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MIHAELA PAULIAN
Research Institute of Plant Protection, Bucharest, Rumania

Green Lacewings (Neuroptera Chrysopidae) in the Aphid-Predator System on Maize in Mild Temperate Climate (*)

Introduction

Corn is an important agricultural resource in mild temperate zone. Few studies report on the relationships between insect pests and their natural enemies in east-European countries, except the works related to the faunistical survey (Maize Ecosystem Researches) carried out in the Hungarian Plain (Mészáros, 1984; Szentkirályi, 1984, 1989; Kozma *et al.*, unpubl.) and a 10-year old programme on corn protection in Rumania (Marin, 1987; Paulian, 1991a, 1991b, 1992).

Corn is the main crop in Rumania, as well in involved surfaces (25 to 30 % of the total ploughed lands) as in yields (more than 10 tons per hectare in the best conditions) and money incomings for farmers. It is cultivated from lower plains to hilly areas, up to about 450 m altitude. The aphids are everywhere considered common insect pests. They are most often satisfyingly controlled by natural enemies, in which predators were estimated to play the key role (Paulian, 1991a, 1992). However, their occurrence is sometimes casual, leading to unexpected damaging outbreaks. The aim of the present report is to investigate if and what farming factors could modify the relationships between aphids and their controlling predators.

Materials and Methods

The studies were carried out over three years, in agricultural district of the so-called "Champ Roumaine". They were conducted in two different series. On one hand, in small experimental plots, we investigated the influence of two farming technics exposed to possible variations in the country, namely the fertilizers and the forerunner crops. The fertilization was one of the three following types: none, considered check in further analysis *vs* [N_{80} + P_{80} + 20 tons manure] or [N_{160} + P_{80}]. The forerunner crop was either the maize itself within a monocultural system, considered check in further analysis *vs* wheat or alfalfa. On the other hand, in order to evaluate the possible influence of some edaphic factors, complementary experiments were carried out in actual farming conditions, namely in large production cornfields of 40 hectares each; the analysis between these fields bore

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on the types of soil which were representative of the more frequent substratum for cultivation (sandy soils) as check *vs* sandy clay or sandy silty soils.

From May to August, *i. e.* from the early stage of maize plant springing to the corn cob full development, the population levels of aphids and beneficial insects were recorded every ten days. In the small plots, observation was made on 50 maize plants, in the central rows of each plot, according to a linear transect method. In the production cornfields, the same method was used, but based on 250 maize plants distributed into five plots, according to a procedure previously described in details in an earlier preliminary study by Paulian (1992). The data concerning aphids were provided by visual *in situ* counts which is considered efficient method in the field (Heathcote, 1972). They are recorded as colonies and registered when the number of individuals was more than 20 per colony. Adults and larvae of the diurnal beneficial insects (coccinellids and nabids), which are both predaceous, were collected by hand net and counted. Because of the nocturnal activity and the escaping ability of adult lacewings and of the camouflaging behaviour of their larvae, chrysopid populations were complementarily estimated by counting *in situ* and collecting eggs laid on the plants. After rearing in the laboratory, the issuing adult green lacewings were identified.

The data were submitted to a variance analysis (ANOVA method) and the retained levels of significance in differences were 0.05 and 0.01.

Result and Discussion

Aphids

Four species of aphids were found on leaves and stems of maize in the investigated crop stands. They were in decreasing importance order: *Rhopalosiphum maidis* (Fitch), *Aphis fabae* Scopoli, *Rhopalosiphum padi* (Linnaeus) and *Sitobion avenae* (Fabricius). Every year, the two first were both together dominant, the ratio between them fluctuating function of the considered area and the climatic conditions of the year. Aphid occurrence began from 15 June to 10 July, function of the cultural technics (dates of sowing), the cultivars and the climatic conditions related to each springtime. During the growing season, the number of maize plants registered with aphid colonies fluctuated between 10 and 100 % and the mean colonization was estimated about one third of the plants. Aphid contamination increased slowly up to July during which it decreased, and increased again in August (Fig. I).

Edaphic and cultural factors influenced the aphid population as following (Table 1). Sandy clay soil played an important role in numbers of contamined plants, but not in numbers of colonies per plant. Sandy silty soil did not differ from the sandy (check) soil condition. Fertilization, of course, promoted both the development of leaves and corn cobs, and a dark-green colour of vegetation. Consequently, it increased the numbers of contamined plants and of colonies per plant; the more the nitrogen intake, the more the aphid occurrence. The two forerunner crops different of maize influenced also the number of contamined plants, only wheat increased significantly the mean number of aphid colonies per plant.

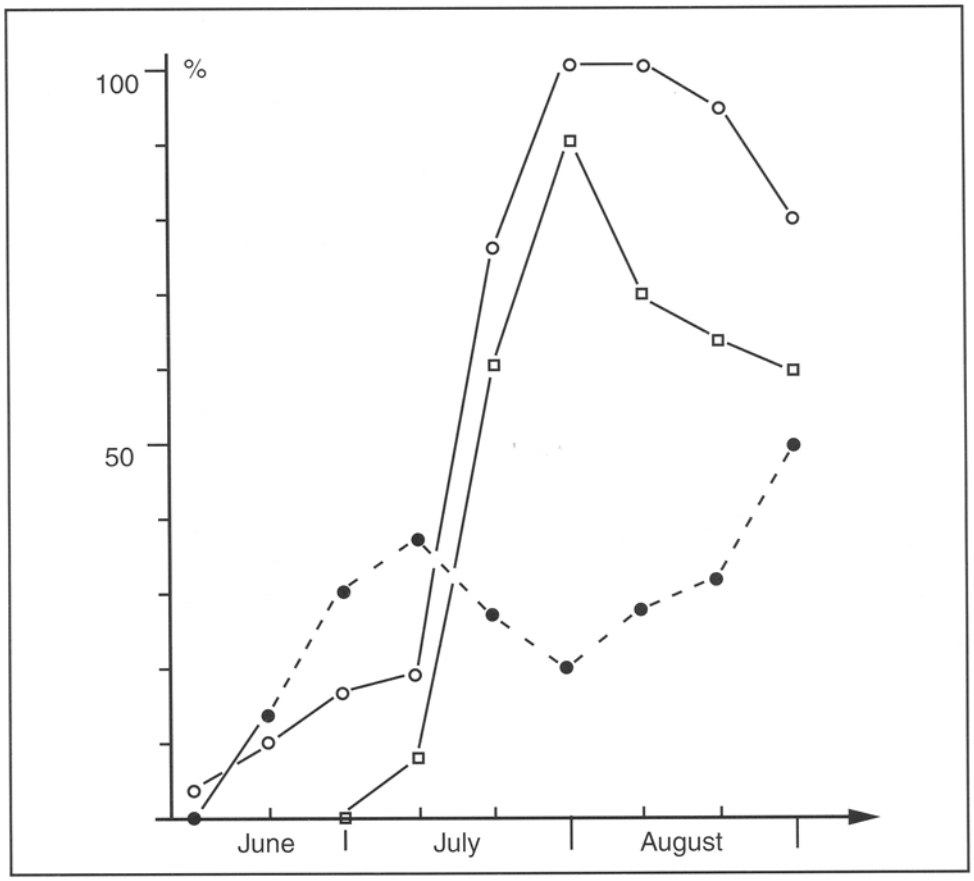

Fig. I. – Colonization of maize plants (%) by aphids (• - - - •) and by their main predators: chrysopids (○——○) and coccinellids (□—□) in the field of the Rumanian Plain.

Predators

Aphidophagous insect predators occurring in the maize cultures are listed in Table 2. Pointing out the numerical importance of adults, we found green lacewings Chrysopidae 48 %, ladybird beetles Coccinellidae 36 %, assassin bugs Nabidae 10 % and hoverflies Syrphidae 6 % (Fig. II). Besides, some spiders having generalistic predatory behaviour were recorded, mainly *Therridium impressum* (Koch) (Aranea: Therridiidae) already recorded in similar cornfield conditions (Paulian, 1991b).

Chrysopids

The green lacewings were the most abundant predators and may be expected to bring a strong aphidophagous pressure on aphids. They belonged mainly to *Chrysoperla carnea* (Stephens) *sensu lato* — the common green lacewings —

Tab. 1. – Influence of the types of soil, fertilizers and forerunner crops on the occurrence of aphids, chrysopids and coccinellids on maize in the Rumanian Plain. F % = frequency of plants with aphids, chrysopids and coccinellids; X_a = mean numbers of aphid colonies (recorded if $n \geq 20$ individuals) per plant; X_e = mean numbers of chrysopid eggs per plant; X_c = mean numbers of coccinellids (larvae and adults) per plant.

	Aphids		Chrysopids		Coccinellids	
	F %	X_a	F %	X_e	F %	X_c
Type of soil:						
sandy (S)	21	1.2	68	3.1	6	1.3
sandy clay	*70*	1.3	*98*	*20*	*62*	*3.7*
sandy silty	28	1.3	87	3.1	*31*	1.8
Fertilization:						
none (T_0)	8	2	40	1.9	6	1.3
$N_{80} + P_{80}$ + manure	*14*	3	*52*	*6.3*	*16*	1.4
$N_{160} + P_{80}$	*23*	*5*	43	*5*	*21*	*3.5*
Forerunner crop:						
corn (M)	8	1.5	63	1.9	10	1.2
wheat	*20*	1.7	*91*	*5.1*	12	1.5
alfalfa	*23*	*6.3*	72	*3.2*	*20*	*6.2*

Significances of the differences between treatments were calculated in comparison with sandy soil (S) for the edaphic factor, with no fertilizer (T_0), and with maize (M) for the forerunner crop factor. Roman types = no significance; Roman *underlined types* = significance at the level 0.05, and *italic types* = at the level 0.01.

which contituted 96 % of the total number of chrysopids occurring in maize. As it was previously precised for the Rumanian fauna (Paulian *et al.*, 1996), the dominant species within the *carnea*-complex is *Chrysoperla kolthoffi* (Navás) (61 %), associated to *Chrysoperla lucasina* (Lacroix) (38 %) and casually *Chrysoperla carnea sensu stricto* (1 %). All *Chrysoperla* Steinmann have predatory larvae, whereas their adults have glycophagous feeding habits. They overwinter as adults in reproductive diapause. Other species recorded in maize (Table 2) belonged to the genus *Chrysopa* Leach; they are predaceous both as larvae and adults, and overwinter as full grown third-instar larvae within the cocoon. *Chrysopa formosa* Brauer and *Chrysopa perla* (Linnaeus) have a tendency to be univoltine (Principi, 1992; Volkovich, 1996); they were more frequent in spring. *Chrysopa pallens* (Rambur), unambiguously multivoltine in all ecological situations (Grimal & Canard, 1991; Volkovich, 1998) was more frequent in late summer.

Chrysopids appeared and established early: the first egg layings were recorded on the maize plants at the beginning of June. At this time, plants just developed four to six leaves, they did not yet harbour aphids, and so the neuropteran predators preceded the aphid prey. Egg layings of green lacewings occurred all along the season. They decreased significantly after the middle of August, when the reproductive diapause of the Chry*soperla* begins to be manifested (*e. g.* Honěk, 1977). However, if freshly laid eggs became more scarce, the relevant larvae originating the wintering adult population continued to prey and to grow

up to cocoon spinning, participating in decreasing on the late aphid population.

In all plots and every year, chrysopids were abundant related to the aphid prey availability. This is contrary to other ecological situations in which neuropteran predators are of secondary importance, as in Quebec (Coderre & Tourneur, 1984). As previously recorded (Paulian, 1992), the frequency of maize plants bearing lacewing eggs reached 100 % as soon as the middle of July; one might record 60 % of leaves with egg layings, and a mean of 32 eggs per plant. In maize fields with 40,000 plants per hectare — a mean density frequently found in Rumania — there were then about 1,300,000 green lacewing eggs per hectare.

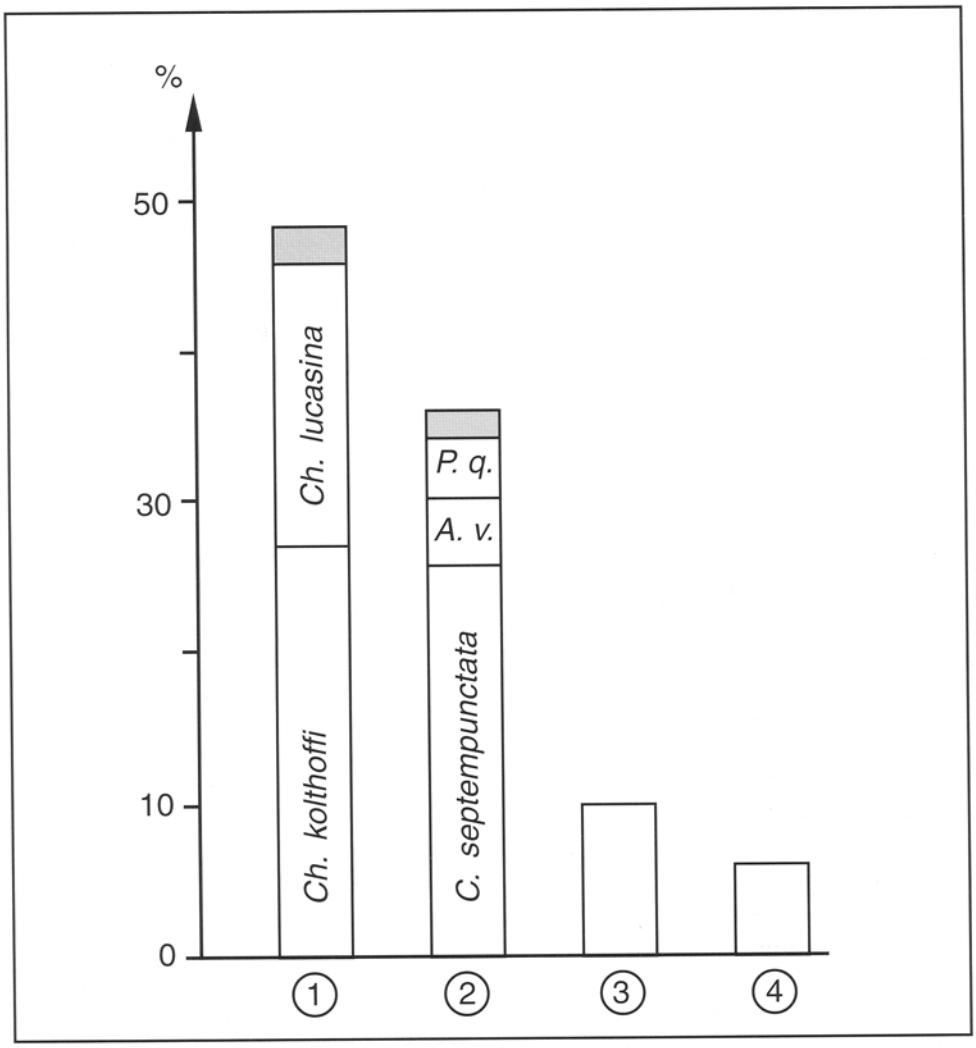

Fig. II. – Percentages of the aphidophagous predators recorded on maize plants in the Rumanian Plain (see Table 2). 1 = Chrysopidae, open: *Chrysoperla* spp.; shaded: other species; 2 = Coccinellidae, *A. v.: Adonia variegata*, *P. q.: Propylea quatuordecimpunctata*, shaded: other species; 3 = Nabidae; 4 = Syrphidae.

Such occurrence and abundance of chrysopids in maize may arise questions about the actual feeding of these predatory larvae. As far we know, green lacewing larvae have a broad spectrum of possible prey (Paulian); they do not select food with accuracy, except a few of them manifesting a tendency to monophagy such as *Chrysopa slossonae* Banks (Bristow, 1988). In absence or in drastic scarcity of aphids which therefore are preferably eaten (Bigler, 1988), the green lacewing larvae are then able to prey on other insects injurious to maize. They are known to do so on *Ostrinia nubilalis* (Hübner) in various ecological situations, such as in Egypt (El Hemeidy & Abbas, 1984), in ex-Yugoslavia (Hergula, 1930) or in North America (Wildermuth, 1932); they also feed on various cicadellids (Vidano *et al.*, 1985), or on acariids (Kosma *et al.*, unpubl.). When usual food gets extremely scarce, they may also survive by oophagy and cannibalism (Canard & Duelli, 1984) or by intraguild predation against coccinellids larvae (Rosenheim *et al.*, 1993; Lucas *et al.*, 1998).

Concerning the farming factors, it was shown (Table 1) that lacewings were highly stimulated in egg laying when the maize grows on clayey soil subtrate. Fertilization by nitrogen, whatever the kind (chemical and/or manure), was favourable to egg laying, but only moderate intake of chemical *plus* manure increased the frequency of harbouring plants. Such an abundance was already noted in maize crops which were preferably choosen as a niche by chrysopids when the colour of leaves was dark-green rather than yellow (stressed plants) (Lorenzetti *et al.*, 1997). Chrysopid abundance was highly (after wheat) or weakly (after alfalfa) stimulated by the forerunner crop.

Coccinellids

Nine ladybird beetles (Table 2) constituted the second aphid predator group in maize (Fig. I). The seven spot ladybird beetle *Coccinella septempunctata* Linnaeus was dominant (72 %).

Unlike for chrysopids, the occurrence of coccinellids on maize began in the middle of July, namely when the plants were sufficiently developed and the aphid populations were large enough to make significantly attractant and arrestant lure. These prerequisite conditions to a colonization by coccinellids were already noticed in other ecological situations by Iperti (1978), Honěk (1981, 1982), Varvara *et al.* (1982), Hemptinne *et al.* (1990), and others. Coccinellids were always found depending on the food (aphid) availability. They showed a delay in appearance after aphid colonization. When aphids were scarce or even lacking, the coccinellids were lacking also, or at least, their presence was sporadic and they did not establish (laid eggs) on the plant in such poor preying conditions (Hodek, 1973; Dixon & Guo, 1993). They avoided laying eggs also when larvae of the same species were present in old aphid colonies (Hemptinne *et al.*, 1992), and so did not aggregate in areas of aphid abundance (Kindlmann & Dixon, 1993). In our experiments, the maximal occurrence of coccinellids was reflected by 90 % of maize plants, with an average density of three adults per plant. Thus, in the above-mentioned theoretical maize field, one could found about 66,000 ladybirds per hectare.

Tab. 2. – Aphidophagous insects recorded on maize in the Rumanian Plain.
* = abundant, ** = dominant species.

Coleoptera: Coccinellidae		*Adalia bipunctata* (Linnaeus)
	*	*Adonia variegata* Goeze
		Coccinella quinquepunctata Linnaeus
	**	*Coccinella septempunctata* Linnaeus
		Halysia vigintiduopunctata (Linnaeus)
		Hippodamia tredecimpunctata (Say)
		Micraspis sedecimpunctata (Linnaeus)
	*	*Propylea quatuordecimpunctata* (Linnaeus)
		Scymnus auritus Thunberg
Diptera: Syrphidae		*Episyrphus balteatus* De Geer
Heteroptera: Nabidae		*Himacerus apterus* Fabricius
Neuroptera: Chrysopidae		*Chrysopa formosa* Brauer
		Chrysopa pallens (Rambur)
		Chrysopa perla (Linnaeus)
	**	*Chrysoperla kolthoffi* (Navás)
	*	*Chrysoperla lucasina* (Lacroix)

As a consequence of the aphid density dependence of coccinellids, the agricultural factors enhancing aphid colonization and multiplication were those favourable to coccinellid occurrence. They were in first sandy clay soil, and at a lower level, a high intake of chemical fertilizers which increased the numbers of recorded individuals. Chemical and manure fertilization induced more plants to be visited by coccinellids but not more individuals per plant. Alfalfa forerunner cropping increased strongly abundance of coccinellids.

Dynamics

Figure I shows the mean aphid and predator occurrence as percentages of infested plants in cornfields during the three years of observation. Due to the early occurrence of the green lacewings capable to slown down outbreaks in aphid colonies, their constant presence during the three crucial months for aphid injuries (June to September), the high numbers and well dispersed egg layings, the chrysopids played the key role in aphid control. Besides, their polyphagous aptitudes bring up help in controlling other damaging insects. On the contrary, coccinellids were sometimes weak or occasional auxiliaries (Hemptinne & Dixon, 1991) because only occuring in situations of relatively high density of aphids.

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SUMMARY

Common aphidophagous predators found on maize were Chrysopidae (Neuroptera), Coccinellidae (Coleoptera), Nabidae (Heteroptera) and Syrphidae (Diptera). Some factors swaying dynamics of the aphid-predator system were investigated in Rumania: types of soil, forerunner crops and fertilizers. All combinations providing the best development of plants were favourable both to aphids and predators. The chrysopids constituted 48 % of the predator guild. They played the key role in controlling aphids. The main species were *Chrysoperla kolthoffi* (Navás) and *Chrysoperla lucasina* (Lacroix). They were components of the common green lacewing complex *Chrysoperla carnea* (Stephens) *sensu lato*. Adult chrysopid occurrence in cornfields was permanent from mid June to mid September, not depending on aphid colony density. The coccinellids constituted 36 % of the predator guild. The dominant species was *Coccinella septempunctata* Linnaeus. Ladybirds got into maize from the beginning of July. They established later, only if plants were strongly colonized by aphids.

KEY WORDS: maize, aphidophagous predator guild, chrysopid, Rumania.

Le Crisope (Neuroptera Chrysopidae) nel sistema Afide-Predatore sul mais nel clima temperato

RIASSUNTO

I predatori afidifagi comunemente rinvenuti sul mais appartenevano ai Chrysopidae (Neuroptera), ai Coccinellidae (Coleoptera), ai Nabidae (Heteroptera) e ai Syrphidae (Diptera). Sono stati studiati alcuni fattori che influenzano la dinamica del sistema afide-predatore in Romania: tipi di suolo, colture precedenti e fertilizzanti. Tutte le combinazioni che garantivano lo sviluppo migliore delle piante erano favorevoli sia agli afidi che ai loro predatori. I crisopidi costituivano il 48% dei predatori e hanno giocato il ruolo chiave nel controllo degli afidi. Le specie principali erano *Chrysoperla kolthoffi* (Navás) e *Chrysoperla lucasina* (Lacroix), entrambe componenti del complesso della crisopa comune *Chrysoperla carnea* (Stephens) *sensu lato*. La presenza di crisopidi adulti nei campi di mais è stata costante da metà giugno a metà settembre, indipendentemente dalla densità della colonia degli afidi. I coccinellidi costituivano il 36% dei predatori. La specie dominante era *Coccinella septempunctata* Linnaeus. Le coccinelle erano presenti nel mais a partire dall'inizio di luglio. Vi si sono stabilizzate più tardi, solo se le piante erano fortemente colonizzate dagli afidi.

PAROLE CHIAVE: mais, insetti predatori afidifagi, Crisopidi, Romania.

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Author's address:
Mihaela Paulian, Aleca Zvoristea n. 3, Bl A42, Sc B, Ap 19, RO-77426 BUCUREŞTI - Romania
e-mail: paulian@adconb.adcon.ro