The Effectiveness of Treating the Varroa Parasite Across Beekeeping Operations

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Varroa destructor parasite on the back of a honey bee (Laskie).

Contents

1. Introduction

The decline of honey bee populations in the United States is staggering. Indeed, the total number of *Apis mellifera*, the common European honey bee, colonies managed in the United States has decreased from "5.9 million... in 1947 to the low of 2.3 million reported in 2008" (vanEngelsdorp and Meixner 82). Honey bees are an important pollinator, and crops that depend on animal pollination "account for 35% of the global food production" (Genersch 87). So, the die-off of honey bees is extremely concerning. "The most devastating" cause of the die-off of honey bees is the *Varroa destructor* parasite, aptly named for its destructiveness and commonly known as the varroa mite (Underwood et al. 3). The varroa mite is responsible for the "death of millions of honey bee colonies" over the last 50 years (Martin et al. 1304).

Originally a problem in Asia, the varroa mite was introduced into the US "in the late 1980s" and "now infests virtually every colony nationwide" (Oldroyd 1196). Varroa feeds off of the "haemolymph" (essentially the blood of invertebrates) of honey bees and spreads viruses throughout the beehive (Donzé and Guerin 305). The varroa parasite primarily spreads through a rapid reproductive strategy in which the female varroa infests a brood cell (the stage where honey bees are still either eggs, larvae, or pupae) and produces "two to four" more adult female varroa mites before the honey bee becomes an adult (305). Since varroa spreads through the rest of the hive quickly, treating the mites efficiently is "considered one of the most important practices for successful beekeeping" (Underwood et al. 3). There are many ways that beekeepers treat this issue. Beekeepers employ organic practices by using oxalic acids or essential oils; they may use non-organic, synthetic pesticides; or they may use non-chemical practices, which can be used in conjunction with chemicals, such as "mite trapping" or "small cell combs" (3). However, none of these strategies are totally effective at safely removing the mites. Non-chemical treatments remove the least amount of mites, and chemical treatments, non-organic and organic, have their own negative effects; they may harm the honey bees if the beekeeper uses this strategy in excess, and the varroa mite often builds a resistance to the chemical treatments (Santiago et al. 469).

The Bee Informed Partnership's National Management Survey, where this project will retrieve its data from, compares the use of varroa treatment with beekeeping operation size. The survey splits operation size into three categories: commercial, sideline, and backyard (Lee et al. 293). The commercial beekeeping category encompasses the largest beekeeping operations. Commercial beekeepers often use their honey bees for pollination purposes or the mass production of honey, and they require "more intensive management practices," whereas backyard beekeepers operate on a much lower-scale with "fewer colonies" and "manage [their colonies] less rigorously" (293). Sideline beekeepers fall in between these two groups. However, beekeeping operations do not all fall nicely into these categories, and "most beekeepers do not necessarily fall into one discrete category," but these categories are helpful for analyzing general differences between groups (Underwood et al. 11).

This project aims to determine whether using any form of treatment on the varroa parasite affects the number of honey bee colonies lost and whether the size of a beekeeping operation affects honey bee colony loss. This project will also examine whether there is an interaction effect between operation size and treatment methods, since treatment methods often vary with operation size. My null hypotheses are that each of these does not have an effect, and there will be a separate, alternative hypothesis for each relationship that states that the null hypothesis is not true. It is likely that applying varroa treatment and operation size both have an effect on colony loss, since varroa treatment is intended to reduce colony loss and as operation size increases, so does the importance of decreasing colony loss. It is unlikely there will be an interaction between the two, since operation size should not change how effective a treatment is. This project will continue with a methods section, in which I explain my data collection and any alterations to the data I've made, an analysis section, in which I analyze any potential effects on colony loss and perform local inference, and a conclusion, in which I interpret my results and address my hypotheses.

2. Methods

This project uses data from the Bee Informed Partnership's National Management Survey, and this survey is extremely representative of beekeeping in the United States. The National Management survey is a survey that has received over 34,000 responses from beekeepers about the varroa parasite within the US since 2010 ("National Management Survey"). This survey was started as a response to the detrimental colonies of honey bees lost in 2008 by a group of "leading research labs, universities of agriculture, commercial beekeeping industries, commercial growers, beekeepers, naturalists and conservationists" and is funded by the United States Department of Agriculture and the National Institute of Food and Agriculture ("Honey Bee Enterprise"). The survey asked beekeepers about the number of colonies they lost each winter (as the winter is the season beekeepers primarily experience colony loss), their management techniques, and any potential causes for colony loss.

This project analyzes the percent of honey bee colonies lost over the winter, since the percent of colonies lost is representative of the severity of the decreasing honey bee populations. Although beekeepers are often able to recoup losses through "colony splitting" or through purchasing new queens, the percent lost tells us mostly how difficult it will be to replace these colonies and whether the beekeeper will have a net loss in colonies (Daberkow et al. 870).

I was, unfortunately, unable to block this data by year. Data from their survey is unavailable for some years for responses that fell under commercial operation size and did not use varroa treatment because the number of responses following these criteria for those years were less than five, and, thus, the National Management Survey did not report them. So, I combined all eleven years of data, and I used the mean proportion for each category so that it would be a balanced design. I sorted the percentage lost by whether varroa treatment was used and by which operation size the proportion fell under. Then I used the standardized arcsin square-root transformation to stabilize the variance, since the data was in proportions.

The transformed data can be seen in a table here:

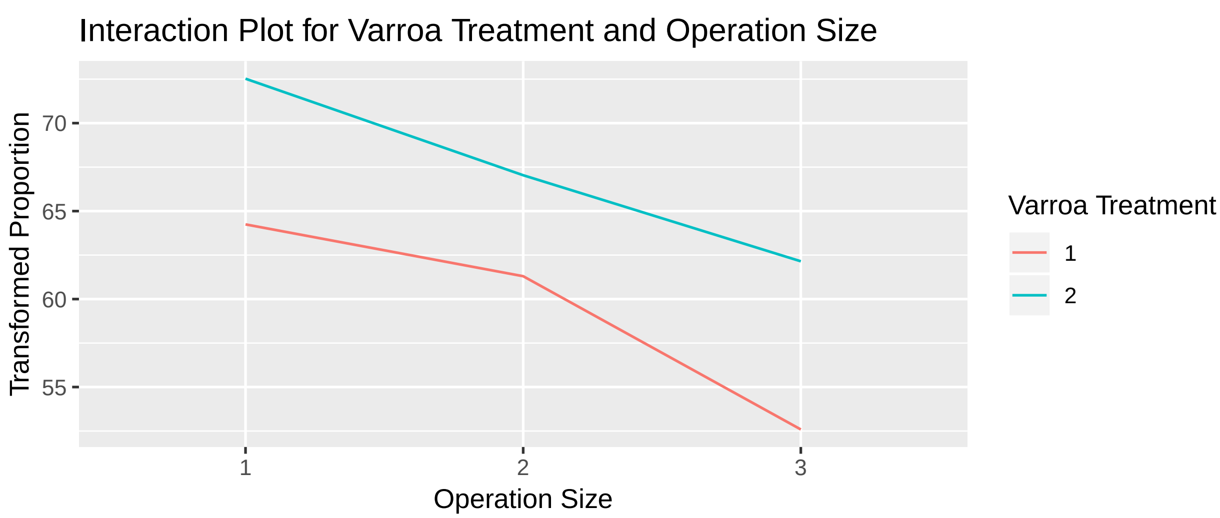
	1	2	3
1	64.2	61.3	52.6
2	72.5	67.0	62.1

Where 1, 2, and 3 in the top row represent backyard, sideline, and commercial operation size respectively. 1 and 2 in the left column represent using the treatment and not using the treatment respectively. The other values in the table are the transformed proportions of colony loss that fall under their respective treatment and operation size. Although there is just one observation per cell, these are average proportions for each category determined from the thousands of responses from the survey. This project will conduct a two-way ANOVA test to determine if there is a main effect for operation size and varroa treatment, and will be followed by local inference.

3. Data Analysis

I will first analyze whether there appears to be an interaction between the operation size and varroa treatment.

Let's look at an interaction plot:



Where, once again, "1" and "2" in the Varroa Treatment legend represent using any form of treating varroa and not using any form of treatment, respectively. "1," "2," and "3" on our x-axis represents backyard, sideline, and commercial operation sizes respectively. Our interaction plot appears to have relatively parallel lines. Therefore, it is unlikely there is an interaction between operation size and treatment. Since it is unlikely there is an interaction between these two factors, it is appropriate to fit an additive model:

$$Y_{ijk} = \mu_{\cdot\cdot} + \alpha_i + \beta_j + \varepsilon_{ijk}$$

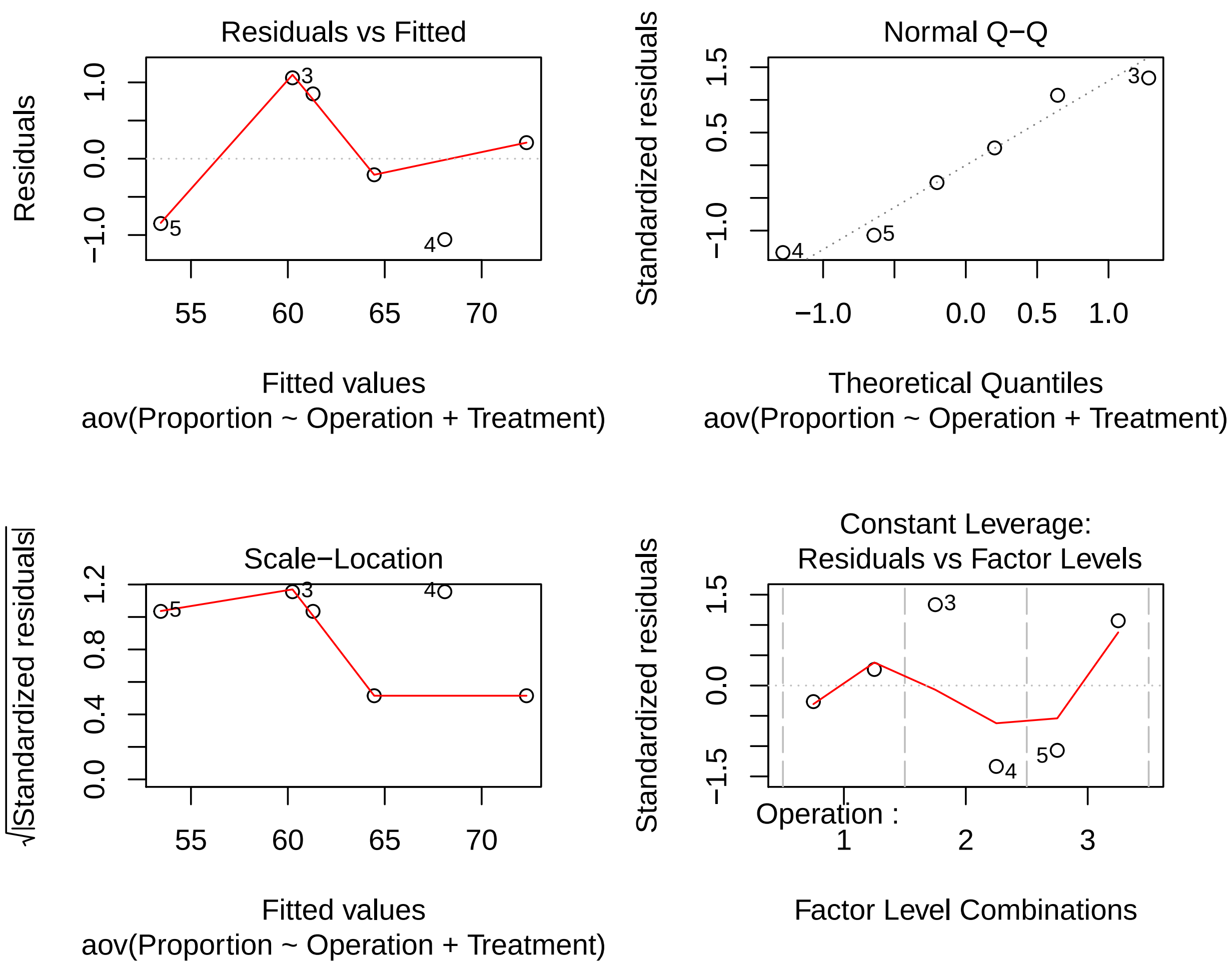
Where α_i represents the effect of the operation size and β_j represents the effect of using varroa treatment. As we have fitted an additive model, it is necessary to see whether the effects of operation size and using varroa treatment are significant. So, with our ANOVA table:

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Operation    2 123.59   61.79   32.70 0.0297 *
## Treatment    1  92.63   92.63   49.03 0.0198 *
```

```
## Residuals    2   3.78    1.89
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We are able to see that both our P-Values (.03 and .02) for our main effects are less than our α-level of .05. Thus, the main effect of operation size on the proportion of bee colonies lost over the winter was significant such that as operation size increases, the proportion decreases, and the main effect of using varroa treatment on the proportion of bee colonies lost over the winter was significant such that operations that use any form of varroa treatment have a lower proportion than operations that do not use any form of treatment.

To conclude that this model is totally appropriate, we will check the assumptions of constant variance, interaction, and normality through our residual plots:



The errors appear to be relatively normally distributed, since our normal probability plot is relatively linear. There is no clear trend in the plots, so this also implies our earlier hypothesis that there is no interaction between the factors. Lastly, it does not exactly appear that we have constant variance, as the residuals for the backyard operation size are much smaller than the others, but we will proceed anyway.

Since we have only one observation per cell, it is impossible to run an ANOVA F-test for an interaction because we do not have enough degrees of freedom. So, we will run a Tukey test for additivity, in which we test for if the interaction is multiplicative by adding an extra term to our model so that we get:

$$Y_{ijk} = \mu_{..} + \alpha_i + \beta_j + D\alpha_i\beta_j + \varepsilon_{ijk}$$

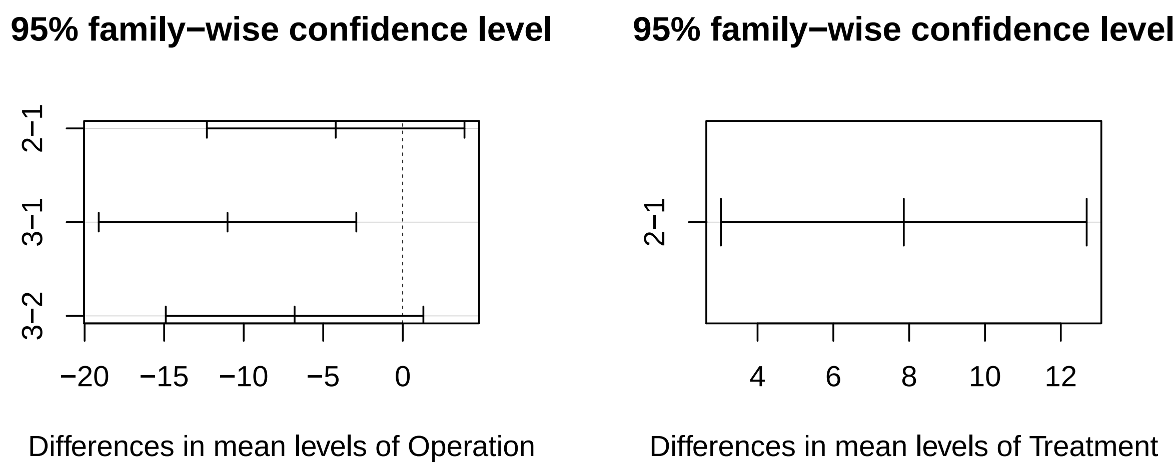
With an $H_o : D = 0$ and an $H_a : D \neq 0$

Our printout returns:

```
##
## Tukey's one df test for additivity
## F = 0.2574034   Denom df = 1    p-value = 0.7011007
```

So, we fail to reject our null hypothesis, since our P-Value $(.7) > \alpha(.05)$. Thus, there is not significant evidence that there is a multiplicative interaction. This reaffirms our belief that there is no interaction between the two factors.

So, now that we can focus on the main effects, we will run a Tukey HSD test to determine any significant differences between the factor levels.



There is a significant difference between the proportions of bee colonies lost over the winter for commercial operation size versus backyard operation size. However, there is not a significant difference between the proportions of sideline operation size vs backyard operation size, and there is not a significant difference between the proportions of commercial operation size vs sideline operation size, since their confidence intervals include zero.

There is a signicant difference in proportions of not using varroa treatment versus using varroa treatment.

4. Conclusion

In the context of a beekeeper's end goal to ultimately reduce the proportion of bee colonies lost over the winter, our Tukey intervals seem to suggest that a beekeeper should increase their operation size to commercial if they run a backyard operation size; any changes from backyard to sideline or sideline to commercial do not result in a significant difference and are not necessary. However, this is obviously not feasible for most backyard beekeepers. They most likely do not have the time, funding, or desire to convert their operation to a large-scale, commercial business. Yet it is most likely not actually having a large operation that causes this reduced colony-loss, but rather how the operation is run. As a large business dependent on honey bees, commercial operations have much more of a stake in their operation because they have the potential to lose their investments if there is a large proportion of colonies lost. So, perhaps it is not a matter of backyard beekeepers increasing their operation size. Instead, they should maintain a similar mindset to commercial operations about limiting the proportion of colonies lost.

Our Tukey intervals and our F-test also demonstrated that there is a large effect of using a form of varroa treatment to reduce the proportion of colonies lost. The significant difference between the proportions demonstrates just how widespread and damaging the varroa parasite is, since beekeepers across the country who used treatment consistently lowered their proportions of colonies lost.

Both factors rejected the null hypothesis that they would not have a main effect, whereas we were unable to demonstrate that there is an interaction between these two factors, as was projected in the introduction. The lack of an interaction truly demonstrates that using a treatment for varroa has the same effect across all operation sizes, and likewise the same for not using a treatment. This suggests that there is still obscurity in recent years about how to efficiently remove varroa mites; neither backyard, sideline, or commercial operations have discovered a better way to remove them. However, these different operation sizes play an important role in treating the varroa parasite because they each have unique characteristics that may make them helpful in solving this issue.

Research going forward should be conducted to reveal the most effective ways to remove the parasite from the hive. If possible, blocking by year could be helpful to identify any other trends in the percent of colonies lost. Evidently, the varroa parasite is still a giant problem, and researchers should continue to analyze how to remove it.