J. Agr. Sci. Tech. (2015) Vol. 17: 1735-1742

Genetic Trends and Parameters of Honey Production, Swarming and Defense Behavior in Iranian Honeybee (*Apis mellifera meda*) Colonies

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ABSTRACT

Genetic parameters were estimated in a base and closed population of Iranian honeybee colonies. Data were obtained on 500-700 Iranian native population of honeybee colonies (honeybee breeding project in central region of Iran) subject to 9 successive generation of selection. These populations had been selected for honey production, swarming behavior, and defense behavior. Heritability of honey production, swarming behavior, and defense behavior were 0.22, 0.34, and 0.44, respectively. Phenotypic and genetic correlations between honey production with swarming tendency and defense behavior were -0.16, -0.59, and 0.21, 0.48, respectively. Phenotypic and genetic correlations between swarming and defense behavior were -0.52 and -0.67 respectively. The genetic and phenotypic trends of swarming behavior, defense behavior, and honey production in the honeybee colonies during the 1999-2009 were desirable. Lower heritability of honey production and its higher dependence on apiary management and environmental or climatic factors caused lower improvement of honey production in breeding plans.

Keywords: Breeding, Defense behavior, Honey production, Iran, Swarming behavior.

INTRODUCTION

Honeybee breeding is a common goal of beekeepers and honeybee researches during the last 150 years, but it does not improve as rapidly as the breeding of other livestock. There are several reasons for this such as multiple mating of queens with drones from different colonies and limitations for control of queens mating, consideration of various traits in honeybee breeding plans simultaneously, mating of queen with 8-12 drones in drone congregation area, and quick decline in brood viability because of increasing homozygosity of sex alleles in isolated mating areas (Page and Laidlaw, 1982; Page and Laidlaw, 1985; Szabo, 1982; Tarpy and Page, 2002; Vessely and Siler, 1963; Woyke, 1988).

The Iranian race of honeybee (*Apis mellifera meda*) is a valuable genetic resource, due to its adaptability to harsh situations, drought climate, poor vegetation covering of most pastures, and native pest and diseases in different regions of Iran (Bienefeld and Pirchner, 1992; Tahmasbi *et al*., 2007).

Honeybee breeding plans have been conducted in different countries in the world. Heritability of honey production was evaluated

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by researchers in different regions. Honey production heritability was evaluated at 0.23 (Pirchner *et al*., 1962), but based on Soller and Cohen (1967) studies, it was 0.58. Heritability of honey production in honeybee colonies of Iran was 0.435 and 0.36 based on Basiri *et al*. (1999) and Mostajeran *et al*. (2004). Based on the results of Bienefeld and Pirchner (1990) research, heritability of honey production was 0.45.

Heritability of defense behavior was 0.1–0.93, based on research by Collins *et al*. (1984), while Basiri *et al*. (1999) found that heritability of defense behavior of Iranian honeybee colonies was 0.638 in Isfahan Province. Defense behavior heritability of honeybee colonies was 0.4 based on research by Bienefeld and Pirchner (1990).

Genetic and phenotypic correlation between honeybee production and swarming behavior was negative in different researches (Basiri *et al.,* 1999; Shaykon and Poscheemid, 1991; Tahmasbi *et al*., 2009; Tahmasbi *et al.,* 1998; Tarpy and Page, 2002).

Phenotypic correlation between honey production and swarming was 0.406 and also phenotypic correlation between defense and swarming behavior was -0.67 in Basiri *et al*. (1999) research.

Comparison of Iranian honeybee with other races in the world such as *carnica*, *ligustica*, *caucasica* and *anatolica* has shown that the Iranian honeybee have better overwintering and consume less food during the winter, but have low honey production, more swarming tendency and aggressive behavior (Ebadi, 1988). Therefore, in the honeybee breeding project of Iran, honey production, swarming, and defense behavior were selected for improvement during the last years. In breeding plans, there is a need for estimation of genetic and phenotypic parameters of traits as well as genetic trends. In this research, the objective was to evaluate the genetic parameters of honey production, swarming, and defense behavior to develop a data base for selection of the best colonies and establishing the next generations.

MATERIALS AND METHODS

The base population of honeybee colonies for the breeding project in central Alborz region of Iran were selected from Tehran, Markazi, Qazvin and Isfahan Provinces. Honeybee breeding project was carried out on nine successive generations.

Five thousand honeybee colonies of different apiaries in different cities of Tehran, Markazi, Qazvin and Isfahan Provinces were evaluated in the spring and summer of 1998 and 864 colonies were selected as the best colonies. Honey production, swarming behavior, calmness, and defense behavior were measured in the apiaries and, finally, the best colonies according to the independent calling level method were selected to supply the basic population of the breeding project for the next years.

During the nine generations, honey production, swarming behavior, and defense behavior were evaluated on 500-700 colonies in the spring and summer every year. In the end of each generation, the best colonies consisting of 100 queen producers and 40 drone producers colonies were selected using the selection index and different trait coefficients. The number of colonies was large, about 500 to 700 colonies in the each generation, in order to avoid inbreeding effects.

In this project, total data of 10,000 Iranian honeybee colonies from the base generation (G_0) to generation 9 were used to estimate the genetic parameters of behavioral and production traits.

Statistical Analyses

The animal model was used to estimate genetic parameters and breeding values. Mixed animal model was applied to estimate the best linear unbiased prediction of breeding values. The (co)variance components and corresponding genetic parameters for the studied traits were estimated by Restricted Maximum Likelihood (REML) method. For

[DOR: 20.1001.1.16807073.2015.17.7.11.4]

this purpose, the following multivariate individual animal model was fitted to the data:

$y_i = X_i b_i + Z_i a_i + e_i$

Where, y_i is the vector of observation for trait *i*, $\boldsymbol{b_i}$ is the vector of fixed effect (include year/location) that were found significant in least square analysis) for trait *i* with associated matrix $\boldsymbol{X_i}$, $\boldsymbol{\alpha_i}$ is the vector of random animal effect for trait *i* with associated matrix $\boldsymbol{Z_i}$ and $\boldsymbol{e}$ is a vector of random residual effects. $\boldsymbol{X_i}$ and $\boldsymbol{Z_i}$ are incidence matrices relating records for trait *i* to fixed and random animal effects, respectively.

It was assumed that additive genetic and residual effects to be normally distributed with mean of zero and variances of $A\sigma_a^2$ and $I_n\sigma_e^2$, respectively. Also σ_a^2 and σ_e^2 are additive genetic and residual variances, respectively. *A* and I_n are the additive numerator relationship matrix and identity matrix with order equal to the number of individuals and records, respectively. Breeding values of individuals were predicted with Best Linear Unbiased Prediction (BLUP) methodology. In order to evaluate the genetic and phenotypic trends, means of predicted breeding values and phenotypes in generation were calculated.

Genetic and phenotypic trends were obtained by regression means of predicted breeding values and phenotypic records, respectively, on generation for each trait using procReg in SAS software package (SAS, 2002).

RESULTS

The results showed that the heritability of honey production, swarming behavior, and defense behavior were 0.22, 0.34, and 0.44, respectively. Phenotypic correlations between honey production with swarming and defense behavior were -0.16 and 0.21 respectively (Table 1). As shown in Table 1, the correlation between defense behavior and swarming tendency was negative (-0.52).

Genetic correlations between honey production, swarming and defense behavior were also -0.59 and 0.48, respectively. Therefore, genetic and environmental correlations between honey production and defense behavior were positive. However, phenotypic and genetic correlations between honey production and swarming behavior were negative in both cases, with high magnitude for the genetic component. Genetic and environmental correlation between defense behavior and swarming behavior were also negative (Table 1).

As shown in Figure 3, the regression coefficient of average breeding value of honey production on generation number was positive (0.918).

The cumulated genetic change for honey production totally increased from G_0 to G_9, except in G_5, G_7, and G_9.

The regression coefficient of average breeding value for swarming behavior on generation number (Figure 2) was negative (-0.207).

Defense behavior exhibited an irregular trend between G_0 to G_9, but generally decreased and its negative trend confirmed the progress in this trait. The regression coefficient of defense behavior was negative, high (-0.385), and significant (Figure 1).

Table 1. Heritability±SE (diagonal), genetic correlations±SE (below diagonal), and phenotypic correlations (above diagonal), of honey production, swarming, and defense behavior of honeybee colonies.

Traits	Honey production	Defense behavior	Swarming behavior
Honey production	0.22±0.018	0.21	-0.16
Defense behavior	0.48±0.037	0.44±0.027	-0.52
Swarming behavior	-0.59±0.051	-0.67±0.038	0.34±0.028

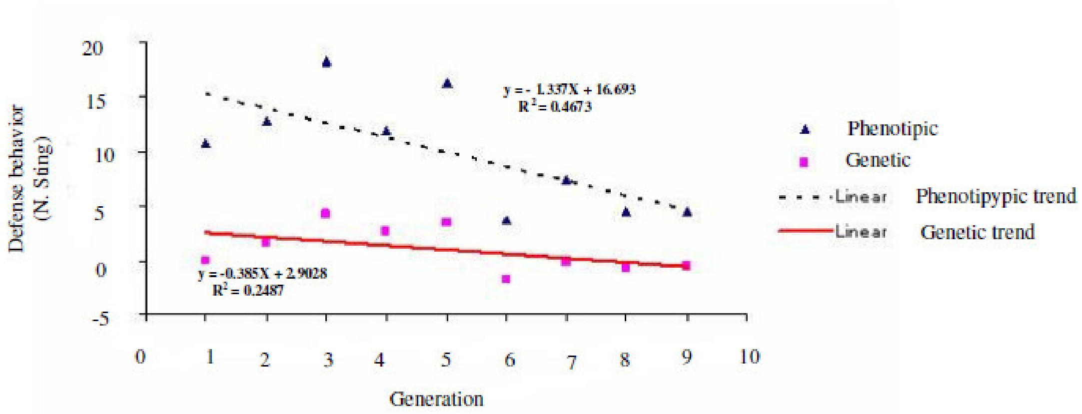

Figure 1. Genetic and phenotypic trends of defense behavior of honeybee colonies in 9 generations of selection.

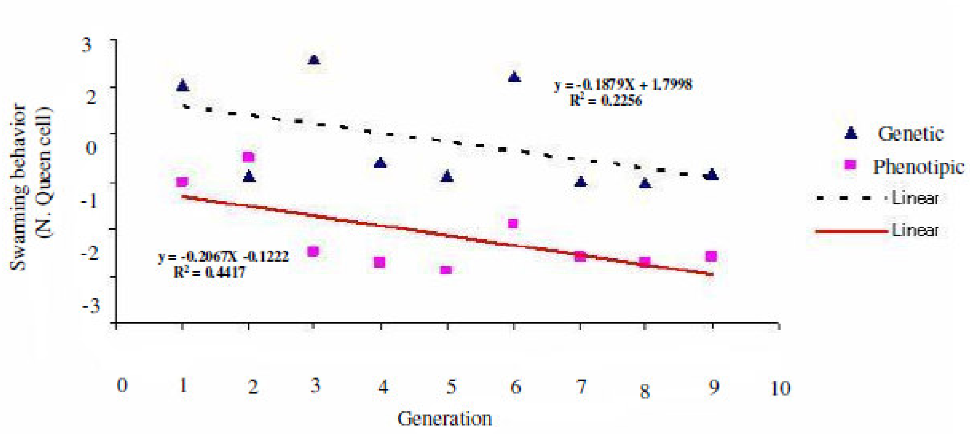

Figure 2. Genetic and phenotypic trends of swarming behavior of honeybee colonies in 9 generations of selection.

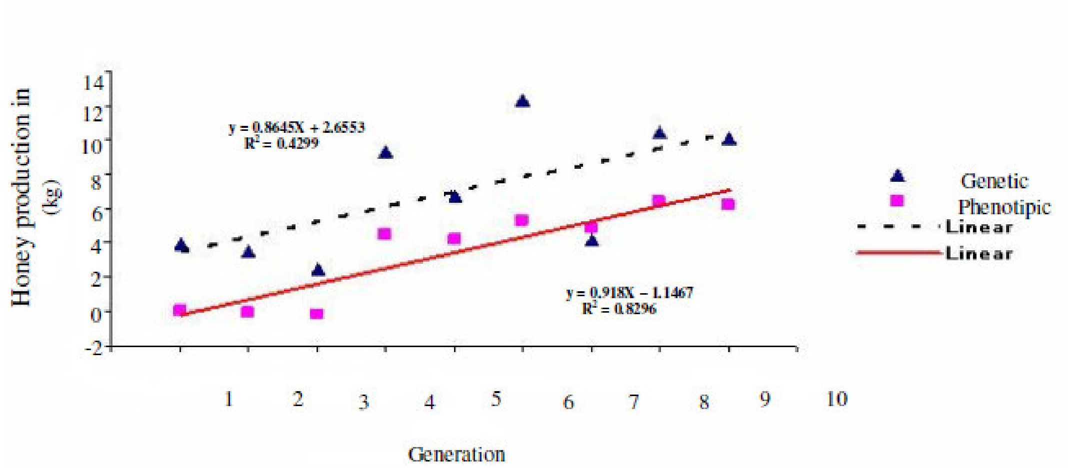

Figure 3. Genetic and phenotypic trends of honey production of honeybee colonies in 9 generations of selection.

[DOR: 20.1001.1.16807073.2015.17.7.11.4]

DISCUSSION

The results showed progress of honeybee colonies performance. Honey production as a more important trait of honeybee colonies had low heritability (0.22). Heritability of honey production was different than in other regions and other researches. Soller and Cohen (1967), Basiri *et al*. (1999), and Mostajeran *et al*. (2000) have reported higher heritability (0.53, 0.435, and 0.36, respectively) for honey production. However, Pirchner *et al.* (1962), Vessely and Siler (1963) and Bienefeld and Pirchner (1990) obtained the same or lower heritability (0.23, 0.16-0.19 and 0.15, respectively) for honey production in other regions. Important factor of relatively lower heritability for this trait in the present research could be related to longer selection period and also large size of this population.

Notably, in most breeding plans of honeybee colonies, honey production has had lower heritability in comparison with behavioral traits, because environmental and management factors have more effects on honey production of colonies. Therefore, the results of our research confirm the latest researches and also verify the need for a longtime selection for obtaining the desired improvement in honey production.

Heritability of swarming behavior in this study was 0.34, so, swarming has the necessary potential as an important trait for honeybee breeding in central Iran.

Basiri *et al*. (1999) reported the same heritability i.e. 0.59, for swarming behavior in Isfahan Province. Ebadi (1988) showed that the swarming behavior was a weak point of Iranian honeybee, *Apis mellifera meda*, in recent years, but during the recent years in this project, swarming was improved in the studied population. Swarming comparison of bred queens of our project and the control queens in central region of Iran confirmed the superiority of the bred queens in 2005 and 2006 (Poklukar and Kezic, 1994; Tahmasbi *et al.,* 2007; Tahmasbi *et al.,* 1998; Tarpy and Page, 2002).

Defense behavior heritability was 0.44 in this research. High heritability of defense behavior showed good potential of this trait for improving in the breeding project in Iran.

Other researchers have obtained similar heritability values for defense behavior. Collins *et al*. (1984), Basiri *et al*. (1999) and Bienefeld and Pirchner (1990) reported heritability of 0.57, 0.64, and 0.40, respectively. The relatively low estimated heritability for this trait could be also due to longer selection period in this program.

The genetic and phenotypic negative correlations between honey production and swarming behaviors showed that the decline of swarming behavior caused the increase in honey yield and vice versa. These results are similar to those reported by Shaykon and Poschmid (1991) for swarming and population size of colonies and also swarming and honey production. Basiri *et al*. (1999) in Isfahan and also Mostajeran *et al*. (2000) reported negative correlation between honey yield and swarming tendency. Thus, the increase in swarming behavior and queen cell production in the colonies caused the decrease of population and, consequently, decline of honey production in the honeybee colonies (Bienefeld and Pirchner, 1991; Bienefeld *et al.,* 1996). In conclusion, the results of this research are in accordance with the results of other researches in different regions and show that selection for increasing the honey yield may decrease the swarming tendency in the colonies.

. This study found a positive correlation between honey production and defense behavior. Their positive correlation showed that improvement in one trait was not detrimental to the other trait. Results differed from those reported by Rinderer and Brown (1983) for honey production and defense behavior. Szabo (1982) reported low correlation between these two traits. Rindere and Brown (1983) also reported low correlation between calmness and honey yield. Basiri *et al*. (1999) reported positive correlation between them, and their results are similar to ours. Therefore, most of previous researches have reported low correlation between honey yield and defense behavior, sometimes negative correlation and sometimes positive correlation, hence, our results are different from other researches and showed positive genetic and phenotypic correlation between these traits. We found a negative correlation between swarming and defense behavior. Our results in this research are similar to the results of Basiri *et al*. (1999) in Isfahan Province. They reported genetic correlation of -0.38, and phenotypic correlation of -0.67, between swarming and defense behavior. So, this showed that selection for decreasing the queen cell production caused increase in the sting number. In other words, improvement of swarming may cause increase in defense behavior of honeybee colonies because the decline in the number of queen cells showed the progress of swarming behavior.

There are desirable phenotypic and genetic trends of swarming tendency, defense behavior, and also honey production in honeybee colonies during nine successive generations in the present research. Swarming and defense behavior trends are so desirable, but honey yield trend is relatively demanded progress. Lower heritability of honey production and its higher dependence on apiary management and environmental or climatic situations may cause lower improvement of honey yield in breeding programs and also in this research. These results confirm those of previous researches. In conclusion, desirable improvement in honey production needs a long time selection in the future. Therefore, study on the selection criteria for the honey production could expedite that.

ACKNOWLEDGEMENTS

We thank Animal science research institute of Iran and Department of livestock affairs, ministry of Jihad Agriculture for their help in this project.

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پارامترهای ژنتیکی و روند ژنتیکی صفات تولید عسل، رفتار بچه دهی و رفتار دفاعی کلنی های زنبورعسل ایرانی(*Apis mellifera meda*)

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چکیده

پارامترهای ژنتیکی صفات تولید عسل، رفتار بچه‌دهی و رفتار دفاعی در جمعیت بسته و تحت بررسی در طرح جامع اصلاح نژاد زنبورعسل ایران مورد ارزیابی قرار گرفت. برای تخمین این پارامترها اطلاعات بدست آمده از ۷۰۰-۵۰۰ کلنی زنبورعسل نژاد ایرانی در ۹ نسل متوالی مورد استفاده قرار گرفت. در این طرح صفات تولید عسل، رفتار بچه دهی و رفتار دفاعی کلنیها ارزیابی و نتایج حاصل برای انتخاب کلنیهای برتر مورد استفاده قرار می‌گرفت. وراثت‌پذیری صفات تولید عسل، بچه‌دهی و رفتار دفاعی کلنی‌های زنبورعسل در این جمعیت به ترتیب ۰/۲۲، ۰/۳۴ و ۰/۴۴ بود. همبستگی ژنتیکی صفت تولید عسل با رفتار بچه دهی و رفتار دفاعی به ترتیب ۰/۵۹- و ۰/۴۸ بود و همبستگی ژنتیکی صفات بچه‌دهی و رفتار دفاعی ۰/۶۷- بود. همبستگی فنوتیپی تولید عسل با رفتار بچه دهی و رفتار دفاعی به ترتیب ۰/۱۶- و ۰/۲۱ و همبستگی فنوتیپی رفتار بچه‌دهی و رفتار دفاعی کلنیها نیز ۰/۵۲- بود.صفات رفتار بچه دهی و رفتار دفاعی و تولید عسل در طی این ۹ نسل از روند ژنتیکی و فنوتیپی مطلوبی برخوردار بودند. وابستگی صفت تولید عسل به مدیریت زنبورستانها و شرایط اقلیمی سبب پایین تر بودن وراثت پذیری این صفت و پیشرفت کمتر این صفت در طرحهای اصلاح نژادی زنبورعسل است. نتایج حاصل از این تحقیق نیز تأیید کننده نتایج تحقیقات قبلی است و بنابراین در طرح اصلاح نژاد زنبورعسل ایران نیز صفت تولید عسل برای نیل به پیشرفت مطلوب نیاز به زمان بیشتر و ادامه انتخاب در طی نسلهای بعدی دارد.

[DOR: 20.1001.1.16807073.2015.17.7.11.4]