EXAMINATION OF THE METHOD FOR ESTIMATING THE BROOD AREA AND NUMBER OF WORKER BEES IN FREE-FLYING BEE COLONIES

English translation of the German article published in Apidologie, 1987, 18 (2), 137-146 "Überprüfung der Schätz Methode zur Ermittlung der Brutfläche und der Anzahl Arbeiterinnen in freifliegenden Bienenvölkern"
DOI: https://doi.org/10.1051/apido:19870204

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SUMMARY

The 'Liebefeld method' for estimating the number of worker bees and the areas of open and capped brood cells was re-examined in 1984. The necessary checks were carried out every three weeks from April to October in two free-flying bee colonies. To begin with, we estimated the number of bees and the area occupied by the brood cells, then compared our estimates with the results obtained by weighing or measuring (planimetry). There was a high correlation between our estimates and the measurement results for both the number of bees ($r^2 = 0.967$; n = 18) and for the capped brood cells ($r^2 = 0.987$). For the open brood cells, the correlation was lower ($r^2 = 0.654$). The total estimated brood area during the experiment exceeded the measured values by 1.6% in one of the colonies and by 5.4% in the other. Estimates of bee numbers were regularly too low. This discrepancy can be rectified by adopting 1200 bees rather than 1100 as the standard population of one face of a comb (Swiss comb = 921cm^2). This method enables the dynamics of bee colonies to be determined quickly and accurately, with minimal disturbance of the bees.

INTRODUCTION

Over time, there has been no shortage of efforts to record brood activity, and attempts, though fewer in number, have also been made to determine the fluctuations in the worker population of bee colonies. As long ago as 28 June 1853, B. v. BERLEPSCH had counted all the occupied worker cells in a colony (Brünnich, 1922). In the same paper, BRUENNICH published his own brood measurements for several colonies over the entire bee season. VON EBERT (1922) performed calculations on the weight change in the colony with the help of brood and weighing measurements. NOLAN (1925), and subsequently many other authors, made further measurements of brood development.

FARRAR (1937) investigated the influence of colony size on the honey harvest by weighing the bees. This method is very precise if, like FARRAR, one determines the average weight of the individual bee per hive at each weighing. It is also very labour-intensive, however. JEFFREE (1951) developed an estimating method which involved comparing each face of the comb occupied by bees with photographs with known numbers of bees. In 1955, he was the first to track the development of the worker populations of various colonies using this method combined with weighings at regular intervals over the entire bee season. In 1958, he estimated brood areas with the aid of a grid the size of the brood frames used.

Based on JEFFREE's work, in the early 1970s WILLE and GERIG developed the 'Liebefeld Estimation Method' examined in this paper for recording the number of worker bees and the open and capped brood areas of a colony (WILLE and GERIG, 1976; GERIG, 1983). Estimates at regular 21-day intervals permit the objective recording of colony weight changes.

MATERIALS AND METHODS

We tested the estimation method on colonies 4 and 8 at the Institute's bee yard in Liebefeld. The colonies were housed in Swiss hives (side-opening, frames running 'warm way') in a bee house. Colony size was estimated nine times at three-week intervals from 17 April to 1 October 1984.

2.1 *Estimation Method*

The estimate was performed in the early morning before the start of flight activity, in a space which no bees could fly out of.

Bees

We assumed that on a densely occupied Swiss-hive-sized brood comb (internal dimensions: height 34.5cm, width 26.7cm, area 921cm^2), there would be around 1100 bees per comb face, including frame, corresponding to approx. 120 closely packed bees per dm^2. If the combs are only partially, and hence more sparsely, covered by bees, one then imagines what proportion of the comb would be covered if all the bees were densely clustered together, e.g. half of the area covered would be equivalent to 550 bees, one-quarter coverage to approx. 250-300 bees, etc. (smallest estimated unit: 50 bees). The result is noted down for each comb face.

Estimating the number of bees which sometimes cluster along the bottom frame of the comb, or on the walls and floor of the hive poses more difficulties. For single-layer dense coverage in the size of a brood comb, again 1100 bees are estimated. For multiple coverage, appropriate additions must be made. Larger clusters of bees, such as seen when bees 'beard' outside the flight entrance of a hive, or on the floor inside the hive, should be recorded by weight for practice.

Brood

The open and capped areas of worker brood per comb face are estimated in dm^2 (smallest estimated unit: 0.1 dm^2). From this, the number of occupied brood cells is then calculated (400 brood cells per dm^2). This figure may be slightly higher or lower, depending on the nature of the wax foundation. The estimated brood area should be checked periodically with a grid frame (10cm x 10cm division) or tape measure.

2.2. *Weighing and Measurement as a Check*

Measurements were made immediately after the estimate in each case.

Bees

All bees from the combs and hive as well as the bees at the windows that had left the hive were carefully brushed into a tared swarm box and weighed. From this, a mixed sample of around 250 bees was extracted and the average weight of one bee determined. From the total weight, we then calculated the number of bees in the colony in question. The drone brood in both experimental colonies was cut out before it hatched.

Brood

The outlines of the open and capped brood areas were traced onto transparent sheets, one comb face at a time. With unsealed brood nests, the percentage of occupied cells was estimated. The exact brood area was measured with a videoplan planimeter and the number of brood cells was calculated, bearing in mind the percentage of occupied cells.

RESULTS AND DISCUSSION

3.1 *Number of Bees*

The weighing process regularly yielded a higher number of bees than the estimation (Figs. 1 and 2). Over the nine measurements taken, colonies 4 and 8 were underestimated by an average of 15.5% and 12.1%, respectively. This underestimation can be explained as follows:

1. Since the underestimation was consistent, it must be assumed that the standard of 1100 bees per densely occupied comb face was too low. Since then we have stipulated 1200 bees per face of a Swiss comb as standard.

2. The bees' behaviour on the comb was not taken into account sufficiently during the estimation process. It was found that the estimation error increased in size if part of the bees ingested food from the cells head-to-head. Because this behaviour varies significantly from measurement to measurement in the same colony, it too must be borne in mind by the estimator. If the bees move about on the comb, around 130 bees per dm^2 should be expected if the comb is densely occupied. BURGETT and BURIKAM (1985) reckoned on 138 bees per dm^2, but if the bees are standing head-to-head in the cells, this number could increase up to 350.

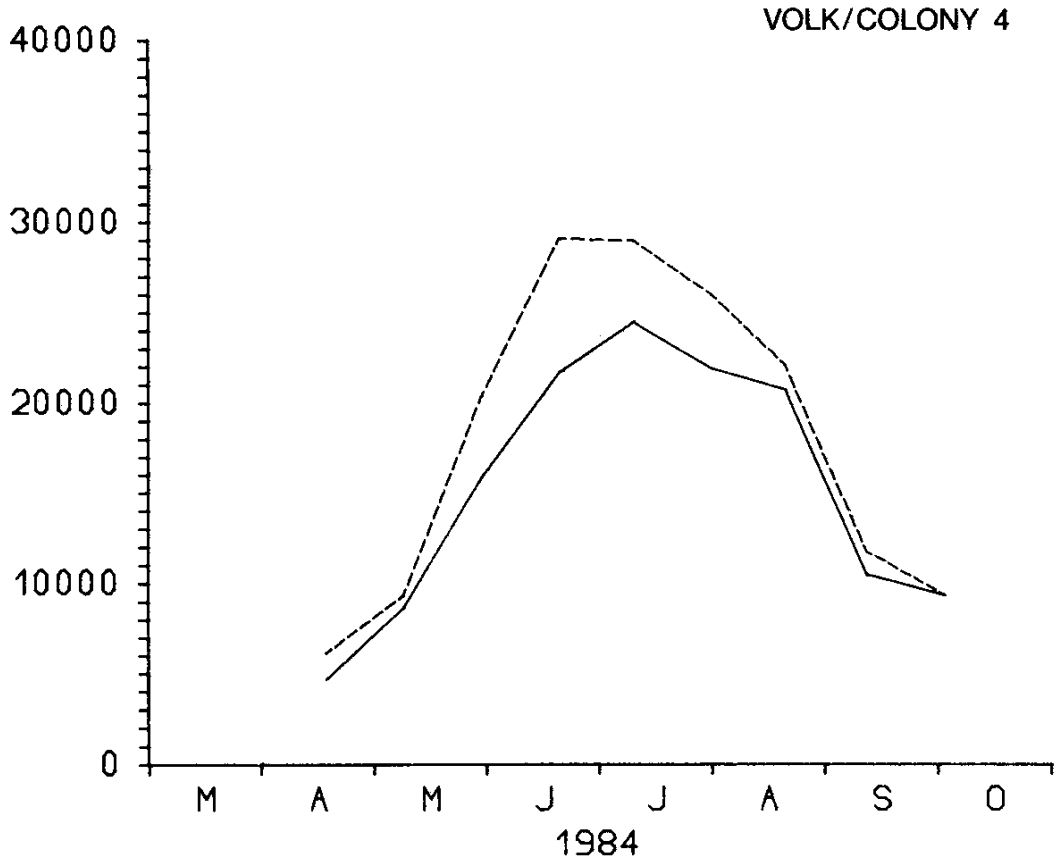

ABB. 1. — *Geschätzte* (————) *und durch Wägen bestimmt* (--------) *Anzahl Bienen*
FIG. 1. — *Number of bees obtained by estimation* (————) *and weighing* (--------)

Despite this underestimation, the accuracy of the method for estimating the number of bees is considerable. Comparing the estimated values to the relevant measured values yields a very high correlation ($r^2 = 0.967$, Fig. 3).

For eight of the measurements, the number of bees was determined independently by three estimators. Their results also correlate very well with one another. The coefficient of determination r^2 for estimators A/B, B/C and A/C was 0.991, 0.992 and 0.975, respectively. These results show that the findings do not lose their significance if various experienced estimators carry out the surveys in an experiment.

3.2 ***Brood***

The brood was both over- and underestimated (Figs. 4 and 5). In the case of the capped brood, estimate accuracy was very high ($r^2 = 0.987$, Fig. 6), owing to the readily visible areas. Greater estimating errors were made with the open brood ($r^2 = 0.654$, Fig. 7). Due to the bees sitting on the combs and the often unsatisfactory light conditions in the beehouse, visually recording the open brood area is difficult. In particular, the areas with eggs are not always easy to record.

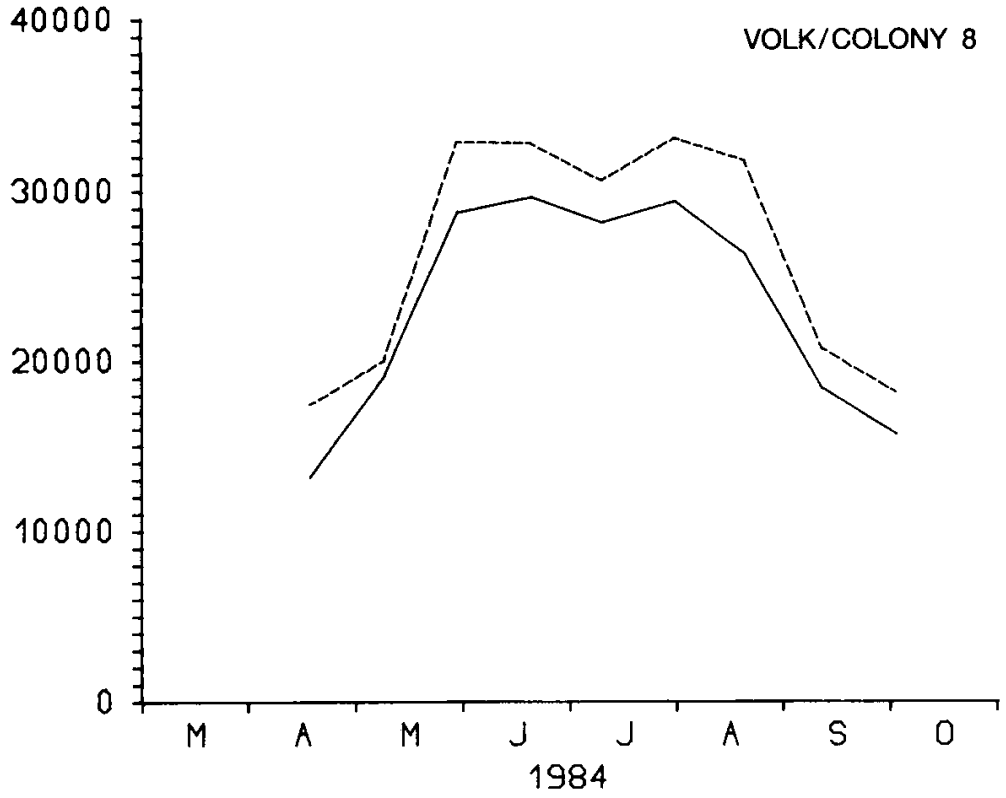

ABB. 2. — *Geschätzte* (————) *und durch Wägen bestimmte* (--------) *Anzahl Bienen*
FIG. 2. — *Number of bees obtained by estimation* (————) *and weighing* (--------)

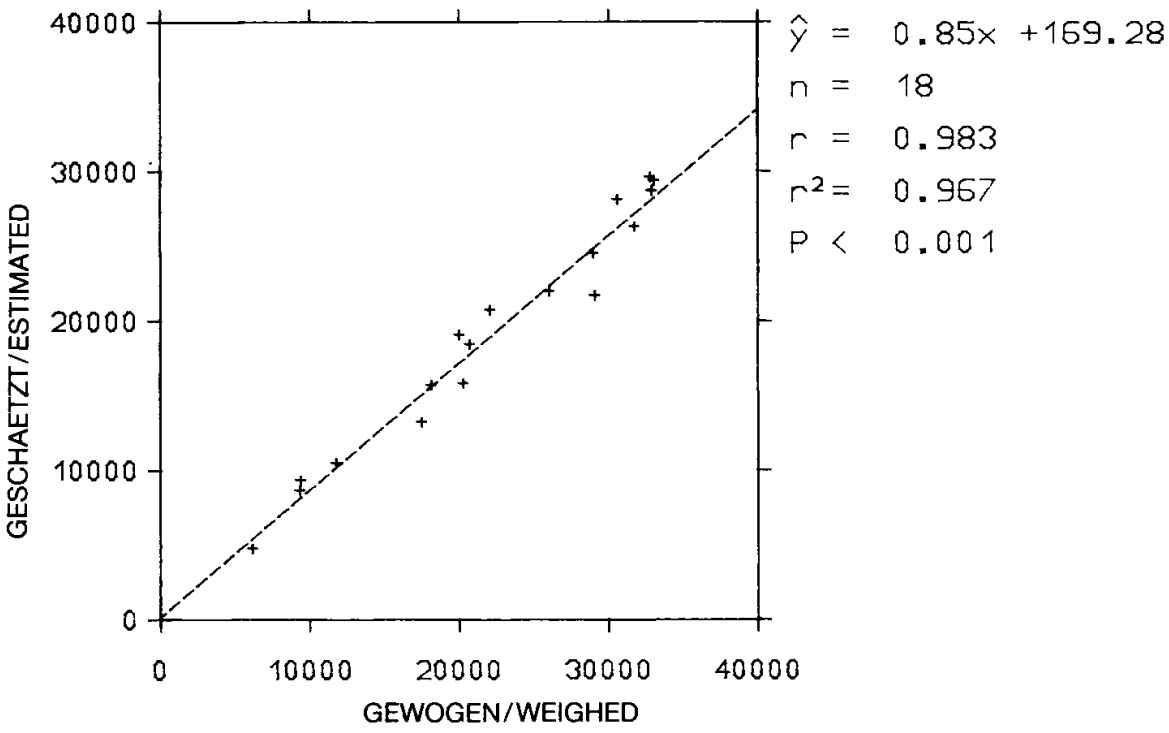

ABB. 3. — *Korrelation zwischen der geschätzten und der durch Wägen bestimmten Anzahl Bienen*
FIG. 3. — *Correlation between estimated and weighed number of bees*

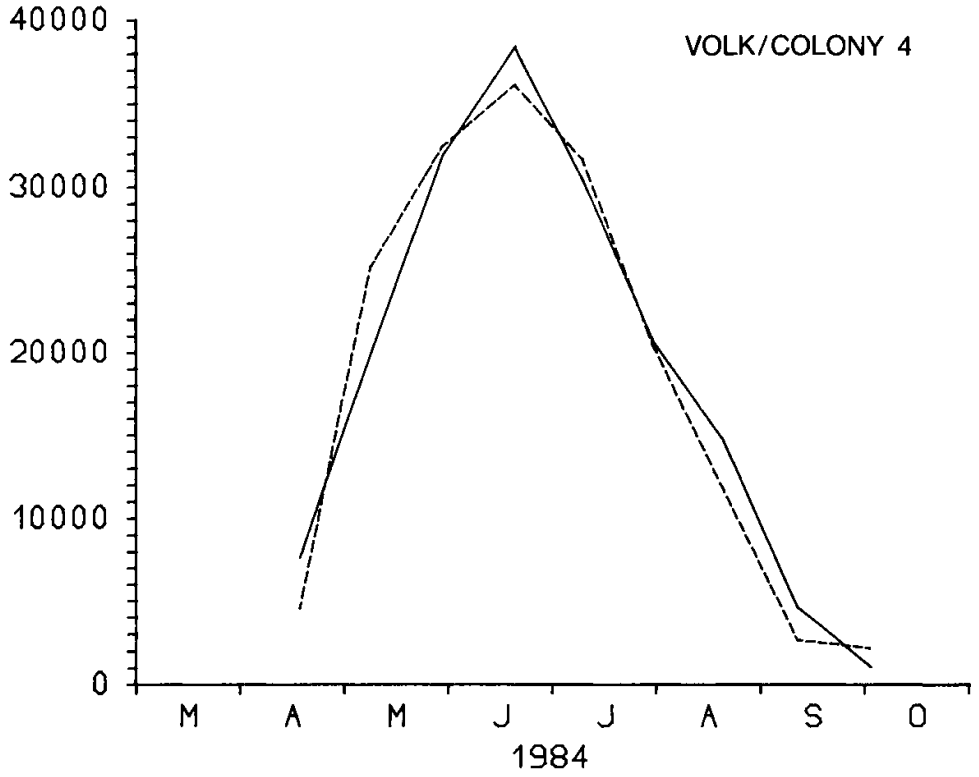

ABB. 4. — *Geschätzte* (————) *und gemessene* (--------) *Anzahl Brutzellen*

FIG. 4. — *Number of brood cells obtained by estimation* (————) *and measurement* (--------)

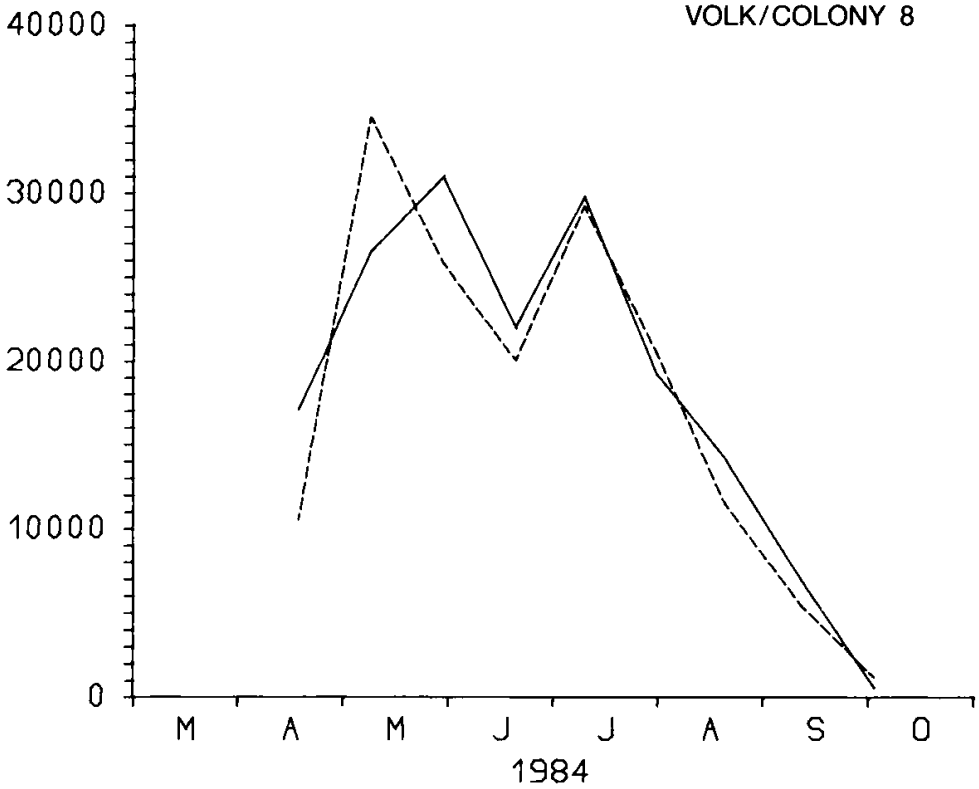

ABB. 5. — *Geschätzte* (————) *und gemessene* (--------) *Anzahl Brutzellen*

FIG. 5. — *Number of brood cells obtained by estimation* (————) *and measurement* (--------)

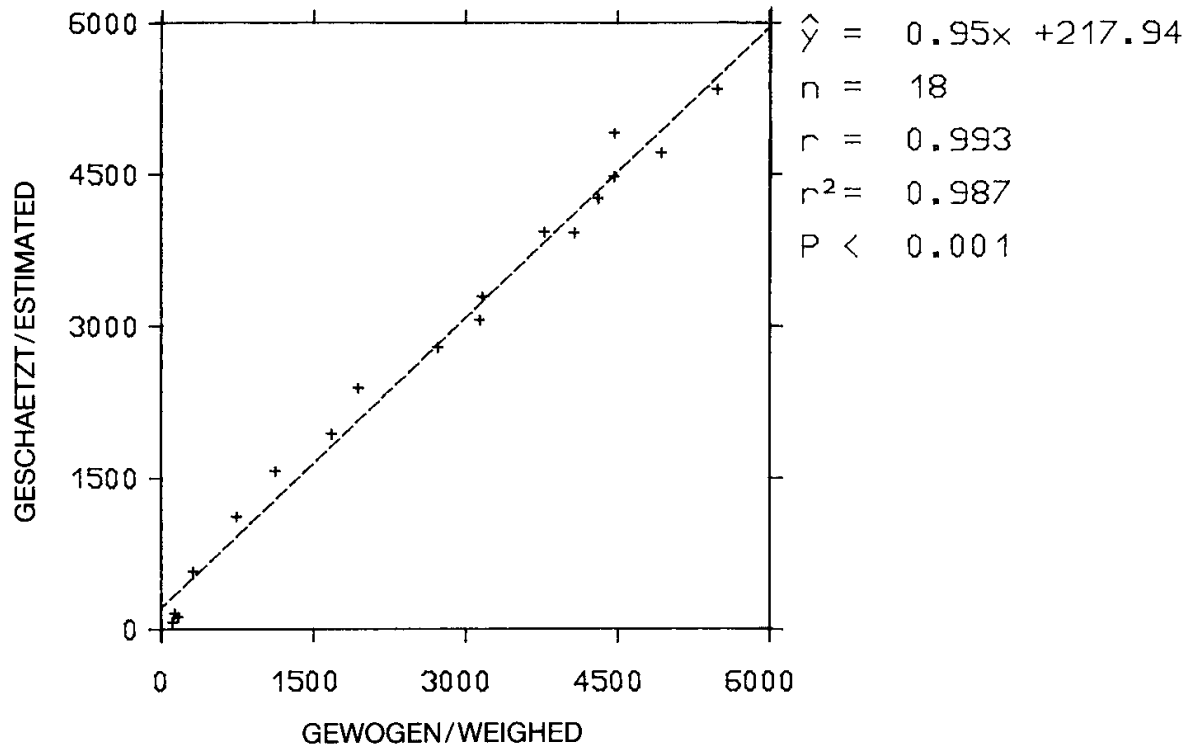

ABB. 6. — *Korrelation zwischen den geschätzten und gemessenen, gedeckelten Brutflächen (cm^2)*
FIG. 6. — *Correlation between estimated and measured areas of sealed brood cells (cm^2)*

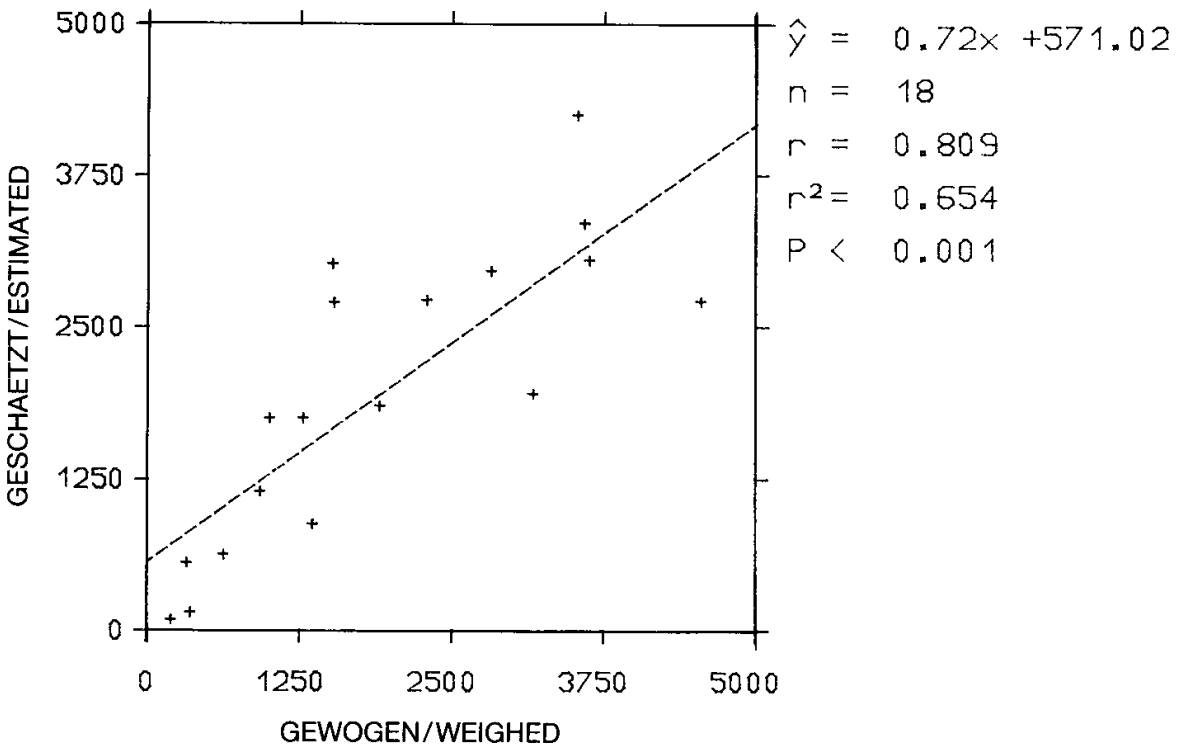

ABB. 7. — *Korrelation zwischen den geschätzten und gemessenen, offenen Brutflächen (cm^2)*
FIG. 7. — *Correlation between estimated and measured areas of open brood cells (cm^2)*

Total brood production over the course of the entire experiment was overestimated by 1.6% and 5.4% respectively for colonies 4 and 8. The small size of these estimating errors confirms the usefulness of the estimation method.

3.3 ***Remarks on the Estimation Method***

As this review shows, the 'Liebefeld Estimation Method' is highly suitable for obtaining raw data for the study of weight change in free-flying bee colonies. Provided that the 21-day estimation intervals are observed, further parameters such as the relationship between brood and adult bees, total brood production, mean age, mean life expectancy, bee-days (i.e. number of emerged workers x lifespan) and much more can be determined by means of calculations and EDP software (BUEHLMANN, 1984, 1985, 1986). Experimenters therefore have recourse to a tool that gives them a better insight into dynamic occurrences in the bee colony. This in turn allows the effects of care measures, remedies, environmental influences and the relationship between the colony and pathogens to be quantified.

The conventional method for determining colony strength by the number of "cells occupied by bees" or "occupied beeways" is imprecise, and in our experience leads to considerable misjudgements. Contenting oneself with estimating colony strength based only on the available brood area leads to completely false results. As other analyses have shown, there is only a loose correlation between brood production and colony strength (BUEHLMANN, 1986).

The amount of work involved per colony and estimate varies strongly according to season, or colony strength and hive system. For an experienced estimator, it takes between 5 and 15 minutes. The person acting as the recorder can be replaced by a handy, reliable tape recorder. It is recommended that control measurements be taken when learning how to estimate.

With bee experiments, the measurements are also carried out during the day, i.e. during bee flight. However, since there are changes in flight intensity dependent on the time of day, weather and honey flow, it is advisable to estimate the colonies of different experimental groups alternately rather than one after the other.

No disturbance to colony development caused by repeated opening of the hives was observed.

Submitted in July 1986.
Accepted in November 1986.

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