# INDIRECT EFFECTS OF INVASIVE INSECT MANAGEMENT ON FOREST INSECT ABUNDANCE

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A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

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DECEMBER 2022

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INDIRECT EFFECTS OF INVASIVE INSECT MANAGEMENT ON FOREST INSECT ABUNDANCE

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## ACKNOWLEDGEMENTS

I would first like to thank my advisor, Dr. Kevin Rice for sparking my interest in entomology and convincing me to trade a world of birds for a world of bugs. His excitement and zeal for entomological research is absolutely contagious. I would also like to thank him for his patience, guidance, and encouragement throughout this journey. I'd also like to thank my committee members, Dr. Deborah Finke and Dr. Thomas Bonnot for their incredibly helpful suggestions and feedback for this manuscript. Further, I would like to thank Justice Boyes, Christopher Kalogeris, Markos McAuliffe, and Eze Pojmann-Ezeonyilo for assisting with my field and laboratory work. Their positive attitudes and hard-working demeanor turned even the hottest and muggiest days of fieldwork into an absolute blast. I am also incredibly grateful for my lab mates, Emily Althoff, Kelsey Benthall, and Layne Leake for their unwavering support and encouragement throughout this endeavor. A special thank you to Andrew Biggs who organized and carried out soybean planting and insecticide applications at our research sites for both years. Without his efforts, none of this would have been possible. And finally, I'd like to thank my incredible husband for putting up with me through the countless sleepless nights, allowing me to drag him out to help with fieldwork, and for being my biggest cheerleader. Thank you.

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## ABSTRACT

Invasive species, climate change, habitat destruction, and pesticides are severely threatening insect biodiversity on a global scale. In particular, invasive species are arriving in novel habitats at accelerating rates and are one of the greatest threats to biodiversity. In agricultural systems, invasive insects disrupt established integrated pest management programs, as growers primarily rely on chemical control. Japanese beetle (*Popillia japonica* Newman) is an invasive insect species that continues to spread throughout the Midwest. Soybean growers manage this pest with 3-4 additional insecticide applications per season, resulting in non-target effects on beneficial insects within agricultural systems. While many studies have quantified these non-target effects within agriculture, none have quantified the effects of these increased insecticides on insect populations in adjacent natural ecosystems. We investigate the effects of insecticide applications targeting Japanese beetle in soybean systems on insect abundance in adjacent forests. Treatments consisted of soybean fields treated with three weekly insecticide applications and untreated control fields. Samples were collected in field-adjacent forests at 4 sample sites along 40-meter straight-line transects. We compared the abundance of arboreal insects using yellow sticky traps deployed throughout forest canopies and ground-dwelling insects using pitfall traps. We observed significant reductions in overall insect abundance including key predator and parasitoid taxa in forests adjacent to insecticide-treated soybean.

# CHAPTER I

# INDIRECT EFFECTS OF INVASIVE INSECT MANAGEMENT ON FOREST INSECT ABUNDANCE

## INTRODUCTION

Biodiversity contributes to ecosystem efficiency, stability, and function by supporting complex food webs and community interactions (Macarthur 1955, Hooper et al. 2005, Cardinale et al. 2012). Biodiversity is increasingly threatened by habitat destruction, climate change, insecticides, and invasive species (Doherty et al. 2016, Maxwell et al. 2016, Raven and Wagner 2021). Numerous studies note significant reductions in the abundance of mammal, bird, reptile, fish, plant, and insect species (Moran et al. 2009, Benítez-López et al. 2010, Baumann et al. 2011, Macfadyen and Zalucki 2012, Guerrero-Casado et al. 2022). Reduced biodiversity has negative effects on ecosystem functions including reduced biomass production, stability, and nutrient cycling (Hooper et al. 2005, Cardinale 2012).

Insects are the most abundant and diverse group of animals on the planet, with over one million described species and an estimated total of 5.5 million species (Stork 2018). Insects provide vital ecosystem services including contributing resources for higher trophic levels, providing biological control, aiding in decomposition, and pollinating wild and agricultural plants (Losey and Vaughan 2006). These combined services are estimated in excess of $50 billion per year in the United States alone (Losey and Vaughan 2006). Therefore, the loss of insect biodiversity is concerning for ecosystems across the globe. As insect biodiversity wanes, ecological and economic services will be directly and indirectly negatively affected, including loss in agricultural

revenue, predator-prey interactions, detrimental changes in food webs, and nutrient losses.

In recent decades, largescale declines in insect abundance and biodiversity have been reported across the globe. In Britain, the abundance of macro-moths captured in light traps over a 35-year sampling period decreased by 31% (Conrad et al. 2006). In Germany, a staggering 76% decline in flying insect biomass was observed across the span of 27 years (Hallmann et al. 2017). In the Netherlands, the abundance of 20 widespread species of butterflies, previously considered to be common, declined approximately 30% over 16 years causing two species to be categorized as endangered and an additional five species to be labeled as vulnerable or near threatened (Van Dyck et al. 2009). In North America, up to 96% decline in the relative abundance of four bumble bee species was observed over the span of 20-30 years (Cameron et al. 2011). In Costa Rica, an estimated loss of 1,056 caterpillar species and 704 parasitoid species was reported over a 22-year study period, including an estimated 77% reduction in caterpillar-parasitoid interactions (Salcido et al. 2020). In Asia, a decline in multiple dolichopodid species was reported (Grichanov et al. 2021).

Insecticide applications are a staple of integrated pest management but often cause severe non-target effects on pollinators, parasitoids and predators (Pimentel 1971, Flexner et al. 1986, de Snoo 1999, Moser and Obrycki 2009, Douglas and Tooker 2016, Mužinić and Želježić 2018). For example, in North America and Europe, insect natural enemy abundance is reduced by ~16% after the use of either seed-applied neonicotinoids, or foliar neonicotinoid or pyrethroid sprays in field crops (Douglas and Tooker 2016). Additionally, predaceous ladybird beetles are greatly reduced in sweet corn and soybean

treated with conventional insecticides, including carbamates, organophosphates, and pyrethroids (Galvan et al. 2005). In yet another example, solitary bee nesting activity and survivorship are significantly decreased in fruit orchards applied with organophosphates (Alston et al. 2007). In pome fruit orchards treated with spinosad, Braconidae and Chalcidoidea parasitoids are reduced by nearly 70% (Civolani et al. 2007). These non-target effects may be intensified with increased insecticide applications targeting invasive insect pest species.

Invasive species, including insects, are arriving in new habitats at accelerating rates and threatening biodiversity both directly through predation and herbivory, and indirectly through competition, transmitting disease, and disrupting ecological succession (Kenis et al. 2009, Lockwood et al. 2013, Klooster et al. 2018). In North America, invasive Chinese mantis created a large reduction in insect herbivores and a subsequent increase in plant biomass when introduced to old successional field plots (Moran and Hurd 1998). In Hawaii, native bird populations decreased sharply after infection with avian malaria transmitted by invasive *Culex* spp. (Van Riper III 1991). In the eastern United States, forest community structure and succession is altered due to high ash mortality caused by invasive emerald ash borer (Flower et al. 2013). Invasive insects generally experience enemy free space and have larger populations in introduced regions (Lockwood et al. 2013), often requiring intense insecticide applications for management in agriculture, leading to secondary pest outbreaks, increased production costs, and non-target effects on beneficial insects (Elton 1958, Leskey, Lee, et al. 2012, Leskey, Short, et al. 2012, Lockwood et al. 2013, Rice et al. 2014).

Insects are killed by direct contact with insecticide chemicals or by ingestion of treated food materials. However, non-target insecticide contact by way of drift, agricultural runoff, and leaching can negatively affect a wide range of organisms including mammals, birds, insect predators, pollinators, and parasitoids especially where agricultural fields are closely adjacent to natural habitats like meadows or forests (de Snoo and de Wit 1998, de Jong et al. 2008). Additionally, natural enemy and pollinator biodiversity is often higher along field edges in agroecosystems, especially when in close proximity to natural habitat that may provide important foraging resources and overwintering space (Duelli 1990, Rand et al. 2006). Therefore, insect species foraging along edge habitats might experience greater non-target effects near agricultural fields.

Japanese beetle, *Popillia japonica* Newman, is a polyphagous invasive insect that was unintentionally introduced to the United States in 1916 (Dickerson and Weiss 1918). Japanese beetle is currently established in 28 states with detections in 13 additional states (Althoff and Rice 2022). Recently, this pest species established large populations in the midwestern United States, becoming a key pest in field crop and fruit systems (Althoff and Rice 2022). Because of the severe economic damage these beetles cause, growers primarily rely on increased foliar insecticide sprays for management (Althoff and Rice 2022), with Midwest field crop growers reporting up to four insecticide applications in field crops per growing season (Rice *unpublished*). While many studies report the effects of agricultural insecticide sprays on non-target insects within agriculture systems (Babendreier et al. 2015, Douglas and Tooker 2016, Main et al. 2020), none have specifically examined the effects of increased agricultural insecticide sprays targeting invasive insects on adjacent natural ecosystems. We investigate the effects of insecticides

targeting invasive insects, namely *P. japonica*, in field crops on neighboring forest insect abundance using passive traps deployed along straight-line transects in forests adjacent to agriculture to measure the abundance of both flying and ground-dwelling insect taxa.

## MATERIALS AND METHODS

### Experimental setup

Three 1.5 ha soybean fields located in central Missouri were selected based on their proximity to dense forested habitats. Two sites were located at Turkey Farm Lake Dam in Shaw, Missouri and were separated from each other by 50 m, and the third site was located at Bradford Research Center in Columbia, Missouri. All sites are located on University of Missouri research farms. Soybean (variety 38XF1) was planted in rows 38.1 cm apart at 140,000 seeds/acre at each site. Each soybean field was split into two 75 m treatments, separated by a 50 m buffer. The treatments consisted of an untreated control and a pyrethroid insecticide spray applied to the forest-adjacent soybean field by a tractor-mounted sprayer. In the insecticide spray treatments, Asana XL (Valent, MFA Incorporated, Jefferson City, MO) was applied during mild weather conditions to the first 30 rows of soybean beginning at the field edge at a rate of 9.5 oz/acre at 20 gal/acre through anti-drip nozzle bodies with Turbo Tee tips (T-Jet) spaced 30 in apart at 40 PSI. The application was repeated once per week for three consecutive weeks in early-mid July of both 2020 and 2021.

Within each treatment, we created three straight-line transects spaced 25 m apart starting from the soybean field edge and continuing into adjacent forest habitat. Transects consisted of four sampling locations beginning at the field edge at 0 m and continuing in

a straight line at 10 m, 20 m, and 40 m into the adjacent forested habitat. We sampled forest insect abundance using yellow sticky and pitfall traps.

**Yellow Sticky Traps**

We used unbaited yellow sticky traps (Alpha Scents, YC Folding) to sample flying insect abundance at each of the four sampling distances in each transect. At each sample location, traps were deployed at two heights to account for vertical stratification of arthropods (Ulyshen 2011). For sampling low-canopy, yellow sticky traps were affixed to wooden posts (Lowes, item number: 348946) 1 m above ground level. For canopy sampling, we installed a pulley system in the highest-most tree branches at the sampling location using a Notch™ Big Shot Slingshot (item number: 83259) and masonry twine (Home Depot, #36 x 250). For the 2021 field season, the twine was upgraded to 3/16-inch Polyester Rope (Amazon.com, Quality Nylon Rope, part number: HM-07587) for better durability. We secured yellow sticky traps to each pulley rope using small binder clips (Amazon.com, Amazon Basics, item number: PC0910) and twist ties (Alpha scents, included with sticky traps) (Fig. 1). Binder clips were not used in 2021 due to the thicker rope. A total of eight sticky traps were deployed per transect.

Yellow sticky traps were deployed during the first week of insecticide applications, third week of insecticide applications, and two weeks after the insecticide applications had concluded for a total of three sampling weeks in 2020. An additional sampling week, four weeks after the final insecticide application, was added in 2021 for a total of 4 sampling weeks. All traps were collected after roughly seven days and stored in a 0°F freezer. All insects on yellow sticky traps in 2020 were counted and identified to family using Introduction to the Study of Insects (Triplehorn et al. 2004). In 2021, yellow sticky

traps were subsampled using a list of 43 taxa selected based on their ecological significance (predators, pollinators, and parasitoids) and 2020 abundance. Data analysis was performed on this subsample of 43 taxa for both years.

**Pitfall Traps**

We used unbaited pitfall traps to sample ground-dwelling insect abundance at each of the four sampling distances in each transect. A single pitfall trap was placed at each sampling location along each transect (Fig. 2), totaling four pitfall traps per transect. Two 16oz deli cups (Amazon.com, DuraHome, item number: 00315) were stacked and fitted into the pit so that the rim of both cups was flush with the soil. The outer cup was used to catch potential leaks and to help maintain the structural integrity of the hole when sampling. The inner cup was filled with ¼ inch of propylene glycol (Lowes, Zecol, item number: 185127). Each week, pitfall traps were drained, and the remaining contents were placed in bags, which were then stored in a 0°F freezer. In 2020, pitfall trap samples were collected weekly for eleven weeks beginning in late June (2 weeks before insecticide application) and ending in mid-September (6 weeks after insecticide applications). In 2021, traps were collected weekly for 8 weeks beginning in early July and ending in early September. A delay in soybean planting due to consistent early-season rain resulted in later sampling in 2021. Insects were subsampled based on most abundant taxa according to Perry et al. (2018).

Partway through the 2020 field season, animal tampering was evident in pitfall traps, so cages were constructed according to Perry et al. (2018) using 8.8 x 8.8-inch squares of hardware cloth (Lowes, Blue Hawk, item number: 492408). Cages were secured in place roughly two inches above the pitfall trap using bendable 14-gauge wire (Lowes, Blue

Hawk, item number: 62931). Hardware cloth cages were re-used for the 2021 field season but were instead secured in place using 6-inch landscaping staples (Amazon.com, SuperMMarK, ASIN: B081RK48LH) that were zip-tied to the edges of the hardware cloth, making the cages sturdier and adding to their reusability.

For data analysis, we used a zero-inflated generalized linear model based on a Poisson distribution (SAS 9.4) to compare insect abundance captured on yellow sticky and pitfall traps between the two treatments. We used the total number of each taxon captured on traps as the response variable, and treatment (insecticide treated soybean or untreated soybean) as an explanatory variable and collection week as a co-variable and repeated measures for sample location. We compared total captures for each taxon on combined yellow sticky traps and combined pitfall traps for all sample locations. We also compared captures of each taxon at each distance independently (a total of two models per location for yellow sticky traps and one model per location for pitfall traps).

**RESULTS**

We investigated the effects of insecticide applications targeting invasive Japanese beetle in field crops on insect abundance in adjacent forest systems. Three pyrethroid applications in soybean greatly reduced insect abundance in neighboring forests compared to forests adjacent to untreated control soybean fields during both years (Tables 1, 2, Figures 3, 4, 5, 6). In 2020, forest systems adjacent to insecticide applications experienced significant reductions in 17 taxa in either pitfall or yellow sticky traps. In 2021, 12 taxa were significantly reduced in either pitfalls or yellow sticky traps in forests adjacent to soybeans treated with insecticides compared to untreated soybean.

When all yellow sticky traps within a single transect were combined (all heights and sample locations totaling eight sticky traps), Flatidae and Xylomyidae were significantly reduced in forested habitats next to insecticide treated soybean in 2020 (Table 1, Figures 7 and 8). Surprisingly, three taxa experienced significant increases in abundance in forest habitats adjacent to insecticide-treated soybean in 2020. Culicidae, Syrphidae, and Ulidiidae were more abundant in habitats adjacent to insecticide applications compared with untreated plots (Table 1, Figures 9, 10, and 11). In 2021, Anthocoridae, Braconidae, Curculionidae, and Phalacridae were reduced in forest habitats next to insecticide treated soybean compared with untreated treatments when all yellow sticky traps within treatments were combined (Table 1, Figures 12, 13, 14, and 15). Ichneumonidae, Lepidoptera, and Mymaridae had greater abundance in forest habitats adjacent to insecticide applications compared with untreated treatments (Table 1, Figures 16, 17, 18). When all pitfall traps within a single transect were combined (four sample locations), Carabidae, Araneae, Formicidae, Gryllidae, Curculionidae, Blattidae, and mites were significantly reduced in forests adjacent to insecticide treated soybean in 2020 (Table 2, Figures 19, 20, 21, 22, 23, 24, and 25). However, in 2021, only Blattidae were significantly reduced in forested habitats adjacent to insecticide treated soybean (Table 2, Figure 26) while Formicidae and mites had greater abundance compared to untreated treatments (Table 2, Figures 27 and 28).

At field edges (0 m) in 2020, yellow sticky traps deployed at 1 m captured significantly fewer Araneae compared with untreated treatments (Table 3, Figure 29). Ulidiidae had significantly greater abundance in 1 m yellow sticky traps compared with untreated treatments (Table 3, Figure 11). Yellow sticky traps deployed in the canopy

captured significantly fewer Cynipidae, Mymaridae, and Staphylinidae compared with untreated treatments (Table 3, Figures 30, 31, 32). Pitfall traps captured significantly fewer Araneae and isopods along field edges (0 m) adjacent to insecticide applications (Table 4, Figures 20 and 33). In 2021, there were no significant differences in insect abundance between treatments on yellow sticky traps deployed at 1 m at field edges. Yellow sticky traps deployed in the canopy captured significantly fewer Dolichopodidae in forest edges next to insecticide treated soybean compared with untreated treatments (Table 5, Figure 34). Pitfall traps captured significantly more Formicidae compared with untreated treatments (Table 4, Figure 27).

At 10 m in 2020, yellow sticky traps deployed at 1 m captured significantly fewer Mymaridae and Xylomyidae compared with untreated treatments (Table 6, Figures 31 and 8). However, canopy yellow sticky traps captured significantly more Coccinellidae and Tachinidae compared with untreated treatments (Table 6, Figures 35 and 36). Pitfall traps captured significantly fewer isopods (Table 7, Figure 33), while both Araneae and Formicidae had increased abundance compared with untreated plots (Table 7, Figures 20 and 21). In 2021 at 10 m, yellow sticky traps deployed at 1 m in forest habitat adjacent to insecticide treatments captured significantly fewer Braconidae and Araneae (Table 8, Figures 13 and 37), but captured significantly more Lepidoptera (Table 8, Figure 17) compared with untreated treatments. Yellow sticky traps deployed in the canopy adjacent to insecticide treatments captured significantly more Ichneumonidae and Mymaridae compared with untreated treatments (Table 8, Figures 16 and 18). There were no significant differences between treatments in pitfall traps at 10 m.

At 20 m in 2020, yellow sticky traps deployed at 1 m captured significantly fewer Lepidoptera and Mymaridae compared with untreated treatments (Table 9, Figures 38 and 31). Canopy yellow sticky traps in forests adjacent to insecticide applications captured significantly fewer Phalacridae compared with untreated treatments (Table 9, Figure 39). Pitfall traps adjacent to insecticide treatments captured fewer Formicidae (Table 10, Figure 21) but captured significantly more Araneae at 20 m (Table 10, Figure 20) compared with untreated treatments. In 2021 at 20 m sampling locations, yellow sticky traps deployed at 1 m adjacent to insecticide-treated soybean captured significantly fewer Curculionidae, Formicidae, and Staphylinidae (Table 11, Figures 14, 40, and 41), but captured significantly more Lepidoptera and Mymaridae (Table 11, Figures 17 and 18) compared with untreated treatments. Canopy yellow sticky traps captured significantly fewer Formicidae (Table 11, Figure 40), but significantly more Ichneumonidae (Table 11, Figure 16) when compared with untreated treatments. Pitfall traps adjacent to insecticide-treated soybean captured significantly fewer isopods and Blattidae when compared with untreated treatments in 2021 (Table 10, Figures 42 and 26).

At 40 m in 2020, yellow sticky traps deployed at 1 m captured significantly fewer Coccinellidae, Panorpidae, Araneae, Staphylinidae, and Xylomyidae in forest habitat adjacent to insecticide-treated soybean compared with untreated treatments (Table 12, Figures 35, 43, 29, 32, and 8). Yellow sticky traps deployed in the canopy captured significantly fewer Ichneumonidae in forest habitat adjacent to insecticide-treated soybean compared with untreated treatments (Table 12, Figure 44). There were no significant differences in pitfall trap captures between treatments at 40 m in 2020 (Table

13). In 2021 at 40-m, there were no significant differences in trap captures on yellow sticky traps deployed at 1 m. Canopy yellow sticky traps in transects adjacent to insecticide-treated soybean captured significantly more Cynipidae compared with untreated treatments (Table 14, Figure 45). There were no significant differences in pitfall trap captures compared with untreated treatments in 2021.

## DISCUSSION

We observed reduced abundance in 20 taxa in either yellow sticky trap or pitfall trap samples in 2020 or 2021 in forested habitats adjacent to insecticide applications. We found that natural enemies (specifically predators and parasitoids) were more susceptible to non-target effects of insecticides than herbivores. Additionally, reductions of beneficial insects remained apparent even at 40 m into forest habitats, perhaps due to insecticide drift. Numerous studies have examined aerial and ground spraying techniques of pesticides suggesting they produce sizeable clouds of airborne particles that can drift hundreds of meters into non-target areas, affecting plants, insects, and mammals (Currier et al. 1982, Woods et al. 2001, Bish et al. 2019).

Overall, we observed strong non-target effects on the abundance of beneficial insects in natural habitats adjacent to agriculture treated with insecticide throughout two years. These findings support the many assertions that application of insecticides is a main factor affecting insect abundance and biodiversity losses across the globe (Relyea 2005, Geiger et al. 2010, van der Sluijs et al. 2015, Hallmann et al. 2017). Insecticides cause substantial non-target reductions in pollinators and natural enemies, resulting in major ecosystem disruptions (Pimentel 1971, de Snoo 1999, Douglas and Tooker 2016). For example, in maize, natural enemies, namely Coccinellidae, Staphylinidae, Araneae,

Hymenoptera, and Chrysopidae, were significantly reduced with neonicotinoid seed treatments compared to untreated seeds (Babendreier et al. 2015). In apple, Forficulidae were significantly reduced after organophosphate applications targeting orchard pests (Fountain and Harris 2015). Predators in soybean including Anthocoridae, Coccinellidae, and Dolichopodidae were significantly reduced after neonicotinoid and pyrethroid foliar applications for Aphididae, Tetranychidae, and Thripidae management (Regan et al. 2017). Additionally, non-target effects are amplified when insecticides are increased during invasive insect management.

While we overwhelmingly observed a reduction in taxa across transects adjacent to insecticide-treated soybean, we surprisingly observed some taxa with greater abundance in transects adjacent to insecticide treatments, including Culicidae, Syrphidae, and Ulidiidae. Most notably, in 2020, when combining all yellow sticky trap sampling locations within a transect, mosquitos (Diptera: Culicidae) had significantly greater abundance on yellow sticky traps in forests adjacent to insecticide-treated soybean (Table 1, Figure 4), suggesting cascading non-target effects in these natural habitats with potential for increased disease transmission and human health concerns. Araneae are a main predator of mosquitos (Strickman et al. 1997, Weterings et al. 2014) and Araneae were significantly reduced in 50% of the sampling distances in 2020, thus potentially causing a subsequent increase in mosquito populations (Tables 2, 5, Figure 12). Additionally, we observed a significant decrease in Mymaridae at some sampling locations in 2020. Mymaridae are egg parasitoids with a wide range of hosts, including some Dipterans (Huber 1986). While Culicidae are not a confirmed host for Mymaridae, very little is known about mymarid biology, and they may potentially be influencing

culicid abundance. Increases in the abundance of pest species after a pyrethroid application have previously been observed in agriculture after the suppression of natural enemies from insecticide treatments (Bitzer et al. 2005, Rose and Dively 2007, Leskey, Hamilton, et al. 2012). Our findings suggest similar interactions may also be happening within natural habitats after insecticide application in adjacent agriculture.

In 2021, we observed slightly fewer significant differences between treatments, and several taxa, including Mymaridae, Formicidae, Lepidoptera, and Ichneumonidae had higher abundance in transects adjacent to insecticide treatments than in transects adjacent to untreated soybean. During the 2021 growing season, field sites received heavy precipitation and flooded on multiple occasions. More importantly, heavy precipitation occurred within 8 hours of the second insecticide application, perhaps reducing efficacy and non-target effects.

Non-target effects of insecticides may be stronger at field edges, where insects from nearby natural ecosystems have greater foraging activity (Duelli 1990, Rand et al. 2006). Buffer strips may mitigate non-target effects of insecticides along field edges. Buffer strips along agricultural commodities protect aquatic stream systems from soil erosion, leaching, and insecticide drift (de Snoo and de Wit 1998). For example, 30 m buffer strips are recommended to protect streams located near eucalyptus plantations treated with aerial sprays of atrazine and at least 50 m wide for plantations sprayed with pyrethroids, however, the buffer width is also affected by the height of the spray (Barton and Davies 1993).

In terrestrial systems, buffer strips effectively mitigate insecticide drift. In general, a six meter no-spray buffer is recommended to reduce non-target effects in neighboring

habitats, but habitat types need to be considered when determining buffer. For example, if a sensitive or vulnerable species resides in a habitat at risk of experiencing drift, larger buffers should be considered. In winter cereal crops, a six meter wide buffer was effective at reducing insecticide drift (Longley and Sotherton 1997). If buffer strips are not feasible, implementing additional behaviorally-based management strategies, like attract-and-kill, can reduce insecticide applications.

Attract-and-kill is a behaviorally-based management strategy that targets specific insect pests by luring them to a specific area, and targeting that small area with insecticides, thereby reducing overall insecticide applications and non-target effects (Lanier 1990, El-sayed et al. 2009). For example, attracticidal spheres effectively manage invasive spotted wing drosophila (*Drosophila suzukii* Matsumura) in small fruit systems while reducing insecticide applications (Rice et al. 2017). In apple orchards, attract-and-kill reduces invasive stink bug damage while reducing insecticide applications and thus reducing non target effects on beneficial insects (Morrison III et al. 2018).

Invasive species have direct negative effects on biodiversity through increased competition for resources and predation (Kenis et al. 2009, Lockwood et al. 2013), but our research shows that invasive insect management can also indirectly affect insect population dynamics which can ultimately affect biodiversity. Our study demonstrates that non-target effects of insecticides extend far beyond the field and likely have multi-trophic impacts on agriculture-adjacent forest ecosystems. More in depth research needs to be done in this area to further our knowledge on how the agricultural use of insecticides affects native insect biodiversity in neighboring habitats. In particular, there

is a great need for additional biodiversity studies in meadows and other dense pollinator habitats that are in close proximity to a majority of America's agricultural fields.

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**Table 1.** Average insect abundance by family captured on yellow sticky traps during 2020 and 2021.

| | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.27 ± 0.05 | 0.37 ± 0.07 | -0.77 | 0.4418 | 0.46 ± 0.06 | 0.22 ± 0.04 | 2.61 | 0.0092 |
| Apidae | 0.01 ± 0.01 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |
| Asilidae | 0.16 ± 0.03 | 0.14 ± 0.03 | 0.24 | 0.8079 | 0.53 ± 0.07 | 0.43 ± 0.08 | 0.75 | 0.4558 |
| Braconidae | 0.46 ± 0.05 | 0.36 ± 0.04 | -0.40 | 0.6893 | 0.59 ± 0.05 | 0.49 ± 0.05 | 1.98 | 0.0479 |
| Cantharidae | 0.07 ± 0.02 | 0.01 ± 0.01 | * | * | 0.08 ± 0.03 | 0.32 ± 0.09 | * | * |
| Carabidae | 0.15 ± 0.03 | 0.14 ± 0.04 | 1.70 | 0.0900 | 0.25 ± 0.05 | 0.22 ± 0.03 | 0.64 | 0.5220 |
| Chalcididae | 0.05 ± 0.01 | 0.05 ± 0.01 | 0.29 | 0.7709 | 0.02 ± 0.01 | 0.05 ± 0.02 | * | * |
| Chrysididae | 0.09 ± 0.02 | 0.09 ± 0.03 | 1.01 | 0.3132 | 0.11 ± 0.02 | 0.11 ± 0.02 | 1.75 | 0.0794 |
| Chrysomelidae | 0.53 ± 0.05 | 0.33 ± 0.04 | 1.56 | 0.1196 | 0.26 ± 0.04 | 0.39 ± 0.05 | -1.89 | 0.0593 |
| Chrysopidae | 0.02 ± 0.01 | 0.07 ± 0.02 | -0.80 | 0.4253 | 0.04 ± 0.01 | 0.05 ± 0.02 | -0.77 | 0.4416 |
| Cixiidae | 0.23 ± 0.04 | 0.41 ± 0.07 | -0.53 | 0.5963 | 0.34 ± 0.05 | 0.37 ± 0.05 | -0.82 | 0.4131 |
| Coccinellidae | 3.18 ± 0.21 | 3.70 ± 0.28 | -0.61 | 0.5393 | 3.81 ± 0.36 | 4.60 ± 0.39 | 0.47 | 0.6354 |
| Coniopterygidae | 0.40 ± 0.07 | 0.29 ± 0.04 | 0.90 | 0.3692 | 0.46 ± 0.10 | 0.37 ± 0.05 | -0.04 | 0.9689 |
| Corylophidae | 0.59 ± 0.06 | 0.86 ± 0.11 | -1.20 | 0.2303 | 0.57 ± 0.09 | 0.67 ± 0.13 | 0.18 | 0.8534 |
| Culicidae | 0.13 ± 0.03 | 0.50 ± 0.09 | -2.26 | 0.0237 | 0.15 ± 0.02 | 0.15 ± 0.03 | 1.24 | 0.2138 |
| Curculionidae | 0.20 ± 0.03 | 0.26 ± 0.03 | -0.54 | 0.5880 | 0.45 ± 0.06 | 0.22 ± 0.03 | 3.56 | 0.0004 |
| Cynipidae | 0.81 ± 0.15 | 0.72 ± 0.07 | 0.37 | 0.7097 | 1.10 ± 0.12 | 0.99 ± 0.11 | -0.33 | 0.7423 |
| Diapriidae | 1.16 ± 0.14 | 0.69 ± 0.09 | 0.80 | 0.4244 | 1.24 ± 0.14 | 1.85 ± 0.20 | -1.80 | 0.0720 |
| Dolichopodidae | 6.40 ± 0.49 | 6.28 ± 0.47 | -0.20 | 0.8431 | 10.40 ± 0.88 | 8.49 ± 0.57 | -0.13 | 0.8975 |
| Erebidae | 0.26 ± 0.20 | 0.02 ± 0.01 | 1.29 | 0.1984 | 0.01 ± 0.00 | 0.03 ± 0.01 | * | * |
| Flatidae | 0.23 ± 0.03 | 0.16 ± 0.03 | 2.20 | 0.0275 | 0.25 ± 0.04 | 0.29 ± 0.04 | -1.02 | 0.3070 |
| Formicidae | 0.98 ± 0.25 | 0.96 ± 0.12 | -0.51 | 0.6122 | 4.82 ± 0.50 | 3.19 ± 0.38 | 1.06 | 0.2899 |
| Halictidae | 0.29 ± 0.04 | 0.25 ± 0.04 | -1.06 | 0.2877 | 0.69 ± 0.11 | 0.69 ± 0.10 | 0.93 | 0.3501 |
| Hesperiidae | 0.80 ± 0.14 | 0.49 ± 0.10 | 0.80 | 0.4264 | - 0.35 ± 0.06 | 0.46 ± 0.08 | -0.76 | 0.4502 |
| Ichenumonidae | 0.73 ± 0.07 | 0.54 ± 0.05 | 0.88 | 0.3795 | 1.06 ± 0.10 | 1.18 ± 0.08 | -2.02 | 0.0439 |
| Lampyridae | 0.17 ±0.03 | 0.07 ± 0.02 | 0.01 | 0.9912 | 0.28 ± 0.04 | 0.47 ± 0.07 | 1.45 | 0.1479 |
| Lepidoptera | 1.80 ± 0.34 | 1.34 ± 0.09 | 1.78 | 0.0745 | 1.49 ± 0.10 | 1.64 ± 0.11 | -1.93 | 0.0540 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 2.44 ± 0.34 | 2.16 ± 0.23 | 0.34 | 0.7313 | 2.42 ± 0.21 | 1.93 ± 0.20 | 0.19 | 0.8472 |
| Mymaridae | 4.79 ± 0.30 | 3.76 ± 0.21 | 1.38 | 0.1677 | 1.24 ± 0.09 | 1.93 ± 0.15 | -2.22 | 0.0267 |
| Nymphalidae | 0.10 ± 0.03 | 0.06 ± 0.02 | 0.86 | 0.3924 | 0.18 ± 0.03 | 0.18 ± 0.04 | -0.32 | 0.7498 |
| Panorpidae | 0.23 ± 0.06 | 0.09 ± 0.03 | 1.71 | 0.0864 | 1.14 ± 0.27 | 1.46 ± 0.24 | -0.53 | 0.5979 |
| Papilionidae | 0 | 0 | * | * | 0.01 ± 0.00 | 0 | * | * |
| Perilampidae | 0.03 ± 0.01 | 0.02 ± 0.01 | * | * | 0.02 ± 0.01 | 0.02 ± 0.01 | * | * |
| Phalacridae | 0.35 ± 0.04 | 0.22 ± 0.03 | 1.39 | 0.1637 | 0.30 ± 0.06 | 0.13 ± 0.02 | 2.12 | 0.0344 |
| Pieridae | 0.07 ± 0.03 | 0.03 ± 0.02 | 0.02 | 0.9875 | 0.02 ± 0.01 | 0.05 ± 0.02 | * | * |
| Psychodidae | 0.74 ± 0.12 | 0.41 ± 0.06 | 1.59 | 0.1121 | 0.32 ± 0.05 | 0.28 ± 0.04 | -0.88 | 0.3810 |
| Araneae | 8.80 ± 0.40 | 7.58 ± 0.34 | 1.18 | 0.2364 | 7.12 ± 0.43 | 5.97 ± 0.29 | 0.17 | 0.8669 |
| Staphylinidae | 1.24 ± 0.11 | 0.93 ± 0.07 | 1.25 | 0.2117 | 0.98 ± 0.08 | 0.82 ± 0.09 | -0.32 | 0.7484 |
| Syrphidae | 0.39 ± 0.04 | 0.44 ± 0.05 | 3.21 | 0.0013 | 1.50 ± 0.16 | 1.35 ± 0.16 | -0.32 | 0.7484 |
| Tachinidae | 0.47 ± 0.06 | 0.36 ± 0.05 | 1.24 | 0.2146 | 0.54 ± 0.07 | 0.54 ± 0.09 | -0.91 | 0.3614 |
| Ulidiidae | 0.25 ± 0.04 | 0.45 ± 0.08 | -2.12 | 0.0338 | 0.37 ± 0.09 | 0.52 ± 0.08 | 0.51 | 0.6128 |
| Vespidae | 0.12 ± 0.02 | 0.10 ± 0.02 | 0.85 | 0.3948 | 0.72 ± 0.08 | .068 ± 0.07 | -0.18 | 0.8576 |
| Xylomyidae | 1.33 ± 0.17 | 0.68 ± 0.16 | 3.21 | 0.0013 | 1.03 ± 0.24 | 1.54 ± 0.29 | -0.32 | 0.7484 |

** Not enough representatives to determine statistical significance*

**Table 2.** Average insect abundance by family captured in pitfall traps during 2020 and 2021.

| | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Carabidae | 2.49 ± 0.20 | 2.18 ± 0.18 | 4.92 | <0.0001 | 0.77 ± 0.08 | 0.90 ± 0.10 | -1.22 | 0.2230 |
| Staphylinidae | 0.29 ± 0.04 | 0.20 ± 0.04 | * | * | 0.28 ± 0.04 | 0.29 ± 0.05 | 0.73 | 0.4650 |
| Araneae | 0.74 ± 0.06 | 0.74 ± 0.07 | 9.31 | <0.0001 | 2.00 ± 0.29 | 1.60 ± 0.18 | -0.28 | 0.7804 |
| Opiliones | 0.41 ± 0.05 | 0.39 ± 0.05 | 0.31 | 0.7573 | 0.52 ± 0.06 | 0.55 ± 0.07 | * | * |
| Formicidae | 3.60 ± 0.25 | 3.12 ± 0.27 | 4.74 | <0.0001 | 3.99 ± 0.29 | 4.13 ± 0.34 | -4.05 | <.0001 |
| Gryllidae | 0.54 ± 0.07 | 0.46 ± 0.06 | 2.52 | 0.0117 | 0.45 ± 0.08 | 0.57 ± 0.17 | 0.52 | 0.6034 |
| Isopoda | 3.64 ± 0.34 | 2.61 ± 0.27 | 1.34 | 0.1798 | 2.69 ± 0.25 | 2.59 ± 0.29 | -0.43 | 0.6691 |
| Centipedes | 0.02 ± 0.01 | 0.05 ± 0.02 | * | * | 0.09 ± 0.02 | 0.24 ± 0.07 | -1.33 | 0.1829 |
| Millipedes | 0.04 ± 0.02 | 0.08 ± 0.02 | * | * | 0.07 ± 0.02 | 0.06 ± 0.03 | * | * |
| Collembola | 0.25 ± 0.04 | 0.26 ± 0.05 | -0.86 | 0.3906 | 6.88 ± 1.03 | 8.77 ± 1.53 | -1.59 | 0.1113 |
| Tenebrionidae | 0.01 ± 0 | 0.01 ± 0.01 | * | * | 0.07 ± 0.02 | 0.03 ± 0.01 | * | * |
| Nitidulidae | 0.31 ± 0.06 | 0.27 ± 0.07 | * | * | 0.18 ± 0.03 | 0.11 ± 0.02 | 0.09 | 0.9296 |
| Histeridae | 0 | 0 | * | * | 0.02 ± 0.01 | 0.02 ± 0.01 | * | * |
| Coccinellidae | 0.01 ± 0 | 0 | * | * | 0 | 0 | * | * |
| Scarabaeidae | 0.25 ± 0.04 | 0.29 ± 0.04 | * | * | 0.23 ± 0.10 | 0.20 ± 0.04 | * | * |
| Elateridae | 0.01 ± 0.01 | 0.02 ± 0.01 | * | * | 0.02 ± 0.01 | 0.02 ± 0.01 | * | * |
| Curculionidae | 1.22 ± 0.15 | 0.98 ± 0.12 | 2.24 | 0.0248 | 1.27 ± 0.20 | 0.45 ± 0.06 | -0.53 | 0.5955 |
| Geotrupidae | 0.01 ± 0.01 | 0.02 ± 0.01 | * | * | 0.01 ± 0.01 | 0.02 ± 0.01 | * | * |
| Silphidae | 0.12 ± 0.04 | 0.02 ± 0.01 | * | * | 0.03 ± 0.02 | 0.03 ± 0.01 | * | * |
| Erotylidae | 0.03 ± 0.01 | 0.01 ± 0.01 | * | * | 0.03 ± 0.01 | 0.02 ± 0.01 | * | * |
| Phalacridae | 0 | 0.02 ± 0.01 | * | * | 0.02 ± 0.01 | 0.03 ± 0.01 | * | * |
| Chrysomelidae | 0.01 ± 0.01 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |
| Ptiliidae | 0.01 ± 0.01 | 0 | * | * | 0 | 0 | * | * |
| Lampyridae | 0.06 ± 0.02 | 0.01 ± 0.01 | * | * | 0.02 ± 0.01 | 0.03 ± 0.01 | * | * |
| Acrididae | 0.04 ± 0.01 | 0.06 ± 0.02 | * | * | 0.02 ± 0.01 | 0.03 ± 0.02 | * | * |
| Tettigoniidae | 0.01 ± 0 | 0.01 ± 0.01 | * | * | 0.01 ± 0.01 | 0 | * | * |
| Blattidae | 0.91 ± 0.08 | 0.85 ± 0.08 | 3.60 | 0.0003 | 1.42 ± 0.17 | 0.95 ± 0.10 | 2.10 | 0.0353 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rhaphidophoridae | 0.57 ± 0.07 | 0.58 ± 0.08 | -0.29 | 0.7744 | 0.59 ± 0.08 | 0.52 ± 0.09 | -0.39 | 0.6932 |
| Diplura | 0.01 ± 0.01 | 0.02 ± 0.02 | * | * | 0 | 0.02 ± 0.01 | * | * |
| Protura | 0.01 ± 0 | 0.02 ± 0.01 | * | * | 0.01 ± 0.01 | 0 | * | * |
| Mites | 0.51 ± 0.07 | 0.39 ± 0.06 | 2.33 | 0.0197 | 1.59 ± 0.17 | 1.68 ± 0.18 | -2.49 | 0.0126 |
| Ticks | 0.02 ± 0.05 | 0.05 ± 0.02 | * | * | 0.09 ± 0.03 | 0.12 ± 0.04 | * | * |

* *Not enough representatives to determine statistical significance*

**Table 3.** Average insect abundance by family captured on yellow sticky traps deployed at field edge (0 m) during 2020.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 1.23 ± 0.28 | 1.42 ± 0.45 | -1.23 | 0.2205 | 0.38 ± 0.18 | 0.50 ± 0.20 | 0 | 1 |
| Apidae | 0.08 ± 0.08 | 0.08 ± 0.05 | * | * | 0 | 0 | * | * |
| Asilidae | 0.62 ± 0.19 | 0.38 ± 0.18 | 0.62 | 0.5384 | 0.05 ± 0.05 | 0.04 ± 0 | * | * |
| Braconidae | 0.65 ± 0.19 | 0.88 ± 0.20 | -1.13 | 0.2567 | 0.38 ± 0.15 | 0.27 ± 0.13 | -0.16 | 0.8729 |
| Cantharidae | 0.12 ± 0.08 | 0 | * | * | 0.05 ± 0.05 | 0.04 ± 0.04 | * | * |
| Carabidae | 0.31 ± 0.12 | 0.54 ± 0.32 | * | * | 0.14 ± 0.08 | 0.08 ± 0.05 | * | * |
| Chalcididae | 0.12 ± 0.08 | 0.15 ± 0.07 | * | * | 0 | 0.04 ± 0 | * | * |
| Chrysididae | 0.15 ± 0.07 | 0.04 ± 0.04 | * | * | 0.10 ± 0.10 | 0.23 ± 0.19 | * | * |
| Chrysomelidae | 0.62 ± 0.15 | 0.31 ± 0.11 | * | * | 0.57 ± 0.18 | 0.31 ± 0.12 | 0.7 | 0.4870 |
| Chrysopidae | 0 | 0.08 ± 0.05 | * | * | 0.19 ± 0.09 | 0.23 ± 0.08 | * | * |
| Cixiidae | 0.65 ± 0.32 | 0.38 ± 0.10 | -0.94 | 0.3491 | 0.24 ± 0.14 | 0.12 ± 0.10 | * | * |
| Coccinellidae | 2.62 ± 0.57 | 2.15 ± 0.38 | 0.38 | 0.7047 | 2.43 ± 0.79 | 5.42 ± 0.93 | -1.00 | 0.3157 |
| Coniopterygidae | 0.15 ± 0.09 | 0.04 ± 0.04 | * | * | 1.33 ± 0.68 | 0.54 ± 0.16 | * | * |
| Corylophidae | 0.77 ± 0.27 | 1.31 ± 0.52 | -1.63 | 0.1021 | 0.48 ± 0.25 | 0.27 ± 0.10 | 0.71 | 0.4775 |
| Culicidae | 0.08 ± 0.08 | 0.88 ± 0.60 | * | * | 0.10 ± 0.07 | 0.92 ± 0.50 | * | * |
| Curculionidae | 0.19 ± 0.10 | 0.58 ± 0.17 | -1.69 | 0.0918 | 0.14 ± 0.10 | 0.15 ± 0.07 | * | * |
| Cynipidae | 0.65 ± 0.17 | 0.42 ± 0.16 | 0.53 | 0.5984 | 1.95 ± 0.53 | 0.73 ± 0.22 | 1.89 | 0.0582 |
| Diapriidae | 0.15 ± 0.07 | 0.42 ± 0.17 | -0.51 | 0.6088 | 0.10 ± 0.07 | 0.15 ± 0.07 | * | * |
| Dolichopodidae | 20.80 ± 2.91 | 18.00 ± 2.10 | 0.25 | 0.8022 | 13.00 ± 1.81 | 11.70 ± 2.20 | 0.38 | 0.7012 |
| Erebidae | 0.04 ± 0.04 | 0 | * | * | 0.05 ± 0.05 | 0.08 ± 0.05 | * | * |
| Flatidae | 0.19 ± 0.08 | 0.12 ± 0.08 | * | * | 0.10 ± 0.07 | 0.15 ± 0.07 | * | * |
| Formicidae | 2.04 ± 0.56 | 2.15 ± 0.62 | -0.65 | 0.5179 | 1.10 ± 0.36 | 0.31 ± 0.14 | 1.23 | 0.2175 |
| Halictidae | 0.77 ± 0.18 | 0.96 ± 0.20 | -0.98 | 0.3265 | 0.19 ± 0.09 | 0.42 ± 0.30 | * | * |
| Hesperiidae | 5.42 ± 1.01 | 4.15 ± 0.87 | 0.61 | 0.5451 | 0.05 ± 0.05 | 0.19 ± 0.08 | * | * |
| Ichenumonidae | 0.50 ± 0.20 | 0.54 ± 0.17 | -0.37 | 0.7097 | 0.86 ± 0.20 | 0.50 ± 0.13 | -0.39 | 0.6969 |
| Lampyridae | 0.35 ± 0.12 | 0.12 ± 0.08 | * | * | 0.19 ± 0.11 | 0.08 ± 0.05 | * | * |
| Lepidoptera | 1.50 ± 0.26 | 1.12± 0.20 | 1.26 | 0.2081 | 2.52 ± 0.51 | 2.35 ± 0.40 | 1.29 | 0.1974 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 12.80 ± 2.17 | 7.27 ± 1.74 | 1.32 | 0.1885 | 1.00 ± 0.31 | 0.92 ± 0.27 | * | * |
| Mymaridae | 2.58 ± 0.41 | 2.96 ± 0.50 | -0.94 | 0.3460 | 5.67 ± 1.84 | 1.96 ± 0.39 | 2.45 | 0.0144 |
| Nymphalidae | 0.73 ± 0.21 | 0.23 ± 0.13 | 1.45 | 0.1468 | 0.10 ± 0.10 | 0 | * | * |
| Panorpidae | 0.73 ± 0.46 | 0.38 ± 0.30 | * | * | 0 | 0 | * | * |
| Papilionidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0.04 ± 0.04 | 0.08 ± 0.05 | * | * | 0 | 0 | * | * |
| Phalacridae | 0.46 ± 0.11 | 0.23 ± 0.08 | 0.69 | 0.4914 | 0.48 ± 0.20 | 0.31 ± 0.13 | -0.59 | 0.5575 |
| Pieridae | 0.62 ± 0.28 | 0.35 ± 0.20 | 0.13 | 0.8928 | 0.05 ± 0.05 | 0 | * | * |
| Psychodidae | 0.58 ± 0.16 | 0.42 ± 0.13 | * | * | 1.38 ± 0.63 | 0.58 ± 0.25 | 1.25 | 0.2130 |
| Araneae | 14.00 ± 1.35 | 10.40 ± 1.12 | 2.52 | 0.0117 | 11.40 ± 1.03 | 9.69 ± 1.28 | 0.27 | 0.7865 |
| Staphylinidae | 2.00 ± 0.37 | 1.35 ± 0.29 | -1.42 | 0.1552 | 1.90 ± 0.36 | 1.38 ± 0.29 | 2.73 | 0.0063 |
| Syrphidae | 0.62 ± 0.15 | 0.73 ± 0.20 | 1.69 | 0.0909 | 0.14 ± 0.08 | 0.19 ± 0.10 | * | * |
| Tachinidae | 1.12 ± 0.27 | 0.46 ± 0.17 | 0.69 | 0.4877 | 1.05 ± 0.29 | 0.92 ± 0.23 | 0.85 | 0.3966 |
| Ulidiidae | 0.65 ± 0.22 | 1.85 ± 0.59 | -2.18 | 0.0292 | 0.05 ± 0.05 | 0.42 ± 0.28 | * | * |
| Vespidae | 0.12 ± 0.06 | 0.08 ± 0.05 | * | * | 0.14 ± 0.08 | 0.15 ± 0.09 | * | * |
| Xylomyidae | 0.23 ± 0.19 | 0 | * | * | 0.05 ± 0.05 | 0.04 ± 0 | * | * |

** Not enough representatives to determine statistical significance*

**Table 4.** Average insect abundance by family captured in pitfall traps deployed at field edge (0 m) during 2020 and 2021.

| | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Carabidae | 2.82 ± 0.42 | 2.87 ± 0.41 | 1.26 | 0.2100 | 1.46 ± 0.22 | 2.17 ± 0.32 | * | * |
| Staphylinidae | 0.18 ± 0.06 | 0.09 ± 0.04 | * | * | 0.21 ± 0.08 | 0.38 ± 0.10 | * | * |
| Araneae | 0.88 ± 0.13 | 0.73 ± 0.12 | 1.96 | 0.0500 | 2.89 ± 0.62 | 2.63 ± 0.39 | * | * |
| Opiliones | 0.45 ± 0.10 | 0.56 ± 0.15 | * | * | 0.46 ± 0.10 | 1.00 ± 0.21 | * | * |
| Formicidae | 4.30 ± 0.53 | 2.83 ± 0.40 | 0.52 | 0.6000 | 4.74 ± 0.63 | 7.05 ± 1.01 | -2.90 | 0.0037 |
| Gryllidae | 0.95 ± 0.22 | 0.81 ± 0.17 | * | * | 0.51 ± 0.13 | 1.10 ± 0.70 | * | * |
| Isopoda | 5.64 ± 0.87 | 3.16 ± 0.70 | 8.57 | <0.0001 | 2.16 ± 0.34 | 3.87 ± 0.93 | * | * |
| Centipedes | 0.06 ± 0.03 | 0.03 ± 0.02 | * | * | 0.07 ± 0.04 | 0.43 ± 0.24 | * | * |
| Millipedes | 0.08 ± 0.06 | 0.10 ± 0.05 | * | * | 0.04 ± 0.02 | 0.05 ± 0.03 | * | * |
| Collembola | 0.28 ± 0.08 | 0.46 ± 0.14 | * | * | 14.47 ± 3.89 | 17.21 ± 3.94 | * | * |
| Tenebrionidae | 0 | 0 | * | * | 0.04 ± 0.02 | 0 | * | * |
| Nitidulidae | 0.16 ± 0.07 | 0.16 ± 0.07 | * | * | 0.05 ± 0.03 | 0.14 ± 0.05 | * | * |
| Histeridae | 0 | 0 | * | * | 0 | 0.02 ± 0.02 | * | * |
| Coccinellidae | 0.02 ± 0.02 | 0 | * | * | 0.02 ± 0.02 | 0.02 ± 0.02 | * | * |
| Scarabaeidae | 0.22 ± 0.09 | 0.26 ± 0.09 | * | * | 0.09 ± 0.05 | 0.22 ± 0.07 | * | * |
| Elateridae | 0.04 ± 0.04 | 0.07 ± 0.04 | * | * | 0.04 ± 0.02 | 0.05 ± 0.03 | * | * |
| Curculionidae | 0.96 ± 0.23 | 0.63 ± 0.16 | * | * | 0.60 ± 0.23 | 0.46 ± 0.11 | * | * |
| Geotrupidae | 0 | 0.03 ± 0.03 | * | * | 0 | 0 | * | * |
| Silphidae | 0.01 ± 0.01 | 0 | * | * | 0 | 0 | * | * |
| Erotylidae | 0.02 ± 0.02 | 0 | * | * | 0 | 0 | * | * |
| Phalacridae | 0 | 0.09 ± 0.06 | * | * | 0.02 ± 0.02 | 0.02 ± 0.02 | * | * |
| Chrysomelidae | 0.04 ± 0.02 | 0.03 ± 0.02 | * | * | 0 | 0 | * | * |
| Ptiliidae | 0.01 ± 0.01 | 0.01 ± 0.01 | * | * | 0.02 ± 0.02 | 0 | * | * |
| Lampyridae | 0.05 ± 0.05 | 0.01 ± 0.01 | * | * | 0.02 ± 0.02 | 0.05 ± 0.04 | * | * |
| Acrididae | 0.07 ± 0.05 | 0.21 ± 0.08 | * | * | 0.07 ± 0.03 | 0.08 ± 0.04 | * | * |
| Tettigoniidae | 0.01 ± 0.01 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Blattidae | 0.34 ± 0.08 | 0.39 ± 0.12 | * | * | 0.79 ± 0.21 | 1.06 ± 0.21 | * | * |
| Rhaphidophoridae | 0.14 ± 0.06 | 0.20 ± 0.09 | * | * | 0.14 ± 0.05 | 0.10 ± .0.4 | * | * |
| Diplura | 0 | 0.01 ± 0.01 | * | * | 0.02 ± 0.02 | 0.03 ± 0.02 | * | * |
| Protura | 0 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |
| Mites | 0.37 ± 0.12 | 0.56 ± 0.16 | * | * | 1.49 ± 0.37 | 2.52 ± 0.60 | * | * |
| Ticks | 0.11 ± 0.05 | 0.07 ± 0.04 | * | * | 0.09 ± 0.04 | 0.29 ± 0.16 | * | * |

* *Not enough representatives to determine statistical significance*

**Table 5.** Average insect abundance by family captured on yellow sticky traps deployed at field edge (0 m) during 2021.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 1.44 ± 0.32 | 0.64 ± 0.15 | 1.72 | 0.0858 | 0.75 ± 0.17 | 0.44 ± 0.19 | * | * |
| Apidae | 0.03 ± 0.03 | 0.03 ± 0.03 | * | * | 0 | 0 | * | * |
| Asilidae | 0.81 ± 0.25 | 0.56 ± 0.13 | 0 | 1 | 0.31 ± 0.10 | 0.16 ± 0.07 | * | * |
| Braconidae | 0.42 ± 0.12 | 0.78 ± 0.13 | -1.26 | 0.2083 | 0.53 ± 0.12 | 0.28 ± 0.10 | * | * |
| Cantharidae | 0.11 ± 0.08 | 0.14 ± 0.11 | * | * | 0.39 ± 0.20 | 0.78 ± 0.42 | * | * |
| Carabidae | 0.81 ± 0.31 | 0.25 ± 0.09 | * | * | 0.08 ± 0.06 | 0.06 ± 0.04 | * | * |
| Chalcididae | 0.06 ± 0.04 | 0.17 ± 0.12 | * | * | 0.06 ± 0.04 | 0.03 ± 0.03 | * | * |
| Chrysididae | 0.19 ± 0.08 | 0.19 ± 0.07 | * | * | 0.11 ± 0.07 | 0.06 ± 0.06 | * | * |
| Chrysomelidae | 0.44 ± 0.15 | 0.33 ± 0.14 | -0.16 | 0.8699 | 0.17 ± 0.06 | 0.25 ± 0.10 | -0.59 | 0.5552 |
| Chrysopidae | 0.03 ± 0.03 | 0 | * | * | 0.11 ± 0.07 | 0.19 ± 0.07 | * | * |
| Cixiidae | 0.50 ± 0.12 | 0.81 ± 0.26 | -0.52 | 0.6032 | 0.14 ± 0.07 | 0.44 ± 0.13 | * | * |
| Coccinellidae | 5.44 ± 1.36 | 4.75 ± 0.74 | 0.23 | 0.8160 | 3.11 ± 0.76 | 3.72 ± 0.85 | -0.38 | 0.7041 |
| Coniopterygidae | 0.81 ± 0.72 | 0.17 ± 0.08 | * | * | 0.67 ± 0.22 | 0.63 ± 0.17 | * | * |
| Corylophidae | 0.22 ± 0.09 | 0.72 ± 0.22 | * | * | 0.17 ± 0.07 | 0.28 ± 0.18 | * | * |
| Culicidae | 0.19 ± 0.07 | 0.22 ± 0.09 | * | * | 0.22 ± 0.07 | 0.16 ± 0.08 | * | * |
| Curculionidae | 0.56 ± 0.21 | 0.17 ± 0.08 | * | * | 0.25 ± 0.12 | 0.28 ± 0.12 | * | * |
| Cynipidae | 1.03 ± 0.39 | 0.89 ± 0.23 | -0.70 | 0.4865 | 2.72 ± 0.39 | 2.09 ± 0.61 | 1 | 0.3190 |
| Diapriidae | 0.53 ± 0.14 | 0.58 ± 0.14 | -0.25 | 0.7991 | 0.14 ± 0.07 | 0.09 ± 0.05 | * | * |
| Dolichopodidae | 31.22 ± 4.39 | 24.33 ± 2.08 | -0.60 | 0.5510 | 20.06 ± 2.86 | 12.94 ± 1.65 | 1.98 | 0.0475 |
| Erebidae | 0 | 0.06 ± 0.04 | * | * | 0 | 0.03 ± 0.03 | * | * |
| Flatidae | 0.08 ± 0.05 | 0.25 ± 0.08 | * | * | 0 | 0.06 ± 0.04 | * | * |
| Formicidae | 3.89 ± 0.63 | 5.28 ± 1.27 | 0.64 | 0.5191 | 3.53 ± 0.57 | 4.75 ± 1.67 | -0.61 | 0.5410 |
| Halictidae | 1.39 ± 0.42 | 2.47 ± 0.51 | 1.81 | 0.0707 | 0.53 ± 0.13 | 0.44 ± 0.14 | 0.51 | 0.6088 |
| Hesperiidae | 1.58 ± 0.33 | 2.42 ± 0.43 | -0.45 | 0.6505 | 0.06 ± 0.04 | 0.16 ± 0.09 | * | * |
| Ichenumonidae | 0.53 ± 0.14 | 1.08 ± 0.16 | -1.04 | 0.2987 | 1.17 ± 0.23 | 0.59 ± 0.19 | 0.66 | 0.5101 |
| Lampyridae | 0.42 ± 0.16 | 0.31 ± 0.10 | * | * | 0.47 ± 0.14 | 1.06 ± 0.38 | * | * |
| Lepidoptera | 1.69 ± 0.29 | 2.06 ± 0.29 | -1.09 | 0.2753 | 2.11 ± 0.34 | 2.41 ± 0.34 | 0.50 | 0.6192 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 1.81 ± 0.24 | 2.00 ± 0.37 | -0.00 | 1 | 0.97 ± 0.34 | 0.94 ± 0.23 | 0.53 | 0.5984 |
| Mymaridae | 0.83 ± 0.18 | 1.31 ± 0.27 | -0.59 | 0.5539 | 0.61 ± 0.16 | 0.11 ± 0.07 | 0.17 | 0.8660 |
| Nymphalidae | 0.50 ± 0.10 | 0.369 ± 0.14 | * | * | 0.11 ± 0.07 | 0.19 ± 0.10 | * | * |
| Panorpidae | 1.64 ± 1.06 | 1.56 ± 0.55 | * | * | 0 | 0 | * | * |
| Papilionidae | 0.03 ± 0.03 | 0 | * | * | 0.03 ± 0.03 | 0 | * | * |
| Perilampidae | 0.06 ± 0.04 | 0 | * | * | 0 | 0.06 ± 0.06 | * | * |
| Phalacridae | 1.11 ± 0.37 | 0.36 ± 0.09 | * | * | 0.31 ± 0.11 | 0.06 ± 0.04 | * | * |
| Pieridae | 0.14 ± 0.07 | 0.39 ± 0.13 | * | * | 0 | 0 | * | * |
| Psychodidae | 0.42 ± 0.15 | 0.36 ± 0.11 | 0.52 | 0.6032 | 0.97 ± 0.31 | 0.88 ± 0.29 | -0.92 | 0.3597 |
| Araneae | 10.81 ± 1.45 | 9.03 ± 0.94 | -0.94 | 0.3454 | 6.06 ± 0.77 | 4.69 ± 0.60 | 0.67 | 0.5019 |
| Staphylinidae | 1.06 ± 0.23 | 1.67 ± 0.55 | -0.44 | 0.6591 | 1.11 ± 0.21 | 0.66 ± 0.17 | 1.08 | 0.2805 |
| Syrphidae | 2.56 ± 0.58 | 2.17 ± 0.57 | 1.87 | 0.0610 | 0.61 ± 0.23 | 1.13 ± 0.32 | * | * |
| Tachinidae | 0.39 ± 0.12 | 0.42 ± 0.14 | 1.25 | 0.2106 | 1.11 ± 0.38 | 2.06 ± 0.50 | -1.47 | 0.1405 |
| Ulidiidae | 1.08 ± 0.48 | 0.56 ± 0.19 | * | * | 0.08 ± 0.05 | 0.13 ± 0.06 | * | * |
| Vespidae | 0.39 ± 0.13 | 0.50 ± 0.18 | * | * | 0.97 ± 0.22 | 0.66 ± 0.17 | 0.73 | 0.4662 |
| Xylomyidae | 0.03 ± 0.13 | 0.11 ± 0.07 | * | * | 0.06 ± 0.04 | 0.09 ± 0.07 | * | * |

** Not enough representatives to determine statistical significance*

**Table 6.** Average insect abundance by family captured on yellow sticky traps deployed at 10 m into the forest during 2020.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.04 ± 0.04 | 0.48 ± 0.28 | * | * | 0.38 ± 0.31 | 0.46 ± 0.42 | * | * |
| Apidae | 0 | 0 | * | * | 0.04 ± 0.04 | 0 | * | * |
| Asilidae | 0.15 ± 0.07 | 0.19 ± 0.08 | * | * | 0.12 ± 0.06 | 0.08 ± 0.06 | * | * |
| Braconidae | 0.69 ± 0.20 | 0.78 ± 0.19 | -0.23 | 0.8219 | 0.23 ± 0.12 | 0.17 ± 0.08 | * | * |
| Cantharidae | 0.15 ± 0.12 | 0 | * | * | 0.04 ± 0.04 | 0 | * | * |
| Carabidae | 0.19 ± 0.08 | 0.33 ± 0.12 | 0.15 | 0.8841 | 0.23 ± 0.12 | 0 | * | * |
| Chalcididae | 0.15 ± 0.09 | 0.04 ± 0.04 | * | * | 0 | 0.04 ± 0.04 | * | * |
| Chrysididae | 0.1 ± 0.08 | 0 | * | * | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * |
| Chrysomelidae | 0.42 ± 0.17 | 0.52 ± 0.20 | -0.26 | 0.7981 | 0.23 ± 0.08 | 0.25 ± 0.11 | -0.42 | 0.6709 |
| Chrysopidae | 0 | 0.04 ± 0.04 | * | * | 0 | 0.17 ± 0.10 | * | * |
| Cixiidae | 0.15 ± 0.09 | 0.19 ± 0.08 | * | * | 0.42 ± 0.18 | 0.63 ± 0.27 | * | * |
| Coccinellidae | 4.81 ± 0.95 | 3.04 ± 0.33 | 0.89 | 0.3750 | 2.38 ± 0.55 | 9.58 ± 1.77 | -3.12 | 0.0018 |
| Coniopterygidae | 0.23 ± 0.13 | 0.22 ± 0.13 | * | * | 0.58 ± 0.18 | 0.29 ± 0.09 | 1.68 | 0.0930 |
| Corylophidae | 0.81 ± 0.25 | 0.27 ± 0.10 | 0.13 | 0.8993 | 0.81 ± 0.25 | 0.46 ± 0.17 | -0.00 | 1 |
| Culicidae | 0 | 0.52 ± 0.38 | * | * | 0.23 ± 0.14 | 0.54 ± 0.17 | * | * |
| Curculionidae | 0.35 ± 0.14 | 0.44 ± 0.16 | 0.68 | 0.4984 | 0.08 ± 0.05 | 0.08 ± 0.06 | * | * |
| Cynipidae | 0.38 ± 0.12 | 0.93 ± 0.26 | -0.77 | 0.4441 | 2.35 ± 1.35 | 1.92 ± 0.49 | -0.11 | 0.9115 |
| Diapriidae | 3.35 ± 0.67 | 1.81 ± 0.40 | 1.45 | 0.1457 | 0.62 ± 0.24 | 0.17 ± 0.07 | * | * |
| Dolichopodidae | 2.54 ± 0.34 | 2.26 ± 0.43 | 0.15 | 0.8803 | 4.15 ± 0.67 | 4.46 ± 0.86 | -1.20 | 0.2309 |
| Erebidae | 0.04 ± 0.04 | 0 | * | * | 0 | 0.04 ± 0.04 | * | * |
| Flatidae | 0.31 ± 0.12 | 0.11 ± 0.06 | 1.06 | 0.2896 | 0.08 ± 0.05 | 0.08 ± 0.06 | * | * |
| Formicidae | 0.85 ± 0.33 | 1.04 ± 0.41 | 0.54 | 0.5913 | 0.50 ± 0.24 | 0.79 ± 0.25 | 0 | 1 |
| Halictidae | 0.23 ± 0.10 | 0 | * | * | 0.15 ± 0.07 | 0.08 ± 0.06 | * | * |
| Hesperiidae | 0.85 ± 0.41 | 0.22 ± 0.08 | * | * | 0 | 0 | * | * |
| Ichenumonidae | 1.42 ± 0.32 | 0.78 ± 0.19 | -1.50 | 0.1328 | 0.27 ± 0.12 | 0.58 ± 0.19 | -0.80 | 0.4235 |
| Lampyridae | 0.04 ± 0.04 | 0.07 ± 0.05 | * | * | 0 | 0.13 ± 0.07 | * | * |
| Lepidoptera | 0.92 ± 0.19 | 1.19 ± 0.31 | -0.48 | 0.6340 | 1.88 ± 0.32 | 1.92 ± 0.41 | 0.39 | 0.6940 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 0.62 ± 0.20 | 1.07 ± 0.41 | -1.19 | 0.2346 | 1.35 ± 0.32 | 1.83 ± 0.76 | -0.54 | 0.5863 |
| Mymaridae | 7.19 ± 1.07 | 4.63 ± 0.63 | 2.28 | 0.0227 | 3.08 ± 0.51 | 5.72 ± 1.23 | -0.82 | 0.4133 |
| Nymphalidae | 0 | 0 | * | * | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * |
| Panorpidae | 0.04 ± 0.04 | 0.19 ± 0.11 | * | * | 0 | 0 | * | * |
| Papilionidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Phalacridae | 0.12 ± 0.06 | 0.07 ± 0.05 | * | * | 0.35 ± 0.12 | 0.13 ± 0.07 | * | * |
| Pieridae | 0 | 0 | * | * | 0 | 0 | * | * |
| Psychodidae | 0.65 ± 0.21 | 0.59 ± 0.27 | -0.84 | 0.4025 | 2.19 ± 1.03 | 0.71 ± 0.32 | 1.64 | 0.1013 |
| Araneae | 10.62 ± 1.16 | 10.30 ± 1.15 | -0.74 | 0.4604 | 5.85 ± 0.81 | 5.08 ± 0.50 | 1.02 | 0.3098 |
| Staphylinidae | 0.77 ± 0.17 | 1.00 ± 0.24 | -0.89 | 0.3727 | 1.38 ± 0.24 | 0.83 ± 0.20 | 1.64 | 0.1005 |
| Syrphidae | 0.35 ± 0.12 | 0.48 ± 0.12 | * | * | 0.23 ± 0.14 | 0.21 ± 0.10 | * | * |
| Tachinidae | 0.08 ± 0.05 | 0.15 ± 0.07 | * | * | 0.58 ± 0.26 | 0.58 ± 0.21 | 2.09 | 0.0363 |
| Ulidiidae | 0.31 ± 0.14 | 0.37 ± 0.18 | * | * | 0 | 0.83 ± 0.36 | * | * |
| Vespidae | 0.04 ± 0.04 | 0.07 ± 0.05 | * | * | 0.27 ± 0.12 | 0.17 ± 0.10 | * | * |
| Xylomyidae | 1.58 ± 0.48 | 0.89 ± 0.52 | 1.93 | 0.0537 | 2.19 ± 1.04 | 0.58 ± 0.18 | * | * |

** Not enough representatives to determine statistical significance*

**Table 7.** Average insect abundance by family captured in pitfall traps deployed at 10 m into the forest during 2020 and 2021.

| | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Carabidae | 2.32 ± 0.54 | 2.35 ± 0.43 | * | * | 0.51 ± 0.13 | 0.39 ± 0.09 | * | * |
| Staphylinidae | 0.32 ± 0.08 | 0.28 ± 0.12 | * | * | 0.22 ± 0.06 | 0.32 ± 0.09 | * | * |
| Araneae | 0.64 ± 0.11 | 0.89 ± 0.13 | 8.89 | <0.0001 | 1.82 ± 0.45 | 1.21 ± 0.20 | -1.16 | 0.2474 |
| Opiliones | 0.39 ± 0.08 | 0.47 ± 0.09 | * | * | 0.78 ± 0.17 | 0.42 ± 0.10 | * | * |
| Formicidae | 2.89 ± 0.39 | 3.33 ± 0.70 | 2.33 | 0.0199 | 4.37 ± 0.75 | 3.91 ± 0.54 | 1.82 | 0.0691 |
| Gryllidae | 0.50 ± 0.11 | 0.46 ± 0.14 | * | * | 0.52 ± 0.17 | 0.50 ± 0.12 | * | * |
| Isopoda | 3.42 ± 0.76 | 2.31 ± 0.48 | -2.09 | 0.0366 | 2.64 ± 0.56 | 2.24 ± 0.47 | -0.30 | 0.7642 |
| Centipedes | 0 | 0.04 ± 0.02 | * | * | 0.10 ± 0.04 | 0.17 ± 0.06 | * | * |
| Millipedes | 0.02 ± 0.02 | 0.09 ± 0.04 | * | * | 0.13 ± 0.07 | 0.12 ± 0.09 | * | * |
| Collembola | 0.13 ± 0.05 | 0.25 ± 0.08 | * | * | 4.01 ± 0.91 | 9.32 ± 3.89 | 1.07 | 0.2846 |
| Tenebrionidae | 0.01 ± 0.01 | 0 | * | * | 0.12 ± 0.05 | 0.05 ± 0.03 | * | * |
| Nitidulidae | 0.26 ± 0.09 | 0.21 ± 0.09 | * | * | 0.24 ± 0.06 | 0.02 ± 0.02 | * | * |
| Histeridae | 0 | 0 | * | * | 0 | 0.03 ± 0.02 | * | * |
| Coccinellidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Scarabaeidae | 0.27 ± 0.09 | 0.28 ± 0.11 | * | * | 0.45 ± 0.35 | 0.30 ± 0.12 | * | * |
| Elateridae | 0 | 0.01 ± 0.01 | * | * | 0.01 ± 0.01 | 0.05 ± 0.03 | * | * |
| Curculionidae | 1.17 ± 0.21 | 0.91 ± 0.19 | * | * | 1.37 ± 0.48 | 0.47 ± 0.12 | * | * |
| Geotrupidae | 0.01 ± 0.01 | 0 | * | * | 0 | 0.06 ± 0.05 | * | * |
| Silphidae | 0.07 ± 0.04 | 0.02 ± 0.02 | * | * | 0 | 0.06 ± 0.05 | * | * |
| Erotylidae | 0.01 ± 0.01 | 0.02 ± 0.02 | * | * | 0.04 ± 0.04 | 0.08 ± 0.04 | * | * |
| Phalacridae | 0.01 ± 0.01 | 0 | * | * | 0 | 0.02 ± 0.02 | * | * |
| Chrysomelidae | 0 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |
| Ptiliidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Lampyridae | 0.06 ± 0.03 | 0.01 ± 0.01 | * | * | 0.03 ± 0.02 | 0.05 ± 0.03 | * | * |
| Acrididae | 0.02 ± 0.02 | 0.04 ± 0.03 | * | * | 0 | 0.05 ± 0.05 | * | * |
| Tettigoniidae | 0 | 0 | * | * | 0.03 ± 0.03 | 0 | * | * |
| Blattidae | 0.88 ± 0.15 | 1.09 ± 0.17 | * | * | 1.27 ± 0.25 | 1.03 ± 0.20 | * | * |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rhaphidophoridae | 0.64 ± 0.13 | 0.52 ± 0.14 | * | * | 0.76 ± 0.17 | 0.83 ± 0.25 | * | * |
| Diplura | 0.02 ± 0.02 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |
| Protura | 0.01 ± 0.01 | 0 | * | * | 0 | 0 | * | * |
| Mites | 0.69 ± 0.14 | 0.59 ± 0.15 | * | * | 2.64 ± 0.48 | 1.82 ± 0.32 | * | * |
| Ticks | 0.08 ± 0.05 | 0.06 ± 0.04 | * | * | 0.09 ± 0.08 | 0.06 ± 0.04 | * | * |

* *Not enough representatives to determine statistical significance*

**Table 8.** Average insect abundance by family captured on yellow sticky traps deployed at 10 m into the forest during 2021.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.72 ± 0.27 | 0.06 ± 0.04 | * | * | 0.28 ± 0.09 | 0.39 ± 0.14 | * | * |
| Apidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Asilidae | 0.81 ± 0.26 | 0.56 ± 0.13 | 1.04 | 0.2973 | 0.28 ± 0.11 | 0.13 ± 0.08 | * | * |
| Braconidae | 0.81 ± 0.16 | 0.50 ± 0.12 | 2.05 | 0.0401 | 0.75 ± 0.23 | 0.45 ± 0.12 | 1.27 | 0.2044 |
| Cantharidae | 0.03 ± 0.03 | 0.31 ± 0.23 | * | * | 0.06 ± 0.04 | 0.19 ± 0.16 | * | * |
| Carabidae | 0.56 ± 0.21 | 0.14 ± 0.07 | * | * | 0.11 ± 0.07 | 0.32 ± 0.10 | * | * |
| Chalcididae | 0 | 0.06 ± 0.04 | * | * | 0 | 0.03 ± 0.03 | * | * |
| Chrysididae | 0.03 ± 0.03 | 0.08 ± 0.06 | * | * | 0.14 ± 0.07 | 0.32 ± 0.11 | * | * |
| Chrysomelidae | 0.42 ± 0.12 | 0.42 ± 0.11 | -0.27 | 0.7871 | 0.17 ± 0.06 | 0.39 ± 0.11 | * | * |
| Chrysopidae | 0 | 0 | * | * | 0.08 ± 0.05 | 0.03 ± 0.03 | * | * |
| Cixiidae | 0.31 ± 0.11 | 0.22 ± 0.08 | * | * | 0.39 ± 0.11 | 0.19 ± 0.10 | * | * |
| Coccinellidae | 3.89 ± 0.54 | 4.44 ± 0.62 | 1.26 | 0.2065 | 4.89 ± 1.35 | 3.10 ± 0.80 | 1.34 | 0.1818 |
| Coniopterygidae | 0.78 ± 0.20 | 0.50 ± 0.23 | * | * | 0.47 ± 0.18 | 0.39 ± 0.15 | * | * |
| Corylophidae | 1.22 ± 0.36 | 1.64 ± 0.89 | 0.61 | 0.5397 | 0.36 ± 0.14 | 0.32 ± 0.13 | * | * |
| Culicidae | 0.06 ± 0.04 | 0.08 ± 0.05 | * | * | 0.22 ± 0.09 | 0.16 ± 0.07 | * | * |
| Curculionidae | 0.53 ± 0.17 | 0.25 ± 0.07 | * | * | 0.28 ± 0.11 | 0.23 ± 0.09 | * | * |
| Cynipidae | 0.92 ± 0.30 | 0.47 ± 0.12 | 1 | 0.3197 | 1.50 ± 0.25 | 1.65 ± 0.38 | -1.31 | 0.1887 |
| Diapriidae | 3.11 ± 0.59 | 4.72 ± 0.67 | -1 | 0.3155 | 0.11 ± 0.05 | 0.35 ± 0.14 | * | * |
| Dolichopodidae | 7.17 ± 0.93 | 6.00 ± 0.77 | 0.75 | 0.4527 | 6.36 ± 1.28 | 5.87 ± 1.00 | -1.66 | 0.0959 |
| Erebidae | 0 | 0 | * | * | 0.03 ± 0.03 | 0.06 ± 0.04 | * | * |
| Flatidae | 0.28 ± 0.10 | 0.44 ± 0.13 | * | * | 0.33 ± 0.10 | 0.13 ± 0.06 | * | * |
| Formicidae | 4.14 ± 1.12 | 1.86 ± 0.61 | -0.17 | 0.8682 | 3.81 ± 0.94 | 2.97 ± 0.70 | 1.29 | 0.1986 |
| Halictidae | 1.42 ± 0.57 | 0.50 ± 0.19 | 0.53 | 0.5943 | 0.50 ± 0.15 | 0.19 ± 0.09 | * | * |
| Hesperiidae | 0.33 ± 0.13 | 0.36 ± 0.18 | * | * | 0.03 ± 0.03 | 0.06 ± 0.04 | * | * |
| Ichenumonidae | 2.17 ± 0.29 | 1.89 ± 0.28 | -0.86 | 0.3880 | 0.64 ± 0.15 | 1.16 ± 0.23 | -1.93 | 0.0542 |
| Lampyridae | 0.17 ± 0.06 | 0.33 ± 0.12 | * | * | 0.17 ± 0.06 | 0.39 ± 0.19 | * | * |
| Lepidoptera | 0.94 ± 0.21 | 1.72 ± 0.34 | -2.55 | 0.0106 | 2.08 ± 0.28 | 1.26 ± 0.32 | 0.65 | 0.5126 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 1.44 ± 0.37 | 1.19 ± 0.44 | -0.37 | 0.7104 | 3.86 ± 0.80 | 2.23 ± 0.41 | 1.33 | 0.1836 |
| Mymaridae | 2.28 ± 0.36 | 2.83 ± 0.59 | -0.82 | 0.4120 | 0.89 ± 0.21 | 2.32 ± 0.52 | -1.97 | 0.0486 |
| Nymphalidae | 0.14 ± 0.07 | 0.03 ± 0.03 | * | * | 0.28 ± 0.12 | 0 | * | * |
| Panorpidae | 1.06 ± 0.33 | 2.17 ± 0.70 | * | * | 0.03 ± 0.03 | 0.06 ± 0.06 | * | * |
| Papilionidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Phalacridae | 0.03 ± 0.03 | 0.11 ± 0.07 | * | * | 0.25 ± 0.09 | 0.10 ± 0.05 | * | * |
| Pieridae | 0 | 0 | * | * | 0 | 0.03 ± 0.03 | * | * |
| Psychodidae | 0.28 ± 0.09 | 0.17 ± 0.06 | 0.61 | 0.5397 | 0.11 ± 0.05 | 0.06 ± 0.04 | * | * |
| Araneae | 10.44 ± 1.31 | 7.31 ± 0.76 | 2.14 | 0.0326 | 4.69 ± 0.63 | 3.71 ± 0.56 | -0.83 | 0.4049 |
| Staphylinidae | 1.36 ± 0.31 | 0.72 ± 0.16 | 0.77 | 0.4426 | 0.72 ± 0.18 | 0.74 ± 0.19 | -1.51 | 0.1321 |
| Syrphidae | 2.36 ± 0.55 | 2.08 ± 0.47 | * | * | 1.00 ± 0.31 | 0.45 ± 0.18 | * | * |
| Tachinidae | 0.22 ± 0.07 | 0.14 ± 0.09 | * | * | 0.72 ± 0.22 | 0.71 ± 0.16 | 0.09 | 0.9298 |
| Ulidiidae | 0.33 ± 0.16 | 0.19 ± 0.08 | * | * | 0.83 ± 0.46 | 1.06 ± 0.30 | * | * |
| Vespidae | 0.47 ± 0.14 | 0.31 ± 0.22 | * | * | 1.28 ± 0.35 | 1.16 ± 0.25 | 0.09 | 0.9300 |
| Xylomyidae | 0.31 ± 0.10 | 0.56 ± 0.12 | -1.10 | 0.2712 | 0.72 ± 0.23 | 1.42 ± 0.40 | -1.53 | 0.1251 |

** Not enough representatives to determine statistical significance*

**Table 9.** Average insect abundance by family captured on yellow sticky traps deployed at 20 m into the forest during 2020.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.38 ± 0.31 | 0.08 ± 0.05 | * | * | 0.08 ± 0.08 | 0.28 ± 0.12 | * | * |
| Apidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Asilidae | 0.19 ± 0.09 | 0.15 ± 0.09 | * | * | 0.08 ± 0.05 | 0.08 ± 0.06 | * | * |
| Braconidae | 0.81 ± 0.18 | 0.58 ± 0.21 | 0.28 | 0.7759 | 0.42 ± 0.13 | 0.32 ± 0.14 | -0.00 | 1 |
| Cantharidae | 0.07 ± 0.05 | 0 | * | * | 0.12 ± 0.12 | 0 | * | * |
| Carabidae | 0.26 ± 0.09 | 0.15 ± 0.09 | * | * | 0.04 ± 0.04 | 0 | * | * |
| Chalcididae | 0.07 ± 0.05 | 0.12 ± 0.06 | * | * | 0 | 0.08 ± 0.06 | * | * |
| Chrysididae | 0 | 0.04 ± 0.04 | * | * | 0.27 ± 0.14 | 0.28 ± 0.17 | 0 | 1 |
| Chrysomelidae | 0.78 ± 0.20 | 0.27 ± 0.14 | * | * | 0.54 ± 0.15 | 0.56 ± 0.26 | * | * |
| Chrysopidae | 0 | 0 | * | * | 0.12 ± 0.06 | 0.04 ± 0.04 | * | * |
| Cixiidae | 0.33 ± 0.13 | 0.54 ± 0.19 | -0.09 | 0.9293 | 0.12 ± 0.08 | 0.40 ± 0.19 | * | * |
| Coccinellidae | 3.22 ± 0.44 | 2.69 ± 0.63 | 1.63 | 0.1033 | 5.08 ± 0.82 | 3.64 ± 0.57 | 1 | 0.3175 |
| Coniopterygidae | 0.11 ± 0.06 | 0.35 ± 0.27 | * | * | 0.46 ± 0.19 | 0.40 ± 0.12 | * | * |
| Corylophidae | 0.70 ± 0.26 | 1.69 ± 0.53 | -1.06 | 0.2896 | 0.58 ± 0.19 | 0.40 ± 0.15 | -0.35 | 0.7273 |
| Culicidae | 0.26 ± 0.19 | 0.38 ± 0.14 | * | * | 0.15 ± 0.07 | 0.28 ± 0.17 | * | * |
| Curculionidae | 0.41 ± 0.13 | 0.38 ± 0.12 | 0.80 | 0.4222 | 0.19 ± 0.08 | 0.16 ± 0.09 | * | * |
| Cynipidae | 0.63 ± 0.18 | 0.46 ± 0.17 | 0.24 | 0.8127 | 0.65 ± 0.21 | 0.96 ± 0.23 | -0.62 | 0.5384 |
| Diapriidae | 2.81 ± 0.61 | 2.00 ± 0.63 | -1.17 | 0.2400 | 0.19 ± 0.11 | 0.16 ± 0.12 | * | * |
| Dolichopodidae | 2.44 ± 0.37 | 2.12 ± 0.50 | -0.16 | 0.8712 | 6.38 ± 0.82 | 7.00 ± 1.24 | 0.49 | 0.6263 |
| Erebidae | 0 | 0 | * | * | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * |
| Flatidae | 0.48 ± 0.15 | 0.35 ± 0.12 | -0.16 | 0.8695 | 0.08 ± 0.05 | 0.08 ± 0.08 | * | * |
| Formicidae | 0.44 ± 0.13 | 1.35 ± 0.57 | -0.53 | 0.5984 | 0.81 ± 0.33 | 0.52 ± 0.16 | 0.35 | 0.7293 |
| Halictidae | 0.19 ± 0.09 | 0.23 ± 0.08 | -0.72 | 0.4707 | 0.27 ± 0.10 | 0.04 ± 0.04 | * | * |
| Hesperiidae | 0.63 ± 0.21 | 0.27 ± 0.12 | -0.15 | 0.8829 | 0.19 ± 0.08 | 0.08 ± 0.06 | * | * |
| Ichenumonidae | 0.85 ± 0.19 | 0.77 ± 0.21 | 0.57 | 0.5721 | 1.00 ± 0.43 | 0.72 ± 0.19 | 0.8 | 0.4236 |
| Lampyridae | 0.15 ± 0.09 | 0.12 ± 0.08 | * | * | 0.04 ± 0.04 | 0.12 ± 0.09 | * | * |
| Lepidoptera | 4.30 ± 3.46 | 0.77 ± 0.17 | 2.84 | 0.0045 | 2.04 ± 0.44 | 1.32 ± 0.30 | 0.33 | 0.7437 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 0.63 ± 0.24 | 1.81 ± 0.49 | -1.87 | 0.0614 | 1.73 ± 0.33 | 1.88 ± 0.45 | -0.13 | 0.8992 |
| Mymaridae | 8.78 ± 1.26 | 4.88 ± 0.77 | 1.95 | 0.0507 | 3.69 ± 0.60 | 3.48 ± 0.51 | -0.10 | 0.9229 |
| Nymphalidae | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * | 0.04 ± 0.04 | 0.12 ± 0.09 | * | * |
| Panorpidae | 0.37 ± 0.17 | 0.19 ± 0.12 | * | * | 0 | 0 | * | * |
| Papilionidae | 0.04 ± 0.04 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0.04 ± 0.04 | 0 | * | * | 0.04 ± 0.04 | 0 | * | * |
| Phalacridae | 0.15 ± 0.07 | 0.18 ± 0.07 | * | * | 0.50 ± 0.15 | 0.32 ± 0.11 | 1.93 | 0.0535 |
| Pieridae | 0 | 0 | * | * | 0 | 0 | * | * |
| Psychodidae | 0.41 ± 0.14 | 0.54 ± 0.13 | -0.77 | 0.4415 | 0.35 ± 0.11 | 0.24 ± 0.17 | 1.82 | 0.0692 |
| Araneae | 10.20 ± 1.00 | 9.00 ± 1.25 | -0.12 | 0.9063 | 5.58 ± 0.56 | 5.52 ± 0.61 | -0.27 | 0.7903 |
| Staphylinidae | 0.52 ± 0.15 | 0.88 ± 0.25 | -0.65 | 0.5137 | 0.73 ± 0.17 | 0.96 ± 0.21 | 0.33 | 0.7424 |
| Syrphidae | 0.67 ± 0.21 | 0.92 ± 0.24 | 0.12 | 0.9079 | 0.19 ± 0.08 | 0.36 ± 0.14 | * | * |
| Tachinidae | 0.30 ± 0.12 | 0.08 ± 0.05 | * | * | 0.46 ± 0.14 | 0.68 ± 0.22 | -0.42 | 0.6709 |
| Ulidiidae | 0.07 ± 0.05 | 0.23 ± 0.10 | * | * | 0.38 ± 0.12 | 0.32 ± 0.14 | 0.77 | 0.4430 |
| Vespidae | 0 | 0 | * | * | 0.38 ± 0.12 | 0.32 ± 0.15 | * | * |
| Xylomyidae | 1.41 ± 0.40 | 0.62 ± 0.28 | * | * | 1.69 ± 0.48 | 0.40 ± 0.12 | * | * |

** Not enough representatives to determine statistical significance*

**Table 10.** Average insect abundance by family captured in pitfall traps deployed at 20 m into the forest during 2020 and 2021.

| | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Carabidae | 2.40 ± 0.34 | 1.84 ± 0.25 | * | * | 0.64 ± 0.13 | 0.60 ± 0.12 | * | * |
| Staphylinidae | 0.26 ± 0.07 | 0.24 ± 0.07 | * | * | 0.36 ± 0.10 | 0.25 ± 0.09 | * | * |
| Araneae | 0.64 ± 0.11 | 0.77 ± 0.13 | 2.67 | 0.0075 | 2.33 ± 0.81 | 1.51 ± 0.48 | 0.35 | 0.7258 |
| Opiliones | 0.43 ± 0.10 | 0.28 ± 0.07 | * | * | 0.56 ± 0.12 | 0.43 ± 0.09 | * | * |
| Formicidae | 3.43 ± 0.41 | 2.66 ± 0.40 | 3.31 | 0.0009 | 3.79 ± 0.50 | 2.99 ± 0.47 | -0.06 | 0.9509 |
| Gryllidae | 0.44 ± 0.09 | 0.28 ± 0.07 | * | * | 0.47 ± 0.21 | 0.36 ± 0.08 | * | * |
| Isopoda | 2.89 ± 0.56 | 2.60 ± 0.51 | 1 | 0.3174 | 3.36 ± 0.64 | 2.06 ± 0.33 | -8.99 | <.0001 |
| Centipedes | 0.02 ± 0.02 | 0.12 ± 0.07 | * | * | 0.09 ± 0.04 | 0.10 ± 0.04 | * | * |
| Millipedes | 0.01 ± 0.01 | 0.10 ± 0.04 | * | * | 0 | 0.04 ± 0.03 | * | * |
| Collembola | 0.26 ± 0.08 | 0.20 ± 0.07 | * | * | 6.61 ± 1.50 | 2.91 ± 0.50 | 0.36 | 0.7198 |
| Tenebrionidae | 0.01 ± 0.01 | 0.02 ± 0.02 | * | * | 0.08 ± 0.04 | 0.01 ± 0.01 | * | * |
| Nitidulidae | 0.31 ± 0.08 | 0.32 ± 0.11 | * | * | 0.27 ± 0.07 | 0.19 ± 0.06 | * | * |
| Histeridae | 0 | 0 | * | * | 0.03 ± 0.02 | 0.01 ± 0.01 | * | * |
| Coccinellidae | 0.01 ± 0.01 | 0 | * | * | 0 | 0 | * | * |
| Scarabaeidae | 0.34 ± 0.09 | 0.38 ± 0.08 | * | * | 0.24 ± 0.11 | 0.16 ± 0.05 | * | * |
| Elateridae | 0.01 ± 0.01 | 0 | * | * | 0.02 ± 0.02 | 0 | * | * |
| Curculionidae | 1.21 ± 0.21 | 1.22 ± 0.30 | * | * | 1.98 ± 0.49 | 0.48 ± 0.14 | * | * |
| Geotrupidae | 0.03 ± 0.02 | 0.02 ± 0.02 | * | * | 0.02 ± 0.02 | 0 | * | * |
| Silphidae | 0.12 ± 0.06 | 0.02 ± 0.02 | * | * | 0.08 ± 0.05 | 0.03 ± 0.02 | * | * |
| Erotylidae | 0 | 0.01 ± 0.01 | * | * | 0.03 ± 0.02 | 0.01 ± 0.01 | * | * |
| Phalacridae | 0 | 0 | * | * | 0 | 0.03 ± 0.03 | * | * |
| Chrysomelidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Ptiliidae | 0.02 ± 0.02 | 0 | * | * | 0 | 0 | * | * |
| Lampyridae | 0.11 ± 0.06 | 0.01 ± 0.01 | * | * | 0.02 ± 0.02 | 0.01 ± 0.01 | * | * |
| Acrididae | 0.02 ± 0.02 | 0 | * | * | 0.03 ± 0.02 | 0 | * | * |
| Tettigoniidae | 0.02 ± 0.02 | 0.02 ± 0.02 | * | * | 0.02 ± 0.02 | 0 | * | * |
| Blattidae | 1.14 ± 0.18 | 0.73 ± 0.14 | * | * | 1.94 ± 0.44 | 0.34 ± 0.08 | 2.78 | 0.0054 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rhaphidophoridae | 0.68 ± 0.14 | 0.62 ± 0.16 | * | * | 0.98 ± 0.21 | 0.36 ± 0.11 | * | * |
| Diplura | 0 | 0 | * | * | 0 | 0.01 ± 0.01 | * | * |
| Protura | 0 | 0.02 ± 0.02 | * | * | 0.02 ± 0.02 | 0 | * | * |
| Mites | 0.51 ± 0.12 | 0.18 ± 0.08 | * | * | 1.12 ± 0.24 | 1.13 ± 0.18 | * | * |
| Ticks | 0.09 ± 0.05 | 0.05 ± 0.04 | * | * | 0.18 ± 0.08 | 0.10 ± 0.04 | * | * |

* *Not enough representatives to determine statistical significance*

**Table 11.** Average insect abundance by family captured on yellow sticky traps deployed at 20 m into the forest during 2021.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.03 ± 0.03 | 0.06 ± 0.06 | * | * | 0.25 ± 0.08 | 0.06 ± 0.06 | * | * |
| Apidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Asilidae | 0.75 ± 0.27 | 0.97 ± 0.36 | * | * | 0.25 ± 0.09 | 0.17 ± 0.06 | * | * |
| Braconidae | 0.61 ± 0.12 | 0.64 ± 0.18 | 0.63 | 0.5265 | 0.50 ± 0.12 | 0.39 ± 0.11 | * | * |
| Cantharidae | 0.03 ± 0.03 | 0.42 ± 0.32 | * | * | 0.03 ± 0.03 | 0.36 ± 0.33 | * | * |
| Carabidae | 0.25 ± 0.08 | 0.19 ± 0.07 | -0.61 | 0.5397 | 0.03 ± 0.03 | 0.28 ± 0.12 | * | * |
| Chalcididae | 0.06 ± 0.04 | 0.03 ± 0.03 | * | * | 0 | 0.08 ± 0.06 | * | * |
| Chrysididae | 0.11 ± 0.08 | 0.08 ± 0.05 | * | * | 0.17 ± 0.06 | 0.08 ± 0.05 | * | * |
| Chrysomelidae | 0.22 ± 0.08 | 0.39 ± 0.11 | -0.34 | 0.7325 | 0.19 ± 0.09 | 0.64 ± 0.16 | -1.70 | 0.0892 |
| Chrysopidae | 0 | 0 | * | * | 0 | 0.06 ± 0.04 | * | * |
| Cixiidae | 0.64 ± 0.26 | 0.28 ± 0.12 | * | * | 0.39 ± 0.13 | 0.22 ± 0.09 | * | * |
| Coccinellidae | 3.28 ± 0.48 | 5.50 ± 0.94 | -0.91 | 0.3602 | 4.47 ± 1.79 | 2.42 ± 0.47 | 1.23 | 0.2176 |
| Coniopterygidae | 0.08 ± 0.05 | 0.39 ± 0.16 | * | * | 0.31 ± 0.12 | 0.44 ± 0.18 | -0.87 | 0.3867 |
| Corylophidae | 1.36 ± 0.46 | 0.92 ± 0.30 | * | * | 0.33 ± 0.13 | 0.22 ± 0.10 | * | * |
| Culicidae | 0.11 ± 0.07 | 0.06 ± 0.04 | * | * | 0.08 ± 0.06 | 0.14 ± 0.07 | * | * |
| Curculionidae | 0.83 ± 0.35 | 0.31 ± 0.11 | 2.16 | 0.0304 | 0.42 ± 0.14 | 0.31 ± 0.11 | 1.41 | 0.1577 |
| Cynipidae | 0.69 ± 0.22 | 0.42 ± 0.11 | 1.5 | 0.1326 | 1.25 ± 0.48 | 0.89 ± 0.23 | 0.39 | 0.6984 |
| Diapriidae | 2.58 ± 0.49 | 4.00 ± 0.70 | -0.66 | 0.5076 | 0.36 ± 0.13 | 0.33 ± 0.12 | * | * |
| Dolichopodidae | 5.08 ± 0.74 | 4.86 ± 0.73 | -1.72 | 0.0858 | 4.75 ± 0.66 | 4.50 ± 0.68 | 1.07 | 0.2832 |
| Erebidae | 0 | 0 | * | * | 0.03 ± 0.03 | 0.03 ± 0.03 | * | * |
| Flatidae | 0.33 ± 0.15 | 0.33 ± 0.13 | * | * | 0.22 ± 0.07 | 0.25 ± 0.09 | -0.73 | 0.4632 |
| Formicidae | 4.64 ± 1.14 | 1.53 ± 0.29 | 2.37 | 0.0176 | 5.03 ± 0.84 | 2.14 ± 0.43 | 2.25 | 0.0247 |
| Halictidae | 0.81 ± 0.36 | 0.58 ± 0.29 | * | * | 0.33 ± 0.20 | 0.28 ± 0.15 | * | * |
| Hesperiidae | 0.33 ± 0.20 | 0.33 ± 0.09 | * | * | 0.06 ± 0.04 | 0.06 ± 0.04 | * | * |
| Ichenumonidae | 2.42 ± 0.51 | 1.25 ± 0.18 | 0.60 | 0.5471 | 0.53 ± 0.14 | 0.89 ± 0.16 | -2.57 | 0.0102 |
| Lampyridae | 0.17 ± 0.06 | 0.36 ± 0.13 | * | * | 0.22 ± 0.09 | 0.56 ± 0.29 | * | * |
| Lepidoptera | 0.83 ± 0.15 | 1.28 ± 0.30 | -2.33 | 0.0198 | 2.19 ± 0.35 | 2.00 ± 0.36 | -0.81 | 0.4173 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 1.28 ± 0.22 | 0.67 ± 0.16 | 0.19 | 0.8471 | 4.69 ± 0.82 | 2.78 ± 0.52 | 1.58 | 0.1137 |
| Mymaridae | 1.28 ± 0.22 | 2.89 ± 0.42 | -2.35 | 0.0190 | 0.83 ± 0.21 | 1.47 ± 0.29 | -0.48 | 0.6288 |
| Nymphalidae | 0.08 ± 0.05 | 0.06 ± 0.04 | * | * | 0.17 ± 0.12 | 0.11 ± 0.05 | * | * |
| Panorpidae | 1.75 ± 0.92 | 1.94 ± 0.62 | * | * | 0.03 ± 0.03 | 0.14 ± 0.05 | * | * |
| Papilionidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0.06 ± 0.06 | 0 | * | * | 0 | 0 | * | * |
| Phalacridae | 0.31 ± 0.10 | 0.08 ± 0.05 | * | * | 0.19 ± 0.08 | 0.14 ± 0.06 | * | * |
| Pieridae | 0 | 0 | * | * | 0 | 0 | * | * |
| Psychodidae | 0.28 ± 0.09 | 0.31 ± 0.09 | -1.37 | 0.1715 | 0.03 ± 0.03 | 0.22 ± 0.08 | * | * |
| Araneae | 10.53 ± 1.84 | 7.42 ± 0.76 | 0.63 | 0.5278 | 3.78 ± 0.45 | 3.78 ± 0.37 | -0.67 | 0.5040 |
| Staphylinidae | 1.36 ± 0.25 | 0.69 ± 0.17 | 2.49 | 0.0128 | 0.64 ± 0.14 | 0.61 ± 0.17 | -0.93 | 0.3503 |
| Syrphidae | 2.36 ± 0.65 | 2.00 ± 0.60 | 0.27 | 0.7849 | 0.72 ± 0.31 | 0.56 ± 0.19 | * | * |
| Tachinidae | 0.22 ± 0.08 | 0.17 ± 0.07 | * | * | 0.97 ± 0.21 | 0.33 ± 0.10 | 1.45 | 0.1457 |
| Ulidiidae | 0.11 ± 0.05 | 0.36 ± 0.13 | * | * | 0.25 ± 0.08 | 0.78 ± 0.25 | * | * |
| Vespidae | 0.36 ± 0.10 | 0.28 ± 0.09 | * | * | 1.33 ± 0.38 | 1.19 ± 0.23 | 0.73 | 0.4626 |
| Xylomyidae | 0.31 ± 0.09 | 0.67 ± 0.19 | -0.56 | 0.5779 | 1.17 ± 0.37 | 1.11 ± 0.30 | 0.15 | 0.8792 |

** Not enough representatives to determine statistical significance*

**Table 12.** Average insect abundance by family captured on yellow sticky traps deployed at 40 m into the forest during 2020.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.07 ± 0.05 | 0.12 ± 0.07 | * | * | 0.33 ± 0.23 | 0.15 ± 0.07 | * | * |
| Apidae | 0 | 0 | * | * | 0 | 0.04 ± 0.04 | * | * |
| Asilidae | 0 | 0.16 ± 0.07 | * | * | 0.11 ± 0.06 | 0.12 ± 0.06 | * | * |
| Braconidae | 0.56 ± 0.17 | 0.36 ± 0.11 | 0.37 | 0.7097 | 0.44 ± 0.11 | 0.23 ± 0.10 | 0.51 | 0.6117 |
| Cantharidae | 0.04 ± 0.04 | 0 | * | * | 0.04 ± 0.04 | 0 | * | * |
| Carabidae | 0.22 ± 0.12 | 0.04 ± 0.04 | * | * | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * |
| Chalcididae | 0.04 ± 0.04 | 0.08 ± 0.08 | * | * | 0.04 ± 0.04 | 0 | * | * |
| Chrysididae | 0 | 0.08 ± 0.06 | * | * | 0.11 ± 0.06 | 0.08 ± 0.05 | * | * |
| Chrysomelidae | 1.00 ± 0.21 | 0.32 ± 0.14 | * | * | 0.81 ± 0.27 | 0.31 ± 0.13 | 1.49 | 0.1350 |
| Chrysopidae | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * | 0 | 0.04 ± 0.04 | * | * |
| Cixiidae | 0.11 ± 0.06 | 1.00 ± 0.65 | * | * | 0.07 ± 0.05 | 0.15 ± 0.09 | * | * |
| Coccinellidae | 5.59 ± 0.92 | 2.00 ± 0.49 | 2.83 | 0.0046 | 3.19 ± 0.64 | 4.96 ± 1.24 | -0.67 | 0.5004 |
| Coniopterygidae | 0.15 ± 0.12 | 0.12 ± 0.09 | * | * | 0.44 ± 0.19 | 0.35 ± 0.11 | * | * |
| Corylophidae | 0.41 ± 0.13 | 0.72 ± 0.25 | -0.19 | 0.8530 | 0.44 ± 0.14 | 0.50 ± 0.13 | 0.61 | 0.5417 |
| Culicidae | 0.11 ± 0.06 | 0.20 ± 0.10 | -0.72 | 0.4707 | 0.15 ± 0.12 | 0.38 ± 0.18 | * | * |
| Curculionidae | 0.37 ± 0.19 | 0.20 ± 0.13 | * | * | 0.11 ± 0.08 | 0.04 ± 0.04 | * | * |
| Cynipidae | 0.33 ± 0.13 | 0.28 ± 0.12 | * | * | 0.44 ± 0.25 | 0.54 ± 0.16 | * | * |
| Diapriidae | 2.81 ± 0.69 | 1.36 ± 0.39 | 1.02 | 0.3096 | 0.04 ± 0.04 | 0.23 ± 0.10 | * | * |
| Dolichopodidae | 2.70 ± 0.63 | 2.08 ± 0.48 | -0.03 | 0.9739 | 6.33 ± 1.1 | 5.38 ± 1.22 | -0.36 | 0.7192 |
| Erebidae | 0 | 0 | * | * | 0.11 ± 0.06 | 0.04 ± 0.04 | * | * |
| Flatidae | 0.56 ± 0.19 | 0.52 ± 0.15 | 1.01 | 0.3144 | 0.26 ± 0.09 | 0 | * | * |
| Formicidae | 0.22 ± 0.10 | 1.28 ± 0.58 | -1.06 | 0.2896 | 0.52 ± 0.27 | 0.46 ± 0.11 | * | * |
| Halictidae | 0.15 ± 0.09 | 0.12 ± 0.07 | * | * | 0.19 ± 0.09 | 0.12 ± 0.08 | * | * |
| Hesperiidae | 0.37 ± 0.12 | 0.28 ± 0.15 | * | * | 0.22 ± 0.16 | 0 | * | * |
| Ichenumonidae | 0.96 ± 0.22 | 0.76 ± 0.17 | 0.40 | 0.6864 | 0.93 ± 0.23 | 0.31 ± 0.13 | 2.06 | 0.0393 |
| Lampyridae | 0.30 ± 0.18 | 0 | * | * | 0.19 ± 0.12 | 0 | * | * |
| Lepidoptera | 0.81 ± 0.19 | 0.76 ± 0.19 | 0.64 | 0.5250 | 1.74 ± 0.30 | 1.50 ± 0.25 | 1.42 | 0.1559 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 0.33 ± 0.16 | 0.44 ± 0.22 | * | * | 3.26 ± 1.29 | 3.19 ± 0.83 | 0.42 | 0.6774 |
| Mymaridae | 6.44 ± 0.80 | 6.04 ± 0.98 | 0.12 | 0.9020 | 3.37 ± 0.64 | 3.08 ± 0.55 | -1.64 | 0.1014 |
| Nymphalidae | 0 | 0.08 ± 0.08 | * | * | 0 | 0.04 ± 0.04 | * | * |
| Panorpidae | 1.19 ± 0.40 | 0.24 ± 0.10 | 2.68 | 0.0074 | 0.07 ± 0.05 | 0 | * | * |
| Papilionidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0 | 0 | * | * | 0.11 ± 0.08 | 0 | * | * |
| Phalacridae | 0.26 ± 0.09 | 0.04 ± 0.04 | * | * | 0.70 ± 0.15 | 0.27 ± 0.10 | 1.80 | 0.0715 |
| Pieridae | 0.04 ± 0.04 | 0.04 ± 0.04 | * | * | 0 | 0 | * | * |
| Psychodidae | 0.56 ± 0.21 | 0.48 ± 0.22 | * | * | 1.07 ± 0.28 | 0.19 ± 0.10 | * | * |
| Araneae | 11.1 ± 1.22 | 5.52 ± 0.59 | 2.09 | 0.0367 | 4.26 ± 0.55 | 4.77 ± 0.71 | -0.31 | 0.7564 |
| Staphylinidae | 1.89 ± 0.78 | 0.56 ± 0.15 | 2.15 | 0.0313 | 1.07 ± 0.38 | 1.12 ± 0.18 | 0.65 | 0.5169 |
| Syrphidae | 0.59 ± 0.19 | 0.68 ± 0.23 | -1.65 | 0.0996 | 0.37 ± 0.12 | 0.12 ± 0.06 | * | * |
| Tachinidae | 0.11 ± 0.06 | 0.16 ± 0.09 | * | * | 0.78 ± 0.26 | 0.54 ± 0.21 | 0.55 | 0.5846 |
| Ulidiidae | 0.48 ± 0.12 | 0.16 ± 0.12 | * | * | 0.26 ± 0.14 | 0.04 ± 0.04 | * | * |
| Vespidae | 0 | 0.08 ± 0.06 | * | * | 0.30 ± 0.10 | 0.08 ± 0.05 | * | * |
| Xylomyidae | 2.33 ± 0.69 | 1.16 ± 0.40 | 2.37 | 0.0178 | 1.19 ± 0.30 | 1.73 ± 1.11 | 1.36 | 0.1726 |

** Not enough representatives to determine statistical significance*

**Table 13.** Average insect abundance by family captured in pitfall traps deployed at 40 m into the forest during 2020 and 2021.

| | 2020 | | | | 2021 | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Carabidae | 2.48 ± 0.32 | 1.76 ± 0.28 | 1.32 | 0.1875 | 0.59 ± 0.16 | 0.51 ± 0.16 | * | * |
| Staphylinidae | 0.40 ± 0.09 | 0.15 ± 0.05 | * | * | 0.32 ± 0.08 | 0.21 ± 0.10 | * | * |
| Araneae | 0.83 ± 0.14 | 0.56 ± 0.13 | * | * | 1.09 ± 0.26 | 1.12 ± 0.30 | 1.80 | 0.0718 |
| Opiliones | 0.38 ± 0.10 | 0.26 ± 0.07 | * | * | 0.27 ± 0.07 | 0.37 ± 0.10 | * | * |
| Formicidae | 3.72 ± 0.63 | 3.64 ± 0.54 | -0.43 | 0.6649 | 3.15 ± 0.41 | 2.76 ± 0.52 | * | * |
| Gryllidae | 0.30 ± 0.07 | 0.33 ± 0.10 | * | * | 0.32 ± 0.09 | 0.36 ± 0.08 | * | * |
| Isopoda | 2.75 ± 0.41 | 2.45 ± 0.45 | -0.70 | 0.4855 | 2.52 ± 0.38 | 2.27 ± 0.40 | 0.32 | 0.7473 |
| Centipedes | 0.01 ± 0.01 | 0.01 ± 0.01 | * | * | 0.11 ± 0.05 | 0.25 ± 0.10 | * | * |
| Millipedes | 0.05 ± 0.04 | 0.04 ± 0.02 | * | * | 0.12 ± 0.05 | 0.03 ± 0.03 | * | * |
| Collembola | 0.33 ± 0.11 | 0.18 ± 0.07 | * | * | 3.48 ± 0.87 | 6.16 ± 2.50 | * | * |
| Tenebrionidae | 0.01 ± 0.01 | 0 | * | * | 0.03 ± 0.02 | 0.07 ± 0.03 | * | * |
| Nitidulidae | 0.51 ± 0.17 | 0.37 ± 0.25 | * | * | 0.12 ± 0.04 | 0.09 ± 0.04 | * | * |
| Histeridae | 0 | 0.01 ± 0.01 | * | * | 0.03 ± 0.03 | 0 | * | * |
| Coccinellidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Scarabaeidae | 0.15 ± 0.05 | 0.24 ± 0.08 | * | * | 0.14 ± 0.04 | 0.10 ± 0.05 | * | * |
| Elateridae | 0.01 ± 0.01 | 0.01 ± 0.01 | * | * | 0.02 ± 0.02 | 0 | * | * |
| Curculionidae | 1.47 ± 0.44 | 1.10 ± 0.25 | * | * | 1.02 ± 0.31 | 0.40 ± 0.11 | * | * |
| Geotrupidae | 0.01 ± 0.01 | 0.03 ± 0.02 | * | * | 0.03 ± 0.02 | 0.03 ± 0.02 | * | * |
| Silphidae | 0.26 ± 0.12 | 0.01 ± 0.01 | * | * | 0.03 ± 0.03 | 0.01 ± 0.01 | * | * |
| Erotylidae | 0.09 ± 0.05 | 0.01 ± 0.01 | * | * | 0.03 ± 0.02 | 0 | * | * |
| Phalacridae | 0 | 0 | * | * | 0.05 ± 0.05 | 0.04 ± 0.03 | * | * |
| Chrysomelidae | 0.02 ± 0.02 | 0.01 ± 0.01 | * | * | 0 | 0 | * | * |
| Ptiliidae | 0.02 ± 0.02 | 0 | * | * | 0 | 0 | * | * |
| Lampyridae | 0.03 ± 0.02 | 0.01 ± 0.01 | * | * | 0 | 0.01 ± 0.01 | * | * |
| Acrididae | 0.03 ± 0.03 | 0.03 ± 0.02 | * | * | 0 | 0.01 ± 0.01 | * | * |
| Tettigoniidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Blattidae | 1.22 ± 0.19 | 1.13 ± 0.20 | -0.69 | 0.4877 | 1.59 ± 0.34 | 1.36 ± 0.23 | 1.55 | 0.1205 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rhaphidophoridae | 0.78 ± 0.18 | 0.94 ± 0.21 | * | * | 0.42 ± 0.11 | 0.79 ± 0.19 | * | * |
| Diplura | 0.03 ± 0.03 | 0.06 ± 0.06 | * | * | 0 | 0.03 ± 0.02 | * | * |
| Protura | 0.01 ± 0.01 | 0.05 ± 0.05 | * | * | 0.03 ± 0.03 | 0.01 ± 0.01 | * | * |
| Mites | 0.46 ± 0.18 | 0.23 ± 0.08 | * | * | 1.08 ± 0.19 | 1.30 ± 0.24 | -1.85 | 0.0650 |
| Ticks | 0.03 ± 0.02 | 0.03 ± 0.03 | * | * | 0.02 ± 0.02 | 0.04 ± 0.03 | * | * |

* *Not enough representatives to determine statistical significance*

**Table 14.** Average insect abundance by family captured on yellow sticky traps deployed at 40 m into the forest during 2021.

| | 1-Meter | | | | Canopy | | | |
|---|---|---|---|---|---|---|---|---|
| **Family** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** | **Control Mean ± SE** | **Treatment Mean ± SE** | ***Z*** | ***P* value** |
| Anthocoridae | 0.03 ± 0.03 | 0.06 ± 0.04 | * | * | 0.17 ± 0.07 | 0.11 ± 0.05 | * | * |
| Apidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Asilidae | 0.75 ± 0.25 | 0.72 ± 0.48 | -0.61 | 0.5397 | 0.33 ± 0.11 | 0.11 ± 0.07 | * | * |
| Braconidae | 0.53 ± 0.12 | 0.42 ± 0.09 | 1.11 | 0.2663 | 0.61 ± 0.20 | 0.47 ± 0.16 | * | * |
| Cantharidae | 0 | 0.25 ± 0.22 | * | * | 0.03 ± 0.03 | 0.14 ± 0.08 | * | * |
| Carabidae | 0.17 ± 0.07 | 0.33 ± 0.08 | * | * | 0 | 0.14 ± 0.07 | * | * |
| Chalcididae | 0.03 ± 0.03 | 0 | * | * | 0 | 0.03 ± 0.03 | * | * |
| Chrysididae | 0.06 ± 0.04 | 0.08 ± 0.05 | * | * | 0.08 ± 0.05 | 0.03 ± 0.03 | * | * |
| Chrysomelidae | 0.42 ± 0.14 | 0.36 ± 0.17 | -1.48 | 0.1376 | 0.08 ± 0.05 | 0.33 ± 0.11 | * | * |
| Chrysopidae | 0.03 ± 0.03 | 0.03 ± 0.03 | * | * | 0.06 ± 0.04 | 0.14 ± 0.09 | * | * |
| Cixiidae | 0.31 ± 0.13 | 0.56 ± 0.21 | * | * | 0.08 ± 0.06 | 0.25 ± 0.09 | * | * |
| Coccinellidae | 3.03 ± 0.40 | 8.50 ± 2.15 | -1.40 | 0.1607 | 2.36 ± 0.39 | 4.06 ± 0.93 | -1.19 | 0.2324 |
| Coniopterygidae | 0.14 ± 0.07 | 0.11 ± 0.07 | * | * | 0.44 ± 0.016 | 0.36 ± 0.12 | * | * |
| Corylophidae | 0.64 ± 0.21 | 0.64 ± 0.20 | -1.29 | 0.1966 | 0.22 ± 0.12 | 0.50 ± 0.18 | * | * |
| Culicidae | 0.11 ± 0.05 | 0.11 ± 0.09 | * | * | 0.19 ± 0.10 | 0.28 ± 0.14 | * | * |
| Curculionidae | 0.47 ± 0.11 | 0.06 ± 0.04 | * | * | 0.31 ± 0.12 | 0.19 ± 0.09 | * | * |
| Cynipidae | 0.25 ± 0.09 | 0.39 ± 0.11 | * | * | 0.42 ± 0.12 | 1.36 ± 0.43 | -2.92 | 0.0035 |
| Diapriidae | 2.83 ± 0.47 | 3.89 ± 0.81 | -0.90 | 0.3656 | 0.22 ± 0.12 | 0.42 ± 0.11 | * | * |
| Dolichopodidae | 4.86 ± 0.68 | 4.36 ± 0.80 | 0.73 | 0.4670 | 3.69 ± 0.45 | 5.19 ± 1.02 | -1.47 | 0.1407 |
| Erebidae | 0 | 0.03 ± 0.03 | * | * | 0 | 0.03 ± 0.03 | * | * |
| Flatidae | 0.56 ± 0.15 | 0.58 ± 0.16 | -0.26 | 0.7977 | 0.19 ± 0.10 | 0.19 ± 0.08 | * | * |
| Formicidae | 7.42 ± 2.99 | 4.75 ± 1.78 | 0.53 | 0.5994 | 6.11 ± 1.59 | 2.42 ± 0.63 | 0.31 | 0.7556 |
| Halictidae | 0.36 ± 0.13 | 0.44 ± 0.20 | * | * | 0.17 ± 0.08 | 0.53 ± 0.19 | * | * |
| Hesperiidae | 0.39 ± 0.17 | 0.14 ± 0.07 | * | * | 0 | 0.08 ± 0.05 | * | * |
| Ichenumonidae | 0.86 ± 0.18 | 1.92 ± 0.27 | -1.55 | 0.1214 | 0.19 ± 0.08 | 0.61 ± 0.13 | -0.61 | 0.5397 |
| Lampyridae | 0.22 ± 0.10 | 0.28 ± 0.09 | * | * | 0.39 ± 0.20 | 0.56 ± 0.18 | * | * |
| Lepidoptera | 0.72 ± 0.14 | 1.08 ± 0.19 | -1.85 | 0.0641 | 1.31 ± 0.26 | 1.36 ± 0.28 | -0.35 | 0.7291 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Membracidae | 0.78 ± 0.17 | 0.31 ± 0.11 | 1.04 | 0.2973 | 4.56 ± 0.81 | 5.25 ± 1.09 | -1.27 | 0.2055 |
| Mymaridae | 2.39 ± 0.38 | 2.11 ± 0.29 | -0.75 | 0.4517 | 0.78 ± 0.16 | 1.58 ± 0.42 | -0.16 | 0.8756 |
| Nymphalidae | 0.11 ± 0.08 | 0.06 ± 0.06 | * | * | 0.08 ± 0.06 | 0.56 ± 0.27 | * | * |
| Panorpidae | 4.56 ± 1.48 | 5.19 ± 1.35 | -0.41 | 0.6791 | 0.03 ± 0.03 | 0.22 ± 0.13 | * | * |
| Papilionidae | 0 | 0 | * | * | 0 | 0 | * | * |
| Perilampidae | 0 | 0.06 ± 0.06 | * | * | 0.06 ± 0.04 | 0.03 ± 0.03 | * | * |
| Phalacridae | 0.08 ± 0.06 | 0.06 ± 0.04 | * | * | 0.14 ± 0.07 | 0.11 ± 0.05 | * | * |
| Pieridae | 0 | 0 | * | * | 0 | 0 | * | * |
| Psychodidae | 0.28 ± 0.09 | 0.17 ± 0.07 | * | * | 0.22 ± 0.08 | 0.14 ± 0.06 | * | * |
| Araneae | 7.78 ± 1.27 | 8.75 ± 1.12 | -1.72 | 0.0863 | 2.86 ± 0.30 | 2.64 ± 0.40 | -0.73 | 0.4645 |
| Staphylinidae | 0.89 ± 0.19 | 0.67 ± 0.14 | 0.5 | 0.6142 | 0.67 ± 0.15 | 0.78 ± 0.20 | 1.01 | 0.3141 |
| Syrphidae | 1.81 ± 0.39 | 1.83 ± 0.55 | 0.98 | 0.3247 | 0.61 ± 0.21 | 0.47 ± 0.16 | * | * |
| Tachinidae | 0.19 ± 0.08 | 0.39 ± 0.36 | * | * | 0.50 ± 0.14 | 0.33 ± 0.14 | * | * |
| Ulidiidae | 0.03 ± 0.03 | 0.33 ± 0.12 | * | * | 0.22 ± 0.10 | 0.75 ± 0.35 | * | * |
| Vespidae | 0.25 ± 0.11 | 0.19 ± 0.07 | * | * | 0.69 ± 0.20 | 1.25 ± 0.27 | -1.60 | 0.1094 |
| Xylomyidae | 1.89 ± 0.86 | 4.92 ± 1.87 | -0.51 | 0.6089 | 3.75 ± 1.60 | 3.28 ± 0.89 | 0.39 | 0.6947 |

** Not enough representatives to determine statistical significance*

**Figure 1.** Yellow sticky traps deployed at the field edge (0 m). Top-canopy trap (left) affixed to rope pulley, and 1 m trap (right) affixed to post.

**Figure 2.** Pitfall trap with tamper-proof hardware cloth installed above. 1 m yellow sticky trap deployed in background.

**Figure 3**. Average insect abundance by family captured on total yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

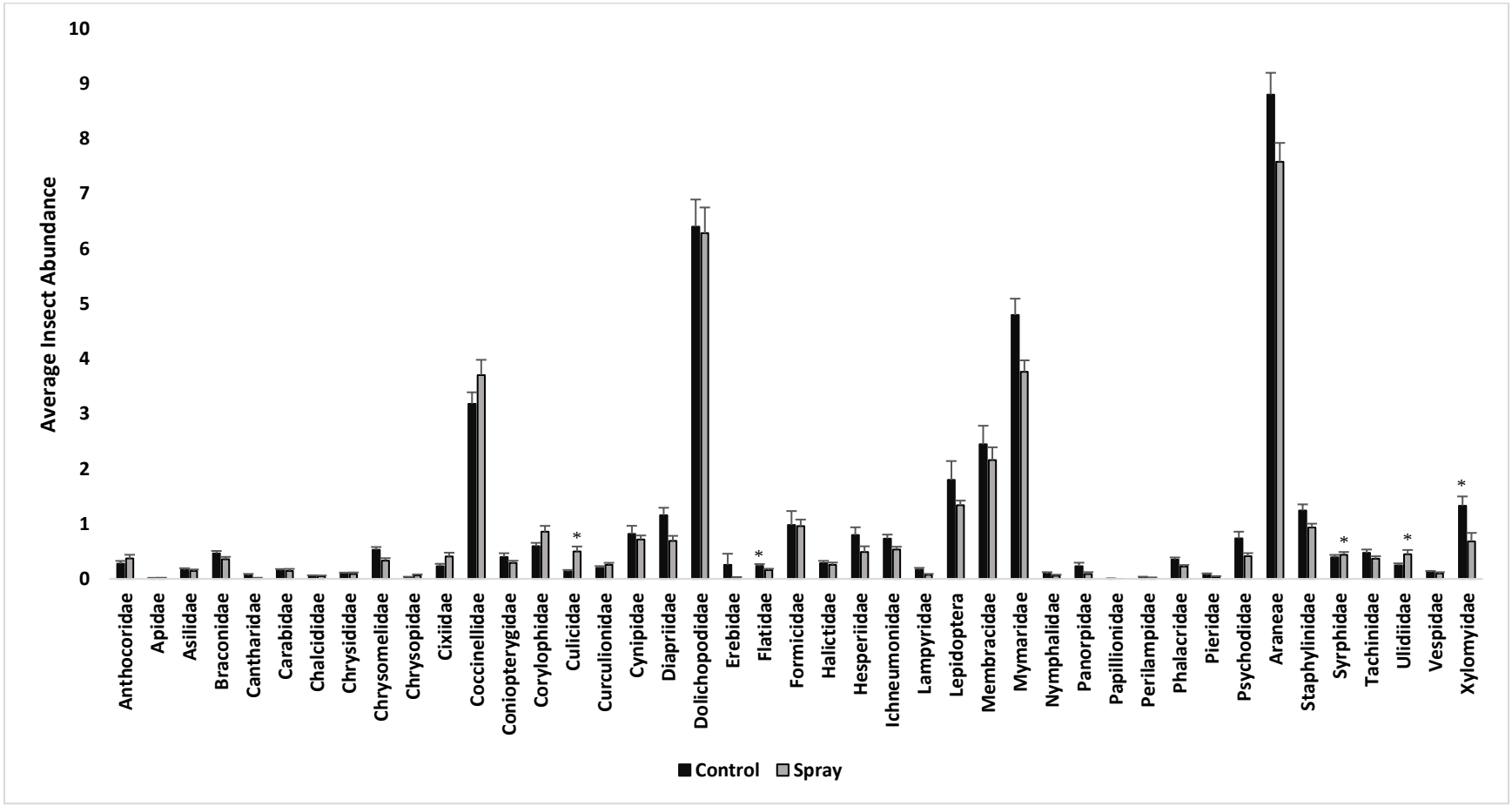


**Figure 4**. Average insect abundance by family captured on total yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

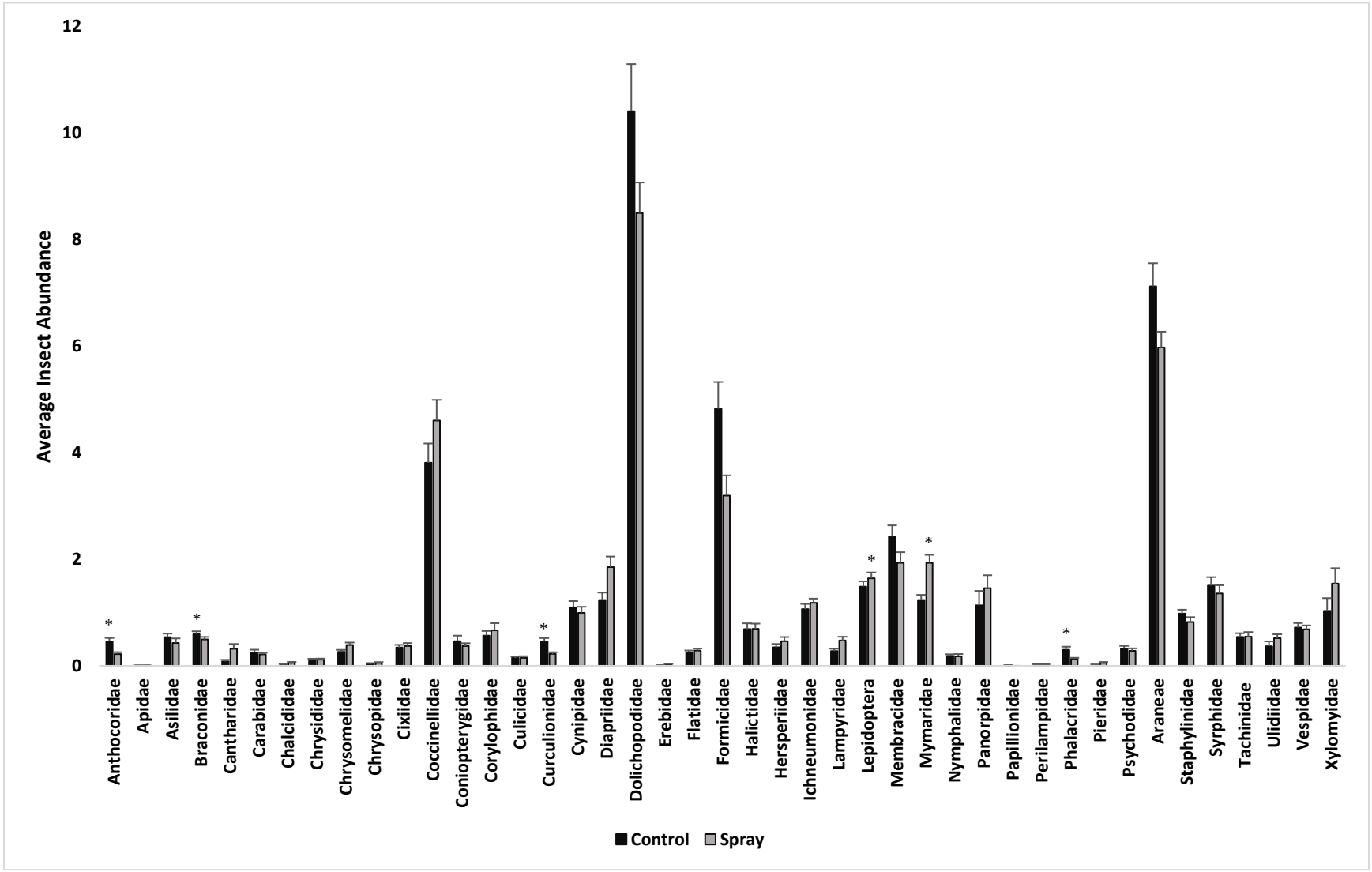


**Figure 5.** Average insect abundance by family captured in total pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

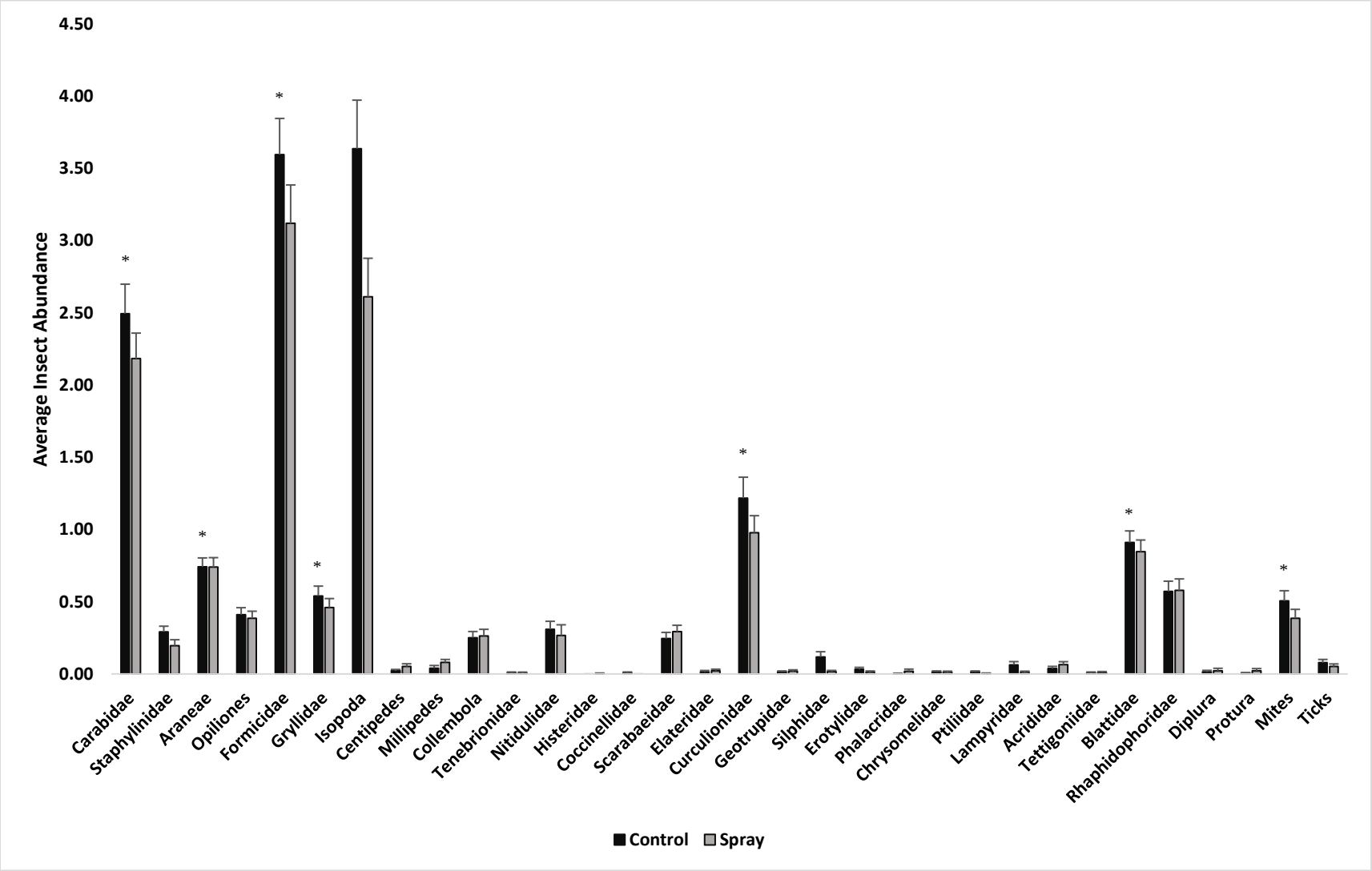


**Figure 6.** Average insect abundance by family captured in total pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

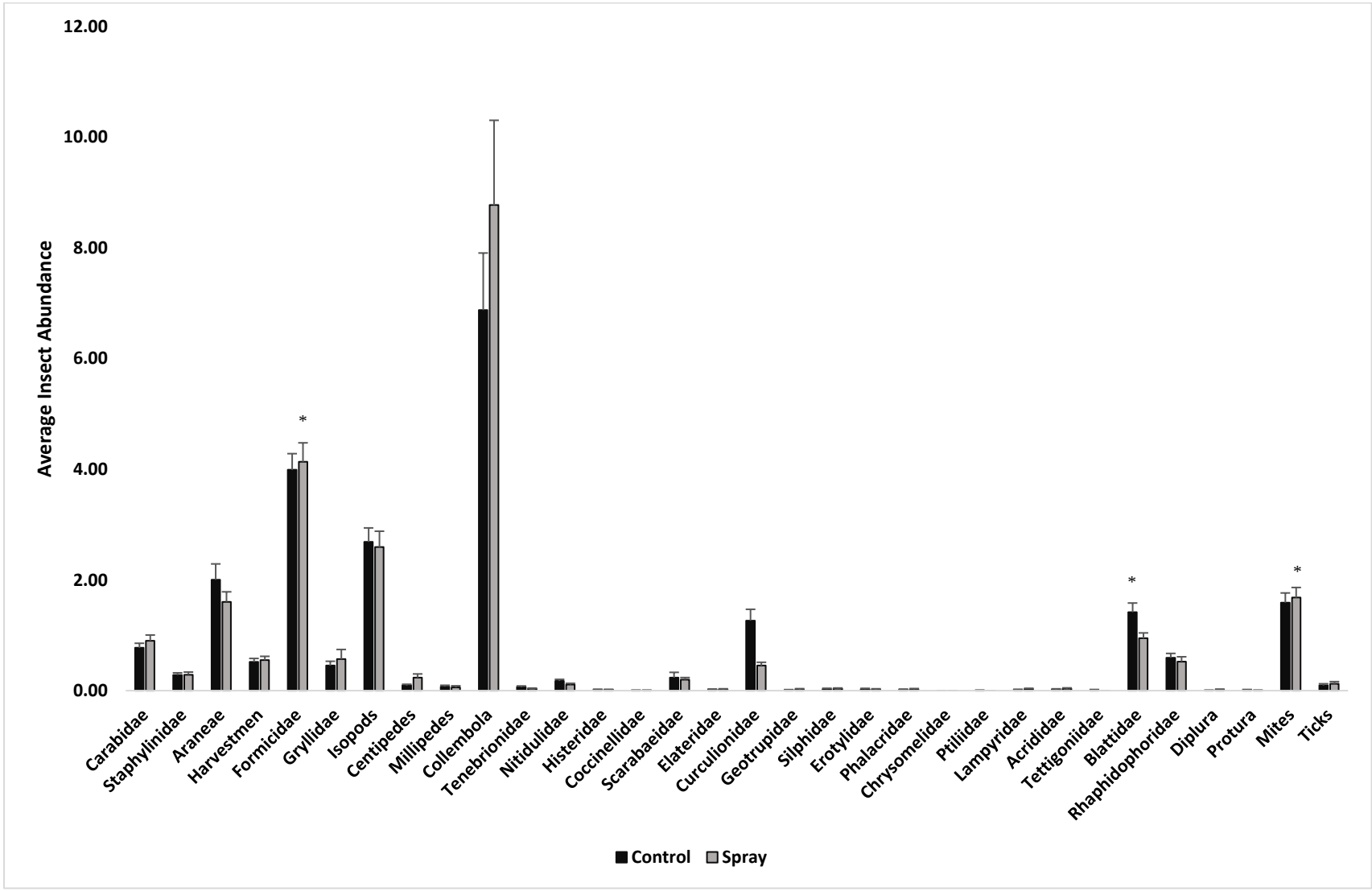
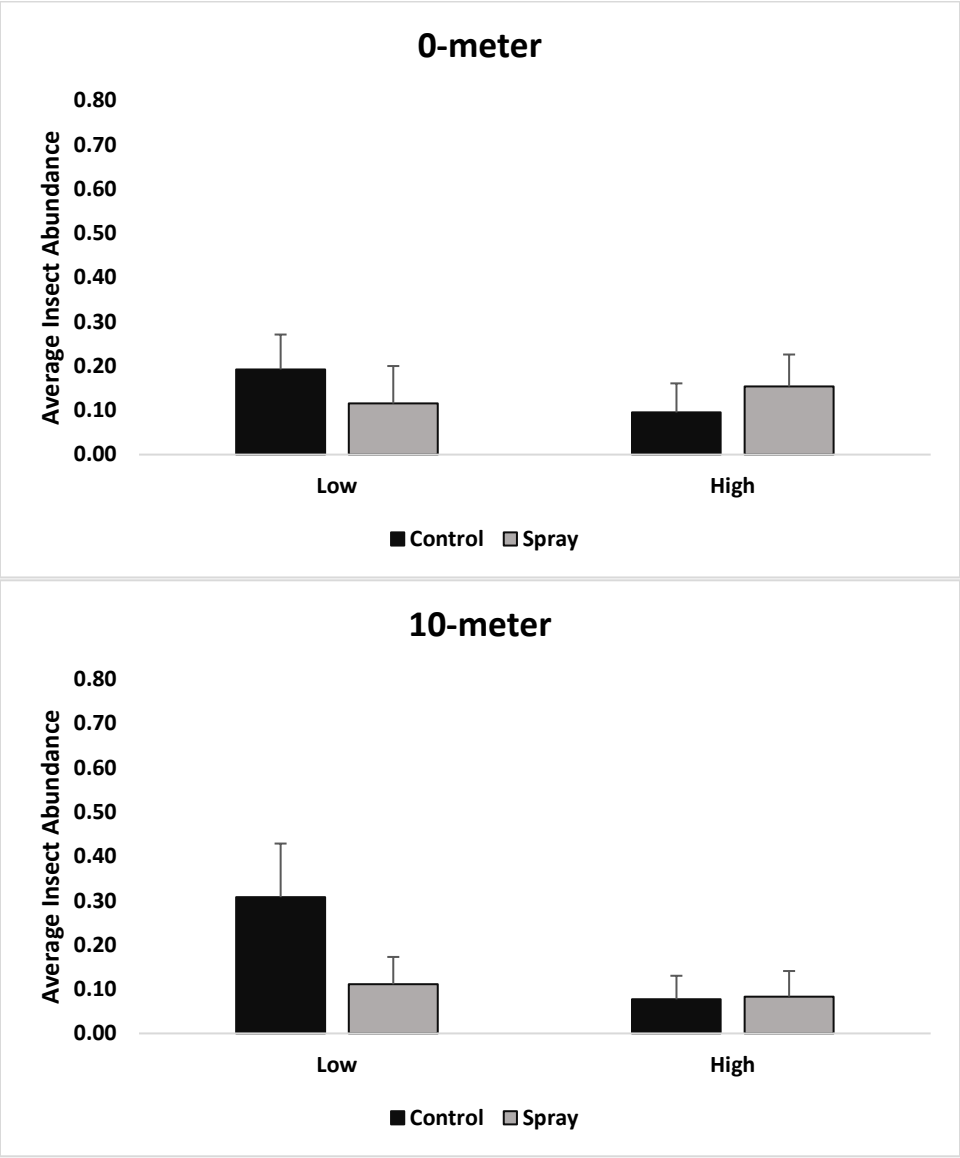
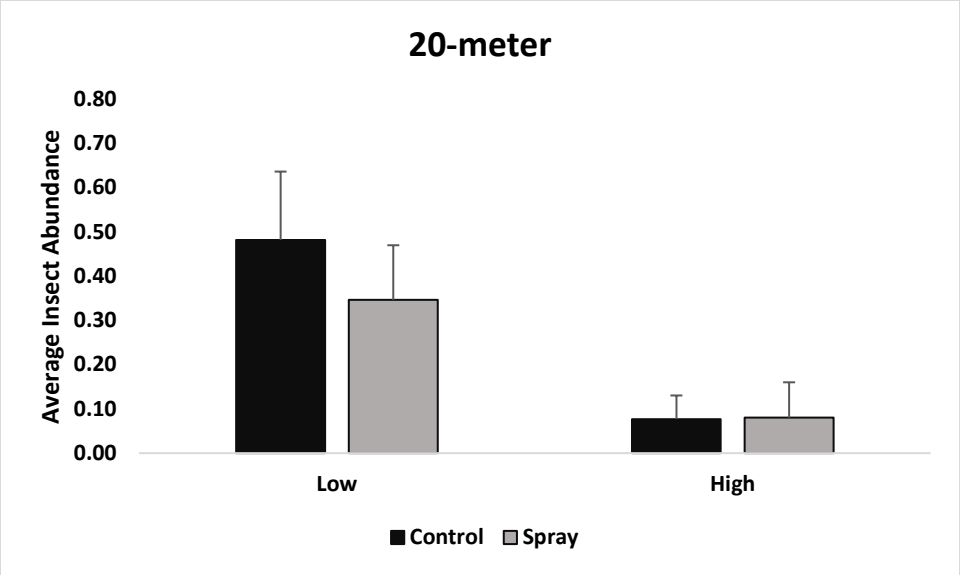


**Figure 7.** Average Flatidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.




20-meter
Average Insect Abundance
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Control
Spray

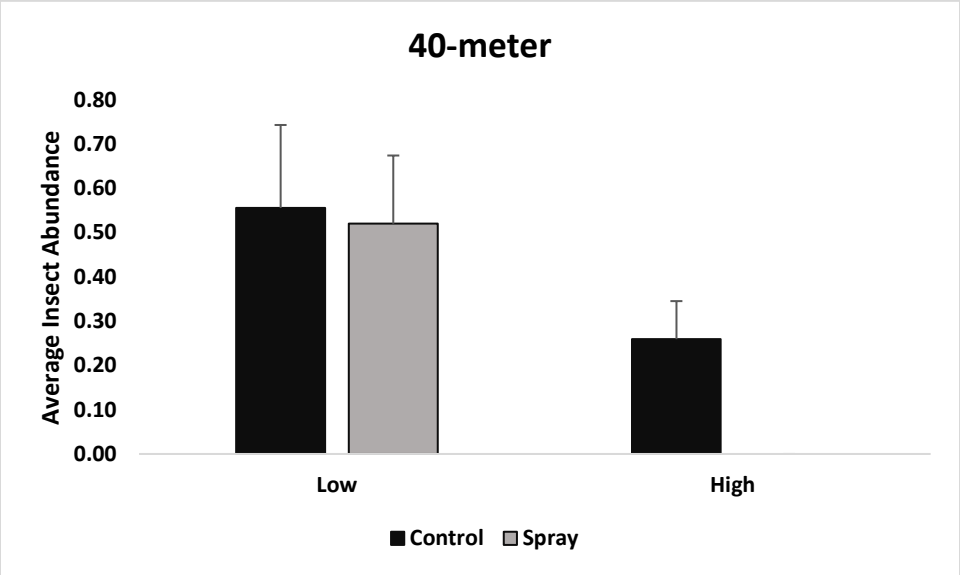
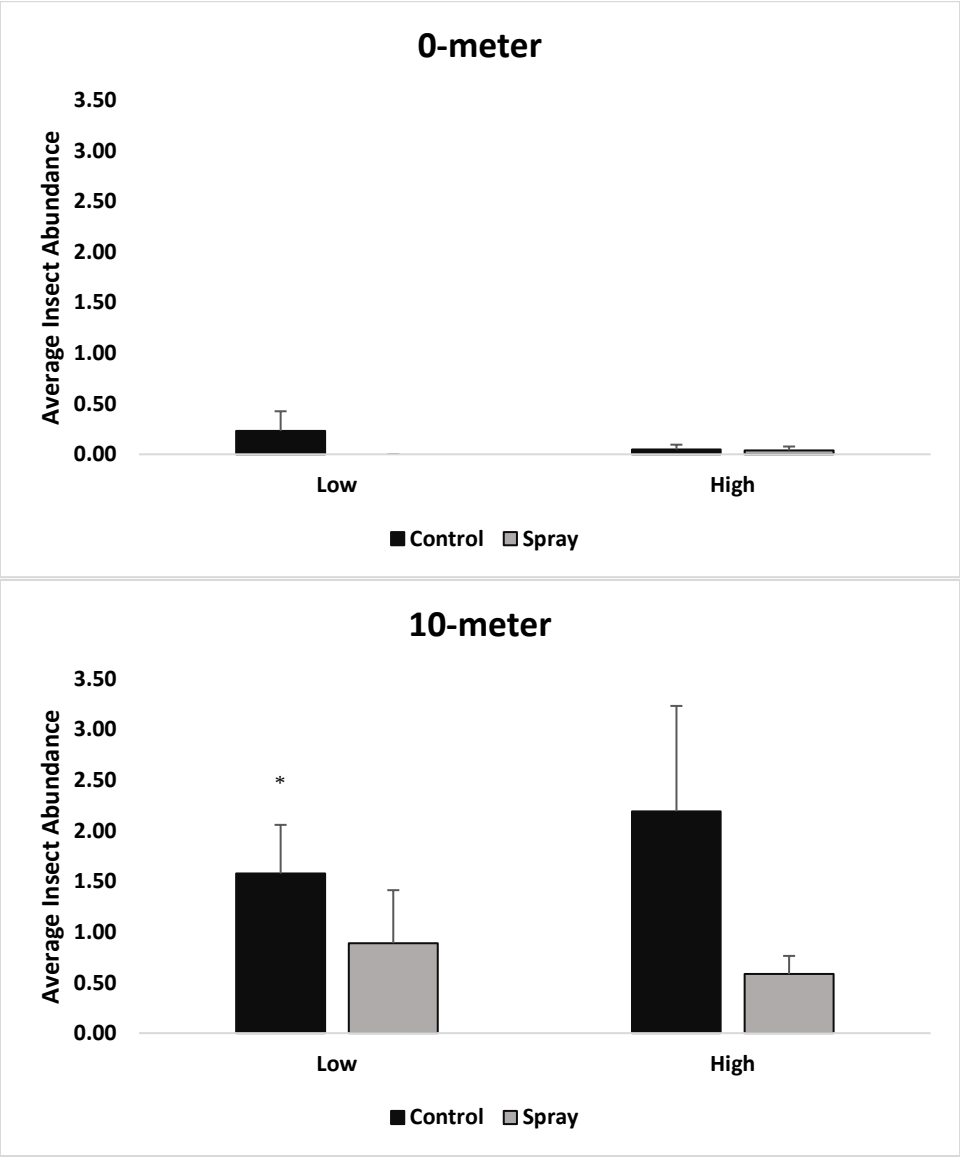
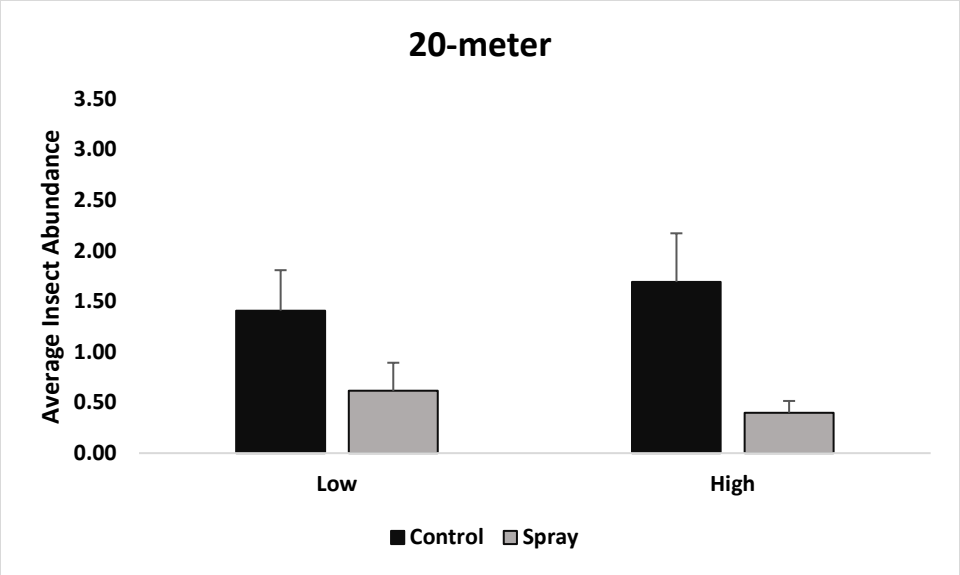

40-meter
Average Insect Abundance
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Control
Spray

**Figure 8.** Average Xylomyidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

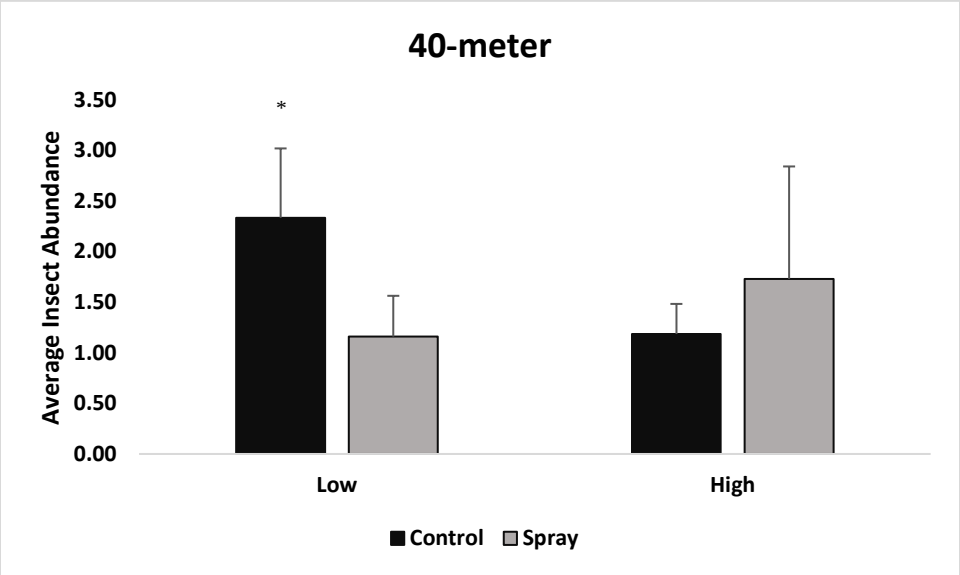
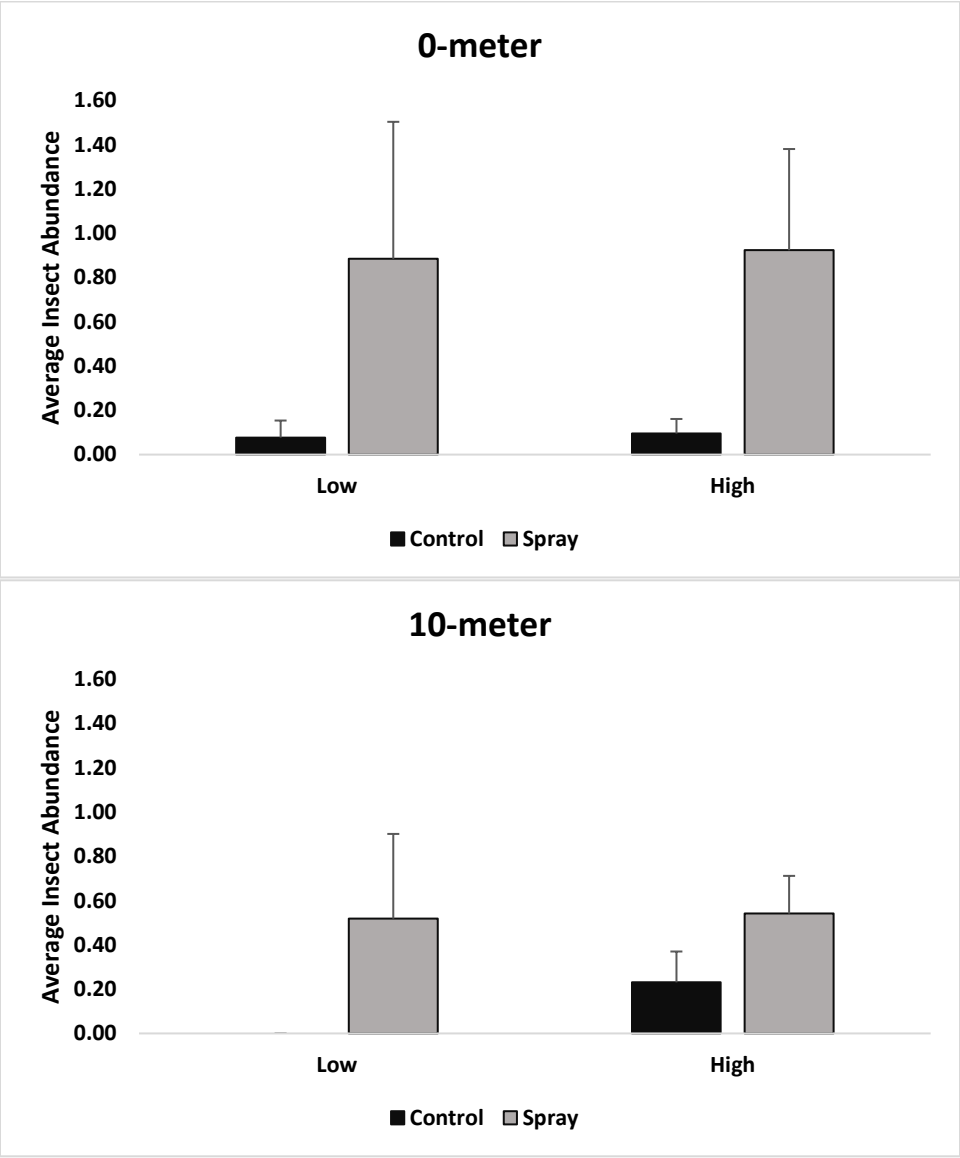
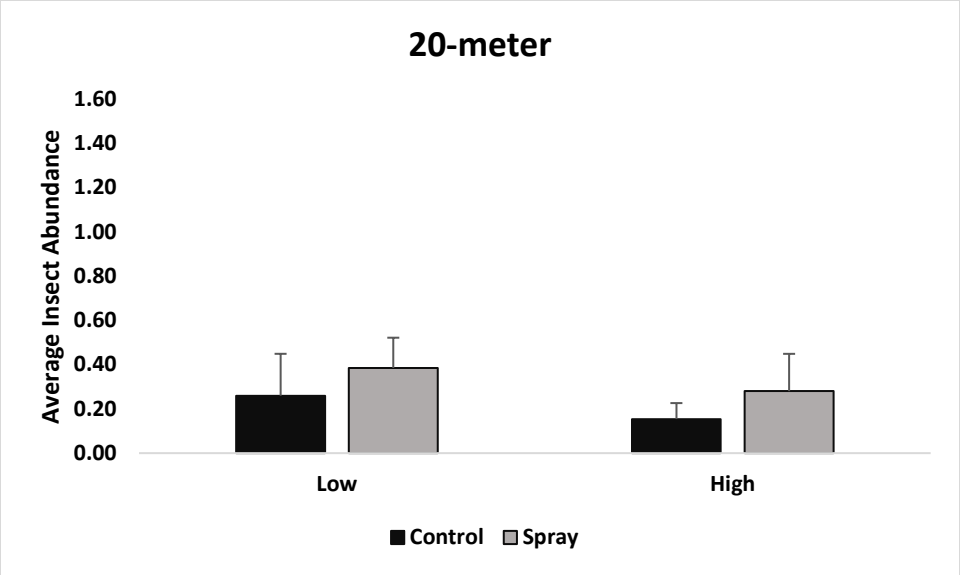

40-meter
Average Insect Abundance
*
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

**Figure 9.** Average Culicidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.




20-meter
Average Insect Abundance
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

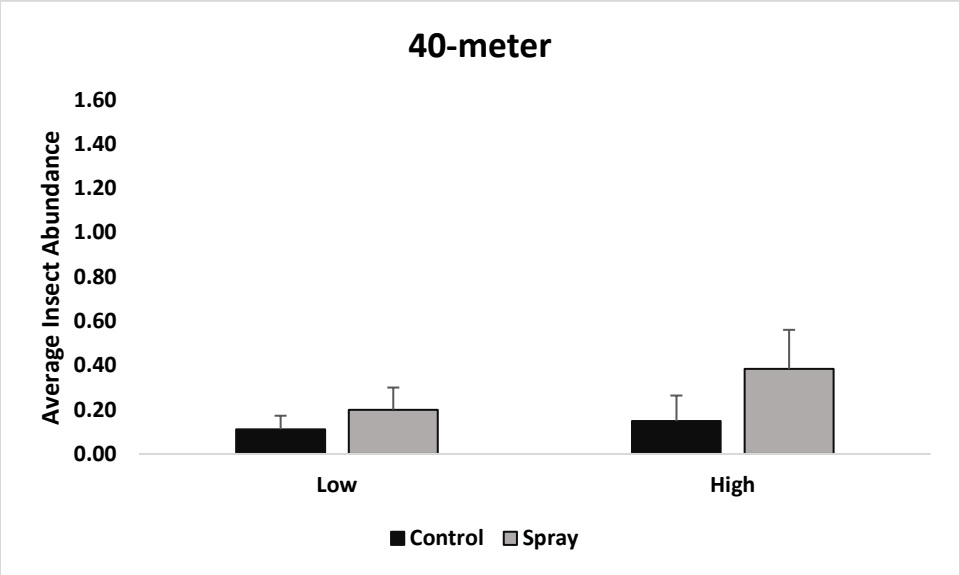
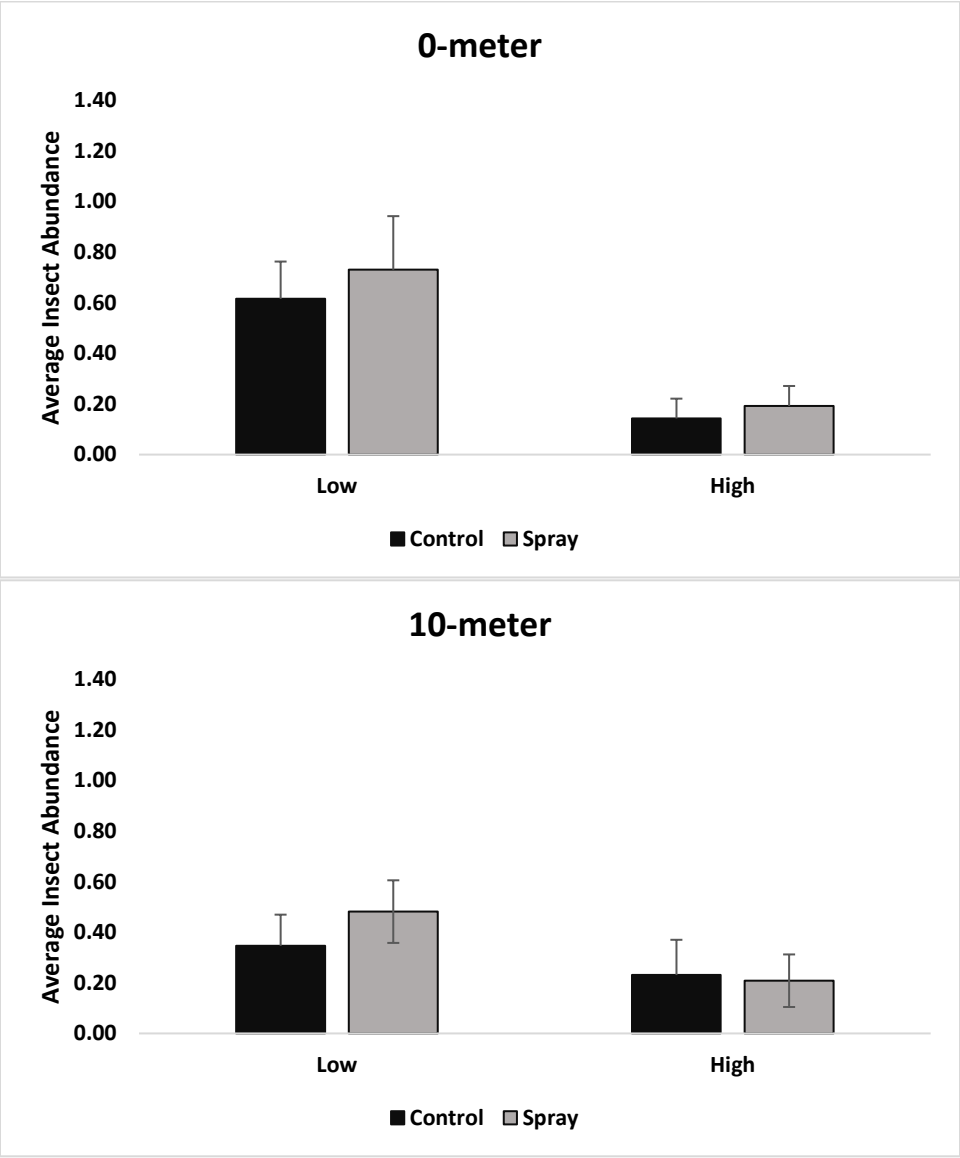
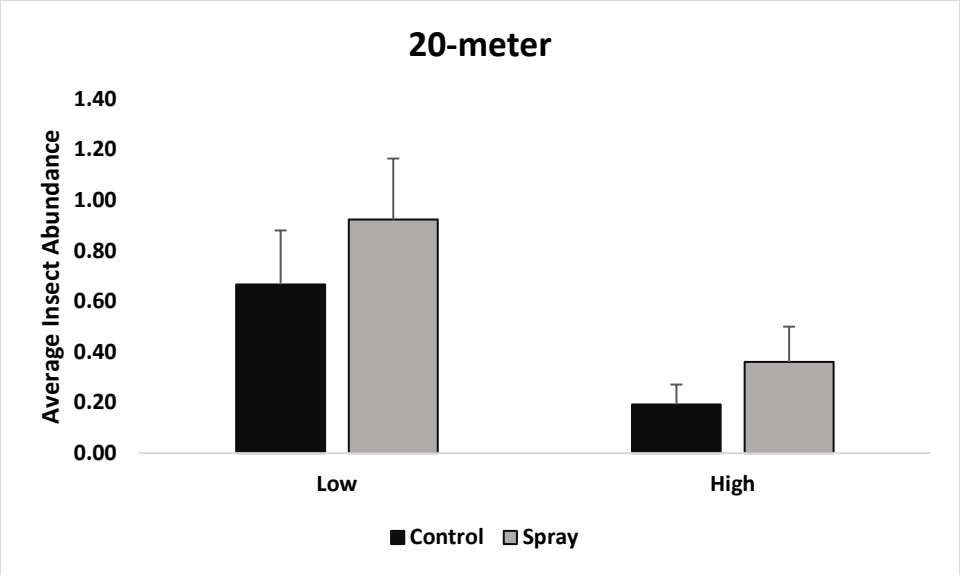

40-meter
Average Insect Abundance
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

**Figure 10.** Average Syrphidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.




20-meter
Average Insect Abundance
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

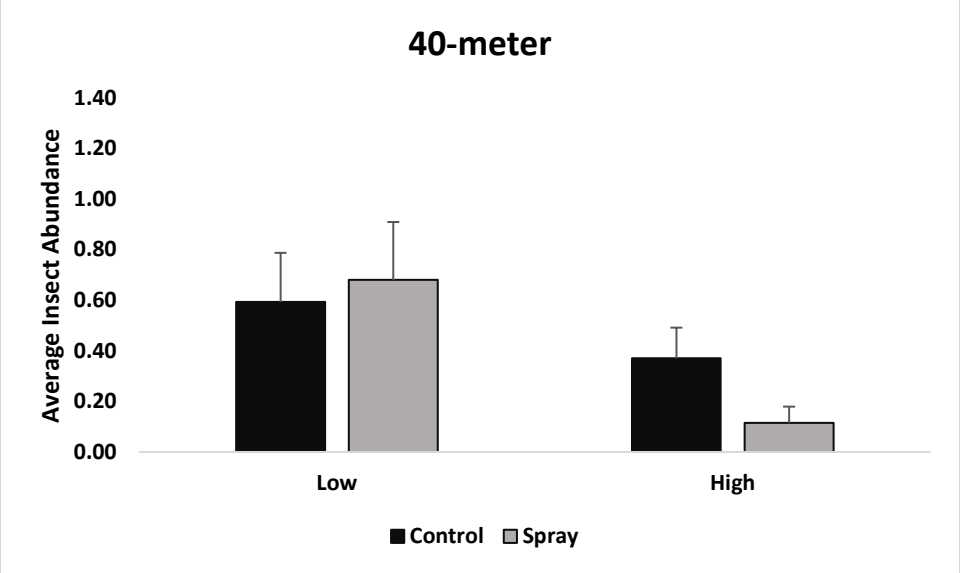
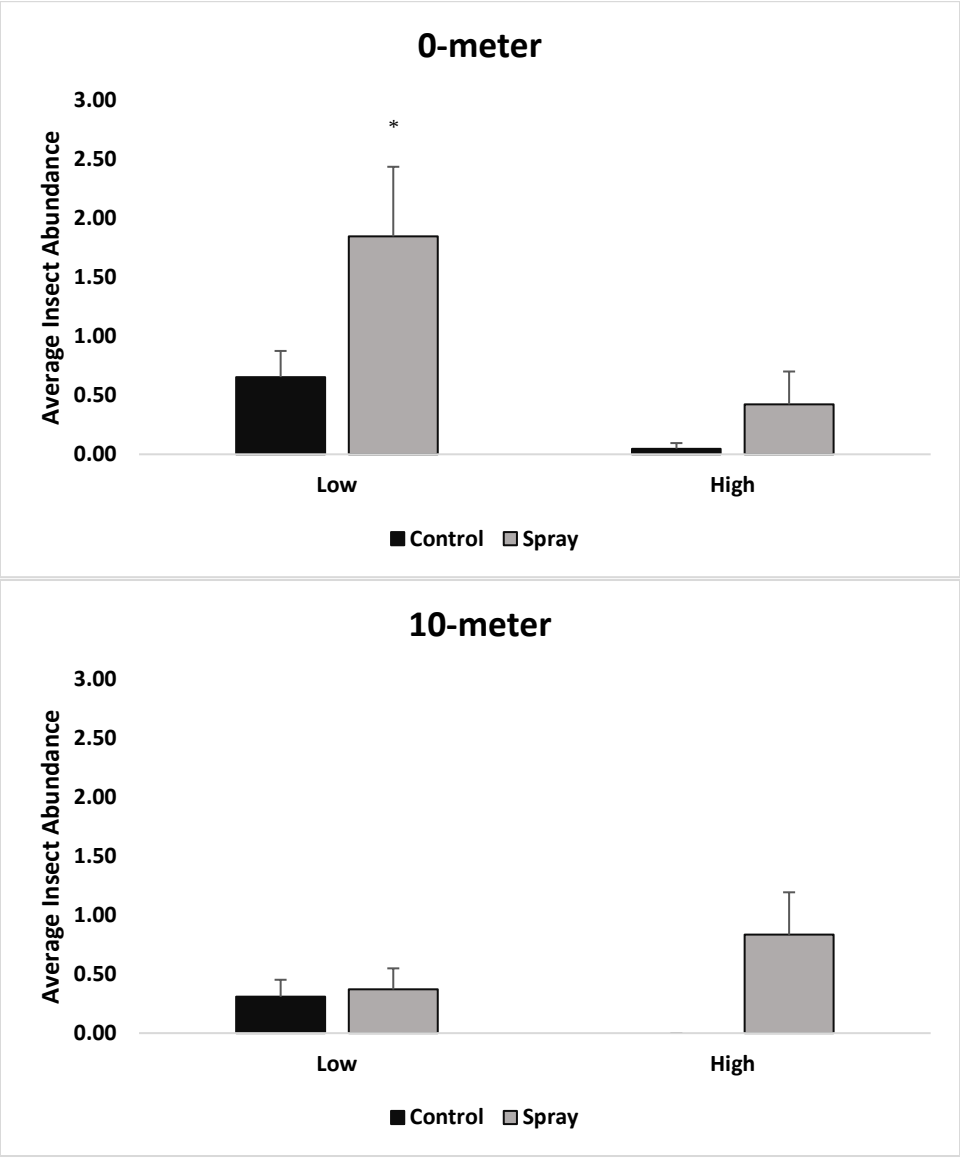
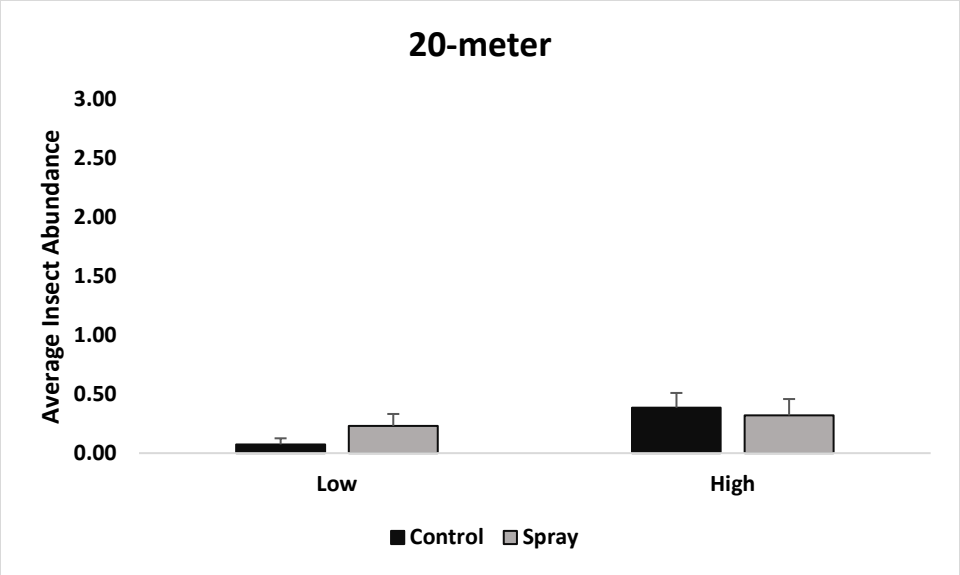

40-meter
Average Insect Abundance
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

**Figure 11.** Average Ulidiidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

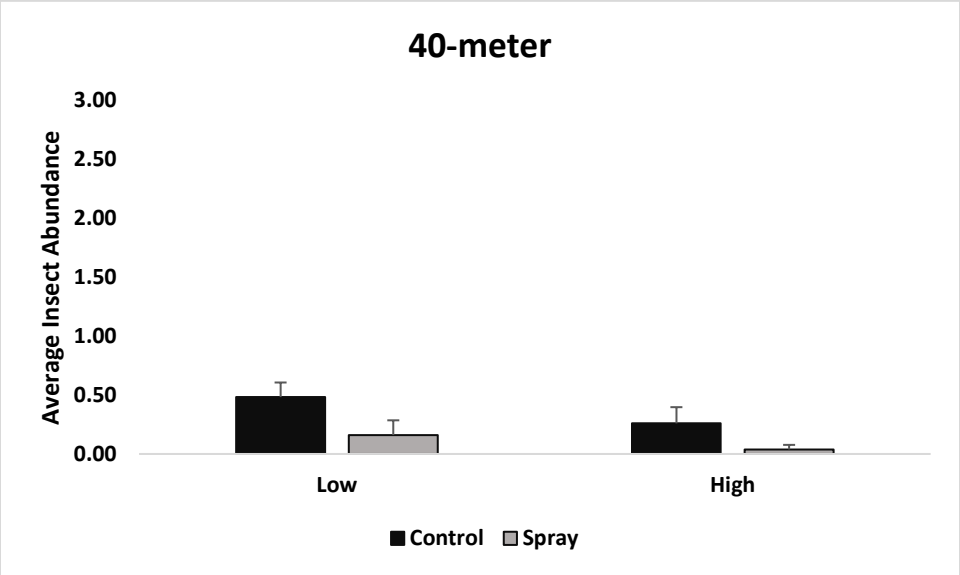
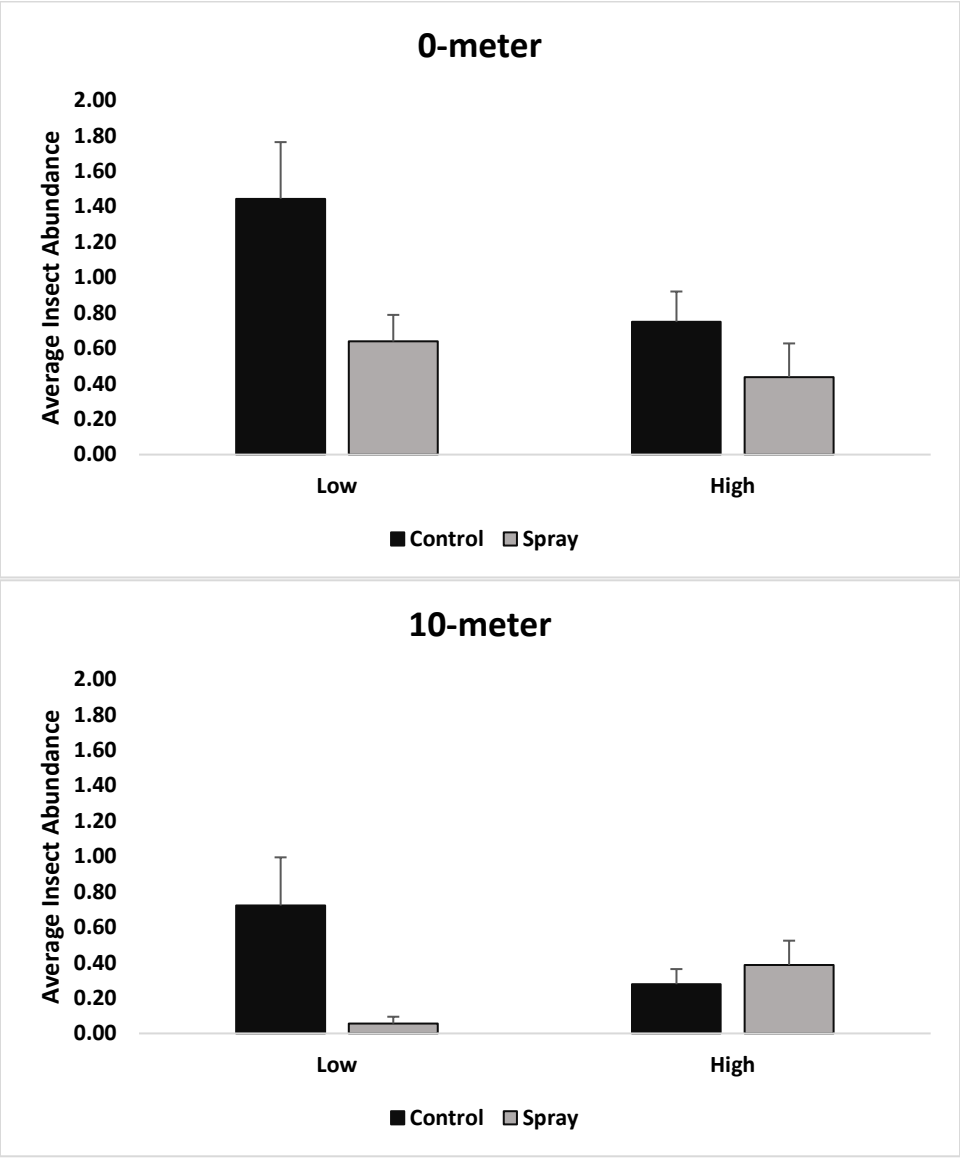
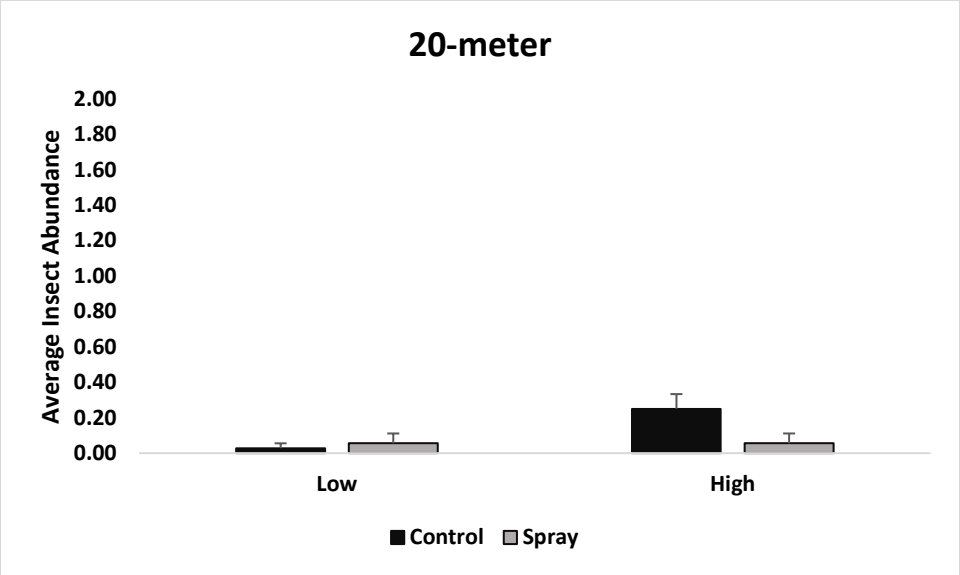

40-meter
Average Insect Abundance
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

**Figure 12.** Average Anthocoridae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Error bars represent standard error.




20-meter
Average Insect Abundance
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

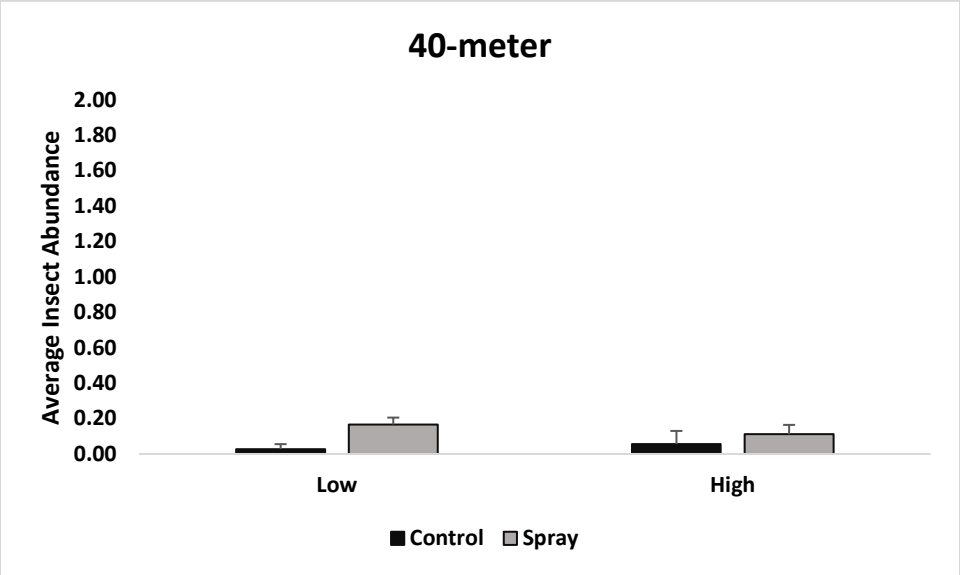
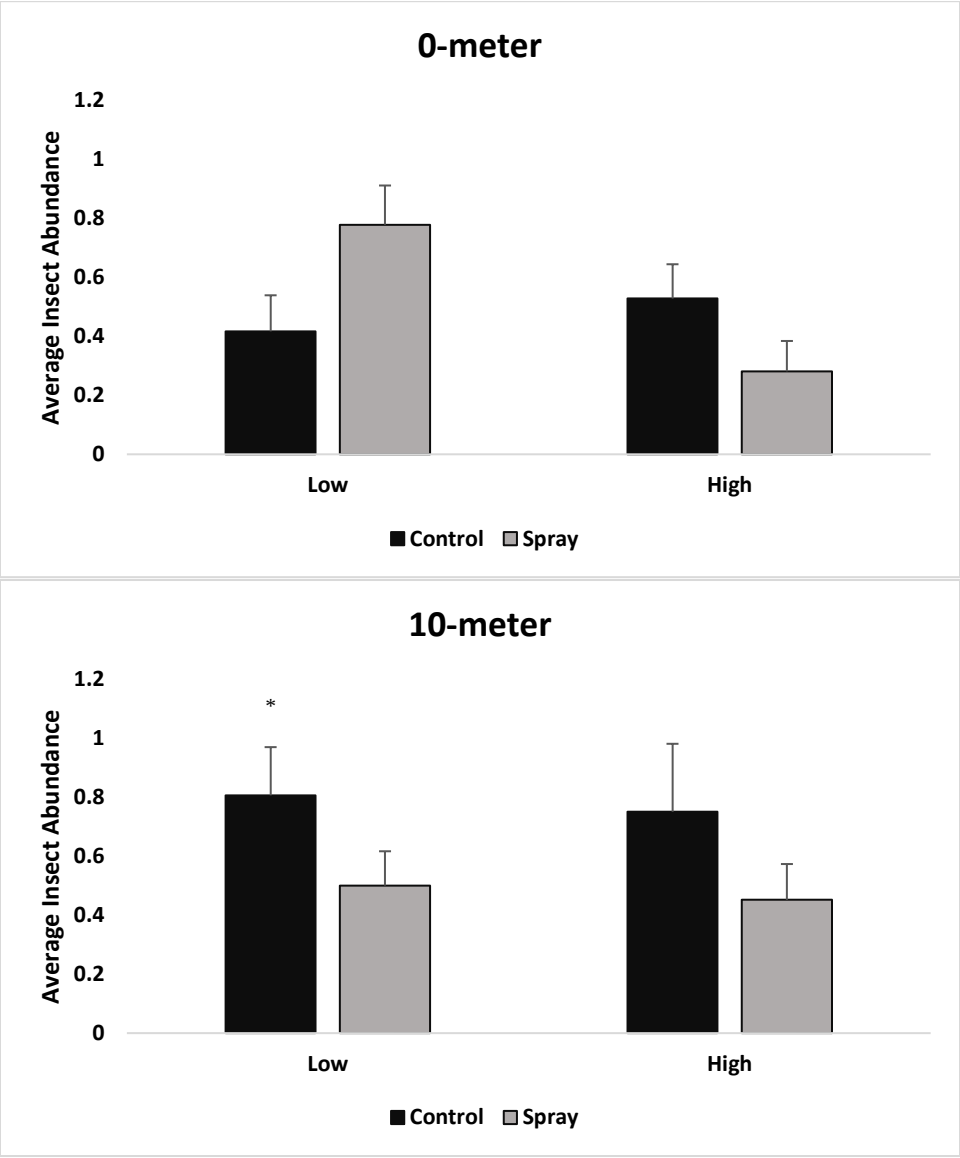
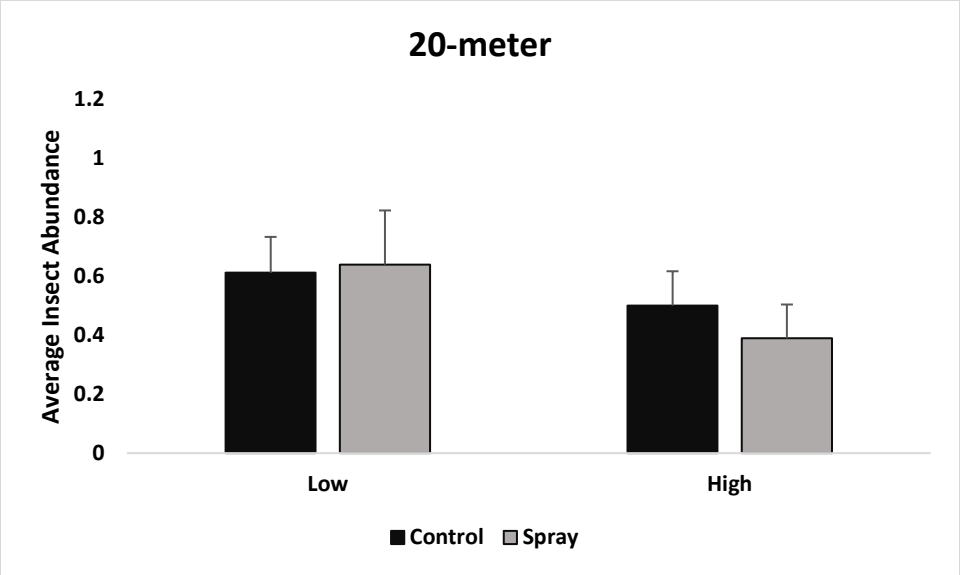

40-meter
Average Insect Abundance
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

**Figure 13.** Average Braconidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
1.2
1
0.8
0.6
0.4
0.2
0
Low
High
Control
Spray

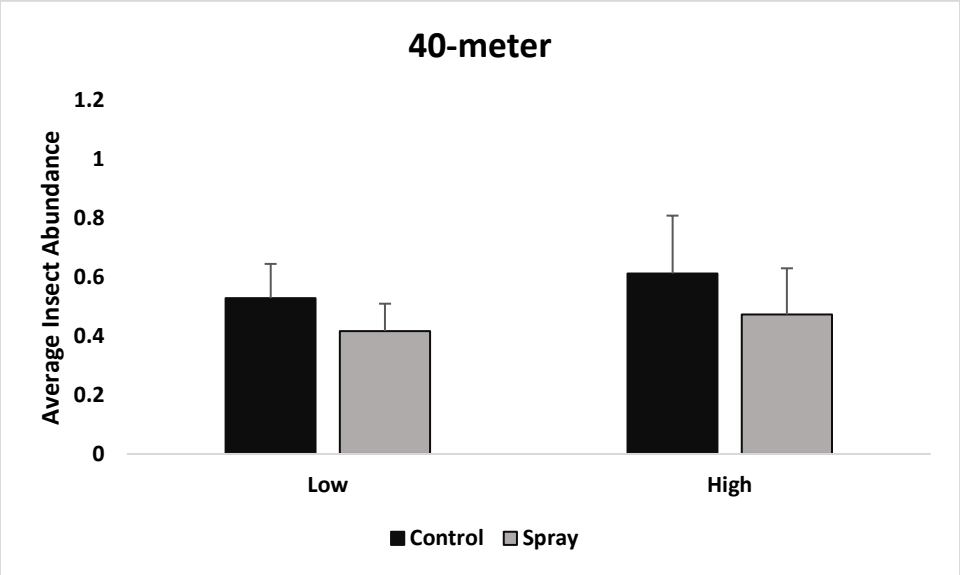
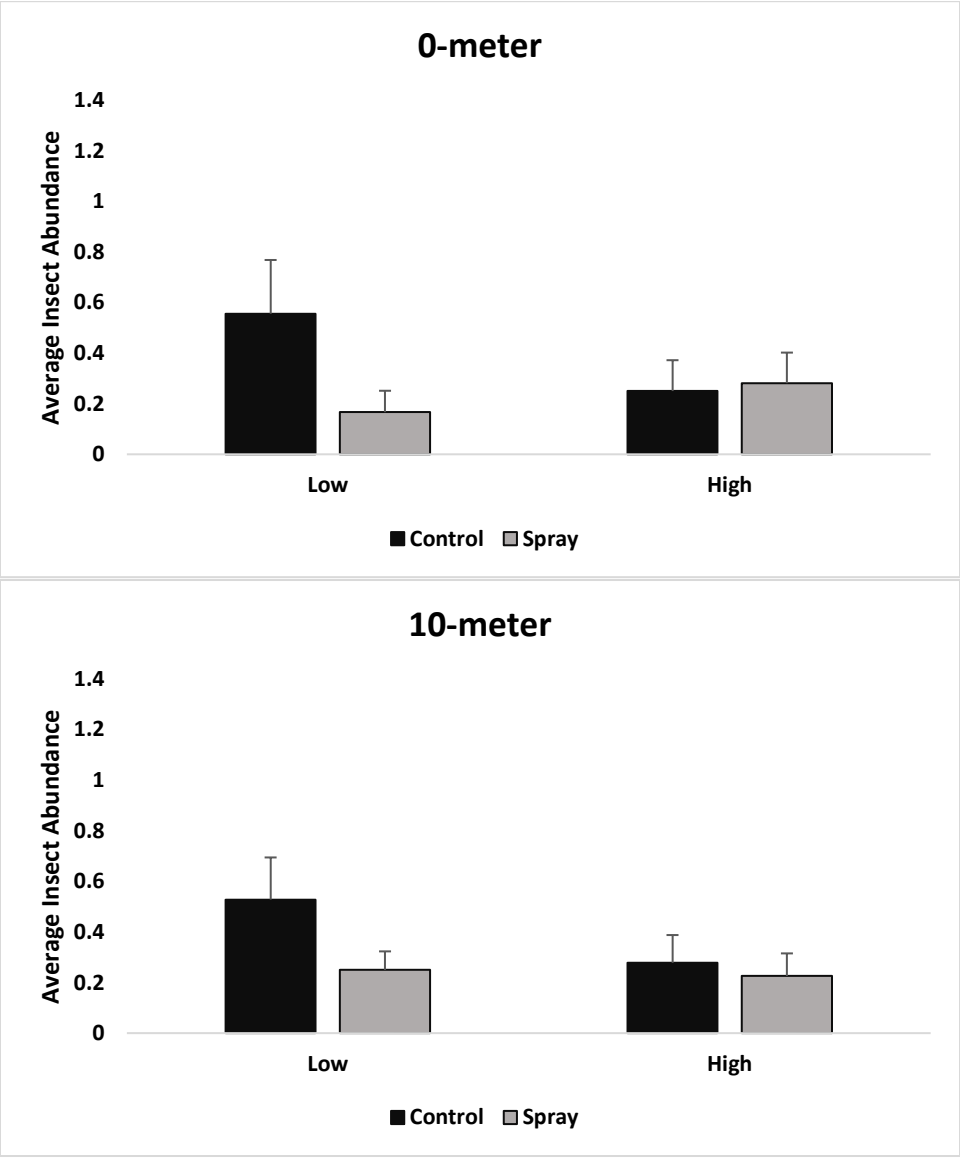
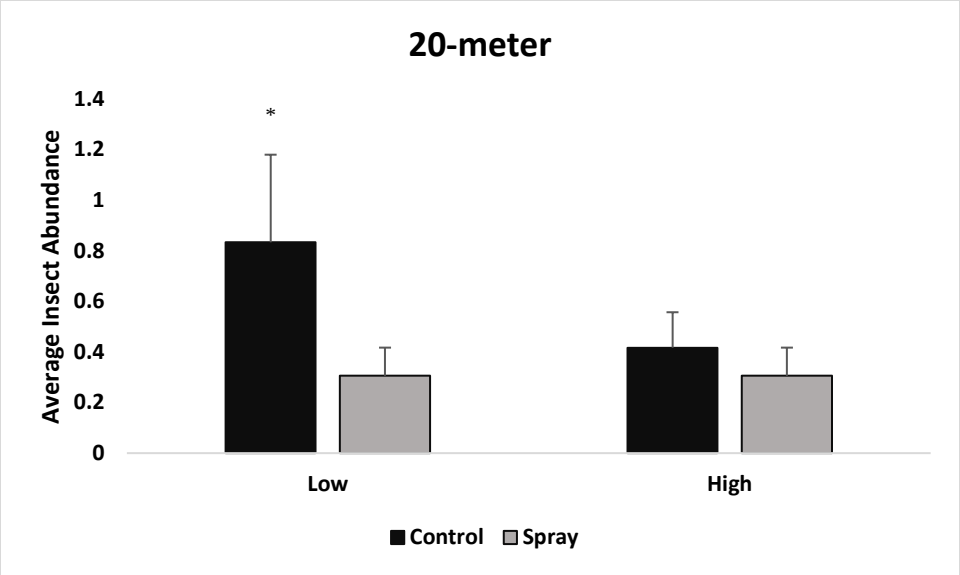

40-meter
Average Insect Abundance
1.2
1
0.8
0.6
0.4
0.2
0
Low
High
Control
Spray

**Figure 14.** Average Curculionidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
1.4
1.2
1
0.8
0.6
0.4
0.2
0
*
Low
High
Control
Spray

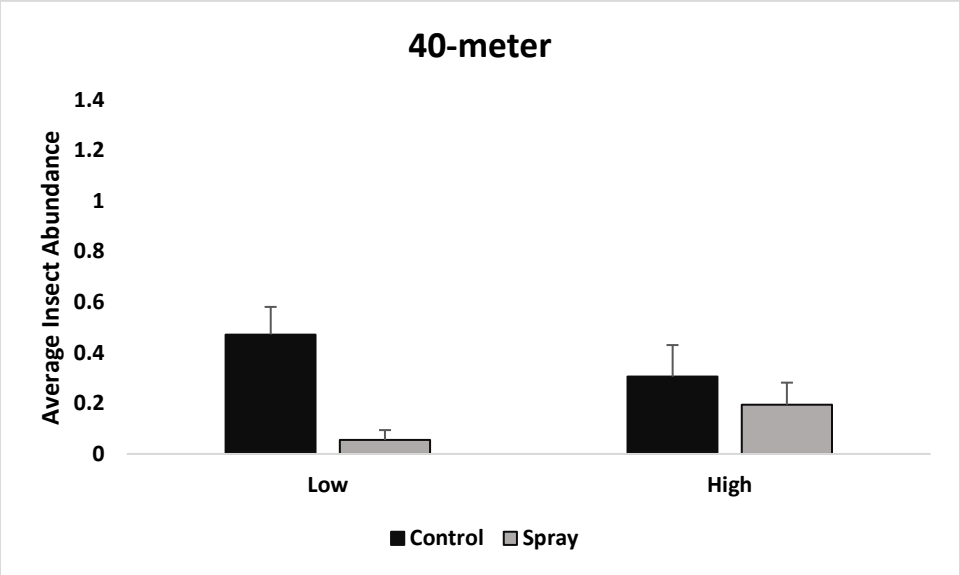
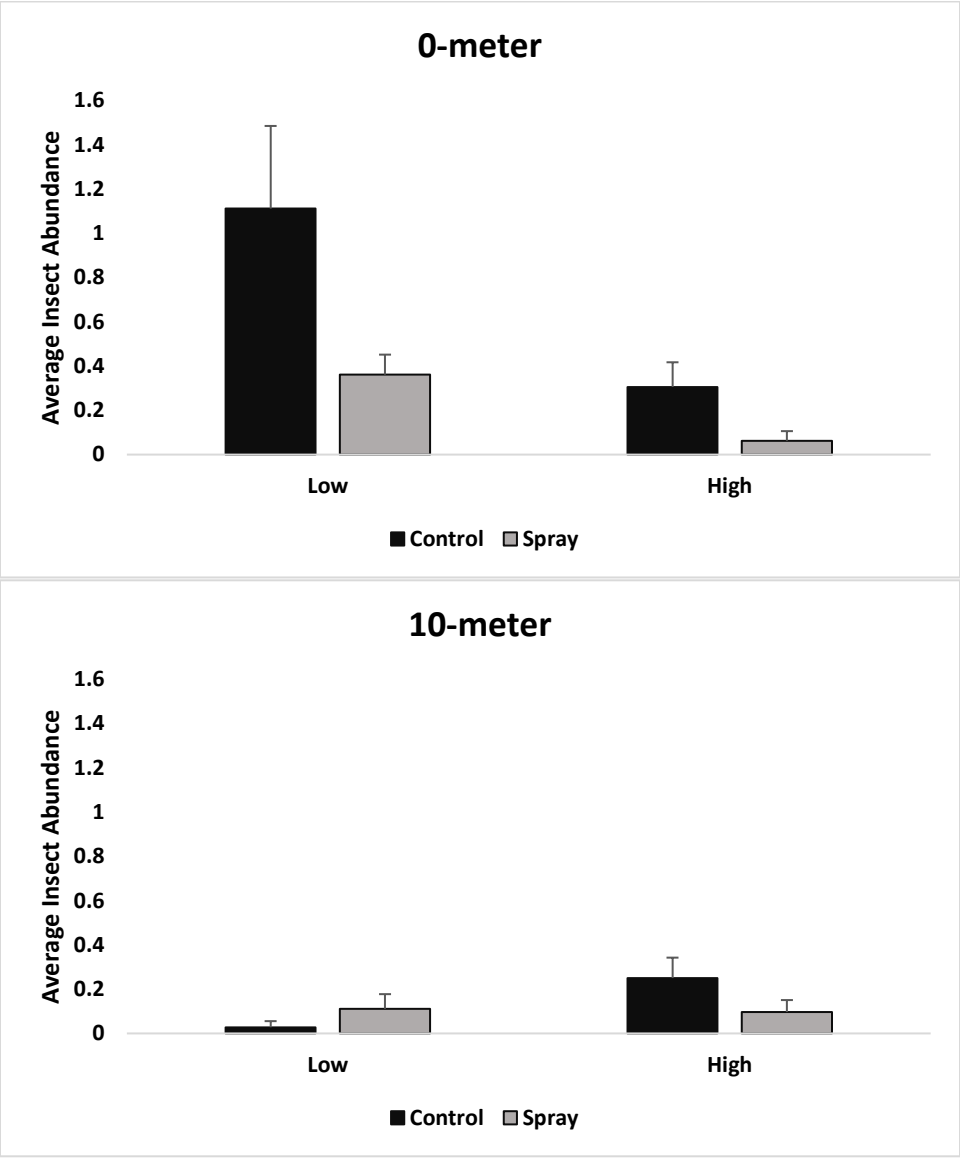
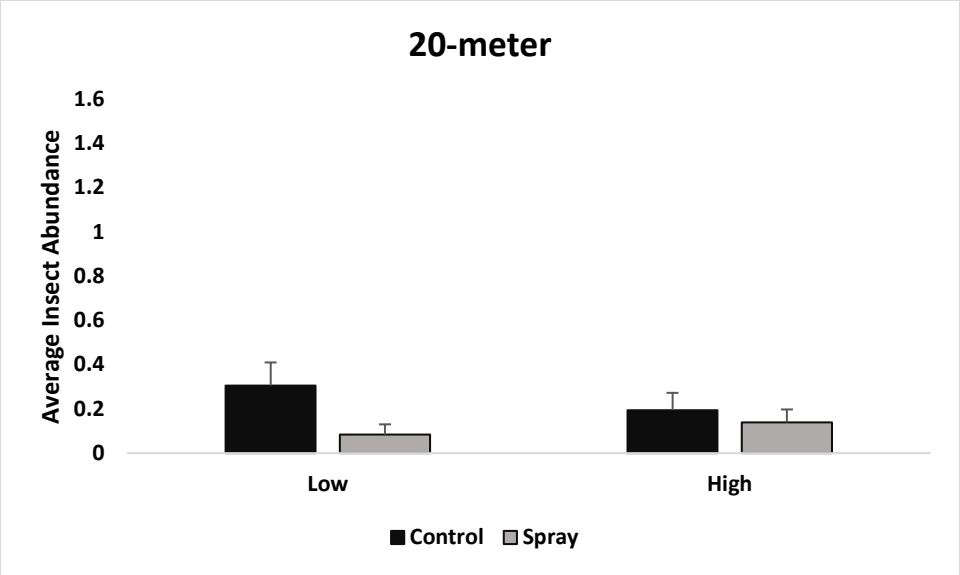

40-meter
Average Insect Abundance
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Low
High
Control
Spray

**Figure 15.** Average Phalacridae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Error bars represent standard error.




20-meter
Average Insect Abundance
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Low
High
Control
Spray

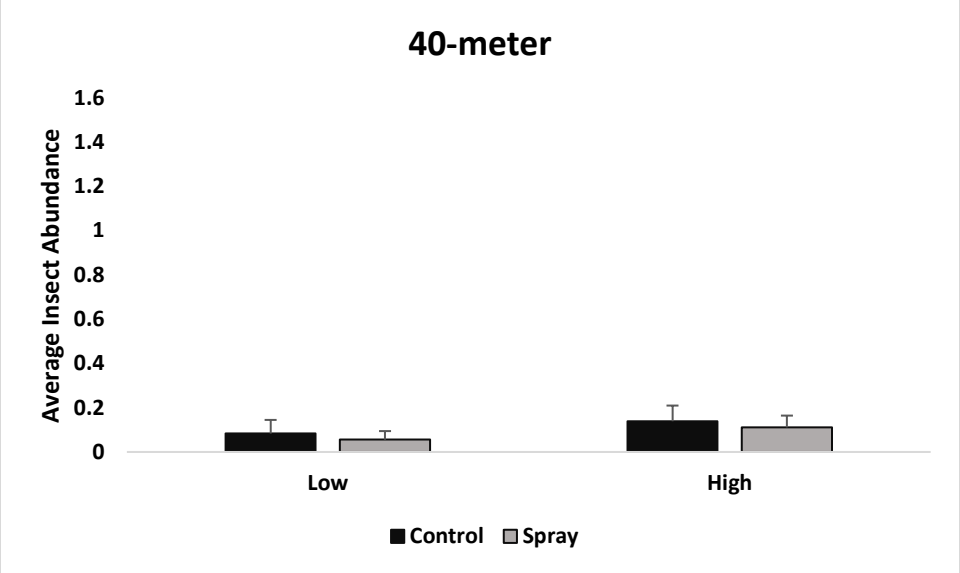
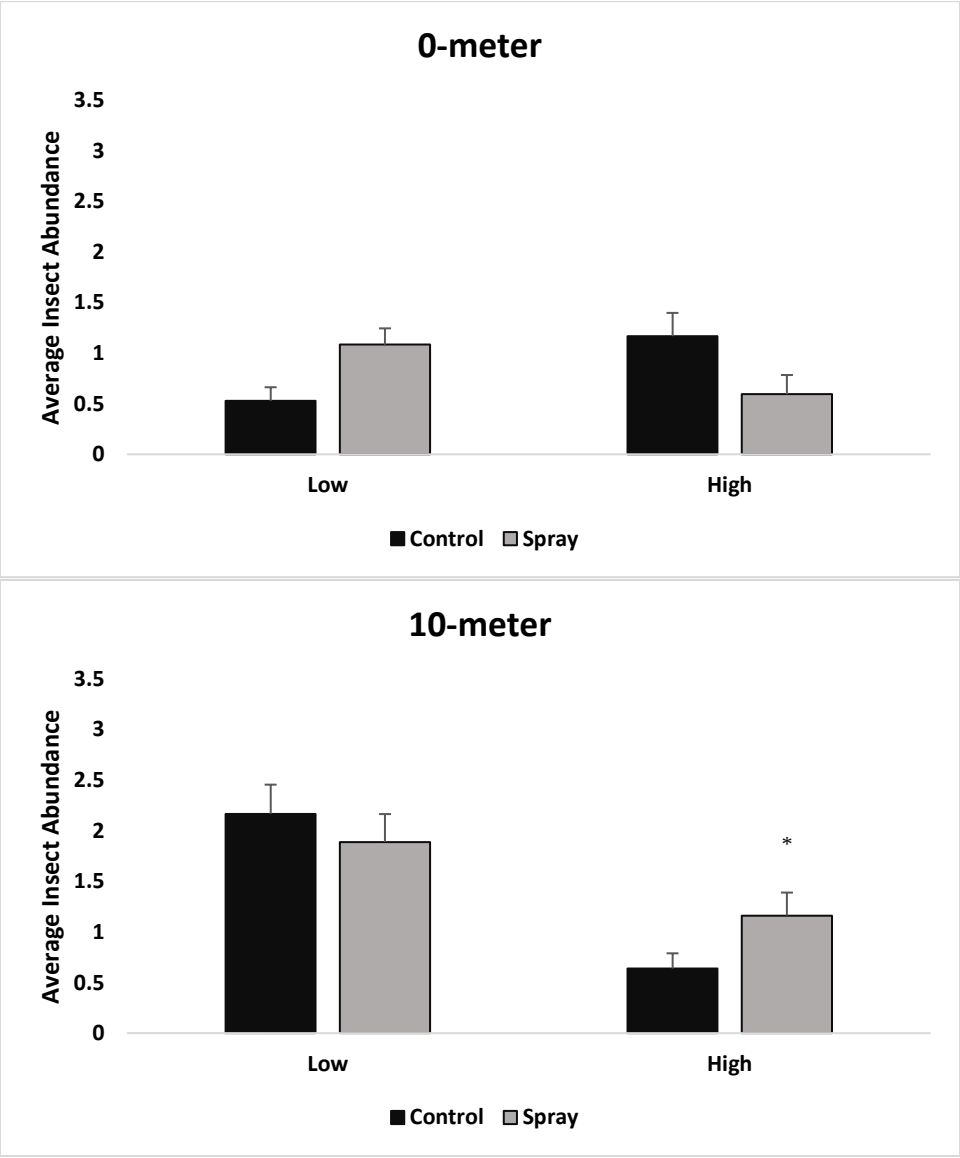
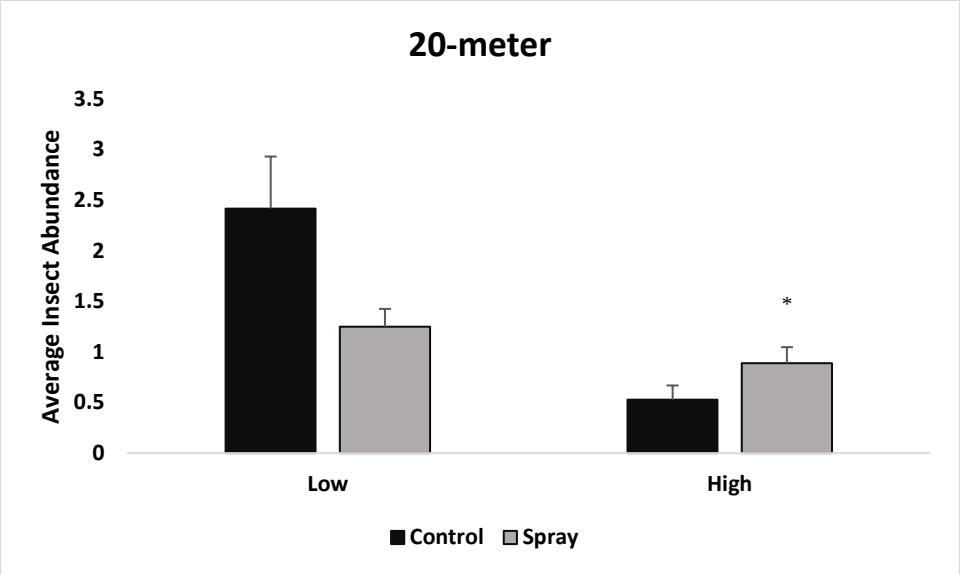

40-meter
Average Insect Abundance
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Low
High
Control
Spray

**Figure 16.** Average Ichneumonidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
3.5
3
2.5
2
1.5
1
0.5
0
*
Low
High
Control
Spray

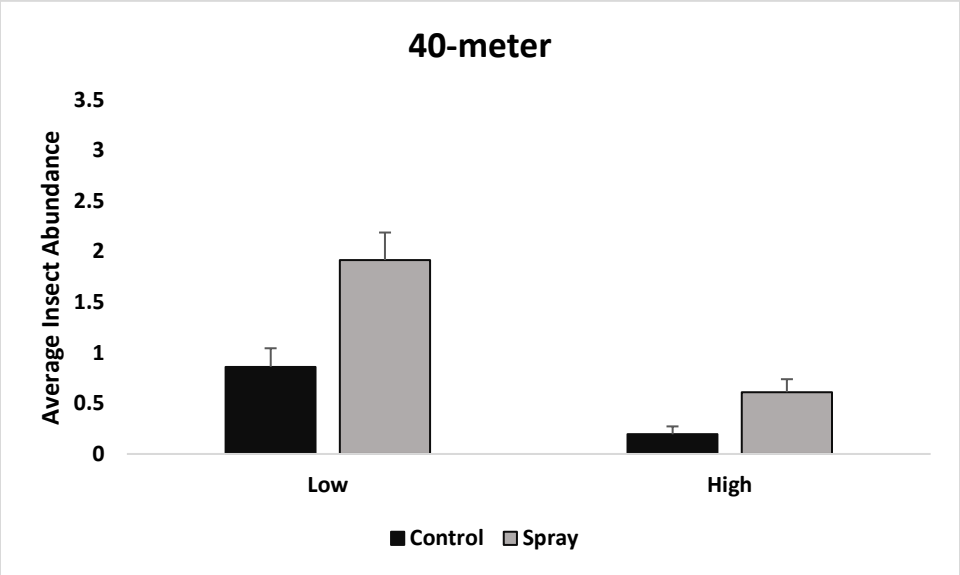
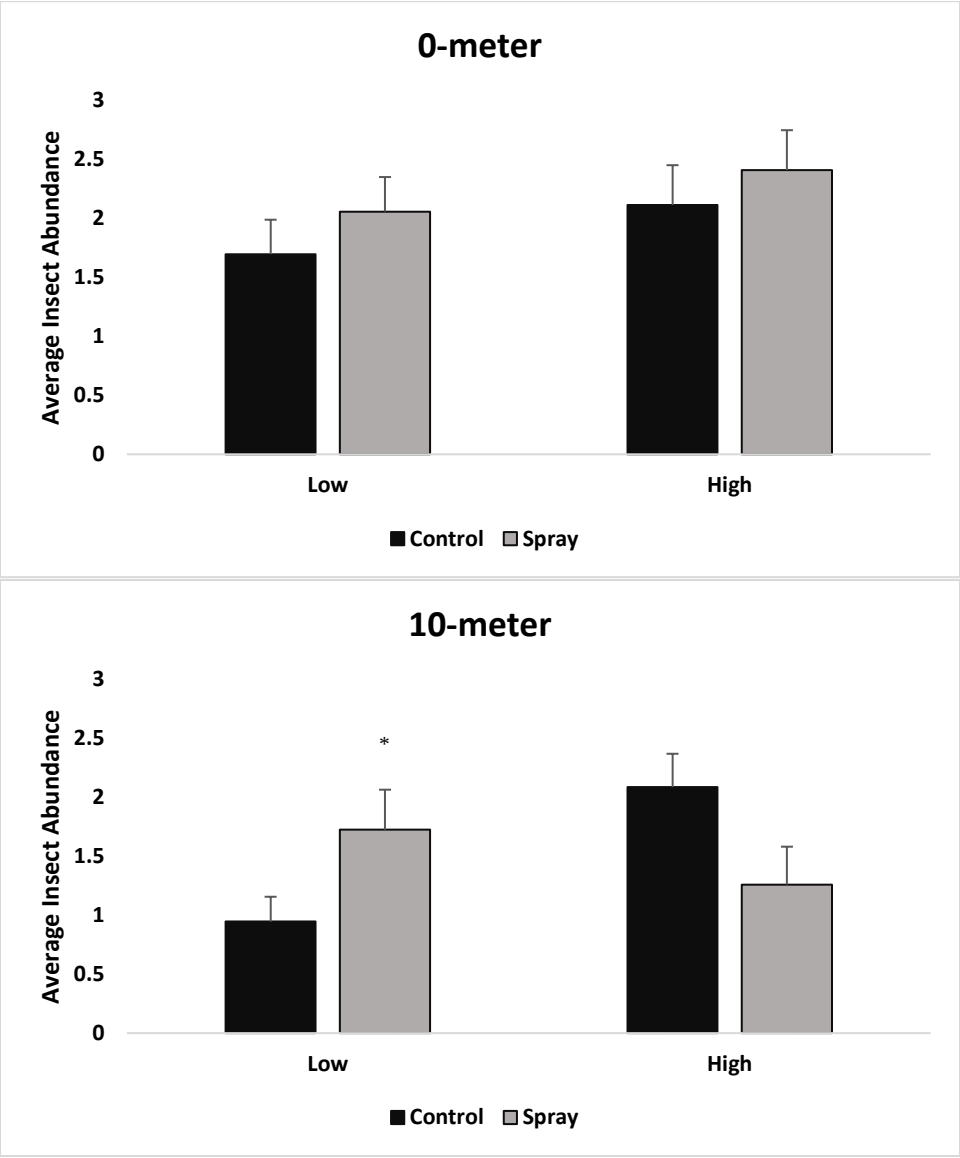
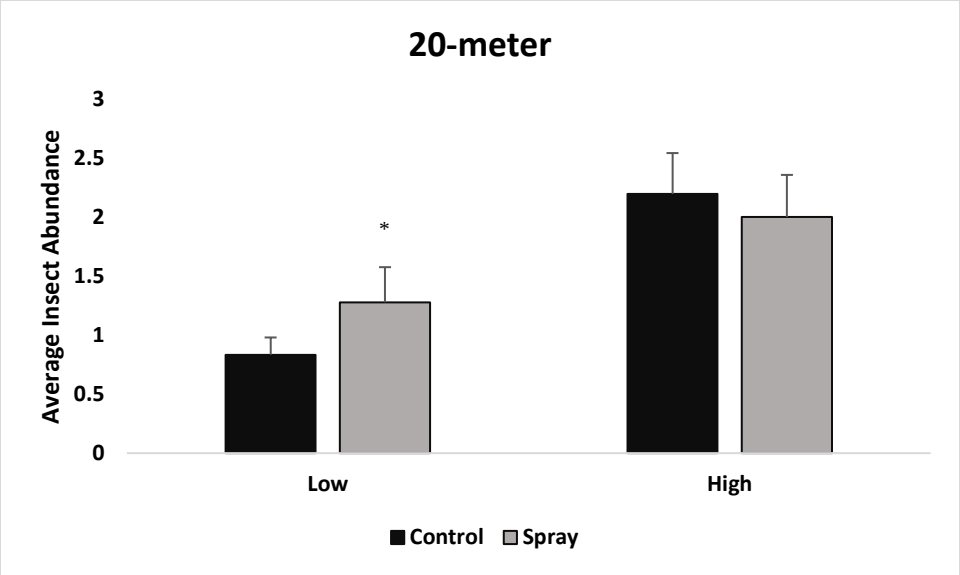

40-meter
Average Insect Abundance
3.5
3
2.5
2
1.5
1
0.5
0
Low
High
Control
Spray

**Figure 17.** Average Lepidoptera abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
3
2.5
2
1.5
1
0.5
0
*
Low
High
Control
Spray

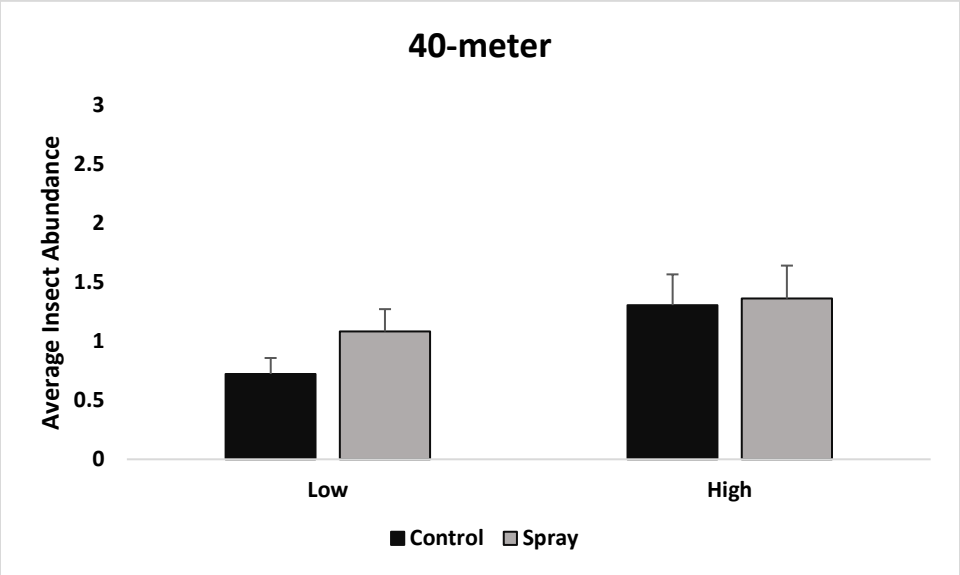
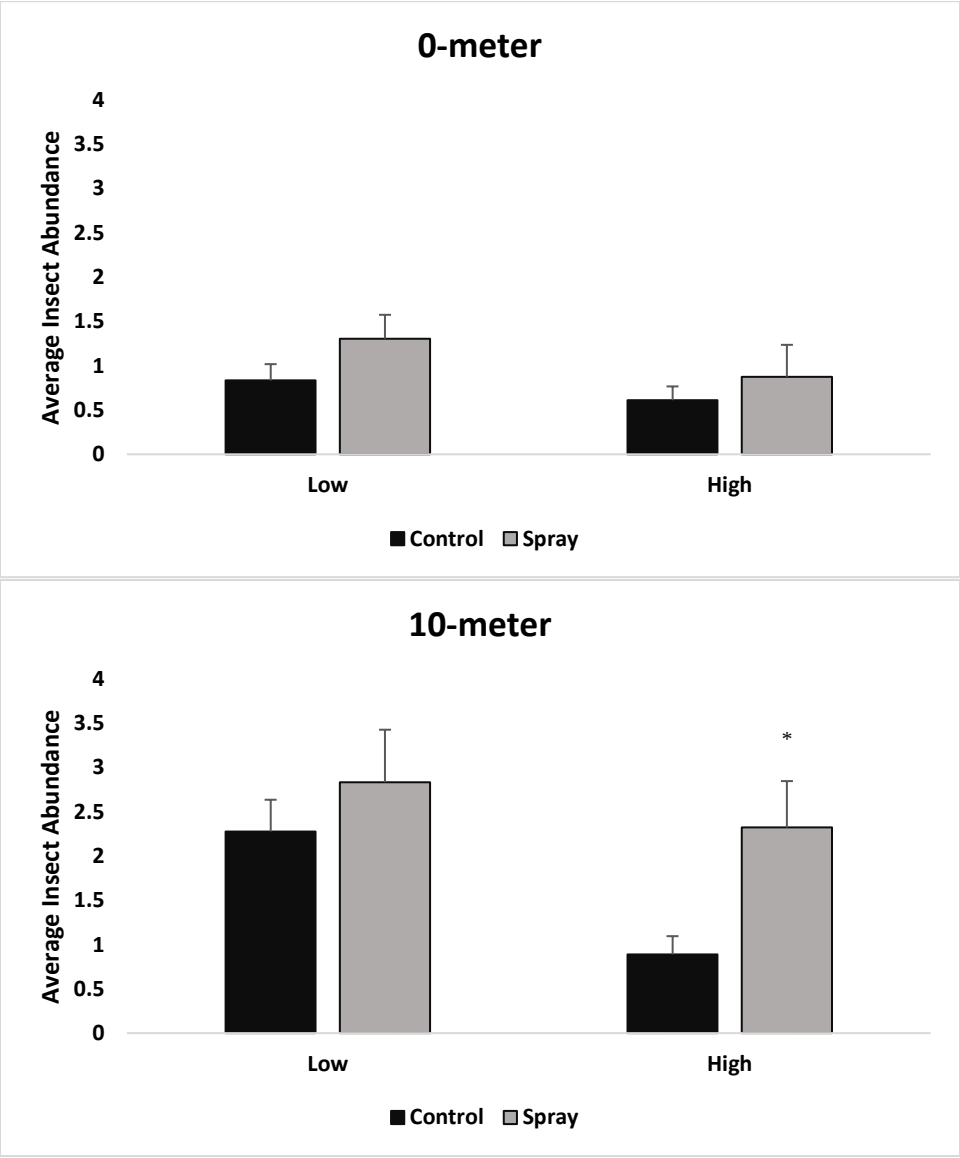
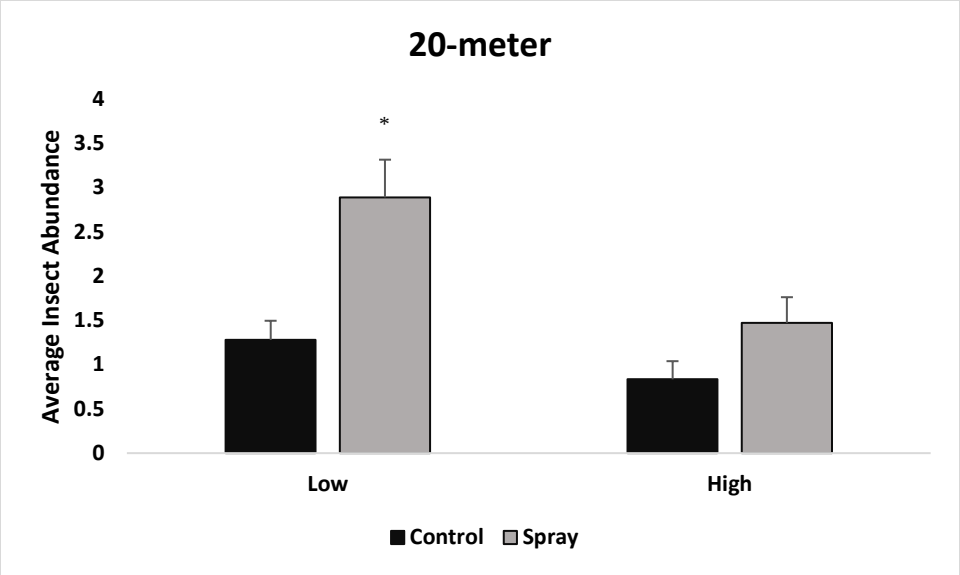

40-meter
Average Insect Abundance
3
2.5
2
1.5
1
0.5
0
Low
High
Control
Spray

**Figure 18.** Average Mymaridae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
4
3.5
3
2.5
2
1.5
1
0.5
0
*
Low
High
Control
Spray

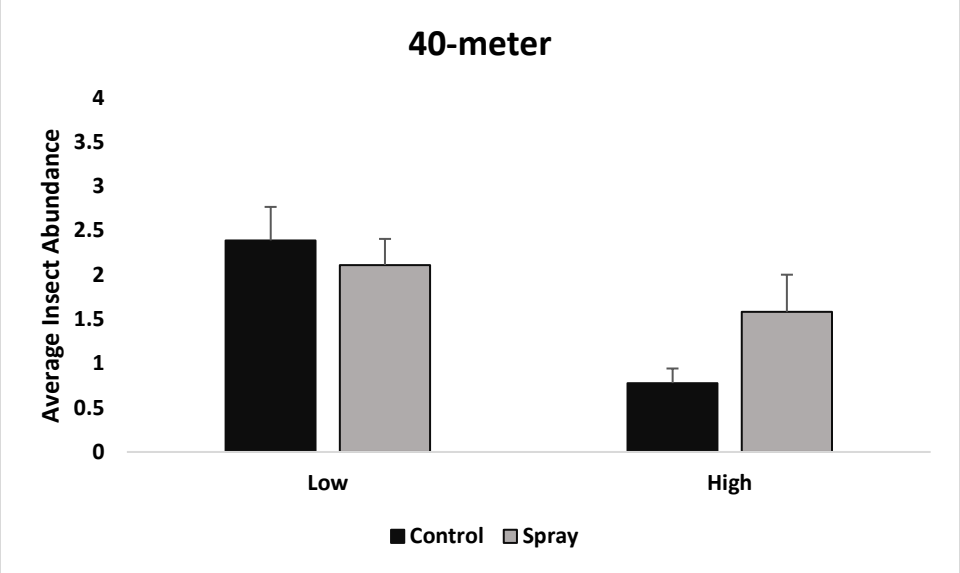

40-meter
Average Insect Abundance
4
3.5
3
2.5
2
1.5
1
0.5
0
Low
High
Control
Spray

**Figure 19.** Average Carabidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.

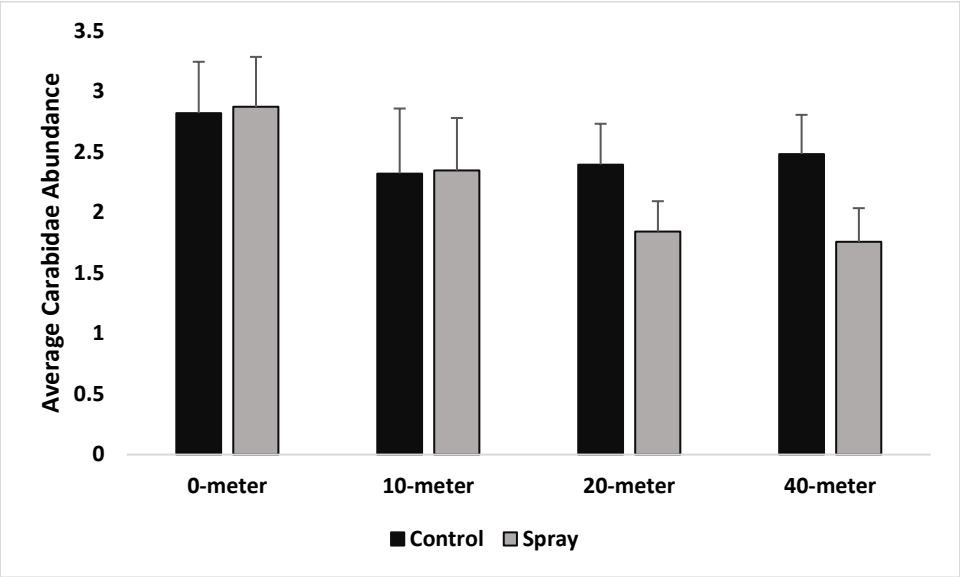



**Figure 20.** Average Araneae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

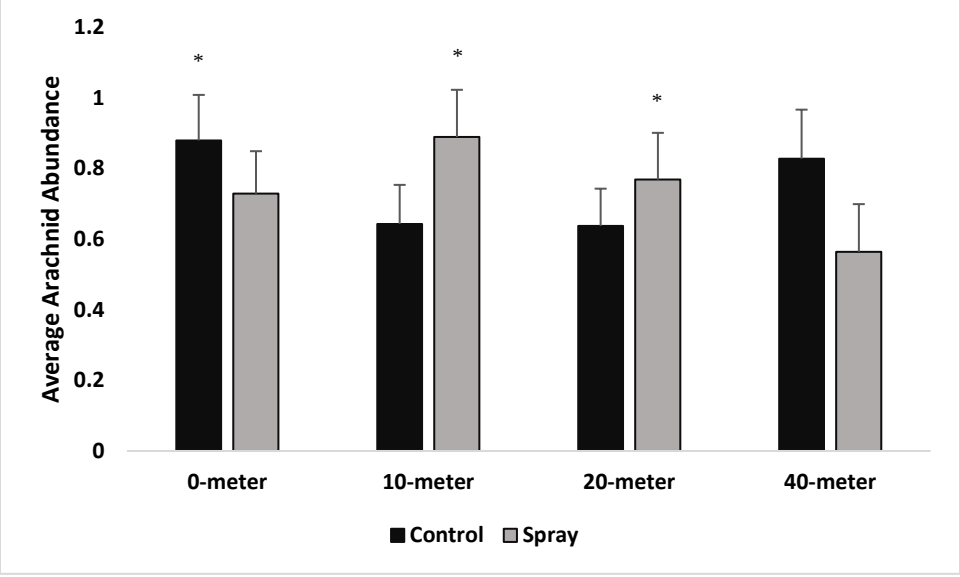


**Figure 21.** Average Formicidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

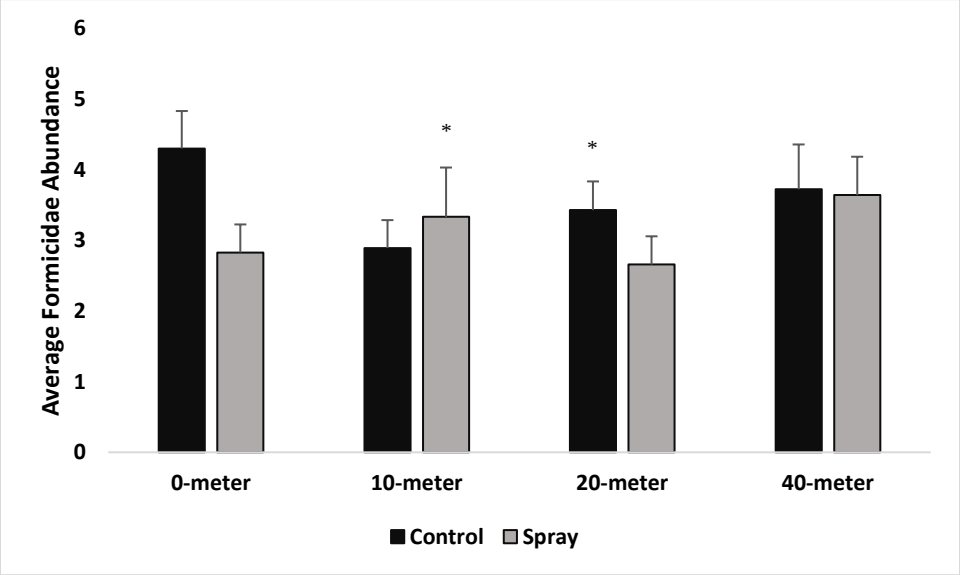



**Figure 22.** Average mite abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.

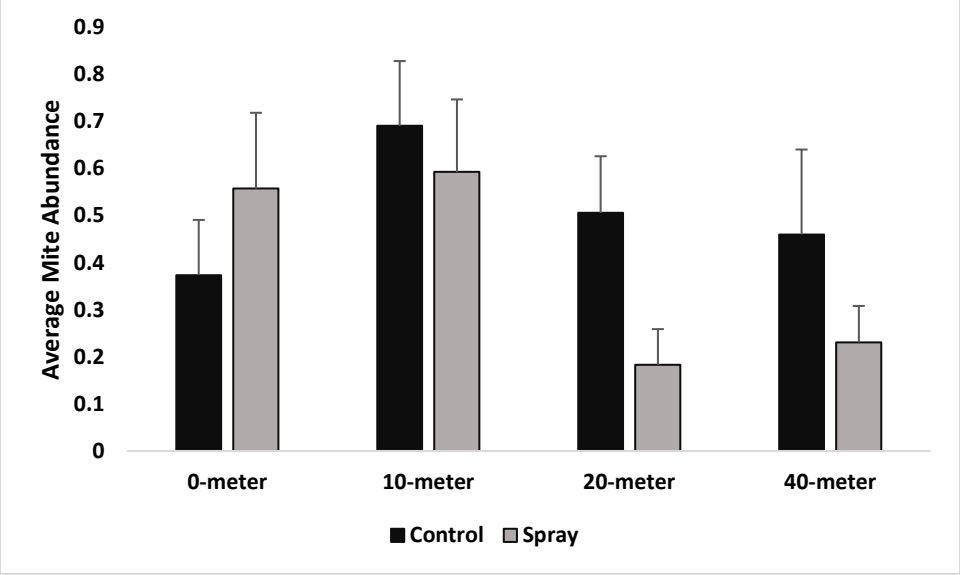


**Figure 23.** Average Gryllidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.

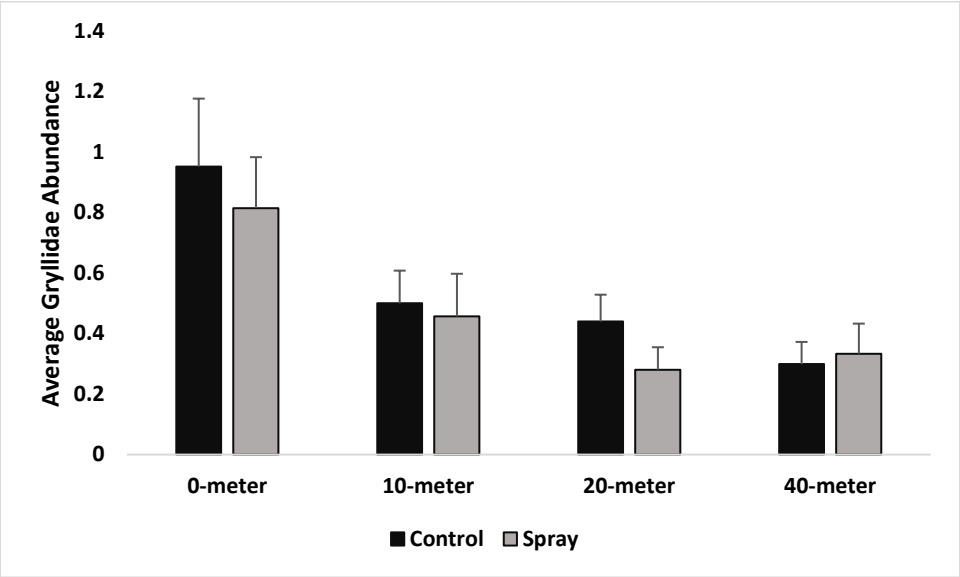



**Figure 24.** Average Curculionidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.

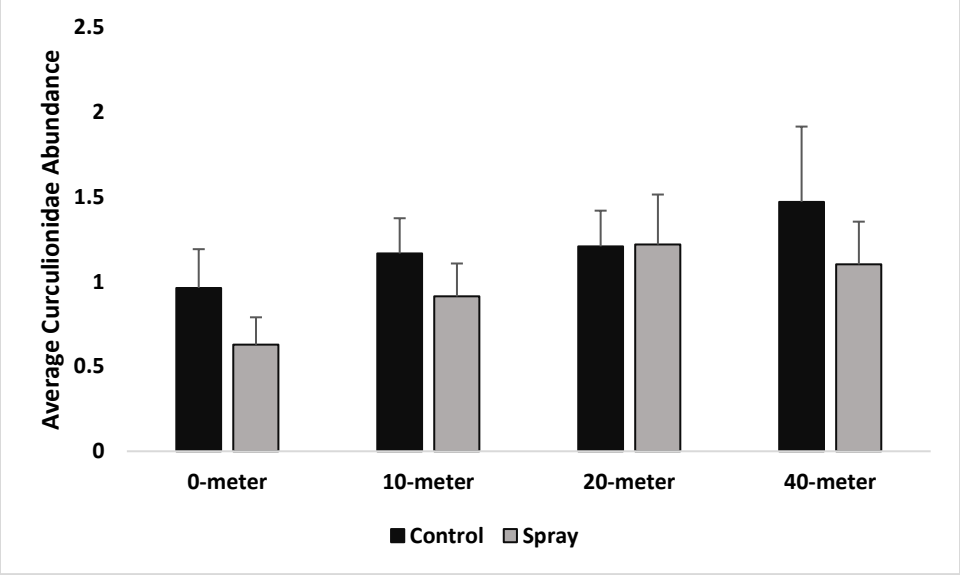


**Figure 25.** Average Blattidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Error bars represent standard error.

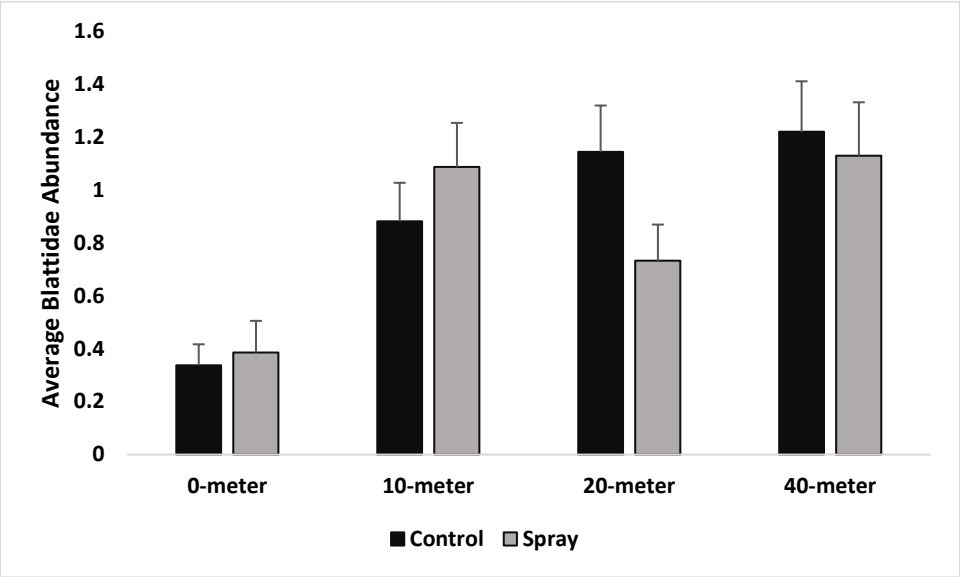



**Figure 26.** Average Blattidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

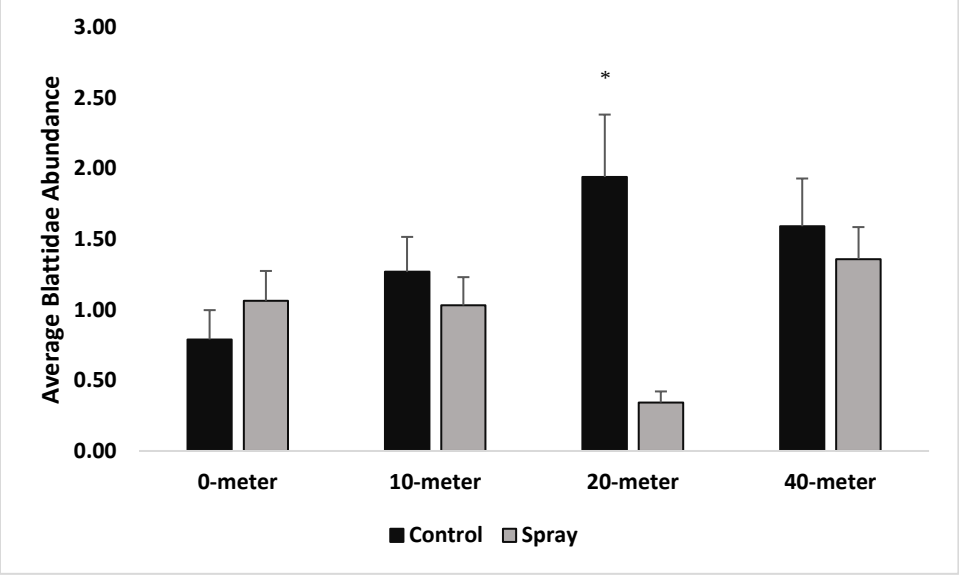


**Figure 27.** Average Formicidae abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

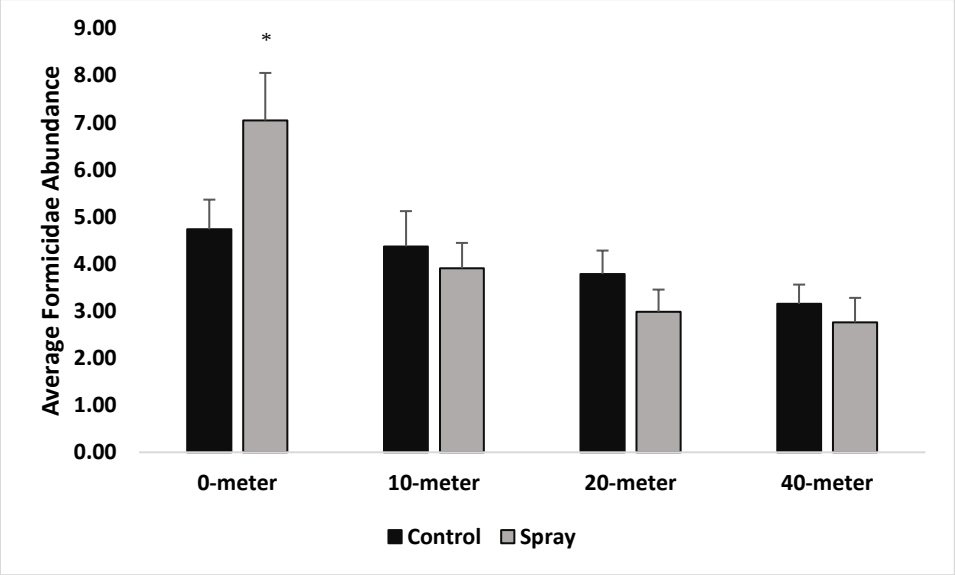



**Figure 28.** Average mite abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Error bars represent standard error.

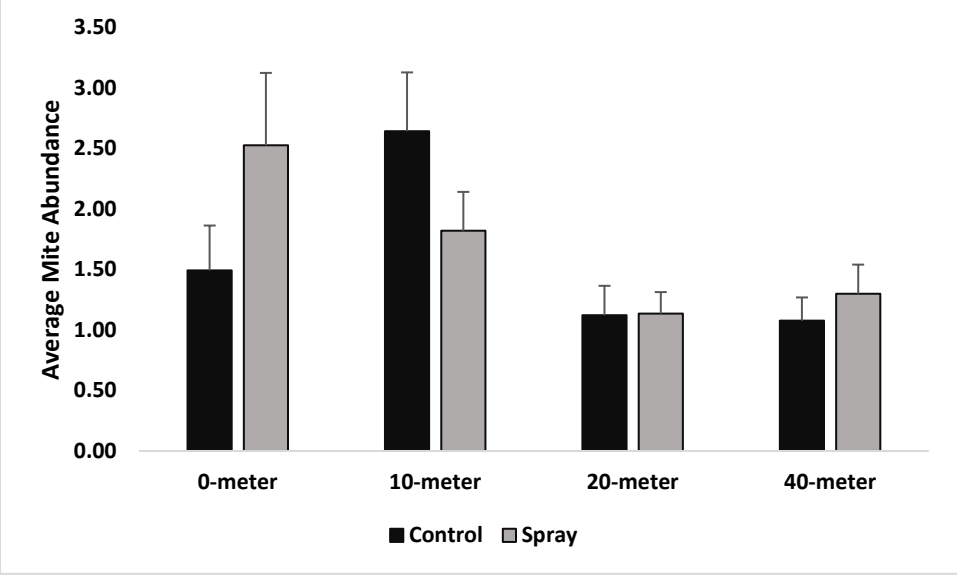
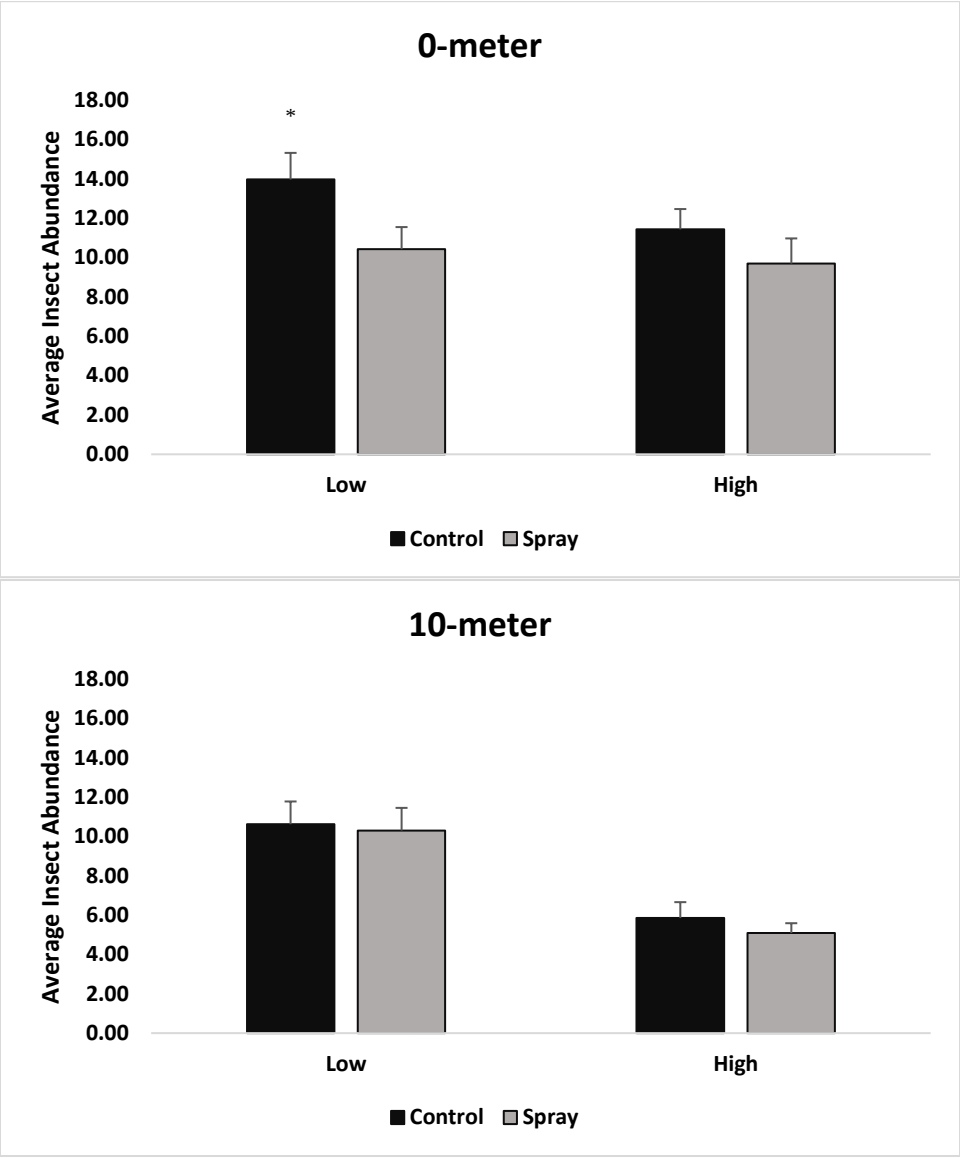
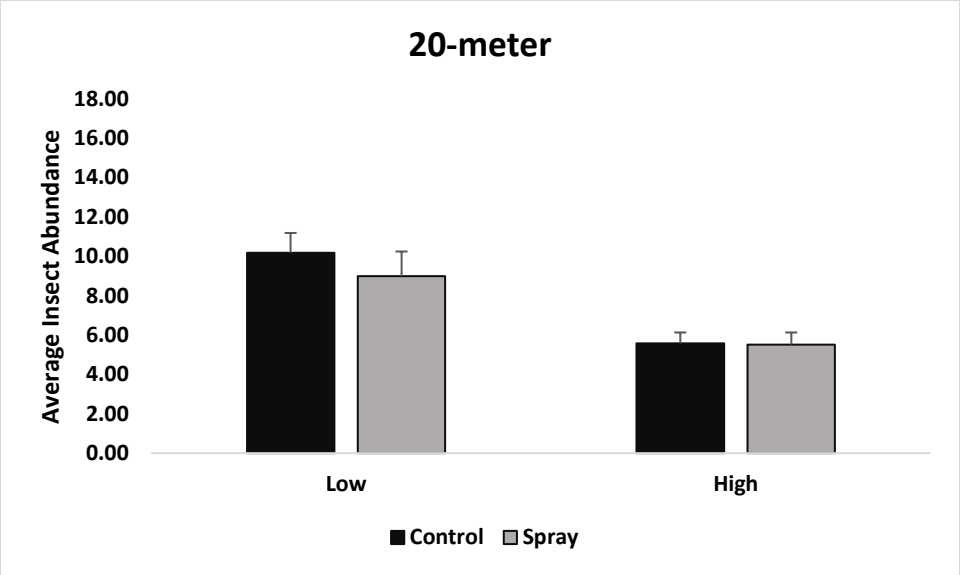


**Figure 29.** Average Araneae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Low
High
Control
Spray

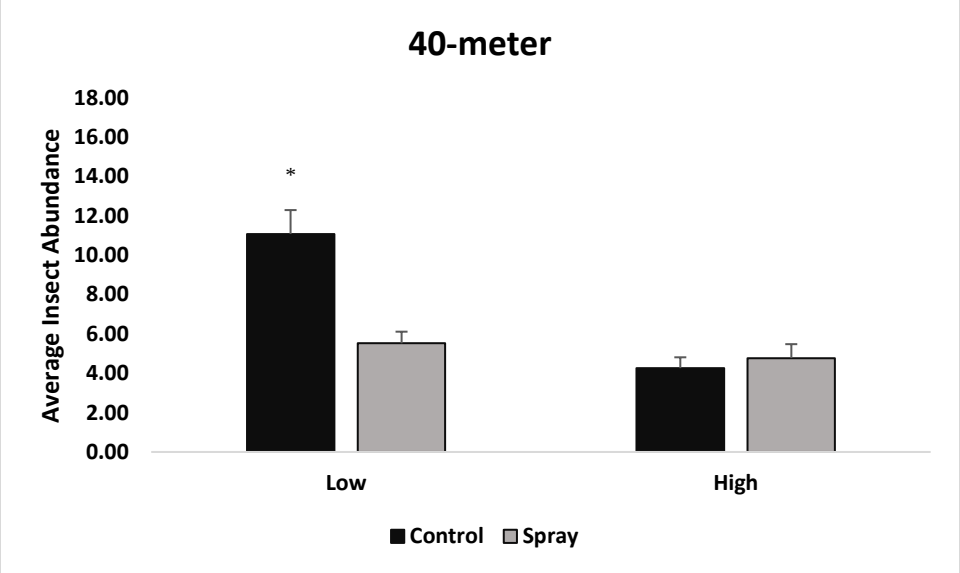
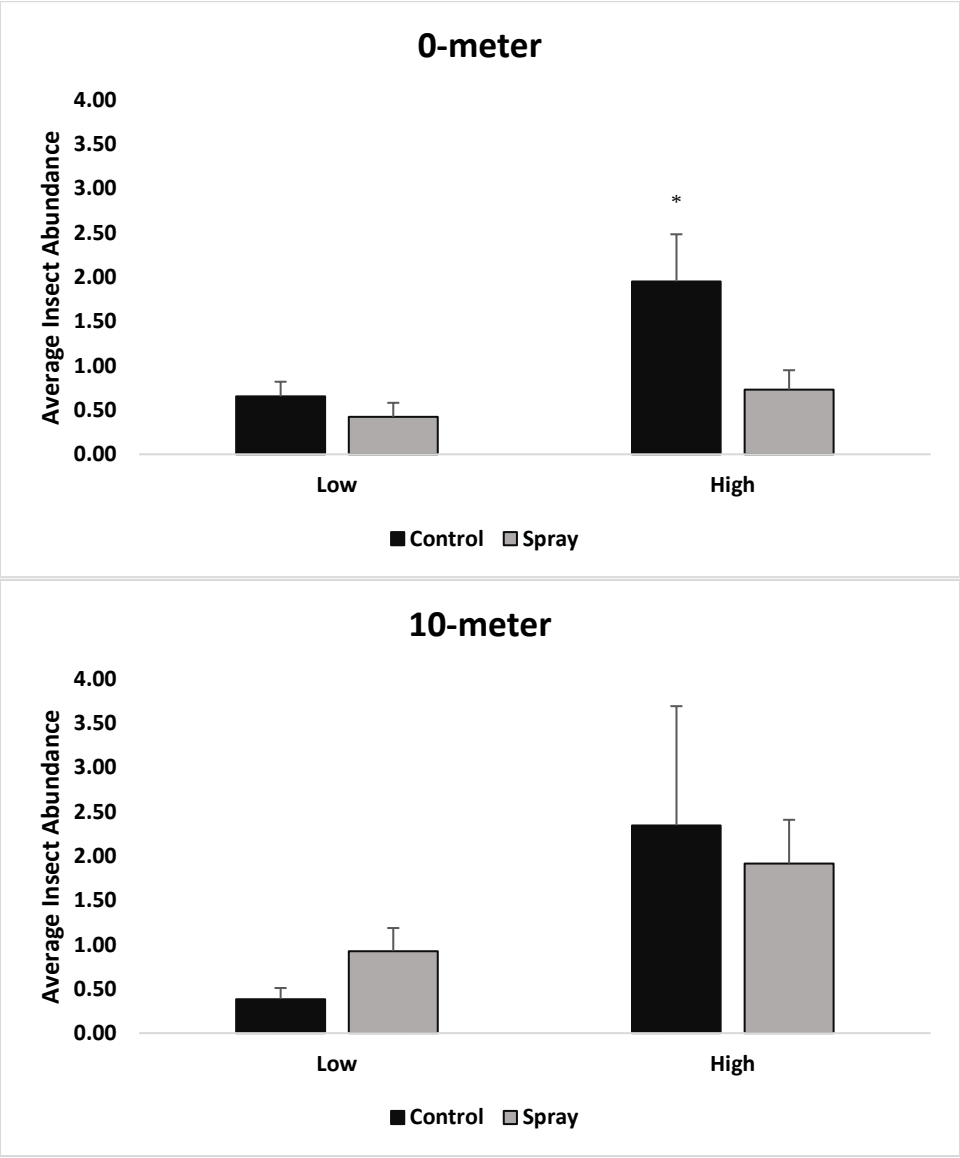
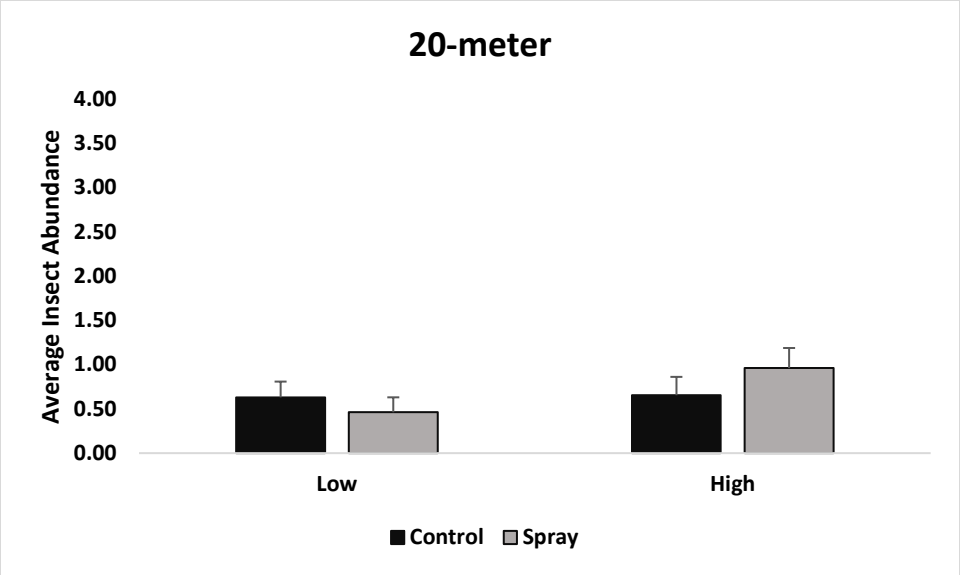

40-meter
Average Insect Abundance
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
*
Low
High
Control
Spray

**Figure 30.** Average Cynipidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

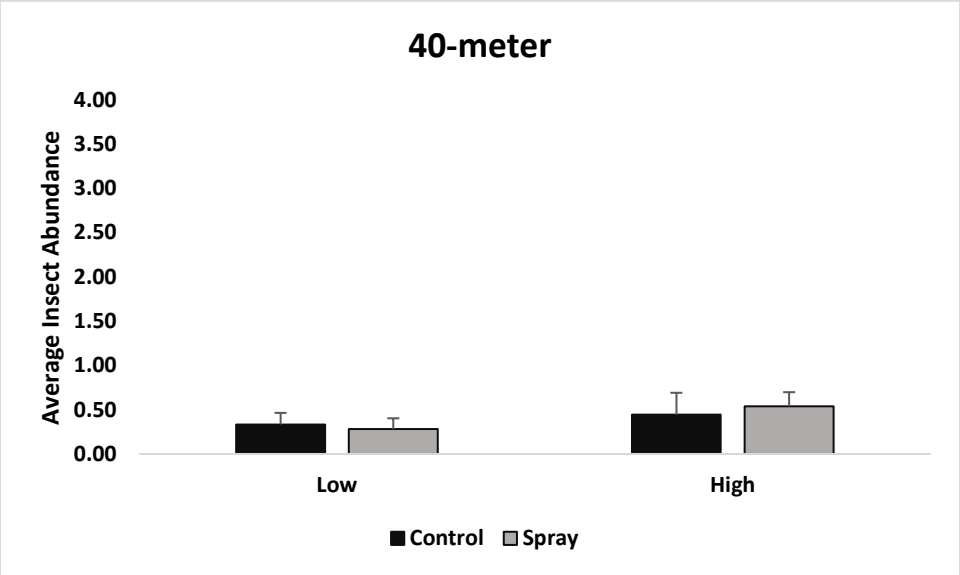
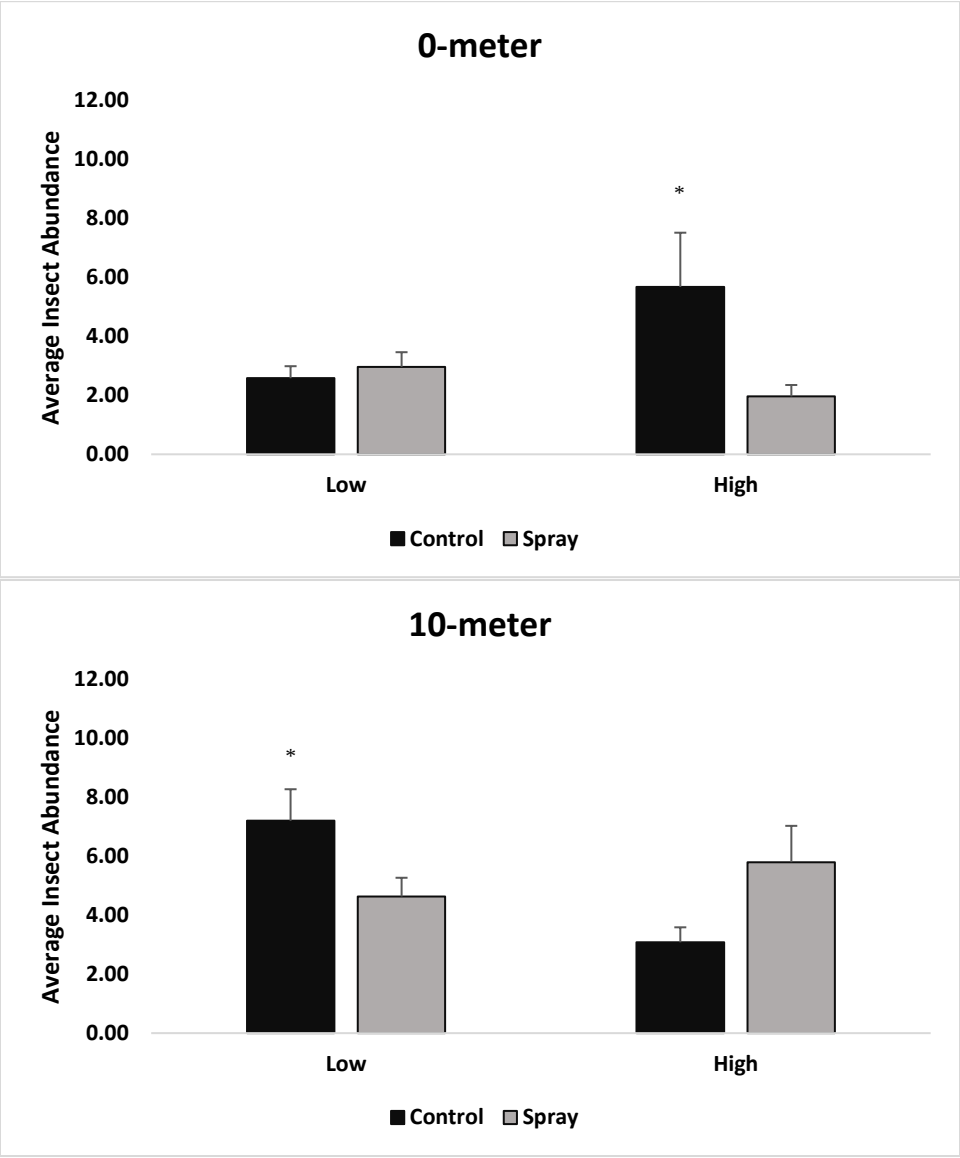
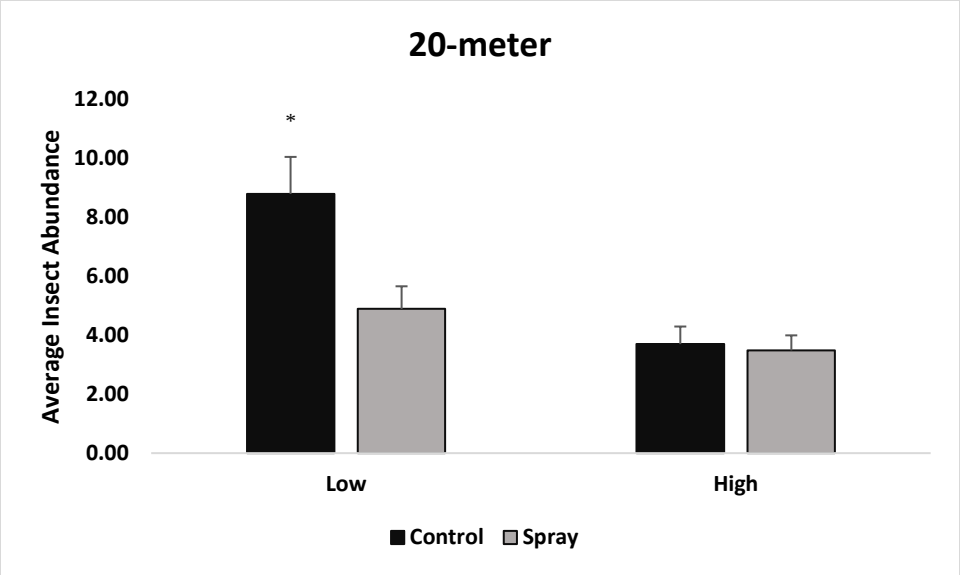

40-meter
Average Insect Abundance
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

**Figure 31.** Average Mymaridae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
12.00
10.00
8.00
6.00
4.00
2.00
0.00
*
Low
High
Control
Spray

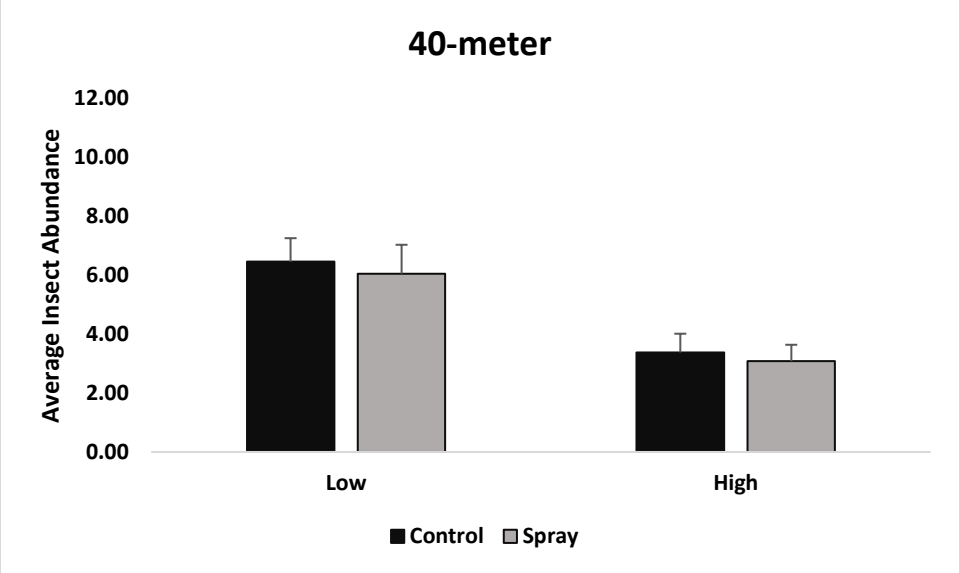
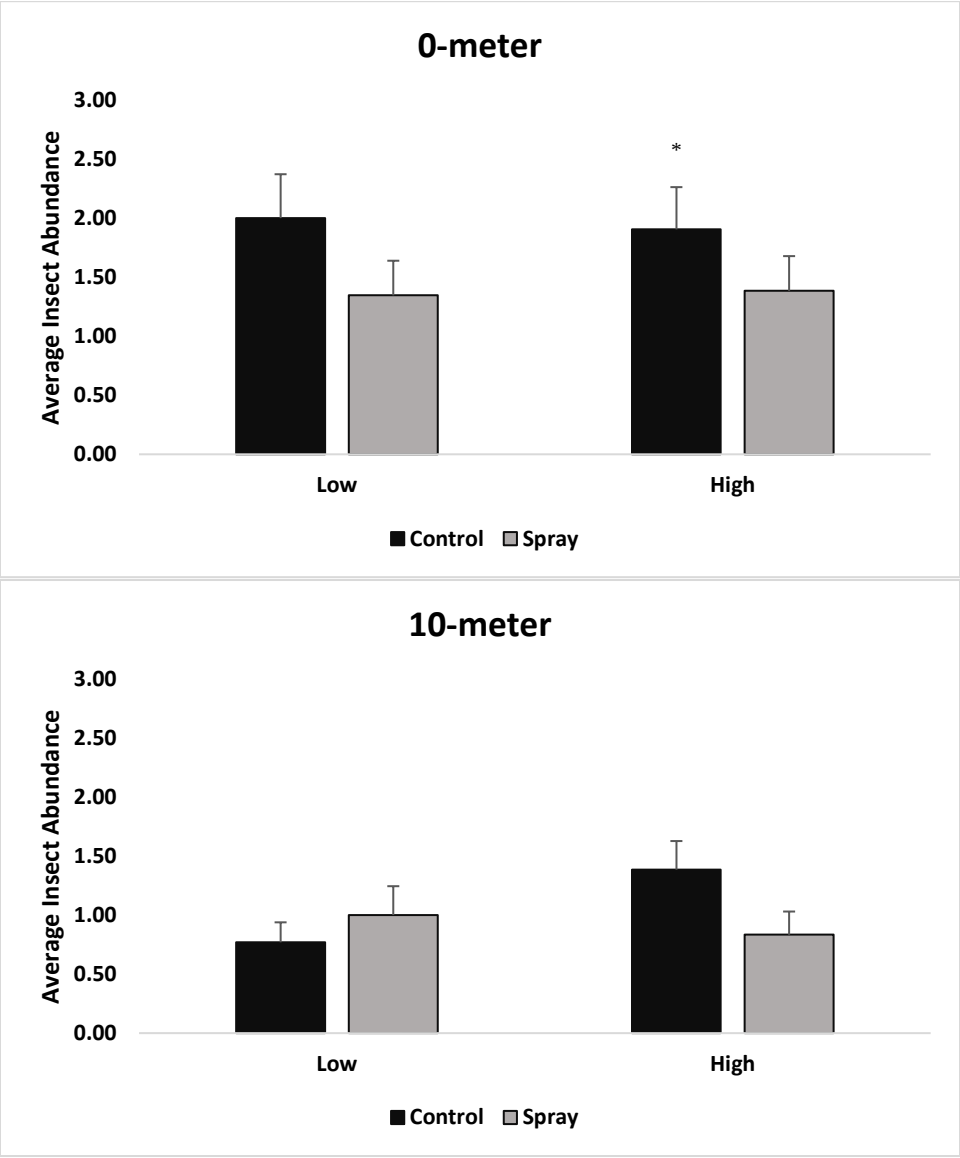
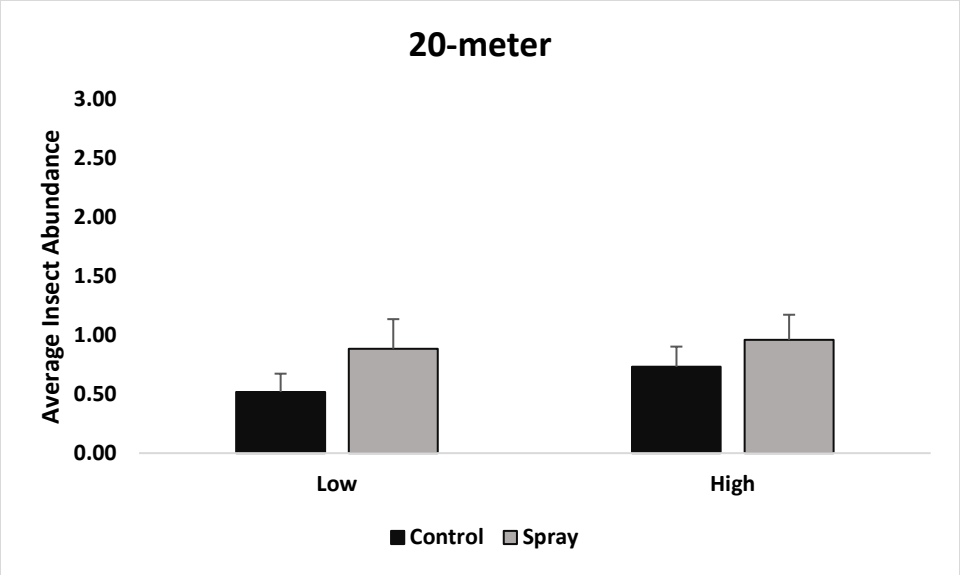

40-meter
Average Insect Abundance
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Low
High
Control
Spray

**Figure 32.** Average Staphylinidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

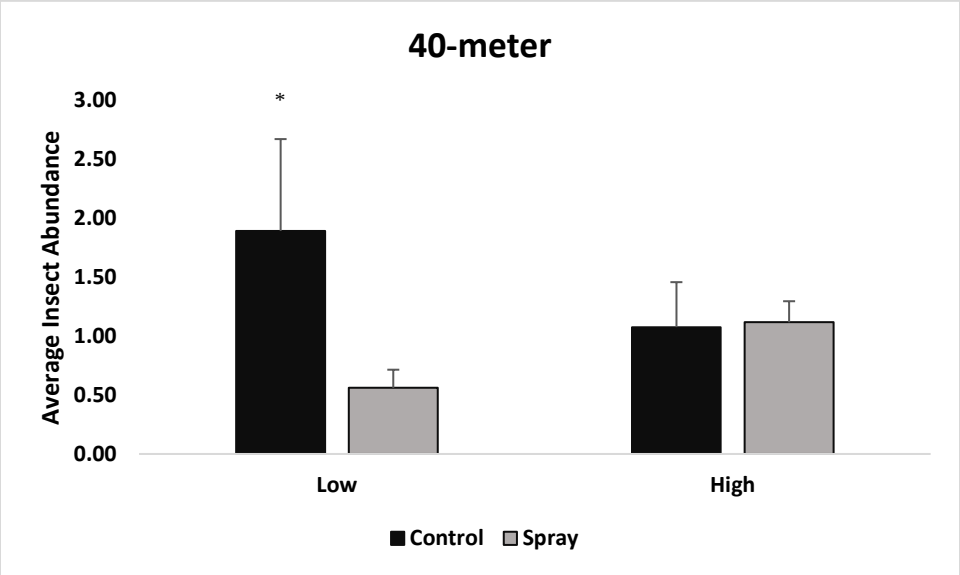

40-meter
Average Insect Abundance
*
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Low
High
Control
Spray

**Figure 33.** Average Isopoda abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

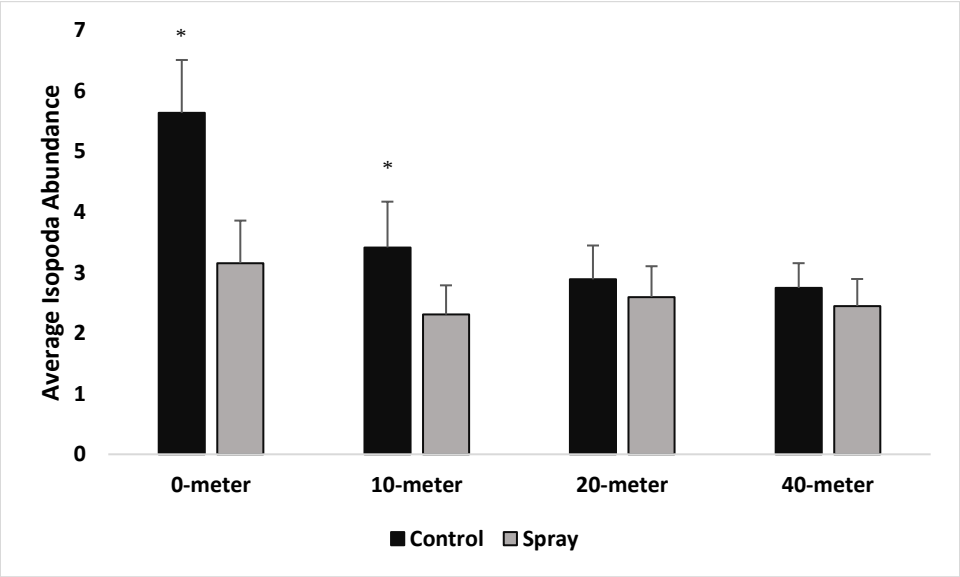
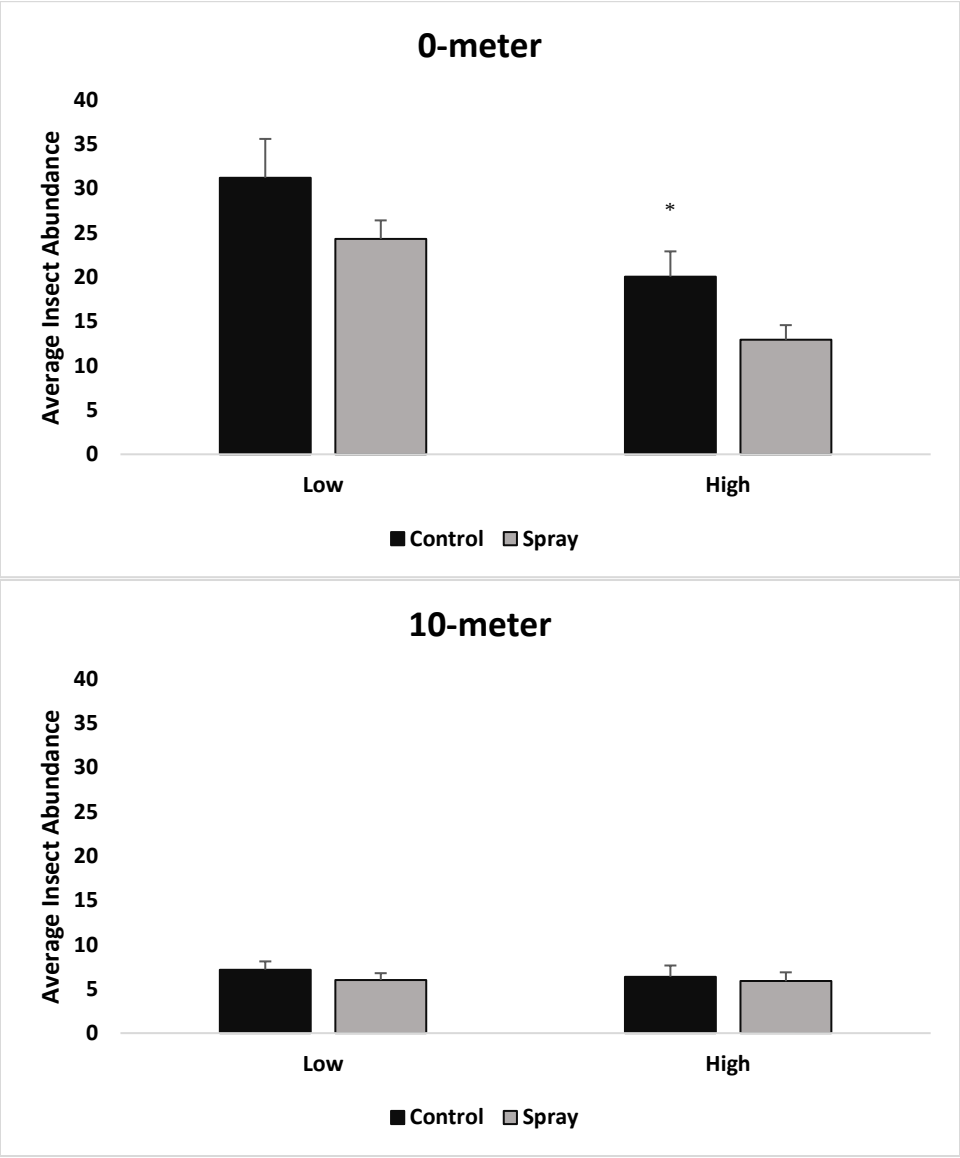
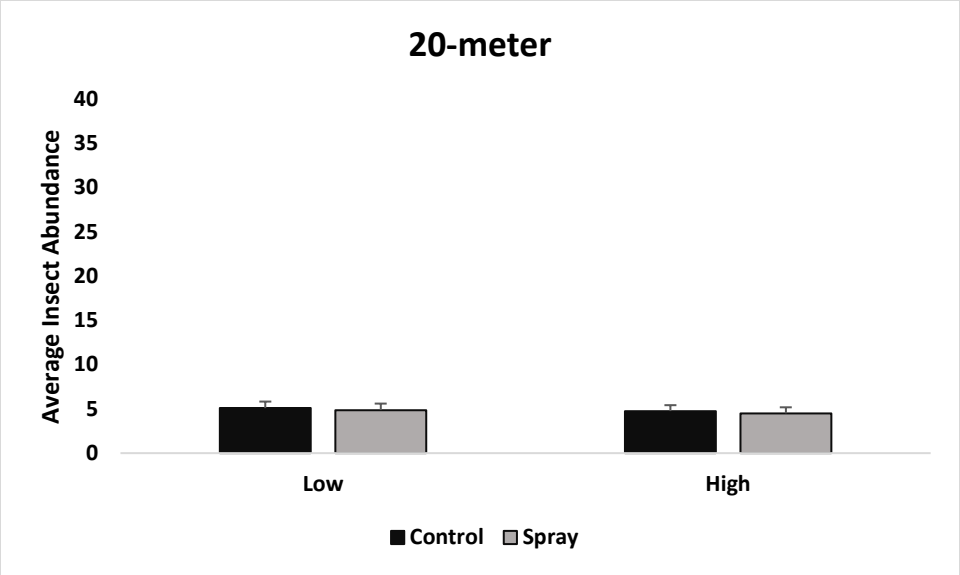


**Figure 34.** Average Dolichopodidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
40
35
30
25
20
15
10
5
0
Low
High
Control
Spray

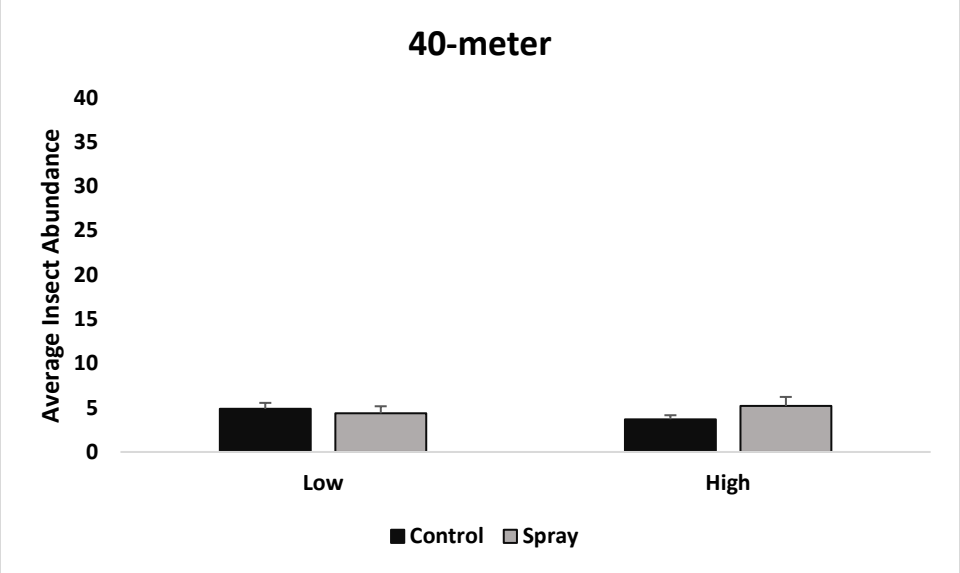
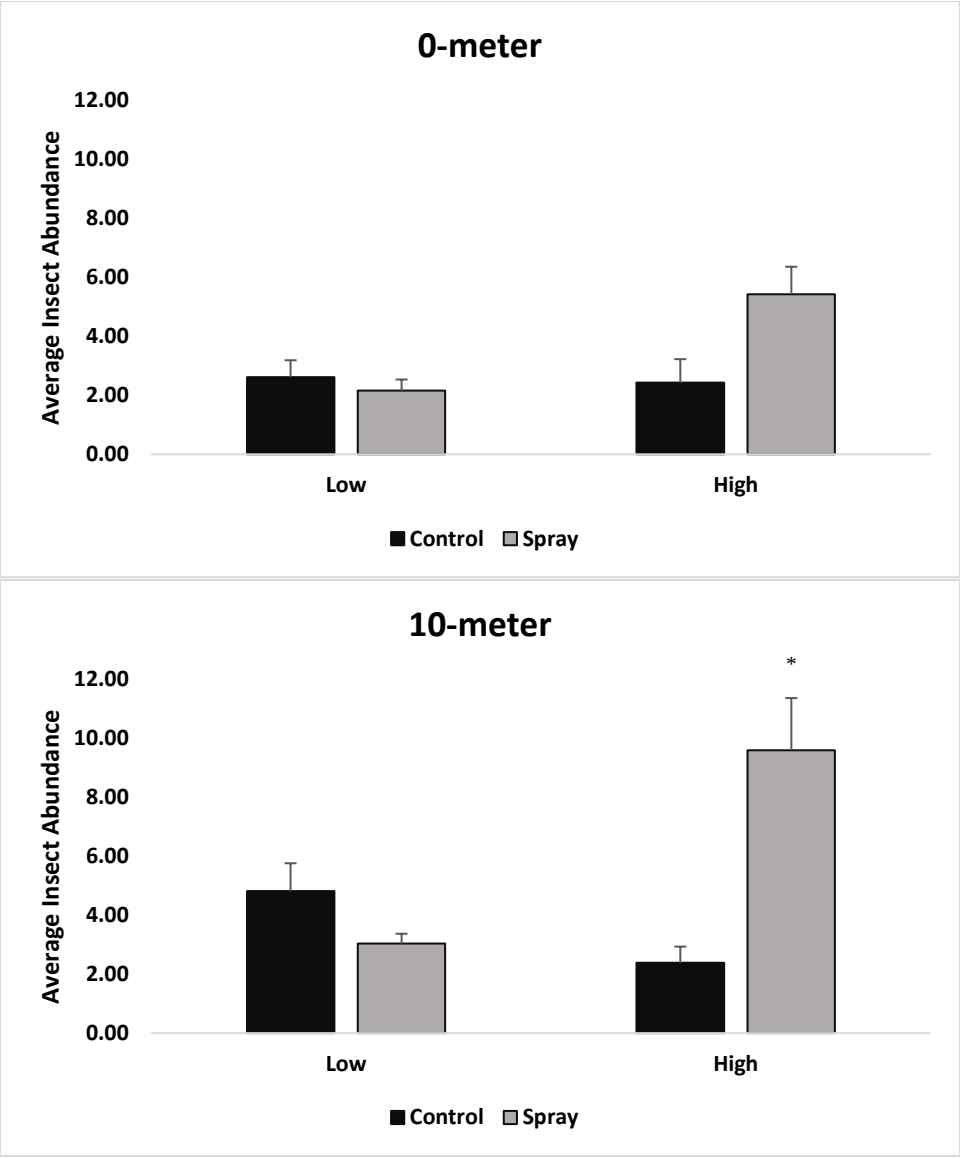
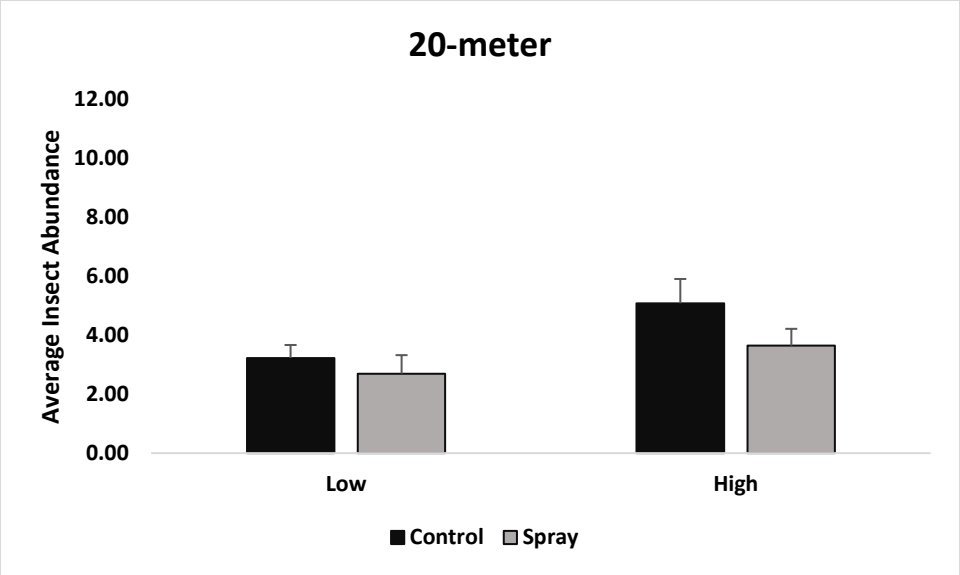

40-meter
Average Insect Abundance
40
35
30
25
20
15
10
5
0
Low
High
Control
Spray

**Figure 35.** Average Coccinellidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Low
High
Control
Spray

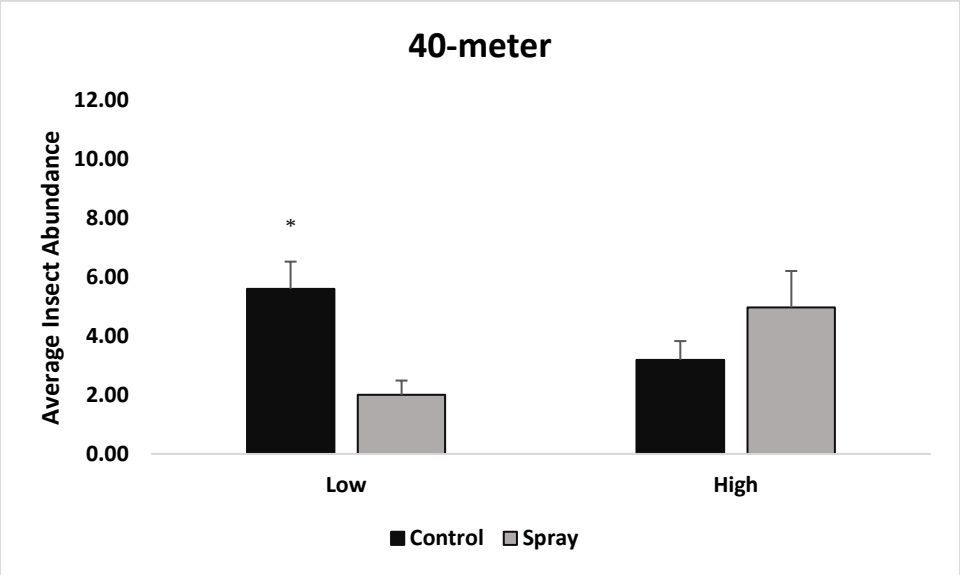
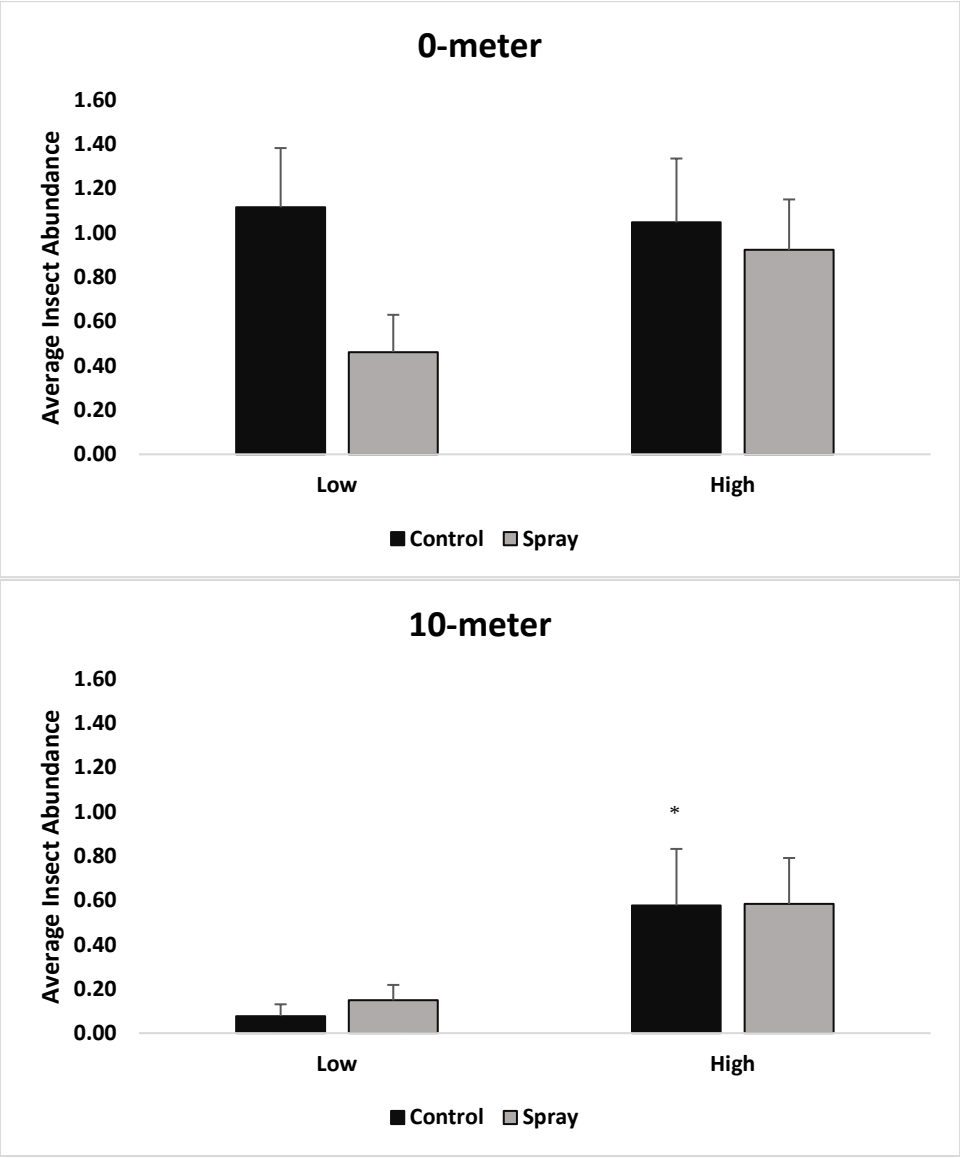
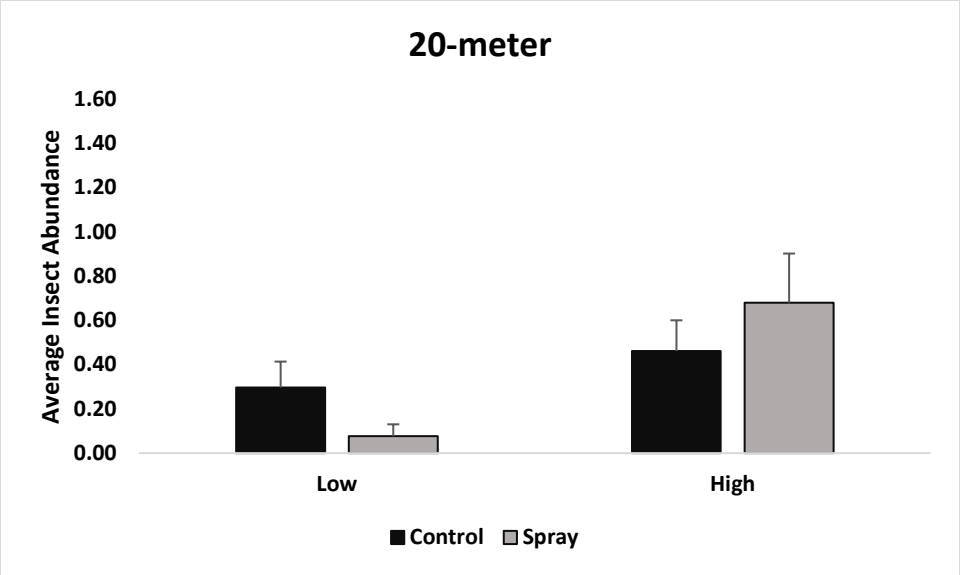

40-meter
Average Insect Abundance
12.00
10.00
8.00
6.00
4.00
2.00
0.00
*
Low
High
Control
Spray

**Figure 36.** Average Tachinidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

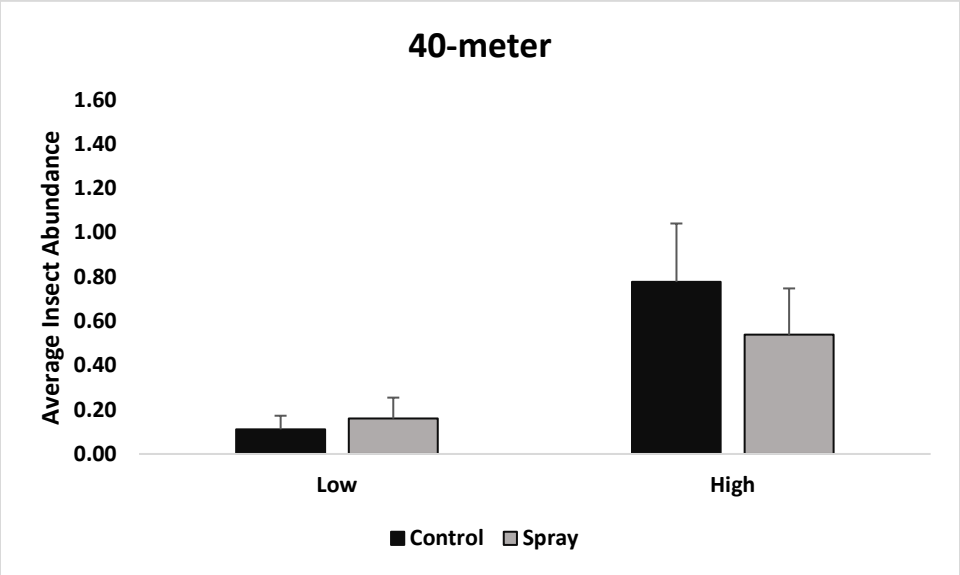
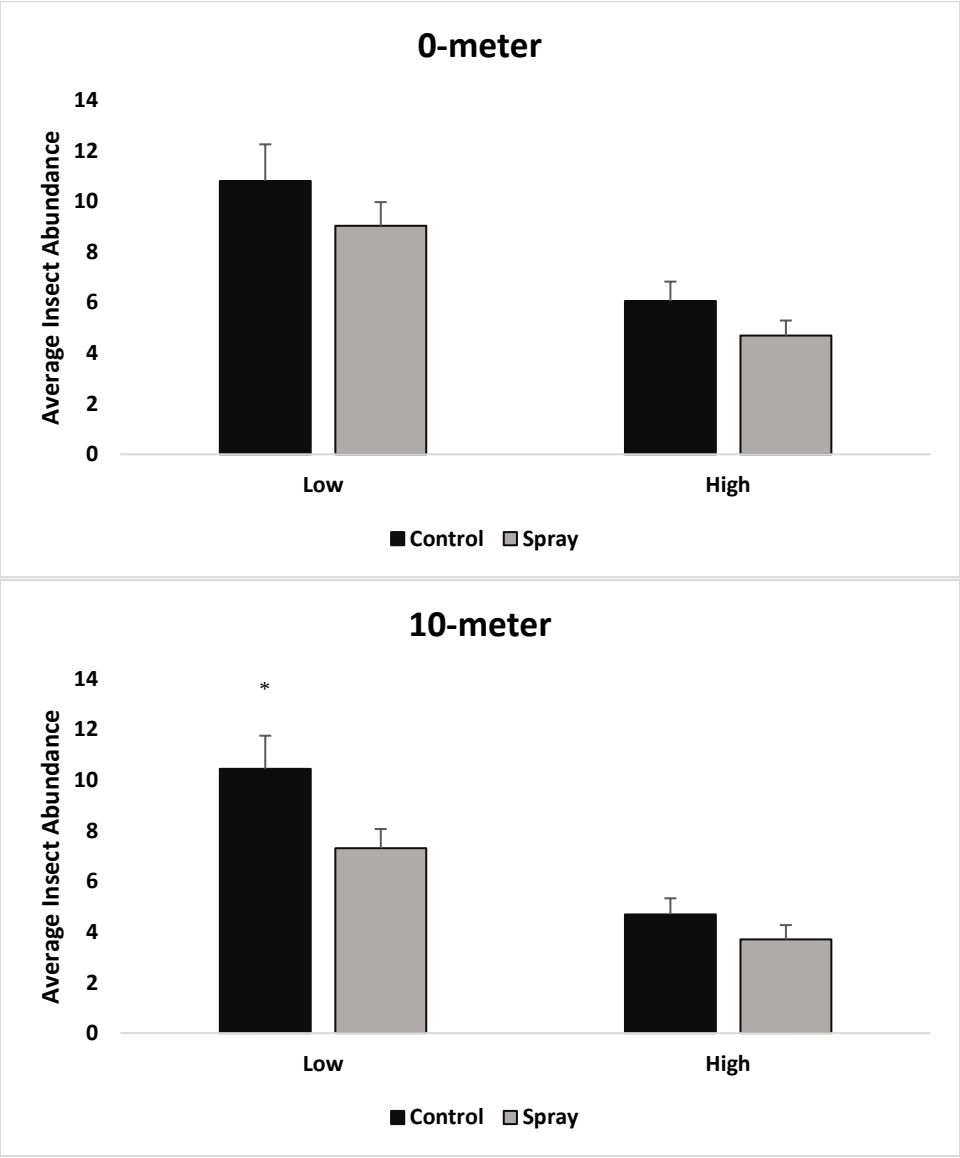
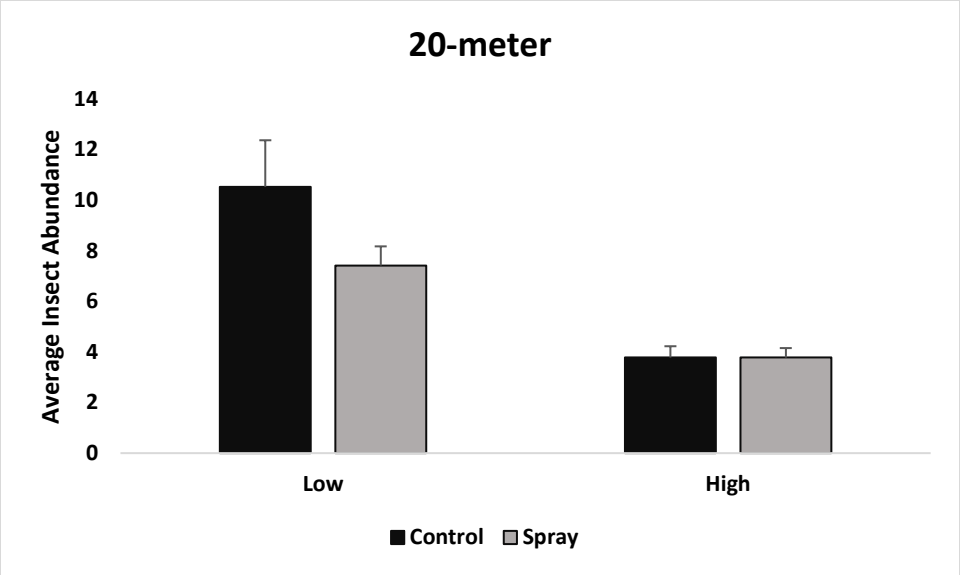

40-meter
Average Insect Abundance
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

**Figure 37.** Average Araneae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
14
12
10
8
6
4
2
0
Low
High
Control
Spray

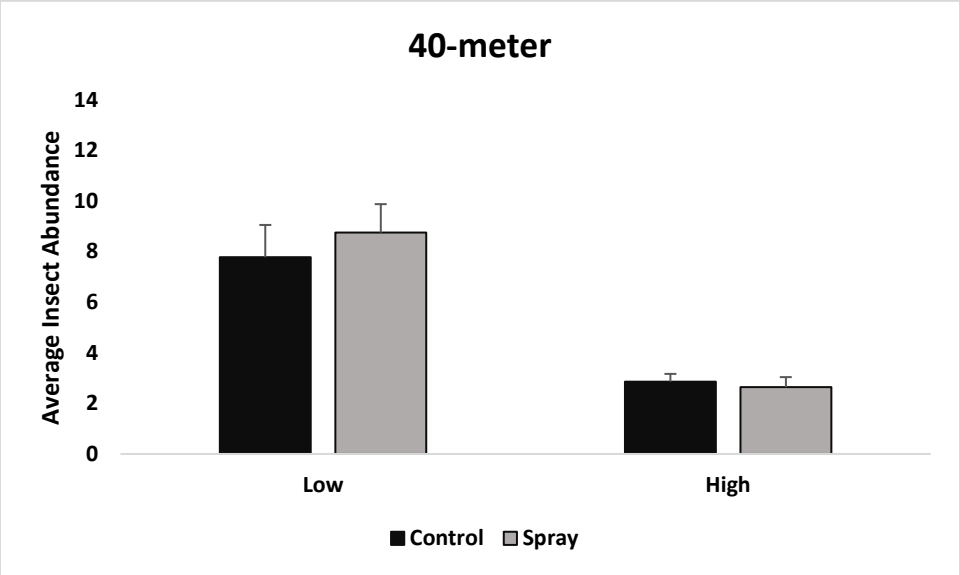
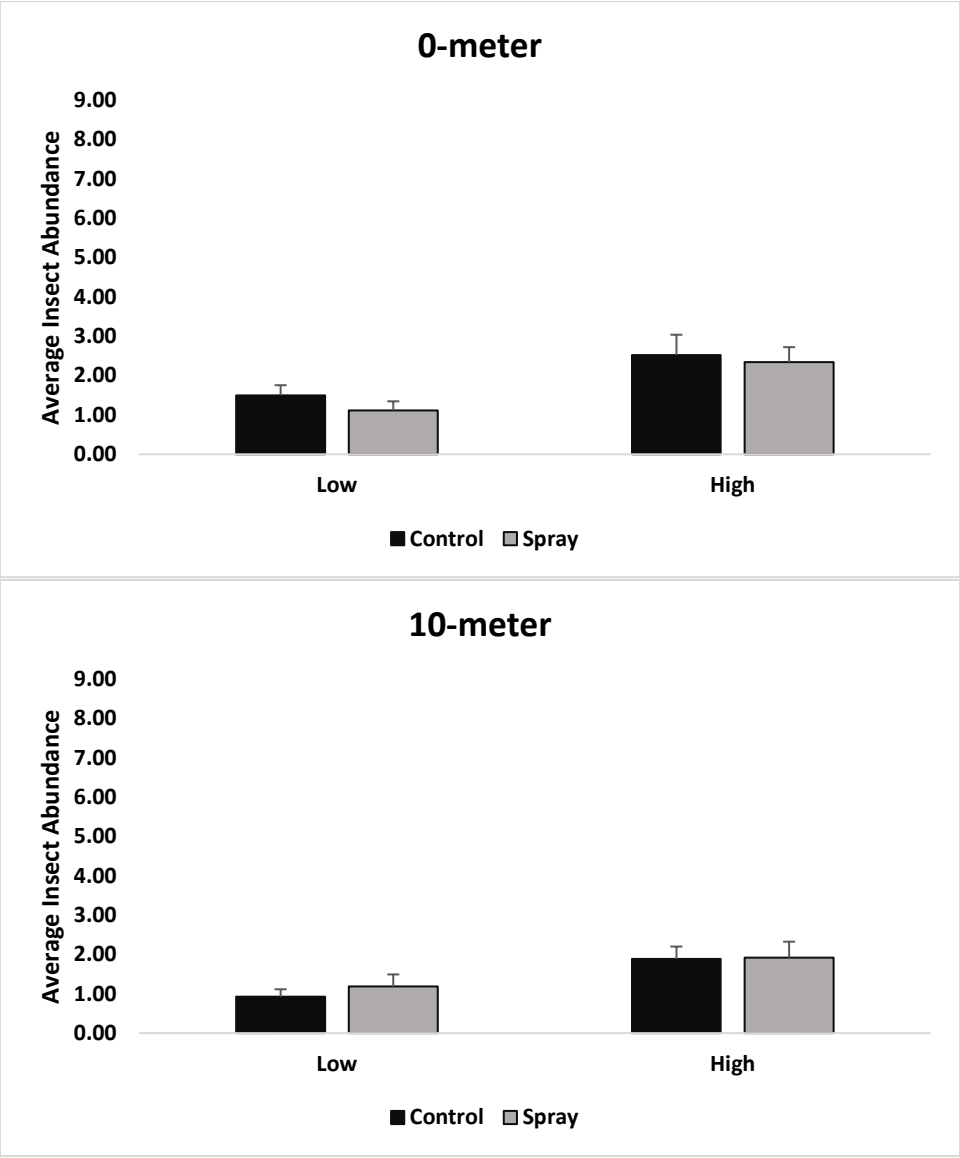
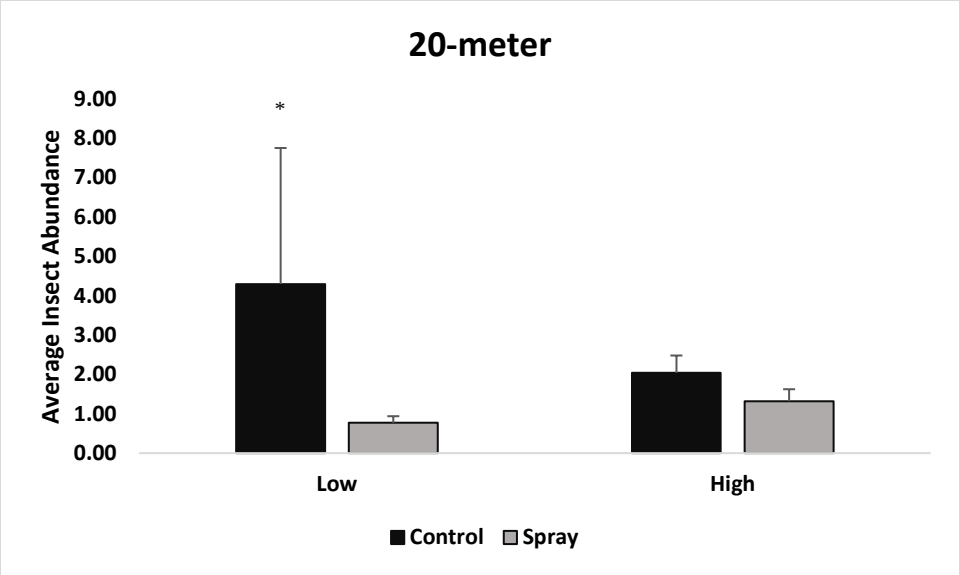

40-meter
Average Insect Abundance
14
12
10
8
6
4
2
0
Low
High
Control
Spray

**Figure 38.** Average Lepidoptera abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
*
Low
High
Control
Spray

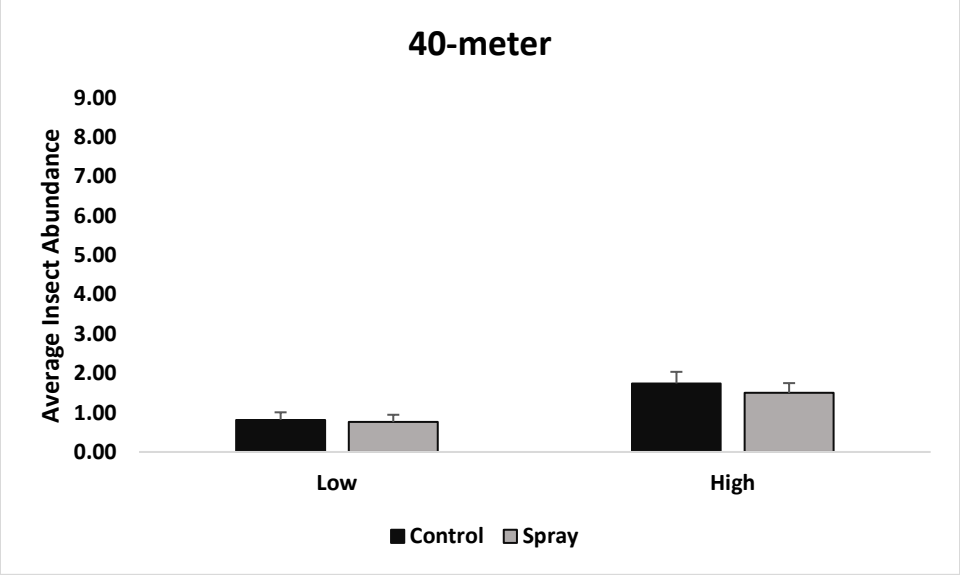
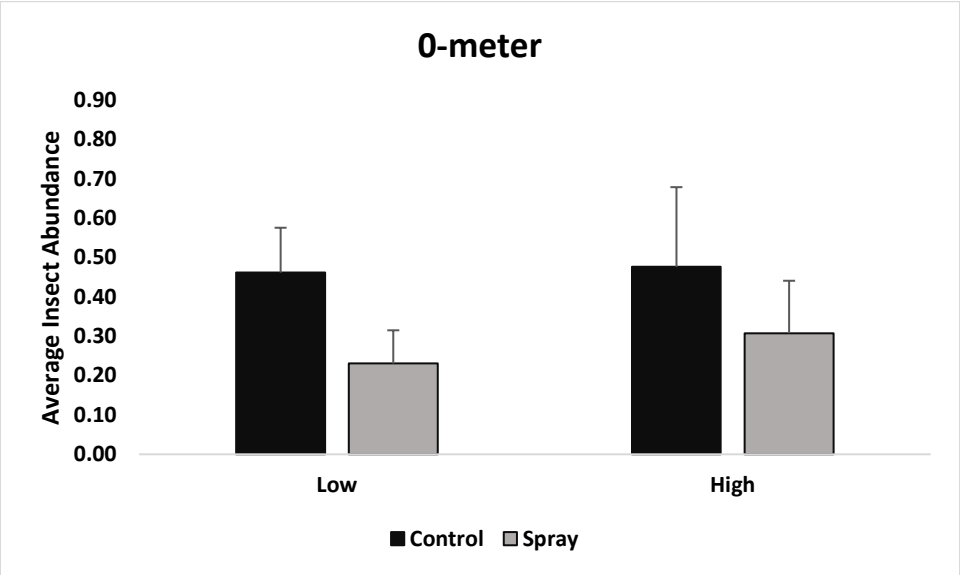
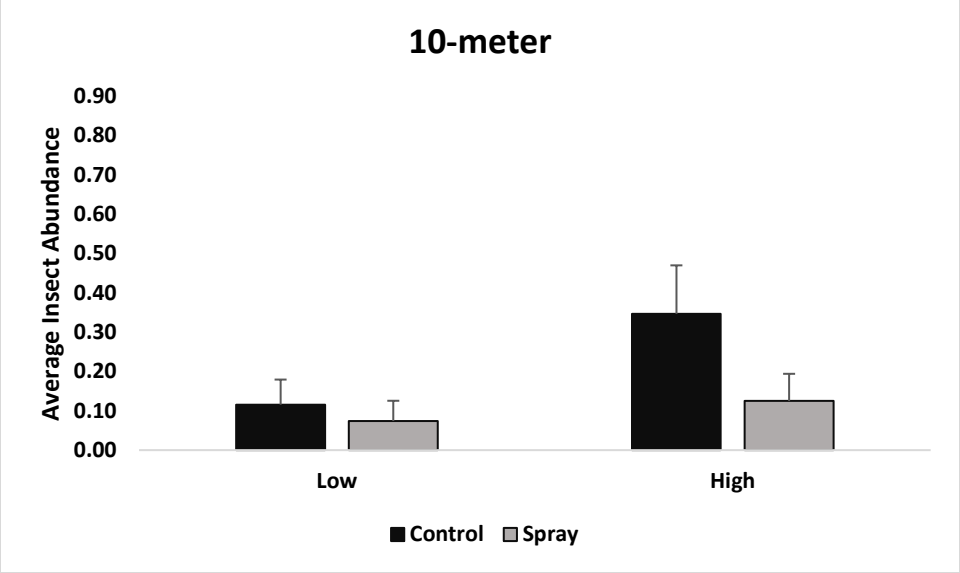
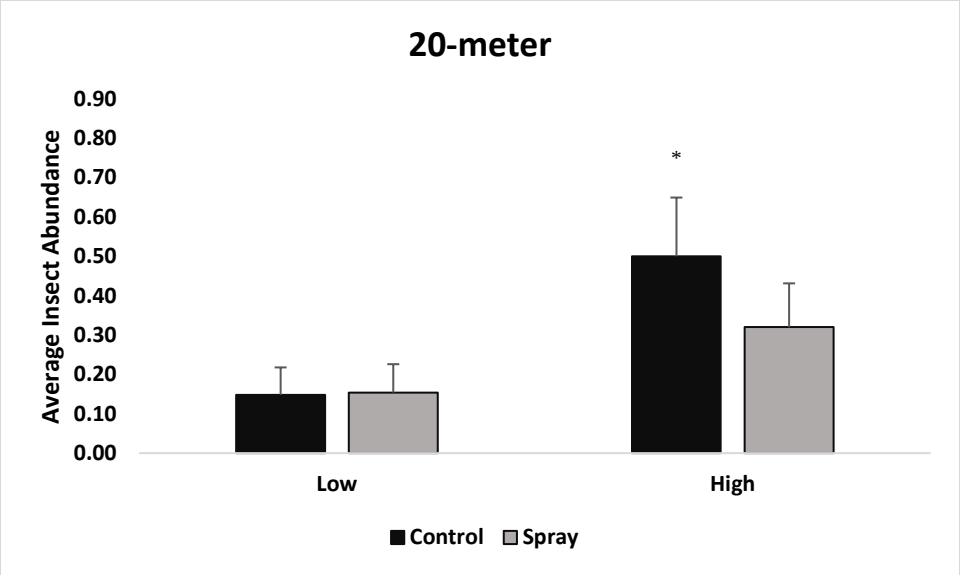

40-meter
Average Insect Abundance
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Low
High
Control
Spray

**Figure 39.** Average Phalacridae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
*
Low
High
Control
Spray

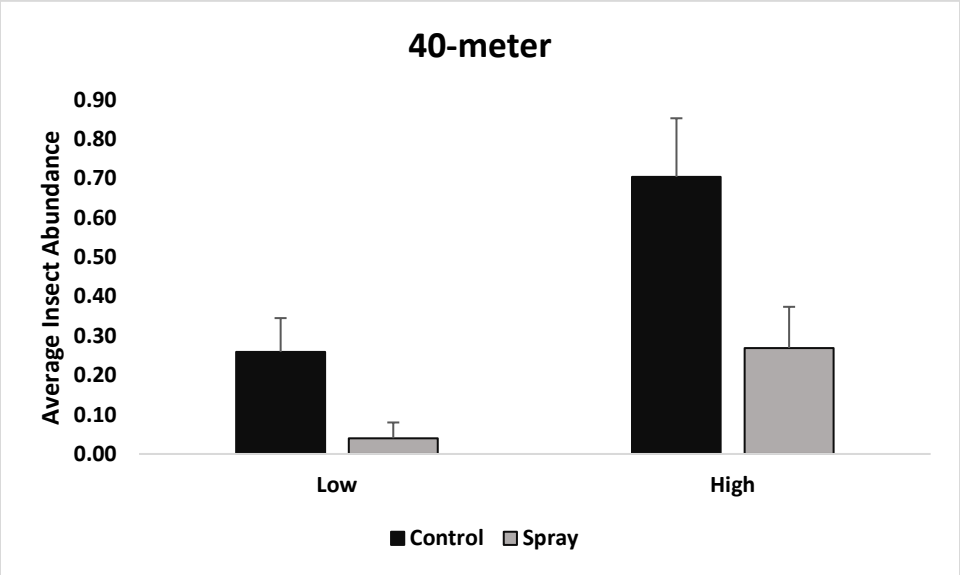
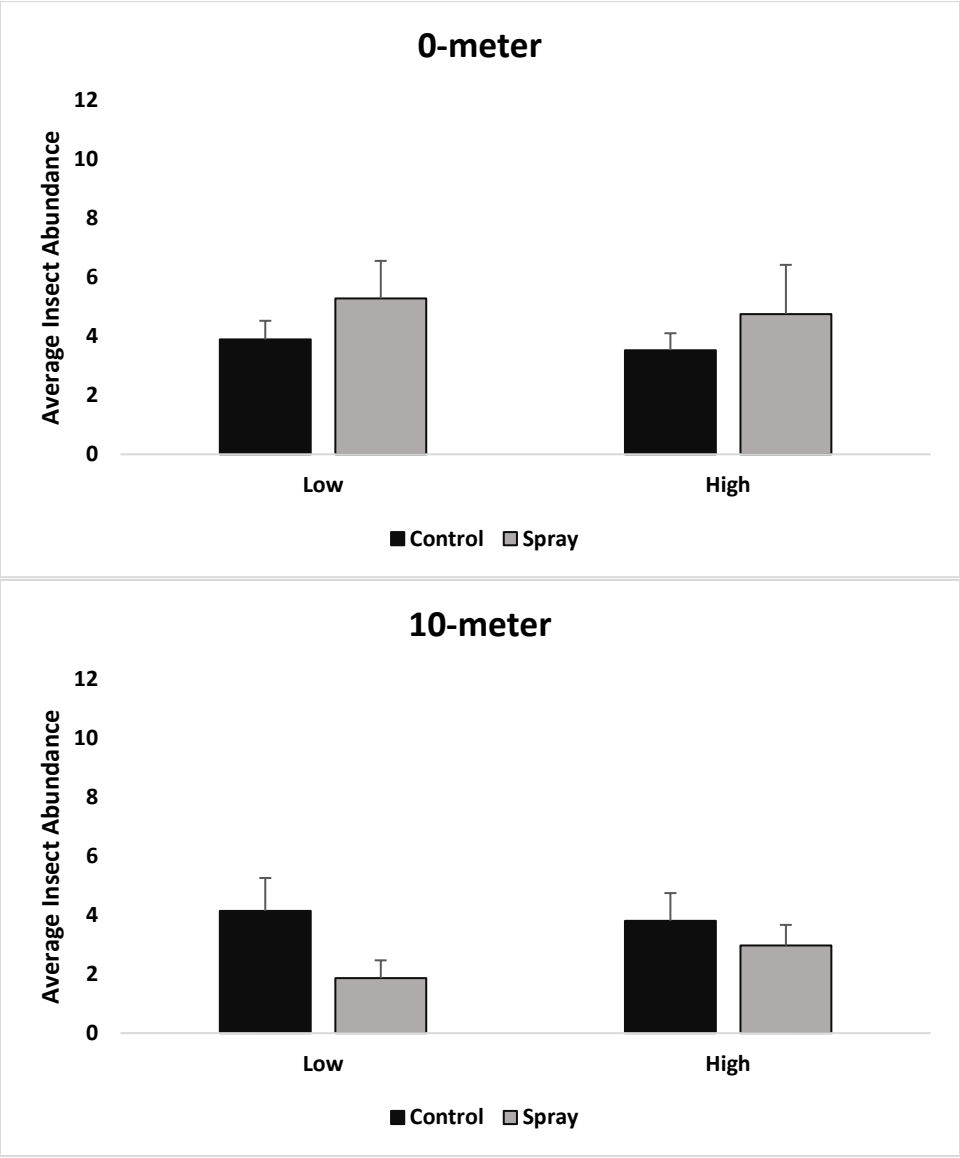
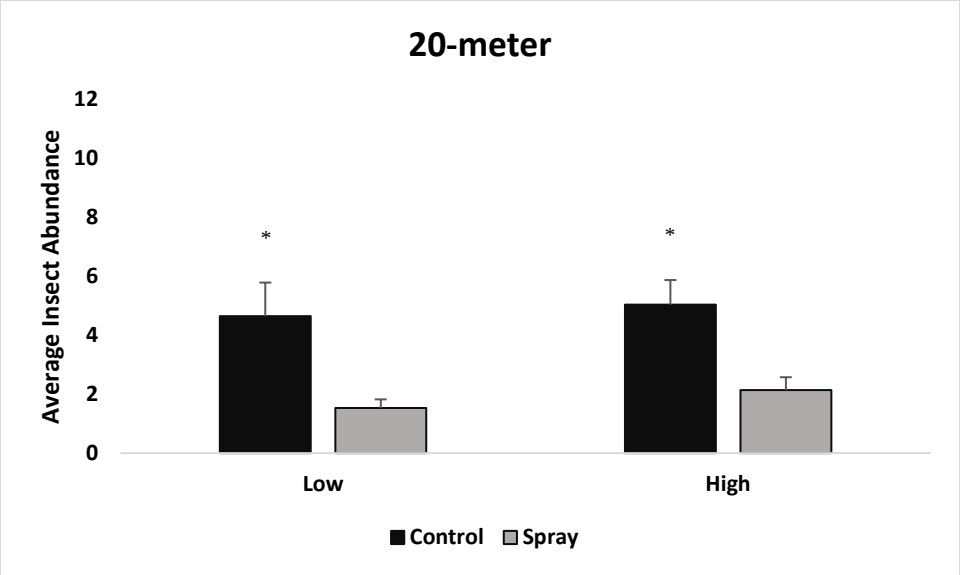

40-meter
Average Insect Abundance
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low
High
Control
Spray

**Figure 40.** Average Formicidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
12
10
8
6
4
2
0
*
*
Low
High
Control
Spray

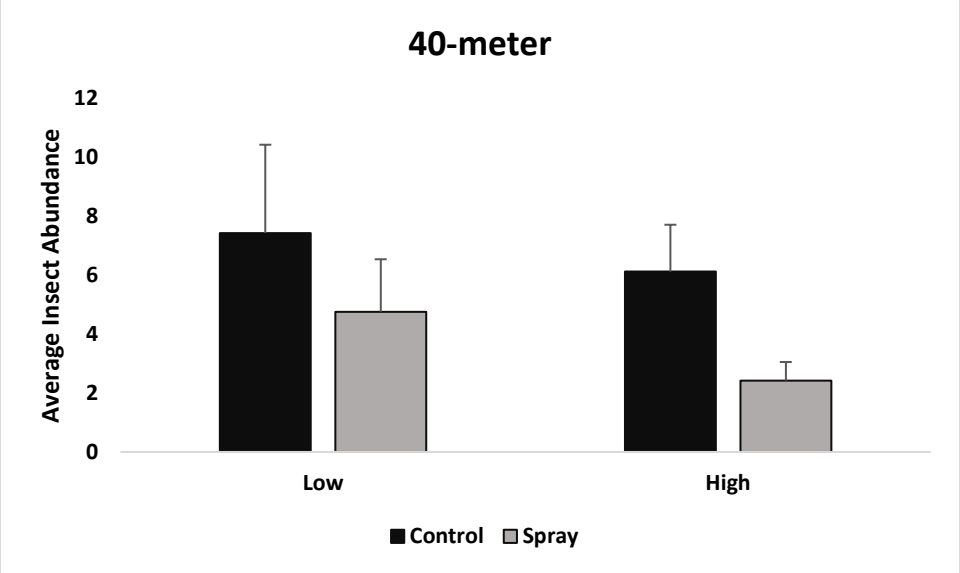
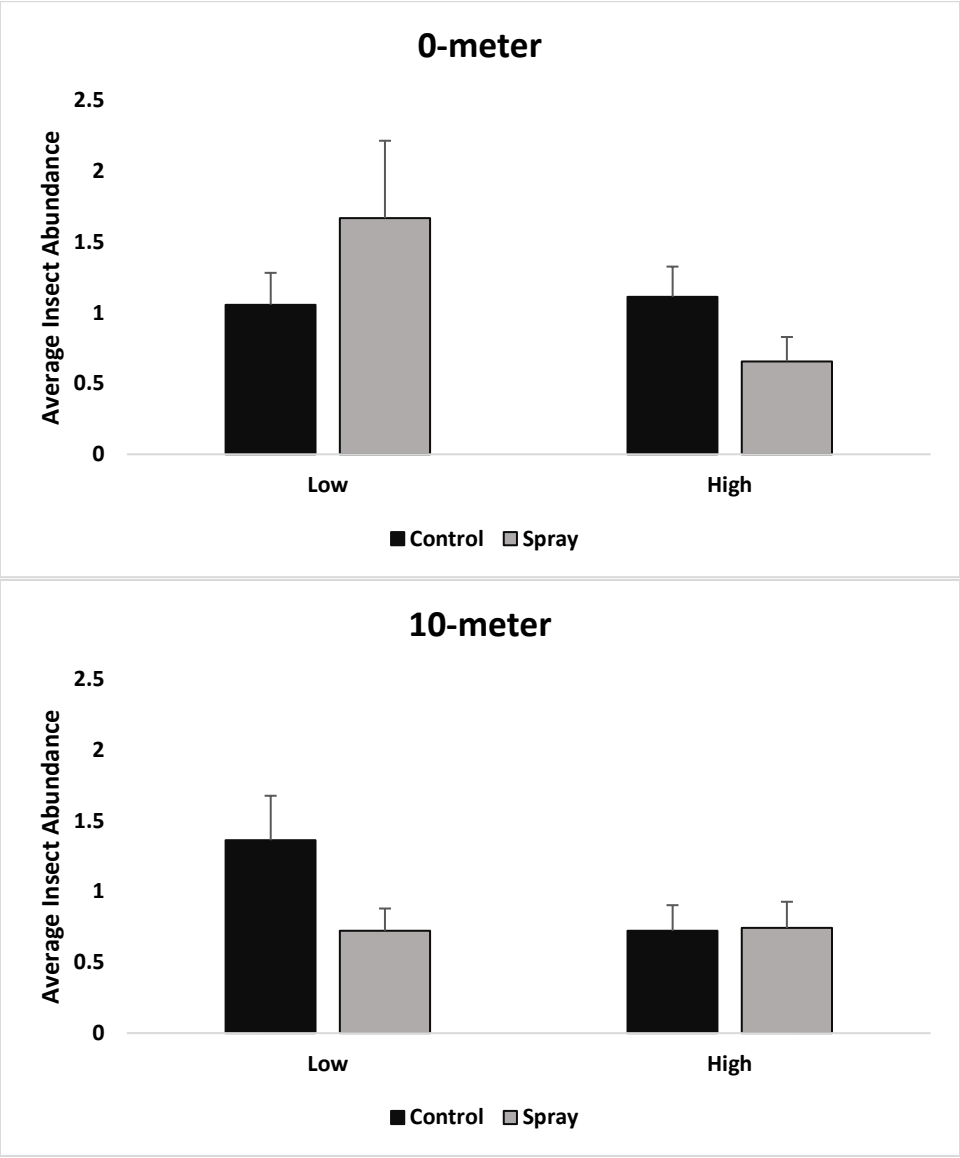
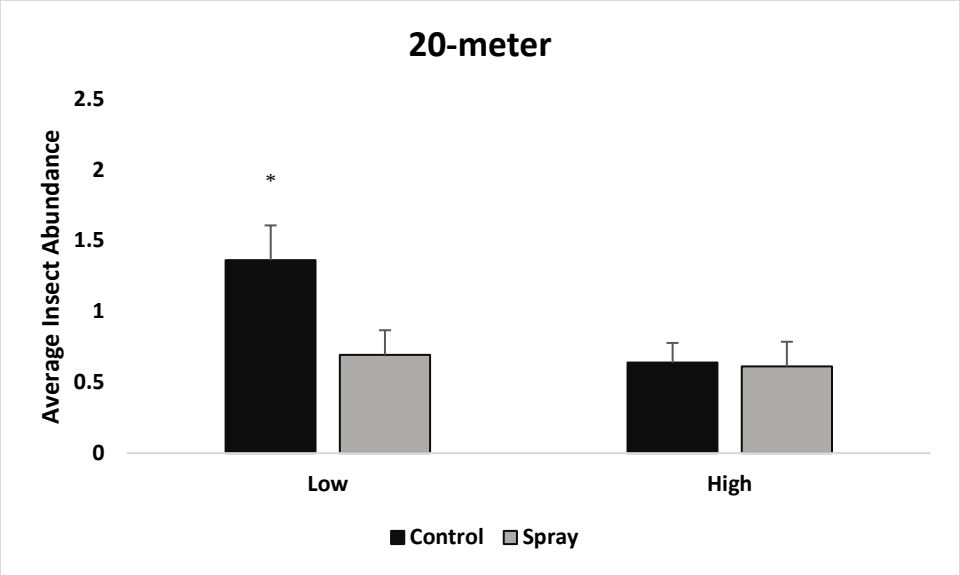

40-meter
Average Insect Abundance
12
10
8
6
4
2
0
Low
High
Control
Spray

**Figure 41.** Average Staphylinidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
2.5
2
1.5
1
0.5
0
*
Low
High
Control
Spray

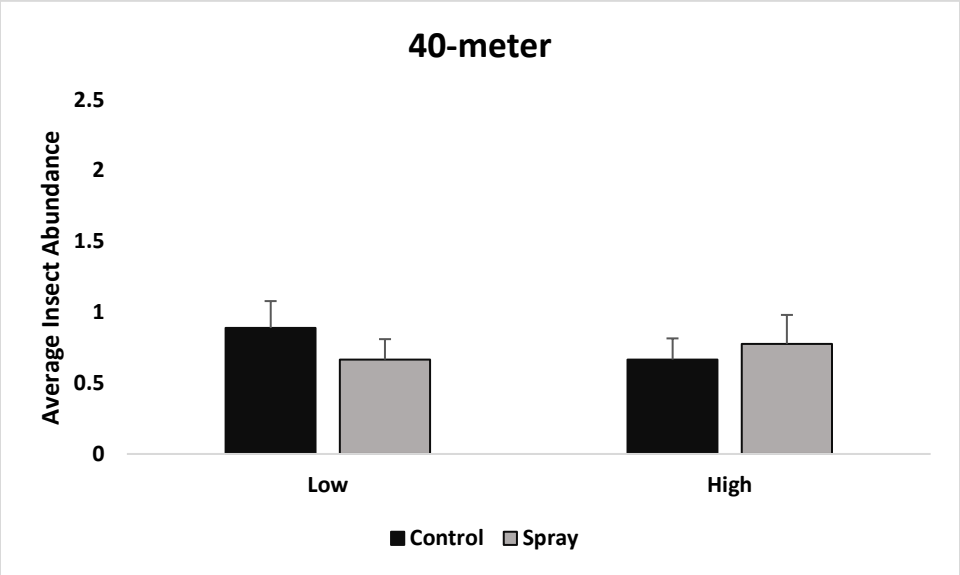

40-meter
Average Insect Abundance
2.5
2
1.5
1
0.5
0
Low
High
Control
Spray

**Figure 42.** Average Isopoda abundance captured in pitfall traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.

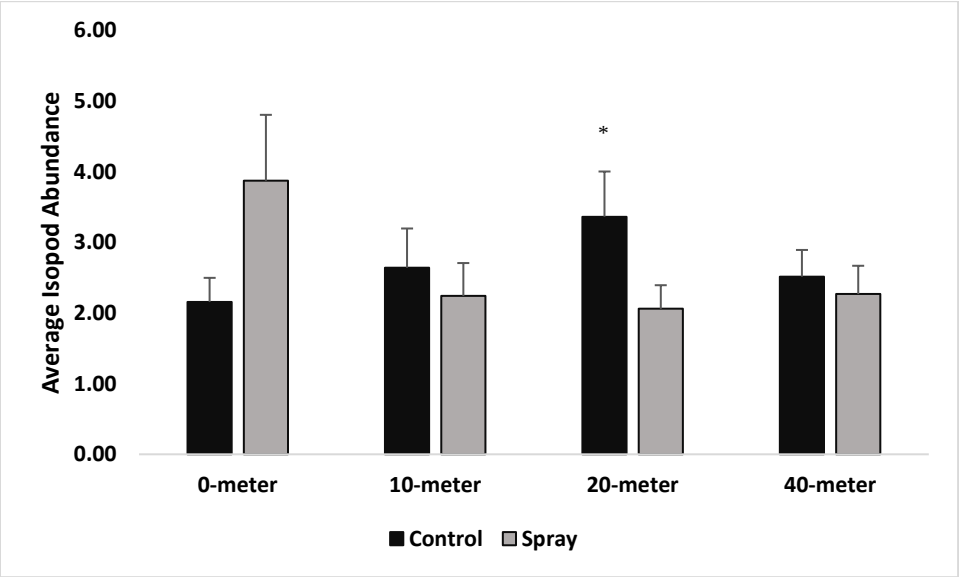
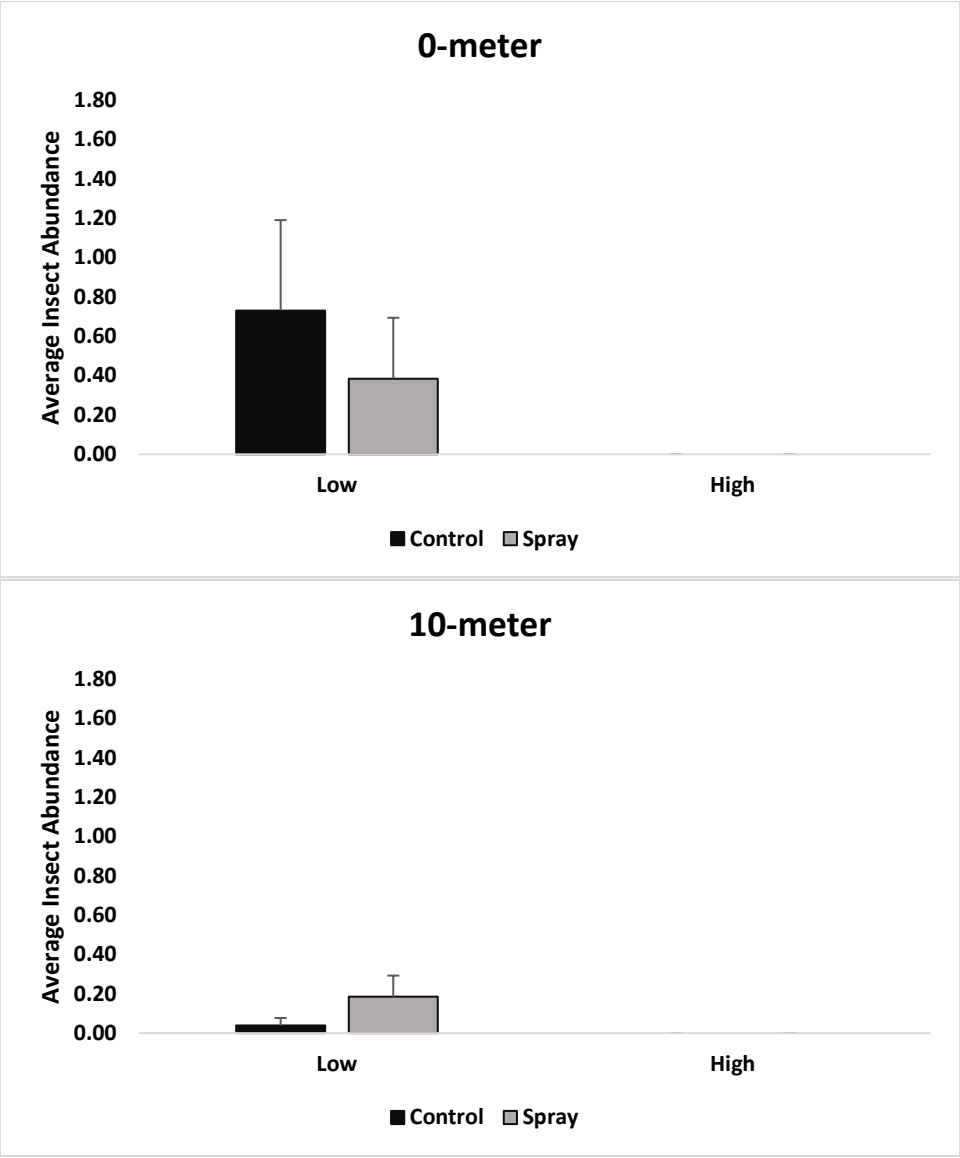
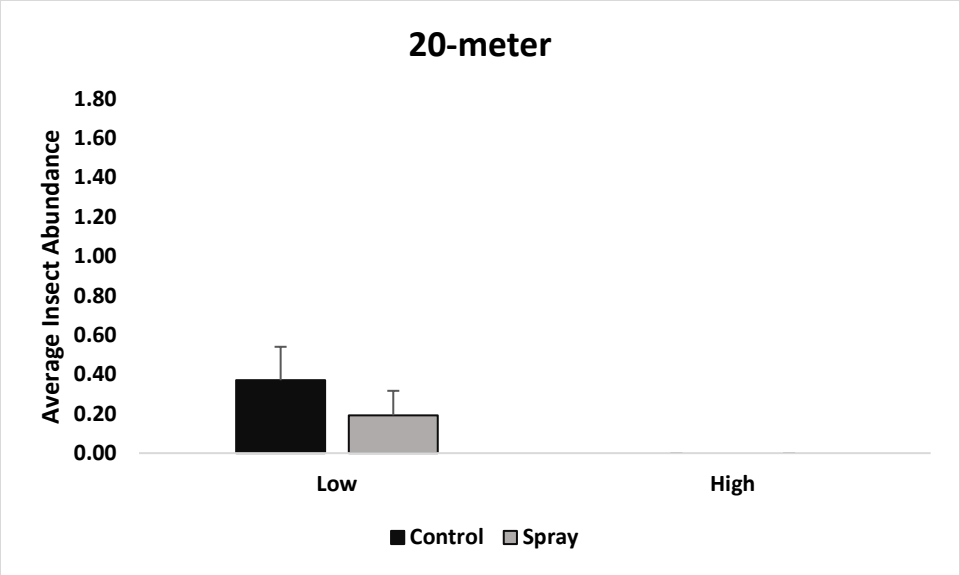


**Figure 43.** Average Panorpidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

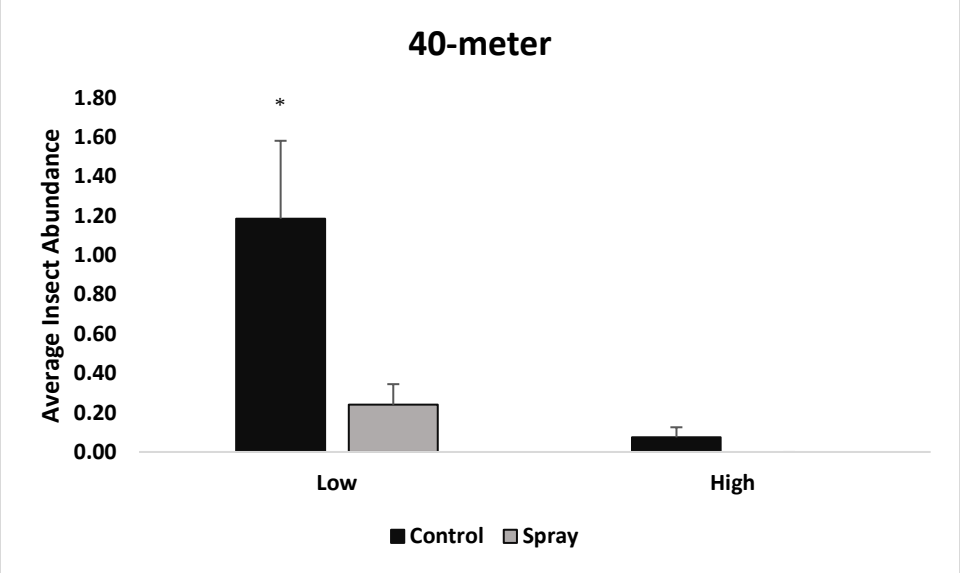
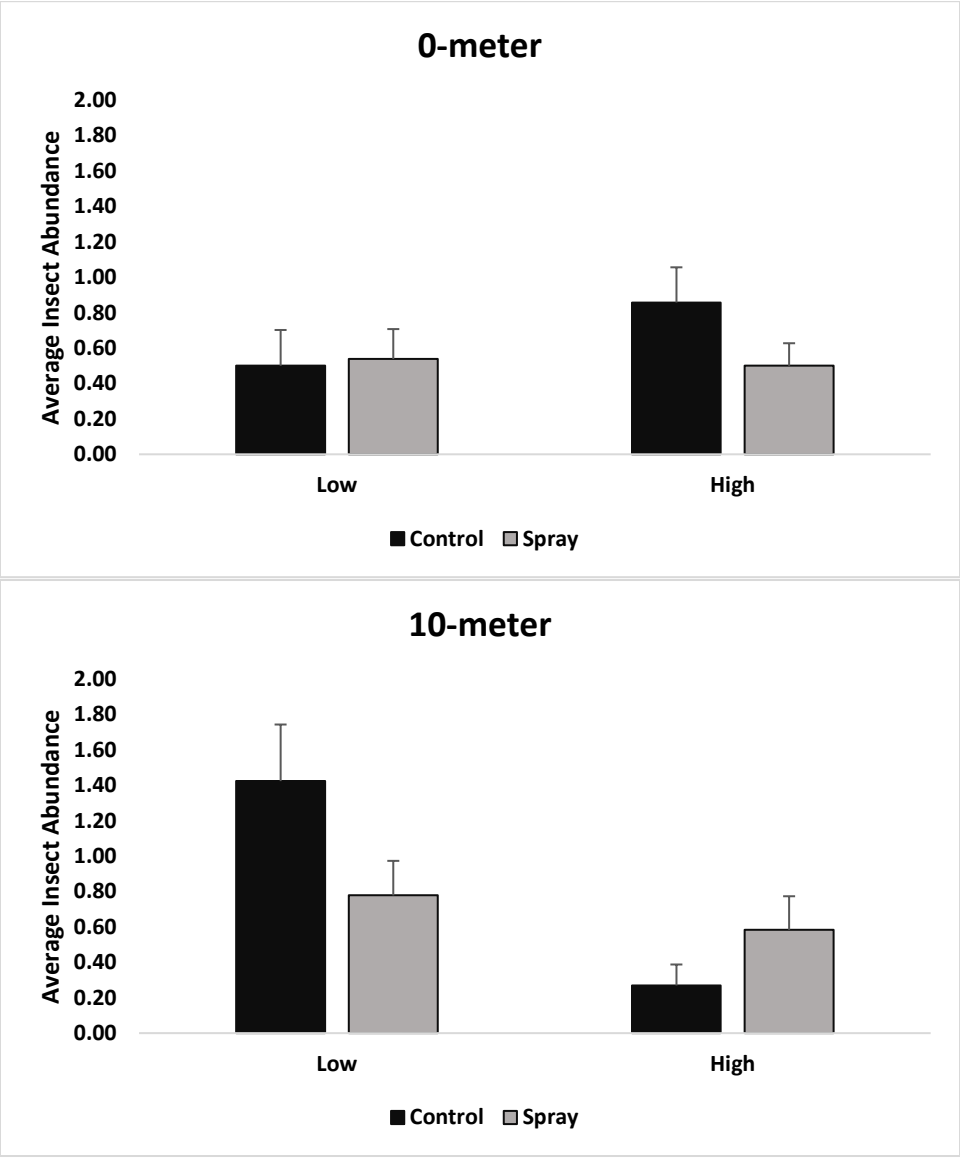
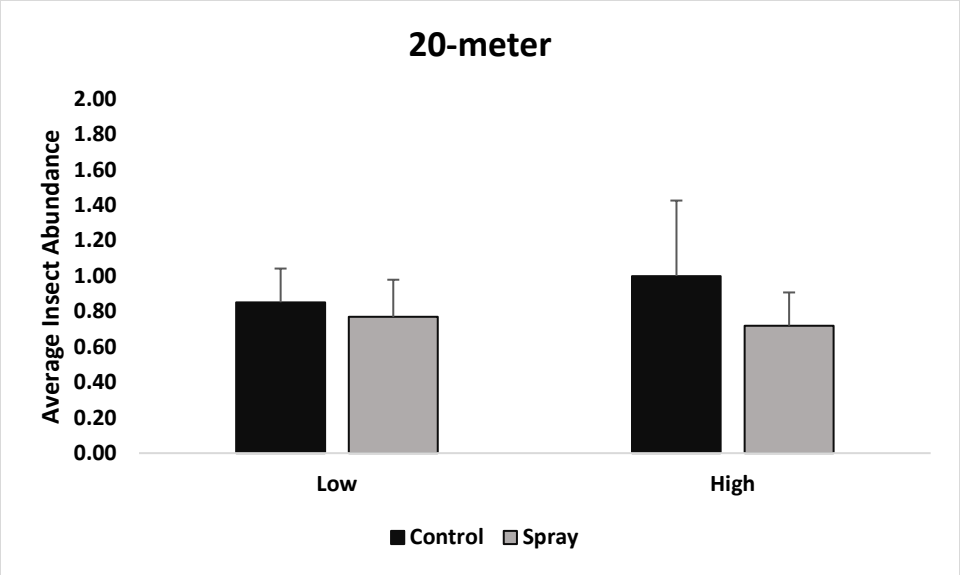

40-meter
Average Insect Abundance
*
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

**Figure 44.** Average Ichneumonidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2020. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Low
High
Control
Spray

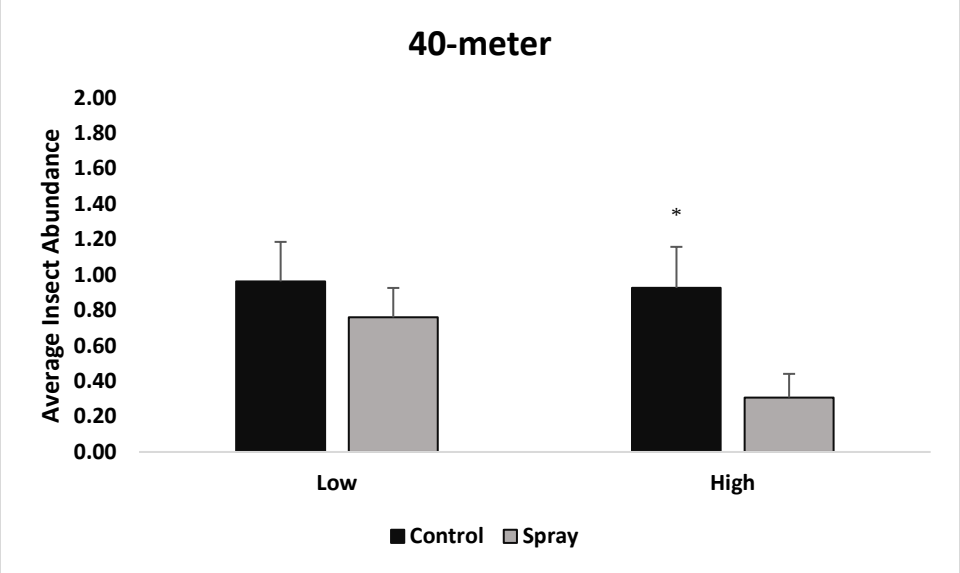
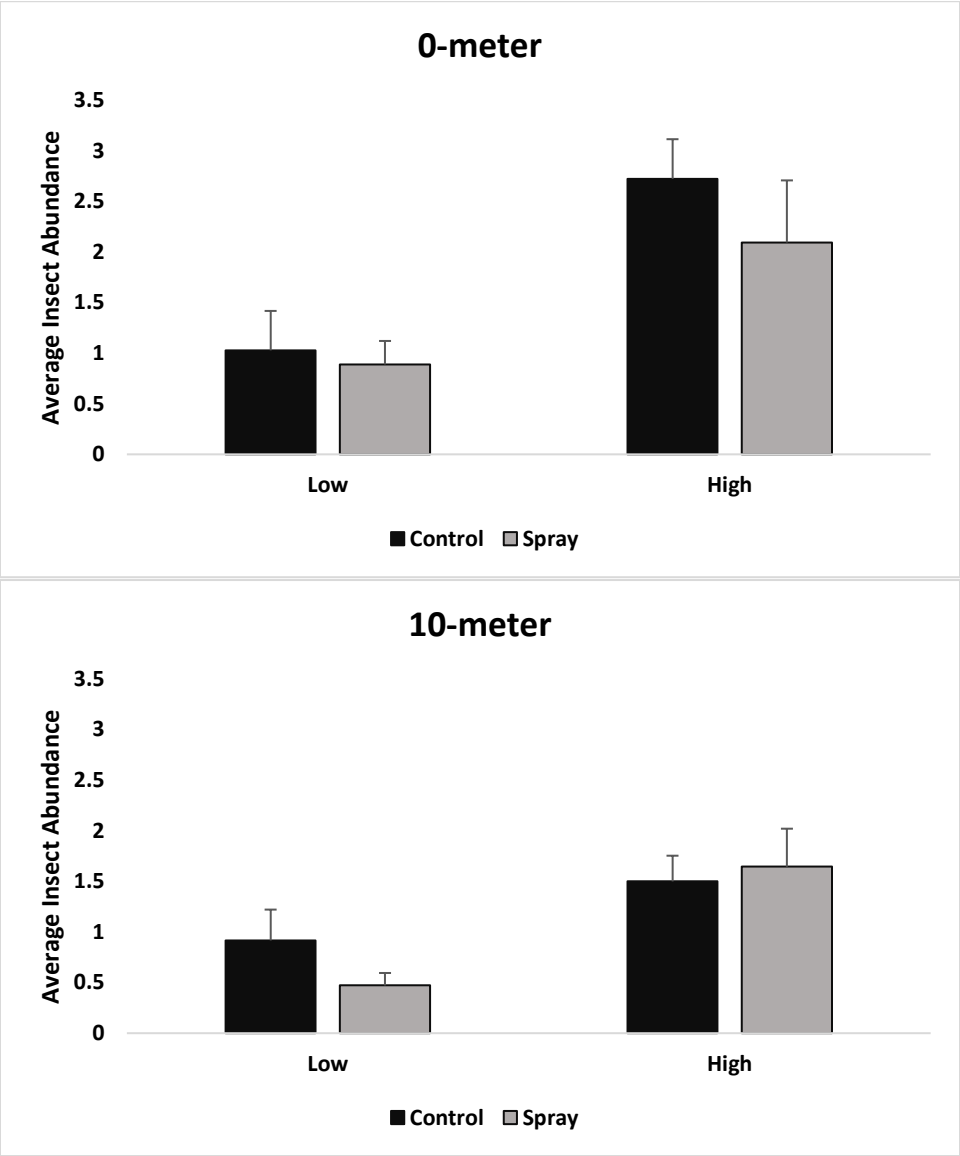
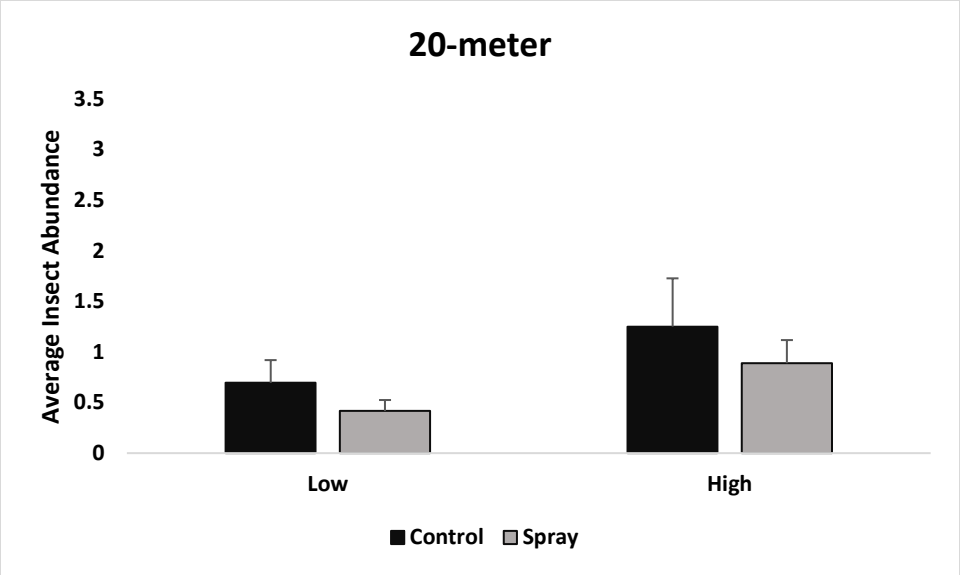
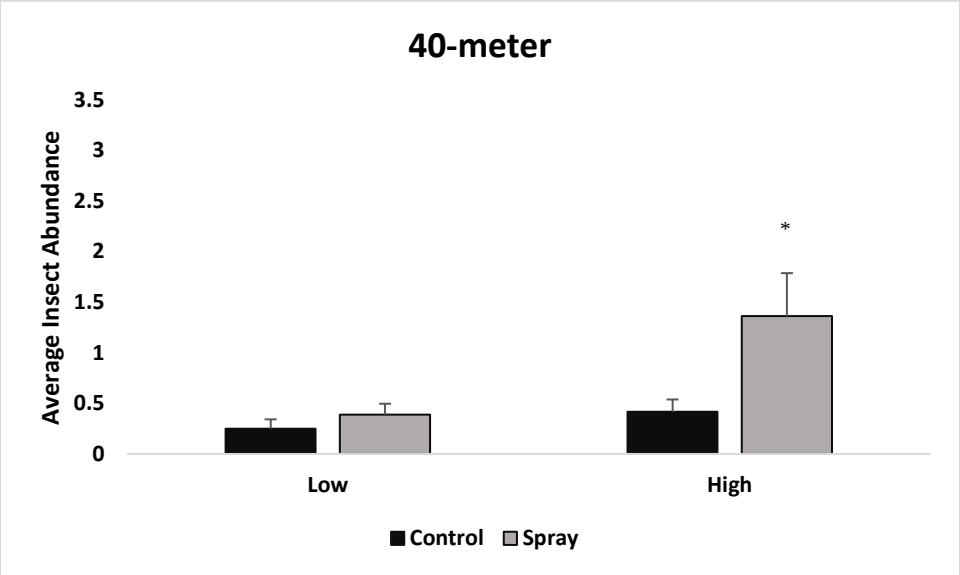

40-meter
Average Insect Abundance
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
*
Low
High
Control
Spray

**Figure 45.** Average Cynipidae abundance captured on yellow sticky traps in forests adjacent to either untreated (Control) soybean or soybean treated with three insecticide applications (Spray) in 2021. Asterisk above bars denotes statistical significance ($P \leq 0.05$). Error bars represent standard error.




20-meter
Average Insect Abundance
3.5
3
2.5
2
1.5
1
0.5
0
Low
High
Control
Spray


40-meter
Average Insect Abundance
3.5
3
2.5
2
1.5
1
0.5
0
*
Low
High
Control
Spray