EFFECT OF VARIOUS HOST-PLANTS ON THE POPULATION GROWTH AND DEVELOPMENT OF THE PEA APHID

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Abstract: The performance of the pea aphid, *Acyrthosiphon pisum* Harris (Homoptera: Aphididae) was studied on several *Fabaceae* species including: pea (*Pisum sativum)*, broad bean (*Vicia faba*), alfalfa (*Medicago sativa)*, bean (*Phaseolus vulgaris*) and red clover (*Trifolium pratense*). Alfalfa, bean and red clover were less accepted by the pea aphid than pea and broad bean. The pea aphid fed on the alfalfa, bean and red clover showed longer pre-reproductive, and shorter reproductive and post-reproductive periods. Alfalfa, bean and red clover also shortened and decreased fecundity of the pea aphid. Mean survival of the pea aphids fed on red clover and bean plants was reduced in comparison to pea aphid fed on pea and broad bean. The other studied population parameters: intrinsic rate of natural increase (r_m), net reproduction (R_0) and mean generation time were also reduced in the case of the pea aphid on alfalfa, red clover and bean. The study of aphid development and reproduction demonstrated that pea and broad bean are suitable host plants for *A. pisum* while alfalfa, red clover and bean are not. It is likely that the rejection of alfalfa, red clover and bean by *A. pisum* was caused by chemical factors in these hosts.

Key words: *Acyrthosiphon pisum*, *Fabaceae*, development time, r_m, R_0, T

INTRODUCTION

The leguminous plants are important agricultural and commercial crops consumed in large quantities by both humans and animals (Farag *et al.* 2007). High nutritional quality of legumes have been determined by the high content of good quality protein and carbohydrates (Cook 1999). In addition to the nutritional components that are important to its use as an animal feed or as food supplements, legumes also contain numerous secondary metabolites that are important in human nutrition (Hatfield 1990; Hernandez *et al.* 1991; Grela and Günter 1995; Oleszek 2000). They are one of the richest sources of chlorophyll and vitamin C, E, B_1, B_2, B_6, B_{12}, niacin, folic acid, biotin, inositol, choline, some digesting enzymes and β-carotene (Duke 1992). More studies have revealed the beneficial or protective effects of consuming legume seeds with regard to hypercholesterolemia, cardiovascular disease, and cancers (Chau *et al.* 1998; Mazur *et al.* 1998; Castle and Thrasher 2002).

Unfortunately, these economically important crops have serious pest – phytophagous insects. Among the aphid species, the pea aphid, *A. pisum* Harris (Homoptera: Aphididae) is generally considered to be one of the most common and is considered to cause the damage to these crops. *A. pisum* occurs all over the world. It is an oligophagous aphid species. The pea aphid, consists of several biotypes living on distinct legume hosts (the pea and broad bean, the red clover and the alfalfa host race) (Cuperus *et al.* 1982; Lane and Walters 1991; Via 1991, 1999; Via and Shaw 1996; Peccoud *et al.* 2009a, b). *A. pisum* is a vector of more than 30 viral diseases, including bean yellow mosaic virus, red clover vein mosaic virus and pea streak virus (Barnett and Diachun 1986; Jones and Proudlove 1991). All viral diseases cause losses in *Fabaceae* yield (Garlinge and Robartson 1998).

According to del Campo *et al.* (2003) plant acceptance by *A. pisum* depends on the presence of host-specific chemical compounds, the allelochemicals. These substances seriously affect insect population processes, aphid behaviour, physiology and metabolism and as a result reduce aphid population on a resistant plant. Many intrinsic characteristics of plants such as nutritional value, secondary chemicals and morphology can influence the fecundity, growth and survival of insect herbivores (Montllor 1991; Legrand and Barbosa 2000).

The pea aphid is a dominant pest on leguminous plants, which are an important crop used for food and fodder production in Poland. Thus, the aim of my study was to investigate the effect of Fabaceae plants on pea aphid performance.

MATERIALS AND METHODS

Plant material

Five species of *Fabaceae* were used in the experiments: *P. sativum* L. var. Tulipan, *Vicia faba* L. var Start, *Medicago sativa* L. var. Radius, *Phaseolus vulgaris* L. var. Laguna and *Trifolium pretense* L. var. Bona. Seed samples of Radius

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were obtained from the Plant Breeding and Acclimatization Institute (IHAR) in Radzików/Błonie (near Warsaw, Poland), and the others were bought from the Horticultural Plant Breeding Seed Production and Nursery in Ożarów Mazowiecki (administrative Warsaw, Poland). Seed samples were germinated in a climate chamber, which was kept at 21±1°C, L16 : D8 photoperiod, and 70% r.h. The plants were grown in 7x7x9 cm plastic pots filled with fine garden soil, commonly used for greenhouse experiments, one plant per pot. The plants were watered regularly. No extra fertilizer was added. Seven-days-old plants were used in the experiments.

Aphids

The pea aphids used in the experiments came from a stock culture kept at the University of Podlasie at Siedlce, Poland. The aphids were reared on broad bean seedlings [*V. faba* L. var. Start (Fabaceae)] in an environmental chamber (21°C, L16 : D8 photoperiod, and 70% r.h.). They were transferred to the studied Fabaceae cultivars for one generation. Then, the adult apterous females were used in the experiments (Apablaza and Robinson 1967).

Performance tests

The tests were conducted in an environmental chamber at L : D = 16 : 8 photoperiod, 21±1°C, and 70% relative humidity. Plexiglass cages with a cheesecloth cover were used. The adult apterous females were caged individually. They were placed on the abaxial side of the youngest, fully expanded leaves of the *Fabaceae* plants and allowed to deposit nymphs. After 24 h, all adult and all offspring except one, were removed from each plant. We conducted 10 replicates for each plant of the studied plant. Aphids were given access to the entire plant. Larval development time (pre-reproductive period), reproduction, and post-reproduction periods were determined (Leszczynski *et al.* 1989). Population parameters were used to determine the influence of the plants on the growth potential of pea aphids. Net reproductive rate (R_0) and mean generation time (T) were calculated using the Birch (1948) equations:

$$R_0 = \sum(l_x m_x)$$

$$T = \sum(x l_x m_x)/\sum(l_x m_x)$$

where:
l_x – age specific survival;
m_x – adult fecundity during age x; x – age of female.

In addition, an intrinsic rate of the natural increase of the *A. pisum* population were calculated according to the Wyatt and White (1977) equation:

$$R_m = [0.74(\ln Md)]/d$$

where:
d – length of the pre-reproduction period;
Md – number of larvae born in the reproduction period which equals the d period; 0.74 – correction factor.

Statistics

Demographic statistics were used to determine the influence of host plants on pea aphid population growth potential. Variation in demographic stastistics of the pea aphid on five *Fabaceae* species was analyzed by analysis of variance (ANOVA) followed by the Duncan's test. The statistic parameters were calculated with the Statistica program for Windows v. 6.0 (StatSoft 2003).

RESULTS

Pea aphid performance on the alfalfa, bean and red clover species was clearly reduced compared to pea aphid performance on pea and broad bean. Alfalfa, bean and red clover, particularly, prolonged larval development of the pea aphid and shortened its reproduction. Generally, these species were less accepted by the pea aphid. This resulted from their negative influence on the growth, development and reproduction of the pea aphid. On clover the reproductive period of the pea aphid began later and finished earlier, but only with respect to bean and alfalfa (Table 1).

Table 1. Pea aphid, *A. pisum*, performance (means ±SD) on *Fabaceae* species

	Fabaceae species				
	pea	broad bean	alfalfa	bean	clover
Pre-reproductive period (days)	5.4c±0.52	5.4c±0.52	13.5a±1.18	6.2b±0.63	5.2c±0.63
Reproductive period (days)	19.7a±0.67	14.6b±0.52	11.6cd±1.51	11.9c±0.32	10.8d±0.42
Post-reproductive period (days)	2.1a±0.57	1.6ab±0.70	1.8a±0.79	1.1bc±0.32	0.7c±0.48
Daily fecundity per female	4.9a±0.17	3.3b±0.21	3.0c±0.50	3.4b±0.18	2.9c±0.32
Total fecundity	95.5a±0.71	48.4b±1.96	32.9d±4.46	40.4c±1.84	30.9d±3.45
Survival (days)	27.2a±1.14	21.6b±0.97	26.9a±2.47	19.2c±0.79	16.7d±0.67

Explanations: for each group of mean values (n = 10), means followed by different letters are different at $p \leq 0.05$ (Duncan's test)

Table 2. Population parameters (means ±SD) for pea aphid, *A. pisum*, on *Fabaceae* species

	Fabaceae species				
	pea	broad bean	alfalfa	bean	clover
Intrinsic rate of natural increase (r_m)	0.22a±0.02	0.17b±0.02	0.06d±0.03	0.15c±0.02	0.15c±0.02
Net reproduction (R_0)	96.06a±0.47	48.4b±0.25	32.89d±0.03	40.4c±0.18	27.78e±0.12
Mean time of generation development (T)	16.53b±0.01	13.27c±0.04	18.62a±0.01	12.51d±0.02	11.99e±0.41

Explanations: for each group of mean values (n = 10), means followed by different letters are different at $p \leq 0.05$ (Duncan's test)

In fact, statistically significant differences were found for all the parameters determined. The aphids fed on the pea and broad bean species showed higher fecundity than the females which fed on the others. The aphids fed on clover started to reproduce much earlier than the females which fed on others and survival of the pea aphid was lower on clover (Table 1).

Plants of red clover, bean and alfalfa species also caused a reduction of other parameters of pea aphid growth and development, such as intrinsic rate of natural increase (r_m) and net reproduction (R_0) (Table 2).

DISCUSSION

In my study I found substantial differences in performance of *A. pisum* on the studied family *Fabaceae* species. *A. pisum* showed a reduction of aphid growth and development on red clover, bean and alfalfa plants. In contrast, pea and broad bean appeared to be a suitable host on which *A. pisum* could rapidly develop and expand in number. Several reports have been published about the effects of host cultivars on pea aphid life histories (Bieri *et al.* 1983; Goławska and Łukasik 2009). Considerable research has been conducted on the demographics of the pea aphid (Hutchison and Hogg 1984; Zeng *et al.* 1993; Legrand and Barbosa 2000) as well as on the effect of different plant species and cultivars and plant morphology on pea aphid development (Soroka and Mackay 1990, 1991; Kaakeh and Dutcher 1993; Sandström 1994; Sandström and Pettersson 1994; Kordan *et al.* 2008).

Edwards *et al.* (2003) found that the growth, survival, and fecundity of three aphid species on *Fabaceae* plants were suppressed on resistant varieties as compared to susceptible varieties. These authors concluded that the mechanisms of resistant species affected the growth, survival, and possibly reproduction of aphids. In this study, I obtained similar results. The growth, survival and fecundity of pea aphid on my studied alfalfas, beans and red clovers were suppressed when compared to the pea and broad bean species. These results were similar to previous studies where pea aphids were reared on peas (Birch and Wratten 1984; Soroka and Mackay 1991; Morgan *et al.* 2001), broad beans (Birch and Wratten 1984), alfalfas (Goławska and Łukasik 2009) and red clovers (Zeng *et al.* 1993). In our study we have come to the conclusion that one of the differences in average larvaes per female per day values, might be caused by host plant influence on pea aphid fecundity.

Previous estimates of intrinsic rates of increase have been given by Morgan *et al.* (2001). Their rates of increase were higher than those reported here. The r_m values from this experiment for the pea aphid, range from 0.0595 to 0.2182 when different plant species of *Fabaceae* family are compared. These differences can be explained by the connection of r_m with the pre-reproductive period. The r_m has been shown to be particularly sensitive to relative changes in the duration of the pre-reproductive period (van Rijn *et al.* 1995). In this study the R_0 and r_m values for pea aphids were lower when the aphids were reared on the red clover, alfalfa and bean. Birch and Wratten (1984), Hutchison and Hogg (1984), and Soroka and Mackay (1991) made similar observations. These authors showed that R_0 and r_m for pea aphids were lower on red clover than on alfalfa and field peas. These may be attributable to greater nutrition in the other crops or different pea aphid populations. Morphological changes of the pea isolines did not alter the total fecundity and the intrinsic rate of increase of the pea aphid nor its location within the plant. When different plant species and cultivars are compared, the pea aphid can exhibit differences in fecundity and r_m (Soroka and Mackay 1990, 1991; Kaakeh and Dutcher 1993; Sandström 1994; Sandström and Pettersson 1994). The literature indicates that the r_m values for the pea aphid range from 0,109 to 0,401 when plant species are compared (Sandström and Pettersson 1994); 0.324–0.402 and 0.288–0.318 when pea cultivars are compared (Soroka and Mackay 1991; Sandström and Pettersson 1994).

The rate of growth and reproduction of aphids depends on the quantity and quality of the consumed food; the phloem sap. I found that the growth, survival and fecundity of the pea aphid on alfalfa, bean and clover were suppressed. This was probably the reason that the feeding process were severely limited. The present results are consistent with earlier observations on the aphid feeding behaviour studied with the help of the EPG method (Goławska *et al.* 2007). Monitoring of the pea aphid feeding behaviour on bean, red clover and alfalfa plants, revealed a greater number of short probes into the seedling tissues and less ingestion of the phloem sap in comparison to the other studied species; pea and broad bean. While probing tissues of the bean, clover and alfalfa species, the phloem sap ingestion was also much lower than on the pea and broad bean. The limiting factors of the feeding of aphids are allelochemicals, which are supposed to have an toxic effect on insect behavior (Adel *et al.* 2000; Agrell *et al.* 2003; Kordan *et al.* 2008).

So, I concluded that the studied species may contain a toxin, or a toxin may be induced in the plants by aphid feeding. The mode of plant allelochemicals on the *A. pisum* has not been extensively studied. But there are some data that demonstrated negative effects of the allelochemicals on *A. pisum*. It was showed that saponins, phenolic and flavonoid compounds may repel or deter the aphids from feeding and may exert a negative influence on growth and reproduction of aphids (Oleszek *et al.* 1992; Goławska 2006, 2007; Goławska *et al.* 2006; Golawska *et al.* 2008; Goławska and Łukasik 2009).

The results of this experiment showed the suitability level of some species from the *Fabaceae* family of plants for *A. pisum*. The pea and broad bean species were more suitable hosts. The results suggest that the selection of *Fabaceae* cultivars should be done carefully since it might eliminate the most important resistance factors towards the pea aphid. One of the most important aspects of such work is the identification and elimination of potential plant metabolites that may serve as sources of resistance, this includes the pea aphid.

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POLISH SUMMARY

WPŁYW RÓŻNYCH ROŚLIN ŻYWICIELSKICH NA WZROST I ROZWÓJ MSZYCY GROCHOWEJ

Obiektem badań była mszyca grochowa, *Acyrthosiphon pisum* (Harris) – szkodnik roślin motylkowych. Badania prowadzono w laboratorium w temperaturze 21±1°C oraz w wilgotności względnej 70%. Analizowano rozwój mszycy grochowej, na powszechnie uprawianych w Polsce roślinach motylkowych, będących roślinami żywicielskimi *A. pisum*. Określono wpływ badanych roślin na długość okresu przedreprodukcyjnego, płodność, przeżywalność oraz tempo wzrostu populacji *A. pisum*. Przeprowadzone obserwacje wykazały, że lucerna, fasola i koniczyna czerwona były w mniejszym stopniu akceptowane przez tego szkodnika. Mszyce żerujące na grochu i bobiku charakteryzowały się wyższą płodnością oraz dłuższą przeżywalnością. Parametry demograficzne populacji (wrodzone tempo wzrostu populacji, tempo reprodukcji netto, tempo zwielokrotnienia liczebności populacji) posiadały znacznie wyższe wartości dla mszyc żerujących na grochu i bobiku.