Genetic characteristics of the honeybee (*Apis mellifera L.*) favour recurrent selection

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SUMMARY

Colony traits in honeybees are an expression of the combined activities of queen and workers. Recent studies have shown a strong negative genetic correlations between the queen's and worker's contribution to economically important traits. By applying recurrent selection one can by pass this negative genetic relationship and can make use of heterosis.

INTRODUCTION

One of the difficulties, which arise in selecting honeybees, is the fact that most characters are affected by the combined activities of many workers (e.g. hoarding behavior) and of the queen (e.g. laying pattern). When deciding on a breeding strategy in this species, especially the genetic correlation between queen and worker effects should be considered.

MATERIALS AND METHODS

The composite character of colony traits in the honeybee, influenced both by maternal (queen) and direct (worker) effects, has its analogy in mammals. Traits like weaning weight depend both on the offspring, whose growth is measured, and on its dam, who furnishes the environment during development. Willham's (1963) approach fits this situation and permits the simultaneous estimation of h^2-values for maternal and (direct) offspring influences and the genetic correlation between them. This model has been adapted for use with the honeybee. Observed covariances of related colonies are expressed as functions of theoretical causal components of phenotypic variance. Covariances were estimated by REML (Restricted Maximum-Likelihood) and weighted parent-offspring covariance analysis. Causal components are then estimated by weighted least squares analysis of this system of equations. The data (n = 5581) for honey production and subjectively judged aggressiveness came from a controlled mated *Apis mellifera carnica* population in northern and middle Germany. Details are given by Bienefeld and Pirchner (1991).

RESULTS AND DISCUSSION

Honey production and aggressiveness showed medium to high h^2-values for workers (0.26/0.41) and queen effects (0.15/0.40). The genetic correlations between workers and queen effects were highly negative for both traits (-0.88/-0.91). This negative genetic relationship impedes selection response, since it reduces the phenotypic variance within population and therefore tends to stabilize it at a particular value, perhaps an optimum (Willham, 1963). This may be advantageous to honeybees under natural conditions, however in breeding programs this antagonism will complicate selecting honeybee queens which fits simultaneously with respect to genes for queen and worker effects. In addition also the following aspects has to be considered when planning a breeding program for the honeybee:

- Specially the worker caste is strongly affected by inbreeding (Bienefeld et al., 1989)
- Large heterosis effects and distinct different results are found when lines or races of honeybees were crossed reciprocally (Melnischenko and Trischina, 1976)

This favours a recurrent breeding program with two lines in a constant maternal and paternal, respectively, position. The maternal line is exclusively used to produce virgin queens for the hybrid colonies to be tested and the paternal line is exclusively used to produce drones in order to inseminate these queens. Assuming this mating scheme, selection will work on two different ways; on the purebred genotyp for queen effects of the maternal line and the combining ability of both lines in terms of the worker effects. In addition there is no real necessity to run the breeding program reciprocally, because honeybee queens can be used for hermaphoditic reproduction. Selected queens are able to supply virgin queens and drones (correspond to gametes because of its haploid status) in order to produce the next generation of purebred parents.

Testing exclusively hybrids in recurrent selection will result in a less erroneous selection, because all colonies have the same level of inbreeding in queens and no inbreeding in workers. Performance tests will become more economical, because outbred worker can compensate for inbreeding of the queen (Bienefeld et al., 1989). The breeding of disease resistant bees is becoming more and more important. In honeybees, as in other animal species, hybrids are found more disease resistant (Melnitschenko and Trischina 1976, Gary et al., 1990). Hybrids in recurrent selection are as well informants as market products, so the buyer can make use of this resistance and the breeder is enabled to test and improve the

resistance by contaminating these informants, to get reliable information without risking the breeding lines.

Practical application of recurrent selection in the honeybee:

In order to assess over-wintering ability and next years's honey yield in spring, mated queens have to be introduced during summer. In a single calender year it is impossible to:

1. Fully assess the performance of the hybrid colonies.
2. Mate the selected (based on this tests) individuals within each line for purebred line propagation.
3. Install the next generation of hybrid colonies.

Consequently, this organisation of the breeding program doesn't allow a continous testing of the hybrid generation resulting in an insufficient exploitation of the testing capacity and a long generation interval. The schedule of the breeding program should be modified as follows: Each pure bred line is devided in two sublines of equal size (M^A and M^B and P^A and P^B, respectively), each with a cycle of selection dephased by one year. M^A represents queens 1-25, M^B queens 26-50 of the maternal, P^A queens 1-20, P^B queens 21-40 of the paternal line. The procedure is illustrated by the Figure. Linking of the corresponding sublines (M^A with M^B and P^A with P^B) by exchanging drones is essential to limit the rate of inbreeding within the pure lines. Because either offspring of M^A and P^A or M^B and P^B, respectively, has to be tested, only half the number of colonies are tested each year. Queens in the hybrid colonies are pure bred and therefore likely to be inbred as well. The presence of inbred queens has little effect on colony performance when workers are outbred, however, there should be more queens in the maternal line than in the paternal line.

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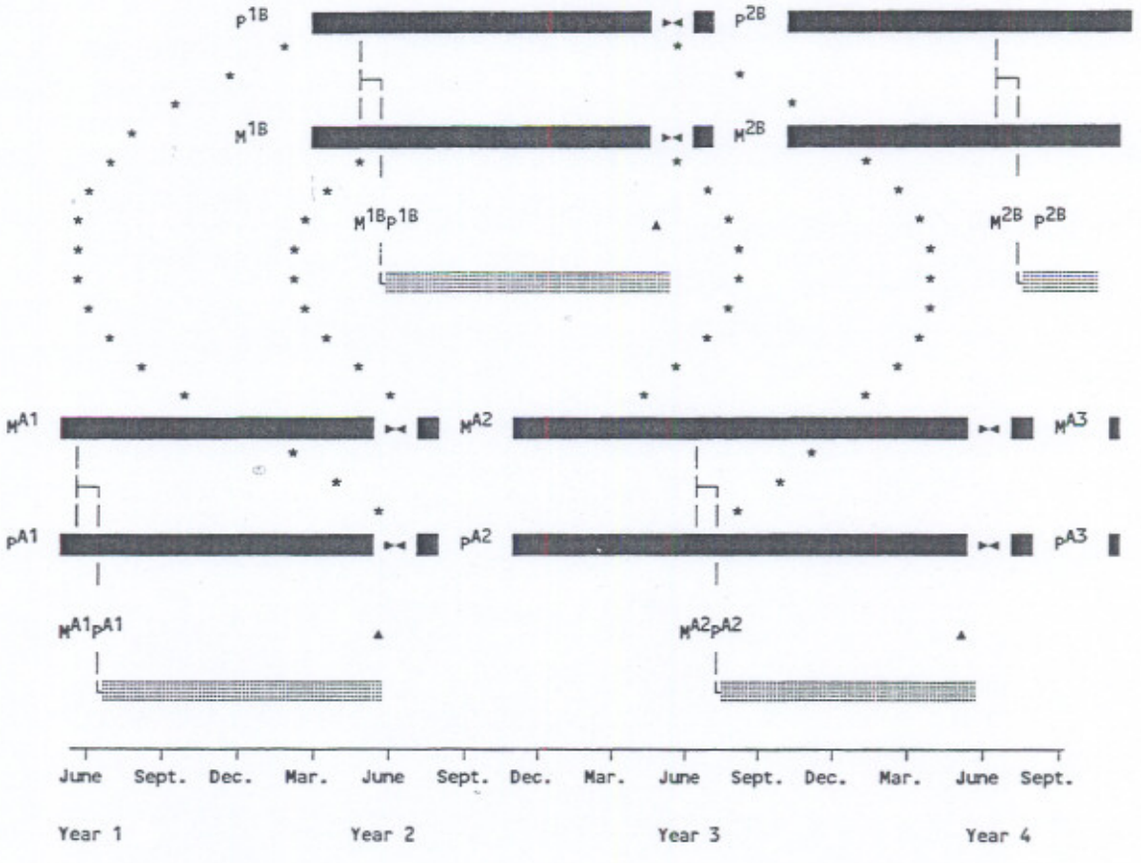
Organisation of recurrent selection in the honeybee



M^A, M^B: Maternal line (production of queens), P^A, P^B: Paternal line (production of drones), M^AP^A and M^BP^B: Hybrids for testing or marked.

⊢ : Crossing of M^A . P^A or M^B . P^B to produce the test cross or marked products.

▲ : Selection of suitable purebred parents with respect to the performances of their crossbred progeny.

▸◂ : Production of the next generation of purebred parents.

* *: Exchange of drones between the purebred sublines (M^A with M^B, P^A with P^B).

⁞⁞⁞ : Testing of the hybrids.