Effects of abiotic factors on plant-insect multitrophic interactions

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Summary

Plants play a central role in mediating species interactions within and between trophic levels. Plants quality and quantity can affect the behavior and development of insect herbivores. Furthermore, these effects may cascade up to higher trophic levels, such as parasitoids and hyperparasitoids, through bottom-up processes. However, in nature, these biotic interactions are inevitably influenced by their complex abiotic environment. Understanding abiotic-biotic interactions is becoming increasingly important in a rapidly changing world. The aim of my thesis was to explore how these climate-related factors impact interactions involving plants, insect herbivores, predators, parasitoids and hyperparasitoids. I first investigated effects of simulated wind and rain on the performance of insect herbivores feeding on their host plants. Secondly, I examined the impact of simulated heatwaves on interactions between parasitoids and hyperparasitoids.

In a greenhouse experiment (chapter 2), I studied direct and plant-mediated effects of simulated wind on the performance of two insect herbivores, *Plutella xylostella* and *Pieris brassicae*, feeding on black mustard plants, *Brassica nigra*. Plants were exposed to four different wind treatments that allowed me to separate direct and indirect effects of wind exposure on herbivores. Morphological and chemical traits of plants and developmental parameters of insect herbivores were measured. The results showed that adults of *P. brassicae* grew larger under conditions of direct wind-exposure, but adults of *P. xylostella* did not. Development time of both herbivores was longer. I further conducted a choice experiment to study effects of wind exposure on the preference of an avian predator (*Parus major*) for caterpillars of *P. brassicae* in an observation room. I found that caterpillars on plants without wind exposure had a higher predation risk than caterpillars on plants with wind exposure. I conclude that *P.*

brassicae can perceive lower predation risk under windy condition, and extends its developmental program by prolonging its larval development to achieve a lager adult body size. Using the same model plant and insect species, I tested the effects of simulated heavy rain on the performance of the two herbivores on plants (chapter 3). Rainfall regimes were set either as a single long or as three short rain showers per day. I found that rain exposure extended the development time of both herbivores and had a strong negative effect on the survival of *P. xylostella*, but not on that of *P. brassicae*. Effects of rain exposure on adult body mass depended on species and rainfall frequency. Overall, plant-mediated effects of rain exposure on the herbivores were generally small. The results suggest that changes in the duration and frequency of rainfall may alter the population dynamics of insects and insect community structure.

In a lab experiment (chapter 4), I examined the effects of different temperature regimes on reproduction and functional responses of two hyperparasitoid species, *Gelis agilis* and *Acrolyta nens*. Host cocoons of two different ages were exposed to three different temperature regimes that represent cool, normal and warm conditions in the Netherlands. I found that temperature had stronger negative effects on the reproduction of *G. agilis* (a less fecund species) than on *A. nens* (a more fecund species). Host cocoons of *C. glomerata* developed faster under warmer conditions. Therefore, I conclude that exposure to simulated heatwaves may change community structure at higher trophic levels. Using the same temperature regimes, I further tested the effects of simulated heatwaves on intrinsic competition between two hyperparasitoids, *Lysibia nana* and *A. nens* (chapter 5). I showed that *L. nana* benefited in competition under warmer conditions. Higher temperature enhanced the competitive advantage of the superior competitor. The results indicate that heatwaves associated with global warming may have the potential to reduce species coexistence in the fourth trophic level.

In conclusion, abiotic factors (wind, rainfall, temperature) had important impacts on the plant-herbivore and parasitoid-hyperparasitoid multitrophic interactions that I tested in this thesis. Wind and rainfall exposure clearly affected the performance of insect herbivores. An extended developmental program was observed in *P. brassicae* as a result of a reduction in predation risk under windy condition. Overall, plant-mediated effects of wind and rainfall exposure were generally small. Exposure to simulated heatwaves differentially influenced reproduction and functional responses of two hyperparasitoid species. Moreover, simulated heatwaves negatively affected fitness of species and species coexistence at the terminal end of food chain. Future studies integrating various climate-related abiotic factors into multitrophic interactions at global scale are urgently needed to mitigate the ecological effects of climate change.