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Cold tolerance of mountain pine beetle: impact on population dynamics and spread in Canada

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Temperature is a key factor limiting the distribution of mountain pine beetle (MPB) and influencing its population dynamics. The long-term climatic suitability of mature pine forests will be a key factor in delimiting the potential distribution of MPB in Canada, while annual weather patterns will influence the growth rate of established populations. Overwinter mortality is often the single largest source of mortality for MPB, and the northern extent of the beetle's range has historically correlated with the -40 °C isotherm. MPB is freeze intolerant, meaning that insects die if their internal water freezes. The temperature at which spontaneous freezing of body water occurs is known as the super-cooling point, and it is also the lower lethal temperature threshold. Insects may also die at temperatures above the super-cooling point due to desiccation or membrane failure, and a comprehensive assessment of cold tolerance requires consideration of mortality associated with extended exposure to temperatures above the lower lethal temperature. The MPB Cold Tolerance project was initiated to improve our understanding of the ability of different life stages of MPB to cold harden and survive cold winter temperatures. Our ultimate goals are to provide the necessary empirical data and understanding of MPB cold tolerance to: improve predictions of annual population trends based on weather events; and improve climatic suitability and spread models to identify regions at risk and the potential for continued eastward spread in Canada.

Assessing the cold tolerance of MPB by measuring the super-cooling point of individual insects.

Methods

We assessed the cold tolerance of MPB by measuring the super-cooling point of individual insects acclimated under a variety of temperature regimes. The median super-cooling point is the temperature at which 50% mortality is expected. We also subjected insects to different cold treatments for various lengths of time and determined the mortality rate. Calculating actual mortality allowed us to ensure that super-cooling points were reflective of expected mortality, and also assess the effect of prolonged exposure to putatively sub-lethal temperatures (i.e., temperatures above the super-cooling point). Walk-in cold rooms or environmental chambers were used to administer the cold treatments. Logs cut from naturally attacked trees at several sites in western or central Alberta provided the source of insects.

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Results

Determining mortality after exposure to various cold temperature treatments.

Most life stages failed to substantially acclimate to cold by lowering their super-cooling point except for larvae. The median super-cooling point of eggs and pupae were -20.5 °C and -18 °C, respectively, and there was little change in their cold tolerance with acclimation. While acclimation of new adults increased their cold tolerance, their median super-cooling point was only -18 °C. However, both eggs and pupae suffered significant pre-freeze mortality with prolonged exposure to temperatures as warm as -7.5 °C and 0 °C. In contrast to eggs and pupae, new brood adults did not suffer from significant pre-freeze mortality. They were able to survive for extended periods at temperatures above their lower lethal temperature threshold. Larvae collected in late September in Alberta were not very cold hardy, but their cold tolerance increased by 20 degrees with an acclimation period. Our best acclimation treatment led to a median super-cooling point of -35.5 °C, meaning that 50% of larvae could survive brief exposure to this temperature. There was little evidence of substantial pre-freeze mortality in late instar larvae; however, significant mortality resulted from the direct effect of internal ice formation. Some early instar larvae had super-cooling points below -30 °C, but early instar larvae tended to suffer more pre-freeze mortality than late instar larvae.

Implications

MPB eggs and pupae are unlikely to survive winter anywhere in Canada due to mortality at relatively mild temperatures. Brood adults are unlikely to survive an average winter in Alberta but could survive a mild winter as they do in southern British Columbia. Early instar larvae are unlikely to survive an average winter in Alberta in significant numbers. Late instar larvae are the most cold-adapted life stage and suffer little mortality until internal ice forms spontaneously. A synchronous one-year life cycle with late instar larvae entering winter will be critical for MPB survival and spread in Alberta. In addition to the life stage(s) overwintering, the growth rate of a population will affect the impact of a cold-associated mortality event. Specifically, the temperature required to control an outbreak will depend on the population's growth rate. Our future goal is to incorporate the results of the MPB Cold Tolerance project into winter survival and population growth models.

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