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Analysis of Colony and Morphological Characters in Honey Bees (*Apis mellifera meda*)

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Abstract: Heritabilities and correlations between Brood Area (BA), Colony Population (CP), Honey Production (HP), Productivity (PR) and some morphological characteristics were estimated on the Iranian honey bees (*Apis mellifera meda*). Heritability estimates were 0.69 ± 0.09 , 0.50 ± 0.08 , 0.46 ± 0.08 , 0.34 ± 0.06 , 0.51 ± 0.08 , 0.42 ± 0.07 , 0.90 ± 0.10 , 0.94 ± 0.10 and 0.72 ± 0.09 , respectively, for Proboscis Length (PL), Femur Length (FL), Tibia Length (TL), Metatarsus Width (MW), Leg Length (LL), Fore Wing Length (FWL), Fore Wing Width (FWW), Hind Wing Length (HWL) and Hind Wing Width (HWW). Phenotypic correlation between PR to BA and CP were significantly negative (-0.38 and -0.35, respectively) and positive to HP (0.65). Colony traits were related to PL, FL, TL, LL, MW, FWL, FWW and HWL. Brood area was correlated to proboscis length significantly positive ($r = 0.20$). Brood area and colony population were correlated significantly positive to tibia length, metatarsus length and width, fore wing length and width and hind wing length. Between proboscis length and productivity there was a negative and high significant correlation ($r = -0.29$). Correlation between tibia length and productivity was significantly negative. Between harvested honey with femur length, tibia length, leg length and fore wing width there were positive and high significant correlations. From these results it is concluded that productivity is correlated directly to honey production and indirectly to brood area and colony population.

Key words: Honey bee, heritability, correlation, morphological character, productivity

INTRODUCTION

Honey production is one of the most complex behavioral characters of honey bees. Honey production is affected by genetics and environment (hive internal and external environment). For breeding and improving honey production two ways have been recommended (Milne, 1985). One is to equal all environmental effects for all honey bee colonies that are evaluated. The second method is colony evaluation according to traits such as morphological characters that are affected by environmental less and are related with honey production closely. Heritability estimates of morphological characters have been high (Collins *et al.*, 1984; Oldroyd *et al.*, 1991; Mostajeran *et al.*, 2002).

Morphological sizes of Africanized honey bees are smaller than European honey bees (Oldroyd *et al.*, 1991). Investigations have showed that Africanized honey bees produce honey less than European ones under similar condition (Rinderer *et al.*, 1985). Africanized honey bees swarm more and they are much aggressive. Morphometric investigations have been done for distinguish and classification of honey bee races (Ruttner, 1988;

Oldroyd *et al.*, 1991). Morphometric characteristics are used for determining honey bees stock purity too. Morphological characters that are related closely to the colony production traits are very interesting for beekeepers and honey bee breeders. One of the most promising characteristics has been the corbicular size (Milne and Pries, 1984). Szabo and Lefkovich (1988) showed that there are significant and positive correlations between honey production with fore and hind wing area.

This study was established for estimating of heritability and phenotypic correlation between many colony traits and morphological characters.

MATERIALS AND METHODS

Thirty mother-queens were selected randomly from the apiary of Isfahan Research Center of Animal Science and Natural Resources (Iran). Five daughter-queens were reared from each mother-queen. Naturally mated daughter-queens were introduced into equalized colonies. Colony brood and population were equalized twice. Colony population and brood area were measured through spring and summer as number of combs. Harvested honey was

measured as a difference between honey combs weight before and after honey extracting. Remained honey was calculated as 330 g dm⁻² of sealed honey comb. Total honey production was calculated from sum of the harvested and remained honey. For calculating of productivity, colony honey production was divided by number of bees per each colony.

In point of morphological characters, 20 worker bees were sampled randomly from each colony. Morphological sizes of each single bee were measured by means of a stereo-dissecting microscope fitted with a calibrated micrometer reticule according to Ruttner's method. Morphological characters included: proboscis length, fore and hind wing length and width, cubital index, number of humuli, femur and tibia length, metatarsus length and width.

STATISTICAL ANALYSIS

Data were analyzed then heritability and phenotypic correlation were estimated by SAS (1995) and Harvey (1990) (LSMLMW) softwares. Two different models were employed in order to partition the sources of variances for the colony traits and worker traits (morphological characters).

For colony traits:

$$Y_{ij} = \mu + m_i + e_{ij}$$

Where:

- Y_{ij} = Value of the j_{th} daughter queen of the i_{th} mother
- μ = Population mean
- m_i = Effect of the i_{th} mother queen
- e_{ij} = Random error.

For morphological characters:

$$Y_{ijk} = \mu + m_i + d_{ij} + e_{ijk}$$

Where:

- Y_{ijk} = Value of the k_{th} worker progeny of the j_{th} daughter queen of the i_{th} mother queen,
- μ = Population mean
- m_i = Effect of the i_{th} mother queen
- d_{ij} = Effect of the j_{th} daughter queen of the i_{th} mother queen
- e_{ijk} = random error

RESULTS

Heritability estimates of morphological characters are shown in Table 1. Heritability values for most of the morphological characters (PL, FL, LL, FWW, CA, CI,

HWL and HWW) were large ($h^2 > 0.5$). These values were as large as literature values (Collins *et al.*, 1984; Oldroyd *et al.*, 1991). Heritabilities for FWW, HWL and HWW are larger than the others, noticeably. Heritability estimates were 0.64 ± 0.09 , 0.46 ± 0.08 , 0.51 ± 0.08 , 0.90 ± 0.10 and 0.72 ± 0.09 , respectively, for Proboscis Length (PL), Tibia Length (TL), Leg Length (LL), Fore Wing Width (FWW) and Hind Wing Width (HWW).

In Table 2 correlations between colony traits are combined. Correlations between colony productivity with harvested, remained and total honey production were estimated (0.65, 0.39 and 0.51, respectively). Woyke (1984) reported the correlations from 0.83 to 0.96 between total honey production and productivity in two years. Correlations between colony productivity with colony brood area and population were found to be significantly negative (-0.38 and -0.35, respectively, Table 2). Proboscis length was correlated to brood area significantly positive ($r = 0.20$, Table 3). Brood area and colony population were correlated significantly and positively with tibia length, metatarsus length and width, leg length, fore wing length and width and hind wing length (Table 3).

Correlation between proboscis length and productivity was negative and highly significant ($r = -0.29$, Table 3). Also productivity was correlated significantly negative with tibia length ($r = -0.22$). Between productivity and forewing length (Table 3) there exists a positive high significant correlation ($r = 0.31$). The correlation between productivity to cubital index and cubital A were found to be negative and high significant. Between harvested honey with femur length, tibia length, leg length and forewing width were estimated positive and high significant correlations and with cubital index negative and high significant correlation (Table 3). Szabo and Lefkovitch (1988) found significant correlations between honey production with forewing length and width, hindwing length and width, femur length, tibia length and metatarsus length. They estimated significant and positive correlations between honey production to fore and hind wing area (0.41 and 0.34, respectively).

A positive and high significant correlation was found between total honey production and metatarsus width ($r = 0.25$, Table 3). Correlation between total honey production and cubital A was negative and significant ($r = -0.19$). The negative correlation to cubital index was situated at the limit of statistical significance ($r = -0.13$). Bienefeld and Pirchner (1992) did not find any correlation between honey production and cubital index in *Apis mellifera carnica*. Also Szabo and Lefkovitch (1988) reported no significant correlations between honey production to cubital A and B and cubital index.

Table 1: Estimates of heritability (\pm SE) (n = 114) of morphological characters

PL	FL	TL	ML	MW	LL	FWL
0.64 \pm 0.09	0.50 \pm 0.08	0.46 \pm 0.08	0.43 \pm 0.07	0.34 \pm 0.06	0.51 \pm 0.08	0.42 \pm 0.07
FWW	HWL	HWW	CI	CA	CB	NH
0.9 \pm 0.100	0.94 \pm 0.10	0.72 \pm 0.09	0.5 \pm 0.08	0.61 \pm 0.08	0.20 \pm 0.05	0.45 \pm 0.07

PL: Proboscis Length, FL: Femur Length, TL: Tibia Length, ML: Metatarsus Length, MW: Metatarsus Width, LL: Leg Length, FWL: Fore Wing Length, FWW: Fore Wing Width, HWL: Hind Wing Length, HWW: Hind Wing Width, CI: Cubital Index, CA: Cubital A, CB: Cubital B and NH: Number of Humuli

Table 2: Correlations^a between colony traits

Traits	Brood area	Colony population	Harvested honey	Remained honey	Total honey
Colony population	0.81**				
Harvested honey	-0.06 ^{ns}	0.01 ^{ns}			
Remained honey	0.27**	0.45**	0.08 ^{ns}		
Total honey	0.22*	0.41**	0.39**	0.88**	
Productivity	-0.38**	-0.35**	0.39**	0.51**	0.65**

** , significant at p<0.01 * , significant at p<0.05 ns, non-significant, ^a(n = 114)

Table 3: Correlations^a between colony traits and morphological characteristics

Traits	BA	CP	HH	RH	TH	PR
PL	0.20*	0.12 ^{ns}	0.08 ^{ns}	-0.17 ^{ns}	0.13 ^{ns}	-0.29**
FL	0.08 ^{ns}	0.04 ^{ns}	0.22**	-0.05 ^{ns}	0.06 ^{ns}	0.03 ^{ns}
TL	0.27**	0.30**	0.27**	-0.11 ^{ns}	0.02 ^{ns}	-0.22**
ML	0.29**	0.29**	0.11 ^{ns}	0.10 ^{ns}	0.14 ^{ns}	-0.12 ^{ns}
LL	0.29**	0.29**	0.27**	-0.04 ^{ns}	0.09 ^{ns}	-0.16 ^{ns}
MW	0.29**	0.32**	0.12 ^{ns}	0.21*	0.25**	0.02 ^{ns}
FWL	0.25**	0.23**	0.06 ^{ns}	0.13 ^{ns}	0.08 ^{ns}	0.31**
FWW	0.23**	0.22**	0.25**	-0.09 ^{ns}	0.04 ^{ns}	-0.12 ^{ns}
CA	-0.02 ^{ns}	-0.02 ^{ns}	-0.18*	-0.11 ^{ns}	-0.19*	-0.25**
CB	-0.02 ^{ns}	0.03 ^{ns}	0.19*	-0.00 ^{ns}	0.00 ^{ns}	0.07 ^{ns}
CI	0.002 ^{ns}	-0.05 ^{ns}	-0.26**	-0.01 ^{ns}	-0.13 ^{ns}	-0.21*
HWL	0.25**	0.18*	0.11 ^{ns}	0.05 ^{ns}	0.03 ^{ns}	0.14 ^{ns}
HWW	0.05 ^{ns}	0.10 ^{ns}	0.10 ^{ns}	-0.14 ^{ns}	0.08 ^{ns}	-0.11 ^{ns}
NH	0.10 ^{ns}	0.10 ^{ns}	-0.08 ^{ns}	0.03 ^{ns}	-0.01 ^{ns}	-0.08 ^{ns}

** , Significant at p<0.01 * , significant at p<0.05 ns, non-significant ^a(n =114), BA: Brood Area, CP: Colony Population, HH: Harvested Honey, RH: Remained Honey, TH: Total Honey, PR: Productivity, PL: Proboscis Length, FL: Femur Length, TL: Tibia Length, ML: Metatarsus Length, MW: Metatarsus Width, LL: Leg Length, FWL: Fore Wing Length, FWW: Fore Wing Width, HWL: Hind Wing Length, HWW: Hind Wing Width, CI: Cubital Index, CA: Cubital A, CB: Cubital B and NH: Number of Humuli

DISCUSSION

Large heritabilities of morphological characters show that these traits are influenced little by environment and there is capacity to increase them by selection.

Productivity showed a positive correlation to honey production and negative correlation to brood area and population. This confirm that as the honey production increases, productivity (honey production per 1000 worker bees) arises and it decreases as the colony population and brood area increase. The colonies that intend to produce high brood and population and deposit less honey, the productivity of the colony would be low. On the other hand colonies that intend to deposit much more honey would not be able to produce much brood. Then these colonies are less populated and their productivity is high. Tibia length and metatarsus length and width are the components of corbicular area then as they become bigger, the corbicular area would be bigger, too. It has been found that as corbicular area increases, pollen load carried by worker bees will increase. Then brood and colony population arise (Milne and Pries,

1984). Since correlations between brood area and colony population to tibia length and metatarsus length and width are direct and positive.

There were positive correlations between brood area and colony population with forewing length and width and hind wing length. It can be concluded that, bees with bigger wing have higher power flight. They could gather more pollen and nectar. As a result more brood would be reared and a powerful colony caused. Positive correlations between honey production to femur length, tibia length, leg length and forewing width could be described that, bees with bigger leg and wing gather more pollen and nectar and produced more honey (in addition to increasing colony population). Milne and Pries (1984) found a positive correlation between honey production and corbicular area ($r>0.57$). Negative correlation between productivity with tibia length can be described as negative correlation between productivity to brood area and colony population. Bees with bigger tibia cause gathering more pollen loud. As a result more brood would be reared and colony population would increase. As brood and colony population increase the productivity would decrease.

Productivity was correlated to fore wing length. This can be described as a positive correlation between fore wing length and width to honey production and honey production to productivity. As fore wing length become bigger, flight power increases and nectar gathering enhances. This causes more honey production and finally higher productivity would achieve. On the other hand these significant phenotypic correlations between colony traits and morphological characters are probably because of genetic correlation. If it is so, honey production would be improved with selection for colonies that have bees with bigger leg and wing.

From these results it is concluded that productivity is correlated directly to honey production and indirectly to brood area and colony population. Some morphological characters that cause higher pollen and nectar gathering would increase brood area, colony population and often honey production. Productivity is positively correlated only to morphological characters that are related directly to nectar hoarding.

Finally from these results, it will be logical to conclude that productive traits are correlated positively to dimensions of bee body (leg and wing). As a result the colonies with bigger bees would produce more brood, population and honey.

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