants (P1 = 0.01127, which corresponds approximately to the rate of increase in the linear model; P2 = 1.3596, which determines the slow down of the developmental rate at higher temperatures; P3 = 31.2693, which corresponds approximately to the point of intersection with x-axis at highest temperature).

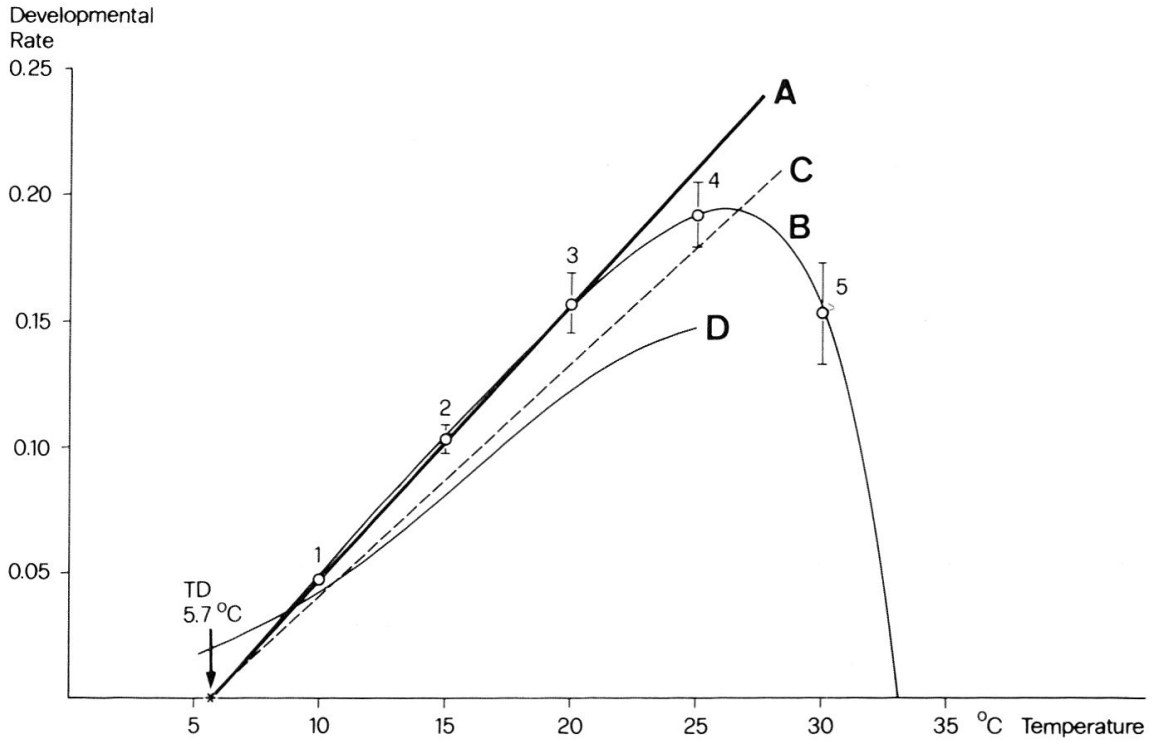

Fig. 2: Models of the developmental rates (DR) of apterous virginoparae of *Acyrthosiphon pisum*
[A = linear model from 10° to 20 °C, DR = (0.0109 * TEMP) - 0.0617;
B = non-linear model from developmental threshold (5.7 °C) to lethal temperature, DR = 0.01127 * (TEMP - 5.7) - 1.3596 ** [(TEMP - 5.7) - 31.2693];
C = function given by CAMPBELL & MACKAUER (1976);
D = function given by SIDDIQUI *et al.* (1973)].

P1, P2, P3 were estimated by means of the program of JENNRICH *et al.* (1981) (fig. 2).

Fecundity and adult longevity

The daily progeny production was determined for each apterous virginopara used for the calculation of the developmental rates. Differences between individual treatments (10°, 15°, 20°, 25° and 30 °C, tab. 1) were evaluated with the NEWMAN-KEULS multiple range test (ZAR, 1974). The age specific fecundity rate was described as a function of time (d) (fig. 4). The fecundity of each apterous virginopara was divided by the maximum progeny produced at 15 °C (tab. 1) and the resulting relative fecundity was described as a non-linear function of temperature using the program by JENNRICH *et al.* (1981).

The age specific fecundity (F) is described by the equation:

$$F = P1 * d / (P2 ** d) \qquad [2]$$

where d= age in days at 15 °C
P1, P2 = constants (P1 = 4.843, initial fecundity rate;
P2 = 1.233, parameter of decrease).

Influence of the host plant variety on aphid development and fecundity under laboratory conditions

a) Host plant varieties at seedling stage:

Six varieties were considered, using the variety «Mars» (no. 19) as reference. Ten seedlings of each pea variety were each infested with a newly born aphid nymph and maintained at long day conditions (16/8) and at 15 °C. The experiment was replicated 3 times (180 aphids for 180 seedlings altogether). Both the development of the aphids and the number of offsprings were checked daily. Immature development, fecundity rate and average adult longevity were compared by an analysis of variance using an SPSS program (NIE *et al.*, 1977) (tab. 2).

Tab. 1: Total number of offsprings (F) per apterous virginopara as affected by constant temperatures (°C). (SD = standard deviation; N = number of replications; «test» means: followed by the same letter the results are not different with $P < 0.05$ in Newman-Keuls' multiple range test).

°C	F ± SD	N	test
10	68.10 ± 14.4	31	a
15	101.36 ± 21.8	28	b
20	89.88 ± 17.4	33	c
25	64.88 ± 15.4	34	a

Tab. 2: Host plant effect on development, fecundity and longevity of *Acyrthosiphon pisum* (P = preimaginal developmental time; F = fecundity; L = longevity; N = number).

Under laboratory conditions					Under field conditions		
On plants at seedling stage				N of pea aphids 15 days after transfer on plants at flowering stage	N of aphids per plant on 3rd June	Index of aphid population increase from 3rd to 12th June	Index of aphid population increase from 12th June to 4th July
Varieties	P	F	L				
Mars (19)	11.38	101.00	24.63	154	0.71	9.55	3.31
no. 01	11.21	107.25	25.71	151	1.43	3.14	1.45
no. 02	11.17	104.13	25.43	181	1.70	3.39	2.82
no. 12	11.61	104.57	27.43	128	1.56	5.01	4.37
no. 17	11.11	106.89	27.67	157	1.31	2.69	1.99
no. 21	10.86	109.86	29.76	143	0.74	6.17	2.04
	Sign. of F	Sign. of F	Sign. of F	Sign. of F	Sign. of F	Sign. of F	Sign. of F
	0.029	0.146	0.016	0.868	0.135	0.417	0.051

b) Host plant variety at flowering stage:

Three plants of each of six pea varieties were grown in pots (18 x 18 x 15 cm) under field conditions during the spring. Five 4th stage nymphs were transferred to each plant having reached the 18th to 20th node. The plants were then protected with plexiglass tubes (15 cm diameter, 52 cm high) and kept at long day conditions (16/8) and 15 °C. The number of aphids per plant was counted 15 days later (tab. 2). The final increase in number per variety was compared with an SPSS analysis of variance program (NIE *et al.*, 1977).

Influence of the host plant variety on aphid population increase under field conditions

Six pea varieties were sown in plots of 4 x 2 m with four replications in a split-split-plot arrangement. The first winged virginopara was observed on 3rd June 1981 and the colonization of the pea plants by the aphids was recorded on the same day. Aphids and associated arthropods were counted on 25 tillers per plot on 12th June and 4th July. The tillers were cut at ground level using a PVC-sampling through (fig. 5) and brought to the laboratory. The data were compared by analysis of variance with an SPSS program (NIE *et al.*, 1977). The variance in the data set on the colonization phase was stabilized after BAUMGÄRTNER *et al.* (1983) while the increase ratios index of aphid population increase between the sampling dates (tab. 2) were log transformed (ZAR, 1974).

RESULTS AND DISCUSSION

Developmental biology

In SACH's (1978) t-test the rates of development of the immature stages appeared to be linearly related to temperatures in the range between 10° and 20 °C (fig. 2). The developmental threshold of 5.7 °C is higher than the value reported by CAMPBELL *et al.* (1974), but close to that calculated by CAMPBELL & MACKAUER (1975). Because the daily mean temperature in north-eastern Switzerland exceeds 20 °C during the growing season, a non-linear model [eq. 1] was required to describe the developmental rates at higher temperatures. By visual examination the model describes them satisfactorily (fig. 2). Nymphal survival did not appear to be affected by constant temperatures between 10 °C and 25°C. In the same temperature range CAMPBELL & MACKAUER (1975) also observed no deleterious effect on pea aphid development. At 30 °C, however, high aphid mortality occurred and aphids reaching the adult stage were pale coloured and did not reproduce. Evidently, both the aphids and the pea varieties were under stress at such high temperatures, as already reported by SIDDIQUI *et al.* (1973). The model fits well with the data obtained experimentally (fig. 3). In general, the observed developmental rates were considerably higher than those reported by American entomologists (fig. 2).

Fecundity and adult longevity

The highest fecundity was observed at 15 °C (tab. 1). Below and above 15 °C the production of offsprings was significantly ($p < 0.05$) reduced (tab. 1, fig. 3). The calculated reduction in the relative fecundity observed at low temperatures (fig. 3) corresponds to the observations made by SIDDIQUI *et al.* (1973). SIDDIQUI *et al.*

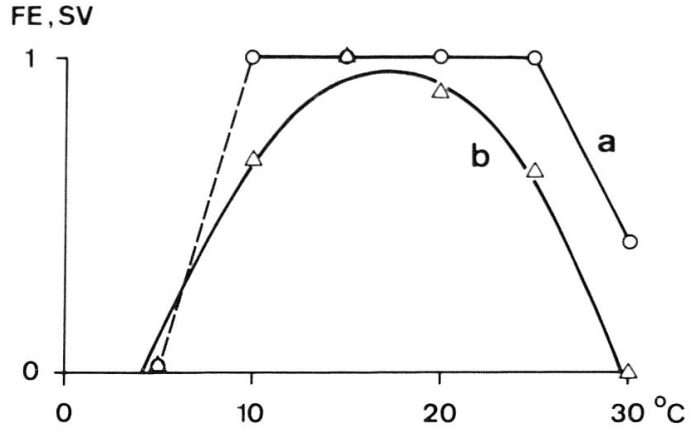

Fig. 3: Survival (SV) of nymphs (a) and relative fecundity (FE; b = -0.760 + 0.204 * TEMP - 0.006 * TEMP ** 2) of *Acyrthosiphon pisum*.

(1973) and CAMPBELL & MACKAUER (1977) observed similar performances in relation to constant temperatures, whereas the values reported by MARKKULA & ROUKKA (1970, 1971) and SHARMA *et al.* (1973) are much lower. The fecundity seems to be more sensitive to adverse temperature than nymphal survival (fig. 3).

At 15 °C age specific survival was reduced only after the fecundity rates had passed the highest values (fig. 4).

The influence of the pea variety on aphid population increase

On plants in the seedling stage, aphid population parameters appeared to be slightly influenced by the tested varieties. Variety no. 21 seems to favour pea aphid development (tab. 2). However, this effect was neither observed on plants at flowering stage nor under field conditions (tab. 2). None of the tested varieties

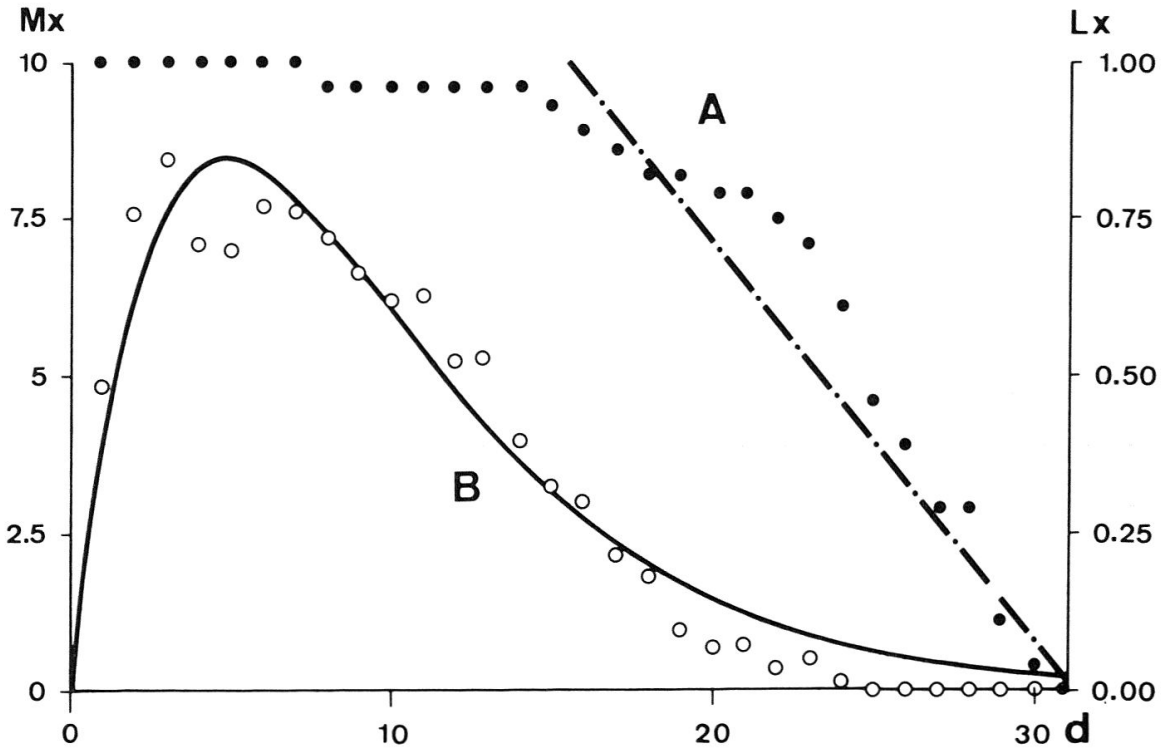

Fig. 4: Fecundity [Mx, B = 4.834 * d/ (1.233 ** d)] and survival (Lx, 0 ≦A ≦1, A = 1.892 - 0.058 * d) rates at 15 °C of apterous virginoparae of *Acyrthosiphon pisum* (d = days).

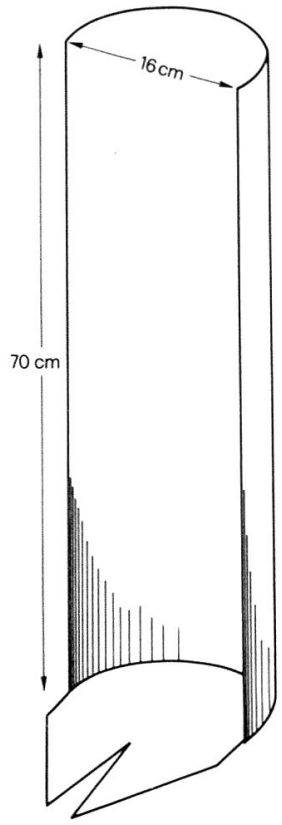

Fig. 5: PVC-trough for aphid sampling in pea fields.

influenced the population growth parameter as mentioned in MARKKULA & ROUKKA (1970, 1971). The aphid counts on 4th July were close to harvest of variety «Mars» (no. 19) (BAUMGÄRTNER *et al.,* 1983). Therefore considerable interplot interferences may have influenced the population development from the first sampling date (12th June) to the second (4th July), making the latter a less reliable estimator for varietal effects on aphid population development under field conditions.

ZUSAMMENFASSUNG

Die Entwicklungsdauer und die Fekundität der Erbsenblattlaus (*Acyrthosiphon pisum* HARRIS) wurde bei unterschiedlichen konstanten Temperaturen (10°, 15°, 20°, 25°, 30°C) untersucht. Für die Entwicklung vom ersten Larvenstadium zu einer ungeflügelten Virginopara wurde mittels linearer Regression zwischen den Entwicklungsraten von 10° bis 20°C, ein Entwicklungsnullpunkt (ENP) von 5,7°C berechnet. Für den Temperaturbereich zwischen ENP und 30°C wurden die Entwicklungsraten in Abhängigkeit der Temperatur durch eine nichtlineare Funktion beschrieben. Bis 25°C konnten keine negativen Einflüsse auf die Entwicklung der juvenilen Tiere festgestellt werden. Die höchste Fekundität der Virginoparae wurde bei 15°C beobachtet. Für diese Temperatur wurden die Funktionen für die altersspezifische Fekundität und die Lebensdauer der ungeflügelten Virginoparae beschrieben.

In einem weiteren Versuch bestimmte man die Fekundität und die Lebensdauer von *A. pisum* auf 6 in der Praxis verwendeten Drescherbsensorten. Die Untersuchungen wurden im Labor bei 15°C auf jungen Samensprossen (4–8 Blattstadium) und auf Pflanzen im Blütenstadium vorgenommen und anschliessend die Ergebnisse in einem Feldversuch überprüft. Es konnte bei keiner der getesteten Sorten eine deutliche Beeinflussung der Populationsparameter von *A. pisum* festgestellt werden.

REFERENCES

BAUMGÄRTNER, J., BIERI, M. & DELUCCHI, V. 1983. *Sampling pea aphids (Acyrthosiphon pisum* HARRIS) *in pea fields.* Mitt. Schweiz. Ent. Ges. (in press).

CARTIER, J. J. 1963. *Varietal resistance of peas to pea aphid biotypes under field and greenhouse conditions.* J. econ. Ent. *56:* 205-213.

CAMPBELL, A., FRAZER, D. B., GILBERT, N., GUTIERREZ, A. P., MACKAUER, M. 1974. *Temperature requirements of some aphids and their parasites.* J. appl. Ecol. *11:* 431-438.

CAMPBELL, A. & MACKAUER, M. 1975. *Thermal constants for development of the pea aphid (Homoptera: Aphididae) and some of its parasites.* Can. Ent. *107:* 419-423.

CAMPBELL, A. & MACKAUER, M. 1977. *Reproduction and population growth of the pea aphid (Homoptera: Aphidae) under laboratory and field conditions.* Can. Ent. *109:* 277-284.

DELUCCHI, V., KELLER, E. R. & KERN, H. 1981. *Züchtung auf Resistenz der Pflanze gegenüber Krankheiten, Schädlingen und Umwelteinwirkungen. Ein Beitrag zur Sicherung der Ernährung von Mensch und Tier.* Schweiz. landw. Forsch. *20:* 449-465.

FRÖHLICH, G. 1962. *Das Verhalten der Grünen Erbsenlaus Acyrthosiphon pisum* HARRIS *gegenüber verschiedenen Wirtspflanzen und Temperaturveränderungen.* Z. angew. Ent. *51:* 55-68.

GUTIERREZ, A. P. & BAUMGÄRTNER, J. (in prep.) *Linking multitrophic levels in the alfalfa ecosystem.*

GUTIERREZ, A. P., SUMMERS, C. G. & BAUMGÄRTNER, J. 1980. *The phenology and the distribution of aphids in California alfalfa as modified by ladybird beetle predation (Coleoptera: Coccinellidae).* Can. Ent. *112:* 489-495.

HARRISON, J. R. & BARLOW, C. A. 1972. *Population growth of the pea aphid Acyrthosiphon pisum (Homoptera: Aphididae) after exposure to extreme temperatures.* An. Ent. Soc. Amer. *65:* 1011-1015.

HARRISON, J. R. & BARLOW, C. A. 1973. *Survival of the pea aphid Acyrthosiphon pisum (Homoptera: Aphididae) at extreme temperatures.* Can. Ent. *105:* 1513-1518.

HARVEY, T. L., HACKEROTT, H. L. & SOERENSEN, E. L. 1972. *Pea aphid resistant alfalfa selected in the field.* J. econ. Ent. *65:* 1661-1663.

JENNRICH, R. 1981. *P3R Nonlinear regression. Chapter 14.1, 290-304. In:* DIXON, W. J., BROWN, M. B., NEGELMAN, L., FRANE, J. W., HILL, M. A., JENNRICH, R. & TOPOREK, J. D. 1981. *BMDP statistical software.* University of California Press, Berkeley, Los Angeles, London: 725 pp.

LAMB, R. J. & POINTING, P. J. 1975. *The reproductive sequence and sex determination in the aphid Acyrthosiphon pisum.* J. Insect Physiol. *21:* 1443-1446.

MARKKULA, M. 1962. *Studies on the pea aphid Acyrthosiphon pisum (Hom., Aphididae), with special reference to the differences in the biology of green and red forms.* Ann. agr. fenn. *7:* 1-30.

MARKKULA, M. & ROUKKA, K. 1970. *Resistance of plants to the pea aphid Acyrthosiphon pisum* HARRIS *(Hom., Aphididae) I. Fecundity of the biotypes on different host plants.* Ann. agr. fenn. *9:* 127-132.

MARKKULA, M. & ROUKKA, K. 1971. *Resistance of plants to the pea aphid Acyrthosiphon pisum* HARRIS *(Hom., Aphididae) III. Fecundity on different pea varieties.* Ann. agr. fenn. *10:* 33-37.

MEIER, W. 1955. *Das Auftreten und die Bekämpfung der Erbsenblattlaus (Acyrthosiphon pisum* HARRIS*) an Drescherbsen.* Mitt. Schweiz. Landw. *3:* 26-30.

MEIER, W. 1956. *Untersuchungen an der Erbsenblattlaus (Acyrthosiphon pisum* HARRIS). Mitt. Schweiz. Landw. *4:* 41-48.

MÜLLER, F. P. 1962. *Biotypen und Unterarten der «Erbsenlaus» Acyrthosiphon pisum* (HARRIS). Z. Pfl.k. Pfl.sch. *69:* 130-136.

NIE, N. H., HULL, C. H., JENKINS, J. G., STEINBERGER, K. & BENT, D. H. 1977. *SPSS - statistical package for the social sciences.* 2nd edition, Mc Graw-Hill, New York: 675 pp.

ROITBERG, B. D. & MYERS, J. H. 1979. *Behavioural and physiological adaptations of pea aphids (Homoptera: Aphididae) to high ground temperatures and predator disturbance.* Can. Ent. *111:* 515-519.

SACHS, L. 1978. *Angewandte Statistik. Statistische Methoden und ihre Anwendungen.* 5th edition, Springer Verlag, Berlin: 552 pp.

SHARMA, M. L., LARRIVEE, J. M. & THERIAULT, M. L. 1973. *Effets de la photopériode et des températures moyennes de 15°C sur la fecondité et la production des sexes chez le puceron du pois, Acyrthosiphon pisum (Aphididae: Homoptera).* Can. Ent. *105:* 947-956.

SHARMA, M. L., LARRIVEE, J. M. & THERIAULT, M. L. 1976. *Durées des stades larvaire chez le puceron du pois, Acyrthosiphon pisum* (HARRIS) *(Aphididae: Homoptera), sur les pois de la varieté Perfection.* Ann. Soc. ent. Québec *21:* 144-146.

SIDDIQUI, W. H., BARLOW, C. A. & RANDOLPH, P. A. 1973. *Effects of some constant and alternating temperatures on population growth of the pea aphid, Acyrthosiphon pisum (Homoptera: Aphididae).* Can. Ent. *105:* 145-156.

SUTER, H. C. 1977. *Populationsdynamik der Erbsenblattlaus (Acyrthosiphon pisum* HARRIS*) und ihre Antagonisten.* Diss. ETH Zürich (no. 5932).

ZAR, J. H. 1974. *Biostatistical Analysis.* Prentice-Hall, Englewood Cliffs N. J.: 620 pp.

(erhalten 5.4.1983)