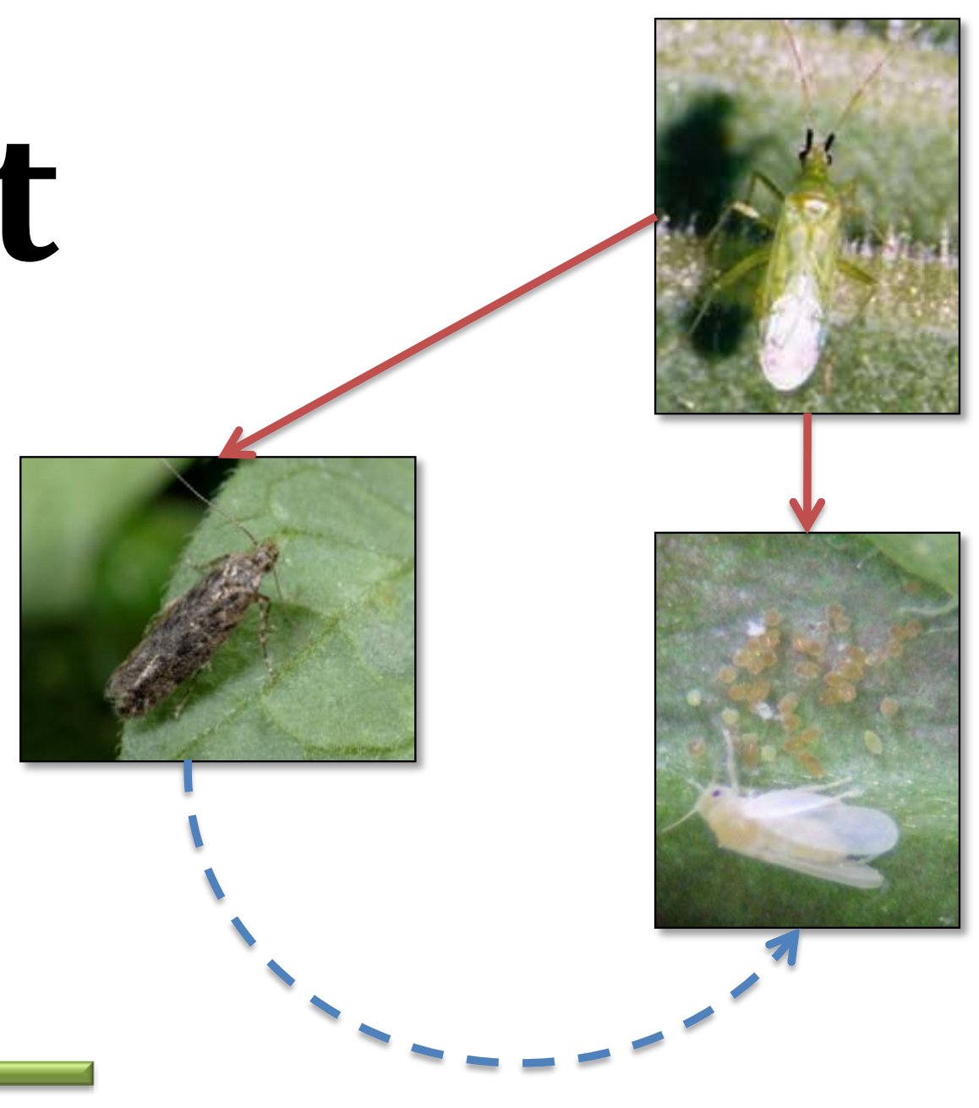
Sharing a predator: can invasive species affect the biological control of an endemic pest?



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Introduction

Direct or indirect biotic interactions have a structuring role in agro-ecosystems (Wootton, 1994). Generalist predators, commonly used in biological control, induce indirect interactions between their prey that can be positive, negative or neutral. An alternative prey can lead to predator development and drastic reduction of the primary prey, through ***"apparent competition"*** (Holt, 1977; Settle & Wilson, 1990). It can also lead to a disrupted predation, resuming of the primary prey growth and ***"apparent mutualism"*** (Abrams & Matsuda, 1996). The outcome of those interactions depends on the predator preference, the time scale and the life history traits of the organisms, and is therefore difficult to predict. Some foraging behaviors of the predator, such as *switching* (specific predation on the most frequent prey), have a stabilizing role on ecosystems (Murdoch, 1969)

In the Mediterranean basin, *Tuta absoluta* is a new invasive pest in tomato greenhouses (Desneux *et al.,* 2010). *Macrolophus pygmaeus*, a generalist predator used in greenhouses to control the whitefly *Bemisia tabaci*, can feed on *T. absoluta* (Urbaneja *et al.,* 2009). Both prey have an economical importance and may interact indirectly through sharing host plant and predator. We carried out preference experiments under controlled conditions and population dynamic experiments in greenhouses in order to assess the indirect effects of *T. absoluta* on *B. tabaci* when sharing the predator *M. pygmaeus* (at different time scales).

Predator preference / short term interactions

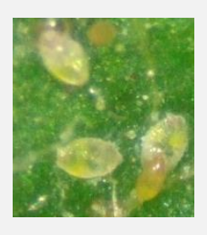
Experimental setup

• Plants: *Lycopersicon esculentum* L.cv. Marmande • Invasive pest: *Tuta absoluta* (T.a.) • Endemic pest: *Bemisia tabaci* (B.t.) (biotype Q) • Predator: *Macrolophus pygmaeus*, starved for 24 h	grown in climatic chambers (24 ± 1°C, HR : 65% photoperiod 16L : 8D)

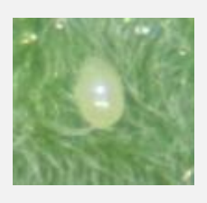
• 5-week tomato plants transferred with the two prey species :
B. tabaci (larvae), *T. absoluta* (eggs + young larvae [L1/L2] equally).
Previous experiments showed that only those stages were significantly eaten by the predator.

• 4 frequencies of prey with a constant total of individuals :
40 B.t./0 T.a. (initial system)
30 B.t./10 T.a.
20 B.t./20T.a.
10 B.t./30 T.a.

• 3 predator treatments: none, 1 larvae, 1 adult (female)
• Surviving prey counted after 48 h



B..tabaci (larvae)



T. absoluta (egg)

T..absoluta (young larvae)

Data analysis

• We used an Anova test to analyze total consumption data set, and a Generalized Linear Model for analyzing potential preference between the two species.

• Preference between the three prey types was studied with Manly equation (Manly, 1994). It gives β_i, the probability for the predator to eat prey *i* when encountering the three prey types in equal proportions ("true" preference).

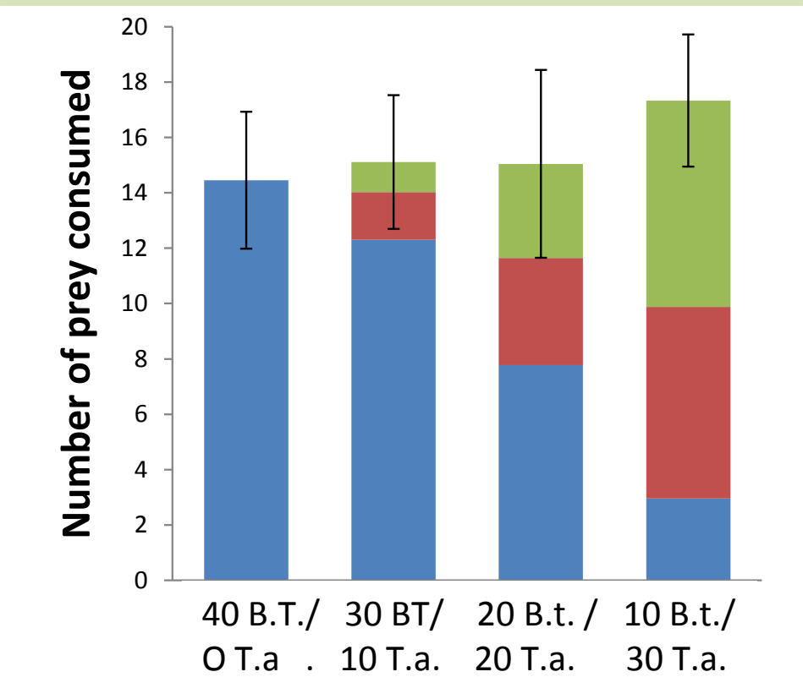


Fig 1. Total and partial prey consumption by adults for each prey frequency. Blue: *B.t.*; red : *T.a.* eggs; green : *T.a.* larvae

Fixed total consumption & disturbed predation

• **Unchanging total consumption** of adults for each frequency (Fig.1)
• **Decrease of the percentage of eaten *B. tabaci*** larvae its frequency ($P < 0.001$)
• Low total consumption rate **sensibility to experimental conditions?**
• Lower, unstable prey consumption for larval predator

Strong impact of prey frequency on predator preference ➔ *switching*

• Significant difference of adult preference at each studied frequency: **the predator preferentially hunted the most frequent prey**, regardless of the random encounter of prey ($P < 0.001$) (Fig.2)
• **Stronger effect of initial frequency** on *B. tabaci* and *T. absoluta* larvae than on *T. absoluta* eggs
• Similar but more unstable results for larval predators.

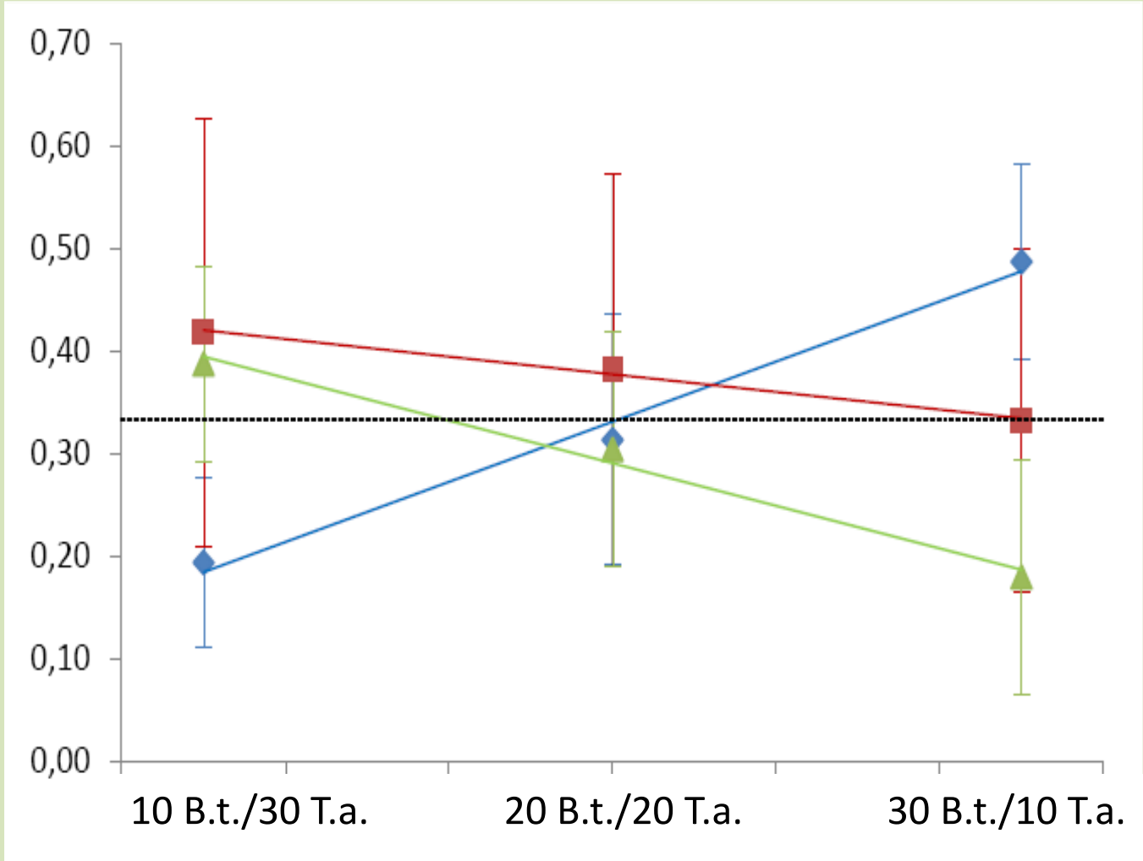


Fig 2. Predator preference (Manly index) for each prey frequency. Black line figures neutral choice
Blue: *B.t.*; red : *T.a.* eggs; green : *T.a.* larvae
All preferences increase with prey frequency.

Population dynamics of the prey in greenhouses / long term interactions

Experimental setup

Fig 3. The experimental greenhouses

• 4 populations : *B. tabaci* alone,
B. tabaci + *T. absoluta* (competition),
B. tabaci + *M. pygmaeus* (predation),
B. tabaci + *T. absoluta* + *M. pygmaeus* (indirect interactions)

• Each population is set up on a tomato row in an fine mesh-enclosed tunnel
• 4 repetitions of the 4 tunnels in the independent compartments of an environment controlled greenhouse (Fig. 3)

• Every week, on 4 leaves/tunnel, data were collected for:
- *B. tabaci* adults, eggs and larvae
- *T. absoluta* eggs, young and old larvae
- *M. pygmaeus* larvae and adults

Fig 4. The inside of a tomato row (continuous vegetal cover)

Direct interactions

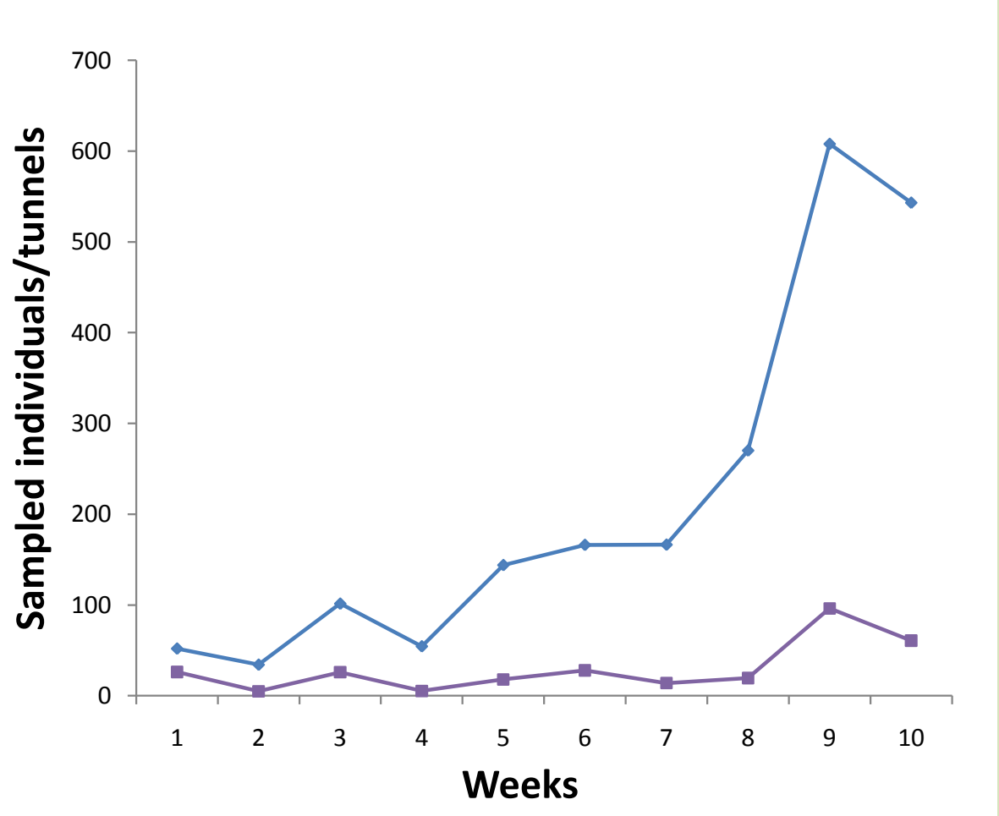


Fig 5. Number of B.t. larvae sampled over weeks when: Blue : B.t. is alone; Purple: with the predator

• Predation on *B. tabaci* (Fig.5)
Limited disturbance : the predator stays efficient against B.t. even with T.a.
(Without *T.a.* P <0,001; with *T.a.* $P = 0.002$)

• Predation on *T. absoluta* (Fig.6)
Strong efficacy of *M. pygmaeus* on T.a. in greenhouse-like conditions with B.t.
$P = 0.004$
After 9 weeks, plants in tunnels with T.a. alone (i.e. no predator) are dead (Fig.7.a)

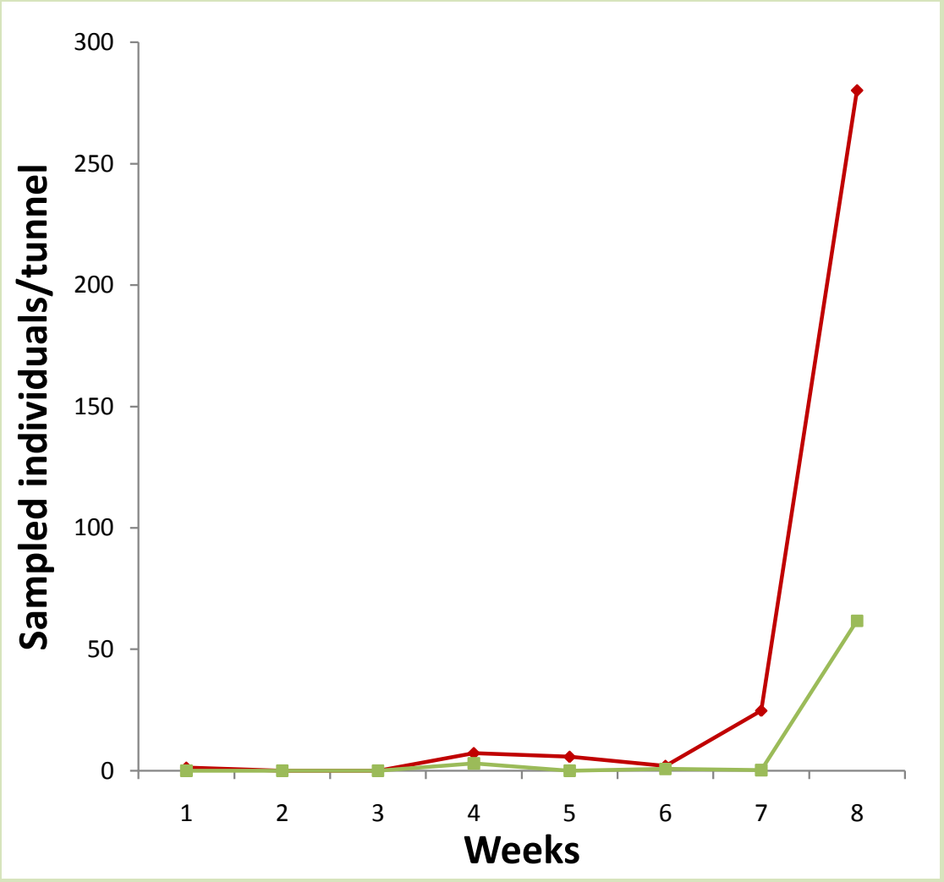


Fig 6. Number of T.a. larvae sampled over weeks. Green : with predator; Red: without predator

Fig 7. Inside of a tomato row with *T. absoluta* the 9th week, without (a) or with (b) predator

Indirect interactions : the effect of *Tuta absoluta* on *Bemisia tabaci*

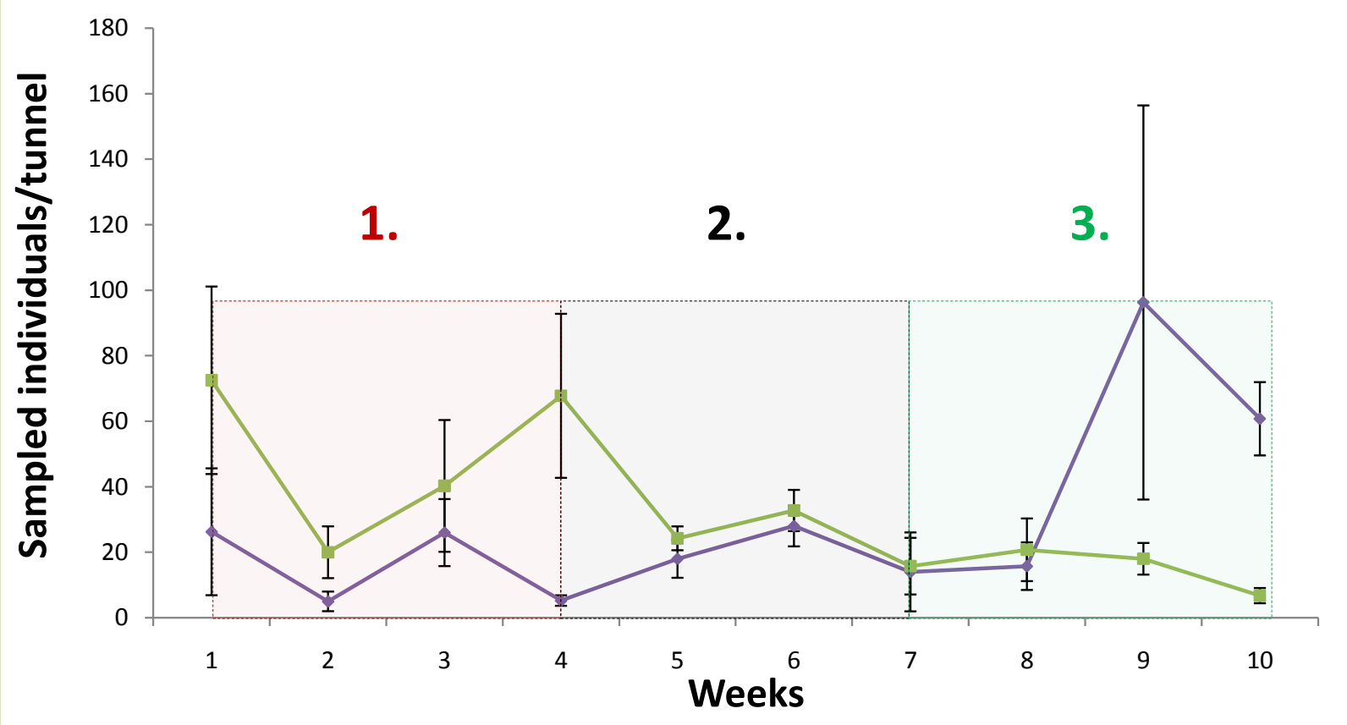


Fig 8. B.t. larvae sampled over weeks. Green: with; Purple: without T.a.

Three distinct periods (Fig.8):

• 1 **Apparent mutualism**: no new predator and limited search. Secondary prey diffuses the predation pressure. $P = 0.003$

• 2 **Neutral interaction**: more new predators in the richer system. Additional predator begin to offset the perturbation effect. $P > 0.05$

• 3 **Apparent competition**: more predators and better prey control in the two-prey system $P < 0.001$

Conclusion

- **Short term**, positive indirect interaction ("**apparent mutualism** ") appears between *T. absoluta* and *B. tabaci*, linked to disruption of *M. pygmaeus* predation, both in laboratory and greenhouse.
- **Long term**, negative interaction ("**apparent competition**") of *T. absoluta* on *B. tabaci*, which appears in greenhouse after 6 weeks.
- **High potential of *M. pygmaeus* for the control of this agro-ecosystem**, both theoretically through *switching*, and practically with a remarkable control of the two pest populations in greenhouses.

The results of this study also can contribute to enhance biological control programs. With inundative biological control, the apparition of a secondary prey only leads to disturbed predation. When multiple prey presence is at risk, the use of generalist predators and inoculative biological control could be more efficient. But generalist predators should be chosen carefully for their preference :
- If **one prey only is a crop pest**, a predator with **simple preference** for the pest should be used. With help of the alternative prey for its development, the predator could strongly reduce the pest.
- If **all prey are crop pests**, a predator with ***switching*** consumption should be used. By concentrating its predation on over-numerous prey, it should be better able to control the ecosystem.

References

Abrams, P., Matsuda, H. (1996). Positive indirect effect between prey species that share predator. *Ecology , 610 -616.*
Desneux, N., *et al.* (2010).Biological invasion of European tomato crops by *Tuta absoluta: ecology, geographic expansion*
Holt, R. D. (1977). Predation, apparent competition, and the structure of prey communities.*Theoretical population biology , 197-299.*
Murdoch. (1969). Switching in general predators : experiments on predator specificity and stability of prey populations. *Ecological Monographs .*
Settle, W., & Wilson, L. (1990). Invasion by the variegated leafhooper and biotic interactions : parasitism, competition, and apparent competition. *Ecology , 1461-1470.*
Urbaneja, A., Monton, H., & Mollà, O. (2009). Suitability of the tomato borer *Tuta absoluta* as prey for *Macrolophus pygmaeus* and *Nesidiocoris tenuis*. *Journal of Applied Entomology , 292 -296.*
Wootton, J. T. (1994). The nature and consequences of indirect effect in ecological communities. *Annual Review of Ecology and Systematics 25 , 443-466.*

Acknowledgements

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