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PHENOTYPIC CORRELATIONS BETWEEN EFFICIENCY AND BEHAVIOUR OF HONEY BEE COLONIES (*Apis mellifera carnica*)

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ABSTRACT

Data from performance tests of 5342 honey bee colonies of *Apis mellifera carnica* were used to calculate the phenotypic correlations between several colony characters. Correlations between partial honey yields within year were medium to poor. The phenotypic relation between total honey yields of different years was 0.2. The correlations between the subjectively judged traits, indicating the ability to perform (wintering ability, spring development etc.) and natural honey and wax production, respectively, were found to between 0.2 and 0.5. Efficiency of colonies and behaviour showed no significant relationships. The cubital index did not correlate with the other characters measured.

INTRODUCTION

The practical value of honey bee colonies is always affected by several traits. To improve several traits of interest simultaneously, selection indices are most efficient (Hazel and Lush, 1943). Bienefeld and Pirchner (1991) published genetic correlations and a selection index that fits the peculiarities of honey bee reproduction. In addition to genetic parameters, phenotypic relationships are necessary. Up to now published phenotypic correlations have been calculated from specially designed scientific experiments with corresponding low data volume (Cale and Gowen, 1956; Sugden and Furgala 1982; Szabo, 1982). If parameters are to be applied in bee breeding practice they also should be estimated under field conditions.

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MATERIALS AND METHODS

The study is based on data collected from approved beekeepers organized in two *A. m. carnica* bee breeding societies in Lower Saxony (F.R.G.) and an *A. m. carnica* bee breeding society in Hamburg (F.R.G.). In addition to the results from "stud-books" of beekeepers (n = 96), the Research Institutes for Bee Breeding in Celle (Lower Saxony, F.R.G.), Kirchhain (Hessia, F.R.G.) and Lunz (Austria) provided data from their testing stations. The performance tests by beekeepers and the Bee Research Institutes were carried out in the same manner, essentially without modifications during the period analysed (1960 to 1984) in accordance with the technical recommendation summarized by Ruttner (1972). In addition to colony traits, 2385 measurements of samples of the cubital index (length proportion of two wing venation forming the boundary of the 3rd cubital cell) were provided by the breeding organizations. In combination with other morphological characters the cubital index of the daughter bees is used to check the pure breed mating of the queen (Ruttner, 1988). Honey yield (n = 5342) was taken as the weight difference of combs before and after extracting honey plus an estimate of honey left in the broodnest. The breeding society in Hamburg and the institute in Celle provided additional information about the partioning of the entire honey yield in the spring (n = 1890), summer (n = 1872), and autumn (n = 1066) yields. Wax production (n = 1724) was estimated by the number of honey and/or drone combs multiplied by a factor between 0.06 to 0.07 (depending on comb size). Aggressiveness (n = 2770), calmness during examination (n = 2764), spring development (n = 2177), wintering ability (n = 946) and swarming tendency (n = 1534) were scored subjectively. The scoring system ranged from 4 (very good) to 1 (very bad). Intermediate marks (for example 2.5) were possible. Because of nonnormal distribution, the subjectively scored traits were transformed $e^{(\text{Variable})}$. Details of the data set are given by Bienefeld *et al.* (1989). All variables were corrected for year and location effects using a SAS generalized least square routine (SAS Institute, 1985).

RESULTS AND DISCUSSION

In Table I correlations between the partial yields of total honey production are combined. Positive but unexpectedly poor correlations were found. Analysis in Israel even resulted in a negative correlation (r = 0.16) between winter and summer performances (Soller and Bar-Cohen, 1967). The reason is that the genetic relationships between the partial yields are only poor, at times even negative (Soller and Bar-Cohen, 1967; Bienefeld and Pirchner, 1991). Different inherited colony development might be the cause. As a result colonies used most effectively that honeyflow period which coincides with their maximum development potential. Prior and following part yields are then inevitably at a disadvantage.

Table I - Correlations between partial yields of honey.

Traits	Summer	Autumn
Spring	.25***	.07*
Summer		.02
Autumn		

*, Significant at $p < 0.05$.
**, Significant at $p < 0.01$.
***, Significant at $p < 0.001$.

Between the honey production in the 1st and 2nd year (Table II) there exists a positive but weak correlation (r = 0.20). Often it has been found, for example by Louveaux (1967), that it is nearly impossible to breed bees which are equally good in all environmental conditions. This is confirmed by the comparatively poor correlation between the 1st and 2nd year total honey. However, the positive highly significant correlation indicates that some colony characters are independent of the climatic situation, a feature of fine or poor colonies. The correlation between honey and wax production was found to be unexpectedly low (r = 0.48, Table II). It must be taken into consideration that wax hasen't only the function of "wrapping material" for honey which would result in a correlation close to 1. Part of the wax production of a colony comes from the drone combs.

Table II - Correlations between hone and wax production of different years.

Traits		2	3
1 Honey	(1st.yr)	.20***	.48***
2 Honey	(2nd.yr)		.04
3 Wax	(1st.yr)		

*, Significant at $p < 0.05$.
**, Significant at $p < 0.01$.
***, Significant at $p < 0.001$.

The correlations between the subjectively registered colony traits are summatized in Table III. Aggressiveness and calmness during inspection were closely related (0.53) and both were significantly correlated with swarming tendency (0.11 and 0.18, respectively). Considering the scoring system (low swarming tendency = high marks) this means that gentle and non running colonies are also judged as having less tendency to swarm.

Table III - Correlations between subjectively scored traits.

Traits	2	3	4	5	6
1 Aggressiveness	.53***	-.05	.01	-.01	.11***
2 Calmness		-.03	.00	-.09*	.18***
2 Wintering ability			.20***	.26***	-.07
4 Spring-develop.				.58***	-.06
5 Colony size					-.13***
6 Swarming tendency					

*, Significant at $p < 0.05$.
**, Significant at $p < 0.01$.
***, Significant at $p < 0.001$.

Scored traits, indicating the ability to perform, such as wintering ability, spring development and colony strength, correlate positively with each other. Correlations between these and colony behaviour are not significant with the exception of the significant negative correlation ($r = -0.13$) between colony size and the swarming tendency of the colonies. The negative correlation reflects the fact that mainly the numerically strong colonies are limited by hive volume and react with swarming preparations.

Table IV indicates the extent of the relationship between the subjective evaluation of colony efficiency (strength, spring development, wintering ability) and their finally achieved honey and wax yields. These correlation are all clearly positive (0.2 to 0.5). In agreement with the results of Table III, the natural honey and wax yields are also not linked with a specific moulding of behaviour. Honey production and aggressiveness play a special role in the evaluation of the colonies. Therefore the correlation between both traits have frequently been the reason for related studies. In some cases this correlation may be considered by the beekeepers as negative (Sudgen and Furgala, 1982). Probably one reason could be an increased aggressiveness of stronger and therefore more efficient colonies. In agreement with Boch and Rothenbuhler (1974) and Sudgen and

Furgala (1982), no significant phenotypic correlations between colony strength and aggressiveness (Table IV, r = 0.01) were evident in our data. The calmness during inspection in larger colonies (-0.1) was significantly judged as more disadvantageous. Contrary to the opinion of some beekeepers no significant correlation between honey yield and aggressiveness has been proven so far (Ebbersten, 1978; Sudgen and Furgala, 1982; Szabo, 1982; Szabo and Lefkovich, 1988). Also in this study the low phenotypic correlations (Table IV) do not verify a reliable relation between these traits (r = 0.04). the assumption of a negative correlation between honey yield and aggressiveness may possibly be the result of hybrid vigor when bee races are crossed. In colonies of free mated queens possibly a more or less substantial share of the offspring might be race hybrids. Unfortunately, their above average efficiency is often linked with increased aggressiveness (Ruttner, 1968).

Table IV - Correlations between natural honey and wax yields, respectively, and subjectively scored traits.

Traits	Honey	Wax
Aggressiveness	.04	.07
Calmness	.01	.03
Wintering ability	.13***	.21***
Sping developm.	.37***	.45***
Colony size	.21***	.36***
Swarming tendency	.00	.07

*, Significant at $p < 0.05$.
**, Significant at $p < 0.01$.
***, Significant at $p < 0.001$.

Beekeepers dislike the swarming propensity and its control because of increased work. In addition the nectar collecting activities of colonies preparing to swarm are decreased, which should result in a negative correlation between honey production and swarming tendency. The r-value of 0.01 in Table IV doesn't point to any relation between the two characteristics. This becomes more understandable if one takes results of Table IV into account, namely the increased swarming tendency (low marks) of stronger colonies (higher marks). Strong colonies are the reason for intensified swarming impulse as well as, under special honey flow conditions, essential for above average honey yields. The diminishing efficiency effect of increased swarming tendency appears to be compensated especially in spring by higher yields of larger colonies (Table V). In summer and autumn one can find the expected coherence between decreasing swarming impulse and increasing honey yield, in the case of the summer yield, this is significant (r = 0.13). The correlations between (swarming stimulating tendencies of) colony strength and partial yields indicate that the relation between summer yield and colony size is lesser, and the corresponding value between colony strength and autumn yield is even slightly negative.

Table V - Correlations between the partial honey yields and subjectively scored traits.

Traits	Sping	Summer	Autumn
Aggressiveness	.06	.10***	.04
Calmness	-.03	.03	-.02
Wintering ability	.17**	.15*	-.07
Sping developm.	.47***	.17***	-.04
Colony size	.32***	.21***	-.16
Swarming tendency	-.04	.13*	.11

*, Significant at $p < 0.05$.
**, Significant at $p < 0.01$.
***, Significant at $p < 0.001$.

Generally, Table V shows that the correlations between the subjective judgement of colony traits, characterising the ability to perform (like wintering ability, spring development etc.), and partial records decline during the course of the year, and, in case of the autumn yield, show even negative tendencies.

Spring honey yields are quite important to the total honey production in Germany. Therefore strong attention is paid to this partial yield in selection. In combination with the selection response archieved with respect to early developing colonies, the poor genetic correlation between spring and following yields may explain these results.

The correlations between colony temper and the partial honey yields are similar to the results of Table IV.

In bee breeding in Central Europe special attention is paid to the cubital index. The selection difference with respect to this character was found to be 30% of the possible value. This is similar to the importance which honey production receives in selection. Consequently a clear rise of this morphological character within the last 25 years has taken place (Bienefeld, 1988). Often positive correlations with important colony traits like honey production or aggressiveness are assumed.

As summarized in Table VI all correlations between the cubital index and colony traits are calculated to be close to zero. Also in another study, Szabo and Lefkovich (1988) reported that a correlation between cubital index and honey production doesn't exist. The cubital index is useful to check the purity of mating. However, further statements concerning the quality of performance of a colony can't be made.

Table VI - Correlations between the cubital index and other traits measured.

Traits	Cubital index
Honey	.00
Wax	-.01
Aggressiveness	.01
Calmness	.01
Wintering ability	-.02
Spring developm.	.03
Colony size	-.05
Swarming tendency	.07

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RESUMO

Dados obtidos a partir de testes de desempenho em 5342 colônias de abelhas *Apis mellifera carnica* foram utilizados para calcular as correlações fenotípicas entre vários caracteres da colônia. Correlações entre produções parciais de mel no ano variaram de médias a baixas. A relação fenotípica entre as produções totais de mel em anos diferentes foi 0,2. As correlações entre dados julgados subjetivamente, indicando a capacidade de desempenho (habilidade de hibernar, desenvolvimento na primavera, etc.) e a produção natural de mel e cera variaram de 0,2 a 0,5. A eficiência das colônias e o comportamento não apresentaram relações significativas. O índice cubital não apresentou correlação com os outros caracteres determinados.

REFERENCES

Bienefled, K. (1988). Dreiβig Jahre Carnica-Reinzucht Überblick und Ergebnisse. *Allg. Dtsch. Imkerztg. 22*: 221-226.

Bienefeld, K., Reinhardt, F. and Pirchner, F. (1989). Inbreeding effects of queen and workers on colony traits in the honeybee. *Apidologie 20*: 439-450.

Bienefeld, K. and Pirchner, F. (1991). Genetic correlations among several colony characters in the honey bee (Hymenoptera: Apidae) taking queen and worker effects into account. *Ann. Entomol. Soc. Am. 84*: 324-331.

Boch, R. and Rothenbuhler, W.C. (1974). Defensive behaviour and production of alarm pheromone in honeybees. *J. Apic. Res. 13*: 217-221.

Cale, G.H. and Gower, J.W. (1956). Heterosis in the honey bee (*Apis mellifera* L.). *Genetics 41*: 292-303.

Ebbersten, K. (1978). Honeybee breeding - Experimental design of data recording from and by beekeepers in the field. *Proc. 4. Inst. Symposium on Pollination*, Maryland.

Hazel, L.N. and Lush, J.L. (1943). The efficiency of three methods of selection. *J. Heredity 33*: 393-399.

Louveaux, J. (1967). Die verschiedenen Arten der Anpassung der Biene (*Apis mellifica* L.) an das natürliche Milieu. *Allg. Dtsch. Imkerztg. 1*: 257-270.

Ruttner, H., (1972). Technische Empfehlung zur Methodik der Leistungsprüfung von Bienenvölkern. Paarungskontrolle und Selektion bei der Honigbiene. *Int. Symposium in Lunz.*

Ruttner, F. (1968). Methods of breeding honeybees: Intra-racial selection or inter-racial hybrids? *Bee World 49*: 66-72.

Ruttner, F. (1988). *Biogeography and Taxonomy of Honeybees*. Springer-Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo.

SAS Institute (1985). *SAS user's guide: statistics.* SAS Institute, Cary, N.C.

Soller, M. and Bar-Cohen, R. (1967). Some observation on the heritability and genetic correlation between honey production and brood area in the honey bee. *J. Apic. Res. 6*: 37-43.

Sudgen, M.A. and Furgala, B. (1982). Evaluation of six commercial honeybee (*Apis mellifera* L.) stocks used in Minnesota. Part 2 -Aggressiveness and swarming. *Am. Bee J. 122*: 185-188.

Szabo, T.I. (1982). Phenotypic correlations between colony traits in the honey bee. *Am. Bee J. 122*: 711-716.

Szabo, T.I. and Lefkovitch, L.P. (1988). Fourth generation of closed population honeybee breeding. 2. Relationship between morphological and colony traits. *Apidologie 19*: 259-274.

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