

**BIOMETRICAL-STATISTICAL ANALYSIS
OF THE GEOGRAPHIC VARIABILITY
OF *APIS MELLIFERA* L.***

I. Material and Methods

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SUMMARY

33 characters were measured in each of 404 samples of honeybees from different regions and examined by multivariate analysis. The quantitative variation of characters, as correlated with the geographical distribution of bees, is shown in a graph.

INTRODUCTION

The species *Apis mellifera* L. has a quite unusually large area of distribution. It extends from Southern Scandinavia in the North to the Cape of Good Hope in the South, from Dakar in the West to the Urals, Mashad and to the coast of Oman in the East. It was experimentally shown that it is in fact a single species, as all the different types from this enormous region, comprising the whole western part of the Old World, interbreed with full fertility.

It is evident that the different types originated by geographic isolation and ecological adaptations. They were partly described as early as the beginning of the 19th century, but this gave rise to quite a lot of confusion due to the lack of definition

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of their taxonomic position. In 1906 H. von BUTTEL-REEPEN tried to organize the multiplicity of types in a rational way by using a trinomial system : First the genus and species designation *Apis mellifica* (nowadays *Apis mellifera* according to the rules of zoological nomenclature) and as third name the geographic race or variety, e.g. *A.m. ligustica* or *A.m. intermissa*. Thus the taxonomy of the honeybee accords with the rules of nomenclature generally accepted in biology.

The description of geographic races, however, was rather imprecise, since it was based nearly exclusively on the criteria of colour and size. There was a tendency to regard all bees with yellow colour on the abdomen as offspring of "Italians", whether they were found in Central Europe, in Rhodos or in North Africa.

Between 1925 and 1940 V. V. ALPATOV and G. GÖTZE provided a more exact basis for describing races of bees by introducing biometrics (that is to say exact measurements) as well as new morphological characters. From that time it was possible to define and to describe *accurately* the various races of bees.

Both these outstanding researchers published books in this field, V. V. ALPATOV "The races of bees and their use in agriculture", 1948 (in Russian); G. GOETZE "The best bee" 1940, and "The honeybee in natural and artificial selection" 1964 (both in German).

The work of GOETZE had a great influence on apiculture in Europe, as it effectively promoted breeding work through the improvement of mating control and selection. The new taxonomic approach has also proved to be indispensable for serious work in our time.

The few characters used by ALPATOV and GOETZE (mainly colour, cubital index, hairs and certain measurements of size) were adequate to discriminate the European races from each other; but a glance at the globe shows that Europe comprises only a very small part of the whole natural distribution area of *A. mellifera*. Furthermore, the bees studied were from the temperate zone, which they had presumably occupied only in the postglacial period, having spread from the old "gene centers" of the honeybee in the warmer zones. To understand correctly the true nature of the races of bees (including these European races) and their relationship, a knowledge of the whole spectrum of bee races is necessary.

A study of the races of bees, based on modern methods in biometrics, is an urgent need because in some regions the local bees are being irreversibly hybridized by heavy importations of other races. For instance, the northwestern border of the *carnica* race in the Alps was clearly located by samples collected in the years 1949/1951 (F. RUTTNER, 1967); but today the honeybees of this region show advanced hybridization.

The object of our long term programme is to characterize as comprehensively as possible the geographic types of the honeybee and to clarify the intraspecific structure of the species. A large number of additional characters were used to establish the basis for multivariate statistical analysis as we assumed that the characters used to

discriminate between European races would not necessarily have the same value in distinguishing between the honeybees of other regions.

The first of a series of publications presents the methods and the material used and a general survey of the total variability of the species.

MATERIAL AND MEASURE METHODS

During extensive preliminary analysis a large number of characters that could be quantified were tested in respect to their taxonomic value. Eventually 42 characters were selected, constituting the "standard programme" for our analysis (table 1; fig. 1 - 10).

TABLE 1. — *List of the characters used for this analysis*

| No. | Character | Author | Fig. |
|--------|--|---------|------|
| 1 | Length of hairs on tergite 5 | GOETZE | 1 |
| 3 | Width of the tomentum band on the side of tergite 4 | GOETZE | 1 |
| 4 | Width of the dark stripe between the tomentum and the posterior rim of the tergite | GOETZE | 1 |
| 5 | Length of the stretched proboscis (glossa + mentum + submentum) | ALPATOV | 2 |
| 6-8 | Length of the hind leg (femur No. 6, tibia No. 7, metatarsus No. 8) | ALPATOV | 3 |
| 9 | Width of metatarsus 3 | ALPATOV | 3 |
| 10-12 | Pigmentation of tergites 2-4, evaluated according to a scale of 10 grades between the darkest (0) and the brightest (9) | GOETZE | 4 |
| 13, 14 | Diameter of tergites 3 and 4, longitudinal (*) | ALPATOV | 5 |
| 15 | Sternite 3, longitudinal (*) | ALPATOV | 6 |
| 16, 17 | Wax mirror, sternite 3, longitudinal and transversal (*) | ALPATOV | 6 |
| 18 | Distance between wax mirrors, tergite 3 | RUTTNER | 6 |
| 19, 20 | Sternite 6, longitudinal and transversal (*) | RUTTNER | 7 |
| 21, 22 | Fore wing, length and width | ALPATOV | 8 |
| 23, 24 | Pigmentation of the scutellum | RUTTNER | 9 |
| 25, 26 | Pigmentation of the labrum | RUTTNER | 10 |
| 27-30 | Segment a and b of cubital cell 3, right and left | ALPATOV | 8 |
| | | GOETZE | |
| 31-41 | 11 angles between lines connecting cross points of the venation on the fore wing (No. 31+ angle A 4, 32 = B 4, 33 = D 7, 34 = E 9, 35 = G 18, 36 = J 10, 37 = J 16, 38 = K 19, 39 = L 13, 40 = N 23, 41 = O 26) | DUPRAW | 11 |
| 42 | Number of hooks on the hind wing | | |

(*) The termini "longitudinal and transversal" are used instead of "length" and "width" which may be misleading.

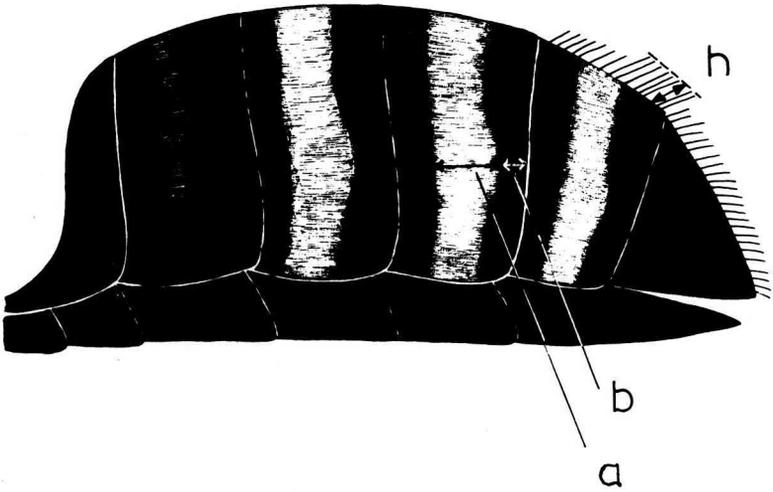


FIG. 1. — *Abdomen of the worker.*
A width of tomentum, tergite 4 (No. 3); b width of the dark stripe between tomentum and posterior rim of the tergite (No. 4); length of hairs on tergite 5 (No. 1)

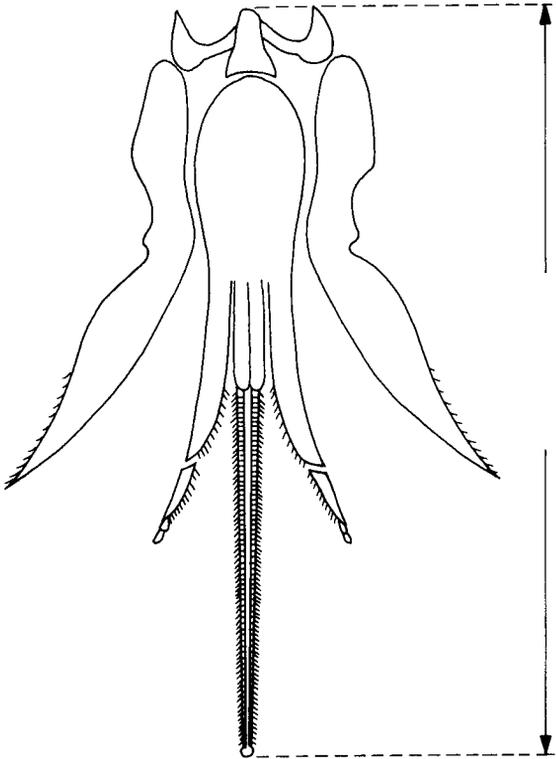


FIG. 2. — *Length of proboscis (No. 5).*

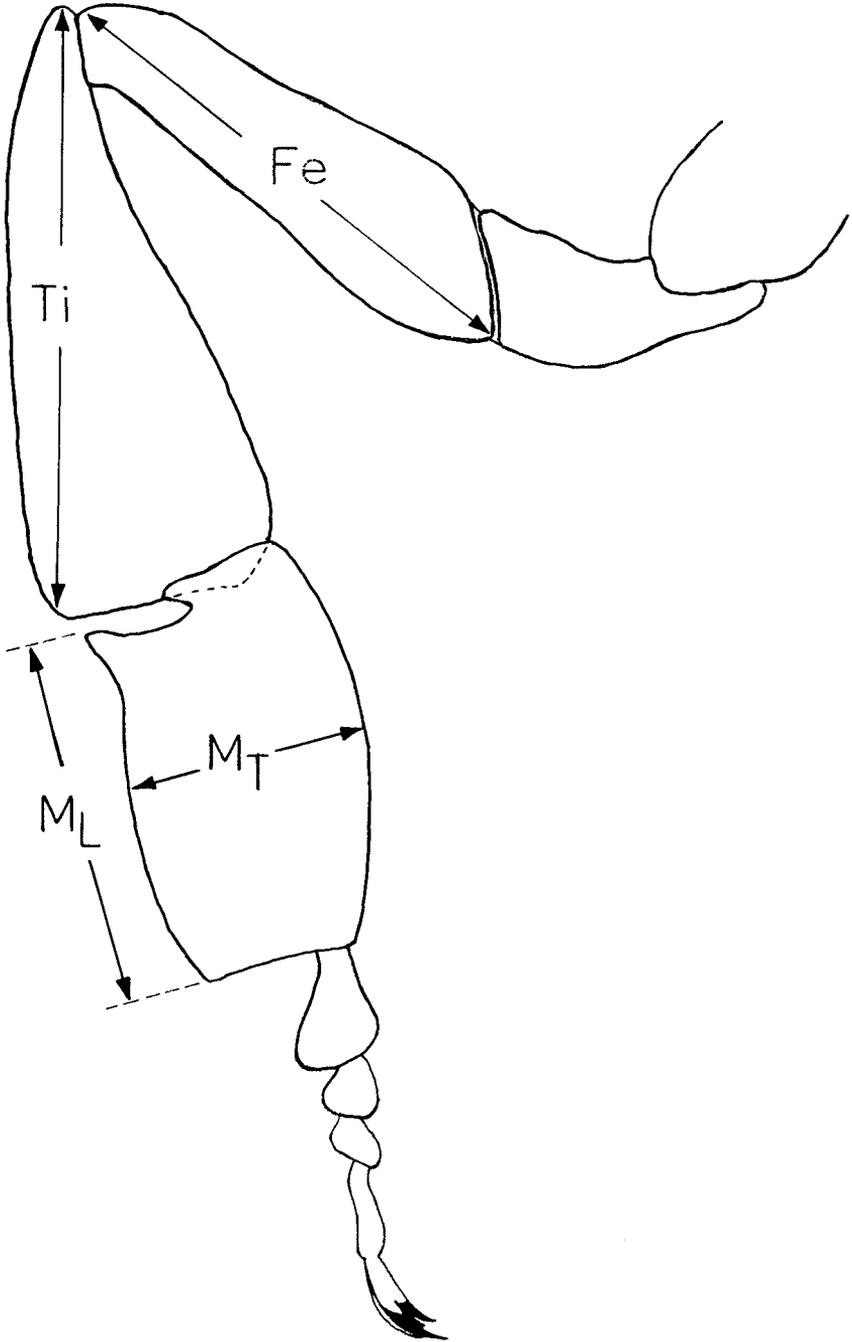


FIG. 3. — *Hind leg of the worker bee.*
Fe length of femur (No. 6); Ti length of tibia (No. 7);
ML length of metatarsus (No. 8); MT width of metatarsus (No. 9).

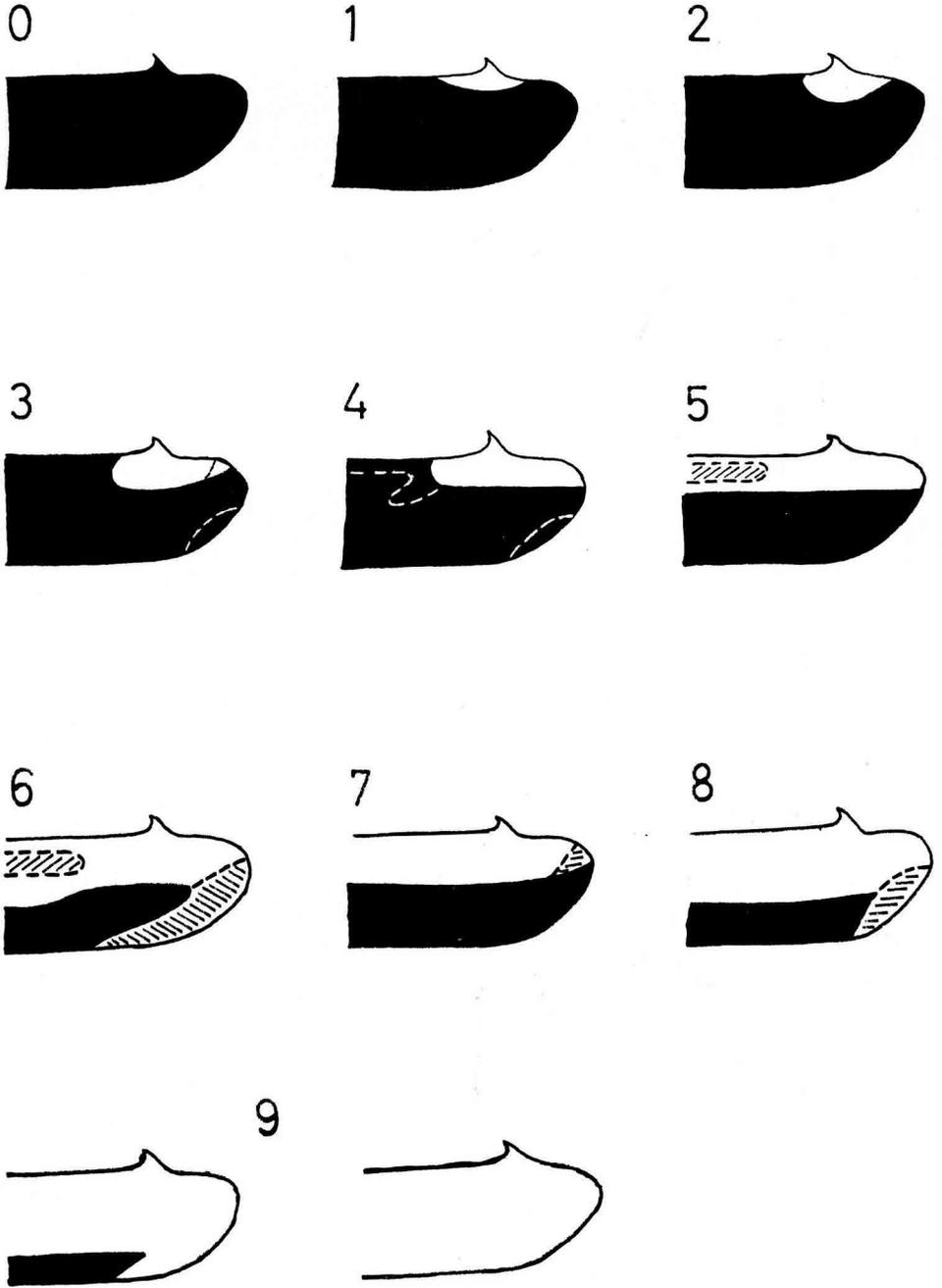


FIG. 4. — Pigmentation of tergite 2-4, evaluated by 10 classes (No. 10-12)

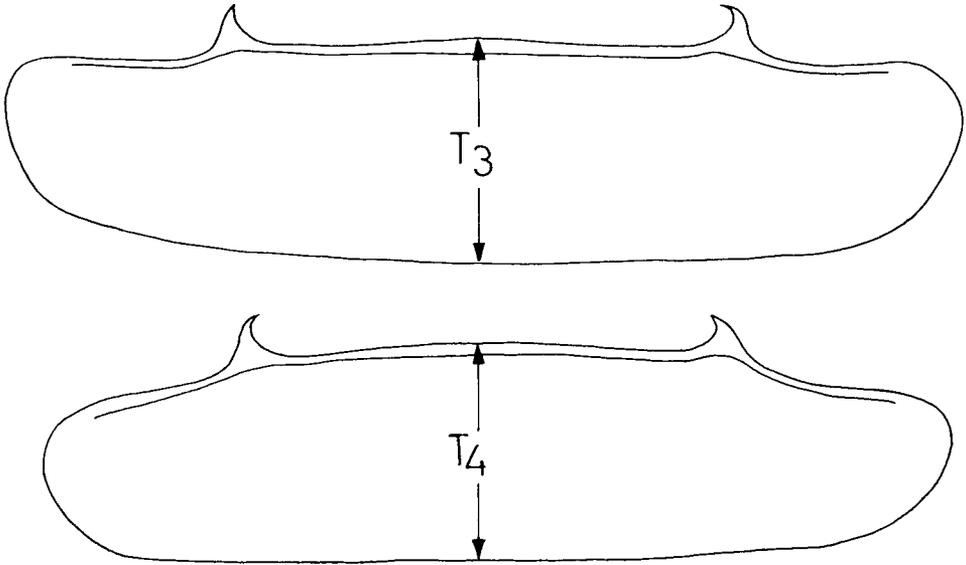


FIG. 5. — Longitudinal diameter of tergite 3 and 4 (No. 13, 14).

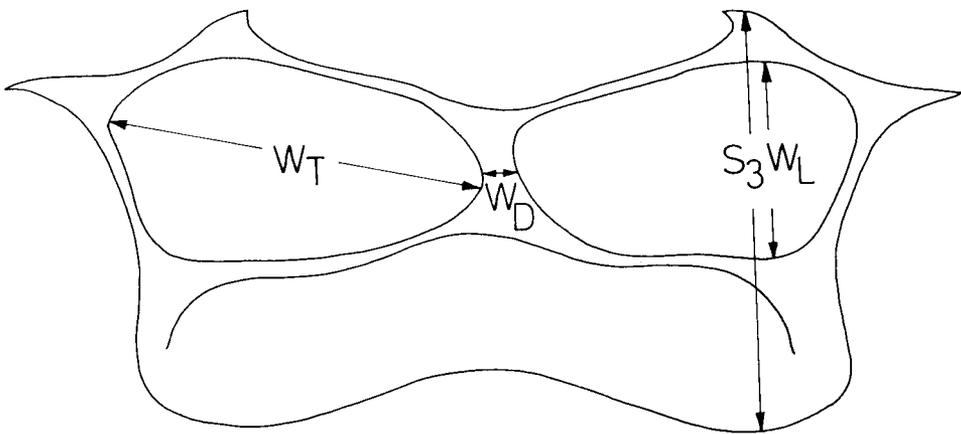


FIG. 6. — Sternite 3

S 3 longitudinal diameter (No. 15); WL wax mirror, longitudinal (No. 16);
 WT wax mirror transversal (No. 17); WD distance between wax mirrors (No. 18).

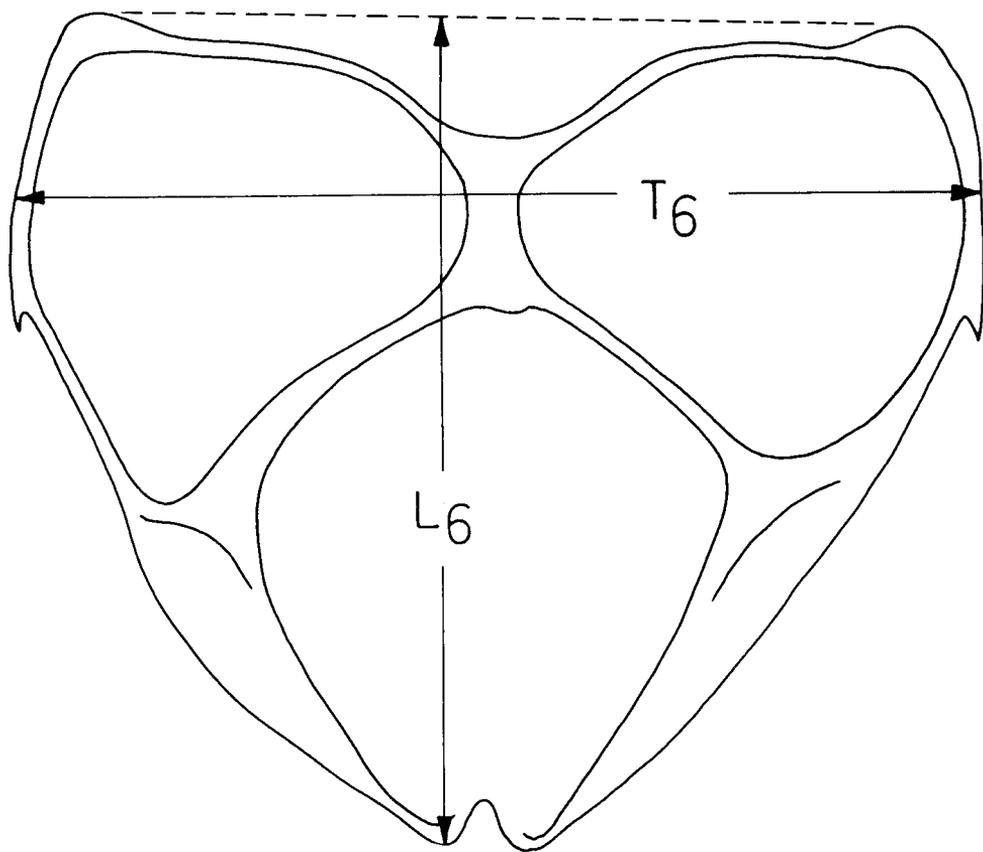


FIG. 7. — *Tergite 6*
L 6 longitudinal (No. 19); T 6 transversal (No. 20).

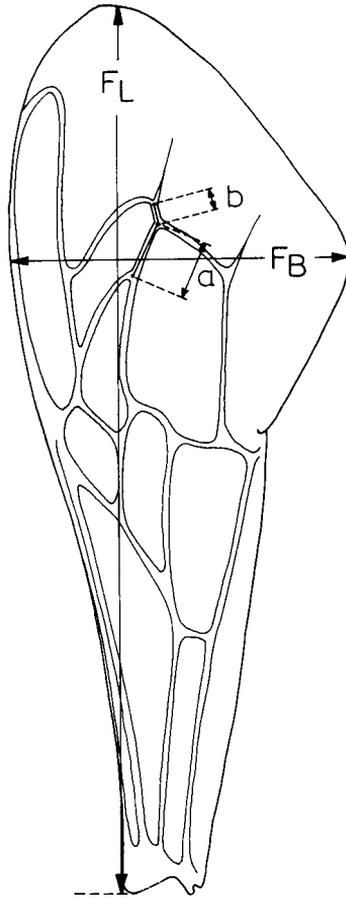


FIG. 8. — *Fore wing*

FL length (No. 21), FB width (No. 22); a cubital vein a (No. 27); b cubital vein b (No. 28).

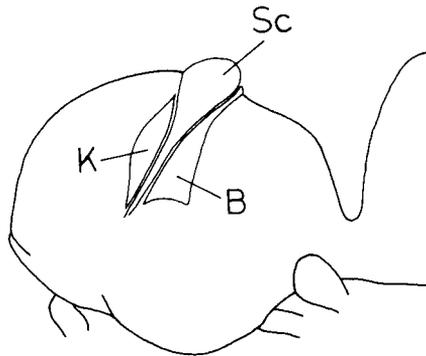


FIG. 9.

Sc scutellum — scale of pigmentation 0 (completely dark) — 9 (yellow).
 B, K Metatergum and mesotergal sclerite — scale of pigmentation 0-5.

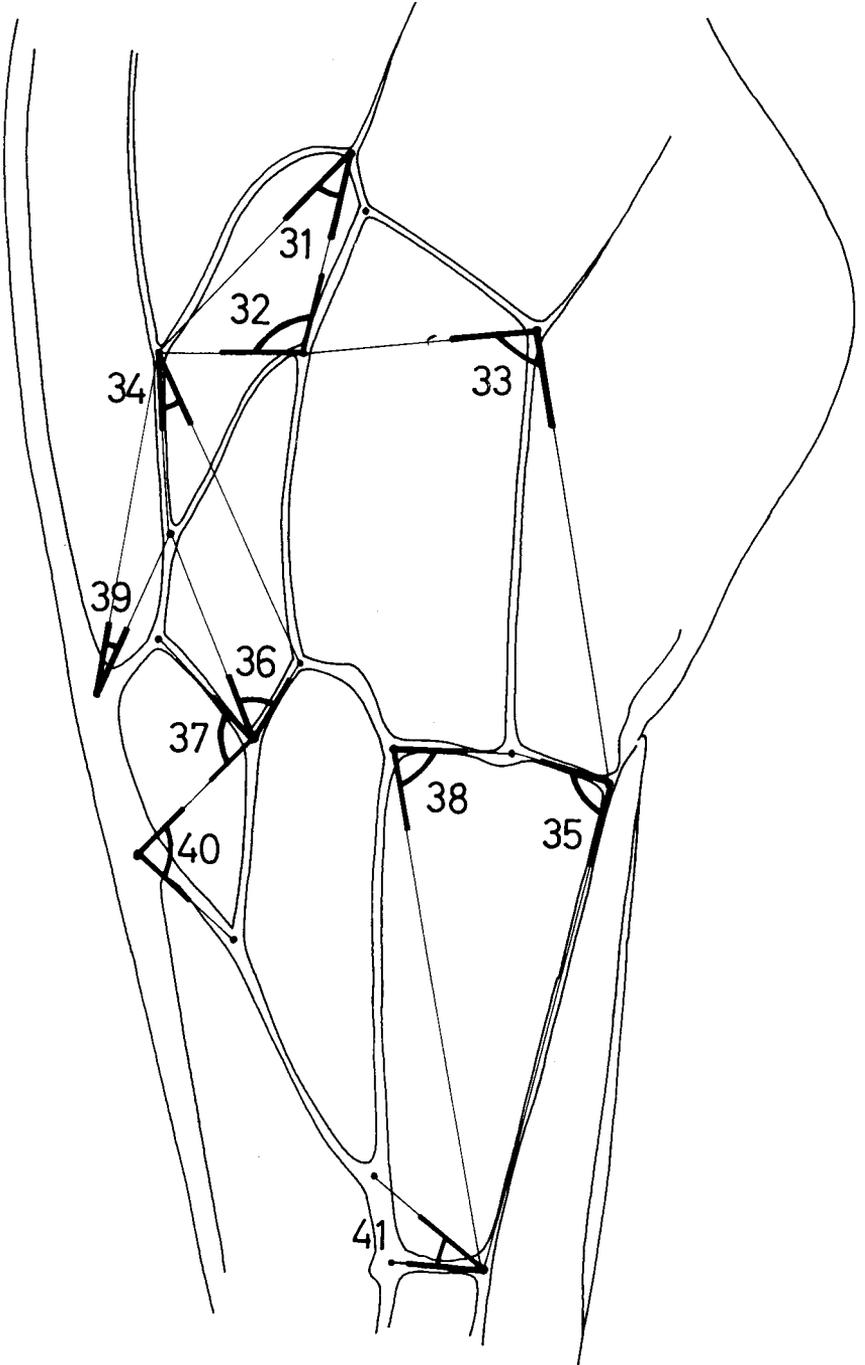


FIG. 10. — *Angles of wing venation, No. 31-41 (see table 1).*

They consist of the characters introduced and tested by ALPATOV and GOETZE, i.e. pilosity, size, colour, cubital venation (Nos. 1, 2, 3-17, 21, 22, 27-30, 42), some of the angles in the wing venation tested by DUPRAW (1964) in collaboration with our laboratory (Nos. 31-41), and some newly selected characters (Nos. 18-20; 23-26). Three of these characters were later eliminated, either because they added no new information (No. 2, length of hairs between the facets of the eye) or because of their proved redundancy (Nos. 27, 28, cubital veins left). At present 39 characters as listed in table 1 are routinely measured.

In addition to these primary measurements, secondary values were calculated by summation and division. For instance, No. 3 : 4 tomentum index, No. 6 + 7 + 8 length of hind leg, 9 : 8 metatarsus index, 13 + 14 value of body size, 19 : 20 "index of slenderness", 29 : 30 cubital index.

For statistical analysis only the primary values were used, but the indices, being independent of body size, are very useful in characterizing a race. Even in early times a race was characterized by broad metatarsi (*A.m. remipes*, GERTSTÄCKER 1860; see v. BUTTEL-REEPEN 1906) or high cubital index (*A.m. carnica*; GOETZE 1940). The "index of slenderness" is an objective measure of a slender or broad body distinguishable even with the naked eye.

A standard sample consists of 20 bees from the same colony, but in some cases, when samples were collected by other persons in regions difficult of access, we had to be content with a smaller number of bees. The bees are killed by ether or hot water (to obtain a fully stretched proboscis) and preserved in Pampell's fixative.

The preparation of the animals and recording of the measurements are organized in such a way that all the values for each individual bee are registered *en bloc*. The measurement of the pilosity is made on the undissected animal. To measure the other characters the parts of the body are adjusted on a slide. The measurements are taken on a profile projector (Leitz), magnification 50 x, or for some characters (hairs, tergites, colour, cubital veins) on a stereomicroscope, magnification 40 x.

With about 40 characters per bee nearly 800 data are accumulated per sample. To date more than 600 samples have been examined, i.e. a total of about 500 000 separate measurements. Drones are also incorporated in our programme, but a smaller number of characters are measured. The present analysis, however, is restricted to worker bees.

The crude data are transferred to perforated cards. Two cards are necessary per bee, each labelled with the no. of the sample, the no. of the bee and of the card, sex, country and region. The first steps of the statistical analysis, made at the Rechenzentrum of the University of Frankfurt are the transformation of the data into a uniform scale of 0,01 mm and computation of the means and standard deviations.

The important next step is the elimination of errors by inspections of the standard deviations. A higher value than usual indicates that a mistake probably was made in writing, reading or punching; the printouts are then compared with the original records and the erroneous cards are replaced.

The procedures employed require that the series of characters should be complete in all samples and for this reason some samples have had to be excluded from this step of treatment. Characters not yet measured in the discarded samples include the length of proboscis, which can be determined correctly only with a completely stretched tongue, and the colour of the labrum for which difficulties in classification exist.

Thus this statistical analysis has so far been made on 33 characters and 404 samples of worker bees from all countries with autochthonous *mellifera* bees available.

The number of characters can probably be reduced much further. H. DALY (1976) using the same characters as we do to analyze the "africanized" bees of Brasil, restricted the number of characters to 19, but later increased it again to 25. In our own analysis we could show that after careful study the number of characters could be reduced to as few as 10 for African bees without any substantial deterioration of the result, that is without diminishing the statistical separation of bees of different geographic origin (detailed publication in preparation). But we must stress that this is valid only for a fixed, selected region. In continental Europe a perfect separation of the autochthonous races is achieved by 4 characters only (No. 1, 11, 29, 30) as previously indicated, or by 5 characters (CORNUET *et al.*, 1975).

To analyze difficult questions and to maintain flexibility while elaborating the total of our material it seems reasonable to retain for the present all the characters measured up to now - at least for as long as the whole variability in the species *A. mellifera* is unknown.

ANALYSIS METHODS

The further statistical analysis took place at the Laboratoire de Biométrie of the I.N.R.A., France.

Basic information subjected to statistical treatment has to be represented by a 404×33 array. Each of the 404 lines is a sample of 20 bees. The 33 components of this vector line are the means of individually measured characters. Multivariate analysis allows a general survey of these data.

It is not easy to imagine a "cloud" of 400 points in a 33 dimensioned space... In order to simplify this problem, an attempt is made to determine a few number of privileged axes : this is the aim of the PRINCIPAL COMPONENT ANALYSIS. From all the correlation coefficients between the first variables two by two, it is possible to obtain histograms on the new axes and point-projections on the planes formed by two of these axes. Interpretation of the results consists in characterizing the clusters of points. The contribution of each of the basic variables, in the formation of the new ones, is estimated. In this way, some little interesting characters can be discarded; since, selection of the most discriminant criteria is the most important goal.

So, in this initial study, the basic tool was the PRINCIPAL COMPONENT ANALYSIS : a descriptive and statistical hypothesis-free method.

The PROGRESSIVE DISCRIMINANT ANALYSIS was also used. It was intensively applied to the African data. With this technique, and using a progressive number of the first variables, it is possible to obtain a border-line between two populations. Then, samples with no "a priori" identification can be classified.

The last objective is to get a picture of each bee-type collected and locate it geographically. The FACTOR ANALYSIS OF CORRESPONDENCES allows to represent on the same plane the profiles of the variables as well as those of the samples. This method was employed with qualitative characters such as breed, location of capture of the bees, etc. Quantitative variables can be introduced after class regrouping. For the last steps, this kind of analysis was used as a demonstrative tool rather than a prospective one.

The most interesting results were integrated into a dendrogram, showing the distances between the samples, or in a three-dimensioned perspective of three choosen factorial planes.

This study will be achieved by the creation of overlapping hierarchies resulting from a CLUSTER ANALYSIS. In a third step, the so-called "DYNAMIC CLOUDS METHOD" will allow partitions to be built among samples.

This last type of statistical analysis permits to obtain "standard-bees" and will lead to a dynamic grouping of samples.

RESULTS

Fig. 11 shows the results obtained by multivariate analysis. Factor 1 on the horizontal axis, computed by the method of principal components from 33 characters, accounts for about 41 % of the total variability of the material and mainly concerns differences in size (the small bees are to the left, the large ones to the right).

Factor 2 (on the vertical axis), comprising 10 % of the total variability, is composed mainly of characteristics of pilosity and of wing venation.

The total variation within the whole species, all races included, is considerable. For length of proboscis it ranges between 5,31 and 7,19 mm (mean of the sample), for wing length between 7,98 and 9,69 mm, for hair length between 0,158 and 0,477 mm and for the cubital index between 1,58 and 3,62.

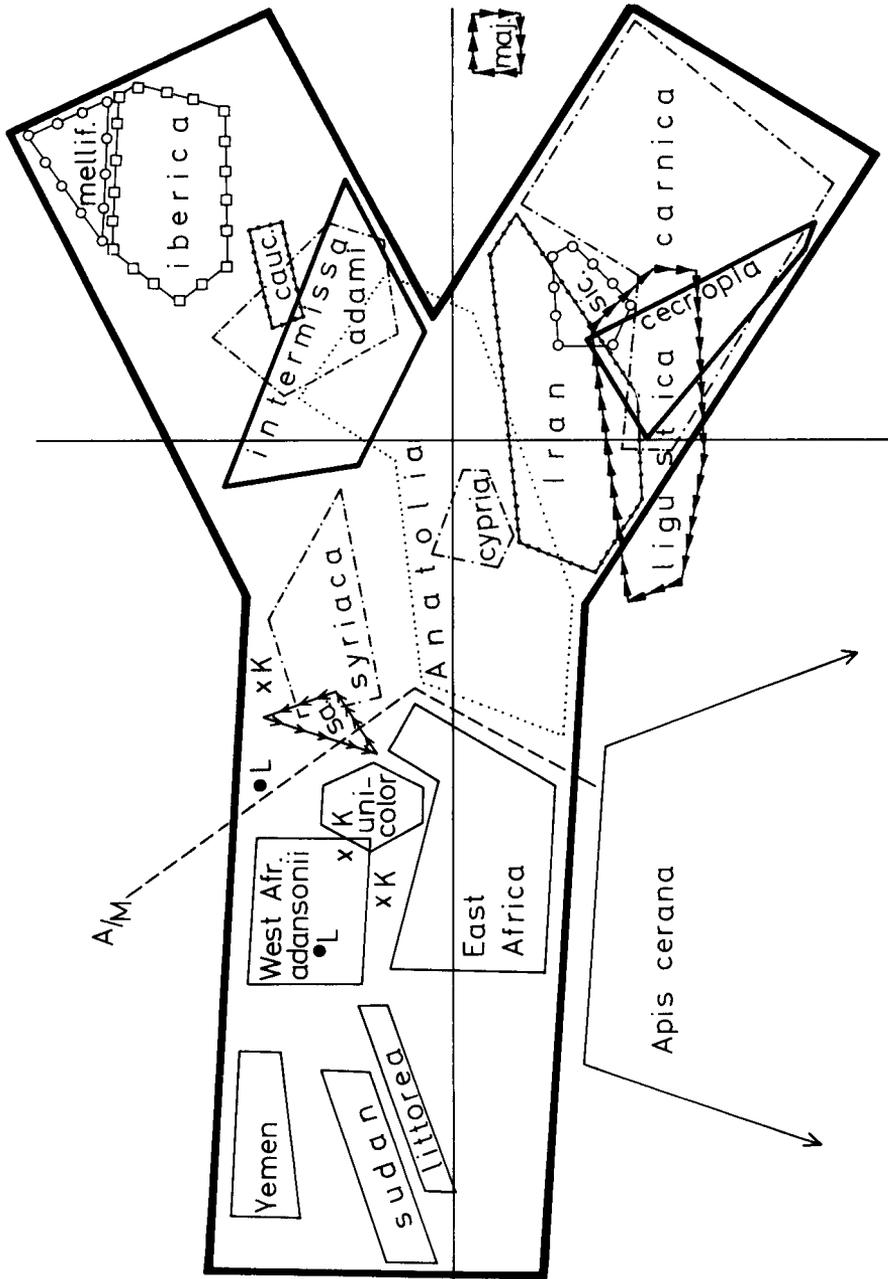


FIG. 11. — Graphical representation of results of an analysis by principal components.

Horizontal axis : factor 1; vertical axis : factor 2. Each field shows

in a somewhat schematized way the clusters of points made

of geographical types of bees. K *capensis*, L *amarckii*, sa. *sahariensis*, cauc. *caucasica*, sic. *sicula*, maj. *major*.

Each individual sample is plotted as a point in the system of coordinates of factor 1 (horizontal axis) and factor 2 as a vertical one. For most of the races the points are arranged in well separated clouds of points (clusters) within a certain field of the system. In fig. 12 the clusters, made up from 404 individual points, are schematically bordered with lines.

First of all the graph shows the clear biometrical separation of the two species *A. mellifera* and *A. cerana*. It should be noted here that the analysis employs only characters that proved to be of value for discrimination *within* the species *A. mellifera*. No character typical for *A. cerana* was incorporated (i.g. tomentum on tergite 5, radial vein on the hind wing, weak barbs on the sting). Otherwise *A. cerana* would shift much further away from *A. mellifera* on the graph.

Considering the total variability of *A. mellifera*, as represented by the two factors 1 and 2, it should be noted that the clusters of points cover a field in the shape of a "Y" lying on its side (fig. 11).

Within the stem of the Y the samples from Africa south of the Sahara are found. They are separated without overlapping from the other samples (dotted line). This field includes the smallest bees of *A. mellifera* so far discovered (*nubica*, *littorea*, *jemenitica*; RUTTNER 1976) and only the dark, big and gentle mountain bee of Africa (*A.m. monticola*) transgresses the line. The points representing this race (not shown in the graph) are grouped round the center of the coordinates.

The inferior branch of the Y contains in its base the broad field of the bees of Anatolia, *A. m. cypria* and the samples from the Iran. Towards the periphery follow *A. m. ligustica*, *sicula*, *cecropia* and, in extreme position, *carnica* (this side, therefore, is called the C-branch).

Some of the clusters show considerable overlap. It should be noted, however, that the aim of this analysis is a general survey of the basic structure of the species, not a special analysis of the different subgroups. For the latter, a more detailed arrangement of the samples according to their geographic origin, the use of other factors and statistical methods, and, in particular, the restriction of the material to be analysed (e.g. analysis of the samples of one sector of the graph only) are necessary and are provided for our future programme.

The groups formed so far have to be considered as strictly provisional; at present, for instance, it is not known how many and which races are hidden within certain geographic regions such as "Anatolia" or "Iran" (fig. 11), although it is evident from the graph that these are heterogenous groups. Answers to this and other questions may be found in the proposed special analysis. It is further problematical whether or not the race "*cecropia*" can be recognized as being distinct.

The upper (M-) branch of the Y shows the sequence *intermissa* and *adami* (RUTTNER, 1975) at the base, then *iberica* and, finally, *mellifera* at the apex. This order confirms very clearly the existing conception of a chain of races *intermissa-*

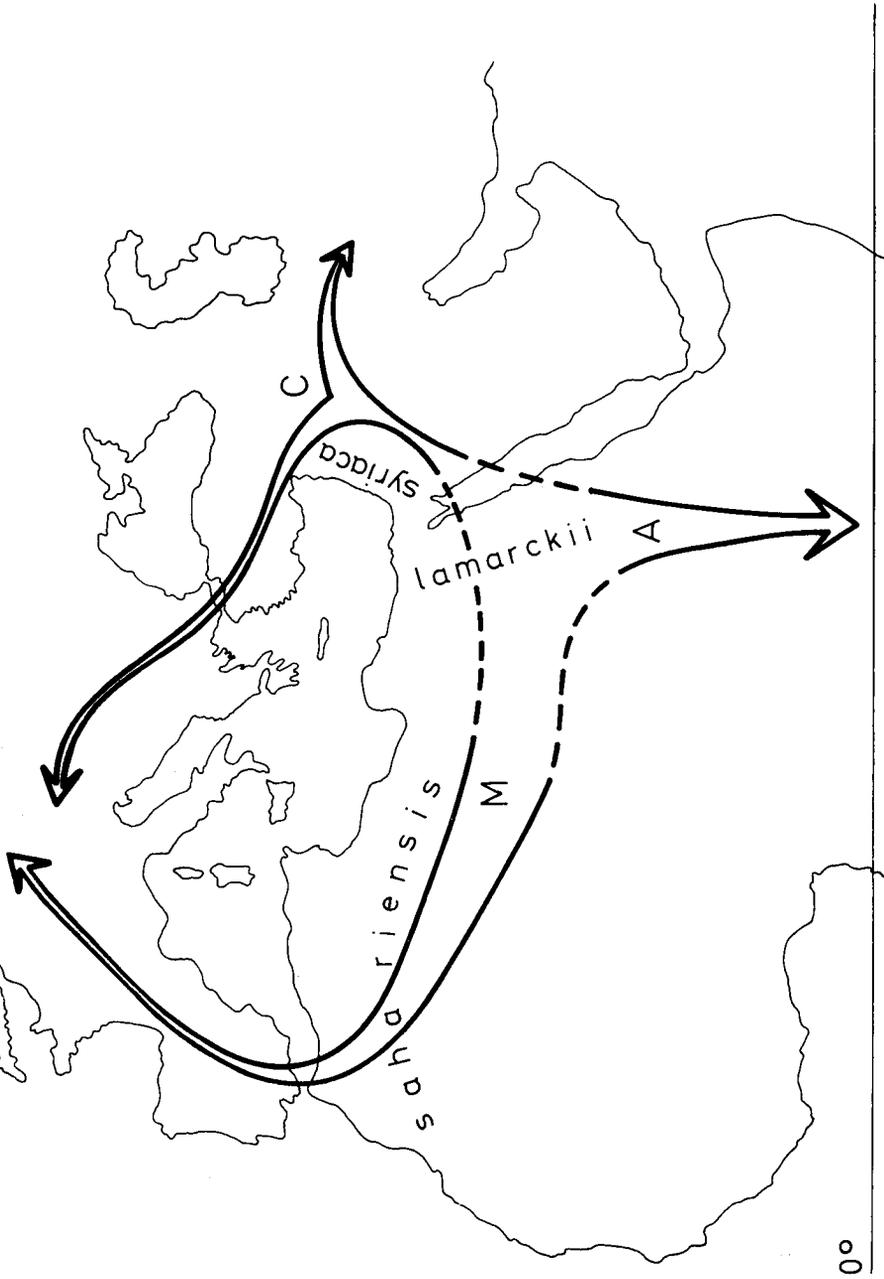


FIG. 12. — The three main branches (A, C, M) of morphogenetic evolution of the races of *A. mellifera*.

iberica-mellifera (RUTTNER, 1972). Furthermore, it is shown how far from each other in the taxonomic system within the species the three races *carnica* + *ligustica* and *mellifera* are situated. In between these two extremes a small local race, the Rif bee *A. m. major*, is found.

Strange is the position of the race *caucasica* within this scheme. It has to be noted, however, that the data derive from two samples only, originating from a Russian breeding station. Thus, neither the error of the small sample, nor the possible influence of another race (*mellifera*?) can be excluded. We hope that an occasion will be found to examine original material in sufficient quantity.

The races near the center of the Y-shaped distribution of *Apis mellifera* are of special interest, i.e. *lamarckii*, *sahariensis* and *syriaca* (The Egyptian bee, *A. m. lamarckii*, is represented on the graph not by a field, but by single points with a "L", the number of samples investigated being very small). The field of the *sahariensis* is situated between that of *intermissa* and the more southerly African races, but closer to the latter. The relatively small population of this race has so far been found in the oases of the Sahara in Morocco and in western Algeria (RUTTNER 1976). There are indications (not yet confirmed) that this bee also occurs farther east in the Algerian Sahara. In this connection it should be remembered that the Sahara was mainly green savanna only about 10 000 years ago. Thus the present populations of the *sahariensis* in the oases presumably are nothing but a remnant of a much more extended population between the Atlas mountains and Central Africa. A closer contact with Egypt may also have existed in this time.

The biometric position of the Egyptian bee (*A. m. lamarckii*) lies close to that of *sahariensis*; for a more precise determination, however, more samples are needed.

A. m. syriaca, from Lebanon, Israel and Jordan, occupies a well defined field in our graph between *sahariensis* and part of the field of the Anatolian bees.

The results of this analysis indicate that the group *sahariensis* - *lamarckii* - *syriaca* represents not only the morphological but also the genetic and historic center of the species *Apis mellifera*. A more detailed examination, focussed on this area and based on an increased amount of material, could help to confirm this hypothesis.

Starting from the southeastern mediterranean region three distinct lines of evolution can be seen: southward to the Central and South African types; northeastward through the races of Anatolia on one side to the Iranian type (not yet described) and on the other side to *carnica* in the region of the Danube, and to *ligustica* and *sicula* in Italy; and to the northwest through *intermissa* on the North African coast to *iberica* and to *mellifera*, the bee of the whole Northern zone of Europe.

This classification was achieved entirely by combining morphological characters that could be measured. No direct evidence for a phylogenetic line of evolution or of an historical process of migration is given by the data. Nevertheless, a connection of this kind is not unlikely and thus an attempt may be ventured to superimpose the

biometric configuration of the Western honeybee on the geographic one (fig. 12). A nearly perfect correspondence results: The African continent in the South and the Mediterranean with the two land bridges in the East and West result necessarily into the shape of a "Y" at the start of geographic spreading.

Of course, the fact that the lines of phylogenetic evolution tend to separate themselves more and more, while the geographic lines converge (*mellifera* - *carnica* in the Alps) or even return near to the region of origin (*sicula*), is an inevitable consequence of the situation.

This model of structure of the species *Apis mellifera* is based on a large amount of representative data. Nevertheless, it has thus far been developed in outline only, its full potential can only be realized by future research.

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ZUSAMMENFASSUNG

BIOMETRISCH-STATISTISCHE ANALYSE DER GEOGRAPHISCHEN VARIABILITÄT VON *APIS MELLIFERA* L. I. MATERIAL UND METHODEN

Ziel dieser auf lange Sicht angelegten Untersuchung ist es, mittels multivariater morphometrischer Methoden eine Analyse der geographischen Variabilität der Spezies *Apis mellifera* durchzuführen. In dieser ersten Mitteilung werden Material und Methoden beschrieben und einige allgemeine Resultate berichtet.

Das Ausgangsmaterial bilden die Messdaten von 41 Merkmalen (Tab. 1, Abb. 1-10); die Merkmale betreffen Grösse, Farbe, Behaarung, Flügelgeäder. Eine Probe (Beobachtung) besteht aus 20 Bienen eines Volkes, also insgesamt aus 820 Messungen, Grundlage für die statistische Auswertung bilden die Mittelwerte für jedes einzelne Merkmal aus den 20 Bienen einer Probe. Für die vorliegende statistische Analyse, die nach der Methode der principal components erfolgte, wurden aus den vorhandenen Daten 33 Merkmale und 402 Proben von Arbeitsbienen von *A. mellifera* ausgewertet.

Bei graphischer Darstellung der mit dieser Methode errechneten Faktoren 1 und 2 in einem Koordinatensystem, wobei über 50 % der Gesamtvariabilität erfasst sind, wird jede einzelne Probe durch einen Punkt repräsentiert. Proben mit ähnlicher Merkmalsausprägung liefern Gruppen von nahe beieinanderliegenden Punkten (« Wolken »).

Es zeigt sich eine gute Übereinstimmung dieser « Wolken » mit der geographischen Verbreitung bestimmter Bienenrassen.

Die Gesamtheit aller Punkte von Völkern der Art *Apis mellifera* bilden sehr deutlich die Form eines liegenden « Y », während die Proben von *A. cerana* eine davon getrennte Position einnehmen (Abb. 11). In den drei Ästen des Buchstabens « Y » liegen in charakteristischer Anordnung die untersuchten Proben: Im Stamm des « Y » die Rassen aus Afrika südlich der Sahara, in dem einen Ast die Rassen aus dem östlichen, in dem anderen diejenigen aus dem westlichen Mediterranengebiet (A-, C- und M-Ast).

Ces données, obtenues par une méthode morphométrico-statistique, montrent une structure de l'espèce qui est en parfaite harmonie avec sa répartition géographique (Abb. 12).

Les races *syriaca*, *lamarckii* et *sahariensis* occupent dans ce système, et peut-être aussi dans l'évolution de l'espèce, une position centrale.

La variabilité morphologique à l'intérieur de l'espèce est extraordinairement élevée. Les valeurs varient entre 5,31 et 7,19 mm pour la longueur de la langue (moyenne de l'échantillon), entre 7,98 et 9,69 mm pour la longueur de l'aile, entre 0,158 et 0,477 mm pour la longueur des poils et entre 1,58 et 3,62 pour l'index cubital.

Morphologiquement, les types extrêmes, le plus éloigné du centre statistique de l'espèce, sont les races les plus petites d'Afrique et d'Arabie d'une part et les races les plus grandes *carnica* et *mellifera* d'autre part (Abb. 12).

Des études de détail doivent être faites pour une discrimination plus fine, géographiquement, de types voisins et pour leur description.

RÉSUMÉ

ANALYSE BIOMÉTRIQUE ET STATISTIQUE DE LA VARIABILITÉ GÉOGRAPHIQUE D'*APIS MELLIFERA* L. I. MATÉRIEL ET MÉTHODES

Le but de cette étude à long terme est de réaliser une analyse de la variabilité géographique de l'espèce *Apis mellifera* au moyen de méthodes morphométriques multivariées. Dans cette première contribution on décrit le matériel et les méthodes et on rapporte quelques résultats généraux.

Les mesures de 41 caractères (tabl. 1, fig. 1-10) constituent le matériel de départ; les caractères concernent la taille, la couleur, la pilosité, les nervures alaires. Un échantillon (observation) comporte 20 abeilles d'une colonie, soit au total 820 mesures. Les moyennes des mesures de chaque caractère pour les 20 abeilles d'un échantillon forment les bases de l'exploitation statistique. Pour l'analyse statistique présentée ici, qui relève de l'analyse en composantes principales, 33 caractères et 402 échantillons d'ouvrières provenant des données disponibles ont été exploités.

Dans la représentation graphique, en un système de coordonnées qui absorbe plus de 50 % de la variabilité totale des facteurs 1 et 2 calculés par cette méthode, chaque échantillon individuel est représenté par un point. Les échantillons qui possèdent des caractères semblables forment des groupes de points rapprochés les uns des autres (« nuages »).

Il existe une bonne concordance entre ces « nuages » et la répartition géographique des races d'abeilles étudiées.

L'ensemble de tous les points des nuages de l'espèce *Apis mellifera* dessine très nettement un « Y » couché, tandis que les échantillons d'*Apis cerana* prennent une position qui s'en éloigne (fig. 11). Dans les 3 branches du « Y », les échantillons étudiés se rangent dans un ordre caractéristique : dans le tronc du « Y » les races d'Afrique au Sud du Sahara, dans une branche les races de la partie orientale de la région méditerranéenne, dans l'autre celles de la partie occidentale (branches A, C et M).

Cette structure de l'espèce obtenue au moyen de la morphométrie et de la statistique montre donc une concordance surprenante avec la répartition géographique (fig. 12).

Les races *syriaca*, *lamarckii* et *sahariensis* occupent dans ce système, et peut-être aussi dans l'évolution de l'espèce, une position centrale.

La variabilité morphologique à l'intérieur de l'espèce est extraordinairement élevée. Les valeurs varient entre 5,31 et 7,19 mm pour la longueur de la langue (moyenne de l'échantillon), entre 7,98 et 9,69 mm pour la longueur de l'aile, entre 0,158 et 0,477 mm pour la longueur des poils et entre 1,58 et 3,62 pour l'index cubital.

Les types morphologiques extrêmes, les plus éloignés du centre statistique de l'espèce, sont d'une part les plus petites races d'Afrique orientale et d'Arabie et d'autre part par les grandes races *carnica* ou *mellifera*.

Des recherches détaillées futures doivent conduire à une discrimination plus fine de types géographiquement voisins et à leur description.

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