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STUDY ON THE HERITABILITY OF SOME MORPHO-PRODUCTIVE CHARACTERS OF APIS MELLIFERA CARPATICA BEE FAMILIES POPULATED IN THE ZONE OF CENTER OF THE REPUBLIC OF MOLDOVA

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Abstract

The aim of the research was to identify the degree of heritability of main biological morph-productive characters of Apis mellifera carpatica bees family to streamline the process of genetic improvement of bee populations. The research was performed on the population of experimental bee apiary of the Institute of Zoology of the Academy of Sciences located stationary in a forest glade in the center of the country. It was studied heritability of major morpho-produtive characters such as queen prolificacy, family strength, brood viability, resistance to disease and the amount of honey gathered in the nest. The heritability coefficient of morpho-productive characters was calculated by the method h^2 *based on determining the genotype correlation of the above mentioned characters at 20 pairs of mother-daughter families. Research results have shown that between homologous characters of mother families and daughter families exist a genotypic correlation at different levels, from below average until strong, depending on selected character and the amplitude of the phenotypic variability of character. It was found that the genotypic correlation between mothers and daughters characters is enough strong at characters with narrow phenotypic variability, such as: disease resistance, queen prolificacy and family strength, and lower at characters with wider phenotypic variability, such as brood viability and the amount of honey gathered in the nest. The amount of genotypic correlation coefficients* (r_{mf}) *of characters from the first group varies within the limits of* $r_{mf} = 0.78 \pm 0.05$ *and* $r_{mf} = 0.85 \pm 0.03$*. The coefficient of heritability* (h^2) *of these characters being also at a high level, in the range of 0.61 to 0.72 having a certitude of the highest threshold of the theory of probability forecasts without error after Student (P<0.001). At the morpho-productive characters from the second group, such as, the brood viability and the amount of honey gathered in the nest, the genotypic correlation had an average level, comprised within the limits of 0.60 ± 0.09 and 0.56 ± 0.09 with enough high certitude, and the coefficients of heritability of these characters were at below average level, in the range of 0.36 0.31 (P< 0,01). The obtained results of researches of heritability of principal biological morpho-productive characters have been used to elaborate the plan for genetic improvement of bee families and prediction selection effect, calculated by the formula* $E_s = h^2 \cdot d$, *where:* E_s *- selection effect of selected character obtained in a generation;* h^2*- heritability coefficient of selected character;* d *- the differential of selection, calculated by the formula:* $d = M_{lp} - M_{st}$*, where:* M_{lp}*- the average value of selected character on families of bees from the breeding stock;* M_{st}*- the average value of the selected character on the bee families from whole apiary. The selection effect of bee families by morph-productive biological characters from first group, with the heritability coefficient* (h^2) *over average, was bigger than the effect achieved in selection of bee families by the characters in the second group, the coefficient of heritability* (h^2) *below average.*

Keywords**:** *honeybee, morpho-productive characters, phenotypic correlations, heritability.*

INTRODUCTION

According to heredity legalities, the genetic information movement, determines all heredity elements: information inheriting from parents, the genotype formation in zygote, basic protein synthesis, organism development under certain life conditions (ontogenesis), its basic reactions to the exterior actions (the reaction norm), the formation of sexual cells and fusion of male and female gametes in the descendant's zygote, (Плохинский Н.А., 1969). The measure (degree), in which parents heredity can be accomplished (transmitted) to the descendant, has held concerned the researchers since a long time. Multiple researches, in this field (Boeking, 2000; Collins, 1984; Ridnerer, 1986; Siceanu, 2005; Siceanu A., 2012; Билаш, 1991; Ильев, 1984), have shown that some morpho-productive characters of bee families

have a greater heredity (inheritance) degree, and others - a lower inheritance degree. This phenomenon in the genetics of populations gave rise to the concept of heritability. The absolute value of the heritability is expressed by coefficient of hereditary transmission, or hereditary coefficient (h^2), which is nothing as the share (measure), which occurs the genotype in formation of given character (Iliev, 1992), or the variability share, determined by heredity (genotypical variability) in the total phenotypic character's variability (Билаш and Кривцов,1991). Given the fact, that the heritability coefficient determines, through calculation formula, directly, the selection efficiency ($Es = h^2 \cdot d$) according to a certain, concrete character, it (the coefficient h^2) becomes one of the most important criteria of population genetics. As bigger the heritability coefficient of a morpho-productive character is, so more efficient its selection will be, and, conversely, as lower the heritability value is, so the selection efficiency by this character will be tougher. Depending on its size, some researchers (Борисенко, 1967) classify the heritability coefficient in: the high level coefficient $h^2 > 0.6$; the middle level coefficient (medium) $h^2 = 0.4 – 0.6$; the low level coefficient $h^2 < 0.4$. Other researchers (Bucătaru, 1993) divide the characters, by the heritability coefficient value (h^2), into three categories: intense heritable characters, where $h^2 > 0.4$; middle heritable characters, where $h^2 = 0.2 – 0.4$ and weak heritable characters, where $h^2 < 0.2$.

Some notorious researchers in animal livestock (Борисенко,1967) reported that, giving a significant importance to heritability as an index of a possible efficiency of the selection , follows, but it must be taken in account, that, the heritability coefficients of the same characters, calculated by the same method, at the different animal breeds, populations, herds, are not the same.

For these reasons, actually, to the heritability coefficient is assigned a major role in the genetic amelioration of livestock population, being determined the h^2 values for almost all main characters and traits of the animal breeds and populations.

In beekeeping, the determination of heritability coefficient of main morpho-productive characters becomes a technological selection procedure of bee families populations, in the works of Кривцов (1980), Collins (1984), Rinderer (1986), Билаш (1991), Boeking (2000).

Researches, concerning the determination of heritability degree of morph-productive characters at *Apis mellifera carpatica* bee families populations, inhabited in the Republic of Moldova, basically, have not been carried out.

In this context, taking into account, the above mentioned, we proposed the research purpose, to identify the heritability degree of some main biological morph-productive characters of *Apis mellifera carpatica* bee colonies, in order to make more efficient the genetic amelioration process of their population.

MATERIALS AND METHODS

The work was carried out, within the institutional applied project: code 11.817.08.17A "Elaboration of performance technology of diversified growth and exploitation of *Apis mellifera carpatica* bee families".

The research has been done on the bee colonies population of experimental apiary of Institute of Zoology of Science Academy from Moldova, located at the stationary, in a forest glade, at the canton no. 9 of Ghidighici forest district, Chisinau. The main melliferous sources from this area were: white acacia (*Robinia pseudacacia*), wide leaf linden (*Tilia cordata Mill*) and spontaneous polyfloral. It has been investigated the heritability of some main morpho-productive characters, such as, the queen's prolificacy, the bee family strength, the brood's viability, the resistance to disease, and the honey quantity gathered in the nest during the linden harvest.

Determination of bee families morpho-productive characters was carried out, according to the methodology developed by us (Cebotari, 2010), for livestock norm, concerning bee families assessment, raising and certification of beekeeping genitor material (Standard livestock for bee families, growth and certification of genitor beekeeping material, 2011).

The heritability coefficient of morpho-productive characters, was calculated by the method h^2, based on the genotypical correlation determination of the characters mentioned above, at 20 pairs of mothers-daughters families (r_{mf}).

The queens prolificacy (eggs/24 hours) was determined during the revision, in late spring (May 28), by dividing the number of cells with capped brood in the nest, by 12 (lifecycle of capped brood development, days), resulting from the eggs number, laid in 24 hours.

The bee family strength has been assessed, by determining the amount of the bees in the nest, at the evaluation moment. By multiplying the number of intervals between frames, filled, uniformly, with bees, for the coefficient of 0.25 for the standard frame Dadant (435x300 mm), was determined the bees amount in kilograms. The strength evaluation of mothers bee families, have been carried out, three times, during the active season. After these three feedback, was determined the average strength of the bee family. The strength of bee families daughters was evaluated only one time, before linden harvest.

The broods viability, as at mothers families, as well at daughters families, was determined by the average of second evaluation, carried out in June, by reporting the number of cells with survived larvae at 4^{th}-5^{th} day after laying, by the total number of cells from the marked surface on the honeycomb, layed compactly with 400 cells (10 x 10 cm), expressed as a percentage. The assessment has been done, twice a year, in every bee family, settling on the average of first two evaluations.

The disease resistance was determined by evaluating the bee families hygienic behaviour, according to the standard test, whereby the brood, on a compact surface, was killed artificially, in order to establish the speed and the accuracy, wherewith the bees identify and remove the dead brood. The evaluation was carried out, during May-July, twice, for the same bee families, under the same environmental conditions and at equal intervals of time. The brood was killed, in the capped stage (stern), by pricking with a fine needle, through the cells cap, on a honeycomb portion from the family's nest, on a square surface of 5 x 5 cm (100 cells), marked, in the corners, with matches. After 24 hours, since the introduction of the comb, into the nest, was evaluated the cells number, from which has been removed the brood. The ratio, between the removed brood and initially killed brood, on the marked honey comb surface, expressed as a percentage, represented the resistance to disease.

The honey quantity, gathered by bees in the nest, was determined during the linden harvest, by weighing frames with honeycombs and diminishing (from their total weight) the total weight of standard combs with frames without honey: for the frame type Dadant (435x300 mm) – 0.6 kg, for the frame type Langstroth (435x230 mm) – 0.5 kg.

The data obtained from research, was processed statistically, using computer software "STATISTICA–6" and was evaluated their certainty, according to variational biometric statistics, by the methods of Плохинский, 1969 (Iliev, 1992).

RESULTS AND DISCUSSIONS

The correlative links research results of the biological morph-productive characters of *Apis mellifera carpatica* bee families from apiary of Institute of Zoology of the ASM, showed that between homologous characters of mothers families and daughters families, there is a genotypical correlation of different levels, from medium to strong, depending on the selected character and amplitude of character's phenotypic variability (Table 1).

Thus, it was found, that the genotypic correlation, between mothers and daughters characters, is strong enough at the characters with low phenotypic variability, such as: resistance to disease, queens prolificacy, family strength, and weaker at characters with wide phenotypic variability, such as brood's viability and the honey quantity gathered in the nest.

Table 1. Genotypical correlation of some morph-productive characters of the *Apis mellifera carpatica* bee colonies from apiary of Institute of Zoology of ASM

No.	Selected character	N	$r_{mf} \pm m$	N_{st}	*P*	h^2	*Cv%*
1	Queens prolificacy, eggs/day	20	0.80 ± 0.04	12	0.001	0.64	5.8
2	Family strength, kg	20	0.78 ± 0.05	13	0.001	0.61	6.3
3	Broods viability, %	20	0.60 ± 0.07	17	0.01	0.36	8.4
4	Resistance to disease, %	20	0.85 ± 0.03	10	0.001	0.72	3.2
5	Honey quantity gathered in the nest, kg	20	0.56 ± 0.09	20	0.01	0.31	22.1

The genotypical correlation coefficients value (r_{mf}) of characters from the first group, varies within the limits contained in the r_{mf} = 0.78 ± 0.05 and r_{mf} = 0.85 ± 0.03. The heritability coefficient (h^2) of these characters is, also, of high level, within the range of 0.61 – 0.72, with a certainty of the highest threshold of probability theory of forecasts without error according to Student (P<0,001). For the morpho-productive characters of the second group, such as, the broods viability and the honey quantity gathered in the nest, the genotypical correlation was of average level, comprised within the limits of 0.60 ± 0.09 and 0.56 ± 0.09, with a quite high certainty, and the heritability coefficients, of these characters, were of bellow average level, comprised within 0.36 – 0.31 (P<0.01).

We have found that the strongest genotypical correlation was registered for the character of resistance to disease, which reflects, in fact, the hygienic instinct of bee families. This correlation is obviously reflected in Table 2 and Figure 1.

Table 2. Resistance to disease of mothers families and daughters families

Classes of resistance to disease, %	**Resistance to disease, %**			
	Mothers families		**Daughters families**	
	N	**M ± m**	**N**	**M ± m**
92 – 94	8	93.0 ± 0.2	11	93.1 ± 0.3
89 – 91	11	90.1 ± 0.2	7	90.3 ± 0.3
86 – 88	1	86.5 ± 0.0	2	86.0 ± 0.2
Average	**20**	**91.1** ± 0.4	**20**	**91.2** ± 0.4

The research has shown that, once with the increasing of resistance to diseases of mothers families, it is noted, almost directly proportional, the increase of resistance to diseases in daughters families. Thus, once with the increasing of resistance to diseases of mothers families from 86.5 ± 0.0 % up to 90.1 ± 0.2%, or with 4.2%, the value of this character at the daughters families increases from 86.0 ± 0.2%, up to 90.3 ± 0.3%, or 5%.

The genotypical correlation coefficient r_{mf} = 0.85 ± 0.03 indicates the fact that this selection character is not an alternative one, but it is one qualitative-quantitative, with a very high genetic determinism. In fact, we sustain the opinion of researchers (Крушинский, 1993), who affirm, that the hygienic behaviour (resistance to diseases) of bee families, "is not a native instinct, not even an obtained character, but it is formed as a result of the mutual interaction between genes and environment".

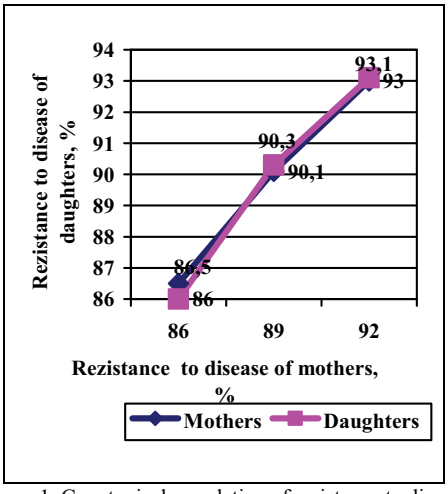

Figure 1. Genotypical correlation of resistance to disease of mothers families and daughters families

The high heritability coefficient (h^2 = 0.72) shows that, the variability share, determined by the genotype in the total phenotypic variability, constitutes 72%, and only 28% of this character's phenotypic variability is determined by environmental conditions. In order to compare, we mention, that Collins et al. (1984) have established such a high heritability coefficient (h^2 = 0.83 – 0.93) at the bee families

defence behaviour, which can be made as a parallel to the hygiene behaviour.

A quite high genotypical correlation, between mothers families and daughters families, was recorded as well, for the queens prolificacy character (Table 3 and Figure 2).

The dependence of daughters queens prolificacy, on mothers queens prolificacy is also quite pronounced, as well as the character of resistance to diseases.

Table 3. Prolificacy of mothers queens and daughters queens

Prolificacy de classes, eggs/day	**Queens prolificacy, eggs/day**			
	Mothers families		**Daughters families**	
	N	**M ± m**	**N**	**M ± m**
1800 – 1899	2	1833 ± 0	6	1837 ± 8
1700 – 1799	7	1761 ± 12	7	1774 ± 12
1600 – 1699	5	1643 ± 12	7	1649 ± 8
1500 – 1599	6	1556 ± 17	0	0 ± 0
Average	**20**	**1677 ± 23**	**20**	**1749 ± 19**

Thus, once with increasing of mothers queens prolificacy from 1643 ± 12 eggs/day up to 1761 ± 12 eggs\day, or with 7,2%, while the daughters queens prolificacy raised from 1649 ± 8 eggs/day until 1774 ± 12 eggs\day, or with 4,6%.

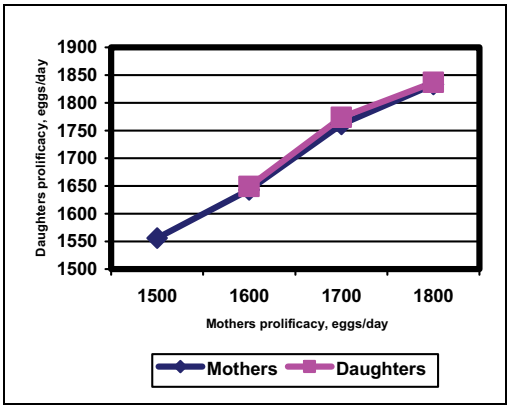

Figure 2. Genotypical correlation of prolificacy of mothers queens and daughters queens

From the graph illustration, we can see that the lines, which reflect the prolificacy of mothers queens and daughters queens raise almost simultaneously to the respective prolificacy levels.

The research results of prolificacy genotypical correlation, prove that, this morpho-productive biological character , of an extraordinarily high importance for the bee family, is also, one quantitative, with a very high genetic determinism. Both the genotypic correlation coefficient (r_{mf} = 0.80 ± 0.04) and the heritability coefficient (h^2 = 0.64), being quite raised, denotes, that the genotypical share of variability value of this character in the total phenotypical variability is quite big - 64%, and the paratypical variability rate, determined by environment, constitutes only 36%. In order to compare, we can mention that Кривцов (1976) had obtained in his research such a heritability coefficient of prolificacy high enough (h^2 = 0.57). This can be explained, primarily, by the genetically determined prolificacy potential of the queen, and, secondly, by the fact that working bees, with their inexhaustible diligence of the queens care, maintain the environmental variability share in the total variability of this character at the minimum possible level.

The bee family strength is a character directly determined by the amount of capped brood in the nest. Given the fact, that the amount of capped brood is obtained, as a result of laying (prolificacy) of the queen, and subsequently, determines, decisively, the quantity of the bee in the nest, the correlative connections between these morph-productive characters are pretty tight. Therefore, the genotypical correlation of the bee family strength (Table 4, Figure 3) has a similar tendency as the queens prolificacy.

It was found, that once with the increasing power of mothers families strength, occurs a significant increase of the daughters families strength.

Table 4. The strength of mothers queens and daughters queens

Strength classes, kg	**Families strength, kg**			
	Mothers families		**Daughters families**	
	N	**M ± m**	**N**	**M ± m**
3.00 – 3.24	14	3.13 ± 0.03	-	-
2.75 – 2.99	6	2.87 ± 0.02	-	-
2.50 – 2.74	-	-	-	-
2.25 – 2.49	-	-	2	2.27 ± 0.02
2.25 – 2.49	-	-	18	2.13 ± 0.02
Average	**20**	**3.06 ± 0.04**	**20**	**2.14 ± 0.02**

So, the quantitative level of the daughters families strength, composed of swarms in spring, is lower, compared to the strength of

mothers families, the genotypical correlation of this character is pretty close, being on average r_{mf} = 0.78 ± 0.05. Hence, also the heritability coefficient, of the bee family strength, is high h^2 = 0.61 (P<0.001) and, significantly, with the highest certainty threshold of the probability theory of forecasts without error according to Student.

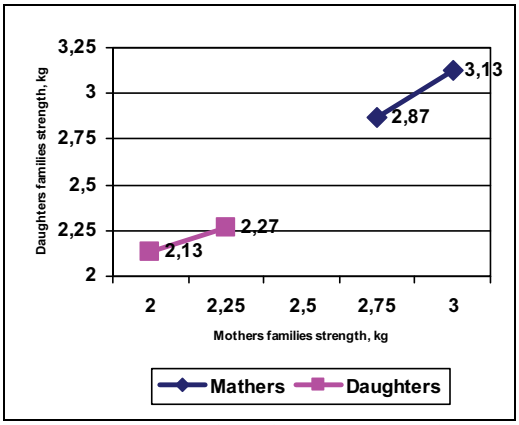

Figure 3. Genotypical correlation between mothers families strength and daughters families strength

Based on the obtained data, we can affirm, that, the bee family strength is a biological morpho-productive quantitatively determined character, mostly (61%), of the family genotype, and influenced, although less (39%), but quite significant, by environmental factors.

Heritability research by another groups of bee families morpho-productive biological characters with a larger phenotypic variability, such as brood's viability and honey quantity gathered in the nest, has shown, that, the genotypical correlation of these characters between mothers families and daughters families has the same tendency, except that the genotypical correlation coefficient value **(r_{mf})** is of average level, and of heritability coefficients **(h^2)** - of bellow average level.

Thus, the genotypical correlation of brood's viability, between mothers families and daughters families, represents, on average, **r_{mf}** = 0.60 ± 0.07, and heritability coefficient value - **h^2** = 0.36 with a quite definite significance (P<0.01).

From obtained data, it was found, that, increasing the brood's viability of mothers families-mothers, leads, moderately, to the brood's viability increasing in daughters families (Table 5, Figure 4).

Once with brood's viability increasing in mothers families from 88.1 ± 0.0% up to 90.0 ± 0.3%, or with 2.2%, will increase also the brood's viability from daughters families, from 87.5 ± 0.0% up to 90.2 ± 0.3%, or with 3.1%. With the continued increase of brood's viability in mothers families from 90.0 ± 0.3%, up to 95.5 ± 0.0%, or with 6.1%, will increase also the brood's viability in daughters families, from 90.2±0.3% up to 95.0±0.0%, or with 5.3%.

Table 5. Broods viability at mothers families and daughters families

Broods viability classes, %	**Broods viability, %**			
	Mothers families		**Daughters families**	
	N	**M ± m**	**N**	**M ± m**
95 – 96	1	95.5 ± 0.0	1	95.0 ± 0.0
93 – 94	-	-	3	93.5 ± 0.1
91 – 92	13	91.7 ± 0.2	11	91.7 ± 0.2
89 – 90	5	90.0 ± 0.3	4	90.2 ± 0.3
87 - 88	1	88.1 ± 0.0	1	87.5 ± 0.0
Average	**20**	**91.3** ± 0.3	**20**	**91.6** ± 0.4

Despite the fact, that, the character's variability of brood's viability is not so big (but only 8.4%), the size of the heritability coefficient is bellow average (0.36). It denotes, that the variability rate, determined by the genotype in the general phenotypic variability, is only 36%, whereas, the paratypical variability share, determined by environment is predominant (64%). The decisive environmental factors, which influence the variability of this important biological character can be some diseases, which are affecting the brood. Hence, it results the conclusion that the selection effectiveness performed according to brood's viability will always be lower than that of characters with a higher heritability coefficient.

Last, and most important biological morpho-productive character of bee families, examined by us, in order to establish the heritability, is the honey quantity gathered in the nest (Table 6, Figure 5). The research has shown, that, between the honey quantity gathered in the nest of mothers families and the honey quantity gathered in the nest of daughters families, is a genotypical correlation of middle level (r_{mf} = 0.56 ± 0.09) and a heritability coeficient of bellow average level (h^2 = 0.31).

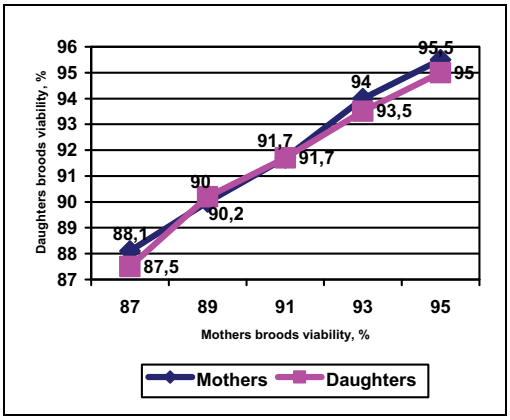

Figure 4. Genotypical correlation of brood's viability between mothers families and daughters families

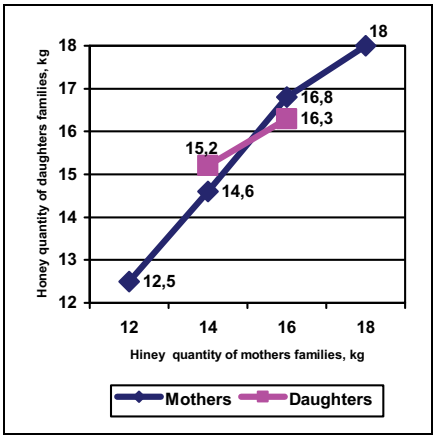

Figure 5. Genotypical correlation of honey quantity gathered in the nest by mothers families and daughters families

Table 6. Honey production gathered in the nest by mothers families and daughters families

Honey quantity classes, kg	Honey quantity, kg			
	Mothers families		Daughters families	
	N	M ± m	N	M ± m
18 – 19	4	18.0 ± 0.0	-	-
16 – 17	7	16.8 ± 0.2	4	16.3 ± 0.1
14 – 15	5	14.6 ± 0.2	16	15.2 ± 0.1
12 – 13	4	12.5 ± 0.3	-	-
Average	**20**	**15.6** ± 0.5	**20**	**15.4** ± 0.2

In order to compare, we mention that, in researches of various authors, the heritability coefficient of honey production of honey is, also, low and varies within limits: 0.23 (Rinderer, 1986); 0.22-0.23 (Билаш, 1991); 0.22-0.25 (Siceanu, 2005).

The Table 6 shows, that once the character value of honey quantity gathered in the nest by mothers families increases, from 14.6 ± 0.2 kg up to 16.8 ± 0.2 kg, or with 15.1%, will be noted an increase of the honey quantity gathered in the nest by daughters families, from 15.2 ± 0.1 kg up to 16.3 ± 0.1 kg, or with 7.2%. The honey quantity gathered in the nest, being a biological morpho-productive character, with the highest phenotypical variability (22.1%), compared to the other biological morpho-productive characters of bee families, has the weakest genotypical correlation between mothers families and daughters families and the lowest heritability coefficient.

This fact denotes, that the genotypical variability rate, determined by heredity in general phenotypical variability of this character, is lower, compared to the other characters, and it is only 31%. Otherwise, the paratypical variability rate in total phenotypical variability of the honey quantity gathered in the nest, prevails, and is determined, mostly preponderant (69%), by the environment factors, such as: harvest melliferous resources, weather conditions, bee families care and maintenance technology, prevention and control of diseases etc.

The results of heritability researches, of the main biological morph-productive characters, obtained by us, are used in the selection process, for bee families genetic improvement plan development and prediction of selection effect, calculated by the formula:

$$E_s = h^2 \cdot d$$

where:

E_s – selection effect of selected character in a generation;

h^2 – heritability coefficient of selected character;

d – selection diferential, calculated by the formula:

$d = M_{lp} - M_{st}$,

where:

M_{lp} – selected characters average value per a bee family from the breeding batch;

M_{st} - selected character's average value per a bee family from whole apiary.

Based on the above mentioned formula, it is clear that the selection efficiency carried out at the apiary of IZ ASM, was bigger at the characters with a higher heritability coefficient such as: resistance to diseases (hygienic instinct), which reached, recent years, the average level at the apiary high enough - up to 90-95%, the broods viability up to 90-94%, quuens prolificacy - 1700 -1800 eggs/day and family strength – 3.0-3.2 kg, while the honey production of bee families, reached in recent years, the level of only 35-40 kg.

The selection effect value varies, depending on the year, selection intensity and, widely, on weather conditions of the respective year.

CONCLUSIONS

According to the heritability coefficient ($\mathbf{h^2}$), the main biological morph-productive characters of *Apis mellifera carpatica* bee families of researched population, can be divided into two groups: the first group - qualitative-quantitative characters with a high genetic determinism and narrow phenotypical variability, whose heritability coefficient $\mathbf{h^2}$ is comprised within the limits of over average of 0.6-0.75; the second group - quantitative characters with reduced genetic determinism subsided and large phenotypical variability, whose heritability coefficient $\mathbf{h^2}$, is contained within the limits of bellow average 0.3-0.4.

The bee families selection effect by biological morpho-productive characters of Ist group, with heritability coefficient ($\mathbf{h^2}$) over average, is much bigger, than the effect achieved in the bee families selection by characters from the second group, with the heritability coefficient ($\mathbf{h^2}$) bellow average.

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