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Aphid-aphidophage community in Alfalfa cultures (*Medicago sativa* L.) in Poland
Part 3. Abundance regulation of *Acyrthosiphon pisum* (HARR.) in a chain of oligophagous predators

[With 17 Tables and 16 Text-figures]

Abstract. Investigations on the number reduction of the pea aphid, *Acyrthosiphon pisum* (HARR.) by an association of oligophagous predators (*Syrphidae, Coccinellidae, Chrysopidae*) were carried out in cultures of alfalfa grown for seed and alfalfa grown for forage in Poland. An increase of pea aphid abundance depended on an increase of alfalfa biomass. The production value of the *A. pisum* population on alfalfa grown for forage during the spring-summer peak of its development was 17329–31130 individuals per sq. m., and during the autumn peak – 2039–10115. On alfalfa grown for seed respectively: 3899–4985 and 620–2912. The total production on alfalfa grown for forage was, on the average, 27680, on alfalfa grown for seed – 4834 individuals per sq. metre. There was a distinct dependence between the aphid density and the denisty of the community of oligophagous predators. The mean density of predators on alfalfa grown for forage was from 9.2 (May) to 0.9 (September) per sq.m. Out of the total number of the produced aphids, the *Coccinellidae* devoured 12.5–43.3%, *Syrphidae* 5.8–14.4%, *Chrysopidae* 1.7–23.3%. The efficiency of their reduction of the *A. pisum* population in the spring-summer peak was three times higher than in the autumn peak. The highest reduction on cultures of alfalfa grown for seed reached 79.8% and was considerably higher than on alfalfa grown for forage (42.1%).

CONTENTS

Praca wykonana w ramach Problemu węzłowego Nr 09.1.3, koordynowanego przez Instytut Ochrony Roślin w Poznaniu. Kierownik tematu: prof. dr hab. Henryk SZELĘGIEWICZ.

1. INTRODUCTION

1.1. Objective and scope of the studies

The present paper is the final stage of investigations on the structure and functioning of an aphid-aphidophage association in alfalfa cultures in Poland. The structure of this association has been studied previously and the exploitation interrelations occurring between particular elements of the food network have been distinguished (Bańkowska et al. 1975). Part 2 of the paper will be published later.

It is the objective of the present paper to estimate the abundance reduction of the pea aphid, *Acyrthosiphon pisum*, population by a community of oligophagous predators of the following composition in percentage of the total number of individuals: the hover-flies [*Syrphidae*: *Melanostoma mellinum* (L.) — 41.5 %, *Sphaerophoria scripta* (L.) — 28 %, *Platycheirus clypeatus* (Meig.) — 10.2 %, *Sphaerophoria taeniata* (Meig.) — 5.7 %, *Platycheirus peltatus* (Meig.) — 5.6 %, *Syrphus corollae* F. — 3.9 %, *Syrphus balteatus* (Deg.) — 3.6 %], the lady birds [*Coccinellidae*: *Propylaea quatuordecimpunctata* (L.) — 62.7 %, *Coccinella septempunctata* L. — 21.3 %, *Coccinula quatuordecimpustulata* (L.) — 6.7 %, *Hippodamia tredecimpunctata* (L.) — 3.5 %, *Tythaspis sedecimpunctata* (L.) — 2.8 %, *Adonia variegata* (Goeze) — 2.1 %], the green lace-wings (*Chrysopidae*: *Chrysopa carnea* Steph. — 87.9 %, *Ch. phyllochroma* Wesm. — 6.8 %, *Ch. commata* Kis et Ujhel. — 5.3 %).

Estimation of parasites part is the subject of a separate paper.

As the basis for this paper there has been accepted the theory of energy flow in the food chain, particularly the methods of full estimation of production by reproduction and the consumption of aphidophages in different stages of their life cycle.

A pea aphid population develops under conditions of a complex system of limiting factors (DUNN and WRIGHT 1955) such as:

1. Agricultural activities, especially mowing and removing the green alfalfa mass from the system,

2. Rainfalls; their influence on aphid abundance is highly diminishing with poorly developed alfalfa biomass,

3. Thermal conditions of cultures determining the rate of reproductive process, particularly those of aphids, and

4. The functioning of a predator and parasite community.

Discussing in detail the part played by the four aforementioned limiting factors, DUNN and WRIGHT (1955) consider the first two to be primary ones and the rest to be secondary factors of supplementary value. Such a way of expressing the problem results both from theoretical data and the applied methods. The model of abundance dynamics of host-parasite and prey-predator worked out by VOLTERRA (1931) is the basis for the estimation of such systems. Basing on VOLTERRA's model and the results of GAUZE's (1935) experimental studies it has been accepted that the reconstruction of the system begins with the phytophagous elements. The possibilities of restoration of a full composition and ratios between particular elements of the community depend on the periodicity of reproduction of both aphids and their predators and parasites. This condition, however, is of basic significance in closed systems only. There is no specific fauna of predators and parasites in particular cultures in agrocenoses. Therefore, due to immigration processes, the restoration of particular elements of the community including predators and parasites may be quicker than it appears from the biotic potentials of that part of the population which remains after the mowing of alfalfa. The use of a sweep-net as the catch technique may also be the reason why biocenotic regulation is considered of little importance in the reduction of the pea aphid population (DUNN and WRIGHT 1955) The selective effect of this method and the lack of data reference to the area or biomass of alfalfa may cause an overestimation of aphid abundance in relation to their predators and parasites.

1.2. Study area and methods

Study area. This paper has been based on materials collected from 1971 to 1975. In the first period (1971–1973) the investigations were carried out in four sites, Chylice, Golkowice, Czechów and Łomna, in the Polish lowland. A detailed description of these sites has been given in the first part of this study (BAŃKOWSKA et al. 1975). In 1974–1975 attempts at the estimation of absolute abundance of aphids and their predators were made in alfalfa cultivations in Łomna.

Methods. The applied methods have been reviewed in the first part of this study (Bańkowska et al. 1975). At the second stage of the investigations mainly catch techniques for absolute abundance estimation of aphids and their predators were used. A biocenometer connected with an aspiration appliance (Gromadzka and Trojan 1967) was the basic instrument for the estimation of aphid abundance; it made a fairly precise determination of aphid concentration in one square metre possible. The data on predator density was obtained basing on catches with the biocenometer as well as a sweep-net.

The occurrence of oligophagous predators corresponds, in outline, with the course of *A. pisum* abundance dynamics (Bańkowska et al. 1975). Ovipositing adults appeared at the beginning of the development of the pea aphid population; their second abundance peak, connected with the completion of their larval development, falls on the summer minimum of aphid abundance. The estimation of the efficiency of the oligophagous predators' activity requires, apart from data on the density of community components, information on the reproductive potential of *A. pisum* and the estimation of the quantity of food taken by predators. These data have been obtained basing on cultures of *Syrphidae* larvae (Polak in litt.) and *Chrysopidae* (Blaschke in litt.). There have also been used numerous data on food demand of aphidophages published in the literature, as well as those from personal observations.

2. METEOROLOGICAL CONDITIONS

The sites in Chylice and Łomna (near Warszawa) where data were collected in 1971, 1972, 1974 and 1975 constituted the basis for quantitative estimation of *Acyrthosiphon pisum* population. The 1972 data were accepted for the comparison of different regions of Poland. The following meteorological data determining air temperature: day maximum at 2 m above the surface of the ground, day minimum at the surface of the ground, ten days mean at 2 m above the ground and precipitation data were obtained from the Institute of Meteorology and Water Economics in Warsaw. Data from the following IMWE Stations were used for the estimation of the meteorological situation in the investigated sites: for Łomna and Chylice — Warszawa-Okęcie Station, for Gołkowice — IMWE Wieluń Station and for Czechów — IMWE Kielce Station.

Warszawa-Okęcie (Fig. 1). In 1971 the period without ground frost lasted from the first decade (ten deys) of May to mid-September. In that period both maximum and decade mean temperatures demonstrated two maxima; one in May with decade mean temperatures up to 19°C and maximum ones up to 29°C, the other at the turn of July and August with mean air temperatures reaching 22°C, and maximum temperatures up to 34°C. The first period of precipitations in May and June was characterized by fairly frequent rainfalls reaching 48 mm. There were no heavy precipitations in July; they appeared only in the second half of August.

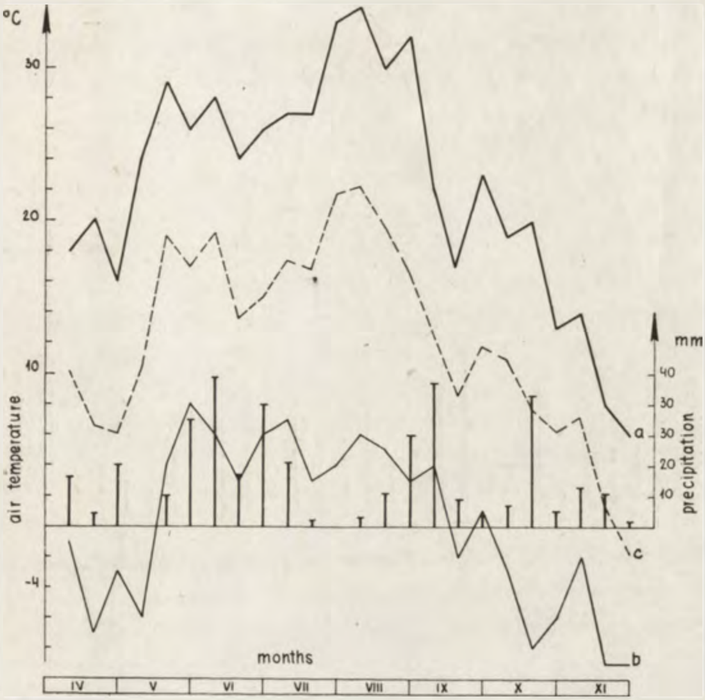

Fig. 1. Weather conditions on Warszawa-Okęcie Station in 1971. Air temperature: a – maximal (2m above ground level), b – minimal (20 cm above ground level), c – ten days average. Vertical line indicates precipitations in mm.

In 1972 (Fig. 2) the period of no ground frost lasted from the beginning of May till the end of September. The curves of air temperature had one peak which occurred in July. The decade mean temperature reached 22°C then, and the maximum temperature 33°C. Both the preceding and the following periods were characterized by decreasing air temperatures. In 1972 precipitations were more evenly distributed during the whole vegetation period and they were greater than in the preceding year, reaching at most 76 mm in July.

In 1974 (Fig. 3) the period of no ground frost was sharter, it started in the second half of May and lasted till the beginning of September. Air temperatures showed one annual maximum in August with the highest decade mean temperature of 18.8°C and the maximum one of 32°C. That year precipitations were less evenly distributed in time. The first period of higher precipitations lasted from mid-May to mid-July. The second period of precipitations began at the end of September and lasted till the end of October. The greatest precipitations in both periods exceeded 50 mm.

In Wieluń in 1972 (Fig. 4) spring ground frosts ended in April and autumn ones began in September. In the vegetative period air temperature had a standard course with one peak in July. The maximum of the decade mean tempe-

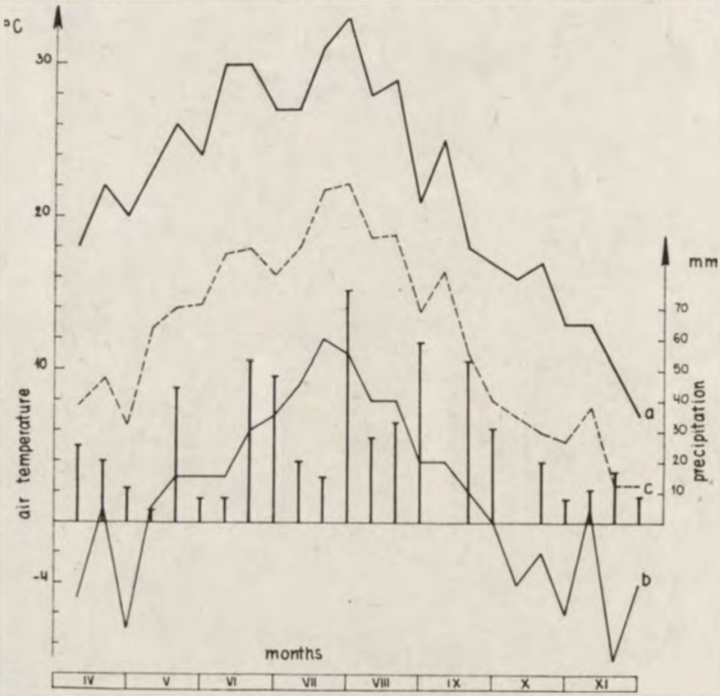

Fig. 2. Weather conditions on Warszawa-Okęcie Station in 1972. For Explanations see Fig. 1.

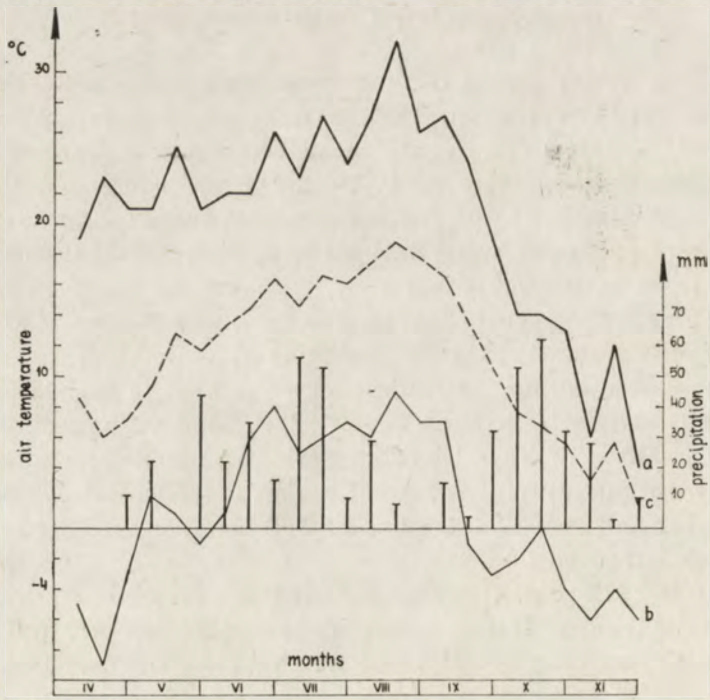

Fig. 3. Weather conditions on Warszawa-Okęcie Station in 1974. For Explanation see Fig 1.

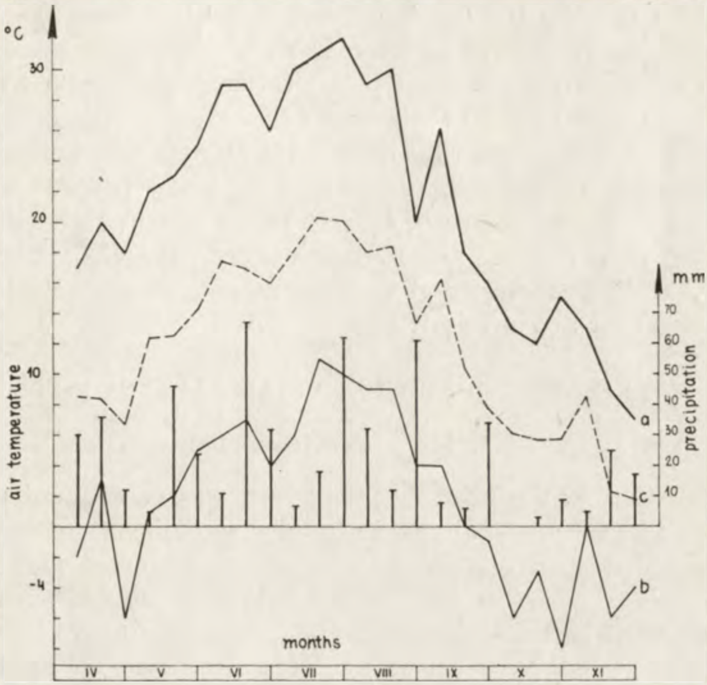

Fig. 4. Weather conditions on Wieluń Station in 1972. For Explanations see Fig. 1.

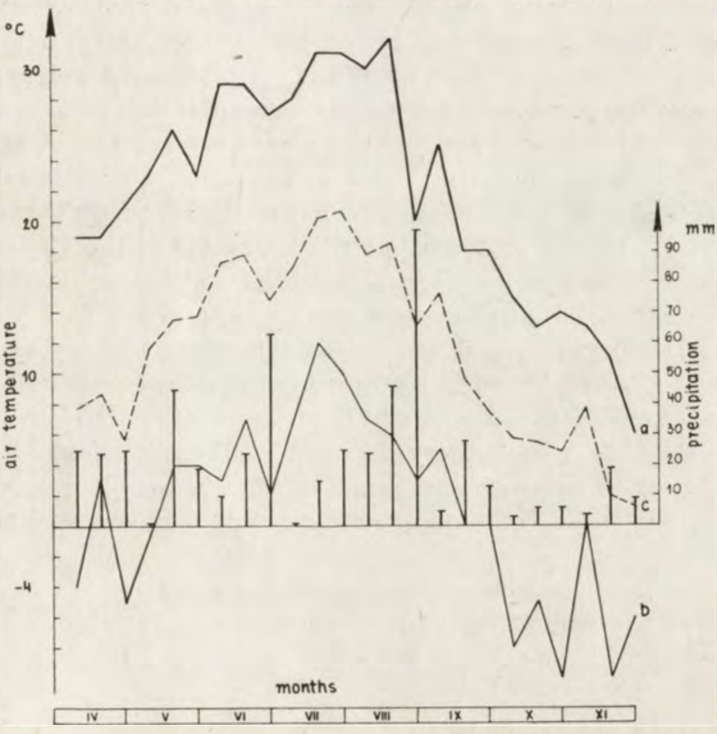

Fig. 5. Weather conditions on Kielce Station in 1972. For Explanations see Fig. 1.

rature was 20.2°C while the maximum day and night temperature was 32°C. Precipitations were of alternating character and were fairly evenly distributed during the vegetation season, great precipitations reaching 60–70 mm.

In Kielce in 1972 (Fig. 5) the period of no ground frost began in the first part of May and lasted nearly till the end of September. Air temperatures in the vegetative season had a one peak course with the highest decade mean temperatures occurring in the latter part of July and the highest maximum temperature of 32°C occurring in mid-August. Precipitations in the vegetative period were evenly distributed, periodically great. The maximum precipitation which occurred in August was over 90 mm.

3. PRIMARY PRODUCTION OF AN ALFALFA FIELD

3.1. Methodical comments

The estimation of the primary production was carried out in Łomna on a two-hectare plantation of alfalfa grown for seed in the second year of its vegetation. In that field mineral fertilization was applied only once during the year, in the early part of April in the following doses of pure component: potassium salt — 85 kg/ha, superphosphate — 72 kg/ha, urea — 46 kg/ha. Then the field was harrowed. No other agricultural activities were applied.

Samples were collected from 20 May to 23 September 1974. In the field every 7 days 10 study plots, of 0.25 m^2 each, were chosen at random. Next, overground parts of all the plants were cut out and put in cloth bags, into a refrigerator. Plant material was sorted into species and, after determining their wet mass, they were dried at 80°C to their permanent weight. The weight determination of the plants was carried out on a analytical scale exact to 0.01 g. Decaying parts of the plants and the roots were not considered in the investigation since, in alfalfa, they could not be examined with standard methods.

Water contents in the plants. The hydration of plant tissues depended on an organ and charged with age. At the beginning of the vegetation season (Fig. 6) water contents in plants was very high, with the highest percentage of water recorded in the alfalfa, *Medicago sativa*, and the quitch grass, *Agropyron repens*. During the vegetation season the content of dry mass in alfalfa and the weeds growing on the plantation increased exponentially. The most rapid increase of dry mass was recorded in the camomile, *Matricaria chamomilla*, the lowest in the pansy, *Viola tricolor*. Young alfalfa shoots had a highly hydrated pith which dried out with the aging of the plants; old plants had stalks empty inside. The water contents of alfalfa plants demonstrated the following values:

at the beginning of the vegetation season	82%
at the end of the vegetation season	50%
at the beginning of blooming	78%
at the end of blooming	76%

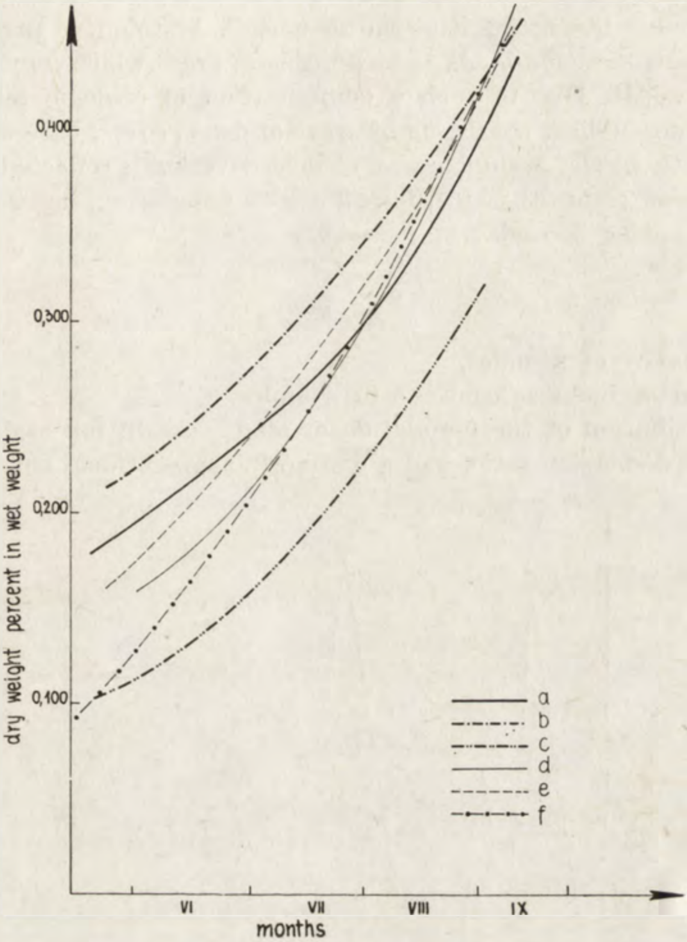

Fig. 6. Changes of water contents in plants: a — *Medicago sativa*, b — *Agropyron repens*, c — *Viola tricolor*, d — *Trifolium pratense*, e — *Polygonum aviculare*, f — *Matricaria chamomilla*.

Similar results have been given by Demolon (1965). The changing water contents in plants makes it impossible to simplify the procedure of primary production investigations, the indicatory estimation of dry mass contents not being possible without the drying of samples.

3.2. Alfalfa production

Alfalfa distribution in a field. In spite of mechanical sawing, alfalfa plants do not cover a plantation regularly. This is due to the influence of incidental factors and the activity of alfalfa pests, especially the vole, *Microtus arvalis* (Pall.). Within the closest neighbourhood of their burrows, these rodents destroy alfalfa completely by cutting it at the root neck. A prolonged presence of these rodents in the cultivation leads to farming bare areas which may become overgrown with weeds. Due to such a configuration of ecologic relations alfalfa cultures are mosaic-like, consisting of areas of dense cover, bare ones and areas overgrown with weeds. A similar way of field covering is reflected in the values of the dispersion ratio (d) which, for an alfalfa population, has been calculated using the following formula:

$$d = \frac{s^2}{\bar{x}},$$

s^2 – the variancy of samples,
$\bar{x}$ – the mean of biomass contents in samples.

The distribution of the population of alfalfa grown for seed, investigated basing on the dispersion ratio, had a distinctly aggregational character (Fig. 7)

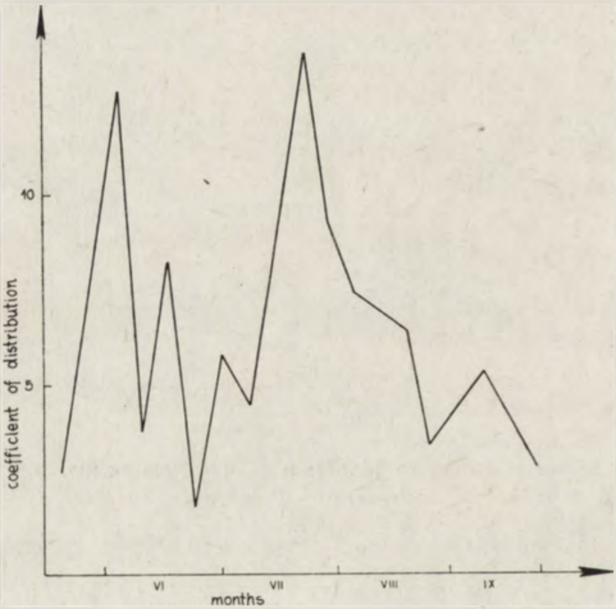

Fig. 7. Spatial distribution of the alfalfa population in growning season.

and demonstrated considerable changes during the vegetation season. The highest values of the aggregation ratio occurred in two periods: in the early part of June and in the latter part of July. In the other periods the degree of population aggregation was markedly lower, nevertheless, the alfalfa population always demonstrated an aggregational character of its distribution in the field.

There could be observed a distinct correlation between the concentration degree of an alfalfa population and the occurrence of weeds. The dispersion ratio was high in periods of a high share of weeds in the total field production, and the aggregational character of alfalfa decreased with a low density of weeds. This correlation was proved by using correlation analysis (Fig. 8). The correlation between weed biomass and the value of the dispersion ratio was rectilinear and the correlation degree ($r = 0.76$) fairly high.

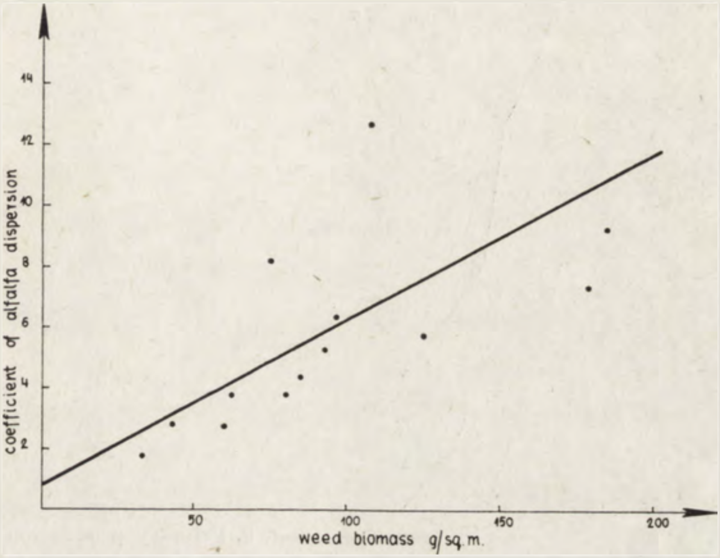

Fig. 8. Correlation between weed biomass and the coefficient of alfalfa dispersion.

Increase of alfalfa biomass. The increase rate of alfalfa biomass demonstrated a considerable differentiation during the vegetation season (Fig. 9). The first and basic period of increase included spring till the first decade of June. In that period the amount of alfalfa biomass reached its maximum and was 386.7 g/m^2. Blooming occurred in that period and the growth of alfalfa was stopped. During the next vegetation phase the amount of biomass decreased considerably. Positive increase began only at the end of June and lasted through August. In that period alfalfa plants formed new shoots, developed seed legumes and the ripening of seeds began. In that period the dry mass contents increased considerably due to low hydration of seeds. At the end of the vegetation season there occurred a second decrease of biomass quantity due to a deterioration of alfalfa leaves and stalks.

The observed developmental rhythm of the investigated alfalfa plantation showed a deviation from the standards both in the course of the biomass quantity curve and in the size of crops (Roder 1964). The total alfalfa production of the investigated field was 237.7 g/ha of green mass and, correspondingly, 46.7 g/ha of dry mass. These data corresponded to $^2/_3$ of the production obtained in Poland (Jelinowska 1970). The production results were lower due both to highly weeded cultures and the time of alfalfa mowing in the first year of the culture.

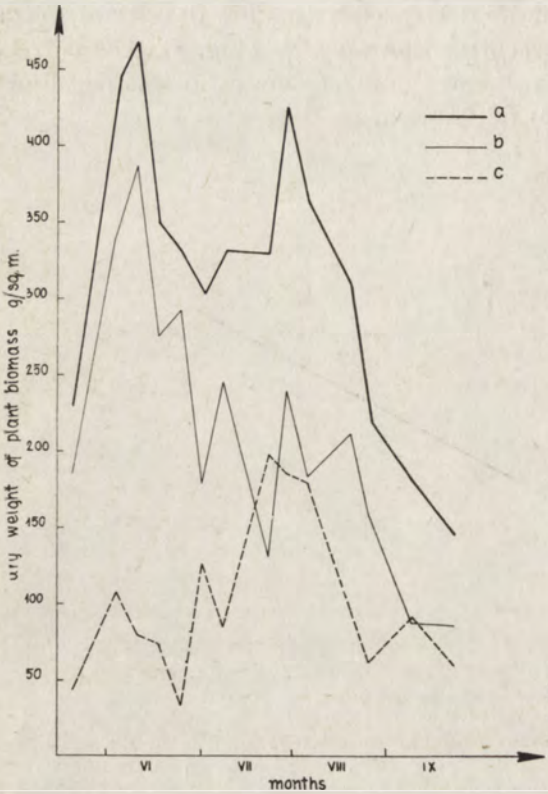

Fig. 9. Primary production of the alfalfa plantation in Łomna; a — total production, b — biomass changes of alfalfa, c — biomass changes of weeds.

3.3. Weed production

The investigated plantation of alfalfa grown for seed was highly overgrown with weeds, on the average about 32 % of the territory (Fig. 10). Weeds had a considerable share in the total production of the field. It was impossible to determine the amount and kind of weeds sown together with alfalfa seeds and those which had previously grown in the field. The following weeds have been considered by Roder (1964) to be the most common ones among alfalfa seeds: *Melilotus* sp., *Plantago* sp., *Daucus carota*, *Setaria viridis*, *Oxalis acetosella*, *Prunella vulgaris*, *Ranunculus* sp. and *Polygonum aviculare*. From among seeds of other cultivated plants, those of *Trifolium pratense* and *Medicago falcata*, have been considered the commonest ones.

On the investigated alfalfa plantation there were recorded 41 weed species. A list of them was compiled basing on the scale of species occurrence constancy (Scamoni 1967) which determines the percentage of samples containing a given species.

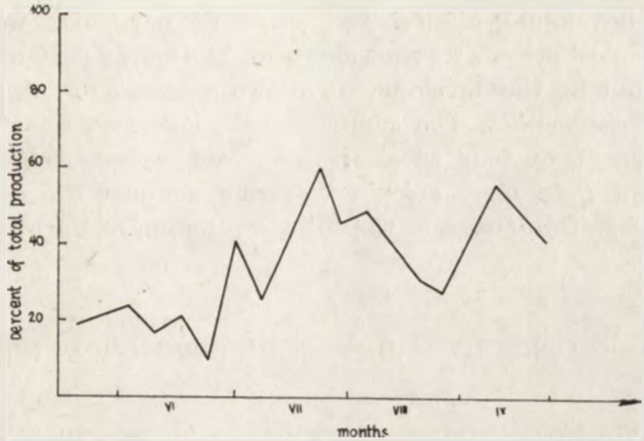

Fig. 10. Contribution of weeds to the total production of the alfalfa plantation.

Class V (81–100% of occurrence): ***Agropyron repens*, *Matricaria chamomilla*, *Polygonum aviculare*, *Trifolium pratense*, *Viola tricolor*, *Stellaria media*.**

Class IV (61–80% of occurrence): ***Chenopodium album*, *Convolvulus arvensis*, *Taraxacum officinale*, *Capsella bursa-pastoris*.**

Class III (41–60% of occurrence): ***Plantago lanceolata*.**

Class II (21–40% of occurrence): ***Poa annua*, *Rumex crispus*, *Trifolium repens*, *Polygonum hydropiper*, *Setaria viridis*, *Cirsium arvense*, *Glechoma hederacea*, *Polygonum convolvulus*.**

Class I (1–20% of occurrence): ***Agrostis alba*, *Anagalis arvensis*, *Brassica napus*, *Echinochloa crus-galli*, *Erigeron canadensis*, *Rorippa silvestris*, *Trifolium arvense*, *Consolida regalis*, *Galium verum*, *Geranium molle*, *Hordeum vulgare*, *Melandrium album*, *Melilotus officinalis*, *Myosurus minimus*, *Papaver rhoeas*, *Rumex acetosa*, *Rumex acetosella*, *Rumex obtusifolius*, *Sonchus arvensis*, *Vicia sepium*.**

From the ecological point of view the above mentioned weed species can be divided into five groups different in respect of the size of biomass production: dominants (5 species), subdominants (7 species) and accompanying ones (29 species).

The average quantity of weed biomass calculated for the whole vegetation period was 102.2 g/m^2. The maximum biomass quantity was recorded in late July (197.3 g/m^2) and it constituted 59.8% of the primary production of the alfalfa plantation. Dominant species had a crucial influence on weed production, their share being 88.4% of the produced biomass. *Agropyron repens* had the highest production – 43.7 g/m^2; *Trifolium pratense*, was the second (18.4 g/m^2).

The highest quantity of weed biomass was recorded in July while, at the same time, alfalfa biomass greately decreased. The spring peak of weed development was less vividly marked. In that period weed growth was hindered by the rapidly developing alfalfa. The share of particular weed species in different phenological periods was not identical. The spring peak of weed biomass was brought about by the development of two species only: *Agropyron repens* and *Matricaria chamomilla*. The summer peak, however, was brought about by the development of four species: *Agropyron repens*, *Trifolium pratense*, *Viola tricolor* and *Polygonum aviculare*. During summer the development of weeds played a significant part in the total production of the alfalfa plantation (Fig. 10).

4. ABUNDANCE DYNAMICS OF *ACYRTHOSIPHON PISUM*

4.1. Fluctuations of aphid abundance in an annual cycle

The investigations on the course of changes of pea aphid abundance in alfalfa cultures in Poland were carried out with the use of two methods. The first – a sweep net – for collecting comparative material from all the sites, the second – a biocoenometer – used at the final stage of the investigations in Łomna site, was employed for the estimation of aphid density per sq. metre. Moreover, both methods were employed in comparative investigations for determining the possibilities of converting the sweep net data into absolute ones. In those studies the abundance determined with the sweep net method demostrated a variability within the range of 4–670 aphids in the samples of 25 strokes of the sweep net; in the samples collected with the biocoenometer the variability of data was 2–320 individuals per sq. metre. There occurred a rectilinear dependence of a high correlation degree ($r = 0.95$) between the mean obtained from the sweep net data and those of the biocoenometer method. That made it possible to calculate the m ratio ($m = 0.45$) which, multiplied by the mean of the sweep net catches, gave an approximate aphid density per sq. metre (Garbarczyk 1976).

The investigations were carried out on five populations; the first was studied in 1971, the next three in 1972 and the last one in 1974.

Chylice 1971 (Fig. 11). The course of the changes in the pea aphid abundance had a fluctuational character. The curve of abundance dynamics had a two-peak from. The spring-summer peak started in May. Throughout June to mid-July the aphid abundance oscillated between 16.5 and 42 individuals/m². Only in late July there occurred a rapid increase of abundance reaching its peak – 282 individuals/m² at the beginning of August. During August the abundance curve decreased rapidly reaching the zero at the beginning of September. During September the pea aphid population was reconstructed but its abundance peak was 13-fold lower than the summer one. In October there occurred a gradual decrease of abundance down to 2.6 individuals/m².

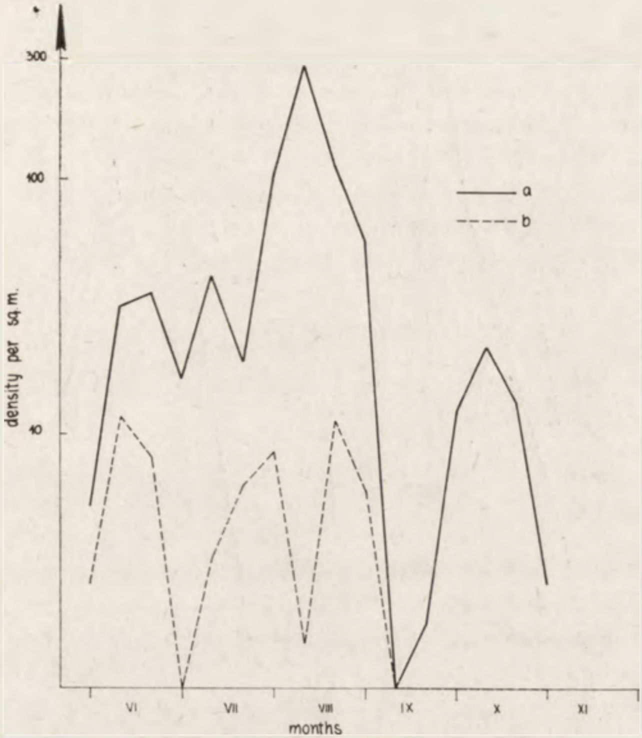

Fig. 11. Fluctuations in numbers of aphids and oligophagous predators in Chylice 1971; a — aphids, b — predators.

Chylice 1972 (Fig. 12). The abundance of the pea aphid population on alfalfa demonstrated three peaks. The first period of abundance increase lasted from the beginning of April to mid-June. The *Acyrthosiphon pisum* density increased in that period from 1.35 to 1561.05 individuals/m^2. The abundance decrease in the latter part of June reduced the pea aphid population to its initial number (1.91 individuals/m^2). The next period of the population increase lasted througout July, with the abundance maximum nearly 14-fold lower than in June. The subsequent abundance decrease, recorded at the end of July, reduced the population to 4.61 individuals/m^2. It was followed by a period of the population development comprising two months; that autumn abundance peak started at the beginning of September and lasted, with a few variations, till the first decade of October. The aphid abundance in that period demonstrated variations from 88.09 to 327.60 individuals per sq. metre. In the latter part of October a decrease of the population abundance occurred, but till mid-November the pea aphid density on alfalfa was fairly high — several dozen of individuals per sq. metre.

In Gołkowice in 1972 (Fig. 12) the course of the changes of pea aphid abundance had a different character. In the early part of May the state of the po-

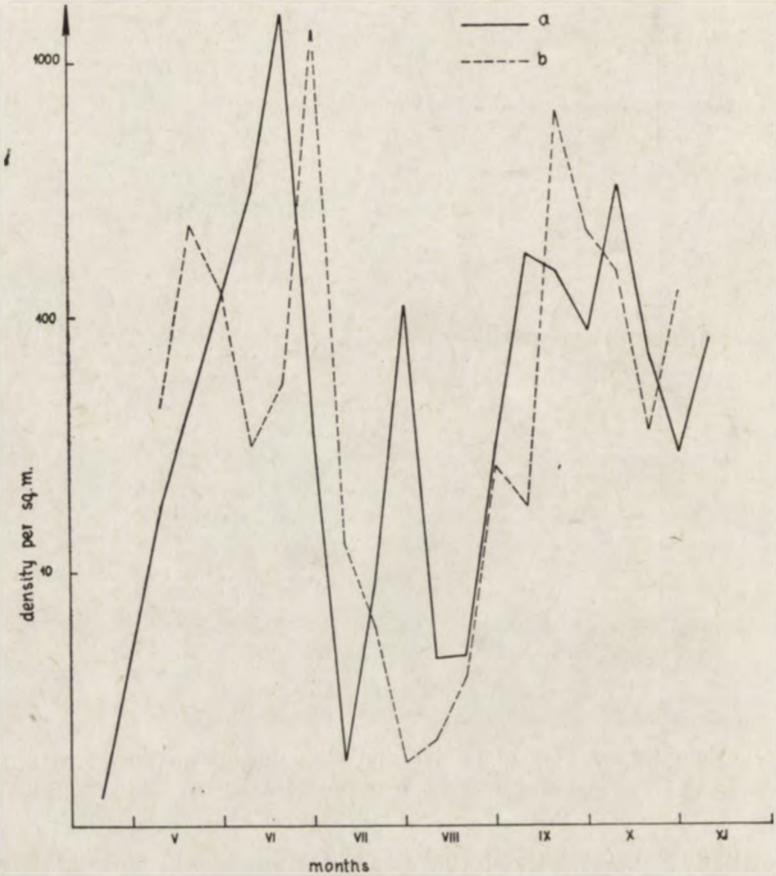

Fig. 12. Fluctuations in the population of pea aphid on fodder alfalfa in (a) Chylice 1972; (b) Gołkowice 1972.

pulation abundance was similar to that in Chylice, but the first abundance peak (230.85 individuals/m^2) occurred in the middle of the same month and it was followed by a decrease of *A. pisum* abundance which lasted for a month. Only at the very end of June the density of the pea aphid reached 1346.40 individuals per m^2 and that was a value comparable to the spring peak recorded in Chylice. Throughout July and August the population abundance remained at a very low level. The increase began in the latter part of August. The autumn abundance peak began in the latter part of September and lasted till the first days of November when a rapid decrease of *A. pisum* abundance took place.

In Czechów in 1972 (Fig. 13) on a population of alfalfa grown for seed the population abundance of pea aphid was the lowest throughout the vegetative season, and its fluctuations were the slightest ones. The spring abundance peak occurred in the early part of June with the *A. pisum* population reaching its

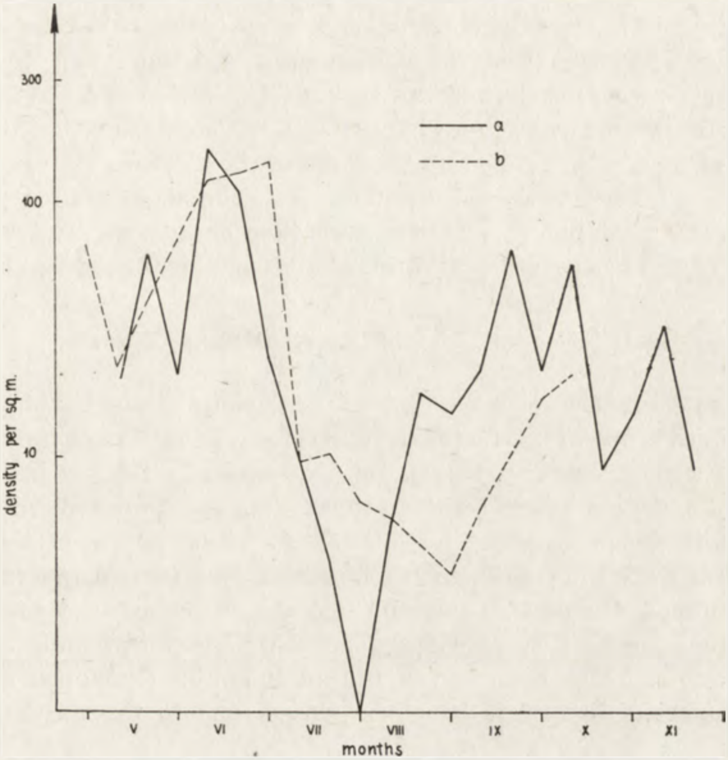

Fig. 13. Fluctuations in the population of pea aphid on seminal alfalfa in (a) Czechów 1972; (b) Łomna 1974.

annual abundance maximum (161.55 individuals/m²). A gradual decrease of aphid abundance lasted till the end of July. In August the population abundance increased with the autumn abundance peak starting in September and lasting till the first days of November. The maximum density of aphids was 65.36 aphids/m². A decrease of the population abundance lasted till the end of November.

Łomna 1974, alfalfa grown for seed (Fig. 13). The population abundance was high already at the end of April (68.5 aphids/m²). The period of abundance increase started in May and the spring density peak lasted throughout June with the density of 120.9–144.8 aphids/m². At the beginning of July the abundance of the pea aphid population decreased to 10 individuals per sq. metre and it remained at a very low level till mid-September. A slight abundance increase which occurred at the end of September was stopped by the mowing of alfalfa.

In the studied fields there simultaneously occurred both red and green biotypes of *Acyrthosiphon pisum*; the green biotype was a distinct dominant and it constituted 86.6 % of individuals in Gołkowice, 97 % in Chylice and 95 % in Czechów.

The course of abundance changes of *Acyrthosiphon pisum* had a fluctuational character. The studied curves of abundance dynamics were in the form of two-peak curves with maxima in the spring (May–June) and the autumn (September–October). However, there happened deviations from that basic pattern. The height of particular peaks and the time of their appearing were difficult to foresee, on the same site they did not occur at the same time every year and within the same year but on different sites they demonstrated deviations both in the time of their occurrence and the abundance level they reached.

4.2. Biotic potential of *Acyrthosiphon pisum*

A precise estimation of a population increase in particular phases of abundance dynamics is one of the factors required for a definition of the extent of the reduction of a population in which the processes of offspring production and individual elimination occur at the same time. The required values may be defined in different ways. The fertility of *A. pisum* has been the subject of many studies. Kenten (1955), in his investigations carried out in a chamber with programmed climate, has established the influence of temperature and photoperiod on the fertility of parthenogenetic pea aphid females. The experimental variant in which both larvae and adult aphids developed in the course of the photoperiod 16/24 has been the closest one to the day-night relation

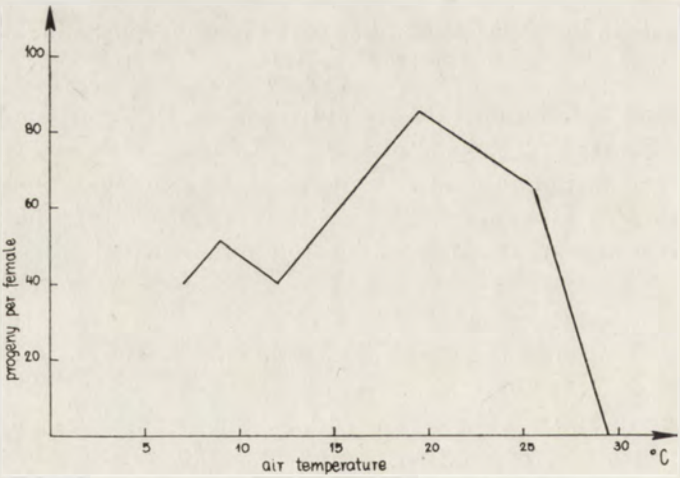

Fig. 14. Influence of air temperature on the fertility of *Acyrthosiphon pisum* females.

at our latitude. In Poland the period of *A. pisum* development lasts from May to September when the day length is nearly 16 hours. Under such conditions the influence of temperature on the fertility of females demonstrates a curvilinear dependence (Fig. 14) with the temperature critical point above 26°C when the fertility of pea aphid equals zero. The thermic optimum of reproduction occurs between 18 and 20°C and in lower temperatures there is a slow fertility decrease. At the lowest day ambient temperatures occurring in the vegetation season the number of offspring produced by one female is not lower than 40 throughout the reproductive period. However, such a method of the estimation of the biotic potential of aphids has been questioned by MESSENGER (1964). Basing on the results of studies on *Therioaphis maculata* he has established that alternating temperatures occurring in the nature have a stimulating effect on the fertility of aphids causing a 50 % increase of the number of their offspring. However, the intrinsic rate of increase (r) used by him requires, for the estimation, precise data on longevity, survival and the day production of offspring in the successive days in the life of a female.

The observations of *Acyrthosiphon pisum* carried out up till now do not provide information essential for calculating this ratio.

In our studies a different principle for the estimation of the biotic potential ratio was applied.

In a population of parthenogenetic females of *Acyrthosiphon pisum* there occur three categories of individuals: 1) juvenile ones in the prereproductive period, 2) adult females in the reproductive period and 3) old females in the postreproductive period.

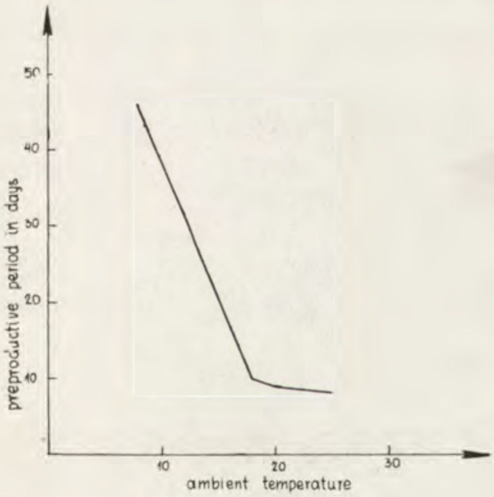

Fig. 15. Influence of ambient temperature on the duration of prereproductive period in *Acyrthosiphon pisum*.

Every individual passes the three stages of life successively and the time they last depends on ambient temperature (Fig. 15). Establishing the relation of the reproductive period to the longevity of a female is of utmost importance. It is done with the use of the ratio of population reproduction (i_r)

$$i_r = \frac{l_{ad}}{l_x},$$

where l_{ad} – length of the reproductive period in days, l_x – longevity in days.

Fluctuations of this ratio (Table I) are usually small, within 0.31–0.55. Its mean value $i_r = 0.50$ applied as a coefficient for aphid abundance makes it possible to estimate the total number of reproducing females of a population.

Table I. Ratio of the reproductive period to longevity of *Acyrthosiphon pisum* viviparous females (juv. – prereproductive period, ad. – reproductive period, sen. – postreproductive period).

Authors	Host-plant	Ambient temperature °C	Longevity in days	Period in days			i_r
				juv.	ad.	sen.	
Cartier 1960	pea	20	39.0	9.0	20.0	10.0	0.51
Smith and Davis 1926	alfalfa	20	30.0	9.7	16.4	3.9	0.55
Markkula 1963	red-clover	–	55.9	13.3	28.0	14.6	0.50
		–	56.6	13.7	25.2	17.7	0.45
		–	59.5	12.8	29.8	16.9	0.49
		–	64.9	12.6	30.7	21.3	0.47
	pea	–	25.4	13.3	10.0	2.1	0.39
		–	20.0	12.3	6.2	1.5	0.31

The fertility of parthenogenetic females of *Acyrthosiphon pisum* living on alfalfa has been precisely calculated in the investigations by Stacherska (1966). Observations were carried out from June to October with the total and day fertility per female thoroughly determined. The data (Table II) indicate that the offspring production of pea aphid in an insectarium, where conditions are close to natural ones, does not reveal any rectilinear relation either to temperature or day length.

Table II. Reproduction of *Acyrthosiphon pisum* on alfalfa in Poland, 1965.
(based on Stacherska 1966)

Month	Mean day length	Mean air temperature	Daily offspring per female
June	16.4	17.0	1.86
July	16.0	16.3	2.70
August	14.4	16.0	2.38
September	12.3	14.8	2.58
October	10.5	7.7	1.69

In July–September the day production of offspring was highest, on the average 2.55 aphids per female. In June, regardless of higher temperature and day length, the aphid production was considerably lower than in the three successive months.

The October decrease of aphid fertility was probably due to lower temperatures and the shortening of days as well as the appearance of sexual individuals, which did not produce offspring on the same principles. Thus prepared data on aphid fertility werre used for the estimation of total offspring production in the population.

4.3. Abundance increase and total aphid production in alfalfa cultures

The estimation of accomplished abundance increases was based on the calculations of the offspring production of pea aphid in particular phenological periods as well as the studied ratios of intrinsic rate of natural increase according to the following formula:

$$P_{NT} = \overline{N}_T \cdot s \cdot r \cdot T,$$

where P_{NT} — total production of individuals in a population per sg. m., N_T — average density of individuals/m² in the studied period, s — share of females in the reproductive period, r — day fertility of females, T — period of time. The data on aphid abundance were obtained by conversion of decade mean ones into data on density; the share of females in the reproductive period was determined basing on data from different regions of Europe and North America Table I). The day offspring production was determined basing on data given hy STACHERSKA (1966); the period of time was 10 days — the same for all experiment. Fundatrices appeared on alfalfa cultures in May, and sowetimes even in April, and began to reproduce. The total offspring production considerably exceeded the abundance recorded for particular fields. The maximum offspring production of aphids registered in Gołkowice in 1972 — 33 932 individuals/m² — was the highest one for the whole vegetation season. The highast abundance of that population — 1346 individuals/m² was reduced at the end of June. The comparable data determining the offspring production of aphids in the studied populations (Table III) indicate that, regardless of considerable

Table III. Monthly offspring production of *Acyrthosiphon pisum*.

Locality	May	June	July	Aug.	Sept.	Oct.	Total VI–IX
Chylice 1971	–	3134.58	8814.83	18999.54	743.04	1296.65	31691.99
Chylice 1972	1759.65	17765.33	1663.07	476.60	5397.23	3612.38	25302.25
Gołkowice 1972	3759.16	13313.51	283.11	387.00	11586.91	2668.42	25570.53
Czechów 1972	943.77	2768.43	199.00	455.18	1417.80	687.32	4840.41
Łomna 1974	1265.10	3720.00	363.15	165.41	579.21	–	4827.77

differences in the course of abundance changes, the total production of 1 m² of the field was similar in the same type of culture. Alfalfa grown for seed yielded a low aphid production not exceeding 5 000 individuals/m² during 4 months;

similar values were obtained in Czechów in 1972 and Łomna in 1974. In the same period alfalfa grown for forage yielded an aphid production 5–6 times higher. July and August were characterized by a low aphid production. The population in Chylice was an exception for, in 1971, the period of its spring-summer abundance increase lasted from the beginning of June to the end of August continuously. The offspring production of *A. pisum* in that month was higher than half of the production of the whole vegetation season.

For the estimation of the efficiency of predators' activity the production was evaluated in accordance with the recorded tendencies of abundance changes (Table IV). In all the studied populations the legnth of time of the spring-summer abundance peak was similar to the autumn one, but there were great differences in the total offspring production in both periods. The number of produced aphids was considerably higher during the spring-summer peak; similar values for both periods were recorded only in Chylice in 1972. The greatest differences were demonstrated by the values of day produciton in spring and summer; on the average the production was 192.5 individuals/m²/day on all sites. In autumn it was only 80.7 individuals/m²/day. Such a differentiation of aphid production in two phenological periods created different conditions of food accessibility for predators in both periods.

Table IV. Offspring production of *Acythosiphon pisum* in two phenological periods of number increase.

Locality	Year	Spring-summer peak		Autumn peak	
		Period	Offspring production	Period	Offspring production
Chylice	1971	21.05–13.08	31130.74	16.09–28.10	2039.69
	1972	11.04– 3.07	19654.84	12.08–9.11	10115.80
Gołkowice	1972	9.05–21.07	17329.99	9.08–18.11	16575.95
Czechów	1972	11.05–19.07	3899.05	7.08–17.11	2912.07
Łomna	1974	6.05–25.06	4985.10	28.08–26.09	620.86

5. ABUNDANCE OF THE COMPLEX OF OLIGOPHAGOUS PREDATORS

The complex of oligophagous predators reducing aphid abundance on alfalfa cultures in Poland consisted of: *Coccinellidae*, *Chrysopidae* and *Syrphidae*. Only in the case of ladybirds, aphids were devoured by adults and larvae; in the other groups by larvae only. In respect of abundance adult ladybirds constituted a predominant group (Table V); they prevailed in all the months but July. Larvae of ladybirds and green lace-wings occurred on alfalfa cultures, practically only from June to August.

Table V. Density of oligophagous predators on alfalfa plantations per sq. m. in Chylice 1971.

Oligophagous predators	May	June	July	Aug	Sept	Oct
Coccinellidae adult	8.4	5.5	0.4	5.7	0.7	0
Coccinellidae larvae	0	0	0.13	0.13	0	0
Chrysopidae larvae	0	0.4	0.2	0.53	0.2	0
Syrphidae larvae	0.8	1.6	4.9	0.1	0	0
Total	9.2	7.5	5.63	6.46	0.9	0

Particular groups of oligophagous predators demonstrated differences both in individual density and the time of occurrence. They reached the highest level of their abundance during the spring-summer peak of the *Acyrthosiphon pisum* population, in the autumn peak their abundance was considerably lower or they did not occur at all.

Coccinellidae (Table VI) had the langest period of occurrence on alfalfa cultures. Adults appeared first and they settled on the plantation in April or early May. The spring peak of their occurrence was at the turn of May and June, the second peak occurred in mid-August. The abundance of adult ladybrids was

Table VI. Mean density per sq. m. of *Coccinellidae* on alfalfa plantations.

Instar	Locality	April	May	June	July	Aug	Sept	Oct	Nov
Adults	Chylice 1971	–	8.4	5.5	0.4	5.7	0.7	0	0.2
	Chylice 1972	0	4.0	3.5	2.0	4.8	5.3	0.4	–
	Gołkowice 1972	–	4.8	1.3	4.5	5.8	2.3	0.2	0.2
	Czechów 1972	–	3.0	1.6	1.2	0.3	0	0.1	0
	Łomna 1973	–	1.4	4.6	1.3	4.2	0	–	–
	Łomna 1974	0.6	4.5	5.7	1.4	1.0	0.4	–	–
	Łomna 1975	0	2.9	1.0	–	–	–	–	–
Larvae	Chylice 1971	–	0	0	0.13	0.13	0	0	0
	Łomna 1974	0	0	0.4	0	–	–	–	–
	Łomna 1975	0	0	0.53	0.27		–	–	–

usually higher in spring than during the summer peak; only in Chylice in 1971 and 1972 the summer abundance was higher than the spring one. The abundance of larval forms was considerably lower than that of adults, with the maximum of larvae occurrence registered in June and July when there usually occurred a decrease of adult abundance.

Syrphidae constituted the second most abundant group of aphid predators on alfalfa cultures. The presence of adult *Diptera* in the alfalfa field was due mainly to the process of ovipositing on alfalfa shoots covered by aphids and to the hatching of imagines from pupae present on alfalfa.

In our climatic conditions polyvoltine *Syrphidae* reach two to three, rarely more, generations in one vegetation season. In the studied alfalfa fields the curve of larva and imago abundance had a two-peak course. Those dependences are presented graphically on the data from the alfalfa field in Chylice in 1971 (Fig. 16). At the end of April and in early May adult females of aphidopagous *Syrphidae* species penetrated, in great numbers, alfalfa cultures ovipositing

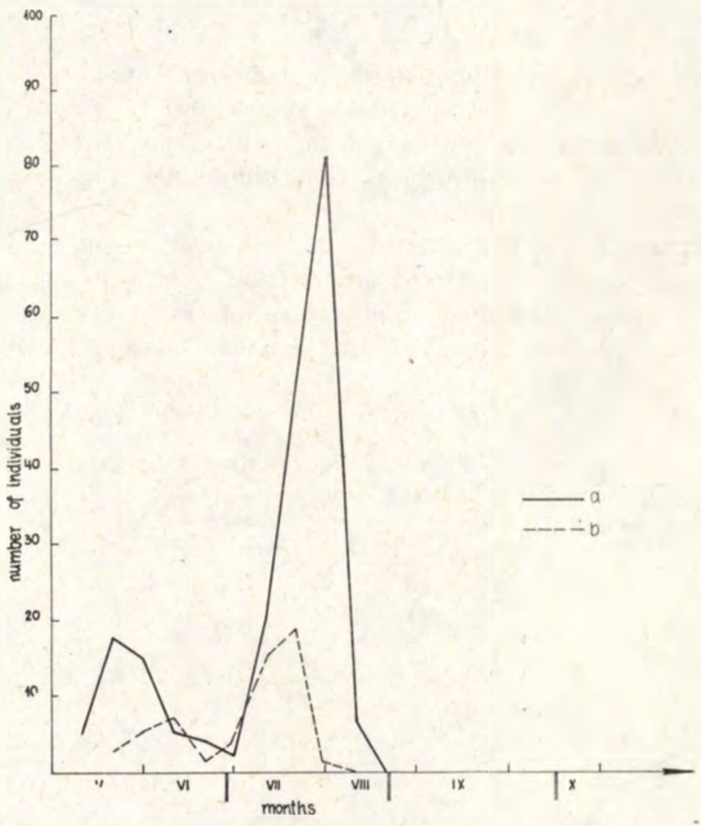

Fig. 16. Fluctuations in numbers of adults (a) and larvae (b) of the hover-flies, *Syrphidae*.

there. From mid-May to mid-June a slow increase of the larva abundance curve took place. In the last decade of May the average density of *Syrphidae* larvae was 0.8 individuals/m^2 and in June – 2, 2.4 and 0.4 individuals/m^2. At the same time the aphid density in the field was considerably high reaching 142 individuals/m^2. The offspring production of aphids was also high in that period, reaching 1326 individuals/m². In the last decade of June most larvae pupated and a most hatching began in the first decade of June. The peak period of the flight of adult *Syrphidae* occurred in the latter part of July and the beginning of August. The second, summer abundance peak of *Syrphidae* larvae in the alfalfa fields, usually higher than the spring one, occurred at the beginning of July. It was difficult to distinguish particular generations of predaceous larvae since they overlapped because a adult female lives up to two or even three months (Lyon 1973, Wilkening 1961) and, during that period, lays eggs successively. For Chylice the average larva density was 4.9 individuals/m² in July and in August, due to the emergence of imagines, it rapidly decreased to 0.1 individuals/m². During the mass appearance of predaceous *Syrphidae* larvae in July the average aphid density was 217 individuals/m² and the increase of the population was 2937 individuals/m² on the average. Towards the end of summer and during autumn only a small percentage of females still laid eggs in alfalfa fields. Most probably it was due to the mowing of alfalfa on the one hand and, on the other hand, to the decrease of aphid density which reached the mean of 2.7 individuals/m² in the last decade of August and the first two decades of September. The mean of increase of the population was 34 aphids per sq. metre. In the last decade of September and in October, when the aphid density again increased up to 88 individuals/m², *Syrphidae* larvae were occasionally found in the alfalfa field but they did not play any significant part in aphid reduction during the autumn peak.

The dynamics of *Syrphidae* abundance in the other alfalfa fields demonstrated a similar course. As a rule there were two abundance peaks but there were certain time changes in relation to the alfalfa field in Chylice.

The mean density of aphidophagous *Syrphidae* larvae (Table VII) demonstrated great differences on particular sites throughout the vegetation season.

Table VII. Mean density of *Syrphidae* larvae in alfalfa fields in Poland.

Locality	May	June	July	Aug	Sept	Mean density
Chylice 1971	0.8	1.6	4.9	0.1	0	1.5
Chylice 1972	1.0	0.4	1.42	0.2	0	0.6
Gołkowice 1972	0.5	4.34	2.65	0.1	0	1.5
Czechów 1972	0.5	0.6	0.2	0	0	0.3
Łomna 1974	0.2	0.5	0.4	0.1	–	0.3

In May the density of larvae in the five studied fields ranged from 0.2–1.0 individuals/m². The lowest density occurred in the alfalfa field in Łomna in 1974. The spring that year was unfavourable for ovipositing by *Syrphidae* females, there occurred prolonged temperature decreases and considerable precipitations (Fig. 3). A small amount of eggs oviposited by *Syrphidae* females during spring and the development conditions of the first generation larvae had a vital influence on the abundance of the successive *Syrphidae* generations throughout the vegetation season and thus on the degree of reduction of the aphid population.

In June the density of larvae in different fields oscillated between 0.4 and 4.3 individuals per square metre. The greatest range of larva abundance was recorded in July, from 0.2 to 4.9 individuals/m^2. In August the density of larvae in all the fields was small, within 0–0.2 individuals/m^2.

The mean annual density of *Syrphidae* larvae on alfalfa grown for seed (Czechów and Łomna) was considerably lower than in the fields of alfalfa grown for forage. Such a regularity seemed to be closely synchronized with the value of total production of aphids in one sq. metre of the studied fields (Table III).

Chrysopidae imagines (Table VIII) appeared on alfalfa in the first decade of May. From about mid-June to the first decade of July there occurred

Table VIII. Mean density per sq. m. of *Chrysopidae*.

Instar	Locality	May	June	July	Aug	Sept	Oct	Nov
Adults	Chylice 1971	0.05	0.05	0	0.05	0.05	0.02	0
	Chylice 1972	0.05	0.05	0.15	0.02	0	0	–
	Gołkowice 1972	0.05	0.10	0.50	0.90	0	0	0
	Czechów 1972	0.15	0.10	0.15	0.02	0	0	0
	Łomna 1972	0.05	0.03	0.05	0.04	0	–	–
	Łomna 1974	0.02	0.03	0.04	0.02	0.02	–	–
	Łomna 1975	0.05	0.05	0.20	–	–	–	–
Larvae	Chylice 1971	0	0.4	0.2	0.5	0.2	0	0
	Chylice 1972	0	0.3	0.1	0.2	0	0	–
	Gołkowice 1972	0	0.2	0.6	0.08	0	0	0
	Czechów 1972	0	0.7	0.6	0.2	0.08	0	0
	Łomna 1973	0	0	0	0.05	0	–	–
	Łomna 1974	0	0	0.4	0.05	0	–	–
	Łomna 1975	0	0.1	0	–	–	–	–

a decrease of their abundance; frequently no samples were caught at all. In July, green lace-wings appeared again in small numbers and occurred till the middle of September.

Larvae had a shorter period of occurrence, they were caught in considerably large amounts, till nearly end of June. Starting in August their abundance slowly decreased. Under unfavourable conditions green lace-wings occurred occasionally in alfalfa fields. Regardless of the occurrence of adult forms, larvae did not develop. In 1973–1975 the abundance of *Chrysopidae* on the cultures in Łomna was so low, and their occurrence so short that it was impossible to consider the settlement of the cultures by green lace-wings as permanent.

The main factors determining the settlement of alfalfa cultures by predaceous forms of *Coccinellidae*, *Syrphidae* and *Chrysopidae* families were the quantity and accessibility of food which, in the case of *Acyrthosiphon pisum* were determined by the population density. A dependence between the abundance of predators and the abundance of aphids was recorded on the studied alfalfa cultures (Fig. 11). It is more distinct when not only the abundance of *A. pisum* population but also the total production of aphid offspring are taken into consideration. In this respect there occurred great differences in two periods of abundance dynamics; the aphid production was usually several times higher in the spring-summer period than in autumn. The predator complex developed most rapidly in spring and summer. In autumn, with a low aphid abundance, the density of predators was minimal. Decrease of population abundance took place in autumn practically without predaceous forms taking part in it.

6. REDUCTION OF APHID ABUNDANCE

Food demand of predators. The estimation of the food demand of aphidophage is the basis for estimating their part in reducing the abundance of aphid populations. Numerous studies carried out on day food rations and the amount of food taken during the development give greatly differing data.

The food demand of aphidophagous *Syrphidae* larvae has been discussed by many authors but there are no data on species dominating in alfalfa fields in Poland. Only two species – *Syrphus corollae* and *S. balteatus* have been the subject of such studies and they occur in our fields in a very small percentage – 3.9% and 3.6%. It has appeared that the amount of food taken throughout the development of a *S. balteatus* larva at a constant temp. of 20°C reaches 400 aphids (Lyon 1973). The values obtained for *S. corollae* demonstrate considerable differences: from 307 aphids (Hagvar 1972) and 346 (Tawfik et al. 1974) to 867 (Bombosch 1962). Such differences in the number of devoured aphids are influenced by many factors, among which the accessibility of food and thermal conditions are very important; in the case of aphids the spatial distribution of a population and its density are of primary value.

There are numerous data on the food demand of *Coccinellidae* (Hodek 1966). However, not *Acyrthosiphon pisum* but other aphid species were devoured or else, some ladybird species, different from those found on alfalfa, served for food. Usually that demand is about several dozen or even over one hundred aphids a day. However, it always depends on temperature and a species, development stage and the density of aphids and ladybirds. Lachidov (1970) reports that under the conditions of Middle Asia a *Coccinella septempunctata* larva of the third stage eats 50 *A. pisum* aphids a day, and a female at the time of ovipositing — 80. A female of ***Propylaea quatuordecimpunctata*** eats 55 specimens of *A. pisum* at the same period of time.

The situation is similar in the case of *Chrysopidae*. The food demand mainly in *Chrysopa carnea*, is discussed by Meyer and Meyer (1946), Wengris (1964), Sundby (1966), Wiąckowski and Dronka (1966), Ickert (1968), Blaschke (in litt.) and others. In this case there also is a great discrepancy of data and, moreover, only some authors consider *A. pisum* a prey of *Chrysopidae*.

For determining the food demand of predaceous species occurring on alfalfa cultures there have been carried out experiments in cages under conditions close to natural ones. For *Syrphidae* the amount of day food ration was the factor differentiating particular experiments. Eggs oviposited by females were placed separately on Petri-dishes. The pea aphid, *Acyrthosiphon pisum* served for food. Each culture variant was repeated ten times, with resu.lts presented as arithmetical means. Those observations made it possible to establish the average length of the larvae period for particular species (Table IX). The day food demand

Table IX. Efficiency of some *Syrphidae* larvae as aphid predators obtained by experimental methods.

Species	The number of aphids consumed by larva during its development	Longevity of larvae	The number of aphids consumed per day
Sphaerophoria scripta	129	9	14
Melanostoma mellinum	150	10	15
Platycheirus clypeatus	135	9	15
Syrphus corollae	254	10	25
Syrphus balteatus	352	8	44

of the studied *Syrphidae* larvae ranged from 14–44 aphids, whereas the consumption for the whole period of larval development was from 129–352 aphids; members of species of large body sizes demonstrated a higher consumption, both day and for the whole development period. However, no distinct differences were recorded during their development.

The established percentage share of particular *Syrphidae* species on alfalfa cultures and their day consumption made it possible to establish the average number of aphid from one square metre devoured by larvae in a day. The average food demand of one *Syrphidae* larva was 16.4 aphids a day.

It follows from the data from the cultures that the food demand of *Coccinellidae* is, on the average, 7.8 *Acyrthosiphon pisum* individuals a day for larvae of *Propylaea quatuordecimpunctata* and 10.1 aphids for *Coccinella septempunctata*. Just as in the case of *Syrphidae* (POLAK in litt.) the larger the food ration, the greater the aphid consumption (Table X). The amount of aphids devoured by adult ladybirds is larger than that devoured by their larvae, and it is 11 aphids a day, regardless of the species.

Table X. Influence of the number of aphids on the consumption of *Coccinella septempunctata* larvae.

Daily number of aphids given as food	5–10	10	10–20	10–20–40	20
Aphids consumed per day	5.8	7.8	9.9	11.6	15.2

In the case of *Chrysopidae*, practically only larvae were of any significance as predators of *A. pisum*. If it is assumed that *Chrysopa carnea* imagines – though feeding on aphids in the culture – under natural conditions do not feed on aphids (ICKERT 1968), then out of the total very small, amount of *Chrysopidae* caught on alfalfa the aphidophagous *Chrysopa phyllochroma* and *Ch. commata* constituted only 10%. Data obtained from the culture shawed that the average day food demand of the two aforementioned species was 8 individuals of *A. pisum*.

Data on the food demand and the possibilities of aphid reduction by *Chrysopidae* larvae are greatly varied. In this study the average of 23.4 aphids per day has been accepted basing on the works of BLASCHKE (in litt.) and WIĄCKOWSKI and DRONKA (1966). In both cases observations were carried out under similar climatic conditions, dealt with the food demand of *Ch. carnea* larvae for *A. pisum* and the obtained results were similar.

Reduction of *A. pisum* population by oligophagous predators

The aphid reduction by particular groups of predators on alfalfa throughout the vegetation season had a very uneven course. In May, in all the studied fields aphids were reduced by ladybirds and *Syrphidae* larvae alone (Tables XI and XII), no larvae of green lace-wings occurred then (Table XIII). In that period, the efficiency of ladybirds in the reduction of aphid populations was, on the average, nearly four times higher than that of *Syrphidae* larvae. In June, however, the density of *Syrphidae* larvae per sq. metre increased and the amount of their aphid reduction increased to 40%, appearing not much lower than that of ladybirds (48%). In that month, *Chrysopidae* larvae also contributed to the reduction, but their share was only up to 12% of aphids killed by preda-

Table XI. Monthly reduction of *Acyrthosiphon pisum* by *Syrphidae* larvae on alfalfa plantations in Poland.

Locality	May	June	July	Aug	Total	%
Chylice 1971	393	787	2411	49	3640	11.4
Chylice 1972	492	197	699	98	1486	5.8
Gołkowice 1972	246	2136	1305	49	3736	14.4
Czechów 1972	246	295	98	0	639	13.2
Łomna 1974	98	246	197	49	590	11.8

tors. In July the number of aphids eaten by ladybirds decreased to 32 % and there was an increase in the share of *A. pisum* devoured by green lace-wings (15 %) and *Syrphidae* larvae (up to 53 %). In August, the efficiency of *Syrphidae* larvae rapidly decreased to 4 %, the consumption of aphids by ladybirds increased to 82 %, but the share of aphid consumption by *Chrysopidae* larvae remained at the same level (14 %). In September the aphid reduction by *Syrphidae* larvae equalled zero, by green lace-wings decreased to 8 % and only ladybird effectively reduced the *A. pisum* population – 92 %. In October only adult ladybirds remained on alfalfa cultures (Table XII).

Table XII. Number of aphids reduced by *Coccinellidae*.

Locality	May	June	July	Aug	Sept	Oct	Total	Per cent
Chylice 1971	818.4	1671.0	272.8	1184.2	42.0	0	3988.4	12.5
Chylice 1972	1364.0	1155.0	682.0	1636.8	1749.0	136.4	6723.2	26.1
Gołkowice 1972	1636.8	429.0	1534.0	1977.0	759.0	68.2	6405.3	25.0
Czechów 1972	1023.0	528.0	409.2	102.3	0	34.1	2096.6	43.3
Łomna 1974	903.0	621.0	–	–	–	–	1524.0	30.6

Table XIII. Number of aphids reduced by *Chrysopidae* larvae.

Locality	May	June	July	Aug	Sept	Oct	Total	Per cent
Chylice 1971	0	280.8	145.1	362.7	140.4	0	929.0	2.9
Chylice 1972	0	210.6	72.5	145.1	0	0	428.2	1.7
Gołkowice 1972	0	140.4	435.2	58.0	0	0	633.6	2.5
Czechów 1972	0	491.4	435.2	145.1	56.1	0	1127.8	23.3
Łomna 1974	0	0	290.2	36.3	0	–	326.5	6.8

The number of aphids eaten by ladybirds was twice as high as by *Syrphidae* larvae throughout the vegetation season. *Chrysopidae* larvae demonstrated the lowest efficiency; on the average, their reduction of aphid numbers was three times lower than that of *Syrphidae* larvae.

The decrease of the pea aphid population numbers in the two peak periods of its abundance was different with particular predator groups. The *Syrphidae* larvae consumed aphids practically only in the spring-summer peak, in the autumn peak of aphids their efficiency was insignificant, the consumption figures did not exceed one per cent for particular fields (Table XIV). The average number of aphids consumed by *Syrphidae* in the spring-summer peak was 27 times higher than the amount of aphids eaten in the autumn peak.

Table XIV. Reduction of aphid number on alfalfa plantations by *Syrphidae* larvae in two phenological periods of number increase.

Locality	Spring-summer peak		Autumn peak	
	Total reduction	Per cent	Total reduction	Per cent
Chylice 1971	3354	10	0	0
Chylice 1972	922	4	66	0.6
Gołkowice 1972	3137	18	33	0.2
Czechów 1972	525	13	0	0
Łomna 1974	230	4	6.5	1

There were no such great differences in the number of aphids consumed by *Chrysopidae* larvae in both phenological periods (Table XVI). In the spring-summer peak the consumption figures were 2.6 times higher than in the autumn peak.

The aphid consumption by *Coccinellidae* was similar (Table XV); the consumption figures were twice as high in the spring-summer peak.

It is worth noting that the reduction of aphid numbers on alfalfa grown for forage was higher than on alfalfa grown for seed. *Syrphidae* larvae consumed five times more aphids on alfalfa grown for forage than on alfalfa grown for seed; for ladybirds the amount was three times higher. *Chrysopidae* larvae alone did not present any significant difference in the amount of *A. pisum* consumed on both types of cultures.

The comparison of the amount of consumed aphids in particular fields and the annual production of aphids in once square metre (Table III) indicates that the total reduction of aphid number by oligophagous predators was considerably higher on alfalfa grown for seed and it sometimes reached up to 80%.

Table XV. Number of aphids reduced by *Coccinellidae* in two phenological periods.

Locality	Spring-summer peak		Autumn peak	
	Number of consumed aphids	Per cent	Number of consumed aphids	Per cent
Chylice 1971	2581	8.3	14	0.7
Chylice 1972	2695	13.7	2849	28.2
Gołkowice 1972	2475	14.3	2079	12.5
Czechów 1972	1472	37.2	88	3.0
Łomna 1974	1018	20.4	—	—

Table XVI. Number of aphids reduced by *Chrysopidae* in two phenological periods.

Locality	Spring-summer peak		Autumn peak	
	Number of consumed aphids	Per cent	Number of consumed aphids	Per cent
Chylice 1971	540.2	1.7	47.8	2.4
Chylice 1972	237.6	1.2	94.0	0.9
Gołkowice 1972	432.4	2.5	51.8	0.3
Czechów 1972	779.4	20.0	150.1	5.2
Łomna 1974	0.8	0.02	5.4	0.8

Table XVII. Number of aphids reduced by oligophagous predators.

Locality	Spring-summer peak		Autumn peak		Total reduction	
	Number of consumed aphids	Per cent	Number of consumed aphids	Per cent	Number of consumed aphids	Per cent
Chylice 1971	6475	20.8	62	3.0	8557	27.0
Chylice 1972	3855	19.6	3009	29.7	8637	33.5
Gołkowice 1972	6044	34.9	2164	13.1	10774	42.1
Czechów 1972	2755	70.7	238	8.2	3863	79.8
Łomna 1974	1249	25.1	12	1.9	2441	50.6

Whereas in fields of alfalfa grown for forage numbers of aphid reduction ranged between 27–42% (Table XVII).

There also occurred great differences in the extent of aphid number reduction by the whole complex of predators in both abundance peaks of *A. pisum* population. On the average, the consumption of aphids in the spring-summer peak was three times higher than in the autumn peak (Table XVII).

7. DISCUSSION

The presented results indicate that, so far, the weight of the effectiveness of a predator and parasite complex as one of the main factors limiting a pea aphid population on alfalfa has been underestimated. That effectiveness is demonstrated by a high percentage of aphid numbers consumed by the oligophagous predators in relation to the total aphid production in one square metre of a field (Table XVII). It is also necessary to point out that the number reduction intensity is highest in the spring-summer peak of pea aphid abundance which, consequently, influences the further development of its population.

Into the number of factors limiting the abundance of aphids, many authors include, apart from unfavourable thermal conditions and prolonged precipitations, agricultural activities, mainly the mowing of alfalfa. Bones (1958), Chauvin, Lecompte (1958), Dunn, Wright (1955), Hozák (1970), Skuhravy et al. (1959) have stressed a rapid bending of the curve of the dynamics of aphid populations and predators which are the object of our study.

The results of our observations only partly agree with those statements. It is true that immediately after a field had been mown the population abundance of both aphids and predators decreased practically down to zero. However, when young, succulent' shoots appeared, the food conditions of aphids improved considerably and due to that, an *A. pisum* population not only restored its previous abundance level in a short period of time but it often exceeded it. The biomass increase of alfalfa grown for forage was higher than that of alfalfa grown for seed since the growth of the former was not stunted by yielding seeds but, on the contrary, it was stimulated by mowing. The water contents in plants was much higher for alfalfa grown for forage throughout the vegetation season which offered much better conditions for the development of pea aphid. Therefore the mowing of alfalfa grown for seed stimulated the development of a pea aphid population. This was proved by the values of the total production per one square metre on both types of cultures (Table III). The total production of aphids on alfalfa grown for forage was five times higher than that on alfalfa grown for seed.

It is necessary to stress that our results concerning the day food demand of predators are lower than the results presented by many authors. Such a situation is probably due to the fact that, up till now, similar experiments have been carried out in laboratory conditions, at a constant and quite high temperature, with a great supply of food which produced optimal conditions, usually not present on alfalfa cultures. Assuming that the food accessibility on alfalfa is limited since *Acyrthosiphon pisum* does not form colonies, the food rations in cultures were differentiated starting with the minimum one, at the threshold of survival rate, then gradually increased up to the one exceeding the consumption possibilities of predators. For providing thermal conditions as close to the field ones as possible, the cultures were kept in the open air where the day and night temperature differences favourably influenced both the length of the larval development of the predator and its consumption possibilities.

In spite of such law values accepted as the basis of aphid consumption by oligophagous predators, the extent of the recorded reduction makes it possible to state that the abundance regulation of as *Acyrthosiphon pisum* population by aphidophagous elements on alfalfa plantations in Poland is the most important factor regulating that population. The other factors mentioned by Dunn and Wright (1955) are less important and the mowing of alfalfa stimulates the development of an aphid population.

8. CONCLUSIONS

1. The mowing of alfalfa grown for forage diminishes, for a short period of time, the abundance of the *Acyrthosiphon pisum* population, but it is a factor stimulating an abundance increase and therefore the restoration of a population is very quick. The final abundance level often exceeds the initial one.

2. Oligophagous predators play the most important part in the reduction of a pea aphid population. Out of the total number of produced individuals 12.5–43.3 % of aphids were consumed by *Coccinellidae*, 5.8–14.4 % by *Syrphidae* and 1.7–23.3 % by *Chrysopidae*.

3. The abundance and efficiency of oligophagous predators depends on the density of aphids. The *A. pisum* numbers reduction is 3 times higher in the spring peak than during the autumn one.

4. The aphid consumption by oligophagous predators on alfalfa grown for seed reached 79.8 % and was considerably higher than on alfalfa grown for forage 42.1 %.

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STRESZCZENIE

[Tytuł: Kompleks faunistyczny mszyce-afidofagi na uprawach lucerny w Polsce. 2. Regulacja liczebności *Acyrthosiphon pisum* w łańcuchu drapieżców wyspecjalizowanych]

Obecne opracowanie stanowi kolejny etap badań nad funkcjonowaniem kompleksu faunistycznego mszyce-afidofagi. Podjęto próbę oceny redukcji populacji mszycy grochowej (*Acyrthosiphon pisum*) przez kompleks drapieżców wyspecjalizowanych: *Syrphidae, Coccinellidae, Chrysopidae*. Oparto się na wynikach uzyskanych w badaniach na lucernie pastewnej (Chylice, Gołkowice) i nasiennej (Czechów, Łomna). Rozpatrywano zależności między warunkami meteorologicznymi (warunki termiczne, opady) a dynamiką kompleksu mszyce-afidofagi na badanych polach w ciągu całego sezonu w poszczególnych latach. W 1974 r. przeprowadzono badania produkcji pierwotnej zarówno lucerny nasiennej, jak i chwastów na polu w Łomnie, metodą cotygodniowego wycinania roślin z określonej powierzchni, suszenia i ważenia. Uzyskano w ten sposób obraz przyrostu biomasy lucerny w ciągu sezonu. Porównano dynamikę liczebności populacji *A. pisum* na wszystkich badanych polach. Przebieg jej obrazuje dwuszczytowa krzywa (rys. 11–13) z maksimami w okresie wiosenno-letnim i jesiennym.

Wyliczono potencjał biotyczny i określono wielkość produkcji populacji mszycy grochowej w poszczególnych fazach jej dynamiki (tab. III, IV), w odniesieniu do m^2 powierzchni pola.

Badania liczebności i zagęszczenia drapieżców wyspecjalizowanych obejmowały stadia odgrywające rolę w redukcji populacji mszyc: larwy *Syrphidae* i *Chrysopidae* oraz larwy i imagines *Coccinellidae*. Poszczególne grupy drapieżców wykazują różnice zarówno w zagęszczeniu, jak i w okresie występowania (tab. V–VIII). W sumie najwyższy poziom liczebności osiągają drapieżce w okresie wiosenno-letniego szczytu rozwoju populacji *A. pisum*. W szczycie jesiennym liczebność ich jest znacznie niższa i praktycznie tylko imagines *Coccinellidae* redukują jeszcze mszycę grochową.

W celu określenia skuteczności redukcji liczebności mszyc przez drapieżce wyspecjalizowane przeprowadzono hodowle, z których wyliczono wielkość zapotrzebowania pokarmowego poszczególnych gatunków drapieżców.

Redukcja populacji mszycy grochowej zarówno w całym sezonie, jak i w obu szczytowych okresach jej liczebności przebiega odmiennie, inny jest też udział poszczególnych grup drapieżców (tab. IV–VI). Skuteczność całkowitej redukcji jest stosunkowo wysoka (tab. XVII).

Streszczając, stwierdzić można, że:

— występuje ścisła zależność między przyrostem biomasy lucerny a wzrostem liczebności mszycy grochowej,
— wpływ na liczebność mszycy grochowej wywiera charakter uprawy: wielkość produkcji populacji *A. pisum* na lucernie pastewnej jest 5-krotnie wyższa niż na lucernie nasiennej,
— wiosenno-letni szczyt liczebności mszyc jest — na ogół — kilkakrotnie wyższy od jesiennego,
— warunki meteorologiczne nie wykazują zdecydowanego i wyraźnego wpływu na przebieg dynamiki liczebności kompleksu mszyce-drapieżce wyspecjalizowane,
— istnieje wyraźna zależność między zagęszczeniem mszyc a zagęszczeniem kompleksu drapieżców wyspecjalizowanych (rys. 11),
— rola drapieżców wyspecjalizowanych w redukcji populacji mszyc jest wyższa niż to utrzymywało wielu autorów. Wielkość redukcji zależy od zagęszczenia mszyc, charakteru uprawy (na lucernie nasiennej drapieżce wyspecjalizowane redukują do 80% produkcji mszyc, na pastewnej — do ponad 40%), okresu (w szczycie wiosenno-letnim redukcja jest trzykrotnie większa od redukcji w szczycie jesiennym) (tab. XVII).

РЕЗЮМЕ

[Заглавие: Фаунистический комплекс тли-афидофаги культуры люцерны в Польше. III. Регуляция численности *Acyrthosiphon pisum* в цепи специализированных хищников]

Настоящая работа составляет очередной этап исследований по функционированию фаунистического комплекса тли-афидофаги. В ней предпринята проба

оценки редукции популяции гороховой тли (*Acyrthosiphon pisum*) комплексом специализированных хищников: *Syrphidae*, *Coccinellidae*, *Chrysopidae*). Основана она на результатах исследований, проведенных на кормовой люцерне (Хылице, Голковице) и на семенной (Чехув, Ломна). Рассмотрена зависимость между метеорологическими условиями (термика, осадки) и динамикой комплекса тли-афидофаги на исследуемых полях на протяжении всего сезона по отдельным годам. В 1974 году проведены исследования первичной продукции как семенной люцерны, так и сорняков на поле в Ломне методом еженедельного кошения растений с определенной поверхности, сушения и взвешивания. Таким образом получена картина прироста биомассы люцерны на протяжении сезона. Сравнительная динамика численности популяций A. *pisum* рассмотрена на всех полях. Ее ход иллюстрирует двувершинная кривая (рис. 11–13). Максимум численности припадает на период весенне-летний и осенний.

Высчитан биотический потенциал и определена величина продукции популяции гороховой тли в отдельных фазах ее динамики (табл. III, IV) в пересчете на 1 $м^2$ поверхности поля.

Исследования численности и плотности специализированных хищников включали те стадии, которые играют роль в редукции популяций тли: личинки *Syrphidae* и *Chrysopidae*, а также личинки и имаго *Coccienllidae*. Отдельные группы хищников различаются как по своей плотности, так и периоду встречаемости (табл. V–VIII). В общем наивысший уровень численности хищников приходится на период весенне-летнего максимума развития популяции *A. pisum*. Во время осеннего максимума их численность гораздо ниже и редукция гороховой тли в этот период происходит за счет имаго *Coccinellidae*.

С целью определения эффективности редукции численности тлей специализированными хищниками произведено экспериментальное лабораторное разведение, при котором была высчитана величина пищевой потребности видов хищников.

Редукция популяции гороховой тли как на протяжении всего сезона, так и обоих максимумов численности происходит иначе; участие в этом процессе отдельных групп хищников также иное (табл. IV–VI). Эффективность полной редукции относительно высокая (табл. XVII).

Подводя итог, можно констатировать, что:

— имеется тесная зависимость между приростом биомассы люцерны и ростом численности гороховой тли,

— на численность гороховой тли влияет характер культуры: величина продукции популяции *A. pisum* на кормовой люцерне в 5 раз выше, чем на семенной люцерне,

— весенне-летний максимум численности тлей в общем в несколько раз выше осеннего,

— метеорологические условия не оказывают решительного и четкого влияния на ход динамики численности комплекса тли-специализированные хищники,

— существует четкая зависимость между плотностью тлей и плотностью комплекса специализированных хищников (рис. 11),

— роль специализированных хищников в редукции популяций тлей значительнее, чем это утверждали многие авторы. Величина редукции зависит от плотности тлей, характера культуры (на семенной люцерне специализированные хищники редуцируют до 80% продукции тлей, на кормовой свыше 40%), периода (в период весенне-летнего максимума редукция тлей в три раза выше, чем в период осеннего максимума) (табл. XVII).

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