UDC 575
DOI: 10.2298/GENSR1201047J
Original scientific paper

HERITABILITY OF PRODUCTION CHARACTERISTICS OF REGIONAL POPULATIONS OF HONEY BEES FROM SERBIA

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Jevtić G., B. Anđelković, Z. Lugić, J. Radović and B. Dinić (2012): *Heritability of production characteristics of regional populations of honey bees from Serbia* . - Genetika, Vol 44, No. 1, 47 - 54.

In this experiment, colonies of six regional populations from the territory of the Republic of Serbia were included, and two generations (maternal colonies and their offspring) were observed. In two inspections (fall and spring), production traits and temperament were observed. Daughter queen bees mated in uncontrolled conditions (free-mating) in order to determine heritability of production traits in terms of practical beekeeping. The heritability coefficients (h^2) for production traits calculated. It was found that the honey yield was mostly determined by genetic, but environmental conditions also had significant influence. Heritability for honey yield (h^2) ranged from 72.72% (Rasina population) to

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81.04% (Banat population). Colony strength was very dependent on external factors, but also from the very population. When it comes to food supply (honey and pollen), in the inspections, large differences in the heritability coefficient were determined, which is explained by the interaction of genetic factors (the foraging instinct) and environmental factors (honey flora and climatic conditions during foraging) and the influence of beekeepers (feeding, etc.).

Key words: honey bee, heritability, .regional populations, production traits, temperament, yield

INTRODUCTION

Heritability allows a comparison of the relative importance of genes and environment to the variation of traits within and across populations. The concept of heritability and its definition as an estimable, dimensionless population parameter was introduced by Sewall Wright and Ronald Fisher nearly a century ago. Despite continuous misunderstandings and controversies over its use and application, heritability remains key to the response to selection in evolutionary biology and agriculture (VISSCHER *et al.* 2008). Heritability estimates vary between 0 and 1 and can be expressed in percents. If a trait has an h^2 close to 1, then it can be changed rapidly by selective breeding. If $h^2 = 0$, selective breeding will fail. For a particular inherited trait, a high h^2 value indicates a greater influence of genetic factors while a lower value indicates a stronger influence of environmental factors (STANIMIROVIĆ *et al.* 2008). Honey bee colonies are characterized by specific behavior and the development cycle, which is greatly influenced by environmental factors and by the factors inside the hive. The main complication in the estimation of heritability of colony traits in honeybees arises from the fact that many characters of economic value are affected by the combined activity of many workers (hoarding behavior, life-span, production of and reaction to isopentyl acetate, etc) and the queen (laying capacity, pheromone production, etc), (BIENFELD and PIRCHNER 1990). The aim of this study was to determine the heritability coefficients for production traits and traits that determine the temperament of colonies of the six regional populations of honey bees from Serbia.

MATERIALS AND METHODS

The experiment was conducted in the apiary of the Institute for forage crops Kruševac. The colonies of regional populations of honey bees (Rasina, Pešter, Morava, Banat, Timok and Kopaonik) were used for this study, three colonies per group. The experiment was set as random plan. The study lasted for four years, and in the first two years queen bee mothers were studied, and in the third and fourth the offspring of selected mothers. In the second year, based on obtained data, from selected queen bees offspring queens were obtained which mated freely in uncontrolled conditions with available drones. The amount of bees, brood area, honey and pollen per colony were estimated visually during the spring and fall inspections. These traits are expressed as the occupied portions of frames (1/10) or as

percentage (SL. GLAS. R.S., 1996). Honey yield was determined as the total honey seized from the colony plus the honey that is left for the winter. The traits that define temperament of colonies were, also, determined during inspections. Aggressiveness was determined on the basis of how bees behaved during the inspections and evaluated by numerical grades 4-1 (MLADENOVIĆ, 2006): 4 - very calm, 3 - calm; 2- agitated (move from brood to the honey), 1 - irritable (leaving the comb or gather in groups). The tendency to swarm and honey robbing were also evaluated numerically, with grades 4-1 (4 - very good, 3 - good bees, 2 – poor, 1 – not satisfactory) depending on whether there was natural swarming impulse in the colony. Only the queens graded with 4 are retained in the further selection.

To determine the heritability, broad sense heritability definition was used.

$$h^2 = \frac{Var(G)}{Var(P)} * 100$$

Broad sense heritability (h^2) is reflected in the contribution of genetic effects on phenotypic variance of the population, including additive, dominant and epistatic (multigenic) interactions, as well as maternal and paternal effects (KEMPTHORNE, 1957). For the calculation of variance ANOVA was used and differences between populations were tested using Fisher's and Student's tests. For calculations, the computer program Statistica 8.0 (StatSoft) was used. This model was chosen because of the uncontrolled conditions in which the queens were mating.

RESULTS AND DISCUSSION

The highest yield was determined in the colonies from Rasina region and the colonies from Kopaonik population had the lowest yield. Regarding the yield of honey, determined average heritability was very high, and average value was 76.79%. The highest value was 81.04% in the colonies from Banat population, and the lowest was 72.72% in Rasina population. Heritability coefficients in Timok and Pešter populations were slightly higher, and in the Morava and Kopaonik somewhat lower than the determined average value (Table 1). Studying the honey yield is often difficult because, in addition to genetics, a big impact on this trait is of other factors such as weather conditions, vegetation, the colony strength, lifespan of worker bees (MILNE 1980), brood amount (GEORGIEV and PLAVŠA 2005) and other factors. MILNE (1985) had reported significantly lower values for heritability coefficients when it comes to this trait (18.8%), noting that the queen bees were mating under controlled conditions in his research. KRAUS *et al* (2005) determined that bz controling the conditions, queen bee matings can be significantly improved. The honey yield had medium strong and strong correlation with the colony strength, while compared with food reserve it had a low coefficient (JEVTIĆ *et al*, 2011).

The occurrence of swarming severely reduces honey yield. In addition to the genetic factors, great impact on this trait also has external conditions (HEPBURN 2006). By variance analysis, it was determined that origin had very significant influence on aggressiveness ($P<0.01$), and significant influence on swarming

(P<0.05), while there were no significant influence on honey robbing. The obtained value of heritability coefficients for swarming in colonies of different populations was average 28.62% and was very consistent. Deviation was only found in colonies of Banat population, where it was significantly lower than the average heritability (10.81%). The highest heritability coefficients were determined in the colonies of Rasina, Morava and Timok populations. Carniolan honey bee has a strong tendency to swarm but this trait may be affected by selection, (KULINČEVIĆ *et al.* 1997).

Table 1. Average values and heritability coefficients (%) for yield and temperament in bee colonies from six regions in Serbia

	Honey yield (kg)		Assessed swarming		Assessed temperament		Assessed honey robbing	
Populations	$\bar{X}$	h^2	$\bar{X}$	h^2	$\bar{X}$	h^2	$\bar{X}$	h^2
Rasina	38,90	72,72	3,83	33,33	3,67	10,81	3,58	35.28
Pešter	33,86	77,93	3,92	27,59	2,58	33,33	3,67	38.15
Morava	38,87	74,29	3,58	33,33	3,67	88,89	3,58	51.12
Banat	38,07	81,04	3,50	10,81	3,75	21,43	3,58	37.75
Timok	32,55	79,64	4,00	33,33	4,00	33,33	3,42	42.36
Kopaonik	30,04	75,14	3,92	33,33	3,58	27,59	3,50	32.54
Average	**35,38**	**76,79**	**3,79**	**28,62**	**3,54**	**35,90**	**3,55**	**39,53**
F	2,07 ^{ns}		2,49*		9,83**		0,09 ^{ns}	
LSD 0.05	7,10		0,33		0,44		0,46	
0.01	9,43		0,44		0,59		0,62	

The average heritability value for aggressiveness was 35.90%, deviations were in Rasina population where it was very low (10.81%) and in Banat population, where it was very high (88.89%). Aggressiveness of honey bee colonies mainly depends on their origin, although the results suggest that there was a significant influence of external factors. BIENFELD *et al.* (1989) claim that the aggressiveness is affected by queen bee phenotype and VELTHUIS (1977) claims that it is caused by differences in the amount of the queen pheromone secretion.

Heritability for honey robbing was 39.53% and was quite consistent among all regional populations. There were some variations in the colonies from Morava population where it is slightly higher (51.12%). JEVTIĆ *et al*. (2007) have determined that the occurrence of honey robbing depended on the origin, but also, on the strength and temperament, so weaker and calmer colonies have had trouble defending themselves.

All production traits of honey bee are highly dependent on external factors. The origin had significant impact on the amount of honey and pollen per colony (P<0.05). The heritability coefficient of production traits is very low because it is greatly affected by the environment (MLADENOVIĆ and MIRJANIĆ 2003). The

heritability coefficients derived from the spring inspections for the amount of bees varied greatly and ranged from 7.28% to 77.13%. A similar situation is in the amount of honey in colonies in the spring inspection (Table 2). There were some variations in heritability coefficients between regional populations for brood amount and the amount of pollen in the spring inspections. The amount of pollen per colony was greatly affected by the amount of brood (GEORGIEV and PLAVŠA 2005) and the colony strength (JEVTIĆ *et al*. 2005).

Table 2. Average values and heritability coefficients (%) for production traits (1/10 of frame) of honey bee colonies from six regions of Serbia (spring inspections)

	Amount of bees		Amount of brood		Amount of honey		Amount of pollen	
Populations	$\overline{X}$	h^2	$\overline{X}$	h^2	$\overline{X}$	h^2	$\overline{X}$	h^2
Rasina	6,16	53,69	2,67	80,23	3,68	59,65	0,54	12,51
Pešter	4,64	7,82	2,07	40,13	3,97	4,53	0,50	33,33
Morava	6,63	77,13	3,09	49,03	3,21	10,81	0,68	33,33
Banat	5,62	33,49	2,79	64,96	2,47	68,29	0,57	31,17
Timok	4,92	40,92	2,12	55,93	3,48	14,28	0,31	50,36
Kopaonik	5,06	12,53	2,39	40,11	2,65	18,82	0,42	57,14
Average	5,51	37,60	2,52	56,56	3,24	29,40	0,50	36,31
F	$1,28^{ns}$		$0,81^{ns}$		3,12*		2,37*	
LSD 0.05	1,93		1,25		0,87		0,24	
0.01	2,57		1,66		1,16		0,31	

Heritability coefficients in the fall inspections for the amount of bees and honey were slightly higher, and for the amount of brood and pollen were slightly lower than the values obtained for these traits in the spring inspections (Table 3). The amount of honey is dependant on the amount of bees per hive, while the amount of brood is related with the amount of pollen per colony. The highest deviation in heritability coefficients the fall was for the amount of honey. The colony strength depends on origin and year of study, while such was not the case with food reserve per colony (JEVTIĆ *et al*. 2011).

Table 3. Average values and heritability coefficients (%) for production traits (1/10 of frame) of honey bee colonies from six regions of Serbia (fall inspections)

	Amount of bees		Amount of brood		Amount of honey		Amount of pollen	
Populations	$\overline{X}$	h^2	$\overline{X}$	h^2	$\overline{X}$	h^2	$\overline{X}$	h^2
Rasina	10,32	53,62	2,28	42,39	5,62	11,17	0,40	10,81
Pešter	8,94	35,56	2,06	42,23	6,45	55,27	0,35	4,05
Morava	10,69	50,29	2,02	43,17	5,72	36,88	0,43	9,60
Banat	11,11	68,99	2,47	54,32	5,61	38,96	0,30	33,33
Timok	8,48	57,46	1,60	51,38	4,92	66,88	0,17	46,15
Kopaonik	8,27	60,45	1,67	67,46	4,21	18,25	0,29	33,33
Average	**9,64**	**54,39**	**2,02**	**50,16**	**5,42**	**37,90**	**0,32**	**22,88**
F	5,50**		0,90 ^{ns}		2,44*		1,06 ^{ns}	
LSD 0.05	1,46		1,02		1,39		0,26	
0,01	1,95		1,36		1,84		0,34	

CONCLUSION

Given the complicated relations between hereditary factors, environmental factors and specific development of colonies, it can be concluded that genetics alone does not play a decisive role when it comes to production traits of honey bee colony. Regardless of the genetic determination of individual productive traits, it is needed for many environmental factors to fit together, so that the colonies could develop their maximum potential and it to be transferred by the queens to their offspring. The results show that the total honey yield had high heritability coefficients, while temperament and production traits had somewhat lower values. High heritability coefficients determined for some traits or in individual populations show that there is justification for the continuation of honey bee selection in order to improve all of production traits.

ACKNOWLEDGEMENTS

This research is part of Project No 31057 financed by the Ministry of Education and Science of Republic of Serbia.

Received October 27th, 2011
Accepted February 23rd, 2012

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HERITABILNOST PROIZVODNIH OSOBINA REGIONALNIH POPULACIJA MEDONOSNE PČELE IZ SRBIJE

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I z v o d

U ogledu u koji su uključena društva iz šest regionalnih populacija sa područja Republike Srbije, praćene su dve generacije (majčinska društva i njihovo potomstvo). Praćene su proizvodne osobine i temperament društava. Matice ćerke su se sparivale u nekontrolisanim uslovima (slobodno sparivanje) u cilju utvrđivanja nasledljivosti proizvodnih osobina u uslovima praktičnog pčelarenja. Za utvrđene proizvodne karakteristike medonosne pčele izračunati su koeficijenti heritabilnosti. Ustanovljeno je da je prinos meda uslovljen genetičkim faktorima, ali i uslovima spoljašnje sredine. Heritabilnost za prinos meda (h^2) je varirala od 72.72% (rasinska populacija) do 81.04% (banatska populacija). Za razliku od prinosa osobine koje determinišu temperament pčela imale su znatno niže koeficijente heritabilnosti. Snaga društva je dosta zavisila od spoljašnjih faktora, ali i od samih populacija. Kada je u pitanju zaliha hrane dobijene su velike razlike u vrednostima koeficijenata heritabilnosti, sto se može objasniti spregom genetičkih (nagon za sakupljanjem) i faktora spoljašnje sredine (medonosno bilje i klimatske prilike tokom medobranja) ali i uticajem pčelara (prihrana društava).

Primljeno 27. X. 2011.
Odobreno 23. II. 2012.