INDOOR STORAGE OF

HONEY BEE COLONIES

IN THE UNITED STATES

HEALTHY HIVES 2020

TABLE OF CONTENTS

INTRODUCTION

Brandon Hopkins

Beekeeping is uniquely challenging profession; one that seems to only grow in difficulty as agriculture and land use continues to change to serve a growing human population. The introduction of Tracheal mites, Nosema, and the notorious Varroa mite (+ viruses) have only amplified the struggle. One of the earliest records of storing colonies indoors is a letter from a beekeeper describing annual winter losses of 30% of his colonies. In a question to Dr. Doolittle, the beekeeper asked for advice to prevent such high losses in the harsh winters in Iowa (Doolittle 1902). The advice given was that insulation of the hives using chaff or placing the colonies in a cellar to protect them from the wind and cold might help reduce losses. Early adoption of sophisticated hive protection was pioneered by Canadian beekeepers to protect colonies from the harsh winter weather. A publication in 1926 titled “Wintering Bees in Canada” described how to prepare colonies for wintering outdoors and indoors. An excellent review of early indoor wintering is provided by McCutcheon (1984). Some of the wisdom from these older publications are still relevant today. While the motivations, timing and scale of indoor storage are different in the US, there is a lot to be gained from the great research and experience of Canadians in this practice.

Northern beekeepers and those drawn to the potential for large honey crops in northern territories have been especially tuned to the need to protect bees from the elements and prepare colonies for winter. In 1926 (Gooderham) wrote that successful wintering in harsh climates required three considerations:

1. Strong colony with young bees
2. Good weight
3. Protection from cold and foul weather

It is the protection from weather that motivated beekeepers in Canada and the northern US to purse the practice of wintering bees indoors. These conditions are still relevant today, along with an additional requirement for successful wintering.

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The wintering of colonies in 2019 have a fourth requirement:

1. Strong colonies with young bees
2. Good weight
3. Protection from cold and foul weather
4. Low Varroa mite population (in September)

The addition of the fourth factor is an essential and complicated factor to wintering success. The Varroa factor impacts the other three requirements and the impacts can be imparted on the colony long before winter preparation occurs. The first requirement from 1926 now needs to be adjusted to state 1.) Strong colony with **healthy** young bees. The health of those strong young winter bees is determined in August and September and is highly negatively correlated with Varroa populations. It is possible to have strong colonies with low Varroa levels in November and have heavy winter losses if Varroa are allowed to feed on and spread viruses during the production of winter bees in August and September, even if the colonies were properly treated for mites in late September or October.

Number 3 on the list above is likely not a major motivating factor for US beekeepers. US beekeepers have had the option to successfully protect bees from the cold winter climates by moving their bees to California (or other southern states) before severe winter weather affects the bees. However, this management style has its own set of consequences – continued brood production, high colony densities, increased feed and labor costs, disease transmission, etc. An increasing number of beekeepers have turned to indoor wintering as a means to avoid the negative consequences of winter holding yards.

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It is important to consider the purpose and/or motivation for the use of indoor storage as part of the overall management strategy of each unique operation. The following statements might have made for a good title for this publication and reflect underlying principles for the recommendations found herein. These sayings have become something of a mantra from beekeepers with experience in managing indoor storage.

"You get out what you put in"

"Garbage in, garbage out"

"Storages are not hospitals"

Indoor storage is not a cure-all and they are not suitable for all operations. All the work and preparation in the month leading up to the storage period are critical.

This document is intended to be a starting block to be built up and create a central repository of knowledge on the practice of indoor honey bee storage and the management surrounding storing bees in buildings. The following sections are the initial collection of invited contributions from individuals with experience from different aspects related to indoor storage.

We expect to learn more and openly invite additional collaborators to add to this work - watch for an online resource coming soon.

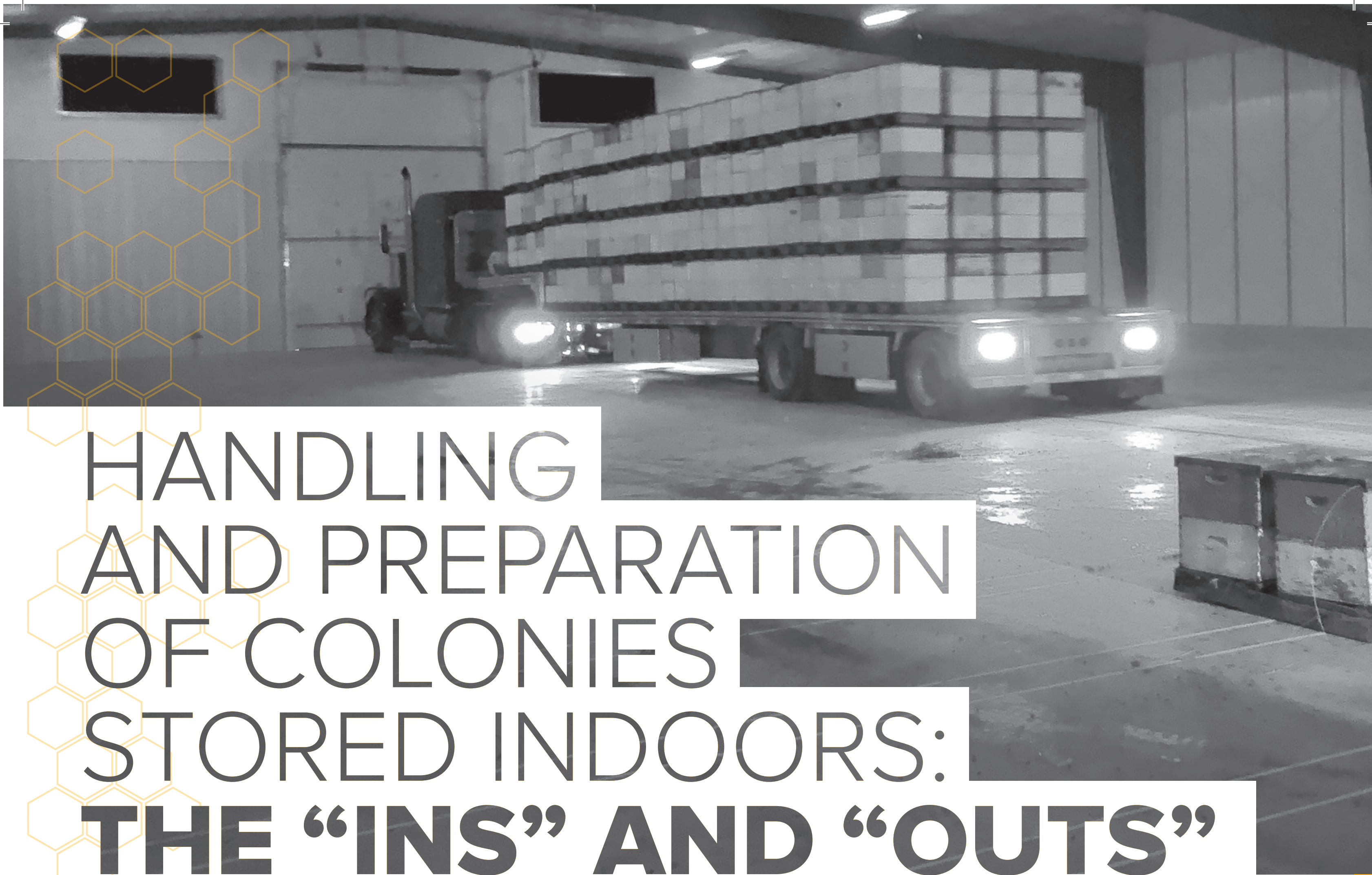
Following this introduction is - The "Ins" and "Outs". A section intended to cover the preparation of colonies before they go into storage and some precautions and advise for treatment of colonies when they get out of storage. This is mainly composed of advice gathered from commercial operations who have been storing bees indoors.

There are always many questions about building requirements for cooling, ventilation, etc. I invited Anthony Molitor from Industrial Ventilation, Inc to produce a section coving these common questions regarding building requirements. He has worked closely with commercial beekeepers and helped design and build successful indoor wintering buildings.

A common concern when presenting research or discussing the practice of indoor wintering is that it is done on such a large scale that smaller commercial beekeepers, sideliners and hobbyists think it doesn't apply to them or the option is out of their reach. Chelsea Cook & Kimberly Drennan were invited to submit a writeup on their ongoing project utilizing smaller modular storage options that might become a more applicable solution for smaller operations or fit unique management styles.

There are constant questions and concerns about the economics of many aspect of commercial beekeeping; it was timely that DeGrandi-Hoffman and colleagues recently published a paper on economic aspects of commercial beekeeping practices which included a comparison of indoor vs outdoor winter storage. She was willing to produce a popularized version of that work based on the peer reviewed publication. Figures 1 & 2 should be carefully studied and considered in the context of each individual operation. Even if the exact numbers and annual management cycle from this study do not align with your operation the implications within figures 1 & 2 have the potential to make an impact in the efficiency of any operation.

The beekeeper question and answer section is meant to cover commonly asked questions with answers from fellow beekeepers all in beekeeper language.



HANDLING AND PREPARATION OF COLONIES STORED INDOORS: **THE "INS" AND "OUTS"**

Brandon Hopkins

"INS"

While this publication is intended to provide some information on storage conditions and information on the buildings used for storing bees; that information and management is relatively very simple compared to the months of work preparing colonies before placing the hives in a building.

Commercial beekeepers who are accustomed to transporting colonies to warmer climates for winter storage might be used to having the time and ability to "fix" colonies during this period. Some operations reportedly use the time when colonies are in California holding yards to combine weak colonies, feed light hives, feed protein supplement to maintain brood production, treat for Varroa mites. None of these approaches are an option if colonies are bound for indoor storage.

IF they are needing to go into the building in November with good weight, young healthy bees, and low Varroa levels; those conditions need to be considered months ahead of closing the doors on them in October or November. The most critical factors for success with storing bees indoors are the actions and decisions made in August and September. Decisions on when to pull honey affects colony weight and when Varroa treatments can occur. September and October can provide time for adding weight but October is too late to produce the needed "healthy young bees". Most "winter bees" (the bees needed to survive 4-5 months) are produced in September or even August. This means you don't want your winter bees parasitized by Varroa mites and infected with viruses during larval development. To get those healthy young winter bees, colonies need good healthy queens combined with low varroa levels. If colonies need to be fed it should be done early enough so the weather allows colonies to consume any protein supplement and/or take the syrup and remove excess moisture from honey stores.

August-September – pull honey, treat mites, fix queen issues, feed

October – feed or put bees in storage

VALUABLE TIP FROM A BEEKEEPER

"You should never be looking at your bees as they are now but when looking at colonies you should be prepping them for where they need to be 3 months from now."

SOMETHING TO CONSIDER

A majority of beekeepers in northern or midwestern locations winter colonies in two deep boxes. There are reports of successfully wintering single deeps and/ nucleus colonies indoors. One comparative study found that the most successful setup in their trials were colonies prepared as singles and then added a super of honey or deep full of honey as the colonies were ready to go indoors (Nelson and Henn 1977). Colonies prepared as singles and then wintered with a super added had the greatest percent survival and had more brood and bees in the spring.

"OUTS"

When colonies come out of storage they are especially eager to fly. They have been unable to defecate for months. There is a considerable amount of bee flight the first opportunity they have to fly. It is important to transport and load colonies out during night and or in cold conditions. The potential for the loss of bees during transportation is great if they are provided conditions for flight. Research looking at the drifting of bees following indoor storage found there were significant losses in colonies placed in the field during daylight hours compared to colonies unloaded during the night (Jay and Harris 1979). They found the rate of drifting and the loss of bees to be greatest on the first day. It is widely reported that bees have a greater tendency to drift when colonies are set in rows in open spaces. It might be expected that the tendency to drift is exaggerated after indoor storage. Therefore, it is beneficial to take greater precautions to minimize potential for drifting. This include: pallets should be spaced out as far as possible, pallets not placed in straight rows, hive entrances oriented randomly, utilize smaller numbers of hives per location, place pallets in circular formations, etc.

Generally, colonies coming out of storage have much less brood compared to colonies wintered outdoors. This provides an opportune time to apply a Varroa treatment. Many beekeepers who have been successful at storing bees indoors allow a few days for the colonies to orient once they get on the ground in California and then they start a regiment of Varroa treatment and feeding (syrup and protein).

TYPES OF INDOOR BEE STORAGES

Anthony Molitor // Industrial Ventilation, Inc

Bee storages can take on many different forms. In the Treasure Valley of western Idaho and eastern Oregon, beekeepers have used everything from existing bulk potato storages, old onion crate storages, cinderblock buildings, or any structure where forced air can be introduced to the hives. Thus far, there is no right or wrong answer to which style of building is best. As we understand it, the key factors for any bee storage are:

1. The ability to provide balanced and consistent airflow to all the hives
2. The ability to maintain a stable and reliable temperature environment within the storage.

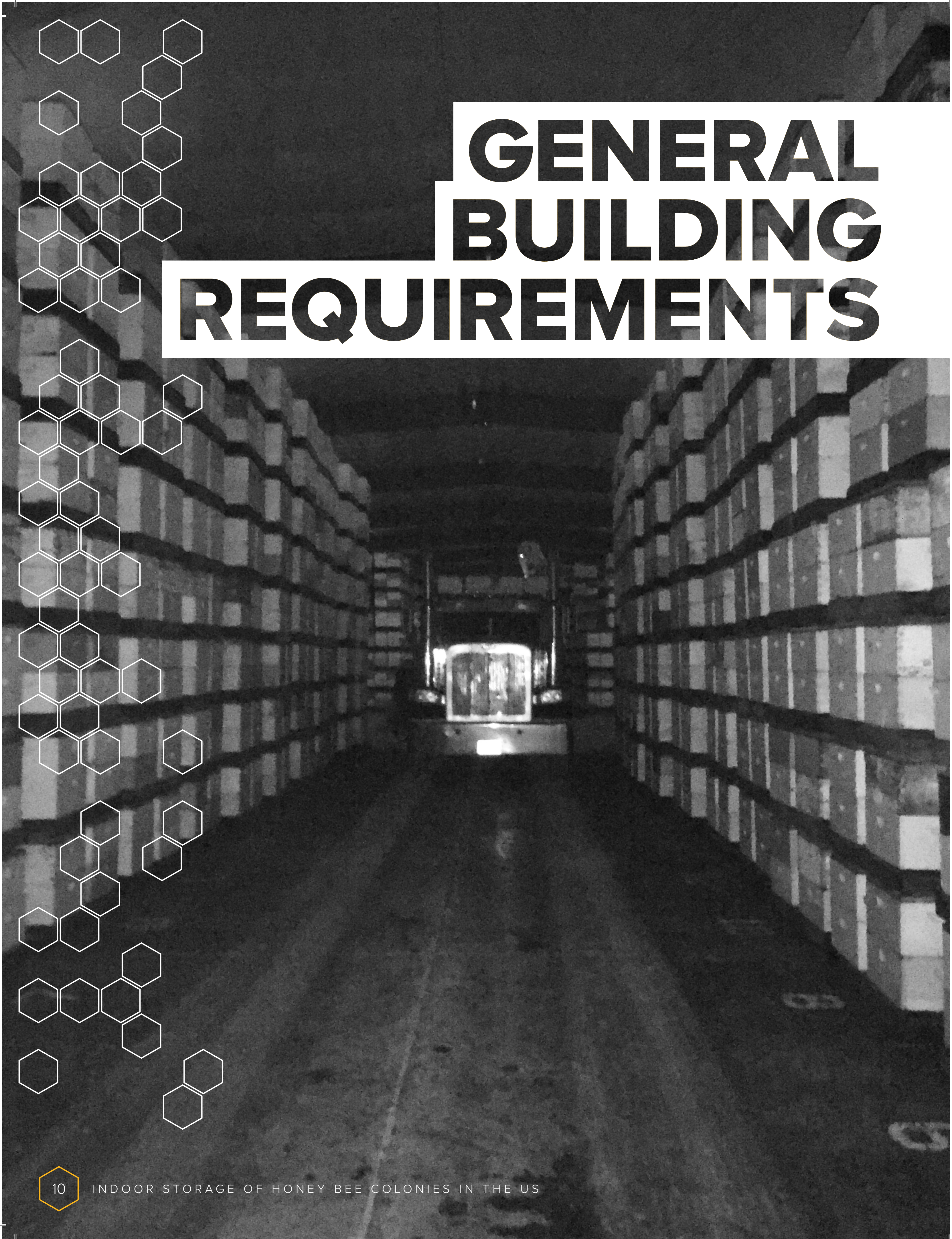
There are essentially three air delivery systems to take into consideration when designing and building a storage: Pressurized air floor, pressurized air wall, and a basic cross ventilation system. There are several considerations when deciding on which delivery system you should choose: First, the size of the storage. Second, the design that will deliver air most effectively. Lastly, cost. All three will provide good airflow to the hives. However, through our experiences in storage for the last 40 years, in nearly all instances an air floor is

the most effective means of delivering air into any storage. The air cup vents guarantee that airflow is introduced equally across the entire flow while also working with the natural flow of the hot air rising. The only downside to the air floor is the cost. It is a large investment when looking at a new storage, however, most customers believe the positives outweigh the negatives.

The following are descriptive differences for the variety of buildings used.

- Cellars: typically a cool and damp environment
- Potato shed: refrigerated systems with humidity and a darker environment but not 100% dark. Also have the ability to purge all the air.
- Purpose built building: specifically designed for bees and will be completely dark
- Controlled Atmosphere is a sealed room that is designed to maintain oxygen, carbon dioxide and nitrogen. Can only be entered once proper atmosphere is met. Most expensive type to build.
- Refrigerated storage: typically a R-30 or better and no outside air for purge.

GENERAL BUILDING REQUIREMENTS



BUILDING STOCKING RATES (HIVES/CUBIC FEET):

The number of hives is something that is determined by the customer. As a ventilation company, we are generally given building dimensions and then asked to maximize the number of hives that can be stored inside of those dimensions, given certain guidelines i.e. hive spacing, forklift driving space, etc.

In one publication they cite one hive per 30-35 ft^3, this is if the building is not air-conditioned (Nelson 1977). In air-conditioned buildings or when colonies are stored as singles, rates can be 15 ft^3/hive (Nelson and Henn 1977, Nelson 1982). Beekeepers in the US report stocking rates of 24 ft^3 per hive in non-refrigerated buildings and 18 ft^3 per hive in refrigerated buildings colonies stored as two deep boxes. Building designs typically incorporate space for trucks to enter for loading and unloading colonies.

VENTILATION & REFRIGERATION:

The ventilation and refrigeration systems are directly linked within a bee storage facility. The two must be sized properly based upon the total number of hives in the storage and the total watts of heat each hive consistently creates. Therefore, the amount refrigeration is the driving force in determining the amount of ventilation airflow within the storage. Through conversations with beekeepers and studying available research, targeting 20 watts/hive creates the proper amount of airflow and refrigeration to mitigate the heat production from the bees. While this sizing is on the higher end of the heat load spectrum, it is not so oversized that the ventilation and refrigeration systems become too expensive and no longer cost effective.

General recommendations for ventilation ranges 0.5–9 CFM (cubic feet/minute) (Nelson 1982). This ventilation rate is variable and dependent on the number of hives per cubic foot in the building, outside temperatures and cooling capacity.

HUMIDITY:

Humidity needs to be controlled within the storage. Excessive humidity and moisture can lead to mold build up, although humidity too low can be equally detrimental to a hive population. Using new computer control panels with precision temperature and humidity sensors allows the beekeeper to maintain very tight tolerances within the storage to eliminate the possibility of too much or too little humidity within the storage.

Little published work has focused on humidity. One study overwintered colonies at three different relative humidity ranges: 45-60%, 45-80% and 60-80%. The results showed little difference in weight loss, bee mortality, or spring buildup.

LIGHTING:

There are two sides to lighting within a bee storage. First, we try and create a lack of light in the storage. Using specialized light block media, this creates a dark interior within the storage while still allowing airflow to exit through the exhaust openings. By blocking as much incoming light as possible, the bees will not be drawn to these light sources and will keep them more relaxed and less active. Second, red lights should be used for the interior lighting as it allows beekeepers to work inside without disturbing the bees as bees cannot see the red color spectrum and will not be drawn to the light.

MODULAR COLD STORAGE OPTIONS

Chelsea Cook & Kimberly Drennan // HiveTech Solutions

To meet the specific needs of beekeepers while optimizing the health, security, and comfort of their honey bees during difficult times of the year, there are modular cold storage options available. Modular cold storage solutions put beekeepers in control; they are an option for beekeepers who want to avoid the stress of transportation or risk of large cold storage facilities. HiveTech Solutions is one company that has developed a modular cold storage unit that they will be optimizing with the USDA during the 2019/2020 winter season. Here are some details of their product.

MODULAR DESIGN:

Units consist of bee storage subunit and a mechanical subunit that controls the environment that the bees are in.

SCALABLE:

Because it is modular, it be scaled to fit any beekeeping operation and grow as a beekeeping operation grows.

ENVIRONMENTAL CONTROL SYSTEMS:

Honey bees are very different from refrigerated produce. Like any living creature, they need a comfortable environment that can provide reliable heating, cooling, fresh air, and proper humidity in order to thrive. This unit has controllable set points for temperature, humidity, and CO2 to keep bees comfortably chilled in any climate zone. Environmental conditions are constantly monitored and controlled remotely.

POWER:

This unit plugs into a standard 240V outlet. A back-up generator with an automatic remote start option can power the unit in the event of power loss. Every component has a redundant system and backups in case of failure. Solar power with battery backup is available for remote locations. The unit can be quickly disassembled if bees need to be removed fast.

TIMING:

Beekeepers are in control of when their bees go into cold storage and can place them in different yards at different times – after they have collected enough food for the winter or before mites become a problem.

LOCATION:

Beekeepers decide where their bees overwinter: It can be placed in all weather conditions and it runs off of a standard 240V outlet, backed up with a generator.

CONSTRUCTION:

This unit can be constructed easily with two people and basic tools within a day. It can be constructed on the ground or on a trailer.

COLD STORAGE TRANSPORTATION:

This modular cold storage unit was created to give honey bees a stable winter environment and testing for cold-storage transportation will take place in the spring of 2020. Cold-Storage transportation benefits include:

1. Reduced temperature stress on colonies and queens.
2. More flexible loading and unloading logistics for beekeepers. The unit can be staged in holding yards, it allows beekeepers to unload in small batches when the weather is cooperating.
3. Pallets are kept clean during overwintering, reducing the time of inspection at state inspection locations.

ADDITIONAL USES FOR A MODULAR COLD STORAGE UNIT:

- This unit is well-suited to put bees into short-term cold storage to induce a brood break to increase efficacy of miticides.
- This unit brings a controlled environment to the field, therefore can be used to rapidly cool and store produce post-harvest, especially for small farmers
- Can be used for storage of tools, boxes, and potentially bee or other livestock feed

THE ECONOMICS OF HONEY BEE MANAGEMENT

AND OVERWINTERING STRATEGIES FOR COLONIES USED TO POLLINATE ALMONDS

Gloria DeGrandi-Hoffman[1] // **Henry Graham** // **Fabiana Ahumada[2]** // **Matthew Smart[3]** // **Nick Ziolkowski[1]**
[1] USDA-ARS, Carl Hayden Bee Research Center, Tucson, AZ
[2] Beta Tec Hops Products Inc. Washington, D.C.
[3] University of Nebraska, Department of Entomology, Lincoln, NE

Commercial honey bee colonies are an integral part of agricultural production in the U.S. Each year, hives are moved across the country to pollinate crops that generate billions of dollars to the agricultural economy. The economic dependence of agricultural sectors on pollination services ranges between $14.2–23.8 billion, but the higher-order economic dependence of industrial sectors that are driven by crop production also is substantial (US $10.3–21.1 billion). The value of crops produced by honey bee pollination cascade through multiple socioeconomic sectors, generating jobs and revenue to small towns and rural areas and to numerous industrial sectors through equipment and machinery manufacturers, agrochemical companies, food processing, shipping and transportation, to name just a few. Honey bee pollinated crops also create export markets that help balance trade deficits. From a perspective of human nutrition, honey bee pollinated crops such as berries, almonds, pome and stone fruits and various seeds are essential to human health and are cornerstones to cancer prevention and heart-healthy diets.

Perhaps no crop is more reliant on honey bees than almonds. Acreages of almonds have been expanding for decades in the Central Valley of California, and by 1973, the pollination needs exceeded the availability of colonies kept in California. Currently, more than a million hives from throughout the U.S. come into the almond growing regions of California to pollinate the nearly 1 million acres (4000 km2) of bearing trees. The almond crop is worth $2.2 billion and adds an estimated $21.5 billion to the California economy and 104,000 jobs in production, processing, manufacturing and marketing.

Though the multibillion-dollar almond crop depends on honey bee pollination, the supply of colonies is unstable. For more than a decade, colony losses have been in excess of 30%. In four of the last five years, losses have been at least 40%. Reasons include poor nutrition, diseases, parasitism by Varroa destructor (Mesostigmata: Varroidae), queen loss, and pesticide exposure. Most colonies are lost from combinations of these factors, and many are lost over the winter. Poor overwintering has a particularly strong impact on beekeepers and almond growers, because almonds bloom in February when colonies are naturally at their lowest populations and just beginning to build. Weak colonies cannot rear enough brood to reach sufficient sizes for almond pollination. Colonies that are lost cannot be replaced by splitting stronger ones because in February there are no drones to mate with queens. Therefore, the number of colonies that survive until February are the number available to rent for almond pollination.

Honey bee colonies have an annual cycle, and management decisions occur within this framework. The cycle begins in the spring with brood rearing, colony growth and reproduction by swarming. Large amounts of forage are needed to optimize colony growth, and almonds can be an excellent early season pollen and nectar source. When almond pollination is over, beekeepers can split their colonies to prevent swarming. The splits also can replace colonies lost over the winter. Throughout the summer, colonies continue to rear brood and grow. However, as fall approaches, egg laying and brood rearing decline and bees store resources in preparation for confinement during winter. In temperate regions, the bees overwinter in a tight thermoregulated cluster surrounding the queen. Alternatively, if colonies are in warmer winter climates typical of southern states or California, bees forage and rear brood throughout the winter. Many colonies used to pollinate almonds are moved from northern latitudes to areas with warmer winters in late fall to overwinter.

There are challenges with placing colonies in areas where bees can rear brood and forage during the winter. Often there are not enough floral resources to keep colonies supplied with nectar and pollen, so beekeepers feed protein supplements and sugar solutions such as high fructose corn syrup (HFCS). Though protein supplements can meet some of the nutritional requirements of honey bees, if pollen is unavailable, colonies will show signs of malnutrition. Populations will decline and there will be increased incidence of disease. HFCS also can present health risks to bees. Keeping colonies in apiaries where bees can forage and rear brood during the winter necessitates monitoring and sampling Varroa populations and possible miticide treatment throughout the fall and winter. If brood is present, Varroa populations can grow as mite reproduction occurs in brood cell. More importantly though, Varroa can migrate into

colonies on foragers particularly in the fall and significantly increase mite populations even in colonies that were previously treated with miticides. Colonies that are infested with mites in the fall have little chance of survival overwinter.

An alternative overwintering method is to place colonies into cold storage (CS) facilities in the fall. There are advantages to this management strategy. Colonies in CS do not forage, so Varroa cannot enter colonies on foragers after a fall miticide treatment. Bees clustered inside the hive rather than foraging have greater longevity and require fewer resources. The cost of overwintering bees in CS also might be lower than in areas with warm winters if resources are limited and bees need supplemental feeding or additional mite treatments.

With the increasing costs of managing and transporting honey bee colonies for pollination, combined with the colony losses beekeepers routinely experience, we compared management costs and survival of colonies overwintered either in apiaries or CS. To do this, we followed 190 commercial honey bee colonies starting in April until the following year just prior to almond bloom. We calculated all expenditures incurred by a commercial beekeeper including salaries, transportation and cost of materials. In the fall, we divided the hives into groups that overwintered either in apiaries in Texas or CS facilities in Idaho. When both groups of colonies were moved from their overwintering sites to almond orchards, we compared the cost of each overwintering strategy. We calculated profit margins based on the percentage of colonies that were large enough to rent for pollination, the cost of the overwintering strategy, and the per colony pollination rental fee. We found that overwintering in CS cost less than in the apiary, but still exceeded our colony rental fees for almond pollination. Our only profitable activity was honey production during the summer. Our study underscores the challenges faced by migratory beekeepers, and their untenable economic position especially if the availability of nectar and pollen sources continue to decline. We conclude with recommendations and possible solutions for maintaining a profitable and sustainable commercial beekeeping industry.

OVERVIEW OF THE STUDY

Our study began in Danbury, Texas where 95 colonies returning from almond pollination in California were split into 190 colonies. A laying European queen was introduced in a self-releasing cage to each of the 190 colonies 48 hrs after making the split. We recorded colony sizes (frames of bees and brood) when they were established, and again in June, September and October. Mite populations were estimated in June and September using an alcohol wash of adult bees and in October using a mite drop count on a sticky board. In the fall, all colonies were fed protein patties (mixture of pollen, brewers yeast, vegetable oil, lemon juice and Pro Sweet Liquid Feed) and sugar syrup (Pro Sweet Liquid Feed) to prepare the bees for overwintering.

MANAGEMENT ACTIONS AND COSTS: SPRING–FALL

The cost of splitting 95 hives to create 190 new colonies including the cost of the queens, labor, transportation and feeding sugar syrup was $6651 (Table 1). The hives averaged 7.0 ± 0.1 frames of bees, 4.0 ± 0.1 frames of brood and 1.0 ± 0.09 mites per 100 bees. An additional $4871 was spent during June and July for sugar syrup feeding and for moving the hives from Danbury, Texas to Baldwin, North Dakota, and for miticide treatments. Of the 190 colonies we established in April, 158 were alive in July. The colonies averaged 15.1 ± 0.6 frames of bees. Later in June, the colonies were moved to apiaries in North Dakota for honey production. There were 1.3 ± 0.1 mites per 100 bees in alcohol wash samples before application of HopGuard II®, and 0.18 ± 0.03 mites per 100 bees 48hrs later.

From July through August, the colonies grew, and collected surplus honey so additional hive bodies with frames were added (i.e., hives were 'supered'). The total cost of managing 158 colonies for honey production (i.e., adding supers to the hives), collecting the honey and extracting it was $3245. The 158 colonies produced 12,160 lbs of honey (77 lbs per hive). The year of the study, extracted unprocessed Dakota honeys sold for $1.67 / lb (USDA-AMS Specialty Crops Program Market News Division, Dec. 23, 2016), so the value of the honey crop was $20,307. Between the time when the colonies were established in April and the honey was removed in August, we invested $15,231 in colony management and honey extraction, so our profit from the 158 hives was $5076 or about $32 per hive.

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Between August and September an additional 18 colonies were lost so that we had 140 remaining. The colonies averaged 15.5 ± 0.1 frames of bees, 8.2 ± 0.14 frames of brood, 4.6 ± 0.3 mites per 100 bees prior to the miticide treatment (cost = $1142). An additional 20 colonies were lost between September and October. Specifically, the colonies with high mite numbers in September (i.e. > 8.0 mites per 100 bees) either were dead by October or severely weakened so that they would not survive overwintering. The surviving colonies averaged 14.4 ± 0.2 frames of bees. Ambient temperatures were too low to open hives and measure brood frames or collect adult bees from the brood area for alcohol wash samples. Only mite drop from sticky boards is reported. Prior to miticide treatment, an average of 10.8 ± 0.7 mites dropped on to sticky boards; 48hrs after the treatment there were 61.7 ± 3.7 mites per sticky board. Of the 190 colonies we established in April, we had 120 colonies remaining to overwinter (37% summer loss).

TABLE 1. **Expenditures for colonies started in April until preparation for overwintering.**

DATE	ACTION	LABOR-HRS* ($16/hr)	TRANSPORT-MILES* 0.88/mile	MATERIALS	COST OF ACTION	TOTAL COST
SPRING						
11-12 Apr	remove queens and split colonies	$768	$56		$824	$824
13-Apr	install new queens, feed sugar syrup	$384	$28	$5,415	$5,827	$6651
13-Jun	sugar syrup feedings	$384	$28	$380	$792	$7443
14-Jun	Inspect and prepare colonies for move to ND	$240	$28		$268	$7711
17-Jun	load and ship colonies on trucks	$223	$28	$1,580*	$1,831	$9,542
SUMMER						
June 21-26	unload hives from truck in ND	$149	$79		$228	$9,770
15-Jul	miticide treatment and add supers	$384	$79	$1,290	$1,753	$11,523
1-Aug	add supers	$192	$79		$271	$11,794
15-Aug	add supers	$192	$79		$271	$12,065
29-Aug	add supers	$192	$79		$271	$12,336
6-Sep	remove honey	$384	$79		$463	$12,799
	honey extraction fee				$2,432	$15,231
9-Sep	miticide treatment	$121	$79	$1,142	$1,342	$16,573
FALL						
1-Oct	feed sugar syrup + Fumagillan	$128	$79	$490	$697	$17,270
12-Oct	feed sugar, protein + Fumagillan	$128	$79	$840	$1,047	$18,317
17-Oct	feed protein	$128	$79	$300	$507	$18,824
21-Oct	move colonies to holding yards	$113	$107		$220	$19,044
24-Oct	miticide treatment	$121	$28	$1,248	$1,397	$20,441
	sugar syrup feeding	$128	$28	$240	$396	$20,837
Total expenditure						**$20,837**
Total income (honey – expenditures) ($20,307 – 20,837)						**-$530**

* Shipping cost by independent carrier

CONTINUED

In preparation for overwintering, the colonies were fed a gallon of sugar syrup with Fumagilan ($490), 2 lbs of protein diet and a gallon of sugar syrup with Fumagilin ($1,047), and protein diet one more time in late October (cost = $507). The colonies were moved to holding yards (cost = $220), and treated with a miticide ($2124).

Between the time when the 190 colonies were established in April and they were moved to overwintering sites, $20,837 was invested. The investment was offset by the honey harvested from the hives in August that generated $20,307. Prior to overwintering, expenditures for the 190 hives (of which 120 still remained) exceeded income by $530.

OVERWINTERING MANAGEMENT AND COSTS

In October, equal numbers of colonies were prepared for overwintering in either Texas apiaries or CS in Idaho. We added colonies to increase our sample sizes, and divided these evenly between the two overwintering groups (CS and apiaries, n = 72 per group). The additional colonies belonging to our collaborating beekeeper were positioned in the same apiaries in North Dakota, and were managed using similar procedures as ours including the October miticide treatment.

CS colonies were fed sugar syrup 1 week prior to shipment (cost- $236) (Table 2). On November 15, colonies were loaded on to trucks and taken to the CS facility in Idaho. The fee for CS was $8 per hive ($8* 72 colonies = $576 total). Colonies remained in CS until February 1 when they were loaded on to trucks and taken to California for almond pollination (cost - $1515). The total cost of overwintering 72 colonies in CS including transportation costs and labor to load and unload the colonies was $2793.

A second set of 72 hives was shipped from North Dakota to Texas to overwinter in apiaries. The cost for shipping the hives was $725. When the hives arrived in the apiaries, they were fed protein patties and sugar syrup (cost-$356). The feeding was repeated monthly until February (4 feedings * $356 = $1424) when the hives were loaded on the trucks and taken to California for almond pollination. Transportation to California and loading/unloading fees cost an additional $1784. The total cost for overwintering 72 colonies in apiaries was $3705 or about $900 more than in CS.

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TABLE 2. **Overwintering costs for placing 72 colonies in either cold storage or outdoors in apiaries.**

OVERWINTERING IN COLD STORAGE

DATE	ACTION	LABOR-HRS* ($16/hr)	TRANSPORT-MILES* 0.88/mile	MATERIALS	COST OF ACTION	TOTAL COST
8 Nov	Feed I gal. of sugar syrup per colony	$64	$28	$144	$236	$236
15-16 Nov	Colony loading, shipping and cold storage fee ($8 / colony)	$34	$432*	$576 (72 * $8)	$1,042	$1,278
3-5 Feb	Ship colonies to California and unload in orchards				$1,515*	$2,793

OVERWINTERING IN APIARIES

DATE	ACTION	LABOR-HRS* ($16/hr)	TRANSPORT-MILES* 0.88/mile	MATERIALS	COST OF ACTION	TOTAL COST
25 Oct	Load colonies for shipping to Texas	$34	$28			$62
27 Oct	Ship colonies to Texas				$725*	$787
29 Oct	Place colonies in apiaries	$68	$28		$96	$883
12 Nov	Check colonies, feed protein patties and sugar syrup	$96	$26	$234	$356	$1,239
28 Nov	Check colonies, feed protein patties and sugar syrup	$96	$26	$234	$356	$1,595
22 Dec	Check colonies, feed protein patties and sugar syrup	$96	$26	$234	$356	$1,921
14 Jan	Check colonies, feed protein patties and sugar syrup	$96	$26	$234	$356	$1,921
1 Feb	Load truck for shipment to California	$29	$28		$57	$1,978
2-5 Feb	Ship colonies to California and unload in orchards				$1,727*	$3,705

* Shipping fee from private contractor

Of the 72 colonies put into CS, 54 (75%) survived overwinter, and 33 (61%) of these were large enough for almond pollination (> 6 frames of bees). The hives rented for almond pollination averaged 8.3 ± 0.55 frames of bees, 1.7 ± 0.15 frames of brood, and 0.04 ± 0.04 mites per 100 bees. Of the 72 hives that overwintered outdoors in Texas, 86% survived (i.e., 62 colonies) and all were of suitable size for almond pollination. Colonies averaged 9.1 ± 0.4 frames of bees, 2.6 ± 0.1 frames of brood, and 0.15 ± 0.05 mites per 100 bees. Colonies sizes (frames of bees) did not differ between the two overwintering methods, but those overwintered in apiaries had significantly more frames of brood (Table 3).

Total expenditures per colony from September after the honey harvest until colonies were put in almond orchards in February was $205 for colonies overwintered in CS and $228 for those overwintered in Texas apiaries. The rental fee was $165 per colony, so there was a loss of $40 per hive for those overwintered in CS and $63 per colony for those overwintered in apiaries. The value of the colonies that were rented for almond pollination was $5445 for those overwintered in CS (33 hives * $165/colony) and $10,230 for those overwintered in apiaries (62 colonies * $165). Based on the cost of managing colonies from September to February, rental fees and colony losses, we absorbed a loss of $9315 for the 72 colonies overwintered in CS and $6186 for those overwintered in apiaries (profit = (number of colonies rented * $165) – (72 * overwinter costs)).

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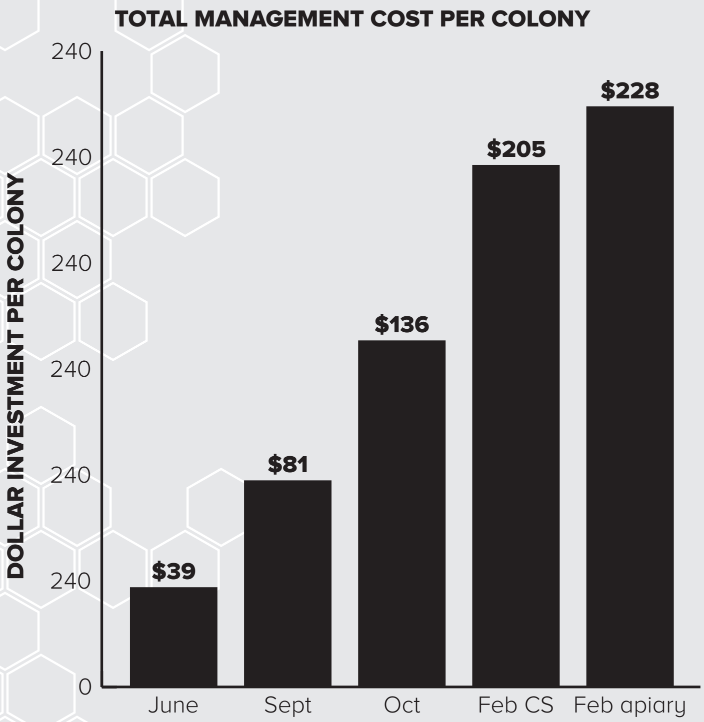

FIGURE 1 The dollar investment per honey bee colony from establishment (April) until rented in February for almond pollination. Colonies were overwintered either in a cold storage facility (Feb. CS) or outdoors in an apiary (Feb. apiary).

COSTS OF COLONY LOSS

Between the time when we established the colonies in April, and we put them in either CS or apiaries in Texas, 37% were lost. Due to our increased investment in the colonies as time went on, the cost of losing colonies increased as the season progressed (Fig. 1). In April, we invested $7410 to create the 190 colonies, or $39 per colony. The loss of 32 colonies in June was $1248 ($39 * 32). Between August and September, another 18 colonies were lost. By this point, we invested $81 per colony, so the cost of losing 18 colonies in late summer was $1458 ($81 * 18). An additional 20 colonies were lost between September and October. We invested $136 per colony by October, so the loss of the 20 colonies was $2720 ($136 * 20). Not all of the 72 colonies that overwintered in either CS or in the Texas apiary were sufficient in size to rent for almond pollination. Per colony losses for those that died or were too small to rent were $205 for those in CS and $228 for those overwintered in the Texas apiary. If the loss of rental fee is added, we estimate the loss of a colony overwintered in CS as $370 ($205 + $165 rental fee) and in apiaries as $393 ($228 + $165 rental fee).

IDENTIFYING COLONIES TO OVERWINTER

We put colonies into CS without concern for their size or mite numbers. Totaling the costs of maintaining a colony from September until almond bloom, every colony was a $205 bet that it would be large enough to rent. To reduce our losses, we should have put only those colonies in CS with a high probability of achieving populations suitable for almond pollination. To help beekeepers decide which colonies to overwinter in CS, we used our data to create a decision-making tool to identify colonies in September that will be large enough to rent for almond pollination. To develop the tool, we conducted two analyses. In the first, we found that colony size and mite numbers from alcohol washes in September were significantly correlated with colony size in February for hives overwintered in CS. This relationship was not significant in colonies we overwintered in apiaries. In the second analysis, we generated probabilities of colonies overwintered in CS being of suitable size for almond pollination rental based on September colony sizes and mite numbers. In the analysis, we used > 6 frames of bees in February as a successfully overwintered colony (Fig. 2). The matrix indicates that probabilities of meeting the minimum of 6 frames of bees is greatly influenced by September mite numbers. Even large colonies with more than 12 frames of bees (about 30,000 bees) have a less than 0.5 probability of being suitable for almond pollination if they have 5 or more mites per 100 bees in September. The analysis also indicates that mite numbers need to be controlled in August so that colonies have low mite numbers in September.

A similar analysis as described above was conducted to create a decision-making tool for colonies overwintered in apiaries. Unlike the CS data, the relationships between colony size and mite numbers in September and October and colony size the following February were not significant. Without significant relationships among these factors, we were unable to generate predictions of which colonies to overwinter in apiaries.

CONCLUSIONS

We managed 190 colonies and recorded all costs from the time of establishment in April until they were placed in almond orchards for pollination the following February. Though we expended considerable resources for feeding and parasite/pathogen control, more than 30% of our colonies died by the fall. Some colonies failed within two months after they were established perhaps due to queen failure since colonies had adequate resources, low mite numbers, and were not exposed to pesticides. The acceptance and retention of introduced queens depends on their health and mating success (i.e., number of spermatozoa in the spermatheca). About 14%–19.0% of commercially produced queens are not fully mated. We lost 17% of the colonies we requeened, well within the range of poorly mated commercially reared queens. We probably also lost colonies from Varroa infestations especially in the fall. Though we treated for Varroa in the summer, some colonies had high numbers of mites in September. These colonies were dead by October or if overwintered in CS had populations that were too small for almond pollination rental. Though statistics on colony losses during the summer and overwinter are available, the value of the colonies and dollars invested in their management can differ greatly. Colony deaths over the winter generate the greatest monetary losses, as they are 5-6 higher than in summer particularly if lost pollination fees are included.

A surprising finding from our study was that the cost of keeping colonies alive from September (after honey harvest) until almond bloom exceeded pollination fees. Overwintering in CS cost less than in apiaries, but did not assure lower losses or more colonies of suitable size for almond pollination. The only profits we realized were from honey production when our colonies were in North Dakota during the summer. Our summer apiaries were in a region that is part of the Northern Great Plains. About 30-40% of the registered colonies in the U.S. spend the summer in this region because the vast expanses of rangeland and pastures, and large acreages of blooming alfalfa and oilseed crops provide abundant forage for the bees (Gallant et al. 2014; Otto et al. 2016). The Great Plains serves as both a respite for colonies stressed by crop pollination practices, and a source of revenue for beekeepers through honey production. In our study, the profits from honey sales provided the funds for late summer and fall colony management in preparation for overwintering. Based on our honey yields though, the costs for overwintering preparations exceeded the honey profits so we had a net loss. The loss could have been avoided by higher per colony honey yields. However, areas with abundant forage that could generate large honey crops are dwindling in the Great Plains. Acreages of crops such as corn and soybean are increasing, and these not only have limited forage value to honey bees, but also may be contaminated with pesticides. The effects of diminishing access to forage reverberate through both the beekeeping and almond industries, as colonies surrounded by non-forage agricultural crops

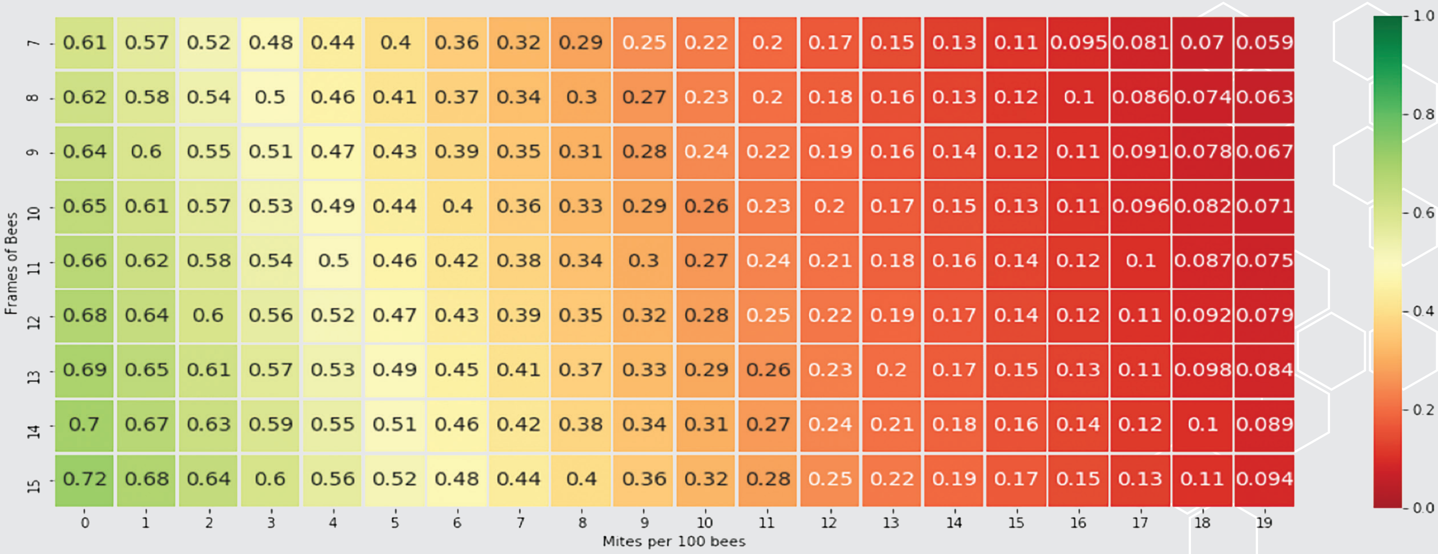

FIGURE 2 Probabilities of colonies consisting of six or more frames of bees in February based on frames of bees and mites per 100 bees in September. Predictions are based on a multifactorial logistic equation.

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are smaller in the fall and for almond pollination than those in grasslands with natural forage.

The costliest management action we performed after colony establishment was treating for Varroa. We used HopGuard II® during the honey flow at a cost of about $8 per colony in material, and Apivar in the fall at about $10 per colony. We could have reduced our costs by using other mite treatments such as formic acid or thymol (e.g., $4-5 in material per application). Though we applied miticides at regular intervals, mite populations increased in during late summer and fall. The increase may have been from the migration of mites into hives on foragers. Mites can enter hives when foragers rob weak colonies that are heavily infested with Varroa. Foragers with mites also can drift into hives when returning from a foraging flight. Our study site (a commercial apiary) had hundreds of colonies that could have been sources of mites. The weakening and loss of colonies from Varroa in the fall and overwinter are well documented, but because management costs were recorded in our study, we could quantify the financial burden caused by this pest. There was a loss of $80-140 per colony for those lost in the fall, and more than $350 (if rental fees are included) over the winter. Since losses from Varroa most often occur in the fall and winter, the mite is financially devastating to beekeepers and a great threat to the solvency of their operations.

One way to reduce financial losses from Varroa is to select colonies to overwinter in CS based on their size and Varroa populations in September since these are correlated to colony size in February. We constructed a decision matrix containing probabilities of colonies reaching sufficient sizes for almond pollination given their size and mite numbers in September. Beekeepers can use the decision matrix to select colonies to overwinter in September, and reduce financial losses associated with preparing, transporting and overwintering hives that are unlikely to reach sizes needed for almond pollination. We will continue to refine the predictions from the decision matrix by collecting data with broader ranges of colony sizes and mite populations to improve the decision tool we created for beekeepers.

Our study began as an economic analysis comparing outcomes of two overwintering strategies. What came to the fore is that reducing colony losses and stabilizing the economics of beekeeping will be difficult, and require cooperation among beekeepers, land managers, growers and federal agencies. A multifaceted approach is required because the challenges beekeepers face arise from a convergence of factors staged in ecosystems that are changing more rapidly and extensively in the second half of the 20th century than in any comparable period in human history. Honey bees and other pollinators along with beekeeping businesses are particularly

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vulnerable to ecosystem alteration. Acreage of pollen and nectar resources are shrinking, and warmer temperatures have altered bloom patterns, and reduced the nutritional values of pollens. In combination with severe stress from pathogens and parasites, and fewer locations protected from pesticide exposure, beekeepers that pollinate almonds and perhaps other crops are experiencing a financial burden not explicitly captured in reports of yearly colony losses. This burden threatens the sustainability of commercial beekeeping and has the potential to impact food production and consumers across institutional scales.

The cost of nationwide colony losses over the winter based on an estimate of 2.8 million colonies, a 35% loss rate, and our costs from September to almond bloom, translates into a $186 – 223 million USD loss for the U.S. beekeeping industry. What can be done to reduce these losses and improve the economics of migratory beekeeping? From our analysis, CS costs less per colony than overwintering in apiaries, and could potentially expand profit margins for colonies used in almond pollination. However, best management practices for CS need to be developed that improve overwinter survival. Those methods should include decision-support tools to improve selection of colonies to overwinter. The optimal timing for placing colonies in CS and the amount of resources required for overwintering also need to be determined. Establishing and enhancing pollinator habitat in the summer and fall are a key part of the solution because colony growth and honey yields are linked to the economic viability of commercial beekeeping. Furthermore, overwintering losses could be reduced with greater forage availability as fat body mass and vitellogenin levels critical for successful overwintering are enhanced when bees have access to fall pollens. The wide-angle view of an economic perspective should generate a sense of urgency to address the challenges faced by the beekeeping industry, so this vital sector of the agricultural economy can remain profitable and sustainable.

ACKNOWLEDGMENTS

The authors thank Randy Verhoek and Harvest Honey for collaborating with us on this project and for providing us colonies and information that made this study possible. We also thank Zac Browning for providing data for the study. We thank Drs. Vanessa Corby-Harris and Chelsea Cook for valuable reviews and suggestions on earlier versions of the manuscript. This work was funded by a USDA-APHIS Grant - 60-2022-6-006. The journal article on which this manuscript was based can be found at: https://academic.oup.com/jee/advance-article/doi/10.1093/jee/toz213/5559417?searchresult=1

BEEKEEPER TO BEEKEEPER: QUESTIONS AND ANSWERS

Sometimes the best advice/knowledge you can get in the beekeeping industry is advice from fellow beekeepers. What follows are questions about indoor wintering posed by commercial beekeepers who are considered storing bees indoors. Those questions were given to commercial beekeepers who have fully integrated indoor storage as part of the management of their operation.

WHEN SHOULD I PUT BEES IN THE BUILDING?

The observant beekeeper knows the long-term temperature averages in the area where his bees will be stored. For example, in North Dakota, drones are being purged by October 5th, and some hives actually achieve brood-free conditions by October 10th.

Hives [double deep] should weigh 120-125 pounds on average by October 15 in Northern tier states. Ideally, daytime highs upon indoor placement are in the 40-degree range. The idea is to store bees as they approach, or enter a dormant state.

For North Dakota, load the building after mid-October & finish by November 10.

HOW LONG SHOULD HIVES STAY INDOORS?

Hives can be safely wintered indoors for months. Unlike outdoors, the hive is in a constant environment. Buildings are very dark. Ideally, buildings are very quiet. Temperatures are constant. Disturbance is limited. No flight occurs. Hives must be well-provisioned and healthy prior to storage. In many instances, hives are in storage for 60-80 days.

EXAMPLE SCHEDULE WHEN BEES ARE TO BE PLACED IN ALMOND POLLINATION:

Optimally, hives arrive in the orchard > 21 days prior to bloom. On average, almond blossoms begin to open February 15. Ideally, hives arrive prior to January 25. Upon arrival, hives should be promptly placed in pre-designated sets. Upon placement, hives can acclimate for 48 hours without drift issues, locate sources of water, and take cleansing flights. Hives should then be worked. Priority: a clean bottom board, a clean feeder, 2 pounds of pollen substitute and feed. This stimulates brood rearing. On February 14, the first brood hatch begins. These infant bees free old bees to forage.

As the number of emerging bees increases, and as old bees die off; the hive is less stressed to meet the growing abundance of fresh almond pollen. Beehive frame counts need not contract through the end of February, when many measured strength inspections occur.

WHAT ARE CONDITIONS INSIDE THE BUILDING?

Ideally, temperature will range between 37-42 degrees F.

Humidity is controlled in a range not to exceed 50%. As bees consume feed, the by products are heat created by muscle use, and humidity from respiration.

Environmental controls are achieved by moving air. Some buildings move air without refrigeration. These buildings are vulnerable to the random warm day[s]. Most buildings use refrigeration to maintain constant temperature regardless of outdoor temperatures. The indoor temperature remains near constant.

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WILL BEES SUFFOCATE?

A pillar of successful indoor storage is: Don't suffocate the bees.

All refrigerated buildings re-circulate a portion of previously refrigerated air.

For example, when outside temperatures are 0 F., the refrigeration easily meets the created heat 'load' from the beehives. However, fresh air minimum draws are a foundation of good storage practice. For example, never less than 5% fresh air is a minimum standard for virtually all refrigerated indoor storage buildings. The 5% is a threshold to prevent suffocation. Equally important is control of CO_2 levels. If CO_2 thresholds exceed certain levels, air handling devices can be pre-programed to introduce more fresh air. When outside temperatures are 0 F., refrigeration may be limited, or unnecessary, with fresh air providing the necessary cooling. It is important to consider where and how air is being distributed in the building and how the hives are stacked to make sure air flow is relatively equal around all the hives.

WHAT CONTROLS THE AMOUNT OF LIGHT IN A BUILDING?

Modern buildings are tight; i.e. virtually no light disturbs the bees.

When indoor work must be accomplished, several approaches work.

Some buildings use fluorescent tube lights, with red tubes covering the white.

Some buildings use red LED lights. Red lights are less disturbing to the bees, creating less flight. Loading crews can see their work. Employees wear red LED headband lights. Many of the buildings have systems set up around all the air ports to block light. Doors are well-sealed

WHAT ARE THE LOGISTICS OF LOADING AND SHIPPING A BUILDING?

Entirely uniform hives, across outfits from 10 to 100,000 is not possible.

Prior to loading a building, the floor of the building floor may be gridded with painted stripes, or color-coded tape to direct stacked-hive placement in conformity with plenum-designed building air flows. The same tactic can be used to identify groups of hives identified prior to loading as: heavy and strong; light and strong, weak and heavy, weak and light, and so on. When done right, shipping crews can ship pre-designated hives to meet different customer requirements.

Safety is a priority: Many buildings have Overhead Doors (OHD) on each end of the building. The OHDs allow semis to pull in and pull out in a straight line, maximizing crew access to the 'loads' designated to a region or a customer in California. Additionally, once the semis are in place for loading, both OHDs are closed, eliminating outside wind/light interference

Often, buildings are outfitted with a sturdy overhead cable and safety harness for use when setting nets and load-securing devices. In cold country, a tarp is placed at the front of the load to eliminate undue chilling.

DO HIVE CONDITIONS CHANGE WHILE IN STORAGE?

A building is not a hospital. Queenless hives will still be queenless after indoor wintering. Many Varroa destructor will die indoor wintering – emerging data

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now documents CO2 levels maintained over a length of time will kill Varroa. Varroa in a brood-free colony have no place to reproduce. However, a hive with Varroa levels above well-documented thresholds will die either inside a building or shortly after. Poorly provisioned hives will starve.

WHAT PREPARATIONS SHOULD HIVES GET BEFORE GOING IN?

If beekeepers are used to shipping bees to California for the winter, they are often able to feed or do some hive repairs during the winter months. For indoor wintering the hives need to be fed to proper weight. Mite levels reduced (ideally by September) and hive strength needs to be 8 frames or better. Feeding, mite treatments, combining hives are all things that can be done during the winter when bees are stored in California, all this need to be done before “going in”. Hive bodies should be in good repair, and tight. Covers must be sound. Pallets must be cleaned of field debris including soil, manure and weeds. Broken pallets should be replaced. Broken pallets collapse. Collapsed pallets cause domino stack- collapse catastrophes. Eliminate hive beetles and red imported fire ants. For pre-inspected indoor buildings; these are mandatory standards.

WHAT TENDING WILL HIVES NEED UPON COMING OUT?

Need to consider that the bees are highly prone to drift after coming off the truck following indoor storage. Need to take care in spreading hives out and arranging the pallets off the truck to reduce drift. Clean the bottom boards. Honey bees continually perish. Housekeepers may carry the accumulating dead to the entrance, and drop them. Housekeepers may witlessly carry the dead from the entrance, into the pitch-black abyss, unable to return and are soon death-chilled. Upon coming out: Open the hive, clean the feeder of any residual feed and accumulated dead bees. A clean hive is a healthier hive. Provide nutrition. Pollen substitute and feed are immediate needs.

HOW MUCH WEIGHT DO HIVES LOSE DURING STORAGE?

Completely dormant hives in a 37-42 F. building will consume about 2 oz. of feed daily. Some hives more, some hives less. The arithmetic: if a hive is stored for 75 days in optimal conditions, @ 2 oz./day = 150 oz. or 9.5 lbs. of feed. Many beekeepers follow a 4 oz./day formula = 75 days @ 4 oz. = 19 lbs. The pillar is: Don’t starve hives. Amazingly, a percentage of hives begin rearing small patches of brood around January 1; hence the ample feed recommendations.

If a hive weighs 120 lbs on November 1st, by January 15, it will weigh around 102 lbs upon shipment. If a semi can haul a 48,000 lb load; a beekeeper can safely ship 456 hives on the semi. If a hive weighs 130# on November 1st, by January 15th, it will weigh around 112 lbs. The 48,000 lb load is about 420 hives. 10,000/456 = 22 semis.

10,000/420 = 24 semis. An 1800 mile one-way trip @ $3.35/mi. = $6,030.

Two loads @ $6K = $12,000; or most of the cost of a tanker load of syrup.

ARE DEAD BEES REMOVED FROM THE FLOOR FROM TIME TO TIME, OR IS IT BETTER TO NOT DISTURB THE STORAGE?

Some storage buildings are cleaned from time to time; others not at all.

The pathogens that may or may not be encased in the dead bee husk is not known.

Bees perish continuously. The floor becomes covered. Various methods are practiced.

Some beekeepers use industrial vacuums to clean the floor. Vacuums must be emptied upon each use, or when full: bees will decay in an enclosed vacuum.

Some beekeepers sweep between columns and rows. The swept bees can be stored in a closed bottom tote for later removal. Again, bees decay, and 'leak' from the bottom of leaky totes, drums, boxes, dumpsters. 15,000 hives will shed about 5 - 275 gallon totes from November 15 to January 15.

If bees are not cleaned from the floor, bees must be cleaned upon shipment, lest the floor becomes a slippery mess. In these conditions, the humans wear respirators. What about the bees?

- If sweeping occurs regularly – every 48 hours, the building will stay clean.
- Irregular sweeping becomes an overwhelming 'push' between rows and columns.
- Stacks are often 6-8 pallets high; hence the numbers of dead accumulate.
- The gridding of the floor works great when sweeping between stacks when the stacks are 25" apart. 24" brooms glide between stacks. 23" between stacks does not accommodate 24" brooms.
- Centers of the building are open. This allows use of 48" brooms.
- A good scoop shovel and several totes throughout the building reduces work.
- It is easier to keep a building clean than to get a building clean.
- Dead bees accumulate beneath pallets.
- Calculate one mouse per every four pallets. If 4,000 pallets load in the building, so are 1,000 mice. Spam bait 40 mouse-traps throughout the building. Inspect, empty, and reset traps regularly. 40 traps will yield 25 mice every 48 hours. By mid-January, fewer mice remain.
- Never, ever leave a vehicle in the building (mice).

Some buildings have floor drains.

Some buildings have no floor drains.

Some building floors are perforated for air-flow.

Each building design has virtues.

Before investing in an indoor wintering facility; and certainly, before renting space in an indoor building:

- Know the operator.
- Define the terms of storage, access, and egress timing.
- Know the other outfits with whom storage space will be shared.
- A building is not a hospital.
- Feed is not expensive until denied. It is a lot more expensive to lose bees to starvation.

CURRENT AND FUTURE WORK ON INDOOR STORAGE

Brandon Hopkins

This is a section that is difficult to put into print and is better suited for online digital form because as soon as it is printed it will be out-of-date or incorrect (online version coming soon). This section is intended to cover a few of the uses for indoor storage buildings that some beekeepers might find suitable to improve management practices and get more from existing or new buildings than 4-5 winter months.

A common concern for beekeepers while their colonies are held in winter storage is the build-up of CO_2. The carbon dioxide is produced as bees consume honey and generate heat; their muscle cells use up oxygen while they respire water vapor and CO_2. Naturally building operators want to ventilate the CO_2 out and get fresh oxygen rich air in the building so the bees do not suffocate.

However, researchers have found that the center of a naturally cluster winter colony can have CO_2 levels of around 6% (60,000 ppm). To put this in perspective the OHSA guidelines for human working environments state that 2,000-5,000 ppm levels are associated with headaches, sleepiness, nausea and 40,000 ppm is immediately harmful due to oxygen deprivation. It might be that beekeepers have been overly concerned with CO_2 levels. Additionally, it might be that increased CO_2 levels can benefit bees and the serve to help control Varroa mites.

Van Nerum and Buelens (1997) studied the effects of altered atmospheric conditions on wintering honey bees in small nucleus colonies and reported that decreased oxygen and elevated carbon dioxide, compared to atmospheric concentrations, were associated with reduced metabolic rates in honey bees. The reduced metabolic rates might translate into a decrease in the consumption of honey stores = bees less likely to starve/need less feed before or after storage?

Carbon dioxide levels of 2.5% at 25°C have been shown to increase the mortality of the parasitic mite Varroa destructor (Kozak and Currie 2011). As such, there exists the potential that altered metabolic gas atmospheres may have benefits to honey bees beyond the direct effect on metabolic rate. Preliminary work at Washington State University and continued work in Rob Currie's lab (Bahreini and Currie 2015) is investigating the use in increased CO_2 levels to have major impacts on Varroa mortality.

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Another exciting possibility would be the ability to treat all the colonies while they are in storage through the use of fumigation. Underwood and Currie (2004) demonstrated the potential of fumigating colonies during indoor winter storage period using formic acid. They were able to significantly increase Varroa mite mortality. However, they report higher than acceptable queen losses. It does seem like a feasible option and leaves a lot of room for the testing of various concentrations, timing of the use of compounds other than formic acid. The idea of being able to apply a treatment to thousands of colonies at once is enticing enough to warrant further research in this area.

The majority or research and effort related to the use of bee storage has been focused on protection from cold and general winter storage. However, there have been some interesting uses for the buildings at times other than winter months. Some beekeepers use the refrigerated/cooled space to work bees during summer months when it is too hot to work colonies outdoors during the day. The building provides a reprieve for both the bees and the people.

The large cool spaces can be used to hold loaded semi-trucks to better time the arrival of the loads headed to a new location or to receive a load that arrives too early in the heat of the day to offload colonies.

The rapid increase in the number of refrigerated buildings designed to hold honey bee colonies has provided opportunity for research related to manipulation of colony brood production. There has been good scientific evidence that forcing a period of broodlessness in the season by caging the queen can provide highly effective and reliable varroa control with a single miticide treatment. This has the advantage of decreasing the chemical inputs on the bees, reducing labor and increasing reliability. The caging of queens will never be commercially viable because of the time and labor required. However, if by placing colonies in a dark refrigerated space for a period of time stops brood production in a similar manner; it would provide a period of broodlessness that beekeepers could take advantage of to gain excellent Varroa control with decreased chemical and labor input.

ACKNOWLEDGMENTS

Special thanks to the Healthy Hives 2020 and Project ApisM groups for supporting the creation of this booklet. Special thanks to Danielle Downey for developing the concept for this publication and editorial improvements; and to Drs. Steve Sheppard and Daniel Schmehl for their valuable input. Thanks also, to the beekeepers who contributed pictures and most of the good pieces of wisdom and advice contained within (John Miller, Tim Hiatt, Nick Noyes, Ryan Thomas, Eric Olson, Larry Johnson, Ryan Razee, Joel Smith, Scott Razee, Keegan Fluke, and Scott Hamilton).

CONFLICTS OF INTEREST STATEMENT

This publication is not intended to endorse, publicize, advertise or otherwise promote any particular product. The authors here who represent independent business were invited to submit writings on specific areas of interest within their respective expertise. Additional parties were invited to contribute to this publication and is the intent to continue to invite authorship from representatives in the industry who have educational input to share.

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