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Population dynamics of the *Ricinodendron* psyllid, *Diclidophlebia xuani* (Hemiptera, Psylloidea), and its predators in Southern Cameroon

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Ricinodendron heudelotii (Euphorbiaceae) is a wild fruit bearing tree in the process of being domesticated in Cameroon. *Diclidophlebia xuani* is the most injurious pest on this tree, especially on the seedlings. The annual variations of the psyllid population on its host plant are described. From 2001 to 2002, arthropods were monitored by weekly counts of psyllids and entomophagous arthropods in an experimental orchard at Nkolondom. The damage of the psyllid was assessed. *Diclidophlebia xuani* was present on the host during the entire study period. Outbreaks occurred from February to June, with a peak in April (111.3 individuals per leaf in 2001 and 94.3 in 2002). This period coincided with the foliage renewal of *R. heudelotii* during the long rainy season. Among the predators, the anthocorids arrived early on psyllid infested plants, reaching a maximum in March; their abundance decreased rapidly between April and May; then they were replaced by syrphids whose peak appeared in April. The mirids arrived later in April and reached a higher peak in May and a lower in September. There were positive and significant correlations between the population size of the three taxa and that of the psyllids (anthocorids: $r = 0.588$, $P < 0.0001$; syrphids: $r = 0.389$, $P = 0.000$; mirids: $r = 0.242$, $P = 0.024$). Nevertheless, the relatively low abundance of these predators was insufficient to control the psyllid. Additional control measures will be necessary for successful protection of *R. heudelotii* against *D. xuani*.

Keywords: climatic factors, entomophagous arthropods, plant phenology, Psyllidae, *Ricinodendron heudelotii*, seasonal variations.

INTRODUCTION

Ricinodendron heudelotii (Baill.) (Euphorbiaceae) is a wild multipurpose plant in the Central African forest region. Its oleaginous seeds are consumed as a culinary spice. In Cameroon there are currently attempts to domesticate the plant but, so far, there are no commercial plantations (Fig. 1). The psyllid *Diclidophlebia xuani* Messi in Messi *et al.*,1998 is a major pest of this tree due to its high prolificness (Aléné *et al.* 2005a, 2005b). It attacks mainly young vegetative structures and seriously damages seedlings growing in open areas (Aléné *et al.* 2006). The highest outbreaks of this pest cause conspicuous leaf rolls and premature shedding of the leaves. This usually induces the withering of the apical buds and consequently the die-back of the stem (Fig. 2). The lack of management strategies represents a major impediment to the domestication and the implementation of *R. heudelotii* as shade plant in tropical agrosystems like cocoa plantations.

Up to now several studies on herbivore-plant relationships have focused on the influence of environmental factors, the biology, the behaviour or host plant

Fig. 1. Healthy young plant of *Ricinodendron heudelotii* (4 months old).

selection in various psyllid species (Krysan & Higbee 1990; Cobbinah 1990; Liu & Tsai 2000; Espirito-Santo & Fernandes 2002). Other studies investigated the pattern of seasonal fluctuations of pest population (Osisanya 1974; Van Den Berg & Deacon 1992; Keyhanian *et al.* 2000) or of their natural enemies (Villajeliu 1990; Scutarreanu *et al.* 1994; Bylemans 1996; Souliotis & Broumas 1998; Sen & Verma

Fig. 2. Damage induced by *Diclidophlebia xuani* on a young plant of *Ricinodendron heudelotii* (4 months old).

1998). In classical biological control, the study of the pest population dynamics is an important step. It provides the essential basis in the search for alternative strategies to chemical control, or for optimising the efficiency of chemicals (Webb 1977). It also provides useful data for developing preventive methods against pest outbreaks that take into account the seasonal fluctuations of both the pests and their natural enemies, potential auxiliaries for the biological control (Nyeko *et al.* 2002). Natural enemies of *D. xuani* are mostly predators (Aléné *et al.* 2005a). The impact of the predators on pest populations depends on their density and the average number of prey they consume. For this reason it is essential to study the population dynamics of the psyllid and its predators.

The purpose of the present study is to describe the pattern of annual fluctuation of *D. xuani* populations, to analyse the correlations between *D. xuani* abundance and the damage on *R. heudelotii* with climatic factors and the abundance of the main predators, as well as to compare *D. xuani* fluctuations with host phenology.

MATERIAL AND METHODS

Study site

As *R. heudelotii* is at the moment not cultivated in Cameroon on a commercial scale, field studies were carried out in an experimental orchard at Nkolondom (03° 57' 07" N – 011° 29' 27" E), a small village situated at the foot of a small mountain (1000 m altitude) in the western neighbourhood of Yaounde. The orchard (540 m^2, 234 trees separated from each others by 1.5 m) was set up in April 2000. Young seedlings were obtained from naturally geminating sets under fruit bearing trees. The orchard was situated near a family market crop garden. Consequently, the surrounding vegetation was dominated by various species of vegetables. During the first two years (from April 2000 to December 2001), plants were regularly watered. Also during the period prior to the beginning of the survey (from April to October 2000), they were protected from insect attack by a monthly chemical treatment using «Cypercal® 100», a pyrethrinoid insecticide. The treatments were stopped two months before the sampling started.

In southern Cameroon there are four seasons: the long dry season from late November to late February or early March, the long rainy season from March to June, the short dry season (which is often relatively humid but lacks heavy rainfall) from July to August and the short rainy season (with much stronger rainfall than during the long rainy season) from September to October.

Host plant phenology

Ricinodendron heudelotii is a deciduous plant, widely distributed throughout the tropical rainforests of Central Africa (Tailfer 1989). Its phenology is closely correlated with the local climatic conditions. Adult trees shed their leaves between November and early February (Mapongmetsem 1994; Aléné 2006), i.e. during most of the long dry season. New leaves appear with the first rainfalls in late January or early February and leaf growth remains intensive during two months, before the plant fully regains its foliage. A bud dormancy is observed between July and August (coinciding with the short dry season) as well as between November and early February (which is the defoliation period). From March to June, usually following the first heavy rainfalls, massive seed germination is observed in freshly cleared areas situated in the vicinity of fruit bearing trees (Kyereh *et al.* 1999; Aléné 2006).

Sampling technique

Leaves of *R. heudelotii* from the orchard were examined from January 2001 to December 2002. For this purpose, ten twigs bearing about ten leaves were collected weekly. Each branch was isolated in a labelled plastic bag and taken to the laboratory. There, the visual examination of the plant material was done in order to (i) assess the level of *D. xuani* damage on the leaves, (ii) count the psyllids (old instar larvae and adults) and the associated entomophagous arthropods. Eggs and young instar larvae were counted under a binocular stereomicroscope (Leica M3Z).

Data analysis

For each sampled branch, the damage index (ID) was calculated as the mean percentage of leaf area affected by the psyllid activity. To estimate the ID, we considered three levels of damage on the leaves: healthy leaves, leaves damaged at less than 50 % of the area and leaves damaged at more than 50 % of the area. Assuming that less than 50 % of area damaged gives an average of 25 % and more than 50 % an average of 75 % respectively, the ID was calculated for each week using the following formula:

$$ID=\frac{(L_0\times 0\%)+(L_1\times 25\%)+(L_2\times 75\%)}{L_0+L_1+L_2}$$

Where:

ID is the weekly damage index expressed in terms of percentage of leaf area affected,
L0 is the total number of healthy leaves collected,
L1 is the total number of leaves with less than 50 % of the area affected,
L2 is the total number of leaves with more than 50 % of the area affected.

The mean monthly ID corresponds to the average of the weekly IDs.

The mean population abundance for each *D. xuani* developmental stage (eggs, larvae, adults) as well as for its predators is expressed as the mean number of individuals per leaf (MNI/leaf):

$$MNI\,/\,leaf=\frac{Ni}{Nl}$$

Where:

MNI is the weekly mean number of individuals,
Ni is the total number of individuals counted,
Nl the total number of leaves examined.

For each month, the MNI/leaf is the average of the weekly values.

The statistical analyses consisted of the analysis of variance (One Way ANOVA), the Student *t* test and the Pearson correlation test, using the SAS software (version 8.0).

RESULTS

Seasonal fluctuations of psyllid damage

The monthly mean damage indices observed on young twigs showed significant variations during the study period (DF = 11, F = 10.55, $P < 10^{-4}$). Over all, two periods could be distinguished. The first, with higher damages (ID > 50 %) ran from March to July in 2001 and from March to May in 2002. This phase coincided with the outbreaks of mobile stages of *D. xuani* (Fig. 3), related to the occurrence of young leaves on the trees. The second phase with lower damages (ID < 50 %) ran from August 2001 to February 2002 and from June to December 2002, corresponding with a period of *D. xuani* population decrease and its maintenance at a low abundance (Fig. 3). This phase was simultaneous with leaf maturation on one hand and the defoliation process on the other.

The annual distribution pattern of the mean monthly ID varied between the two years (DF = 1, F = 7.79, P = 0.007). In 2001 there was a progressive increase of the IDs from a minimum in January to a peak in May, followed by a progressive decrease from May to August. In 2002 the low ID values observed at the end of 2001 were maintained up to March when they slightly increased towards a peak in April and suddenly decreased towards a minimum in June (Fig. 3a). Thus, the mean ID in 2001 (48.09 %) was higher than that of 2002 (43.59 %) (Student *t* test, *t* = 2.15, P = 0.04).

The monthly variation of the ID was positively and significantly correlated with that of the mean number of *D. xuani* larvae per leaf (r = 0.70, p < 0.01).

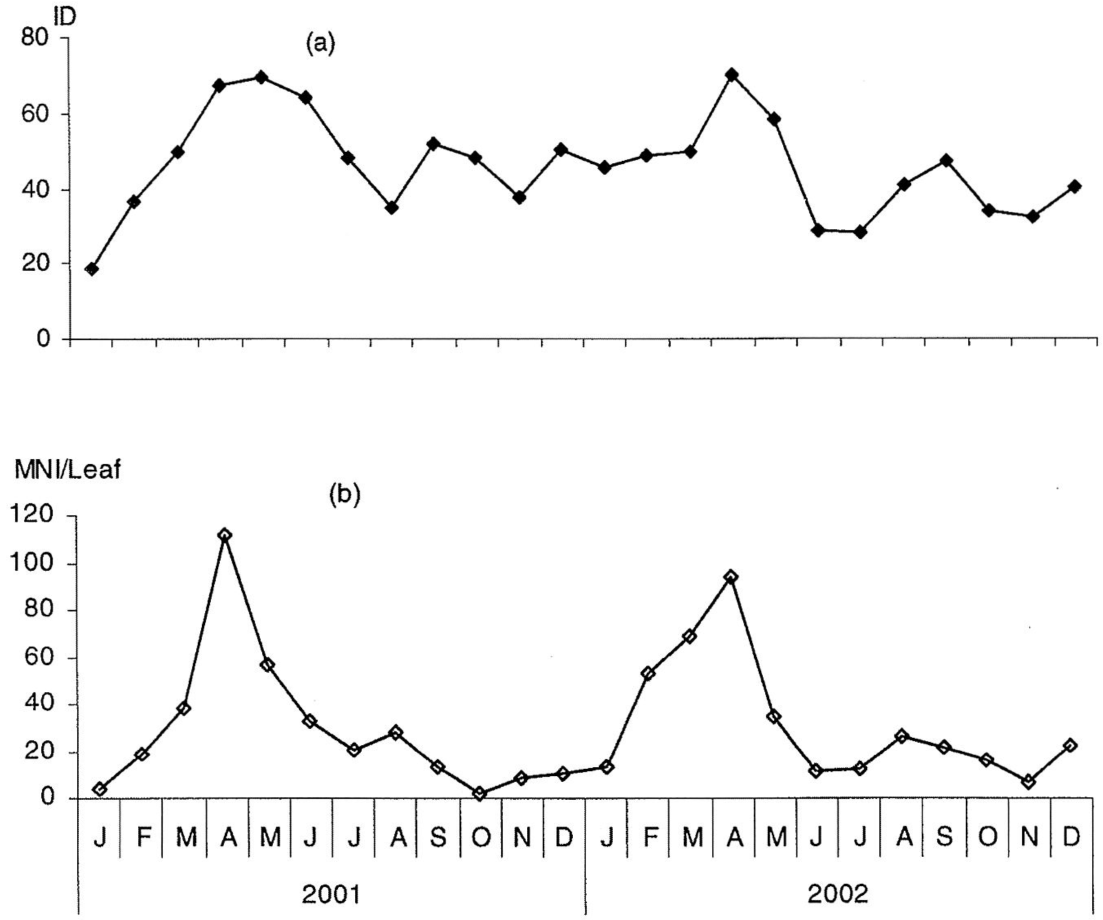


Fig. 3. (a) Monthly variations of *Diclidophlebia xuani* damages. — (b) Monthly variations of *Diclidophlebia xuani* population abundance (mobile instars: all larval instars and adults) on young seedlings of *Ricinodendron heudelotii* in the experimental orchard at Nkolondom. ID: index of damage; MNI/leaf: mean number of individuals per leaf.

Seasonal variafluctuations of mobile stages

At any time of the year, the psyllid population consisted of individuals of various stage and generations overlapped. Therefore, the weekly fluctuations of the population abundance were not likely to be due to a generation effect. For this reason, we analysed our data in terms of monthly mean abundance. The population abundance of the mobile forms of *D. xuani* presented significant monthly variation during the two years (DF = 11, F = 3.30, P = 10^{-3}) (Fig. 3b). In 2001, the mean number of mobile forms per leaf was ranging from 3.3 in January, 111.3 in April to 1.9 in October. In 2002, it ranged from 12.6 in January, 94.3 in April to 6.1 in November. Two phases could be distinguished in each annual cycle. The first one was an intensive infestation phase with a mean number of individuals per leaf over 20. In 2001 it lasted from March to August and in 2002 from January to September, with a severe decline in June and July. During the second phase the population abundance was low with a mean of less than 20 individuals per leaf. This phase ran from September 2001 to January 2002 and from October to December 2002.

This result reveals that the most severe damage (Fig. 3a) coincided with the period of the highest psyllid abundance (Fig. 3b). The period of high psyllid abun-

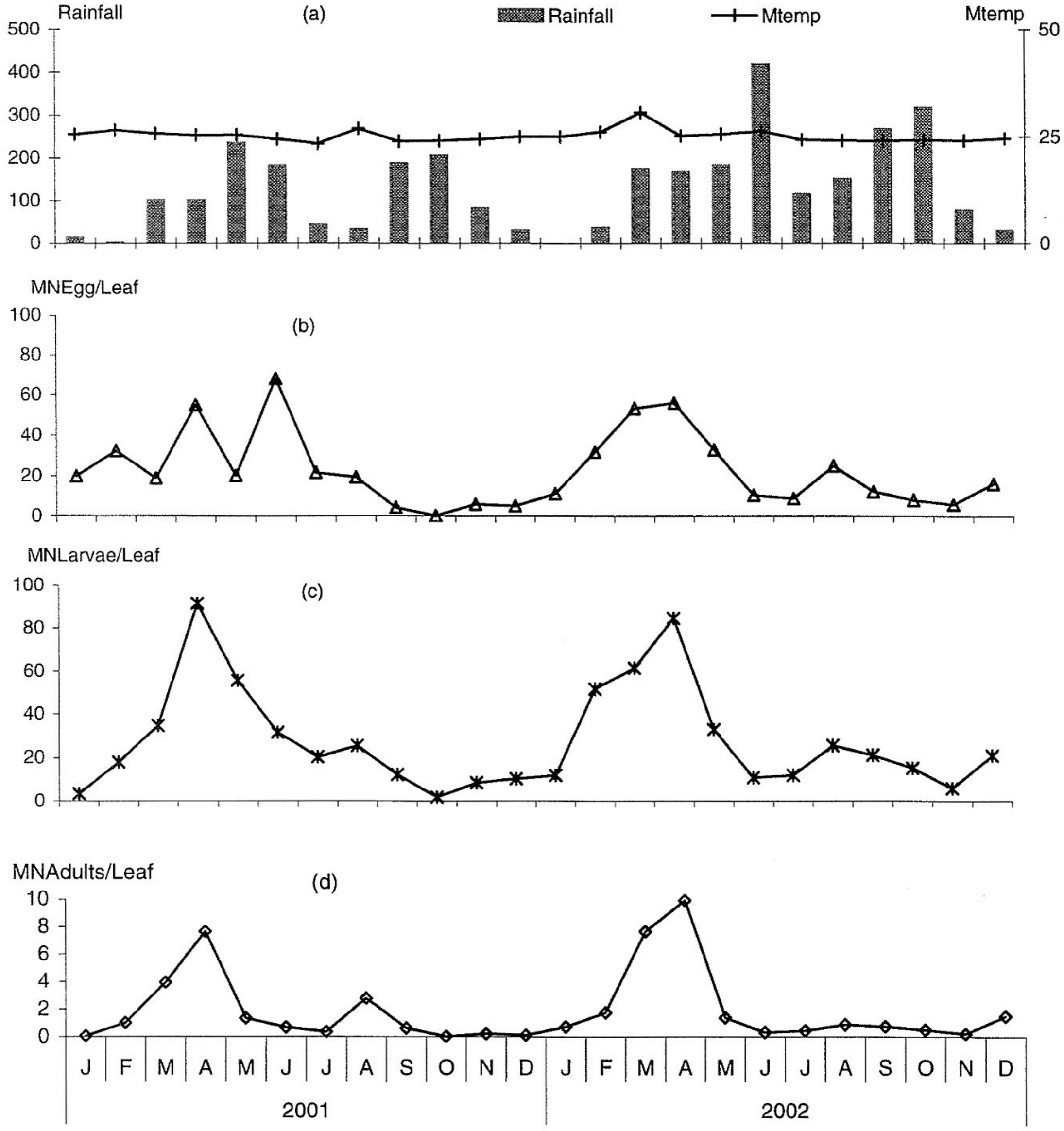
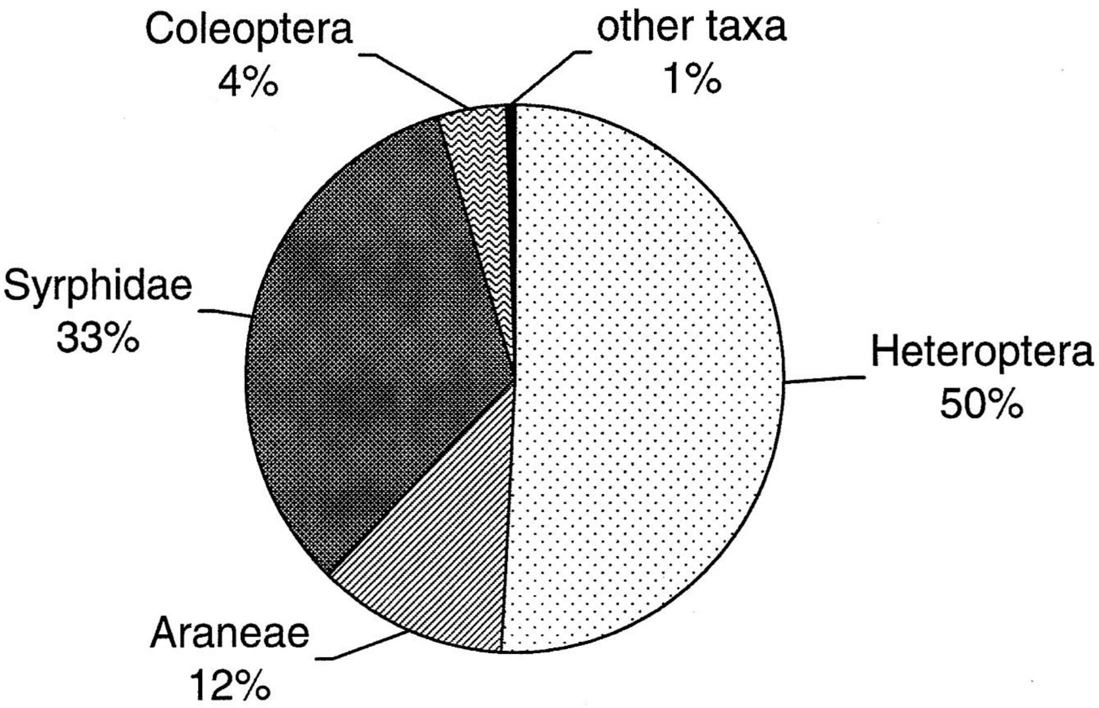


Fig. 4. (a) Ombrothermic diagramme of the Yaounde station; (b), (c), (d), monthly variations of *Diclidophlebia xuani* population abundance at several stages of development on young seedlings of *Ricinodendron heudelotii* in the experimental orchard at Nkolondom. MNEgg/leaf: mean number of eggs per leaf; MNLarvae/leaf: mean number of larvae per leaf; MNAdults/leaf: mean number of adults per leaf.

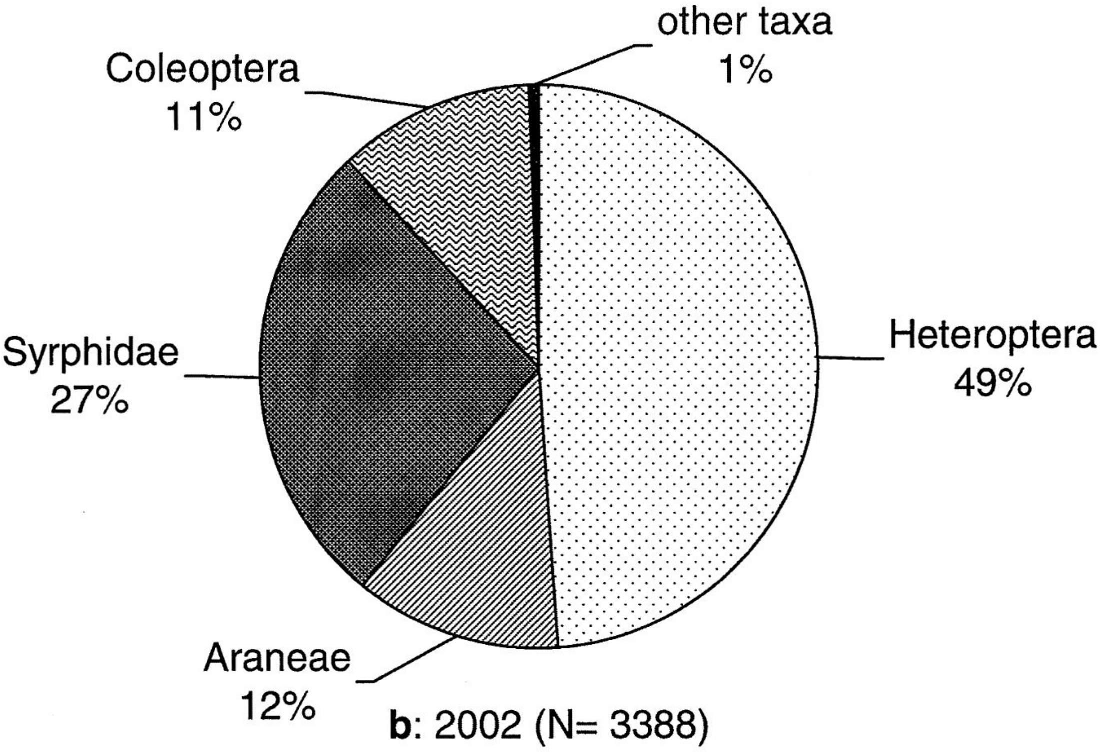
dance and high damage started at the end of the long dry season and lasted the entire long rainy season (Fig. 4a).

Seasonal fluctuations of egg abundance

The monthly variation of egg abundance revealed two main periods (Fig. 4b): (i) the high oviposition phase (over 20 eggs per leaf) ran from February to July in 2001, with an important monthly fluctuation that determined three different peaks in February, April and June respectively, and from February to August in 2002, with a strong decline in June and July; (ii) the low oviposition phase with a monthly



a: 2001 (N = 1936)



b: 2002 (N= 3388)

Fig. 5. Distribution of predators recorded on *Ricinodendron heudelotii* in the experimental orchard at Nkolondom in 2001 (a) and 2002 (b).

mean number of eggs per leaf inferior to 20. The second period is characterised by a progressive decline of the mean egg abundance until October 2001 and November 2002 respectively when the oviposition rate began to increase very slowly.

The general pattern of the monthly variation of the mean number of eggs per leaf varied significantly between the two years (DF = 11, F = 6.01, $P < 10^{-4}$). Moreover, this variation was significantly and positively correlated with temperature (r = 0.42, P = 0.04). Consequently, the mean number of eggs per leaf in 2001 was smaller than that in 2002, with respective average temperatures of 25.0 °C and 25.4 °C. By contrast, the variation of the mean number of eggs per leaf was negatively and non-significantly correlated with rainfall (r = –0.03, p = 0.87) or with relative humidity (r = –0.22, p = 0.28). The decline of the mean number of eggs per leaf observed in March and May 2001, and in June and July 2002 (Fig. 4b) coincided with a great increase of the rainfall during these months (Fig. 4a).

Seasonal fluctuations of larval abundance

The general pattern of monthly mean number of larvae per leaf is similar to that of the eggs. Thus, larvae population increased progressively from January up to a peak in April, and then decreased progressively to a minimal value in October 2001 and November 2002 respectively (Fig. 4c). The fluctuation of egg abundance observed from February to May 2001 but not in 2002 (Fig. 4b) was reflected in the differences between larva abundance in February (17.86 in 2001, 51.52 in 2002) and in March (34.65 in 2001, 61.31 in 2002) (Fig. 4c). Consequently, the larva abundance in 2002 is significantly higher than that recorded in 2001 ($t = 2.48$; P = 0.02).

Despite the occurrence of the two annual peaks in the same months of the two years (April for the first and the higher one, August for the second and lower one), the general annual pattern of monthly variations of the mean number of larvae per leaf varied significantly (DF = 11; F = 3.19; P = 0.002).

The variation of the mean numbers of *D. xuani* larvae per leaf is not significantly influenced by the climatic factors (rainfall: r = 0.06, p = 0.79; temperature: r = 0.39; p = 0.06; relative humidity: r = –0.30, p = 0.15). Nevertheless, it is correlated with that of the eggs (r = 0.77, p < 0.01).

Seasonal fluctuations of adult abundance

Concerning the adults, the distribution pattern of the monthly mean number per leaf is similar to that of larvae for the period of high infestation. During the low attack phase, the pattern, although similar to that of larvae in 2001, was different in 2002 (Fig. 4 c,d). For instance, the small peak observed in August 2001 did not occur in 2002. However, the distribution pattern of the mean number of individuals per leaf did not vary between the two years (DF = 11, F = 1.11, P = 0.37). Consequently, the mean number of individuals observed was not significantly different between the two years ($t = 1.18$; p = 0.24)

The abundance of *D. xuani* adults was neither correlated with rainfall (R = –0.009, P = 0.967) nor with temperature (R = 0.289, P = 0.171) and relative humidity (R = –0.219, P = 0.305).

Seasonal fluctuations of predators

The main predators collected on *R. heudelotii* were: Heteroptera (Miridae and Anthocoridae), Diptera (Syrphidae), Araneae and Coleoptera (Coccinellidae and Staphylinidae) (Fig. 5). The numerically most important taxon, the Heteroptera, was dominated by mirids (> 75 % of the total number of individuals) and anthocorids (> 21 %) (Fig. 6). During the study period, the mean predator abundance, 0.47 individuals per leaf in 2001 and 0.98 in 2002, appeared very low compared to that of the psyllid, which varied from 28.9 in 2001 to 33.2 in 2002 (Fig. 7). The distribution of the monthly abundances of different taxa in the predator community varied slightly from one year to another but generally followed that of the psyllid population (Fig. 7).

The monthly abundance of the main predators (Heteroptera, Diptera, Araneae, Fig. 7) showed slight variations, related to different developmental stages of *D. xuani* (Fig. 4b, c, d; Table 1). It appeared that: (i) the highest peaks of mirids occurring in May 2001 and 2002 followed those of the adult psyllids observed in April, while the lowest observed in August 2001 and September 2002 respectively followed those of the psyllids observed in August; The two parameters are significantly correlated (Tab. 1); (ii) the peaks determined by the anthocorid populations followed the same pattern, but appeared earlier. As for heteropterans, syrphid abundance was correlated with that of the mobile psyllid instars (Tab. 1), but their larvae fed exclusively on the psyllid larvae. Contrary to heteropterans and syrphids, the pattern of population dynamics of the spiders was not superposable to that of the psyllids since the spider populations showed weak monthly variations throughout the year (Fig. 7). Due to insufficient numbers the Coleoptera abundace was not analysed.

DISCUSSION AND CONCLUSIONS

The data obtained from monthly variations of *D. xuani* abundance at various stages indicated two main annual phases: (i) high population abundance from February to September, with a severe decline from June to July, (ii) low population abundance from October to December. This may be linked to the influence of the rainfall on the plant phenology. The main outbreak was observed early in the small rainy season. This corresponded to the active foliage renewal of trees that followed the defoliation during the long dry season as well as massive germination of seeds that occurred in April and May (Aléné 2006). A similar synchronisation was described in *Diclidophlebia harrisoni* Osisanya, 1969, a psyllid feeding on *Triplochiton scleroxylon* (Osisanya 1974), in *Dysaphis pyri* (Boyer de Fonscolombe, 1841), an aphid feeding on pear trees (Cruz de Boelpaepe *et al.* 1987) and in *Toxoptera citricida* (Kirkaldy, 1907), an aphid associated with *Citrus* spp. (Michaud & Browning 1999). Webb & Moran (1978) noted that populations of the psyllid *Acizzia russellae* Webb & Moran, 1974 reached the maximal densities on *Acacia karoo* during leaf renewal of pruned trees; similar observations were done on pear pyllids by Scutareanu *et al.* (1994). In the same way, Cobbinah (1986) showed that the number of *Phytolyma lata* (Scott, 1882) galls was positively correlated to the proportion of young leaves on its host plant *Milicia regia*.

The population abundance of *D. xuani* showed a decrease from a maximum in April to a minimum in August. This minimal value was more or less maintained until December. This population decrease corresponds (i) to the slowdown of foliage

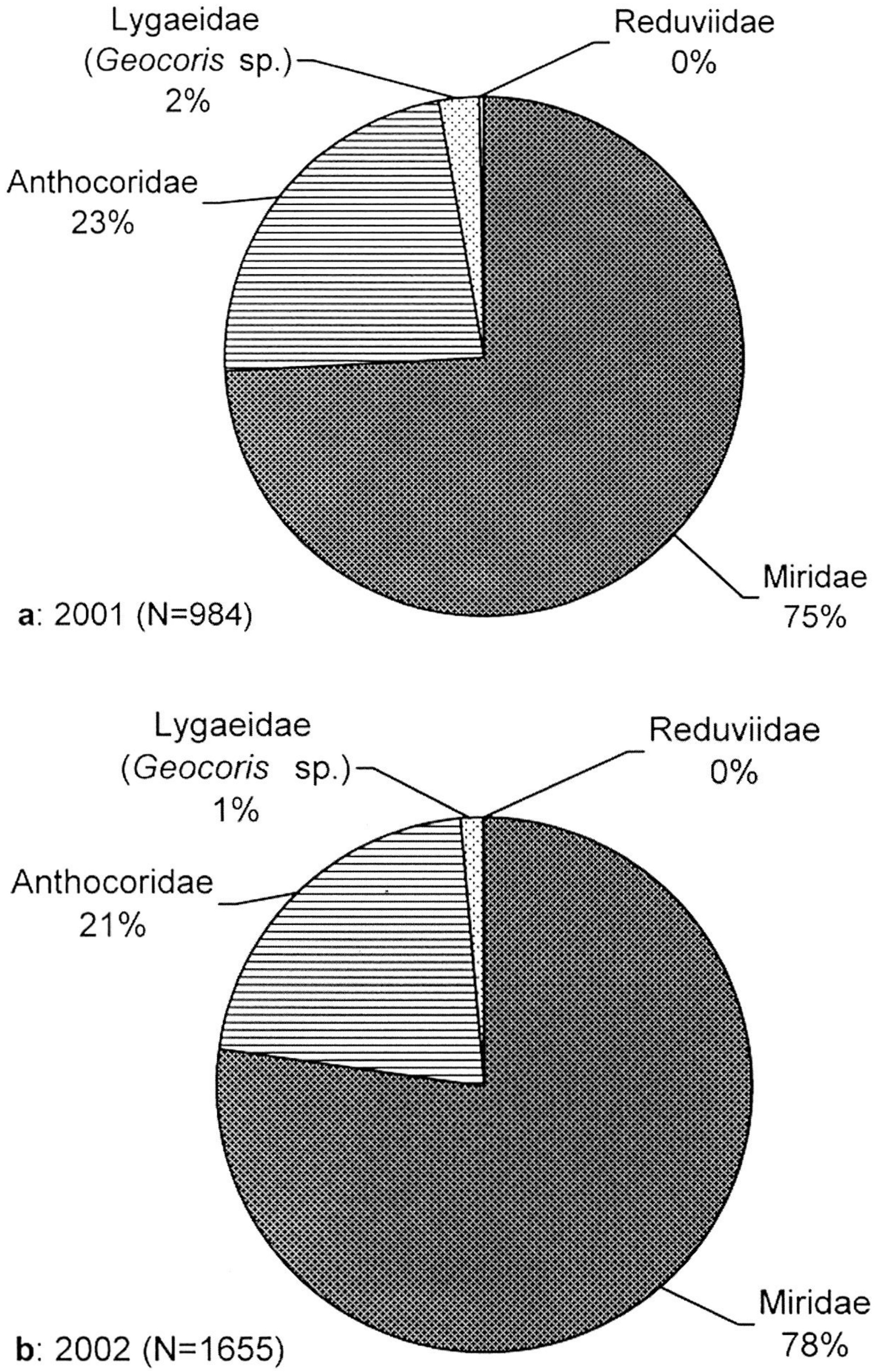


Fig. 6. Distribution of the predacious heteropterans recorded on *Ricinodendron heudelotii* in the experimental orchard at Nkolondom in 2001 (a) and 2002 (b).

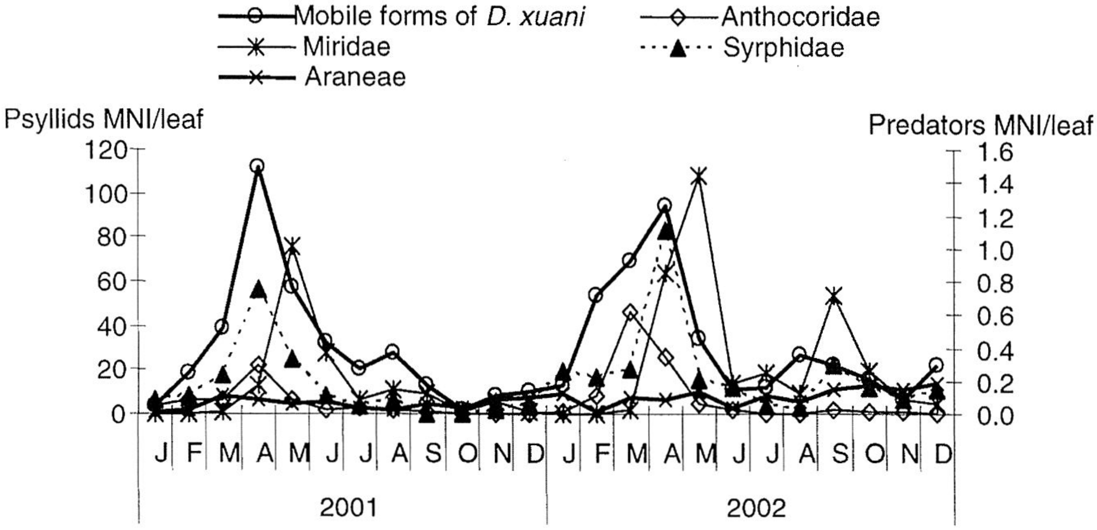


Fig. 7. Monthly variations of the abundance of mobile forms of *Diclidophlebia xuani* and that of its main predators on young seedlings of *Ricinodendron heudelotii* in the experimental orchard at Nkolondom. MNI/leaf: mean number of individuals per leaf.

renewal and the leaf maturation (May to October) and (ii) to the defoliation (November to December). An important strategy of phytophagous insects for survival on a particular host consists in the synchronisation of the insect and host phenologies, necessitating a decrease of population size of the parasite when host sources reach a critical level (Webb & Moran 1978). This hypothesis is supported by Souliotis & Broumas (1998) who showed that the lack of young growth on pear trees during winter plays a significant role in the reduction of the psyllid population size. Purvis *et al.* (2002) explained this phenomenon by the influence of the physiological state of the plant on the population size determinism in the eucalypt psyllid, *Ctenarytaina eucalypti* (Maskell, 1890). Espirito Santo & Fernandes (2002) focused on the importance of the vigour of the plant *Baccharis dracunculifolia* on the development and the survival of the psyllid *Baccharopelma dracunculifoliae* Burckhardt *et al.*, 2004 (cited as *Neopelma baccharidis*).

The decline of the population size observed from May to July depends on two factors: (i) the maturation of leaves that become less palatable for the psyllids, (ii) the increase of the rainfall intensity that could negatively affect the psyllid populations (not significant in the analysis). The decrease of rainfall from July to August may explain the slight increase observed.

In temperate regions psyllid life cycles and survival are often directly related to climatic factors (Bylemans 1996; Sahu & Mandal 1997; Souliotis & Broumas 1998; Keyhanian *et al.* 2000; Kheder & Jerraya 2001; Tedeschi *et al.* 2002). This is not always true for tropical psyllids where the influence of these factors is often indirect. In *D. xuani* the first population increase was closely related to the plant phenology rather than to weather. It began in February, a few weeks before the rainy season. This corroborates the observations of Osisanya (1974) who noted on *Tryplochiton scleroxylon* that *Diclidophlebia eastopi* Vondráček, 1964 and *D. harrisoni* generally appear in the dry season, when the plant undergoes a water stress, stimulating the shedding of old leaves and the production of the new ones. Since

Tab. 1. Correlations between the *Diclidophlebia xuani* populations and predatory community associated with *Ricinodendron heudelotii* at Nkolondom from 2001 to 2002. n.s. = non significant; * = significant; ** = highly significant; *** = very highly significant.

Predatory	*D. xuani* eggs		*D. xuani* larvae		*D. xuani* mobile forms	
	r	p	r	p	r	p
Anthocoridae	0.588	< 0.0001 ***	0.717	< 0.0001 ***	0.736	< 0.0001 ***
Syrphidae	0.389	0.000 **	0.626	< 0.0001 ***	0.625	< 0.0001 ***
Miridae	0.242	0.024 *	0.378	0.000 **	0.351	0.001 **
Araneae	- 0.126	0.245 n.s.	- 0.108	0.319 n.s.	- 0.112	0.304 n.s.

defoliation and leaf renewal of R. *heudelotii* are not simultaneous but rather separate in time (Mapongmetsem 1994), the peaks of *D. xuani* populations are observed early in the small rainy season in April, and during the rainfall decline in August. This does not allow correlating the *D. xuani* population fluctuations with climatic variations (rainfall, temperature, relative humidity). In fact, the larvae and the teneral adults of this psyllid live in very conspicuous leaf roll galls, formed by the plant as a reaction to the infestation. These shelters probably protect them efficiently from the influence of the weather; so that they closely depend on the physiological state of the host plant. Similar observations have been made by Osisanya (1974) on the *T. scleroxilon* psyllids. There, the larvae of *D. eastopi* live on the lower face of the leaves, sheltered from the rainfall but exposed to variations of temperature and relative humidity. On the other hand, larvae of *D. harrisoni* as those of *D. xuani* live in leaf roll galls, where climatic conditions are relatively stable. Consequently, they do not undergo the effects of the local weather. However, egg abundance is correlated with the temperature. This may be due to the fact that the temperature is a stimulating factor for the sexual activity and egg laying in psyllids (Krysan & Higbee 1990; Rieux *et al.* 1990). The *R. heudelotii* phenology appears as the main regulating factor of *D. xuani* population dynamics.

Among the entomophagous fauna associated with *R. heudelotii*, heteropterans were most abundant. The results show a correlation between the populations of Heteroptera and psyllids, especially with regard to the anthocorids. Indeed, many studies on population dynamics of psyllids and their natural enemies show that among predators, the anthocorids play a predominant role in the regulation of the psyllid populations (Vilajeliu 1990; Artigues *et al.* 1996; Souliotis 1999; Jaworska *et al.* 2002). Moreover, our results corroborate those of Scutareanu *et al.* (1999) who showed very significant correlations between the anthocorids and the preimaginal instars of the pear psyllid, but less significant correlations between the anthocorids and the adults of the psyllid. This pattern might be due to the fact that anthocorids feed especially on psyllid eggs and young larvae (Brunner & Burts 1975; Mori & Sancassani 1984). It could also be due to the fact that anthocorids are more attracted by the phenolic compounds produced by the psyllid infested plants than the other predators (Molleman *et al.* 1997).

The slight gap observed between mirid and psyllid peaks comes close to the ecological model in predator/prey systems described by Barbault (1990) and suggests the presence of a strong pressure of this entomophagous bug on the *D. xuani* population. However, some authors consider that the trend to phytophagy of these bugs might reduce their effectiveness as a biological auxiliary against psyllids (Fauvel & Atger 1981; Dolling 1991). Nevertheless, Artigues *et al.* (1996) attribute them a relatively significant role in the natural regulation of pear psyllid populations in Spain.

Unlike in Heteroptera, the peaks of the syrphids were closely synchronized with those of the psyllids. This synchronization might be related to the fact that the syrphid larvae are less agile than the other predators and are feeding mostly on the young psyllid larvae. Moreover, it has been observed by Molleman *et al.* (1997) that the gravid females of syrphids, as anthocorids, are attracted by chemical compounds produced by the psyllid infested plants. We agree with Cadahia (1986) that the syrphids may be of great efficiency in psyllid control. However, in this study their density was too low to suppress, alone, the damage caused by *D. xuani* to *R. heudelotii*. In contrast, the most important predators of the eucalypt psyllid in Chile are syrphids (Olivares *et al.* 2002).

In the predatory community of *D. xuani*, spiders were poorly represented and their population fluctuations were not correlated with those of the psyllids since they do not feed exclusively on psyllids. For this reason, Braza (1987) considered spiders as bad control agents against *Heteropsylla cubana* Crawford, 1914 on *Leucaena leucocephala*. However, in the absence of other prey, they might considerably limit the psyllid populations. Thus Van der Blom *et al.* (1985) attributed to these predacious arthropods an important role in the control of pear psyllid populations. In the same way, Van Den Berg *et al.* (1992) showed that although the spiders were unable to maintain citrus psyllid populations on a tolerable level, they could contribute to the reduction of their number.

As other psyllids, *D. xuani* is preyed upon by several arthropod species which constitute potential auxiliaries for an integrated pest management. Nevertheless, as Solomon *et al.* (2000) emphasized, the low density and the polyphagy of these predators render an exclusively biological control of the psyllid inefficient. As chemical control, apart from being too expensive, destroys also the auxiliary fauna, other control strategies have to be developed. Three areas for further research are suggested here: (i) Aléné *et al.* (2005a) and Aléné (2006) reported *Psyllaephagus* sp. (Hymenoptera, Encyrtidae) as parasitoid of *D. xuani*. As the parasitoid was very rare, it was not included in the analyses and further studies are necessary to examine its potential for efficient pest control. (ii) The search for varieties of *R. heudelotii* which are less susceptible or resistant to insect attack seems a promising field as documented for pear psylla (Bell & Puterka 2004, Pasqualini *et al.* 2006). (iii) Aléné *et al.* (2006) showed that shaded young *R. heudelotii* plants suffered less from *D. xuani* infestation than those grown without shade. This is an easy and inexpensive measure to improve the cultivation success which also avoids monoculture.

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