SCIENTIFIC NOTE

EDUCATION IS THE KEY TO SUCCESS: THE LEARNING JOURNEY OF PARASITOID WASPS

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Summary

The learning journey for parasitoid wasps to find their host is unique to species. All parasitoid wasps need exposure to the correct plant volatile compound, so that they can learn how to find their hosts as adults. Depending on the wasp species, they may require multiple exposure events throughout their life cycle. *Aphidius ervi*, for example, is a species that requires two exposure events, whereas *Hyssopus pallidus* only requires one. Due to species differences, these learning opportunities must be tailored to species. It's important to understand this, because in artificial rearing conditions, incorrect or absent learning opportunities results in subpar integrative pest management.

Keywords: plant volatiles, exposure, host, chemical compounds

INTRODUCTION

The interaction between parasitoid wasp and host can be so fast, you might blink and miss it. What we see is the result of a lifelong learning journey. What we don't see is how the wasps, even from their larval stage, learn to respond to plant volatile compounds to achieve their goal (Gandolfi *et al.* 2003a,b; Tokemoto *et al.* 2012). Plant volatile compounds are produced by plants when they are damaged through herbivory (Unsicker *et al.* 2009). Parasitoid wasps can learn to respond to the compounds presence to find their host insect (Gandolfi *et al.* 2003a,b; Tokemoto *et al.* 2012). Parasitoid wasps are utilised as an important aspect of integrated pest management in agriculture (Wang *et al.* 2019). They act as a line of defence against the threat of insect pest species such as aphids (Wang *et al.* 2019; Tokemoto *et al.* 2012). It's important to understand the learning needs of wasps that are reared for this purpose. Wasps that do not know how to find their host using plant volatile compounds are a poor line of defence.

THE LEARNING PROCESS: A CASE STUDY FOR *APHIDIUS ERVI*

Parasitoid wasps begin learning from the larval stage (Takemoto *et al.* 2012; Gandolfi *et al.* 2003b). However, some wasps require multiple learning exposures (Takemoto *et al.* 2012). The wasp *Aphidius ervi* needs exposure in their larval stage, but also as an adult (Takemoto *et al.* 2012). They need multiple exposures to be able to learn and retain the information (Takemoto *et al.* 2012). Conversely, other species don't need multiple exposures throughout their life (Gandolfi *et al.* 2003b). There is no hard rule for the learning requirements the wasps need, as the learning process varies between species. Species can vary in the plant volatile compound they need present to learn, and the level of exposure required (Takemoto *et al.* 2012; Gandolfi *et al.* 2003b). It's important to understand the variety of learning requirements between species. Failing to tailor learning experiences to specific species can result in wasps that find it harder to find their host insects as an adult.

Aphidius ervi demonstrated their requirement for learning opportunities at both the larval and adult stage (Tokemoto *et al.* 2012). This double exposure provided *A. ervi* with a learned preference for the right plant volatile compound for their hosts plant (Tokemoto *et al.* 2012). Alternatively, other *A. ervi* that had been exposed to clean air with no volatiles at either of these stages, indicated no preference for different plant volatile compounds (Tokemoto *et al.* 2012). This research demonstrated that this wasp species needed two exposure events, and that one exposure event was not enough.

For *A. ervi*, failure to be exposed to the plant volatile cues that indicated that the aphids (their host insect) were present, resulted in preferences for plant volatile compounds that did not benefit the wasps (Takemoto *et al.* 2012). The wasps in their natural environment would respond to the volatile compounds of *Vicia faba*

(Takemoto *et al.* 2012). If they are not exposed to these specific compounds as a larva, they might respond to plants that are not associated with their host in the wild (Takemoto *et al.* 2012). Exposure to different combinations of plant volatiles (clean air and plants not associated with their host) at larval and adult stages, created different non-beneficial preferences (Tokemoto *et al.* 2012). Ultimately, absence of exposure to specific plant volatiles impacted their ability as an adult.

THE LEARNING PROCESS: A CASE STUDY FOR HYSSOPUS PALLIDUS

The wasp species, *Hyssopus pallidus*, is also impacted by the absence of learning opportunities as a larva (Gandolfi *et al.* 2003b). These wasps use the plant volatile compounds of the host plant (an apple tree in this case), but also the chemical cues provided by the frass of the caterpillar host (Gandolfi *et al.* 2003b). It's important to recognise the difference between *H. pallidus* and *A. ervi*. While both wasps are responding to and learn from plant volatiles, it is occurring only from specific plants. Exposure to the plant volatile compounds provided by the apple trees as a larva, meant as adults they had a stronger response to the chemical cues provided by the caterpillar frass (Gandolfi *et al.* 2003b).

Similarly, Gandolfi *et al.* (2003a), found that when these wasps were exposed to caterpillars impacting a non-host plant, it once again resulted in a situation where the wasps didn't learn to prefer the right plant. The host insects were provided with a wheat germ diet instead of an apple tree diet (Gandolfi *et al.* 2003a). This diet resulted in exposure to different plant volatiles (Gandolfi *et al.* 2003a). The wasps showed no preference between apple tree produced frass and wheat germ frass (Gandolfi *et al.* 2003a). This would impact them as adults, since their caterpillar host in natural environments utilises apple trees, not wheat (Gandolfi *et al.* 2003a).

In this situation, a second exposure of the chemical cues as an adult were not required (Gandolfi *et al.* 2003b). The information was retained from their larval stage, as a clear example of pre-imaginal learning (Gandolfi *et al.* 2003b). Previously, Gandolfi *et al.* (2003a) found that this association with the apple tree volatile compounds could only be learned as a larva. Failure to ever be exposed to the plants chemical cues as a larva could not be corrected in their adult stage (Gandolfi *et al.* 2003a). The absence of this learning opportunity affected them for the rest of their lives.

CLOSING COMMENTS

It's important to realise that the learning process is not a "one size fits all" situation. It is essential for crop managers to receive optimum biological control, and therefore, learning methods must be tailored to the species. Parasitoid wasps can be reared and released to protect crops from pests, but their success at this is impacted by the presence of species tailored learning opportunities (Gandolfi *et al.* 2003a,b; Tokemoto *et al.* 2012). The failure to learn what plant volatile compounds are the right ones to respond to, can result in subpar biological control in crops (Gandolfi *et al.* 2003b). How biological control agents respond to plant volatile cues is incredibly important (Gandolfi *et al.* 2003a). Therefore, testing their response can decide whether they will be effective in integrated pest management (Gandolfi *et al.* 2003a). In artificial rearing conditions, it is up to program managers to ensure wasps are exposed to these learning opportunities to achieve the best result in biological control. Continuing to expand our understanding of parasitoid wasp learning needs, will be critical in their use in biological control schemes going into the future.

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