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Review

Phytoseiid mites under environmental stress

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HIGHLIGHTS

- We present an overview of the effect of environmental stressors on phytoseiid mites.
- We discuss the strategies used by phytoseiid mites to avoid or tolerate environmental stress.
- The factors that either promote or depress stress tolerance in phytoseiid mites are emphasized.

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ABSTRACT

Predatory mites of the family Phytoseiidae are important natural enemies of phytophagous mites and small insects. Phytoseiid mites often experience a variety of stresses brought about by changing or fluctuating environmental factors in the field or laboratory or during their commercial production. These factors include abiotic stressors such as extreme temperature and humidity, ultraviolet radiation, and pesticides, and biotic stressors such as cannibalism, intraguild predation, food shortage, and pathogens, all of which affect the biocontrol potential of phytoseiid mites. The extent to which an environmental stressor may affect the biocontrol efficacy of phytoseiid mites depends on the characteristics of the species and on other concurrent stresses. In this review, we discuss the effects of environmental stressors on various biological and ecological aspects of phytoseiid mites, such as development, survival, reproduction, and predation, and the mites' adaptation strategies to these stressors.

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1. Introduction

No living organisms live alone or without environmental stress. This holds true for predatory phytoseiid mites (the family Phytoseiidae of the order Mesostigmata), which are well known natural enemies of spider mites and small insects. The potential of these predatory mites is always suppressed, and their performance lowered, by environmental stress.

Phytoseiid mites are important natural enemies of several agricultural pests such as spider mites, thrips, and scale insects. Applied research on this group of mites started in 1839 with C.L Koch (Chant, 1992) and showed great progress in the 1960s when chemical control of spider mites was jeopardized by acaricide resistance in the field. There are currently 2709 described species of phytoseiid mites within 91 genera, although this species number includes 273 synonyms (Demite et al., 2014). There is no question that phytoseiid mites play a key role in the population dynamics of herbivorous prey species in the field, and this ability is taken advantage of in agricultural pest management. Commercial production of phytoseiid mites (as biological control agents) began in 1968, and 25 commercial products (species) were available by 2010 (van Lenteren, 2012). Attention is now focused on not only expanding the commercial production of these beneficial mites but also enhancing product quality.

Phytoseiid mites are small, with a body shorter than half a millimeter long. Their biological potential is assured by high rates of development and reproduction, which are basically regulated by temperature and prey availability. Under favorable environmental and biological conditions, mites grow rapidly through four immature stages (egg, larva, protonymph, and deutonymph), and mated females, which have a pseudo-arrhenotokous reproductive system (Sabelis and Nagelkerke, 1988), produce several eggs per day. Thus, commercial mass production in the laboratory is relatively easy once the biological requirements of the mites have been met. However, in the field, it is uncommon to see large populations of phytoseiid mites, suggesting that a number of factors influence their abundance in the natural environment (Ferragut et al., 1987; Duso and Pasqualetto, 1993).

Changing or fluctuating environments provoke a range of stresses in phytoseiid mites that adversely affect development, reproduction, survival, and overall biocontrol potential. Environmental stressors that affect phytoseiid mites may be broadly categorized as (1) abiotic stressors, which include temperature, humidity, ultraviolet radiation, and pesticides, and (2) biotic stressors such as cannibalism, intraguild predation within phytoseiid guilds, food shortage and pathogens. Also non-phytoseiid predators, such as non-phytoseiid mite predators, insect predators or spiders, may be important biotic stressors, which may exert both lethal and non-lethal effects (MacRae and Croft, 1996; Venzon et al., 2001; for overviews Gerson et al., 2003a, and Hoy, 2011). However, the knowledge on non-phytoseiid predators of phytoseiid mites is too scarce to account for it in a meaningful way in this review.

The extent to which an environmental stressor influences the potential of phytoseiid mites is coupled with the magnitude and duration of the stress and the concurrency of one or more other stresses (i.e. interaction). Moreover, an environmental stress may be highly species-specific and may vary depending on developmental stage, physiological status (i.e. diapause capability), and sex. For instance, phytoseiid mites may tolerate extremely high or low temperatures or food shortages if the ambient humidity is high (Mori and Chant, 1966a; Stenseth, 1979; Gaede, 1992). Likewise, low humidity may be better tolerated if the temperature is modest and food is available (Walzer et al., 2007). Limited access to food increases the tendency of phytoseiid mites to cannibalize each other or renders them vulnerable to, and easily affected by, pesticides or attack by pathogens (Croft and van de Baan, 1988; Lighthart et al., 1988; Schausberger, 2003). However, phytoseiid mites may perceive environmental cues and exhibit a range of behavioral and physiological phenotypic plasticity (i.e. diapause, acclimatization, anti-predation behavior, or dispersal) in response to stressful conditions. In this review, we will discuss the different aspects of environmental stress and the strategies used by phytoseiid mites to avoid or tolerate stress.

2. Abiotic stressors

2.1. Temperature

Temperature is perhaps the most important abiotic factor controlling the behavioral and physiological parameters of animals. Each phytoseiid mite performs optimally in terms of survival, development, and reproduction in a specific temperature range. However, because the mites are poikilotherms, their body temperature is influenced largely by, and varies with, the ambient temperature. Extremely low or high temperatures provoke stress and could have detrimental effects on phytoseiid mite populations; these effects can range from reduced survival and interrupted development and reproduction to death under chronic exposure. Nevertheless, some species of phytoseiid mites—if not all of them—have evolved adaptation measures such as hibernation to survive harsh temperature conditions. They may also recognize environmental cues early, before the harsh conditions begin, to enter a state of arrested activity such as reproductive diapause (Veerman, 1992). Here, we consider the responses, adaptation strategies, and factors that enable phytoseiid mites to cope with cold stress, including cold storage used for augmentation purposes in commercial enterprises, as well as heat stress.

2.1.1. Cold

Cold stress is caused by the suboptimal temperatures like for instance during winter; it can be divided into chilling stress (from temperatures above zero) and freezing stress (from temperatures below zero) (Salt, 1961). Cold hardening is among the mechanisms used by arthropods to increase their cold tolerance. It is an inher-