ATTTA
Atlantic Tech Transfer Team
for Apiculture

EXAMINING THE EFFECT OF HONEY BEE COLONY STOCKING DENSITY IN WILD BLUEBERRIES

ATLANTIC TECH TRANSFER TEAM FOR APICULTURE

PROJECT OVERVIEW

This document summarizes research conducted by the Atlantic Tech Transfer Team for Apiculture (ATTTA) examining the effect of honey bee colony stocking density in wild blueberries in New Brunswick and Nova Scotia, 2017-2019.

PROJECT OBJECTIVES

The objectives of this research project were to:

a. Determine the effect of stocking density on colony growth during pollination

b. Determine the effect of stocking density on pollination success

c. Determine the effect of stocking density on berry mass at harvest

d. Determine the effect of stocking density on yield

e. Determine the effect of stocking density on bee abundance and diversity

MATERIALS AND METHODS

The study was carried out in Gloucester, Northumberland, Kent, and Westmorland counties in New Brunswick, and in Colchester County, Nova Scotia, over three years (2017-2019). A completely randomized design was used with one factor (honey bee hive stocking density) at three levels: 2, 3, and 4 hives per acre. All colonies were housed similarly, with at least two to three boxes (e.g. two brood chambers and a honey super, or one brood chamber and one-two honey supers). In 2019, we began the trial with 11 fields (3 at 2 hives per acre, 4 at 3 hives per acre, and 4 at 4 hives per acre). Due to grower decisions (described further in discussion), our field sites in 2019 changed to 0 fields at 2 hives per acre, 3 fields at 3 hives per acre, and 6 fields at 4 hives per acre. In 2018, we began the trial with 11 fields, but due to the severe frost in June 2018, we were left with four fields to measure bee growth (2 fields at 2 hives per acre, one field at 3 hives per acre, and 1 field at 4 hives per acre). This is because in fields severely impacted by frost, beekeepers moved hives out of blueberry fields. Hives remained in fields that were less severely impacted by frost. We also had 9 fields to measure all other endpoints (2 fields at 2 hives per acre, 5 fields at 3 hives per acre, and 2 hives at 4 hives per acre). Where appropriate, statistics from our 2017 field season are included in this report.

Growers were selected based on their isolation (isolated from other study sites by at least 3 km, and only in fields

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Subventions et Contributions

Bleuets NB Blueberries
New Brunswick Beekeepers Association Inc.
Nova Scotia Beekeepers' Association
Wild Blueberry Producers' Association of Nova Scotia
Prince Edward Island Wild Blueberry Growers Association
PEI Beekeepers' Association
Jasper Wyman and Son

with nearby fields stocked at the same honey bee stocking densities being studied). Permission was granted from individual beekeepers to assess colony strength. Colony strength was quantified at the beginning and end of blueberry bloom by recording the number of seams of bees (Nasr et al. 1990). The first sampling period occurred within three days of the hives being placed in blueberry fields, and the second sampling occurred within three days of the colonies being removed from blueberry fields. The hives studied were in their first blueberry pollination to reduce variability. Thirty stems within each study field were randomly selected before flowering (early May) by walking slowly through the fields in a zig-zag pattern (Chiasson and Argall 1996; Drummond 2002). Each stem was 1m apart and tagged with flagging tape with a corresponding sample number in order to track number of flowers (May), fruit set (July), and harvest (August). In 2017, 50 stems per field were tagged and in 2018 and 2019, 30 stems per field were tagged.

In 2019, we introduced transects to conduct bee surveys. These transects were constructed approximately 20 m from honey bee hive locations and were 2 m wide by 30 m long. The transects ran in an East-West orientation. Thirty-minute bee walks were conducted during pollination in each study field, and observations were recorded for all honey bees (*Apis*) and native bees (non-*Apis*). Transect walks were done as inconspicuously as possible to avoid startling pollinators.

STATISTICS

Analysis of variance (ANOVA) using a general linear model was used to detect any differences among the following measured endpoints: 1) colony growth during blueberry pollination (final seam count – initial seam count), 2) pollination success at different stocking densities, 3) mean berry mass at different stocking densities, 4) yield at different stocking densities, and 5) effect of stocking density on honey bee and native bee abundance and diversity. The model assumptions of normal distribution of error terms and constant variance of the residuals were met for all analyses except bee abundance and diversity, which underwent a square root transformation. Letter groupings were produced to show significant differences among means using $\alpha = 0.05$ and generated using Fishers LSD. All statistical analyses were carried out using Minitab (Minitab 2018).

Data from 2018 and 2019 were included to analyze the effect of stocking density on colony growth. The average hive growth per field was used as a replicate and the individual hives were used as a pseudo-replicate. Since different number of hives were used among fields and among years, and there were different numbers of stems between 2017, and 2018-2019, we used the average growth of hives per field, or average number of berries per stem per field, as a metric for more accurate comparison. Data were collected in 2017 on colony growth, but due to variability in colony size and management, were excluded for analysis (more information provided in discussion).

To analyze the effect of stocking density on pollination success, the average success rate per field (number of flowers divided by the number of berries in August divided by the number of flowers in May, multiplied by 100%) was used as a replicate, and individual stems were used as a pseudo-replicate. Data from 2017 and 2019 were included, while data from 2018 was excluded due to the severe frost experienced in June 2018.

To evaluate the effect of stocking density on berry mass at harvest, the average berry mass per field was used as a replicate, while individual berries were used as a pseudo-replicate. Tagged stems were picked individually and berries were harvested. The total weight of all the berries per stem was calculated, and then divided by the total number of berries per stem to get an average weight per berry per stem. Data were included from 2017, 2018, and 2019.

To evaluate the effect of stocking density on total yield at harvest, we used blueberry hand rakes (34 cm wide by 23 cm long) to collect yield data from 1m^2 plots. We harvested 5 replicates of blueberry transects per field (in random locations throughout study fields) and then took the blueberry yield from each quadrat and multiplied the weight per quadrat (kg/m^2) harvested by 8921.79 to convert units to lbs per acre. Data for this analysis were only collected in 2019.

In 2019 we added an experiment to evaluate the effect of honey bee stocking density on honey bee and native bee abundance. We also examined the impact of honey bee stocking density on honey bee (*Apis*) and native bee (non-*Apis*) abundance.

RESULTS

Effect of Stocking Density on Colony Growth

The effect of honey bee stocking density (hives per acre) on colony growth (seams of bees) was tested in New Brunswick and Nova Scotia wild blueberry fields across two years (2018 and 2019). Three different stocking densities were compared: 2 hives per acre (n= 2 fields), 3 hives per acre (n= 2 fields), and 4 hives per acre (n= 7 fields). There was no significant effect of honey bee stocking density on colony growth during pollination ($F_{2,8} = 0.48$; $P = 0.634$) **(Figure 1)**.

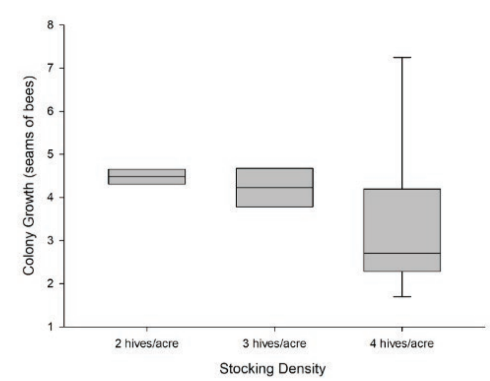

Figure 1. Boxplot demonstrating the effect of honey bee hive stocking density (hives per acre) on colony growth in New Brunswick and Nova Scotia study fields, 2018-2019.

Colonies stocked at 2 hives per acre grew an average of 4.5 (SE ± 0.18) seams of bees, while colonies stocked at 3 hives per acre grew an average of 4.2 (SE ±0.45) seams of bees. Colonies stocked at 4 hives per acre grew an average of 3.4 (SE ± 0.71) seams of bees.

EFFECT OF STOCKING DENSITY ON POLLINATION SUCCESS

The effect of honey bee stocking density (hives per acre) on pollination success (number of berries at harvest time divided by the number of flowers during pollination) was tested in New Brunswick and Nova Scotia wild blueberry fields across three years (2017-2019). Due to the severe frost and its impact on pollination success in 2018, only data from 2017 and 2019 are presented. Three different stocking densities were compared: 2 hives per acre (n= 2 fields), 3 hives per acre (n= 5 fields), and 4 hives per acre (n= 6 fields). There was no significant effect of honey bee stocking density on pollination success ($F_{2,11}$ = 2.29; P = 0.147) **(Figure 2)**.

Fields stocked at 2 hives per acre resulted in a pollination success rate of 50.5% (SE ± 15.2) on average, while colonies stocked at 3 hives per acre had an average pollination success rate of 66.4% (SE ± 5.0). Colonies stocked at 4 hives per acre had an average pollination success rate of 72.5% (SE ± 4.2).

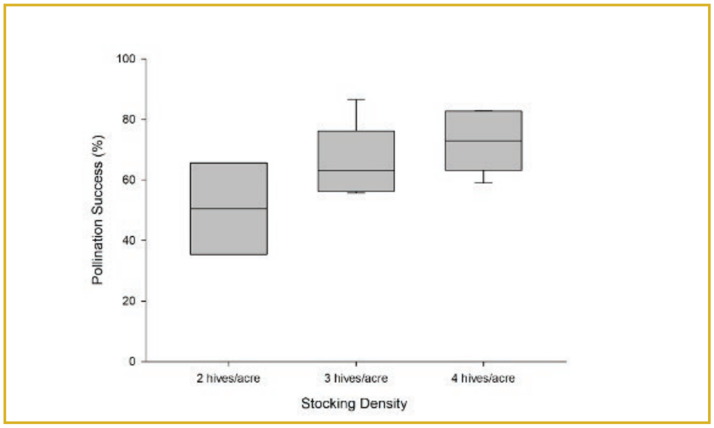

Figure 2. **The effect of honey bee hive stocking density (hives per acre) on pollination success (%) in New Brunswick and Nova Scotia study fields, 2017 and 2019.**

EFFECT OF STOCKING DENSITY ON BERRY MASS AT HARVEST

The average berry mass at harvest was compared among three different stocking densities: 2 hives per acre (n = 4), 3 hives per acre (n= 11) and 4 hives per acre (n= 7) and across three years: 2017-2019. There was no significant effect of honey bee stocking density on average berry mass at harvest ($F_{2,20}$ = 0.39; P = 0.684) **(Figure 3)**.

Fields stocked at 2 hives per acre produced berries weighing on average 0.30 g (SE ± 0.03) while fields stocked at 3 hives per acre produced berries weighing on average 0.39 g (SE ± 0.04). Fields stocked at 4 hives per acre produced berries weighing on average 0.39 g (SE ± 0.07).

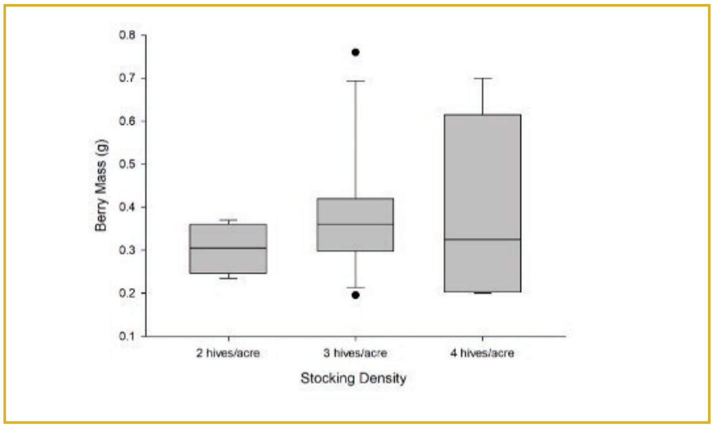

Figure 3. **Boxplot demonstrating the effect of honey bee hive stocking density (hives per acre) on average wild blueberry mass (g) in New Brunswick study fields in 2018 and 2019.**

EFFECT OF STOCKING DENSITY ON BERRY YIELD

Wild blueberry yield at harvest (lbs per acre) was compared among two different stocking densities (3 hives per acre (n = 3) and 4 hives per acre (n= 6)) in New Brunswick in 2019. There was no significant effect of honey bee stocking density on yield at harvest ($F_{1,7}$ = 0.24; P = 0.639) **(Figure 4)**.

Fields stocked at 3 hives per acre produced on average 6,654 lbs (SE ± 878lbs) per acre, while fields stocked at 4 hives per acre produced on average 7,143 lbs (SE ± 565 lbs) per acre.

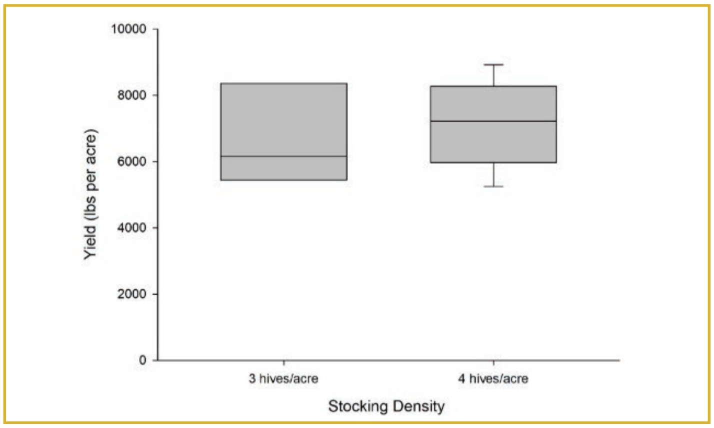

Figure 4. **Wild blueberry yield in the two honey bee stocking density treatments tested in New Brunswick in 2019: 3 and 4 hives per acre.**

EFFECT OF STOCKING DENSITY ON BEE ABUNDANCE AND DIVERSITY

We found no significant interaction of honey bee stocking density and bee type (*Apis* or non-*Apis*) ($F_{1,14}$ = 0.02; P = 0.899) **(Figure 5)**. There was no significant effect of honey bee stocking density on bee abundance ($F_{1,14}$ = 0.22; P = 0.643) nor bee type ($F_{1,14}$ = 1.28; P = 0.276) observed during our thirty minute transect surveys. In fields stocked at 3 hives per acre, we observed on average 40 (SE ± 5.29) honey bees and 25.33 (SE ± 6.36) other bees. In fields stocked at 4 hives per acre of honey bees, we found 33 (SE ± 14.8) honey bees and 21.33 (SE ± 4.28) other bees.

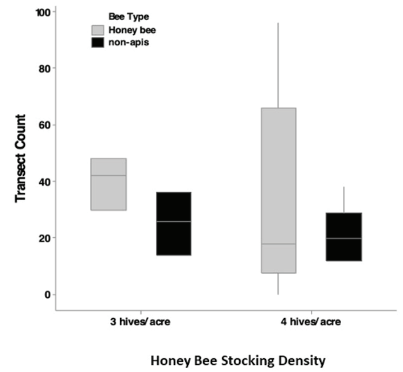

Figure 5. The effect of honey bee stocking density on abundance of honey bees (*Apis*) and other bees (non-*Apis*) in New Brunswick wild blueberry fields in 2019.

DISCUSSION

Effect of Stocking Density on Colony Growth

We found that colonies stocked at 2 hives per acre displayed the greatest growth, although not significantly more than hives stocked at 3 and 4 hives per acre.

The New Brunswick pollination standard is

https://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/bees/pollination.html

- At least 2 boxes or supers
- Contain a laying queen and brood
- 25,000-30,000 honey bees

The Nova Scotia pollination standard is

http://www.nsbeekeepers.ca/newBeekeepersDetail.php?Pollination-Standard-12

- 4 frames of brood with 100% brood coverage (or equivalent)
- 8 frames of bees with 100% bee coverage (or equivalent)
- 2 frames of honey
- 1 laying queen

Our findings suggest a trend of decreasing colony growth as stocking density increases, but when hives are sent at the pollination standard, they display optimal growth without swarming. Regardless of stocking density, it is important that all hives meet the pollination standard. When hives are stocked at high densities, it may be even more important to send colonies with high populations, and extra honey and pollen reserves. Colonies sent below pollination standard to high stocking densities may be negatively impacted by pollination and may even shut down egg-laying to conserve resources. We observed decreased growth at higher stocking densities (3 and 4 hives per acre) compared to 2 hives per acre, although not significantly so. Based on pollination success data of 73% at 4 hives per acre, it may not be in the best interest of colony health to stock at densities higher than 4 hives per acre, particularly as it may not be possible to achieve pollination success rates higher than 73%.

Hives that were sent to pollination weak (did not meet the standard) did not grow during pollination and were excluded from analysis. Hives that were sent too strong (many of the hives in 2019) swarmed and potentially negatively impacted pollination. When hives are sent too weak, there is an inadequate foraging force available to pollinate. When hives are sent too strong, the hive is not at its optimal strength and does not have the same capacity or ability to pollinate (e.g. egg-laying slows down before swarming, and with reduced young bees "brood" to feed, there is a decreased need to forage for pollen (Sammataro and Avitabile 2011; Schneider 2015)). This also negatively impacts the beekeeper; when hives swarm in blueberry fields, there are reduced populations of bees to forage for honey after pollination or divide colonies to make up new colonies for sale or replacement. When hives are sent at the standard, an adequate foraging force is available to pollinate, the hive can maximize its potential growth in blueberry fields, and provide increased populations to collect honey after pollination or be able to be divided (split) after pollination, providing increased hive numbers or revenue for beekeepers.

EFFECT OF STOCKING DENSITY ON POLLINATION SUCCESS

Although we did not detect significant differences in pollination success among different stocking densities, we did notice a positive trend in pollination success as stocking density increased. At the current industry standard of 2 hives per acre, pollination success rates of 50.5% were achieved. By increasing stocking density to 3 hives per acre, pollination success rates of 66.4% were achieved, and increased at 4 hives per acre to 72.5%. It is unknown what the pollination success limit was in these study fields, as pollination success can depend on genotype, weather, pollinator abundance, degree of self-sterility, and proportion of other clones, among other factors (Drummond 2002). In New Brunswick, pollination success rates of 40-50% are considered "very good", while rates of 50-60% would be considered "excellent" (Chaisson 1996). Using these results, stocking hives at 3 and 4 hives per acre achieved above excellent pollination success in our study fields. Weather during the 2019 pollination season was optimal for pollinator foraging, and weather during the 2017 pollination season was also ideal; this factor may have improved the pollination success results observed.

EFFECT OF STOCKING DENSITY ON BERRY MASS AT HARVEST

We did not detect a significant difference in berry mass at harvest among different stocking densities tested (2, 3 and 4 hives per acre). Fields stocked at 3 and 4 hives per acre did produce heavier berries than fields stocked at the current industry standard of 2 hives per acre, although not significantly so. We found that at 4 hives per acre, berry mass was more variable. For example, some berries were large (indicating better pollination), but some berries were smaller and more variable.

EFFECT OF STOCKING DENSITY ON BERRY YIELD

We found that fields stocked at 4 hives per acre did not produce significantly more yield than fields stocked at 3 hives per acre in New Brunswick. However, the difference in yield at 4 hives per acre, compared to 3 hives per acre, allowed for more than the cost of an additional pollinating unit, based on $0.45 per pound for blueberries. We also found less variability in yield at 4 hives per acre; fields stocked at this density produced more consistent crops than fields stocked at 3 hives per acre. Yield information was only collected in 2019 in New Brunswick, which allowed for comparison of similar fields and reduced variability. However, this also means our recommendations need to be tailored to specific growers and regions. For example, what makes sense in New Brunswick fields (with typically higher yield potentials) may not make sense in other parts of the Maritimes (e.g. fields with lower yield potentials). If fields are not consistently producing above 6,500 lbs per acre, stocking at 4 hives per acre may not be economically viable, based on our data. This experiment should be repeated in additional regions including Nova Scotia and Prince Edward Island.

In Nova Scotia, Eaton and Nams (2012) saw a linear increase in blueberry yield up to 4 hives per hectare (1.6 hives per acre). However, the highest yield they cited in the study was 5000 kg/ha (approximately 4500 lbs per acre) (Eaton and Nams 2012), meaning their upper yield limit of fields studied would be considered relatively poor producing fields in our study in New Brunswick. In this Nova Scotia study, the authors suggested that variability was too high above 1.6 hives per acre to make recommendations on stocking density; in our study, we are now able to make recommendations up to 4 hives per acre. This emphasizes the need for regional decisions based on regional research, individual fields, and yield potential.

EFFECT OF STOCKING DENSITY ON BEE ABUNDANCE AND DIVERSITY

Honey bee stocking density did not significantly impact the number of honey bees or native bees we observed in the same fields. There was greater variability in the number of honey bees detected in fields stocked at 4 hives per acre, but this could be due to increased competition for floral resources, and honey bees using their large foraging range (up to 5 km) to access floral resources elsewhere. We found no evidence for competition between honey bees and native bees at higher honey bee stocking densities, suggesting using managed pollinators at these stocking densities (up to 4 hives per acre) does not displace native bees that provide base pollination, potentially due to the short pollination window that managed bees are placed in blueberry fields.

CHALLENGES

As with most field research, we encountered challenges during the three years of study. There were major challenges surrounding grower and beekeeper communication. For example, each year we carefully designed an experiment that considered adequate replication for statistics (e.g. number of fields with the same stocking densities of honey bee hives). Each year, we encountered situations where we lost replication due to stocking densities changing, or hives moving in and out of fields prematurely. We also encountered challenges with honey bee colony strength. For example, colonies monitored for growth during pollination in 2017 were excluded from all analyses as many of the colonies did not meet the New Brunswick recommended pollination standard or were not managed similarly (e.g. different hive configurations, from different sources in and outside of New Brunswick). Hives studied in 2018 and 2019 were from fewer beekeeper sources that generally followed similar management practices. These hives consistently met the recommended pollination standard, and were stronger, except for one field studied in 2019 (these weak hives were omitted from statistical analyses).

These challenges also highlight the importance of studying the optimal strength of honey bee hives entering wild blueberry pollination, a future goal of our project. For the past three years of study, we omitted hives from statistical analyses if they did not meet the pollination standard or were managed very uniquely. We also tried to work with fewer beekeepers to reduce variability and ensure we met the pollination standard. In future work, we will also examine if there is a correlation between starting strength of hives and colony growth as well as pollination success, berry mass, and yield. This information could allow us to determine if the current pollination standard is adequate, or if new recommendations should be made.

Moving forward, grower and beekeeper communication is key with researchers, but we also advocate this is a two-way street. We aim to design high-quality experiments and work with farmers as best we can to ensure accurate data are collected. We as researchers, however, are also responsible for sharing results in a timely manner.

GENERAL RECOMMENDATIONS

Our study shows that increasing honey bee stocking densities can reduce variability in pollination success and yield but may only be economically viable in fields with higher yield potential, and when blueberry prices are optimal.

Colony growth decreased as stocking density increased, although not significantly so. More importantly, hives sent to pollination meeting the pollination standard grew well and did consistently better than weak hives. There are benefits to the blueberry grower and beekeeper to send hives at the pollination standard, at least up to 4 hives per acre as we studied, at the yield potentials that we studied. Communicating the pollination standard and its benefits more clearly to both parties, as well as sharing tips to achieve the standard may be helpful for this industry. For example, we would recommend beekeepers send hives to pollination with enough room to grow; this enforces sending hives at the correct strength but allows for potential growth and swarm prevention. Factors that need to be considered include colony strength, yield potential, weather forecasts and projected price. If high-potential fields are stocked at high stocking densities (e.g. 4 hives per acre and above), there are steps to take to protect colonies including meeting the pollination standard and sending hives with pollen substitute. Good communication between beekeepers and blueberry growers to prepare for pollination is essential to achieving high pollination success rates and healthy colonies.

Grower and beekeeper participation and collaboration in our study is fundamental in what we can achieve. We appreciate those who worked with us to gather this information.

REFERENCES

Chaisson, G. 1996. Pollination of wild blueberries. https://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/wild_blueberries/pollination.html

Chiasson, G. and Argall, J. 1996. Determining percent fruit set in wild blueberry fields. http://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/wild_blueberries/determining_percent_fruit_set.html

Drummond, F. A. 2002. Bees - 629-Honey Bees and Blueberry Pollination. https://extension.umaine.edu/blueberries/factsheets/bees/629-honey-bees-and-blueberry-pollination/

Eaton, L. J. and Nams, V. O. 2012. Honey bee stocking numbers and wild blueberry production in Nova Scotia. Canadian Journal of Plant Science 92: 1305-1310.

Minitab Statistical Software. 2018. State College, PA.

Nasr, M. E., Thorp, R. W., Tyler, T. L. and Briggs, D. L. 1990. Estimating honey bee (Hymenoptera: Apidae) colony strength by a simple method: measuring cluster size. Journal of Economic Entomology 83: 748-754.

Sammataro, D. and Avitabile, A. 2011. The Beekeeper's Handbook. 4th Edition. Cornell University Press. Ithaca, New York.

Schneider, S. S. 2015. The honey bee colony: life history. Chapter 4 of The Hive and the Honey Bee (ed. Joe Graham). Dadant and Sons. Inc. Hamilton, Illinois. Pp. 89-94.

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