Ecological cultivation of cassava: to render natural antagonists of sucking pests more effective and reliable
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Ecological cultivation of cassava: to render natural antagonists of sucking pests more effective and reliable

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1. Summary

Successful biological control of insect herbivores implies the use of effective natural antagonists. Many desirable attributes and selection criteria of beneficial organisms have been defined. However, many failures of biological control agents to regulate pest populations could be attributed to a lack of understanding behavioural characteristics of parasitoids in the field, and/or releasing laboratory reared insects of poor behavioural quality. The aim of this study was to elucidate in a comparative approach behavioural traits of two encyrtid endo-parasitoids *Aenasius vexans* Kerrich (Hymenoptera: Encyrtidae) and *Acerophagus coccois* Smith (Hymenoptera: Encyrtidae) related to successful parasitism. Both parasitoid species are significant for biological control of the cassava mealybug, *Phenacoccus herreni* Cox & Williams (Sternorrhyncha: Pseudococcidae) a major Latin American pest of cassava, *Manihot esculenta* Crantz (Euphorbiaceae), an important root crop.

The first chapter (Chapter 4) addresses the host specificity level and the comparative foraging behaviour of *An. vexans* and *Ac. coccois*. The host specificity level of the two parasitoids had to be established as a basis for behavioural studies. Host acceptance and parasitism were analysed in seven mealybug species, with different degrees of polyphagy, occurring in and around cassava fields. Results demonstrated that, in the cassava ecosystem, *An. vexans* is a specialist both at the plant and the host level. *Ac. coccois* is a generalist on the plant and the host level. Of the seven mealybug species, *P. herreni* and *P. madeirensis* Green (Sternorrhyncha: Pseudococcidae) were the most acceptable hosts for *Ac. coccois*, followed by *Ferrisia virgata* Cockerell (Sternorrhyncha: Pseudococcidae). *Ac. coccois* did not accept the other four mealybug species, thus it has a narrow host range. These findings clarified speculations of the host range of the two species. Meaningful host range tests should be performed including components of the target ecosystem into which the antagonist should be released.

The comparative foraging behaviour of individual parasitoids of the two species was observed in bioassays on cassava leaves infested by *P. herreni*. The two
species used different strategies to locate their host. *An. vexans* spent significantly more time walking and standing on an infested leaf and examined a host longer than did *Ac. coccus*. *Ac. coccus*, in contrast, spent more time for oviposition. As a consequence *An. vexans* parasitised more hosts in a given time than did *Ac. coccus*. The rate of offspring production of the two species did not differ. These results suggest that, on short term, the specialist parasitoid is the more efficient forager, while the generalist may better persist on alternate pseudococcid hosts.

The second chapter (Chapter 5) elucidates the possibility to enhance parasitoid performance through releasing locomotory active parasitoids, which were mass-primed prior to release. The two parasitoid species differed in their locomotory activity. *An. vexans* females were increasingly active from approximately four hours after the start of the photophase to three hours before the start of the scotophase. *Ac. coccus* females were already highly active at the beginning of the photophase. For efficient field application releasing the two parasitoid species in their period of increased locomotory activity may be most promising. Mass-priming procedures relied on different contact stimuli from the plant-host complex. Groups of female parasitoids were primed for either 15 minutes or for 18 hours to a host damaged cassava leaf from which mealybugs and by-products were removed, or they were allowed to oviposit. Both naive and mass-primed parasitoids of both species were able to locate the host microhabitat. Surprisingly, there was no significant effect of mass-priming on the number of parasitoids in both species locating the host microhabitat under the conditions of our trials. The rate of offspring production in the different mass-priming treatments was similar as in the naive control groups. The conclusive reason why the foraging success of the specialist *An. vexans* the generalist *Ac. coccus* was not enhanced with a mass-priming experience could not be elucidated. In recent year, however, more questions on generalising learning abilities of natural antagonists have risen. The results suggest, that the examined mass-priming treatments are not a promising tool for the two parasitoid species of cassava mealybug, and that methods to prime individuals may not be directly transferred to mass-priming.
The third chapter (Chapter 6) characterises the influence of a mixed species infestation by mealybugs and spider mites, *Mononychellus tanajoa* Bondar (Acari: Tetranychidae) or whiteflies, *Aleurotrachelus socialis* Bondar (Sterorrhyncha: Pseudococidae), on the mealybug pest and its parasitoids. Mealybug development, distribution and reproduction as well as the post-alighting foraging behaviour and reproduction of the two parasitoid species were analysed in a mixed species infestation as compared to an infestation by mealybugs only. Our results show that total female mealybug development was accelerated when an additional herbivore species was feeding on the same plant. The duration of the third larval instar was shorter when spider mites were also present, and the duration of the second larval instar was shorter when whiteflies were present. Mealybug reproduction was not affected, nor was the ratio of their distribution on the adaxial and the abaxial surface of the cassava leaf. Infestation type and time influenced abundance of mealybugs over their life cycle. The post-alighting foraging behaviour of the specialist parasitoid *An. vexans* differed in the simple and the complex tritrophic systems. The preference of the females for foraging on the adaxial leaf surface in the infestation by mealybugs only disappeared in either of the mixed species infestations. In contrast, the foraging behaviour of the generalist parasitoid *Ac. coccoides* was similar in the simple and complex tritrophic systems. Under the conditions of our trials, both parasitoid species ultimately located hosts, and reproduction did not differ between the single and the mixed species infestations. In field situations diversity is apparent at each trophic level. To evaluate biological control agents in these complex systems, I suggest using defined systems, which reflect this diversity by including relevant species at each trophic level.

In conclusion:
Based on the facts that the solitary specialist *An. vexans* has a high oviposition rate, an efficient host searching behaviour, and a changed foraging behaviour in complex tritrophic systems, and that the gregarious generalist *Ac. coccoides* has a lower oviposition rate, alternate host in the cassava ecosystem, an expanded
locomotory activity during daytime, and an unchanged foraging behaviour in complex tritrophic systems.

- I assume that the two encyrtid species co-exist in the cassava agro-ecosystem through differences in the preferences for host instar and host species, and through differences in locomotory activity and foraging strategy. When released together, the two species may complement each other and enhance biological control effect of *P. herreni*. 
2. Zusammenfassung


Wirtsspezifität von Nutzorganismen zu prüfen sollten das Ökosystem, in welches sie freigelassen werden sollten, mit einbeziehen.


Parasitoide sammelten durch den Kontakt mit verschiedenen Reizen des Pflanzen-Wirts-Komplexes Erfahrungen ("Priming"). Gruppen von Parasitoidenweibchen wurden "geprimt", indem sie während 15 Minuten bzw. 18 Stunden ein durch die Schmierlaus geschädigtes Maniokblatt, ohne den Schädling, berühren, bzw. eine Schmierlaus auf einem Maniokblatt parasitieren konnten. Unerfahrene und erfahrene Parasitoiden beider Arten fanden in diesem Halbfreilandversuch das schmierlausbefallene Blatt einer


Dies führt zu diesen Schlussfolgerungen:

Basierend auf den Tatsachen, dass der solitäre Spezialist *An. vexans* eine hohe Eiablagerate und ein effizientes Wirtssuchverhalten hat, und er sein Suchverhalten in komplexen tritrophischen Systemen verändert; der gregäre Generalist *Ac. coccus* eine tiefere Eiablagerate, alternative Wirte im Maniokökosystem, eine ausgedehnte Bewegungsaktivität, und ein unverändertes Suchverhalten in komplexen tritrophischen Systemen hat schliesse ich:

1. Die beiden Parasitoidenarten *An. vexans* und *Ac. coccus* können durch unterschiedliche Präferenzen für das Wirtslarvenalter und die Wirtsart, sowie durch unterschiedliche Bewegungsaktivitäten und Suchstrategien im Maniokökossystem koexistieren. Würden die beiden Arten gemeinsam zur Reduzierung der Maniokschmierlaus freigelassen, könnten sie sich in ihrer Wirksamkeit ergänzen, und die biologische Schädlingsbekämpfung gegen *P. herreni* hierdurch verbessert werden.