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The Cell - Heart of the Hive

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The small cell theory for varroa control

Two years ago I was totally unaware of any difference in the sizes of the cells in the bee colony, other than the difference between a worker cell and a drone cell (and, of course, the queen cell). I thought the foundation manufacturers gave us beekeepers what was natural and best for the bees; what the bees would choose, themselves. It was self evident in my thought, if I ever thought about it. I had totally forgotten I had published a small article on cell sizes about ten years ago in the Swedish bee journal *Bitidningen* (Nov 1990) (I'm editor of that journal). At that time there had been some experiments in Germany with big cell sizes, or rather cells with enlarged cell bottoms. Today you don't hear anything about these. On the contrary, you do hear a lot about small cell sizes.

For more than 10 years I've been involved in trying to breed tolerance for the varroa mite into the our honey bee. Soon enough, I was aware of the seemingly higher tolerance in bees with African origin, in Brazil especially at that time. I got a strong gut feeling that African bees might have something in common, making it easier for them to deal with the varroa mite. And fate or God's providence or whatever you would like to call it, I prefer the latter, made it possible for me to participate in bringing breeding material of an easily handled and hardy African mountain bee to Sweden (eggs and semen) (**1**). Like others in the field, I concentrated on the rate of the increase in number of mites in the bee colony. Soon I realized that this was a dead end. In these tests being done during just one season, the colony never reached the amount of mites where it leveled out and you got a "normal" amount of mites. You never got an idea of how the bees could handle a situation with a high level of mites, how they could stand the secondary infections and whether they would get rid of mites themselves, in any way.

Especially through the experiences of Poul-Erik Karlsen on Bornholm(**2**), I also became aware of the two sides of treatment with acaricides against the mite. Besides killing mites they have unwanted effects. In this case, creating a reduction of the bees' own fighting ability against the mite, and a reduction in their tolerance to secondary infections, thus reducing what we call varroa tolerance.

Ed and Dee Lusby

Less then two years ago I became aware of Ed and Dee Lusby in Arizona and their stubborn defense of the very strong importance of a small cell size in connection with tolerance to the varroa mite, as well as the tracheal mite and secondary infections. Yes, the health of the bee, to put it simply. No, I couldn't believe the solution was so simple. And, a difference of some fractions of millimeters couldn't have such an impact. And, what they were talking about must be significantly smaller than what was natural to our bees.

But, I have never trusted authorities right away. People repeat a lot of what others say, and when you have heard it enough times, you recognize it and therefore regard it a truth. And what always has haunted me, since I was very young, is a statement by Albert Einstein. He said that if you want to make progress in science and community, you have to dare to question what is generally accepted and search yourself for the facts that will form the foundation for your thoughts.

So, in spite of my first negative feelings about small cell size, I knew I had to dare to find out a little more about the issue, though I thought I was on the right track with just breeding tolerance. I started emailing Dee Lusby in Tucson, Arizona, and got overhelmed with information. I dug through it and had to admit she had found out a lot of things about what was natural to the bees. And she and her husband, Ed, had a lot of experience to back up what they were saying.

They have a totally organic approach to beekeeping. To the contrary of what many may seem to think, they are not fanatics about small cell size in the sense that it should be the only and sole solution to every problem related to bees. They say cell size is 1/3 of the answer, 1/3 is breeding and 1/3 is environment, where they especially stress natural food for the bees - honey and pollen, and only that, for emergency feeding when necessary. Are they right? Well, they can't be totally wrong because they haven't been using any kind of beekeeping medication for many, many years. They had gone from 1000 colonies to 104, but now they are up at 700 and steadily increasing. At the end of 2001 they count on 800, and in 2002 they plan to sell nucs on frames with the cell size of 4.9 mm.

Natural selection

Natural selection has two criteria: *survival and reproduction.* And they are both dependent on a) the environment and b) the gene pool of the population.

Natural honey bee selection has been underway for a longer time than man's selection process. Natural selection is able to recognize every kind of trait and every kind of variation and its influence on survival and reproduction in the environment, where the population is living. Man is just a beginner at this science.

The issue of bee size

Man wants to interfere wherever he can and most often he thinks he knows best. And since the days when wax foundation first was made, man has manipulated the size of the cells in the beehive. And since breeding queens began, man has preferred big queens and big bees. Bigger bees had longer tongues and bigger honey sacs (but fewer flying abilities due to aerodynamics). The most popular bee most of these years has been the Italian bee. It has been bred yellower and bigger, and from being probably the smallest European bee(**3**), today it is the biggest in many places, if not most. For good or for bad? - probably for bad.

The size of the bee

The size of the bee is dependent on a) *the heritage* and b) *the size of the cell* it's born in. This later is connected also to how the larvae is fed by the nurse bees. Photo 1 illustrates how genetics for smaller bees and smaller cells give bigger bees in bigger artificial cells, but all genetics seem not to be affected alike by the cell size.

Photo 1. Two black African bees born in big cells. Together with one European bee in the middle.

The size of the cell

The size of the cell is dependent on a) *the size of the bee,* and b) *its heritage.*

At the end of the 19th century Cowan, editor of the *British Bee Journal,* measured natural worker cell size to be between 4.72 (0.186 inch) and 5.36 mm (0.211 inch)(**4**). The effects on the area of the cell itself and on the number of cells in a brood box can be quite considerable for different cell sizes. We can also see that worker bee size and worker cell size has an effect on drone cell size and, thus, also on drone size. And, the size of the drone has an effect on its flying and competing abilities. Smaller is better! See Table 1.

Table 1.

Cells/dm^2	Cellwidth	Cellvolume	Dronecell
650	6,0	360	7,6
700	5,75	328	7,3
750	5,55	301	7,0
800	5,4	277	6,8
850	5,2	256	6,6
900	5,06	237	6,4
950	4,9	222	6,2
1000	4,8	206	6,1
1050	4,7	192	6,0

From The influence of cell size, *The Bee World*, jan 1934, page 3.

4.8 -> 5.4 increase of area/volume ≈ 35%
4.9 -> 5.55 increase of area/volume ≈ 36%

Number of cells in 1 Langstroth frame:
4.8 – 9000, 4.9 – 8600, 5.0 – 8200, 5.1 – 7900, 5.2 – 7600,
5.44 – 7000, 5.6 – 6600

5.6 -> 4.9 – about 20,000 more cells in one box

The least confusing way of measuring cell size is to measure 10 cells in a row from midwall to midwall (including thus one cell wall for each cell) and divide by ten, measuring over the parallel sides (see Photo 2).

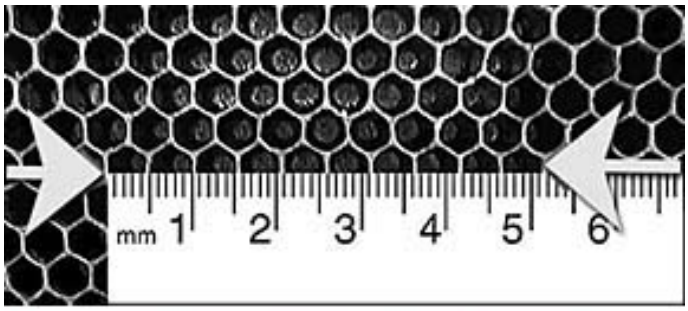


Photo 2. Measure ten cells in a row with a mm ruler, midwall to midwall.

But, when measuring commercial wax foundation, one direction of measuring (often along the top portion) will give higher value due to a stretching factor when milling. Therefore, measuring all three ways that are possible is a preferred method (Photo 3). According to Lusby, to be able to regulate varroa mites, the size should

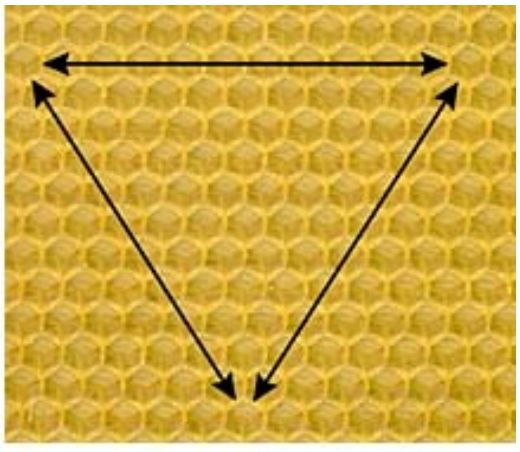


Photo 3. Commercial wax foundation is most often not completely regular. Therefore, it's good to measure all three ways.

most often not completely regular. Therefore, it's good to measure all three ways.

never exceed 4.9 mm in any direction.

Though born in 5.5 mm, I have measured my bees to build naturally 4.95-5.5 mm as the smallest size. You also see that the bees build cells intended for brood smaller than cells intended for honey storage. It can vary quite a lot. Then, it's important to recognize what type of cells you are measuring when you measure naturally built comb. When my bees in coming seasons will be born in smaller cells than 5.5mm. they will also build still smaller naturally if given the opportunity. This was already discovered by the greatest enlargement prophet himself, Usmar Baudoux, at the beginning of the 20th century.(**5**) Where this downsizing will end is, of course, set by the genetics, but also by environment. The Lusbys have pointed out that, as is the case in other animals, size and color will naturally vary due to height above sea level and distance from the equator.(**6**)

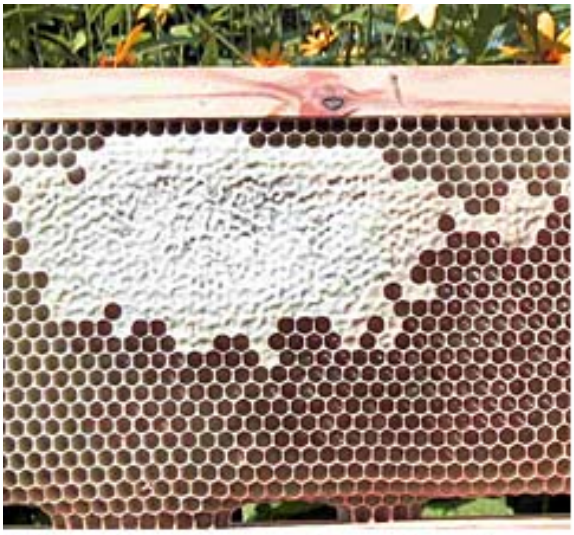


Photo 4. A perfectly drawn 4.8 mm foundation from my bees in summer 2000.

I couldn't resist buying a handmill from Tom Industries in California (now Arizona) to be able to find out myself how small cell size would affect my bees. The season of 2000 I tested about 70 of my 100 colonies and gave them foundation for 4.8 mm cell size. (As I milled with a thin plastic wrapping of the wax sheets, I got no stretching that the mill was "prepared" for. Therefore, I got 4.8 mm cell size instead of 4.9 mm.) One of the colonies drew the foundation surprisingly well (Photo 4).

Five colonies drew out the foundation well enough, while 10 did it satisfactorily. Some were wintered on entirely 4.8 mm cell size 2000-2001 (Photo 5.) I was amazed how small the bees were in these colonies! The small cell size had a larger impact than I thought on bee size, especially the abdomen. But this did not hinder the colonies from wintering, even better than their

Photo 5. The five colonies on entirely 4.8 cell size (two 12-frame shallow boxes packed with bees, but no insulation) wintered at least as good as my other colonies in Sweden where

size (two 12-frame shallow boxes packed with bees, but no insulation) wintered at least as good as my other colonies in Sweden where we have long and cold winters. They looked this way both in November 2000 and in the beginning of April 2001.

larger close relatives. I live at the latitude of 59º in Sweden. But, the warm Gulf stream in the Atlantic gives us a fairly good climate here in Scandinavia. Well, in the season of 2001 I will discover if these small bees can produce any honey: Probably they will, as the small size of the Africanized bees in Brazil has not hindered them from collecting a lot more honey than the previous European type.

Photo 6. Larger bees that couldn't draw small-cell sized foundation.

Ten of my colonies in 2000 couldn't draw 4.8-foundation at all, which resulted in awful combs that I melted down (Photo 6). Most colonies can't return immediately to small cell size due to the current bees being too large, which results from enlarged cell sizes and genetically selected large bees. You have to downsize your cell and honey bee size more slowly. You can read about how to do it on the website *beesource.com.*(**7**)

Non-European *Mellifera*

Honey bees from outside Europe have not been under selection for larger size and are normally not kept with enlarged wax foundation, even if they, no doubt, could be kept that way, too. It is noticable that where European *rnellifera* are kept on enlarged cells is where we have the major problems with mites and secondary infections. Could this be a part of the explanation? (Table 2).

Table 2.

Race	Combdistance (cc) mm	Cellsize mm	Quota to dronecell
A mellifera			
Europa*	32-38	5,1-5,5	1,3
USA*		5,3**	1,23**
A m syriaca		4,9	
A mellifera Africa			
A m scutallata	32	4,7-4,9	
A m lamarckii	32	4,6	1,33
"tropiskt bi"	32	4,77-4,94	1,38
A m capensis	31,8	4,86	
A m monticola		5,0	
Afrikaniserade		4,5-5,0	
A cerana Asia			
Japan	30	4,7-4,8	1,13
Kashmir	35	4,9	1,08
Higher Himalaya	30	4,9	
Southern Himalaya	32	4,3	
Filippines	30	3,6-4,0	

* Cellsize in Europe and USA is not the natural but is due to the cellinprints on the wax foundation sold commercially.

** Figure from 1970. Today the size is more varied, mostly bigger.

From Crane, Eve, *Bees and Beekeeping*, 1990

Natural selection concerning cell size and size of the bee
All flying objects, manmade or natural-made, have to deal with the aerodynamic laws dependent on gravity and air friction. Air friction is subject to body area. Gravity is subject to body weight.

When you increase an object proportionally, the area increases by the factor of four and the weight by the factor of eight. That's why a bomber is slower than a fighter, and a bumblebee is "clumsier" and slower than a honey bee. That's why big bees and big drones are slower and "clumsier" than small bees and small drones. Quicker and better flyers, of course, have a better chance to reach the virgin queens first. It's not difficult to visualize small drones hitting first. So natural selection most probably goes for small. And the size of drones and workers are correlated. Could that be an explanation of why Africanized drones most often reach the virgins first in Africanized areas?

In nature no one is giving the colonies new comb. The colonies use their old brood comb year after year, with cocoons making them smaller each year, thus making the bees born in them smaller. This, causes those bees to have smaller cell size. Natural selection thus selects for small - small bees and small cell size, at least, smaller cells than we use on our enlarged wax foundation. This fact pushes us to investigate what kind of effects these smaller, more natural cell size and bee size will have on the performance of the honey bee colony.

You may ask if all those large-cell sized combs that have been in the hive for many years haven't been reduced sufficiently already? Well, maybe, but as the distance between the combs

is much bigger than what the bees would choose (35-38 mm instead of 32-33 mm), most of the cocoons probably end up at the bottom of the cells, so it will take some years to get the cells small enough that way. And, these old frames don't give the bees a smaller brood nest that will be easier to keep the brood temperature at the higher 35ºC, instead of the lower 33ºC, which can occur in the outer frames of the broodnest. It is this lower temperature that gives the optimum environment for mite reproduction.(**8**)

A bee business with varroa, but without any type of chemical

Photo 7. This is one of the Lusby Apiaries.

Dee and Ed Lusby in southern Arizona have never used any type of chemical to fight any type of mite. This caused their bee business to crash more than once when the mites arrived, first tracheal mites and then varroa mites. From having 1000 colonies in 1986, they went down to about 400 colonies in 1989 and started up again, after having changed over to 5.0-5.1 mm cell size when the tracheal mite hit. When varroa hit in 1993, they were up over 900 again, but fell down to 104 colonies in the spring of 1998. They started to give their colonies 4.8-4.9 foundation in 1997. They say 4.9 mm cell size is crucial and is the main reason why they now are back in business and increasing their number of hives and honey crops (Photo 7), while many others using chemicals are going the other way.

My wife, daughter and I visited the Lusbys in April-May 2000. I "fled" from my 50th birthday to Arizona from Sweden. That was a good choice. Lovely people and an interesting country you have over there. I received my cowboy hat and belt, though I'm not really worthy of them. I looked in 225 hives in 13 apiaries and encountered a couple of colonies that resembled the descriptions of so-called killer bees. Lusbys bred for small bees and a short cappings period of the brood for many years before the Africanized (AHB) bees arrived in the area. Their drones probably compete well with the Africanized drones. Very important, too, seems to be the observation by them that mixed colored bees, which the Africanized honey bee is said to be, don't have drones as early and as late as black bees. So, they let their virgins mate early and late in the season. And, they go for small black bees.

Photos 8 and 9. Ed Lusby and Erik Osterlund showing nice broodcombs. Also a nice honeycomb. Africanized honey bees? I wouldn't care what such good bees are called.

Another interesting observation of theirs concerning cell size and bee size is that swarms they collect that can't adapt to 4.9 (thrive and draw 4.9 after two months, two generations of bees), even after being forced down through already drawn 4.9 comb, will all die due to the mites and secondary infections. (They seem to be too big genetically. Maybe this has been caused through man's selection?) One of the characteristics of these larger bees genetically is that they are on the lighter colored side.

Where can you purchase small-cell sized foundation (4.9 mm)?

You can buy your 4.9-foundation from Dadant and Sons, Inc. (**9**), if you don't want to mill your own with a mill from Tom Industries.

Footnotes

1) Osterlund, Erik, 1991, Exploring Monticola - Efforts to find an Acceptable Varroa Resistant Honey Bee. *Am. Bee J.* 131:49-56.

2) Osterlund, Erik, 2001, The Elgon Bee and Varroa mites, *Am. Bee J.,* 141:174-177

3) Erslev, Hans, 1950, Forer i Biavl, Forers i biavls forlag, Rosklide, Denmark. A new edition of the original from 1887, which in its turn is a translation of an English original by Cowan, Thos. Wm.

4) Cowan, Thos. Wm, *The Honey-bee; its Natural History, Anatomy, and Physiology,* page 180. Referred to in *Gleanings of Bee Culture,* April 1898, p. 261.

5) Baudoux, U.,1933, The influence of cell size. *The Bee World,* vol XIV, no 4, April, page 40. Baudoux, U., 1961, *Handboek van de imker door,* Edm. Leysen, pp 13-19 (in Flemish language).

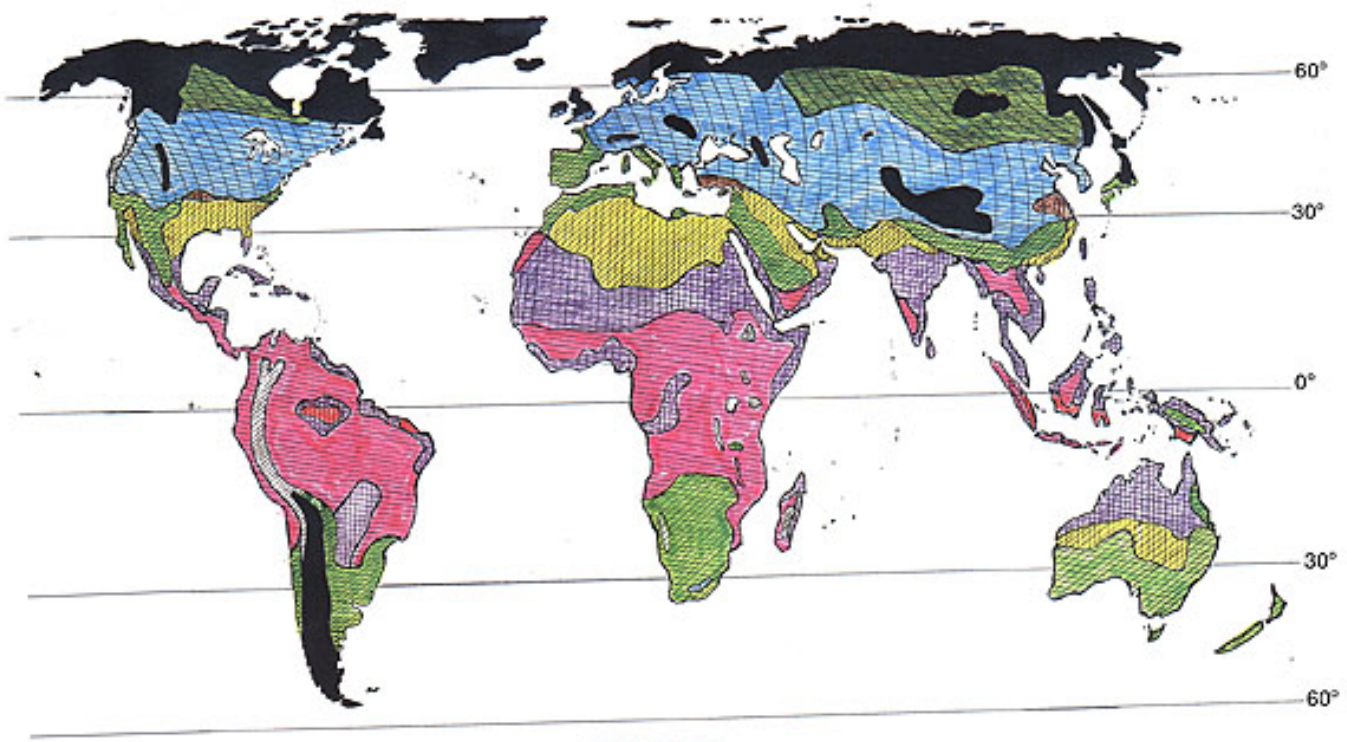
6) http://www.beesource.com/pov/lusby/therm_map.htm

7) http://beesource.com/eob/4dot9/index.htm

8) Velthuis, Hayo H W, Kraus, Bernhard, 2000. The Impact of Humidity and Temperature Gradients in the Brood Nest of Honeybees on the Reproduction of *Varroa jacobsoni:* Laboratory Observations, *Second International Conference on Africanized Honey Bees and Bee Mites,* 10-12 April 2000, Tucson.
Velthuis, Hayo H W, Kraus, Bernhard, 2000. The Impact of Humidity and Temperature Gradients in the Brood Nest of Honeybees on the Reproduction of *Varroa jacobsoni:* Field Experiments, *Second International Conference on Africanized Honey Bees and Bee Mites,* 10-12 April 2000, Tucson.

9) http://www.beesource.com/dadant/index.htm

Honeybee Thermology/Cell Size Zones



MONTHLY TEMPERATURE MEANS			GENERAL CELL SIZES	COLOR ZONE
-0F	-	60F / 80F	5.0 mm - 5.2 mm	
0 / 40F	-	60F / 80F	4.9 mm - 5.1 mm	
0 / 40F	-	above 80F	4.8 mm - 4.9 mm	
40F / 60F	-	40F / 60F	4.9 mm	
40F / 60F	-	60F / 80F	4.8 mm - 5.0 mm	
40F / 60F	-	above 80F	4.7 mm - 4.9 mm	
60F / 80F	-	60F / 80F	4.6 mm - 4.8 mm	
60F / 80F	-	above 80F	4.7 mm - 4.9 mm	
above 80F	-	above 80F	4.5 mm - 4.7 mm	

Note: Cell sizes are recorded in general for zones, and where altitude and higher latitude occur, use Humbolt's Law for deviations.

Special Note: After studying correlations, we believe brood 4.9 mm cell size could be the upper limit for cell size control for mites worldwide.

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Converting to a non-chemical 'back to basics' approach to beekeeping

Part 1 (Below) Part 2

Since 1997, the Lusby's have successfully maintained their honeybee colonies the traditional way, without the use of drugs, essential oils, or chemical treatments. Through their experience, they believe to be successful at keeping bees the "non-chemical" way, three elements make up the solution; matching comb size to the natural environment is 1/3, diet is 1/3, and breeding is 1/3.

After reading through historical documents that the Lusby's have compiled from countless hours of research through periodicals, journals, scientific papers and books, it is clear that a deliberate change took place back in the early 1900's to go to the outer bounds of possibilty in creating a bigger honeybee. A point can be made that a sudden increase in bee diseases and pests also happened at the same time.

Seeing that our country was founded upon and originally used 4.83mm cell sizing, the Lusby's have found that there is naturally an optimal cell size for ones own geographic area, of which they have complied these sizes on a world map for reference. Many beekeepers throughout the world, either have, or are in the process of converting to a natural cell size for their bees. I have decided to do the same and will be posting here, the progress and steps taken to convert 8 colonies over to 4.9mm cell size and then monitor them for their abilities to deal with todays pests and diseases.

It is may opinion that an extreme emphasis over the years on breeding a bigger and better bee that produces more to supposedly pay back the beekeeper more has lead to a problematic honeybee. I guess it's human nature to always want to improve and push the limits to get more and more back, but at what price?

While the Lusby's have shown that it is possible, and now just as profitable as well, for a commercial beekeeper to convert over to biological beekeeping, my goal is to duplicate and show the steps taken for the benefit of hobby beekeepers.

Retrogressing bees hived on 5.4mm cell size, to 4.9mm.

April 26, 2000

I started this year by using the swarming season as a means of gathering my needed base stock for comb building. As the swarm cells were produced in several hives this year due to an unusually mild late winter and early spring, I was able to easily gather several swarms to start my nucs with.

Once a swarm had settled, the cluster was brushed into a 4-frame nuc that contained frames with only a 1 inch starter strip of 4.9mm foundation.

A point should be made here that bees would build a cell size close to the size they were on before if no cell pattern was given for them to build off of. When you look at your newly caught swarm, if the bees look like the same size as in your hives then they have swarmed out of a large domestic hive and will have to be retrogressed. If the bees in the swarm appear half and half in size then the queen was mated part way in matings to feral size. If you look at the swarm and the bees all look small then they will probably go to the smaller size right away without too much difficulty.

I know my swarms came out of my hives and the bees are big so it will take several steps to regress the bee size down.

I gave sugar water right away to the newly hived swarm and let them settle down for a few days. Three days later (April 29), I moved the bees and four frames out of the nuc and placed in the center of a single deep hive body that had the remaining six frames with starter strips installed. On May 2nd, an inspection of the combs revealed that the queen had started to lay eggs. The bees are taking in a quart of syrup everyday now.

May 6

Checked on the apairy this morning and noticed another small swarm on the trunk of a nearby sapling. I'm starting to run out of available hive bodies. Last week I decided to be better prepared for the next swarm so I made up 10 new frames, all with 1" starter strips of 4.9mm foundation, and had it sitting in the apairy all closed up just waiting for this situation. Of course I would have to find it just 15 minutes before I had to leave to take my son and buddies out for games on his birthday.

I was able to place the single deep hive body with frames on top of a 4 foot ladder and be within a few inches of the cluster. Since time was of the essence, I grabbed my queen catcher in one hand, and with the other, started to gently scrape a handful of bees at a time off the cluster and onto the top bars, always looking for the queen. Usually the queen will be high up in the cluster and as far to the center as possible. After 2/3 of the bees were scraped off onto the hive, I finally saw the queen run across the remaining cluster and take flight. I paused for about a minute and assumed she would fly right back as all the bees were fanning and staying put. Sure enough, there she was again moving across the remaining

cluster on the tree. I caught her in the queen cage and knew the hard part was over.

Running out of time, I spread two frames apart just enough to allow me to slide the queen catcher down between the frames and wedge itself in place. I layed an inner cover over the top leaving a gap by placing a stick under it so the remaining bees could get in through the top. I returned 2 hours later to find all the bees had moved into the hive and settled down.

To increase my odds that the swarm would stay after I released the queen, I decided to take a frame with bees from the first swarm's hive that had been drawn out halfway and had a few eggs in it, and place it down in the center of the cluster of this swarm, one frame away from the caged queen. After waiting about 15 minutes to allow the bees time to sense the open brood cells, I took the queen cage out from between the frames and opened it up on top of the bars. She came right out and headed right down between the frames. I put the inner cover back on and placed a feeder jar of sugar water over the center hole and closed it up. I expect this will be my second hive on it's way down to 4.9mm cell size.

May 15

Today was cloudy with temps around 52°F and a 25 mph wind. Not a good day to be pulling frames of brood out and inspecting. Both hives are building comb at a progressive rate. Hive 1 (first swarm) has comb on 9 frames with brood of various stages on 3 to 4 frames. They should be ready for a second deep hive body in about a week. I prepared 10 more frames with starter strips and have another hive body ready to go.

It's interesting to see how the bees first start building comb on the rear (opposite of entrance) of the frames and work forward with their cresent shaped comb design.

As I go down this road of regressing the bees to smaller cell size with the goal of being able to manage my bees and produce honey, without resorting to chemicals or drugs to keep the bees healthy from disease and alive from the ravages of the mites, a lot of questions come up as to the best way to make this change. All my hives were started on Duragilt foundation which measures 5.4mm across 10 cells. Last week I was able to do a quick measure of one frame of comb that had brood in it from Hive 1 and it measured 5.2mm across 10 cells. As soon as the first round of brood emerge I will take several measurements from these combs to get a better average. Assuming 5.2mm is the average, and the bees regress in size by .2mm after each swarm or shake down, I will need to go through this process one more time before I can safely put them on full sheets of 4.9mm foundation and have them drawing it at that size.

I wonder about this late summer when all my hives will have developed substantial levels of Varroa mite infestation. This is a stage in the regression process that the two hives will be