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INCREASE IN LIFE-SPAN, UNIT HONEY PRODUCTIVITY AND HONEY SURPLUS WITH FUMAGILLIN TREATMENT OF HONEYBEES

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Summary

An apiary of 24 overwintered colonies of honeybees (*Apis mellifera*) was divided in the spring into 2 groups so that each group contained weak, medium and strong colonies with similar amounts of brood. All colonies were fed with sugar syrup and each colony of one group received in addition 70 mg fumagillin. Treatment with fumagillin increased both brood production and length of worker life by 20%, resulting in a 40% increase in colony population. Fumagillin treatment also increased unit honey production by 19%, so that the total increase in honey surplus amounted to 58%. Unit productivity was not correlated with any of the 7 parameters of colony strength that were measured and so should be treated as an independent genetic character.

Introduction

Several authors have analysed the complex of internal factors of a colony which influence honey production (Laidlaw & Eckert, 1950; Doull, 1973/1974; Wille & Gerig, 1976; and others). In addition to colony populations, factors such as oviposition rate, brood viability and longevity (length of life) of workers were involved. The last three factors are difficult to evaluate in practical beekeeping operations. Because of brood mortality, daily oviposition rate is not equal to the number of brood cells divided by the development period. Woyke (1981, 1984) introduced such factors as average daily brood production and average productive longevity of worker bees. The complex of internal factors affecting honey production, therefore, may be presented in a form of 2 truistic equations (1) honey production = colony population × unit productivity (weight of honey produced by 1000 bees), and (2) colony population = average daily brood production × average length of productive life of workers. Whereas all beekeepers take care to increase brood production and colony population, almost nothing is done to increase the length of life or industry of bees in honey production. Beekeepers mostly do not realize this, and have no idea how to improve these factors. Certainly many methods exist. In the present investigation, the influence of fumagillin treatment has been examined.

Earlier work on fumagillin treatment was reviewed by Goetze and Zeutzschel (1959). Mostly the influence of fumagillin on specific factors affecting honey production, as well as on honey yield itself, has been investigated (Moeller, 1962; Gochnauer & Furgala, 1969, 1981; Furgala & Gochnauer, 1969; Furgala & Boch, 1970). Although mortality of treated and untreated workers in cages was investigated by Furgala and Boch (1970), average length of life of workers in treated and untreated colonies was not compared, nor was the influence of fumagillin on unit productivity of bees investigated. The purpose of this investigation was not only to record the effect of fumagillin treatment on honey production, but also to identify the basic colony factors through which the effect might be achieved.

Materials and Methods

Twenty-four honeybee colonies comprising hybrids of *A. m. mellifera*, *A. m. caucasica* and *A. m. carnica* were used. On 20 April, 25 workers collected from the upper part of the beeways between outside combs were checked for *Nosema apis* spores. The amount of brood on both sides of each comb was estimated on 26 April by measuring both axes of the elliptical area occupied by the brood and calculating the number of brood cells per unit area (Woyke, 1980). The colonies were then divided into 2 groups so that each group contained weak, medium and strong colonies with the same number of brood combs and brood cells. Starting on 5 May, each colony was given five 250-ml feedings of 33% sugar syrup every third day. Colonies in the control group received sugar syrup only, while 5 g fumagillin (Chinon, Budapest) was added to the syrup for the treated group. Each treated colony received altogether 1·25 litres of sugar syrup with 2 g fumagillin equivalent to 71 mg pure (DCH) compound.

Brood areas were measured 21 days after the beginning of the experiment (17 May) and again at 42 days (7 June). Colonies were moved to a raspberry crop at the beginning of the nectar flow on 2 June. At this time queen excluders were placed between the brood nests and the supers. Worker numbers were estimated on 7 June by shaking all the bees in a hive into a box, weighing them, and dividing the net weight by 114 mg (Woyke, 1984). The average size of the field force was estimated as 15%. This was done by shaking all workers from the combs of 5 hives during the day, weighing them and holding them outside the hive, then repeating the procedure in the evening for field bees returning to the hive. To compensate for absent field bees, therefore, the estimate of worker population was increased by 15%. The honey was harvested on 1 July, the yield being estimated as the difference between comb weight before and after extracting the honey. Average length of productive worker life was calculated from the relation between number of workers and total number of brood cells present in a colony 42 and 21 days earlier (Woyke, 1984). Unit productivity was expressed as g honey/1000 workers.

Student's *t*-test ($P<0{\cdot}05$) was used to test the significance of the differences between the means of the experimental and control groups of colonies.

Results

In the examination of bees for *Nosema* all colonies were found to be infected.

At the beginning of the investigation, control and treatment colonies had averages of 3·3 and 3·4 brood combs and 6300 and 6100 brood cells respectively (Table 1). Colonies treated with fumagillin had more brood at 21 days after the initial brood measurement (Table 1). A considerable increase in brood production was evident in the weakest colonies. Colonies of

TABLE 1. Brood production, worker population, average productive life of workers and honey surplus stored by control and fumagillin-treated groups of honeybee colonies.

Twelve colonies were used in each group.
Initial cell counts were made on 26 April and subsequent counts on 17 May (after 21 days) and 7 June (after 42 days). Fumagillin treatment began on 5 May. Honey was extracted on 1 July.
Numbers of brood cells and worker bees are in thousands.
Means in the same row followed by different letters are significantly different ($P<0{\cdot}05$).

Colony parameter	*Control (C)*		*Fumagillin-treated (T)*		
	Range	*Mean±SD*	*Range*	*Mean±SD*	*T/C (%)*
Initial no. brood combs	2·0– 5·0	3·3±0·8a	2·0– 5·0	3·4±0·8a	103
Initial no. brood cells	2·9–12·8	6·3±2·8a	3·0–10·3	6·1±2·1a	97
No. brood cells at 21 days	10·9–32·5	17·4–6·6a	14·0–31·3	21·6±5·0b	124
Combined brood cell counts	14·6–45·3	23·7±9·3	17·0–41·8	27·7±6·7	117
No. brood cells at 42 days	11·4–30·9	22·1±6·6a	17·7–32·0	26·4±4·2a	119
No. worker bees at 42 days	9·1–35·8	18·4±8·5a	13·6–50·9	26·0±9·6b	141
Average days of productive worker life	18·6–46·0	33·0±8·9a	28·4–68·8	40·0±11·5b	120
Kg honey harvested	2·6–34·7	14·7±9·3a	12·2–36·5	23·2±8·3b	158
Grams honey/1000 workers	245–1272	761±197a	614–1375	907±226·2b	119

medium strength in the control group had 11 000–20 000 brood cells and medium-strength colonies of the treated group, 18 000–25 000. No increase with treatment was noted in the strongest colonies. On average the increase with fumagillin treatment was 24%. An increase of about 20% was found in the combined measurements of 26 April and 17 May, as well as for the count of 7 June (after 42 days).

Significantly more worker bees were found in the treated colonies than in the controls. The intermediate-strength control colonies had 13 000–24 000 workers and the corresponding treated colonies 22 000–29 000. One treated colony was especially strong, having 51 000 workers. It had 3 deep supers of honey while the others had two. On the average 18 400 workers were found in the control colonies and 26 000 in the treated ones, an increase of 41% in the latter.

A significant increase was noticed in the life-span of workers in the treated colonies, the smallest increase for the treated bees being 10 days and the largest 22 days over the average for

control bees. Workers in the control group lived 33 days on average and those in the treated group 40 days, or 20% longer.

By 1 July the 3 weakest colonies in the control group had produced 2·6, 3·0 and 6·3 kg of honey and corresponding treated colonies 12·2, 14·5 and 14·6 kg. On average, treated colonies stored 58% more honey (14·7 *vs* 23·2 kg). Unit productivity, or mean weight of honey produced per 1000 workers, was 19% higher in treated colonies.

The overall effect of fumagillin treatment, therefore, was to increase both brood production and average productive life-span of workers by 20% (resulting in a 40% increase in population) and unit productivity by 19% to produce an increase in stored honey of 58%.

Correlations between honey production and several parameters of colony strength are listed in Table 2. Weight of stored honey was correlated most closely with colony population during honey flow and amount of brood 3 weeks before the flow (17 May). A significant correlation was also found for weight of honey, and both worker life-span ($r = +0{\cdot}55$) and unit productivity ($r = +0{\cdot}60$).

In contrast to the correlations between honey produced per colony, correlation coefficients between unit productivity and various colony parameters (Table 3) were low and non-significant, indicating that unit productivity was not dependent upon these parameters, and should be regarded as an independent genetic factor.

TABLE 2. Correlation coefficients between stored honey and various colony parameters in control and fumagillin-treated honeybee colonies.

Parameter	*Control colonies*	*Treated colonies*	*All colonies*
No. brood cells at 21 days	+0·74*	+0·62*	+0·75*
Total brood cells at 21 and 42 days	+0·71*	+0·61*	+0·69*
No. workers at 42 days	+0·89*	+0·77*	+0·85*
Worker life span	+0·46	+0·52	+0·55*
Honey/1000 bees	+0·65*	+0·44	+0·60*

*Significant at $P<0{\cdot}05$

TABLE 3. Correlation coefficients between unit productivity and various colony parameters in control and fumagillin-treated honeybee colonies.

Parameter	*Control colonies*	*Treated colonies*	*All colonies*
No. workers	+0·27	−0·21	+0·15
Worker life span	+0·18	−0·30	+0·04
No. brood cells at 21 days	+0·25	+0·16	+0·29
Ratio brood cells/workers at 21 days	−0·20	+0·06	−0·06
No. brood cells during nectar flow	+0·38	−0·17	+0·29
Ratio brood cells/workers at 42 days	−0·06	+0·13	−0·06

Discussion

The extent of the effects of fumagillin treatment on various colony parameters observed in the present study differed somewhat from those reported by other investigators.

Moeller (1962), Furgala and Gochnauer (1969) and Gochnauer and Furgala (1969, 1981) found that fumagillin fed in the spring to package bee colonies either failed to increase brood production or increased it by only 10% or less. Autumn feeding increased brood production the next year by 27% in a study by Gochnauer and Furgala (1969). Spring feeding of fumagillin to overwintered colonies in the present study increased brood production by 20%.

In the experiments of Furgala and Gochnauer (1969) fumagillin feeding of package colonies increased worker population by 4%, in contrast to an increase of 41% for the overwintered colonies in the present study.

Fumagillin reduced mortality of caged workers from 76% to 22–45% (Furgala & Boch, 1970). In the same investigation average worker life-span in treated colonies was increased by 20%. The average life-span for workers from the untreated colonies in my investigation (33 days) was close to the average of 30 days reported by Free and Spencer-Booth (1959), Sekiguchi and Sakagami (1966), Sakagami and Fukuda (1968) and Taranov and Azimov (1972). However, the average for my treated colonies (40 days) was longer than any previously reported.

The increase of 58% in stored honey in this investigation was intermediate between the increase for fumagillin treatment of package colonies in spring of 27–37% reported by Moeller (1962) and increases of as much as several-fold for colonies treated in autumn (Furgala & Gochnauer, 1969).

In a recent study (Woyke, 1984) honey surplus was closely related to unit productivity, and unit productivity was correlated to a varying degree with worker population and life-span. Coefficients of determination indicated that honey production was determined by population only to the extent of 14–49%. Unexpectedly, in the present experiment, the only close association was between unit productivity of workers and total honey production of the colony.

References

Doull, K. M. (1973/1974) Biological and technical factors affecting profitability in beekeeping. *Australas. Beekpr* 75 : 40-42, 71-73, 97-99, 118-120, 146-147, 163-167

Free, J. B.; Spencer-Booth, Y. (1959) The longevity of worker honey bees. *Proc. R. ent. Soc.* Lond. 34 : 141-150

Furgala, B.; Boch, R. (1970) The effect of Fumidil B, Nosemack and Humatin on *Nosema apis*. *J. apic. Res.* 9(2) : 79-85

Furgala, B.; Gochnauer, T. A. (1969) Chemotherapy of nosema disease. Effect of treatment method with fumidil-B. *Am. Bee J.* 109(10) : 380-381, 392

Gochauer, T. A.; Furgala, B. (1969) Chemotherapy of nosema disease. Compatibility of fumagillin with other chemicals. *Am. Bee J.* 109 : 309-311, 392

———(1981) Chemotherapy of nosema disease: further studies on the interaction of fumagillin and the antibacterial agents, sodium sulfathiazole and oxytetracycline. *Am. Bee J.* 121(4) : 253-254

Goetze, G.; Zeutzschel, B. (1959) Nosema disease of honeybees, and its control with drugs: review of research work since 1954. *Bee Wld* 40(9) : 217-225

Laidlaw, H. H.; Eckert, J. E. (1950) Queen rearing. *Hamilton, IL: Dadant & Sons*

Moeller, F. (1962) Nosema disease control in package bees. *Am. Bee J.* 102(10) : 390-392

Sakagami, S.; Fukuda, H. (1968) Life tables for worker honeybees. *Researches Popul. Ecol. Kyoto Univ.* 10(2) : 127-139

Sekiguchi, K.; Sakagami, S. F. (1966) Structure of foraging population and related problems in the honeybee, with considerations on the division of labour in bee colonies. *Rep. Hokkaido Natn. agric. Exp. Stn No.* 69

Taranov, G. F.; Azimov, T. N. (1972) Prodolzitelnost zizni pcel. *Pchelovodstvo* (3) : 16-17

Wille, H.; Gerig, L. (1976) Massenwechsel des Bienenvolkes IV. Zusammenspiel der Eilegetätigkeit der Königin, der Bienenschlüpfrate und der Lebensdauer der Arbeiterinnen (*Apis mellifica* L) *Schweiz. Bienenztg* 99 : 16-25, 125-140, 244-257

Woyke, J. (1980) Effect of sex allele homo-heterozygosity on honeybee colony population and on their honey production. I. Favourable development conditions. *J. apic. Res.* 19(1) : 51-63

———(1981) Influence of internal factors of the bee colony on honey production in El Salvador. *28 int. Beekeep. Congr. Acapulco* : 298-304

———(1984) Correlations and interactions between population, longevity and honey production by honeybees in temperate zone. *J. apic. Res.* 23(3) :