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Tritrophic effects of plant growth regulators in an aphid-parasitoid system

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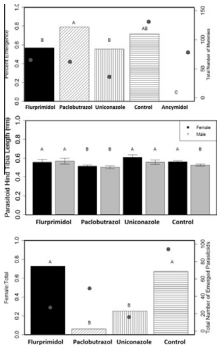
HIGHLIGHTS

- We did not observe any significant effect of PGR on aphid abundance.
- We observed significantly less mummies on paclobutrazol treated plants.
- PGRs can significantly reduce parasitoid emergence, size and female ratio.

GRAPHICAL ABSTRACT



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ABSTRACT

Plant growth regulators (PGRs) have the potential to negatively affect the outcome of biological control via plant architectural changes and plant chemical changes. Despite studies demonstrating the negative effects of PGRs on herbivore survival and development, to date, no studies have investigated the tritrophic effects of PGRs on parasitoid life history traits. In this study we investigated the effect of four commonly used PGRs on *Myzus persicae* abundance and suppression, and *Aphidius colemani* fitness in a greenhouse experiment. None of the PGRs reduced aphid abundance alone or affected aphid suppression by *A. colemani*. However, paclobutrazol reduced the number of mummies that developed on plants. PGRs had a range of negative effects on parasitoid fitness. No adult parasitoids eclosed from mummies on ancymidol treated plants. Paclobutrazol reduced parasitoid size, and paclobutrazol and uniconazole reduced female:total ratio. This study shows that PGRs can negatively affect parasitoid fitness, and reduce parasitism, suggesting the potential for negative long-term effects on the efficacy of biological control.

1. Introduction

The efficacy of augmentation biological control is often unpredictable as it is influenced by many biotic and abiotic factor (Collier and Van Steenwyk, 2004; Frank, 2010). Although the effect of many ecological interactions on biological control efficacy has been well studied (Holt and Lawton, 1994; Martinou et al., 2010; Fill et al., 2012), we know little about the impact of common horticulture practices such as the use of plant growth regulators (but see Oetting and Latimer, 1995 and Uçkan et al., 2008). Plant growth regulators (PGRs) are non-nutrient, organic compounds used in ornamental plant production to modify plant growth and development (Basra, 2000). PGRs can be used to reduce plant growth rate, improve coloring, increase branching and bushiness, or synchronize flowering times (Basra, 2000). By changing plant chemistry, physiology, and architecture PGRs may alter arthropod behavior and development (e.g. Prado and Frank, 2013). Although PGRs are widely used in horticulture and agriculture, still much remains to be known about their effects on herbivores, natural enemies, and their interactions.

PGRs have the potential to reduce pest population growth by reducing fecundity, egg viability, and increasing development time (Visscher, 1980; Coffelt et al., 1993; Kaur and Rup, 2002). For

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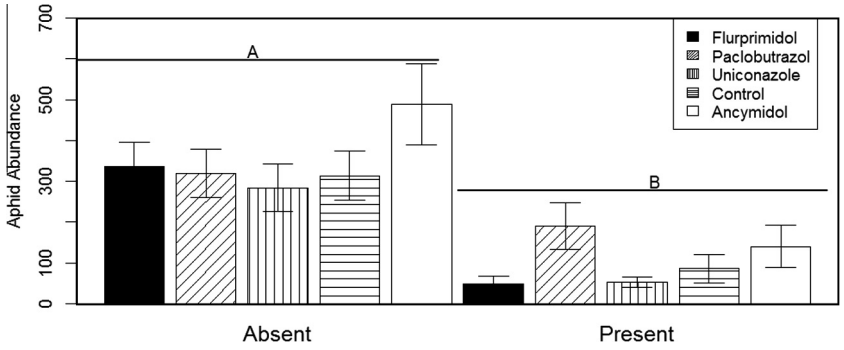

Fig. 1. Overall mean (±SE) number of aphids on caged pepper plants during a three week experiment in which plants were untreated or treated with one of four PGRs and had parasitoids absent or present within the cages. Though a non-parametric mixed-effects ANOVA was performed to determine the effects of parasitoids and PGRs on aphid abundance, the untransformed aphid abundances are presented in this graph. Different letters above horizontal bars indicate significant ($P < 0.05$) main effect of parasitoids on aphid abundance.

example, Coffelt et al. (1993) showed that high doses of paclobutrazol significantly slowed the development and decreased the survival of *Anisota senatoria* Smith (Lepidoptera: Saturnidae). Several phloem feeding insects including aphids and lace bugs are also negatively affected by PGRs (Honeyborne, 1969; Coffelt and Schultz, 1988). Chlormequat chloride was found to reduce *Aphis fabae* Scopoli (Hemiptera: Aphididae) fecundity and survival, and ethylene-bisnitrourethane to reduce its size (Honeyborne, 1969). Although we have some evidence that PGRs can compromise herbivore development (e.g. Visscher, 1980; Coffelt et al., 1993; Kaur and Rup, 2002), few studies have investigated the effects of these chemicals on natural enemies.

By affecting the quality of aphid hosts, PGRs could alter parasitoid abundance, fitness, or efficacy. For example, Honeyborne (1969) found that chlormequat chloride and N-dimethylaminosuccinamic acid (B995) reduce aphid size. Parasitoids developing in these smaller hosts may also be reduced in size (Sequeira and Mackauer, 1992) resulting in reduced fecundity (Ellers et al., 1998; Eijs and van Alphen, 1999; Sampaio et al., 2008). Parasitoids developing in small hosts also tend to have higher male sex ratio and mortality rates than those developing in large hosts (Jarosik et al., 2003). Additionally, small parasitoids tend to have fewer fat reserves (Ellers et al., 1998; Eijs and van Alphen, 1999), thus reducing their dispersal potential (Ellers et al., 1998) and their ability to survive when food is unavailable (Ellers et al., 1998; Eijs and van Alphen, 1999). Along with altering parasitoid life history traits, PGRs can reduce parasitism by increasing plant architectural complexity (Prado and Frank, 2013). Thus, the potential benefit of PGRs to reduce pest population growth could be nullified if negative effects on parasitoids disrupt biological control programs.

Myzus persicae Sulzer (Hemiptera: Aphididae) is one of the most important pests of greenhouse ornamental and vegetable crops (Heathcote, 1962). *M. persicae* feeds on over 100 vegetable and ornamental plant species (Baker, 1994), many of which are treated with plant growth regulators during greenhouse production. *Aphidius colemani* Viereck (Hymenoptera: Braconidae) is a solitary, koinobiont, endoparasitoid (Starý, 1975) used for biological control of economically important pest aphids including *M. persicae* (van Steenis, 1995). As such, *A. colemani* development is closely tied to its hosts' development, making it vulnerable to changes in host quality, when its host feeds on toxic or low quality plant material (Kalule and Wright, 2005). In a previous experiment, we showed that the PGR paclobutrazol reduced aphid suppression by *A. colemani* by increasing plant architectural complexity (Prado and Frank, 2013). In this study, we expand on our previous research to include four of the most commonly used PGRs (Whipker and Evans, 2012) to determine (1) how different PGRs interact with *A. colemani* to affect *M. persicae* abundance and suppression, and (2) how different PGRs affect *A. colemani* fitness and abundance. To achieve our objectives, we compared aphid populations on ornamental Black Pearl Pepper plants (*Capsicum annuum* 'Black Pearl') treated with one of four plant growth regulators to each other and to untreated plants in the presence and absence of *A. colemani*. Furthermore, we compared life history traits of parasitoids reared on treated and untreated plants. This research will be the first to document the effects of multiple PGRs on an aphid parasitoid's fitness and efficacy, and should assist in improving biological control programs.

2. Methods

2.1. Study system

A. colemani were purchased from Koppert Biological Systems (Howell, MI) (product: Aphipar). Upon receipt, the mummies were placed in a 61 × 61 cm cage where the parasitoids could emerge and mate. During that time, they were provided with a 25%

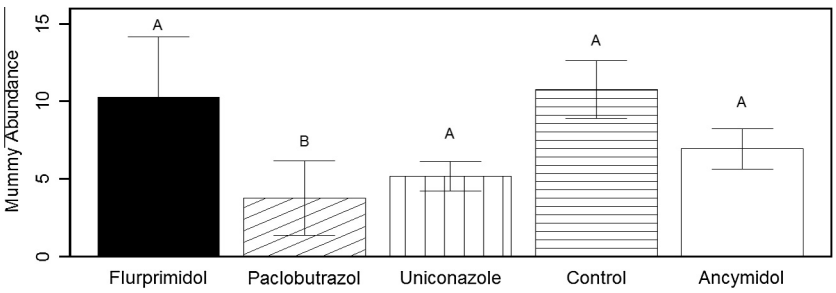

Fig. 2. Overall mean (±SE) number of aphid mummies on caged pepper plants with parasitoids during a three week experiment in which plants were untreated or treated with PGRs. Though a non-parametric mixed-effects ANOVA was performed to determine the effect of each treatment on mummy abundance, the untransformed mummy abundances are presented in this graph. Means with different letters are significantly different at the $P = 0.05$ level.