



Thermal physiology of dung beetles exposed to ivermectin, a veterinary drug

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ABSTRACT

Global changes, including increasing temperatures and pesticide contamination threaten insect survival and reproduction by altering metabolism and stress responses. Of particular importance are insects that provide ecosystem services and are threatened by multiple stressors, such as dung beetles, which bury dung in forests and cattle pastures. This study investigated how elevated temperature and ivermectin, a common antiparasitic medication used in cattle that is excreted in dung, affect the thermal physiology of *Euoniticellus intermedius* dung beetles under controlled laboratory conditions. Our study evaluated, under laboratory conditions, the effect of the combination of high temperature and ivermectin, on heat tolerance, metabolic rate, and survival of female dung beetles *E. intermedius*. We found that ivermectin reduced survival at 29 °C but not at 33 °C, potentially due to heat-induced hormetic effects, which activate defense systems, protecting organisms from the effects of a second stressor, in this case, ivermectin. Ivermectin and high temperature increased metabolic rate, which could have potential negative effects on oxidative stress and longevity. Finally, critical thermal maximum was not affected by ivermectin or temperature. By impacting physiological traits and individual survival, high temperatures and pesticides may disrupt population dynamics and ecosystem services provided by dung beetles.

1. Introduction

Surviving high temperatures is challenging for ectotherms such as insects (Paaijmans et al., 2013; Stillman, 2019; González-Tokman et al., 2020a). Elevated temperatures challenge insect physiology by increasing metabolic demands and reducing the energy available for essential functions such as growth and reproduction (Atkinson, 1994; Blanckenhorn, 2000; Gardner et al., 2011; Halsch et al., 2021; Harvey et al., 2023). Similarly, high temperatures increase the energetic demands required to keep spiracles open (Chown et al., 2006; Karise and Mänd, 2015), while avoiding water loss and causing death by desiccation (Chown et al., 2006; Ma et al., 2021). Metabolic rates reach the highest values when organisms are at their thermal limit (Ma et al., 2021), but exposure to heat in early life could lead to greater thermal tolerance or heat acclimation when organisms are well nourished (Stillman, 2003; Iltis et al., 2021), favoring survival at high temperature

(Zizzari and Ellers, 2014; Meng et al., 2022). Knowing the extent to which insects respond to increasing temperatures caused by climate change is important since it will define their survival (Tran et al., 2018; Stahlschmidt et al., 2022; Verheyen and Stoks, 2023), reproduction (Iltis et al., 2020; Stahlschmidt et al., 2022) and the persistence of natural populations (Pennuelas and Filella, 2001; Root et al., 2003).

By increasing metabolic rates, high temperatures reduce the energy available for detoxification processes, which are required during pesticide exposure (Dinh Van et al., 2014; Karise and Mänd, 2015; Iltis et al., 2020; Meng et al., 2022; Stahlschmidt et al., 2022; Kenna et al., 2023). Consequently, insects exposed to toxic pesticides can show less stress tolerance, as in damselflies *Ischnura elegans* (Odonata: Coenagrionidae), which show reduced thermal tolerance when exposed to the insecticide chlorpyrifos (Verheyen et al., 2019).

In nature, insects are simultaneously affected by the combination of stressors, including high temperatures and pesticides (Colinet et al.,

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