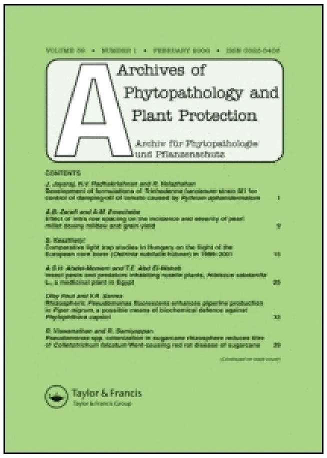

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Numerical response of predatory ladybirds (Coccinellidae) to aphid outbreaks and their diversity in major rice ecosystems of Cameroon

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Abstract
Field study conducted on upland rice fields in North Cameroon showed that *Rhopalosiphum rufiabdominalis* (Sasaki) and *Hysteroneura setariae* (Thomas) are the most important aphid species feeding on rice crops compared with *Rhopalosiphum maidis* (Fitch) and *Schizaphis minuta* (van der Goot) in term of numbers. The investigations also revealed the occurrence of 13 species of predatory coccinellids dominated by *Xanthadalia effusa* ssp. *rufescens* (Mulsant) and the *Scymnus* spp. The dynamics of the individual species was different according to growing seasons. The aphid *H. setariae* and *Scymnus* spp. were the most numerous during the rice early growing season, whereas during the mid- to late growing period high occurrence of *R. rufiabdominalis* and *X. effusa rufescens* was recorded. In both growing seasons synchronization between the development of aphids and coccinellids was observed. Significant positive correlation was found between aphids and ladybirds during the second half growing season. Species richness and the Shannon indexes fluctuated from year to year in rice irrigated plots.

Keywords: *Aphids, Coccinellids, number dynamics, species composition, synchronization*

Introduction

Aphids include serious pests of many of the world's crops, including several grain crops, and cause severe economic damage, sometime as virus vectors. Rice cultivation seems to have suffered little from aphids except from a few species in limited areas and particular seasons (Yano et al. 1983). Throughout the warmer climates, the aphid *Rhopalosiphum rufiabdominalis* (Sasaki) is seen as the most important species of economic interest feeding on rice and may cause reduction in yield as high as 50% in Japan (Tanaka 1961), 30% in Latin America (Ferreira et al. 1995). In North Cameroon, this species has been reported particularly damaging rice plant (Nonveiller 1984). In West African agro-ecosystems, severe attacks on rice crop by another species, *Hysteroneura setariae* (Thomas), in countries such as Sierra Leone (Akibo-Betts & Raymundo 1978) and Nigeria (Akinlosotu 1980) are common.

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One of the major basic aspects of the effectiveness of biological control for every pest in rice ecosystems requires the assessment of the existing potential bio-control agents and their stability (Weber & Parada 1994). Because most ladybirds adults and larvae are predatory, feeding generally on aphids, mealybugs, scale insects, and plant mites, but occasionally on other insects, they are thus of major economic importance (Booth et al. 1990; Woin & Wetzel 1998).

Although some information is available on predators and parasitoids of the cotton aphid in North Cameroon (Ekukole & Ajayi 1995), no investigations have been carried out on aphids and their specific-predators dwelling on rice crops. Field trials were therefore conducted in the Benue valley from 1995 – 1997 to assess the species composition of aphid and ladybeetle populations as well as the numerical response of the latter to the outbreaks of the former.

Material and methods

In 1995 and 1996, observations were conducted from the third week of September to the second week of November, a period which corresponds to the rice mid- to late growing season (Season 2) and covers the panicle initiation to mature rice grain stage. From 1999 to 2002, samplings were carried out only in irrigated rice fields between January and June.

Sites of study

The Benue valley is located in a savannah region dominated by a Sudano-Sahelian climate characterized by high temperatures from March to June. From June to January it is much cooler, especially during the nights. The mean annual temperatures are 26 – 28°C. The rainy season lasts from April to October. The yearly total rainfall ($\geqslant$1000 mm) is affected by its irregular distribution over the season. The relative humidity remains generally very high (78 – 95%) from May to October and drops between January and April although it may still be strongly affected by the 'Harmatan' wind ($\geqslant$5 m/s).

Experimental fields

The studies were conducted on smallholders' farms. The fields where the experiments were carried out were always embedded in a set of at least 8 ha adjacent farms. Upland rice in North Cameroon is rain-fed when the rains have stabilized (2nd fortnight of June – July) and harvested from November to December. There is generally one rice crop a year. Fields were surrounded by other cereals dominated by maize and sorghum.

Sampling techniques

Direct counting and sweeping with nets were used to assess the abundance of the investigated arthropods. Samplings were collected weekly. From direct counts, 300 shoots (stems, leaves and panicles) were surveyed in the fields and all aphids were recorded. Each survey was performed on batches of 50 shoots localized randomly in six positions. Pooter was also used to suck up individuals, whose identification on rice shoots was difficult by hand lens (magnification of $\times$20).

Numbers of coccinellids were estimated from counts of all developmental stages on 0.5×0.5 m plots. There were 15 plots in 1995 – 1996 and 20 plots in 1997. Based on these counts, mean densities of ladybeetles per m^2 were assessed. Coccinellids that could not directly be identified by hand lens on the rice shoots were sucked up by pooter for later examination.

In addition to the direct counting, the relative abundance of aphids, ladybirds (including larvae) dwelling at the upper part of the rice shoot was assessed using sweep nets in the first two years (Season 2). A set of three sweeps (with 25 doubled sweeps each) at 15 m and 100 m transects from the edges were performed weekly over the survey period. The sweep consisted of a circular (diameter 30 cm) nylon sweep net. Arthropods were swept up after 10 am according to weather conditions. Experiments to assess the diversity of coccinellids in irrigated paddy fields were conducted weekly with sweep nets between January and June.

Insects sampled by sweep nets and by pooters during visual counting were collected separately. In the laboratory, the adult alatae, adult apterae and the fourth-instar nymphs of each aphid species including ladybeetles were distinguished and counted. They were then stored in a refrigerator and sorted under a stereoscopic binocular microscope, then transferred to 70% alcohol. The number dynamics of aphids and coccinellids were graphically presented. Sweep net data were transformed to log (x) before computing simple linear regression between aphidophagous and their prey numbers.

Results

Species composition and abundance of aphids

Four aphid species occurred in all study years, in order of importance: *Rhopalosiphum rufiabdominalis* (Sasaki), *Hysteroneura setariae* (Thomas), *Rhopalosiphum maidis* (Fitch) and *Schizaphis minuta* (van der Goot) which averaged 73,1; 23,0; 3,6 and 0,3%, respectively.

In 1995, the population of *R. rufiabdominalis* increased rapidly, reaching a peak of 4743/100 shoots in the first week of October and then declined continuously to catch up with the start level in late September. *H. setariae* was moderately abundant at the beginning and in late October with peaks of 1260 and 1364/100 shoots, respectively (see Figure 1a). In 1996, the abundance of *R. rufiabdominalis* peaked at 3644/100 shoots in mid-October, whereas *H. setariae* was not common until the period middle to late third week of October (see Figure 1c). Whereas in 1995 and 1996 the aphid populations was dominated by the species *R. rufiabdominalis, H. setariae* was the most abundant species during the early growing season (1997). Its population in the field was already 1201/100 shoots as observations begun and a peak was reached in late June. The first individuals of *R. rufiabdominalis* were recorded in mid-June and its activity was low over the experimental period (see Figure 1e).

Species composition and abundance of coccinellids

The community of ladybirds consisted of 13 species: *Lioadalia (Adalia) intermedia* Crotch, *Lioadalia (Adalia) signifera* (Reiche), *Cheilomenes lunata* (Fabricius), *Cheilomenes sulphurea* (Olivier), *Cheilomenes vicina* (Mulsant), *Scymnus* sp. near *declaratus* Mader, *Scymnus floralis* (Fabricius), *Scymnus levaillanti* Mulsant, *Scymnus pallidulus* Wollaston (= *S. rubiginosus* Mader), *Scymnus (Pullus) acutiumerosus* Fürsch (1998) [sp. n.], *Scymnus scapuliferus* Mulsant, *Scymnus senegalensis* Mader, *Xanthadalia effusa* ssp. *rufescens* (Mulsant).

In 1995 – 1996 (Season 2), *X. effusa rufescens* was the most abundant while the *Scymnus* spp. individiduals were most abundant during Season 1 (1997), followed by *Cheilomenes* spp. (see Table I). Adults of *X. effusa rufescens* were the most observed in the fields during the mid- to late growing season. Whereas the peak of abundance (86 m^{-2}) in the first year was obtained during the second 10-day of October, in the following year and in the same month, the population of this species was at its maximum activity (104 m^{-2}) at the beginning fourth week. In the second abundance position came the *Scymnus* spp. individuals with a maximum

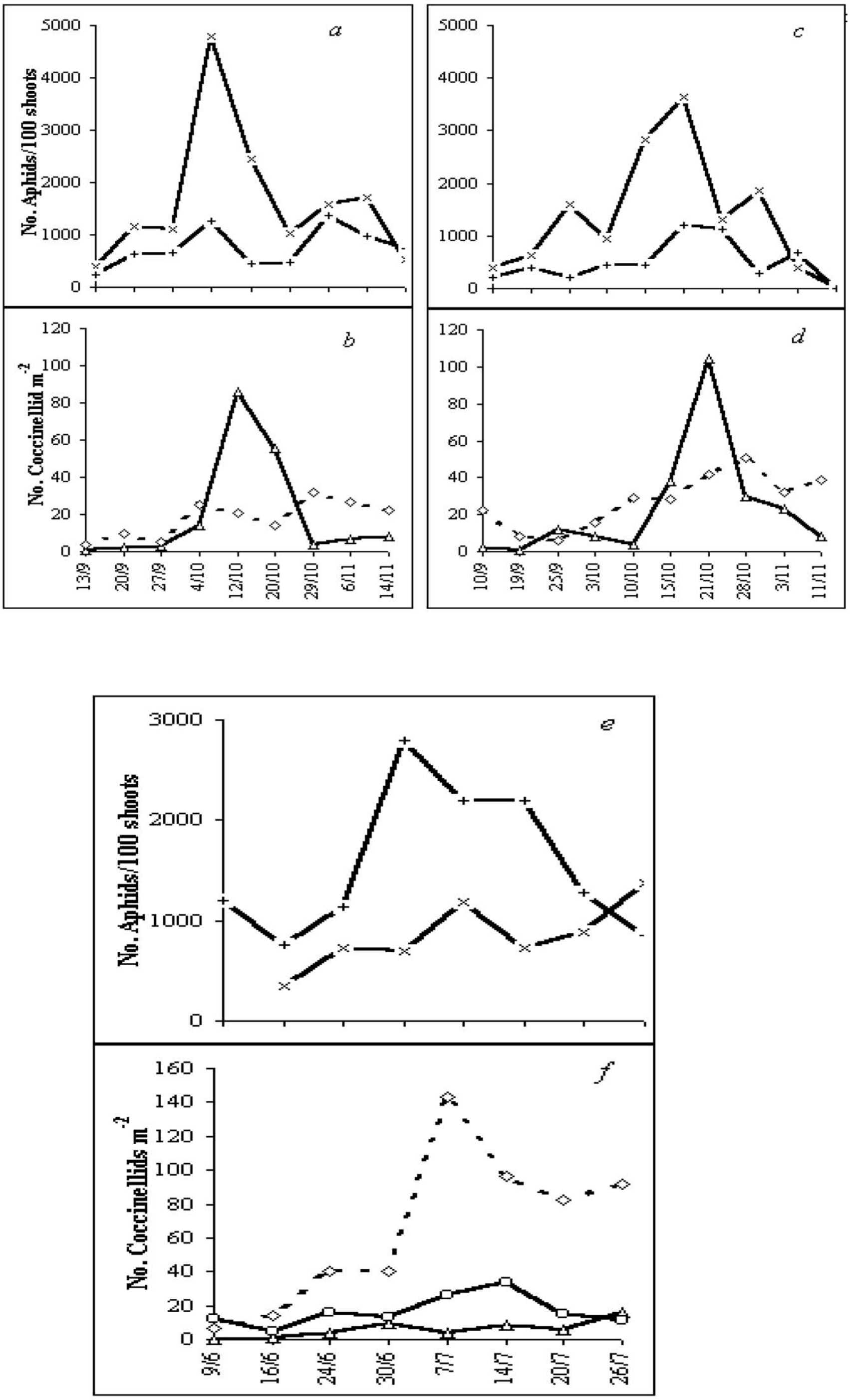

Figure 1. Number dynamics of major aphid species: (*a, c, e*: –x–, *Rhopalosiphum rufiabdominalis*; – + –, *Hysteroneura setariae*) Number dynamics of major ladybird species: (*b, d, f*. –Δ–, *Xanthadalia effusa rufescens*; -◇- , *Scymnus* spp.; – ○ –, *Cheilomenes* spp.) (*a*), (*b*): Year 1995. (*c*), (*d*): Year 1996. (*e*), (*f*): Year 1997.

Table I. Dominant structure (%) of Coccinellidae in Season 1 (1995, 1996) and Season 2 (1997).

		Years		
Sub-families	Species	1995	1996	1997
Coccinellinae	*Lioadalia (Adalia) intermedia* Crotch	0.9	1.4	-
	Lioadalia (Adalia) signifera (Reiche)	1.3	1.0	0.1
	Xanthadalia effuse spp. *rufescens* (Mulsant)	71.0	66.1	6.3
	Cheilomenes lunata (Fabricius)	5.1	7.9	14.2
	Cheilomenes sulphurea (Olivier)	2.3	1.1	6.8
	Cheilomenes vicina (Mulsant)	-	-	19.4
Scymninae	*Scymnus* sp. near *declaratus* Mader	3.6	2.9	9.1
	Scymnus floralis (Fabricius)	3.4	3.8	8.2
	Scymnus levaillanti Mulsant	2.9	4.9	4.7
	Scymnus pallidulus Wollaston (= *S. rubiginosus* Mader)	4.8	5.9	13.7
	Scymnus (Pullus) acutiumerosus Fürsch 1998 [sp.n.]	0.6	0.4	-
	Scymnus scapuliferus Mulsant	2.2	2.4	12.6
	Scymnus senegalensis Mader	1.9	2.2	4.9

density of 32 m^{-2} and 48 m^{-2} in late October 1995 and 1996, respectively (see Figures 1b and 1d).

In 1997 (Season 1), with a density of 143 m^{-2} in earlier July, the *Scymnus*-group was ranked as the most common among the occurred coccinellids, followed by *Cheilomenes* spp. individuals (34 m^{-2}). In contrast to Season 2, the coccinellid *X. effusa rufescens* had no clearly defined peak and appeared with the lowest number (see Figure 1f) in the aforementioned season.

Beetles diversity over four years (1999–2002) totalized 13 species. Species richness of the individual varied from year to year in irrigated plots and the Shannon indexes also marginally fluctuated (see Table II).

Results obtained by sweeping with nets indicated that an increase in aphid population induced a rise in the number of the ladybirds on the fields. When plotting coccinellids number/100 sweeps against aphids number/100 sweeps, a positive significant correlation was found between the two variables in 1995 (Figure 2a) [$r = 0.564$; $p = 0.05$; $n = 18$] and 1996 (Figure 2b) [$r = 0.727$; $p = 0.01$; $n = 18$].

Discussion

Apart from *S. minuta* which has been recorded from rice fields without evidence that rice was colonized (Yasumatsu et al. 1981), the other aphid species are known as feeding on rice in tropical regions, although their economic pest status may vary in space and seasons (Eastop 1961; Garg & Sethi 1978; Dale 1994).

Differences were found in the abundance of aphid species occurring in Season 1 and Season 2. Also seasonal population dynamics and synchronization of aphids and their stenophagous predators were quite different according to both seasons. Earlier studies showed that insects living in rice fields may have a close ecological relationship with the surrounding environment. The insects may move between the two environments or they may move one way only (Yano et al. 1983).

Table II: Ecological data obtained from 1999 to 2002. Values marked with same letter are not significantly different.

Variable	1999	2000	2001	2002
Species richness	11	10	13	9
Population density	2444	2327	1427	1714
Diversity index (H')	2.01[a]	1.77[b]	1.93[b]	2.12[c]
Evenness (E)	0.79	0.69	0.75	0.88

The high abundance of the rusty plum aphid *H. setariae* during Season 1 is probably due to the fact that this species appears in large numbers with May rains in West African agro-ecosystems and remains active on the rice crop until December (Akinlosotu 1980). The relative high occurrence of *Cheilomenes* spp. in Season 1 might be linked to the status of *H. setariae* as prey of *Cheilomenes lunata* (Fabricius) reported by Akinlosotu (1980). The rice root aphid *R. rufiabdominalis* populations congregate on the upper parts of rice roots just above the soil surface, when soils are free-draining and water tables are below the roots of the rice crop (Yano et al. 1983). Its virtual low population level on rice plants during the early growing season, may be caused by favourable conditions at the ground level.

In contrast to Season 1, the aphid population in Season 2 was dominated by *R. rufiabdominalis.* They generally feed on the stem and leaf bases when the aphid population becomes very high and especially when the upper portions of the roots are submerged (Tanaka 1961). Given that water tables in paddy fields in Benue valley remain high from August to October because of heavy rains, this could explain the high colonization of rice shoots and particularly panicles during the watery and milky-ripe grain stages by the species. Studies conducted on seasonal changes in the aerial fauna of rice fields in central India by Reynolds and Wilson (1989) showed that *R. rufiabdominalis* (almost 2/3 of aphid populations in the present study) was the most numerous aphid species in the October (end of raining season crop similarly to North Cameroon) netting samples. In both years, 12 species of coccinellid were found, the most abundant being *X. effusa rufescens* also known as a predator of cotton aphid (Deguine & Ekukole 1996), while *Cheilomenes vicina* (Mulsant), an important predator of aphids in West African agro-ecosystems (Ekukole 1993; Ofuya 1997) was not caught during the above mentioned season.

In both growing seasons and all study years, the coincidence of aphids and ladybirds was synchronized. The change in dominance of aphid as well as that of coccinellid species was observed. The significant positive correlation found between aphid and ladybird populations is a step to gain some insight on the relative importance of this aphid-specific predator group, although the existence of such correlation is not proof of a causal relationship between pest and natural enemies numbers, other possible causes such as migration and weather should be also explored (Wratten 1987). Furthermore, the intensity of the windborne in the site of study is such that aphids would almost inevitably be able to colonize even isolated cropping areas e.g., rice paddy fields surrounded by large areas of rain-fed agriculture.

As shown in Table II, the diversity indexes are relatively low, which indicated according to Mühlenberg (1993) that the paddy fields were moderately populated since the H' values are below 2.40. Woin et al. (2000) also found low diversity index in irrigated rice plots with the same ecology which led to their conclusion that the survival of ladybeetle individuals depends probably on the diversity, quantity and quality of prey availability. A further detailed study on the development cycle and ecology of coccinellids in relation to the meaningful aphid species present in rice environments of the studied site would provide more useful information for an integrated insect pest management scheme.

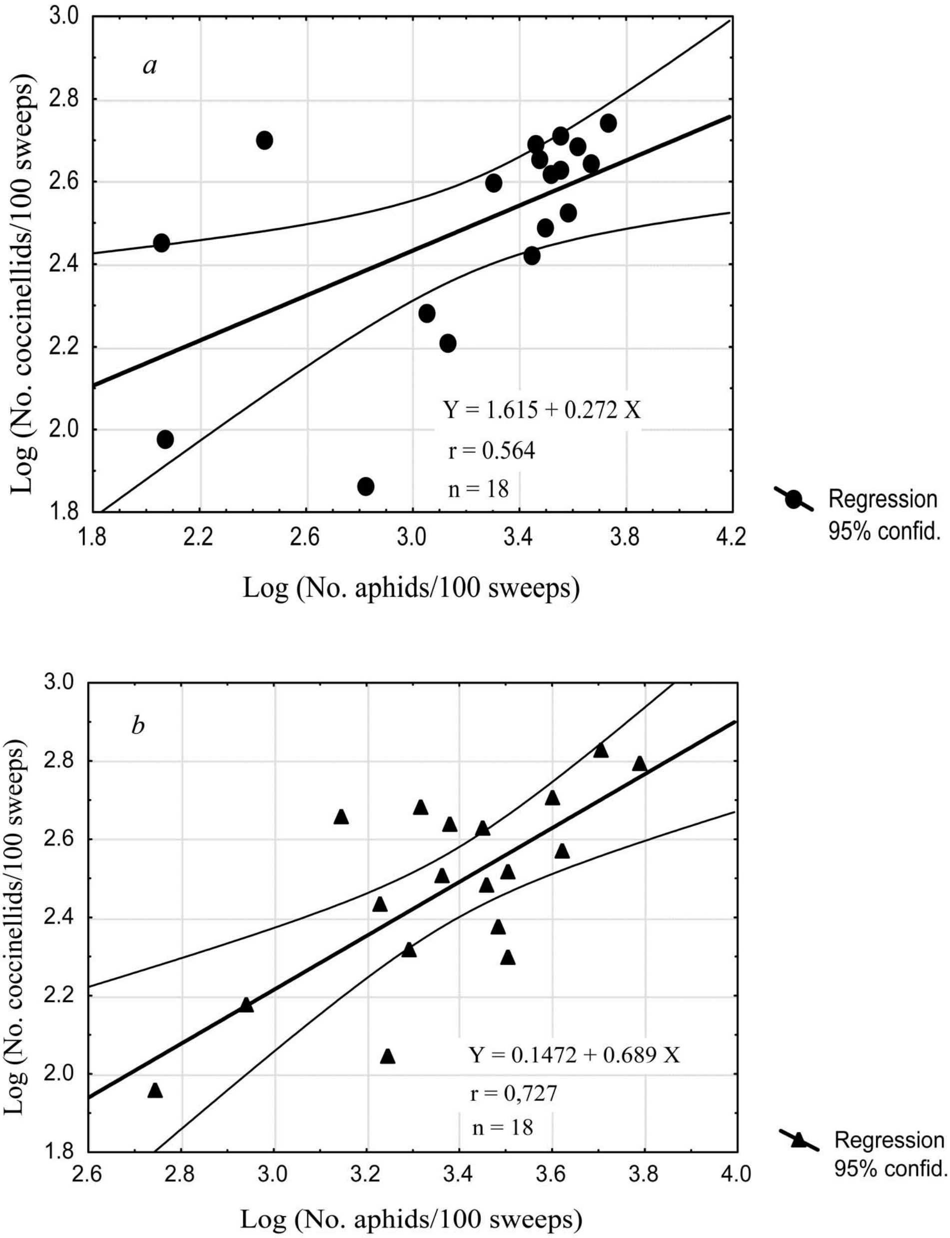

Figure 2. Relationship between aphid and coccinellid populations (1995 (*a*); 1996 (*b*)).

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