Impact of the design and material of the hives on honey production of bees

A R Bykov¹ and G A Zaitsev²

¹ Bunin Yelets State University, 28 Kommunarov street, Yelets, Russia
² Ufa Institute of biology, Ufa Federal Research Centre of the Russian Academy of Sciences, 69 October avenue, Ufa, Russia

E-mail: ikt-inform@mail.ru

Abstract. The influence of the hive's design and material on the development and productivity of bee colonies have been studied. Reducing the size of honey cases has positively impacted the bee family's development. In this case, it is simpler for bees to develop without honey in the nest and regular expansion of the beehive with honey cases. Based on a detailed 3-year analysis of changes in the structure of beehives, we have found the hive's optimal structure, which makes it possible to maximize the possibilities of bee colonies in the conditions of the Lipetsk region.

1. Introduction

Among the beekeeping equipment, the hive is the most important, and it must meet the biological necessities of bee colonies and be easy to operate [1]. When choosing the type of hive, it is necessary to consider the honey-borne and climatic conditions and the biological characteristics of the breed of bees used in the area [2]. Beekeeping techniques, the type of products produced and the need to improve productivity in sizeable specialized apiary must also be considered.

Frame hives are divided into two groups: vertical and horizontal. In vertical hives, the honeycomb frames are arranged in several tiers (cases), in horizontal ones in only one-tier. The volume of vertical hives increases with the bee colonies’ growth and honey collection in height, while in horizontal beehives, it increases in width. Frame hives have been in use for several decades, and during this time, their construction is constantly improving [3].

Hive designs also differ in the arrangement of honeycomb frames in the nest relative to the beehive entrance. The honeycomb frames can be arranged perpendicularly (cold way) and parallel (warm way) in relation to the beehive entrance. The honeycomb frames are most often placed in a cold way, ensuring the nest's good ventilation [4].

Nowadays, in addition to combining various constructions and positioning of honeycomb frames inside the hives, there is an active search for innovative materials from which the hive body is made. The most commonly used material to make hives is wood. Foam polystyrene (FP) is one of the most recent alternatives used for beehives. This material beats wood in its characteristics and is preferred for further bee breeding [5]. Studies have shown that FP is harmless to organisms when used under normal conditions [6-9]. Only when FP is heated to 210°C can hazardous substances be produced, which neither bees nor weather can do. Even the bees themselves prefer FP rather than wood because of the best microclimate in the nest. It has good thermal insulation properties that prevent the nest from being heated or cooled from the outside [10].
Although there has been much recent research into the design of beehives and the materials from which they are produced, there is still little information on how they affect bee families' productivity. Therefore, our studies' purpose was to examine the influence of the hives' design and material on the development of bee families in the same natural conditions.

2. Materials and methods
The study was carried out on a private apiary in the Lipetsk region (Russia). For three years, the best hive of the previous season was compared to the hive of another design. The Carpathian breed of bees was chosen for research.

Four different beehive designs with a Dadan-Blatta honeycomb frame were selected for analysis:

- 12-frame wooden beehive with full-size (300 x 435 mm) honeycomb frames;
- 12-frame foamed polystyrene (FP) beehive with full-size (300 x 435 mm) honeycomb frames;
- 10-frame FP beehive with full-size (300 x 435 mm) honeycomb frames;
- 10-frame FP beehive with half-size (145 x 435 mm) honeycomb frames.

The hives' inner part, where the bee families accumulated honey, was called the honey part, and where the new generations were bred called the nest part. The principle of the honey and nest parts' location in various designs of beehives is presented in figure 1.

![Figure 1](image.png)

Figure 1. The honey and nest parts location in hives: with 12 full-size frames (A), with 10 full-size frames (B) and with 10 half-size frames (C) (1 – honey part, 2 – dividing grid, 3 – nest part). The honey is grey; the rising generation is white.

The bee families were selected for analysis with queen bee-sisters, and in April, each occupied six honeycomb frames. Each season, two groups of bees were compared. Each group had ten hives. The bee families in each group were maintained at a similar development stage and occupied only the hive's nesting part before the season. Bee families developed without stimulating feeding, and the anti-mite treatment (against *Varroa destructor* (Acari: Varroidae)) was carried out only with oxalic acid.

3. Results and discussions
In the first season (2017-2018), two groups from multiple-storey beehives with 12 honeycomb frames were compared. The first group of bees evolved in wooden hives, the second in FP beehives with a netted bottom. In May, bees in FP beehives developed more actively and behaved more calmly during warm or cool weather periods. In contrast, in wooden hives, the nest expands in heat and is compressed through cold periods. Late May, bee colonies inside FP hives occupied all the honeycomb frames. Bee
colonies in wooden hives occupied 11 honeycomb frames out of 12, showing less development due to the nest's intermittent compress during the cold.

In early June, the first group of bee families occupied all 12 honeycomb frames. Group II bee colonies were equipped with a second FP hive with a complete set (12 pieces) of honeycomb frames through a dividing grid to limit the queen-bee movement in the body of the first hive. When filling the second hives, the honeycomb frames were gradually moved, and the wax foundation was installed in their place. A warm diaphragm separated the space of the second hive. As of June, the first group of bee families occupied the first hive and the eight honeycomb frames of the second hive, and the nucleus is transferred from them to two honeycomb frames of the sealed brood as an anti-swarming measure. This way, the second group of bees filled out 14 wax foundation in one month, while the first group was only 8.

In July, honeycomb frames were no longer added to both groups of bees. The honeycombs were gradually removed from the second hive at the end of July, replacing them with new empty honeycomb frames. After the honey was collected in mid-August, both groups were relieved of their second hives and began preparing the bees for winter. A comparison of the honey productivity (2017-2018 season) of the two groups of bee families is presented in table 1.

Table 1. A comparison of honey productivity for the 2017-2018 season (a kilo of honey per beehive).

| Feature                      | Beehive number |
|------------------------------|----------------|
|                              | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
| Group I bee colonies (wooden hives) | 41.0 | 38.5 | 42.2 | 40.1 | 39.8 | 43.5 | 41.2 | 42.7 | 37.6 | 41.5 |
| Group II bee colonies (FP hives)    | 52.7 | 54.2 | 50.1 | 49.0 | 51.8 | 53.2 | 50.4 | 48.7 | 51.0 | 52.5 |

In the 2017-2018 season, the first group of bees produced an average of 40.81 kg of honey per hive, while the second group of bees produced an average of 51.36 kg of honey. Thereby, the second group of bee colonies produced ten kilograms more honey and made ten nuclei, which had evolved to eight honeycomb frames by the fall. During wintering, the bee families in the wooden hives ate six honeycomb frames, while the colonies in the FP beehives ate only four frames. Also, bee families in the FP beehives began to develop earlier and already in April, their development was ahead of families from wooden hives.

In the second season (2018-2019), two groups of bee families were compared, each of which was in FP hives with a netted bottom. In the first group, the bees were settled in 12-frame multi-board hives, the second group in 10-frame beehives.

In May, bee families developed in the same way, and by the end of the month, all colonies in the first group occupied their hive complete. From the second group of bee families occupied all ten honeycomb frames, one nucleus has been moved to two honeycomb frames in a sealed brood to eliminate the swarming state.

In early June, the same works were carried out as last season. By this time, the second group of bees had filled the two hives and given not two but three frames of a sealed brood because of a smaller nest. So, all the bee colonies filled 14 wax foundation for one month. However, the second group of bees produced two nuclei each, one of them in May. The May nucleus was wholly developed before the gathering of honey and occupied an entire 10-frame hive. Hence, half-size honeycomb frames were added to the hive for these bee families. Since these bee families were separated from the second group of primary colonies, their honey productivity was taken into account in the cumulative amount of honey collected. A comparison of the honey productivity (2018-2019 season) of the two groups of bee families is presented in table 2.
Table 2. A comparison of honey productivity for the 2018-2019 season (a kilo of honey per beehive).

| Feature                                      | Beehive number |
|----------------------------------------------|----------------|
|                                              | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
| Group I bee colonies (FP 12-frame hives)     | 53.6 | 52.0 | 54.1 | 51.2 | 49.8 | 51.4 | 52.4 | 49.5 | 48.7 | 55.1 |
| Group II bee colonies (FP 10-frame hives)    | 59.7 | 59.2 | 59.5 | 58.7 | 60.2 | 61.0 | 57.2 | 58.4 | 60.4 | 59.4 |
| The May nucleus from Group II                 | 25.8 | 24.7 | 26.4 | 23.0 | 27.4 | 25.2 | 24.5 | 23.7 | 26.8 | 52.7 |

Therefore, through the 2018-2019 season, the first group of bees received an average of 51.78 kg of honey per family, while the second group of bees and their nucleus collected 84.39 kg per colony. The second group of bees in each colony received 30 kilograms more honey and formed 20 nuclei, which evolved into mature families in 10-frame hives.

The third season (2019-2020) compared the development and productivity of two groups of bee families evolving in FP 10-frame hives with a netted bottom. For the first group of bees, a second hive with a full-size honeycomb frame was used (as in previous seasons), while for the other group of bees, the store-bought half-size honeycombs were added inside the hives.

Throughout the season, work on the apiary was carried out on the identical schedule as in previous years. Bee families in both groups developed roughly the same. As the hives had empty half-size honeycomb, the second group of bees redistributed the breeding grounds and honey stocks. Honey, mainly, the bees of this group were stored on empty half-size frames, and the vacant space was filled with other breeding. Being an effect of the diverse positions of the nucleus in the nest, from the second group, apart from the May brood, it was possible to make two more in June, which combined two before collecting the honey. The honey accumulated by these bee families, which had matured into full-fledged colonies, accounted for the total amount of honey collected from the second group of bees. A comparison of the honey productivity (2019-2020 season) of the two groups of bee families is presented in table 3.

Table 3. A comparison of honey productivity for the 2019-2020 season (a kilo of honey per beehive).

| Feature                                      | Beehive number |
|----------------------------------------------|----------------|
|                                              | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
| Group I bee colonies (FP 10-frame hives with | 58.2 | 57.1 | 60.2 | 59.7 | 58.0 | 55.4 | 58.4 | 56.7 | 61.2 | 57.4 |
| a full-size honeycomb)                       | 23.7 | 25.1 | 26.8 | 24.7 | 23.3 | 25.7 | 20.4 | 21.8 | 24.6 | 23.1 |
| The May nucleus from Group I                 | 65.4 | 67.8 | 64.2 | 66.1 | 64.6 | 68.0 | 68.2 | 65.7 | 66.4 | 68.1 |
| Group II bee colonies FP 10-frame hives with | 22.2 | 24.1 | 25.7 | 20.6 | 21.7 | 28.1 | 25.9 | 27.7 | 24.1 | 26.1 |
The June nucleus from Group II

|       | 25.4 | 20.8 | 21.7 | 22.4 | 25.8 | -    | -    | -    | -    |

On average, the first group of bees (together with their nucleus) collected 82.15 kg of honey per colony, and the second group (along with their nucleus) received 114.61 kg of honey. The second group of bees collected 30 kilograms more honey per colony. Throughout the season, they also produced 25 nuclei which evolved into mature families in 10 frame hives.

4. Conclusion

In summary, bee families, utilising the vacant space in the hive, redistribute the store of honey in such a way as to increase the area for geniture in the nest. That improves the vitality of bee families and increases the amount of honey collected. Besides, store-bought extensions for hives with half-size honeycomb frames are more convenient at the expense of lighter weight. If placed through a dividing grid, when cold falls occur, bee families can cut to a minimum in the nesting part of the hive without sacrificing their descendants.

Acknowledgments

The authors would like to acknowledge Russian Foundation for Basic Research for their financial support of investigations (grant № 20-34-90045).

References

[1] Komlackij V I, Loginov S V and Svistunov S V 2012 Beekeeper’s Handbook (Rostov-on-Don: Fenix)
[2] Krivtsov N I, Kozin R B, Lebedev V I and Maslenkova V I 2010 Beekeeping: Textbook (Saint Petersburg: Lan)
[3] Tikhomirov N A 2013 Beekeeper’s Handbook (Kharkov: Folio)
[4] Lebedev V I and Bilash N G 1991 Biology of the Honeybee (Moscow: Agropromizdat)
[5] Prendergast K S 2019 Scientific note: mass-nesting of a native bee Hylaeus (Euprosopoides) ruficeps kalamundae (Cockerell, 1915) (Hymenoptera: Colletidae: Hylaeinae) in polystyrene Apidologie 51(1) 107-11
[6] MacIvor J S and Moore A E 2013 Bees collect polyurethane and polyethylene plastics as novel nest materials Ecosphere 4(12) 1-6
[7] Hassan A H, Kamel S M, Osman M A M, Mahmoud M F, Bedeir E H and Shebl M A 2016 Conservation of the mason bees Osmia latrellei Spinola (Hymenoptera Megachilidae) in Egypt Egyptian Journal of Applied Science 31(6) 73-84
[8] MacIvor J S 2016 Cavity-nest boxes for solitary bees: a century of design and research Apidologie 48(3) 311-27
[9] Wang K, Li J, Zhao L, Mu X, Wang C, Wang M, Xue X, Qi S and Wu L 2021 Gut microbiota protects honey bees (Apis mellifera L.) against polystyrene microplastics exposure risks Journal of Hazardous Materials 402 123828
[10] Starks P T and Gilley D C 1999 Heat shielding: a novel method of colonial thermoregulation in honey bees Naturwissenschaften 86(9) 438-40