

PLANT AND ENTOMOLOGICAL DIVERSITIES IN AN ANCIENT PIT MINE: EXAMPLE OF LEPIDOPTERA AND ORTHOPTERA

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Abstract

Description of the subject: Under given climatic conditions, the composition of phytophagous insect community depends on the nature of the plants present and on the existence of ancient perturbations. Insects show varying degrees of dependence on plant species as they feed on a genus, a family or several plant families. The specialization often comes from molecules produced by plants, repulsive or impeding digestion. In parallel, there is a succession of species that will colonize an environment following a disturbance. Pioneer species endowed with great capacity of displacement are followed by intermediaries and then by more competitive ones.

Objective: Through the example of an old open pit mine rehabilitated for 14 years, the relationships between floristic and entomological compositions (Orthoptera and Lepidoptera) are examined in prairie environment.

Methods: As regard Orthoptera-plant relationship, 42 samplings were performed from May to September 2011, on 10 m x 10 m surfaces. As for Lepidoptera, we pooled all the records made in the same period for plants and these insects and considered the host plants of each caterpillar species from bibliography.

Results: It appears that the diversity of Poaceae alone plays a major role in the richness of Orthoptera, being the main nutritive resource of the most diversified group, i.e. the Gomphocerinae subfamily. On the other hand, we observed a proportionality between the diversity of each family of plants with the richness of the Lepidoptera.

Conclusion: In the case of Poaceae-Orthoptera relationship, the repelling secondary metabolites are at a low level, resulting in a quasi-absence of plant species selection. In the case of Lepidoptera, most dicotyledone families produce highly repellent molecules, particularly in Asteraceae and Apiaceae.

Key words: Orthoptera; Lepidoptera; richness; ecological succession.

DIVERSITÉ FLORISTIQUE ET ENTOMOLOGIQUE DANS UNE ANCIENNE MINE: EXEMPLE DES LÉPIDOPTÈRES ET DES ORTHOPTÈRES.

Résumé

Description du sujet: Sous des conditions climatiques définies, la composition des peuplements d'insectes phytophages dépend de la nature des plantes présentes mais aussi d'anciennes perturbations. Les insectes montrent des degrés variés de dépendance vis-à-vis des plantes dont ils se nourrissent: cela peut être un genre, une ou plusieurs familles. La spécialisation vient souvent de molécules produites par les plantes, répulsives ou gênant la digestion. En parallèle, il y a une succession d'espèces qui colonisent un milieu à la suite d'une perturbation. Les espèces pionnières manifestent une grande capacité de déplacement et sont suivies par des espèces intermédiaires et ensuite par des espèces tardives plus compétitives.

Objectifs: A travers l'exemple d'une ancienne mine réhabilitée depuis 14 ans, les relations entre les compositions floristiques et entomologiques sont examinées dans un environnement de prairies.

Méthodes: Concernant les relations Orthoptera-plantes, 42 stations ont été étudiées entre mai et septembre 2011, sur des surfaces de 10 m x 10 m. Pour les Lepidoptera, nous avons rassemblé toutes les données enregistrées pendant la même période concernant les plantes et ces insectes et considéré les plantes hôtes des chenilles de chaque espèce de papillon à partir de la bibliographie.

Résultats: Il apparaît que la diversité des Poaceae seule joue un grand rôle dans la richesse des Orthoptera, étant la principale ressource nutritive du groupe le plus diversifié, à savoir la sous-famille des Gomphocerinae. Par ailleurs, on observe une proportionnalité entre la diversité de chaque famille de plantes et la richesse des Lepidoptera.

Conclusion: Dans le cas de la relation Poaceae-Orthoptera, les molécules répulsives des métabolites secondaires sont à un faible niveau, ce qui entraîne une quasi-absence de choix pour les plantes. Dans le cas des Lepidoptera, la plupart des familles de dicotylédones produisent des molécules hautement répulsives, particulièrement chez les Asteraceae et Apiaceae.

Mots clés : Orthoptera, Lepidoptera, richesse, succession écologique.

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INTRODUCTION

Diversity and abundance of phytophagous insects are largely dependent on vegetation, in terms of species richness, cover, and height [1, 2]. However, there is another factor affecting this relationship: the times elapsed since the last disturbance, or in other words the frequency and intensity of disturbance. In the case of ecological primary succession, the fauna and flora start from a sub complete absence at time zero, because of a huge destroying activity from man for example. Thus, the disturbance appears once, followed by natural processes of colonization. In the flora-insect system, the insect settlement in the new available area is conditioned by flora and interactions between insect species [3, 4].

During the process of succession, we observe primary (pioneers), secondary (intermediate) and later colonizers for which the proportions are yearly changing. Our previous works described the situation for the first 9 years of succession for flora and Orthoptera in Limousin region [3, 4, 5]. We hypothesized that the equilibrium between the different kinds of colonizers was reached at the end of the 9th year, given that the 3rd year was critical, remarkable by a peak of diversity [6]. The first aim of this work was thus to compare the proportion in the different colonizers between 9 years and several years later in the same area.

The second aim was to test the correlation between community parameters of flora and of two orders of Insects, i.e. Orthoptera and Lepidoptera, at the end of 15 years in a succession process. It is well known that in Western Europe, most Caelifera are on grass because they almost feed on Poaceae and allied families (Cyperaceae and Juncaceae), whereas most Ensifera are polyphagous on plant and other insects. A few number of species as *Oedipodacaerulescens* and *Calliptamus barbarous* can eat forbs, i.e. dicotyledones as Fabaceae [7]. In contrast, the larvae of Lepidoptera (caterpillars) can feed on a large variety of plant families at the scale of the family, but on several species in a preferred plant family at the scale of butterfly species. In the case of Pieridae for example, *Leptidea sinapis* feeds on several herbaceous Fabaceae,

whereas *Pieris brassicae* and *P. rapae* on several Brassicaceae. Our hypothesis is that the insect diversity follows plant family diversity.

To conduct this study, we took advantage of the authorization from AREVA to prospect a former Uranium mine site for which the company provided information on the reclamation process and on the starting date of natural colonization.

MATERIAL AND METHODS

The location for this research is a mine site, property of the AREVA company, situated at the coordinates: N 46 5.855, E 1 23.41 which is 0.8 km south-east from Bellezane, in the village of Bessines-sur-Gartempe (Haute-Vienne). The surface of the mine sites is 24,87 ha, of which about 20 ha are composed of regularly mown prairies. From 1975 until 1992 the mine site was used for the extraction of the mineral Uranium. In 1997 there has been a partial filling up with residues of stone and addition of soil from meadows [8]. Seeds embedded with fertilizers were thrown on all the flat areas. The seed mix was mainly composed of *Festuca rubra*, *Festuca ovina*, *Poa pratensis*, *Lotus corniculatus*, and *Lupinus perennis*. The sides of the location are high banks of granitic stone with terraces retaining some soil where a few species of trees were planted (Fig. 1). The most abundant ones were *Pinus sylvestris* and *Pseudotsuga menziesii*.

Each day of sampling, 42 stations were investigated for plant and insect counting in 2011. There were 6 sunny and windless days from the 13 of May and the 1st of July, and 2 extra days in September of the same year. For the analysis of plant species, we recorded the cover of each species over a surface of 10 x 10 m, recognized as homogeneous by its vegetation. For insects, we noted the number of individuals of each species encountered in the same place as vegetation. Some critical species were collected with a sweep net, kept in plastic boxes to be examined in detail in laboratory and identified with specific books for Orthoptera [9, 10] and Lepidoptera [11-13]. Using these references, we also recorded the host plants of each Lepidoptera species. The aim was to associate for each plant family the number of plant species of the site belonging to this family and the number of Lepidoptera species preferring this family as host plant.

For example, the issue was to count the number of Poaceae and Lepidoptera species for which this grass family is the preferred host plant.

We also took into account the observations carried out during the spring of 2006 for plants

and in August of the same year for Orthoptera[8].

To test the relationship between community parameters of plant and insects, correlation analyses were made using PAST 2.17 [14].



Figure 1. View of the mine site. The prairie is on a lower level, dominated by granite cliffs.

RESULTS

We found 141 plants, 19 Orthoptera and 28 Lepidoptera species. Among this last order, the most abundant species were *Brenthis daphne*, *Aglais urticae*, *Maniola jurtina*, and *Melanargia galathea*. Among Orthoptera, Gomphocerinae (6 species) is the dominant group within Caelifera, and *Chorthippus parallelus*, *Euchorthippus declivus*, and *Chorthippus brunneus* are the most abundant species. Among Ensifera, the most represented family is Tettigoniidae with 5 species, of which *Platycleis tessellata* is the most frequently encountered.

1. Comparison of Orthoptera community composition on the whole site between 2006 and 2011

As shown previously [3, 4], grasshoppers, crickets and bush crickets in Limousin region can be divided in pioneer, intermediary and late colonizers (see the list in [8]). The total richness remains unchanged in 2006 and 2011 with about 19 species, but the proportions between colonizers are still changing, as shown in table 1.

There is an increase in the proportion of late species, which came dominant, replacing almost the intermediary ones which were the most abundant in 2006.

Table 1. Percentages of different colonizers in 2006 and 2011.

	2006	2011
Pioneer species	11.3 %	21.1 %
Intermediary species	61.5 %	20.0 %
Late species	27.2 %	58.9 %

2. Relationship between community parameters of flora and insects

Among the data on flora, we took into account the whole list of plants, and the lists of the major families recorded (Poaceae, Asteraceae, Fabaceae, and Brassicaceae). The results of correlation between community parameters of insect and the three most abundant plant families are presented in table 2.

Table 2. Correlation analysis between three plant families and Orthoptera and Lepidoptera. The Pearson coefficient was indicated with the associated p-value.

	Total richness	Total abundance	Poacearichn	Poaceaeabund	Fabaceae richn	Fabaceae abund	Asteraceae richn	Asteraceae abund	Brassicaceae richn	Brassicaceaeabund
Orthopterarichness	0.505	0.518*	0.718**	0.611*	0.621*	0.496	0.285	0.32	0.199	0.199
Orthopteraabundance	0.395	0.436	0.651	0.532*	0.505	0.425	0.139	0.166	0.053	0.053
Lepidopterarichness	0.081	0.073	0.031	0.138	0.052	-0.145	0.233	0.240	-0.036	-0.117
Lepidopteraabundance	0.328	0.307	0.023	0.049	0.216	0.021	0.152	0.206	0.318	0.278

Abbreviations: * = p-0.05; **: p< 0.01; no indication: non-significant.

It appears that Orthoptera richness is mainly dependent on Poaceae richness and at a lesser extent on Fabaceae richness, Poaceae abundance, and total flora abundance. Orthoptera abundance is only dependent on Poaceae abundance. The figure 2 illustrates the strong link between vegetation and Orthoptera richness.

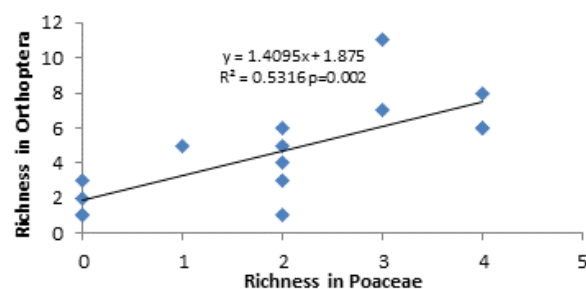


Figure 2. Richness in Poaceae and Orthoptera.

In contrast, we did not evidence factors affecting Lepidoptera community parameters. To go further in this issue, we considered for each plant family the butterfly species for which their larvae feed preferentially on this family. For example, there were three butterfly species (*Araschnia levana*, *Aglais urticae* and *Inachis io*) living on Urticaceae (*Urtica dioica*), and one butterfly species (*Papilio machaon*) living on Apiaceae (*Daucus carota*). The Asteraceae have been removed from the selection because *Tyria jacobaeae* was the only one species living on this family (*Jacobaea vulgaris*).

Finally, 28 Lepidoptera species and 68 plant species were taken into account.

It appears that the number of Lepidoptera species growing preferentially on a given plant family increases with the richness of this family (Fig. 3).

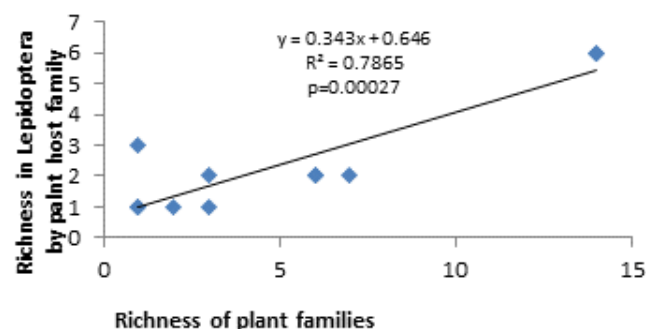


Figure 3. Richness in plant families and Lepidoptera.

DISCUSSION

The observation of the mine site 14 years after rehabilitation reveals markedly changes by comparison to the situation 5 years before. In Orthoptera, the group of later colonizers is now dominant, at the expense of the intermediary ones which were very abundant before. This could be explained by interactions between these kinds of species [3, 4, 6]. It demonstrates that the succession process is very long, and could be due to the relative isolated position of prairies in the lower level of the mine from surrounding environment. New investigations should be carried out to test if there is a decrease in diversity in the future, due to interspecific competition.

CONCLUSION

We found contrasted relationships between flora and insect diversities. It was logical to find an increase of Orthoptera richness with flora: Gomphocerinae, which is the dominant group, is oligophagous on Poaceae, and at a lesser extent on Joncaceae and Cyperaceae. This would not be true in other regions as arid areas in Algeria [15, 16] as many grasshopper species feed on dicotyledones. In spite of the different tests, we were unable to prove that an increase in flora richness influences Lepidoptera richness. It could come from the sampling surface considered: units of 10 m² are certainly too low to provide a good estimation of butterfly richness, as these insects can move easily on larger distances. However, taken the mine site as a whole, there was a proportionality between the richness of plant families and the number of butterflies growing on given families. This relationship was defeated in the case of Asteraceae which accumulate many secondary metabolites (sesquiterpens and glucosids) that repel phytophagous insects. We predict that the strength of association between entomofauna and flora increases in time, through the replacement of insect species more and more specialized toward trophic sources, but this idea should be tested.

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