Suggested short title:

COMPARATIVE STUDY OF ORYZAEPHILUS SURINAMENSIS (L.) AND O.MERCATOR (FAUV.).

# A COMPARATIVE STUDY OF THE SAW-TOOTHED GRAIN BEETLE, *ORYZAEPHILUS SURINAMENSIS* (L.) AND OF THE MERCHANT GRAIN BEETLE, *ORYZAEPHILUS MERCATOR* (FAUV.), (COLEOPTERA, CUCUJIDAE).

by

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A thesis submitted to the Faculty of Graduate Studies and Research, McGill University, in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

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August, 1967

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# A COMPARATIVE STUDY OF THE SAW-TOOTHED GRAIN BEETLE, ORYZAEPHILUS SURINAMENSIS (L.) AND OF THE MERCHANT GRAIN BEETLE, ORYZAEPHILUS MERCATOR (FAUV.), (COLEOPTERA, CUCUJIDAE).

## ABSTRACT

Morphological and biological comparison studies of *Oryzaephilus surinamensis* (L.) and *O.mercator* (Fauv.) confirm that the two species are distinct. The differences in chaetotaxy of larvae, adult eye characters and male genitalia, can be used as criteria for distinguishing between the two species. Five different temperatures and three different types of food were used for comparing the rate of development. *O.mercator* is more sensitive than *O.surinamensis* to temperature conditions. The life-cycle from egg to adult shows *O.surinamensis* to be considerably faster than *O.mercator* at the same temperature. With respect to food conditions, *O.surinamensis* can be expected to multiply more quickly than *O.mercator* when both are fed on a cereal foodstuff. On oilseed, however, the reverse is true. Adult *O.surinamensis* show much more resistance than *O.mercator* to low temperature.

## ACKNOWLEDGEMENTS

The author wishes to express his grateful appreciation to Dr.F.O.Morrison, Professor of Entomology, McGill University, director of this research, for his many helpful suggestions and assistance. Sincere thanks are also expressed to Dr.R.K.Stewart, Assistant Professor of Entomology, for his able guidance, helpful criticism and invaluable assistance in the execution of this project and in compiling this manuscript.

Thanks are due to Mrs.P.Cannadine for typing this manuscript and Mr.D.Francoeur for taking the photographs presented in the text.

I must express my gratitude to the External Aid Office of Canada for the financing of this project under the auspices of the Colombo Plan.

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# I. INTRODUCTION

The saw-toothed grain beetle, Oryzaephilus surinamensis (L.), and the merchant grain beetle, O.mercator (Fauv.) are two common insects which attack stored food (Howe, 1956). The former is found on a wide variety of foodstuffs, but is primarily a pest of stored grain and grain products (Thomas and Shepard 1940, Back and Cotton 1926). Armstrong and Howe (1963) considered it a major cause of the recent increase in infestation of farm-stored grain in Great Britain. The latter is unlikely to be as serious a pest as the former and is seldom reported as causing any heavy damage in Great Britain. The principal reason for this difference is that O.surinamensis is cold hardy and O.mercator is not (Howe, 1956).

Both species are common in temperate regions, as well as in the warmer parts of the world and may be found in almost any stored food of vegetable origin. O.surinamensis has been recorded principally from Australia and South America, associated chiefly with starchy foods, while O.mercator has been recorded principally from Africa and Asia, associated chiefly with oilseeds and their derivatives (Howe and Freeman 1955, Howe 1956). Damage done by the beetles is secondary, following that of other insects such as the rice weevil, Sitophilus oryzae (L.)(Back and Cotton, 1926).

Very few detailed studies of O.mercator have previously been made (Howe 1956, Slow 1958); but many observations on the life-history of O.surinamensis have been carried out, and many short accounts of its distribution, habits, and biology have appeared in various reports. There has been some confusion in the taxonomy of Oryzaephilus, as some authorities wrongly considered that O.mercator was merely a variety of O.surinamensis and not a separate species (Howe,1953). Grouvelle (1912) maintained that O.mercator and O. surinamensis were not distinct because the eye/temple ratio formed a continuous series. Chittenden (1896), Zacher (1942), and Hinton and Corbet (1943) regarded the two species as distinct. Howe (1956) stated that most of the well-known keys to Coleoptera did not agree with Grouvelle and still included both species, but he pointed out that some people, including some workers in the British Museum, accepted Grouvelle's opinion and identified both species under the name Oryzaephilus surinamensis. In fact, there are reasons for considering the two species as distinct. Slow (1958) found that they did not interbreed in laboratory tests, she also showed that they can be distinguished by the relative lengths of their eyes and temples and by the different structures of the male genitalia.

The present study was undertaken with the object of determining possible morphological and physiological differences between the two species. These would allow a more definite conclusion as to taxonomic status of the insects, and would go some way towards prediction of their success or failure, in different environmental conditions.

## II. REVIEW OF THE LITERATURE

### A. TAXONOMIC POSITION

The saw-toothed grain beetle and the merchant grain beetle belong to the genus *Oryzaephilus* of the sub-family Silvaninae of the Cucujidae.

Leng (1920), in his Catalogues of the Coleoptera in America, north of Mexico, listed four species of *Oryzaephilus* as follows:

*O. surinamensis* (Linné)
*O. bicornis* (Erichson)
*O. mercator* (Fauvel)
*O. gossypii* (Chittenden)

*O.bicornis* was later considered as a variety of *O.surinamensis*, and *O.gossypii* as a variety of *O. mercator* (Spilman 1960). Thus the genus *Oryzaephilus* is now composed of only two species. Both species are common stored grain pests and widely distributed by trade. They are *O.surinamensis* and *O.mercator*.

Hatch (1962), in his the Beetles of the Pacific Northwest, distinguishes the characters of *Oryzaephilus* from the other genera of Silvaninae as follows: "Rufotestaceous, shining, with fine decumbent yellowish pubescence; head densely coarsely punctate, with a finely impressed nuchal line; pronotum elongate, densely coarsely punctate, oval, the side each usually with 6 acute prominent subequal teeth including those at the anterior and posterior angles, the disc with a median and a pair of sublateral obtuse longitudinal carinae, the 2 latter demarking a somewhat flattened discal area; elytra with 9 more-or-less impressed longitudinal series of punctures, the alternate internals somewhat prominent."

Oryzaephilus surinamensis

Linné (1767) made the original description of the species at which time he placed surinamensis in the genus Dermestes. He received specimens of this insect from Surinam (Dutch Guiana) and for that reason gave it the specific name surinamensis. This species was redescribed under several names after Linné's account. Geer (1775) placed it in the genus Tenebrio and named it Tenebrio surinamensis. Fabricius, in the same year (1775), described it as Anobium frumentarium. Oliver (1790) named it as Ips frumentaria. Fabricius (1792) placed it in still another genus, referring to it as Colydium frumentarium and in the same year (1792) he described the same species under the names Dermestes sexdentatus and Scarites cursor.

Kugelann (1794) described it as Lyctus sexdentatus, Paykull (1800) as Colydium sexdentatum, and Gyllenhal (1813) as Silvanus sexdentatus. Stephens (1830) followed Gyllenhal in placing the species in genus Silvanus and used the specific name surinamensis, and from then until comparatively recently it was known as Silvanus surinamensis.

In 1899, Ganglbauer divided the genus Silvanus into two subgenera, Oryzaephilus with six teeth on the lateral margins of the thorax, and Silvanus with two or none, and placed the species surinamensis in the new subgenus Oryzaephilus. Reitter (1911) raised these two subgenera to the status of genera, and the saw-toothed grain beetle is now known as Oryzaephilus surinamensis.

Oryzaephilus mercator

This insect was described as Silvanus mercator by Fauvel (1889), who first distinguished the two species by the eye/temple ratio. When Ganglbauer divided the genus Silvanus into two subgenera, and Reitter raised them to the status of genera, the merchant grain beetle became Oryzaephilus mercator.

## B. BIOLOGY AND MORPHOLOGY

The literature on O.surinamensis will be dealt with first.

Blisson (1894) gave a detailed description of the immature stages, with brief notes on the habits and development of the insect.

Perris (1953) presented a brief account of the habits of the larva.

Chittenden (1896) gave brief notes on the habits of this insect. He found that the life-cycle required from 6 to 10 weeks in early spring, and about 24 days in midsummer in the vicinity of Washington,D.C.

Dean (1913) obtained results similar to those of Chittenden in Kansas. He stated that the pupal stage required 6 to 12 days and that in Kansas there were from 4 to 6 generations a year.

Back and Cotton (1926) studied in detail the biology of the saw-toothed grain beetle but they did not control the temperature or humidity in their work. They found that the egg was 0.83 to 0.88 mm. in length and 0.25 mm. in width. Eggs hatched in from 3 to 5 days in midsummer and 8 to 17 days in cooler weather after deposition. The length of the preoviposition period ranged from 5 to 8 days under favorable conditions, to 207 days when climatic conditions were less favorable. The oviposition period ranged from about 2 to 5 months. The total number of eggs laid by an individual ranged from 45 to 285. The length of larva when first hatched was about 0.80 to 0.90 mm., and the width of the head capsule was 0.24 mm. When fully grown the larva attained the length of from 2.5 to 2.8 mm., and the head capsule width was from 0.46 to 0.54 mm. Under favorable midsummer conditions Back and Cotton found that larvae required about 12 days for development, and about 4 to 7 weeks were required from hatching to pupation in the spring. Under less favorable conditions larvae required 10 weeks for development. Larval moults ranged from 2 to 4 times, the majority moulting 3 times. The length of the pupal period ranged from 6 to 21 days. The life-cycle from egg to adult may be passed in as few as 22 days under the most favorable environmental conditions. The longest period required for the same development was 108 days, when the mean average temperature for the period was 69° F.

Thomas and Shepard (1940) worked with several combinations of temperature, relative humidity and food. They found that eggs did not hatch at temperatures of 15° and 40° C. They also noted that a humidity range from 5 to 88% R.H. had little effect on the egg or pupal periods. On rolled oats as food and at 5 mm. saturation deficit, they found that the total life-cycle from egg to adult required 69.06 days at 20° C., 30.31 days at 25° C., 20.67 days at 30° C., and 18 days at 35° C. The rate of development on rolled oats was faster than on either walnuts or raisins.

Fraenkel and Blewett (1943) cultured *O.surinamensis* on a variety of foodstuffs at a temperature of 25° C. and relative humidity ranging from 12.5 to 70%. They found that this species would grow at a relative humidity of 12.5% on wholemeal flour, but the number of insects which completed development decreased as the humidity decreased below 70%. Fraenkel and Blewett also found that *O.surinamensis* larvae, whether freshly hatched or nearly half grown, could not develop on wheat grains unless these had been previously considerably damaged.

The biology of O.*surinamensis* and O.*mercator* has been studied in detail by Howe (1956) who found that eggs of both species hatched at temperatures from 17.5 to 40° C. Low humidity had little effect on the egg period and did not affect the length of the stadia. He observed that the preoviposition period of both species at 30 and 33° C. was 3 to 8 days, usually about 5. O.*mercator* reached a peak of 3 eggs per female per day and O.*surinamensis* of 6 to 10 per female per day. The oviposition period he observed was over 2 months for O.*surinamensis*, and over 3 months for O.*mercator*. The average number of eggs laid by O.*mercator* was about 200 and by O.*surinamensis* about 375. The usual number of larval moults before pupation for O.*surinamensis* was 3, but a few individuals had 4 or 2. O.*mercator* usually had 3 moults, a few had 4 and none had 2. Howe stated "this tendency for O.*mercator* to have a fractionally greater average number of moults partly explains its longer larval period, but each larval instar, especially the first, is slightly longer in O.*mercator* than in O. *surinamensis*." On wheatfeed, he found that the larvae of O.*mercator* grew more slowly than that of O.*surinamensis*. The optimum temperature for O.*mercator* was about 30 to 32.5° C. and that for O.*surinamensis* about 30 to 35° C.

On coconut meal at 30° C. and 70% R.H., he found O.mercator grew faster than O.surinamensis. Both species could not complete development on ground-nut meal unless yeast powder was added.

On weighing adults, Howe found that Oryzaephilus beetles weighed only about 0.3 to 0.5 mg., he made no mention of either species or sex; these could not be weighed with accuracy, he claimed, since no torsion balance was available to him.

The length of individuals of adults of both species has been studied by many authors. Back and Cotton (1926) gave the average length of O.surinamensis as about one-tenth of an inch (2.54 mm.). Haydak (1936) gave the average length of O.surinamensis as 2.20 mm. for the male, 2.26 mm. for the female, and O.mercator as 2.87 mm. for the male, 2.77 mm. for the female. Slow (1958) found that the adult of O.surinamensis was from about 2.75 to 3.25 mm. long, and that of O.mercator was from about 3 mm. to nearly 4 mm.

Slow (1958) working on the morphology of adult O.surinamensis and O.mercator, measured the eye/temple ratio and found that it differed considerably in the two species. She found no other measurement or ratio which did not overlap.

The male genitalia of some Cucujidae have been described by Sharp and Muir (1912), Tanner (1927), and Wilson (1930), and all of them observed that the male genital structures in the species are of a highly complex character. Agrawal (1955) gave a more detailed description of the male genitalia of O.surinamensis. The most detailed description of the male genitalia of O.surinamensis and O.mercator was given by Slow (1958), who found there was a number of marked differences between the two insects in the structure of these.

The saw-toothed grain beetle is quite resistant to low temperature. De Ong (1921) working with cold storage control of insects, claimed that an exposure of 3 months at temperatures of 10° to 36° F. was needed to kill the larvae, pupae, and adults of this insect.

Back and Cotton (1926) found that all stages of O.surinamensis were killed in 1 week within a temperature range of 20° to 25° F., and exposure to 0° to 5° F. killed all stages in 1 day.

Thomas and Shepard (1940), working on the lethal effects of low temperature on the adult stage of O.surinamensis, found that adult saw-toothed grain beetles exposed at 10° C. and 2° C. gave 50 per cent mortality values at 30 days and 105 hours respectively. They referred to the experiments on Tribolium confusum conducted by Negal and Shepard (1934) who studied the effect of low temperatures on various stages of this insect and found that the exposure periods necessary to obtain a 50 per cent mortality of the adult at 7°, -6°, -12°, and -18° C. were 336, 8.4, 0.32, and 0.15 hours respectively. Thomas and Shepard claimed "It is impossible from these determinations to say whether Oryzaephilus differs significantly from T.confusum in resistance to low temperature".

Solomon and Adamson (1955) exposed both species of Oryzaephilus to winter conditions in various kinds of buildings in Britain, and found that O.mercator survived in none, but O.surinamensis survived in all their tests. This difference was confirmed in short exposures of 4 days or less to sub-zero temperature. In all these tests there were more survivors among O.surinamensis than among O.mercator.

## C. DISTRIBUTION AND EPIDEMIOLOGY

O.surinamensis is cosmopolitan in distribution and is found in almost any stored food especially in stored grain and grain products (Thomas and Shepard 1940, Back and Cotton 1926). O.mercator is widespread throughout the tropics and is continually introduced by trade into temperate countries (Howe,1956). In Nigeria, previous records have shown that O.surinamensis occurs on dried bananas (Golding, 1946), rice and imported biscuits (Howe,1952), and imported closed tins of rolled oats (Giles, 1964). It has been found as an important pest attacking walnuts in storage in California (Michelbacher and Ortega, 1958). In Ghana, O.surinamensis has been found on sorghum in granaries (Forsyth, 1962).

Nothing has been found in the literature on the distribution of these two species at the present time in Canada, but quite a few papers record the results of work on the distribution of O.surinamensis during the past several decades. Ross and Caesar (1928, 1931), Stirrett and Arnott (1932) reported that it was the most common pest of stored grain and grain products in Ontario. It was especially important in the counties of Essex and Kent where it occurred in grain stored in farmers' granaries. In British Columbia and in Western Ontario, it has been reported as a pest on wide range of cereal foodstuffs, raisins and walnuts (Gray 1934, Spencer 1942).

In Northern Nigeria, O.mercator has been reported from Kano (Howe, 1952) where it is widely spread among groundnuts and extremely numerous in localised areas. Giles (1964) reported that O.mercator is common on sorghum, maize, millet and wheat in granaries in Northern Nigeria.

Identification of specimens of Oryzaephilus collected on ships docking at ports in the United Kingdom, has shown that O.surinamensis is principally recorded as coming from Australia and South America and is associated chiefly with cereals. O.mercator is principally recorded as coming from Africa and Asia and is chiefly associated with oilseeds (Howe and Freeman 1955, Howe 1956).

Very few papers have been found in the literature on the economic status of O.mercator. Recently in Canada, O.mercator has been recognized in increasing numbers on processed cereals, dried fruits and nuts, and this situation is being investigated by the Canada Department of Agriculture (F.O.Morrison personal communication). According to Howe (1956) O. mercator is a common species but not a serious pest. Both species of Oryzaephilus were introduced into Britain in considerable numbers, and while O.mercator has been seldom reported as causing any damage, O.surinamensis has been frequently reported as a cause of considerable annoyance and damage, especially in the late summer.

Armstrong and Howe (1963) reported that *O. surinamensis* is a major cause of the heavy infestation of farm-stored grain in Great Britain. In Canada, it has been reported as one of the most important and injurious species causing considerable damage in grain stored in farmers' granaries throughout Essex and Kent counties (Stirrett and Arnott, 1932). This species has also been recognized recently in Canada and the pattern seems to be that it occurs mostly in whole grain in storage (F.O.Morrison personal communication).

## III. MATERIALS AND METHODS

### A. REARING METHODS

Specimens of the saw-toothed grain beetle and the merchant grain beetle were sent by Dr.L.B.Smith, Research Station, Canada Agriculture, Winnipeg,Manitoba. Both species were fed on two different diets; rolled oats, and a food mixture prepared after the method described by Surtees (1965), i.e., 4 parts wheatfeed, 4 parts rolled oats and 1 part dried yeast powder. The cultures were kept in an incubator controlled at a constant temperature of 32.5 $\pm$ 0.5° C. and relative humidity of 75 to 80%, and in a culture room at temperature of 28.5 to 30° C., 50 to 55% R.H. The studies are based on both living and preserved specimens.

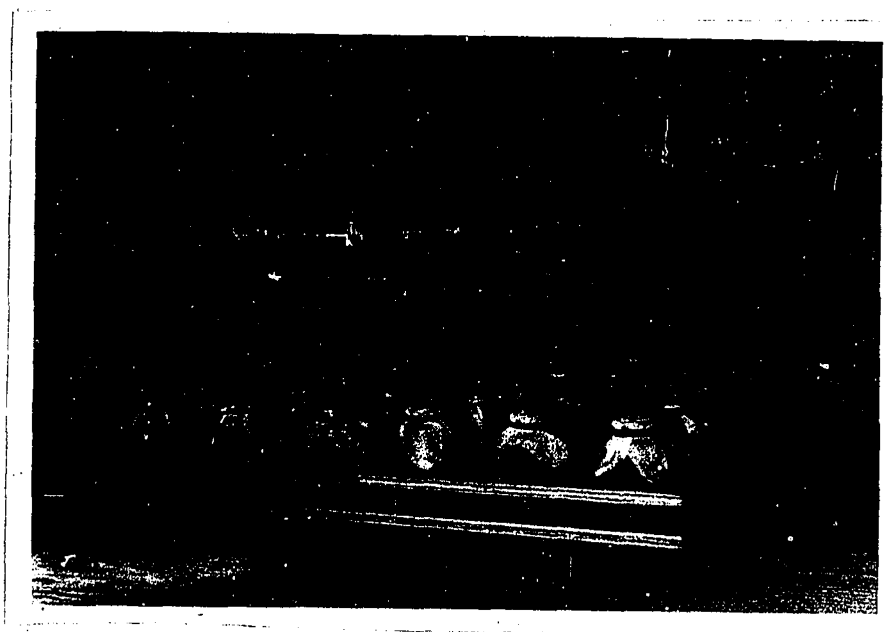
### B. COMPARATIVE MORPHOLOGY STUDIES

At 32.5° C. the adults laid eggs readily and these eggs were used for morphological studies. To obtain larvae, the eggs were placed without food in groups of 2 to 3 in 2 x 1 in. glass vials (Plate I, A and B) closed at the top by cotton cambric and were placed in the incubator. These vials were checked every day and the dates the eggs hatched were recorded. Larvae obtained were fed with Surtees' diet. Fresh food was provided at weekly intervals. The vials were examined daily until the larvae had pupated. Examples of each instar, including the pupa

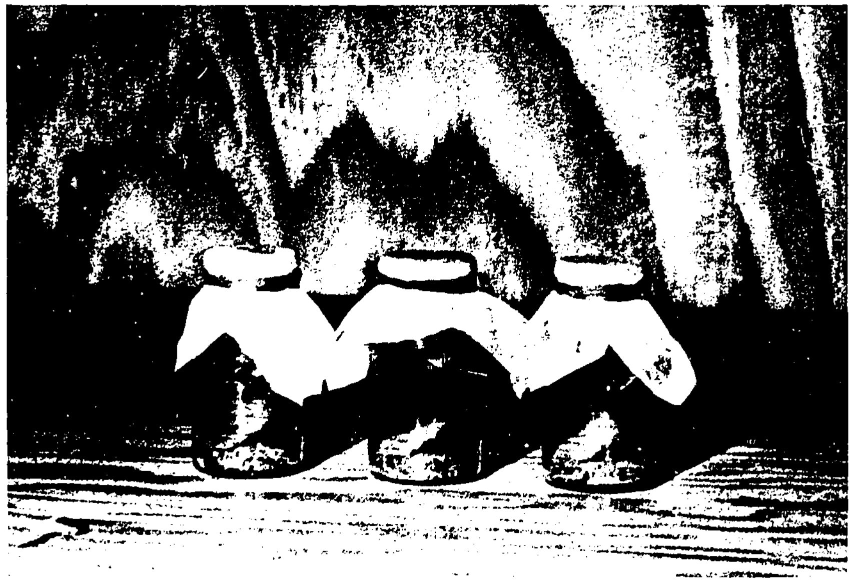
Plate I A, Type of glass vials used in larval and pupal rearings (x.56)

B, Type of supporter (x.25)

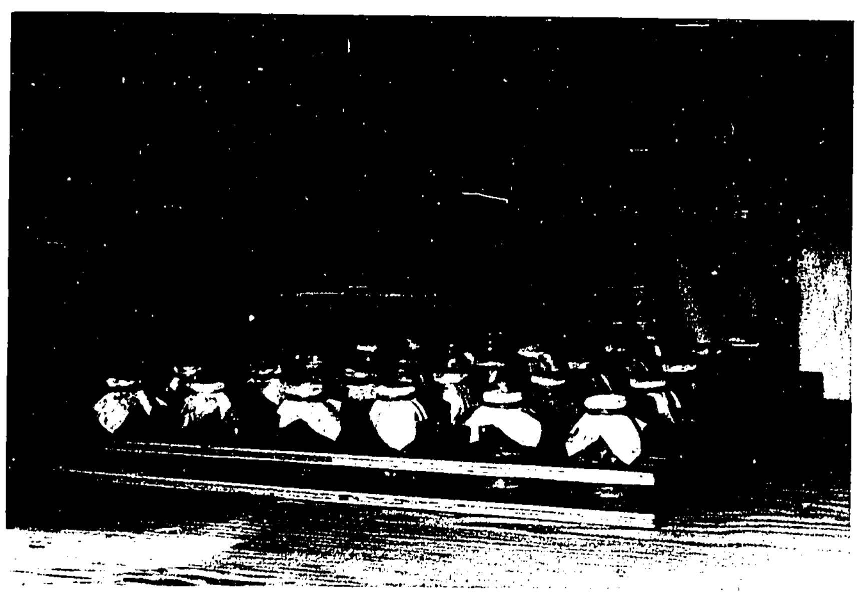
A



B



A



B

were obtained by preserving them in 70% alcohol 2 to 3 days after moulting. For microscopical examination, larvae were mounted on slides in Hoyer's solution (Beirne 1955) using 5 cc. distilled water, 3 g. gum arabic, 20 g. chloral hydrate and 2 g. glycerine.

Measurements of the size and weight of adults were made from fresh specimens. They were killed by putting a few drops of ethyl acetate on to a small piece of filter paper in a vial containing the living adults.

Fresh specimens of adults were also used for morphological studies on the male genitalia. Preparation of genitalia was as follows: The legs were first removed with forceps and a whole specimen was placed in a hot but not boiling 10% potassium hydroxide solution for about 15 minutes. This softened the specimen and destroyed the soft internal tissues. After removal from the potassium hydroxide solution, the specimen was rinsed thoroughly in distilled water, dehydrated rapidly in 70% and 100% alcohol and then transferred into a bath of clove oil for one minute. The specimen was then dissected on the slide under a steromicroscope by using a very fine pair of dissecting needles, carefully pulling the abdomen apart from the thorax by placing one pin on the thorax and the other on the ninth sternite. When the pins were pulled away from each other the genitalia were exposed and slid easily from the abdomen. The genitalia were then mounted on slides in Hoyer's solution.

### C. OVIPOSITION STUDIES

Virgin adults of both species were obtained by isolating fully fed larvae in individual vials and keeping them in the incubator. The adults of both species were sexed upon emergence by examining the metathoracic legs. In the male the trochanter and femur of these carry spines which are absent in the female (Fig.1, A and B).

Fourteen pairs of each species were formed by placing one male and one female on a thin layer of Surtees' diet in a 2 x 1 in. glass vial covered at the top by muslin. The food had previously been passed through a sieve of 60 meshes to the inch. A small amount of fresh food was supplied weekly. When only a small amount of food was supplied it was easier to obtain the daily egg record, as some eggs were laid in the food material and large amounts of food tended to obscure these. The vials were kept in the 32.5° C. incubator and the number of eggs laid by individuals of each species was counted

Fig.1 Metathoracic legs of *O.surinamensis*

A, male; B, female

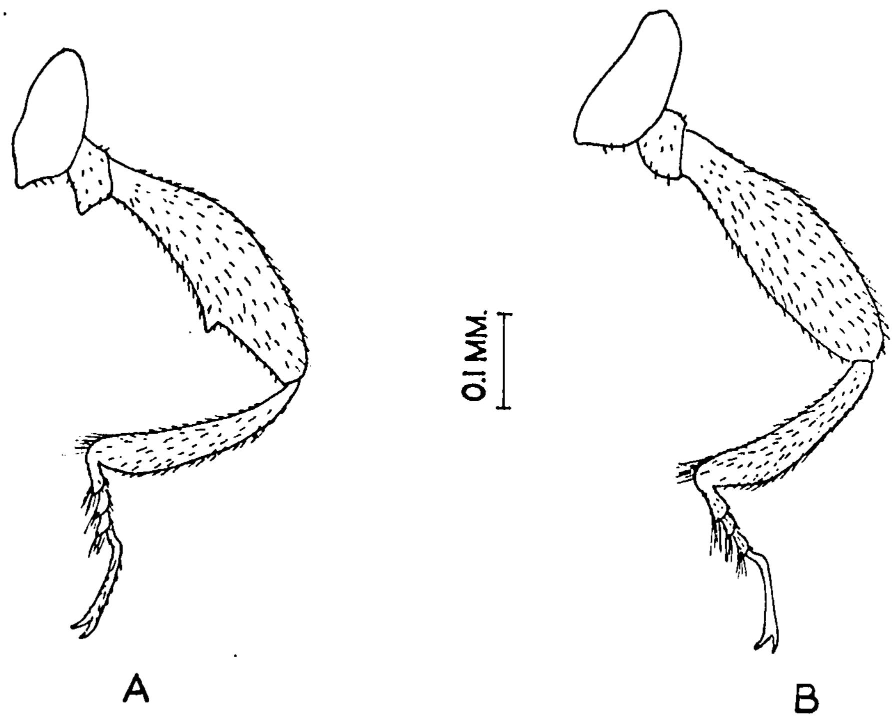



FIGURE 1

at the same time every day using a stereomicroscope. The date of egg-laying was recorded. The counted eggs were picked off from the vial, one by one, with a fine camel hair brush. These eggs were then used for studying development.

D. METHODS OF STUDYING RATE OF DEVELOPMENT

The rate of development was studied at constant temperatures of 17.5°, 22.5°, 27.5°, 32.5°, and 37.5° C. The temperatures of 27.5°, 32.5° and 37.5° C. were obtained in thermostatically controlled incubators which did not vary more than ± 0.5° C. The temperatures of 17.5 ± 1° C. and 22.5 ± 1° C. were obtained in a refrigerated incubator. Insects were fed on Surtees' diet and held at 75-80% R.H.

Three different types of food were used; rolled oats, Surtees' diet, and crushed groundnut. The rates of development of both species fed these diets were compared at 32.5° C. and 75-80% R.H.

The eggs of each species obtained from the oviposition studies were used. These were placed in the experimental conditions without food in a group of

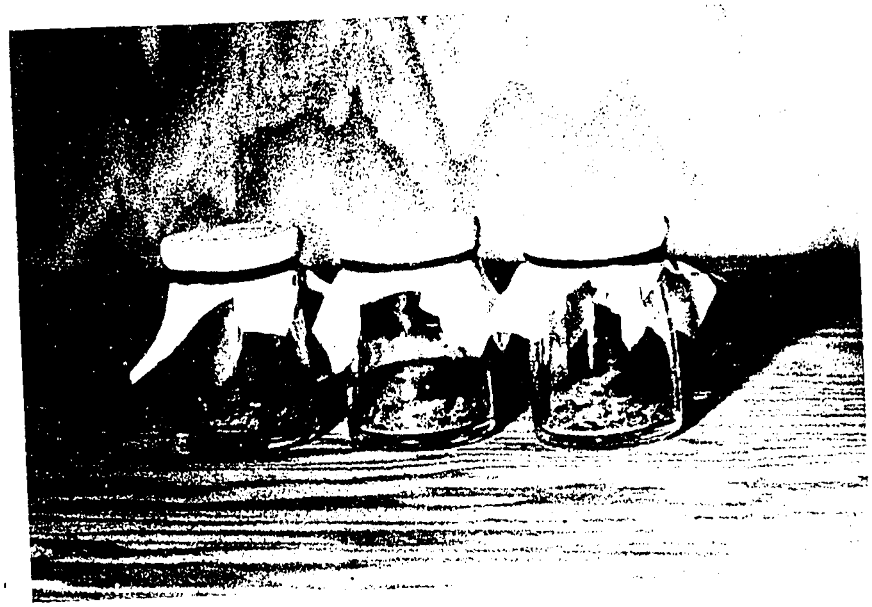
2 or 3 in a 2 x 1 in. glass vial closed at the top by cotton cambric. Examinations were made at the same time every day and the date of hatching was recorded. After hatching, only one of the first instar larvae was kept in each vial, the rest were discarded. About 200 mg. of food was supplied weekly and the vial tops were closed with muslin. The vials were checked daily at the same time, and the dates of larval moults, of pupation and of emergence to adult for each individual of both species were recorded.

## E. COLD HARDINESS OF ADULTS

The insects used for studying resistance to low temperature were obtained from the culture room at a temperature of 28.5 to 30° C., and a relative humidity of 50 to 55%. The cultures had been maintained for several months. No attempt was made to study the effect of age on their cold resistance, those used were healthy, active and vigourous.

Adults of both species were exposed to a temperature of $2 \pm 1^\circ$ C. in a refrigerator, and held at a relative humidity of 50 to 55%. The beetles were placed in 2 x 1.5 in. glass jars (Plate II), 15 individuals in each, 10 jars of each species. Each jar contained a

Plate II Type of glass jars used in the study of cold hardiness of adults (x.56)



small amount of Surtees' diet and was covered at the top with muslin. Deaths were recorded daily. The moribund or dead beetles were removed from the jars and 2 days were allowed for a possible recovery before mortality was determined. Beetles not injured sufficiently to die as a result of their cold treatment were counted as survivors and were discarded.

The percentage mortality was calculated by $\frac{d}{x-y}(100)$, where d is the number of dead, x is the number of test insects, and y is the number of survivors.

## IV. RESULTS AND DISCUSSION

### A. COMPARATIVE MORPHOLOGY STUDIES

#### 1. Eggs

Eggs of *O. surinamensis* and *O. mercator* (Plate III) are elongate-oval in form. The chorion is white and shiny. When the eggs mature, the chorion becomes wrinkled and the eggs are rather flattened before eclosion of the larvae.

Egg measurements are shown in Table I. The measurements were made with a micrometer eyepiece using a stereomicroscope. The mean differences in length and width between the two species are 0.05 and 0.0 mm. respectively. It is concluded that neither their morphological characters nor their sizes can be used to differentiate the eggs of the two species, since no specific differences have been found in morphological characters and the sizes overlap.

#### 2. Larvae

First instar larvae

First instar larvae of both species have a white body colour when first hatched and the body is rather flattened. The colour soon becomes pale-yellowish,

Plate III Eggs of *Oryzaephilus mercator* (x 53)

Table 1 Average length and width in mm. of eggs of *O. surinamensis* and *O. mercator*.

| Species | Number | Length: Average | Length: Standard deviation | Width: Average | Width: Standard deviation |
|---|---|---|---|---|---|
| *O. surinamensis* | 25 | .81 | ± .023 | .26 | ± .012 |
| *O. mercator* | 25 | .76 | ± .022 | .26 | ± .013 |

with brown transverse bands on the dorsal surface of the thoracic and abdominal segments and the body becomes rounded. There is a considerable number of long setae on the thoracic and abdominal segments (Figs. 2 and 3). The head capsule of both species is a pale yellowish brown. Larval length ranges from 0.73 to 0.85 mm. in O.surinamensis, and from 0.72 to 0.85 mm. in O.mercator, the averages of 20 specimens being 0.81 and 0.77 mm. respectively. The head capsule width averages being 0.24 mm. in O.surinamensis and 0.23 mm. in O.mercator.

Second instar larvae

Second instar larvae of both species have a white to pale yellow body colour. The head capsule is a pale yellowish brown. Other morphological characters are as same as first instar larvae. Larval length ranges from 1.07 to 1.25 mm. in O.surinamensis, and from 1.13 to 1.27 mm. in O.mercator, the averages being 1.16 and 1.19 mm. respectively. The average head capsule width is 0.30 mm. in O.surinamensis and 0.27 mm. in O.mercator.

Third instar larvae

In both species, third instar larvae have a white to pale yellow body colour. The head capsule is pale yellowish brown in both species. Larval length ranges from 1.50 to 1.73 mm. in O.surinamensis, and from

Fig.2 Larvae of <u>O.surinamensis</u> from the dorsal aspect (drawn from slides, x 32).

A, first instar; B, second instar;

C, third instar; D, fourth instar.

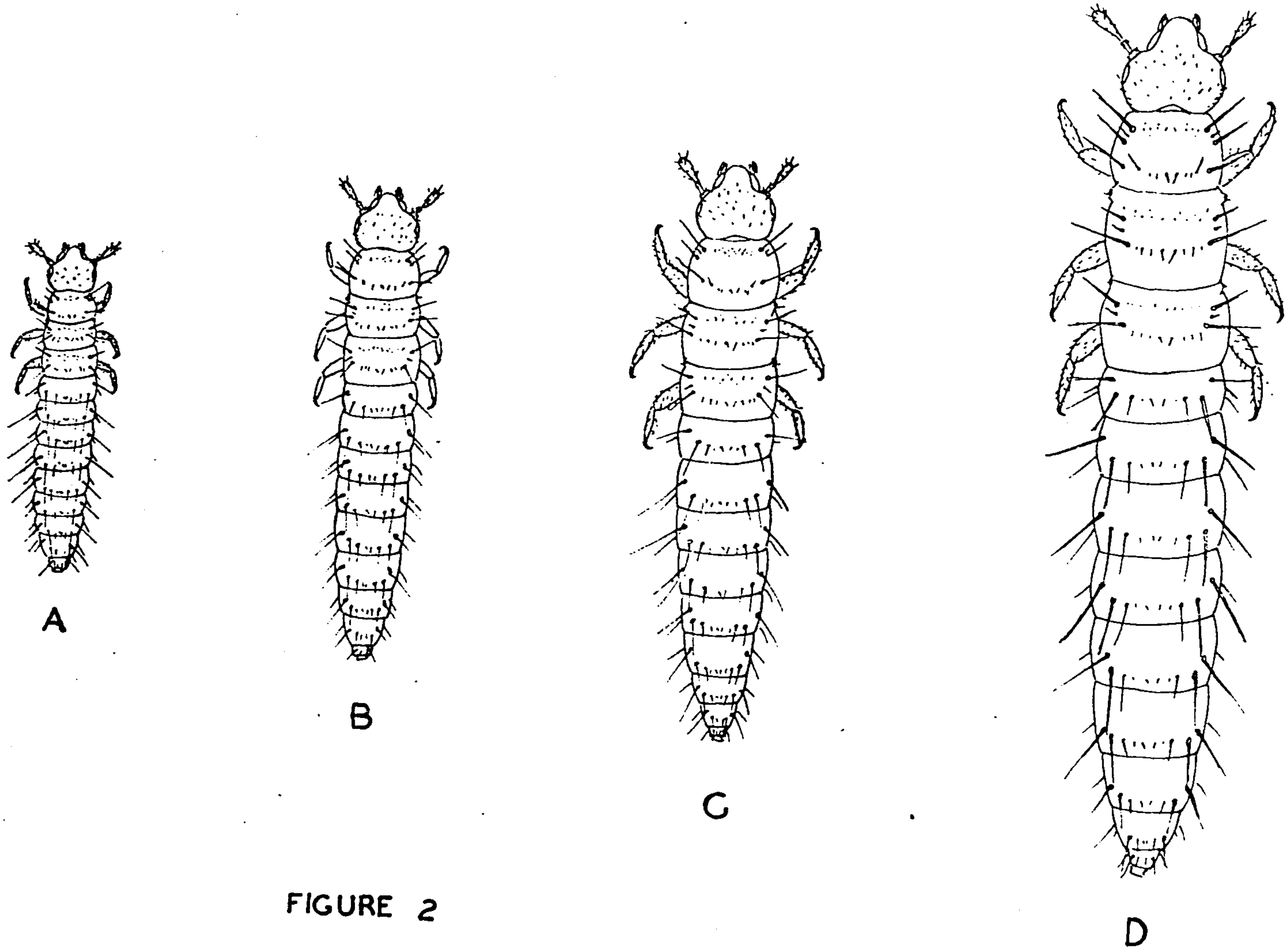



FIGURE 2

Fig. 3 Larvae of O.surinamensis from the ventral aspect (drawn from slides, x 32).

A, first instar; B, second instar;

C, third instar; D, fourth instar.

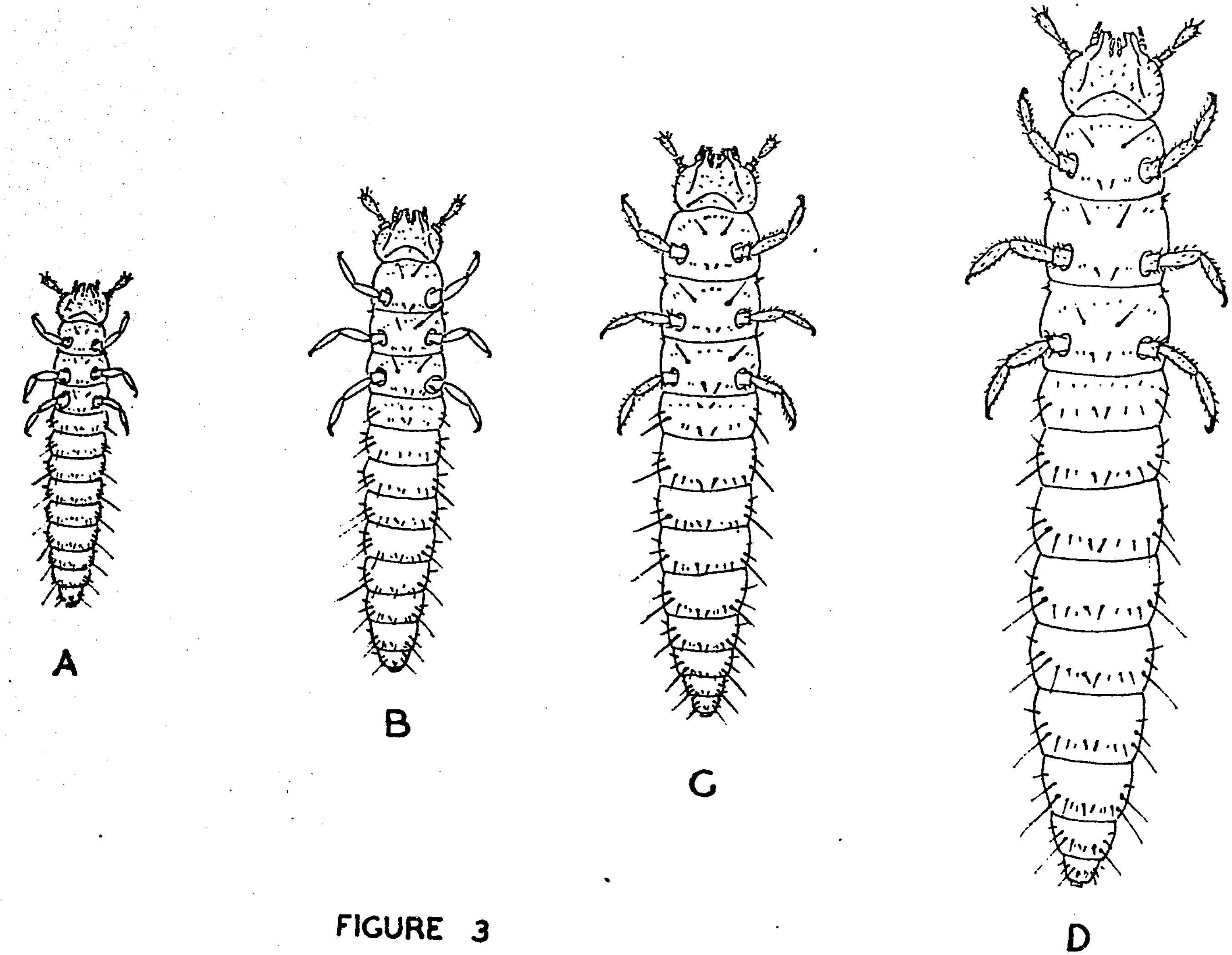



FIGURE 3

1.57 to 1.80 mm. in _O.mercator_, the averages being 1.62 and 1.75 mm. respectively. The average width of head capsule is 0.40 mm. in _O.surinamensis_ and 0.39 mm. in _O.mercator_.

Fourth instar larvae

The body colour of fourth instar larvae of both species is whitish to pale yellowish. The head capsule is pale yellowish brown. Larval length ranges from 1.90 to 2.43 mm. in _O.surinamensis_, and from 2.00 to 2.43 mm. in _O.mercator_, the averages being 2.17 and 2.29 mm. respectively. The average head capsule width is 0.49 mm. in _O.surinamensis_ and 0.46 mm. in _O.mercator_.

Fifth instar larvae

Fifth instar larvae of both species have a body colour white to pale yellow. The head capsule is pale yellowish brown in both species. Larval length ranges from 2.33 to 2.66 mm. in _O.surinamensis_, and from 2.60 to 2.80 mm. in _O.mercator_, the averages being 2.58 and 2.68 mm. respectively. The average width of head capsule is 0.51 mm. in _O.surinamensis_ and 0.50 mm. in _O.mercator_.

Larval measurements are summarized in Table II, using 1 division of the ocular scale being equal to 0.033 mm. Histograms of the frequency distribution of the head

Table II Average head capsule width and body length in mm. of larvae of O. surinamensis and O. mercator.

| Species | Instar | Number | Head capsule width: Average | Head capsule width: Standard deviation | Body length: Average | Body length: Standard deviation | Range (mm.) |
|---|---|---|---|---|---|---|---|
| O. surinamensis | I | 20 | .24 | ± .012 | .81 | ± .032 | .73- .85 |
| | II | 20 | .30 | ± .017 | 1.16 | ± .048 | 1.07-1.25 |
| | III | 20 | .40 | ± .010 | 1.62 | ± .058 | 1.50-1.73 |
| | IV | 20 | .49 | ± .021 | 2.17 | ± .167 | 1.90-2.43 |
| | V | 8 | .51 | ± .020 | 2.58 | ± .117 | 2.33-2.66 |
| O. mercator | I | 20 | .23 | ± .008 | .77 | ± .033 | .72- .85 |
| | II | 20 | .27 | ± .004 | 1.19 | ± .046 | 1.13-1.27 |
| | III | 20 | .39 | ± .030 | 1.75 | ± .120 | 1.57-1.80 |
| | IV | 20 | .46 | ± .017 | 2.29 | ± .111 | 2.00-2.43 |
| | V | 12 | .50 | ± .016 | 2.68 | ± .019 | 2.60-2.80 |

capsule measurements for both species are shown in Figs. 4 and 5. Measurements of larval head capsule width and body length of both species were made on 20 individuals for each instar except the fifth. Only 8 fifth instar larvae of O.surinamensis and 12 O.mercator were measured. This was due to the difficulties in obtaining this instar. Since these fifth instar numbers were considered inadequate, attempts were repeatedly made to obtain more. Fifty-seven individuals of O.surinamensis were reared from hatching but no fifth instar were produced. Only 1 specimen of O.mercator was obtained by rearing 51 first instar to adults. This failure to obtain fifth instar larvae is due to the fact that the majority of larvae of both species moult 3 times before pupation, and only a few moult 4 times. The number of instars will be discussed again later.

As indicated in Table II, Figs. 4 and 5, there is overlapping in measurements of fourth and fifth instar larvae, both of head capsule width and of body length in both species, although the means may be widely different.

In the observations made, only one, the difference in the length of setae on the dorsum of thoracic segments has been found reliable for distinguishing the species. The arrangement of thoracic setae of both species is illustrated in Fig.6, A and B. In O.mercator (Fig.6,B) the setae on the posterior margin of the mesothorax and metathorax are longer than those of O.surinamensis (Fig.6, A). This difference has been found in all larval instars.

Fig.4 Head capsule widths of larvae of *O.surinamensis*.

Fig.5 Head capsule widths of larvae of *O.mercator*.

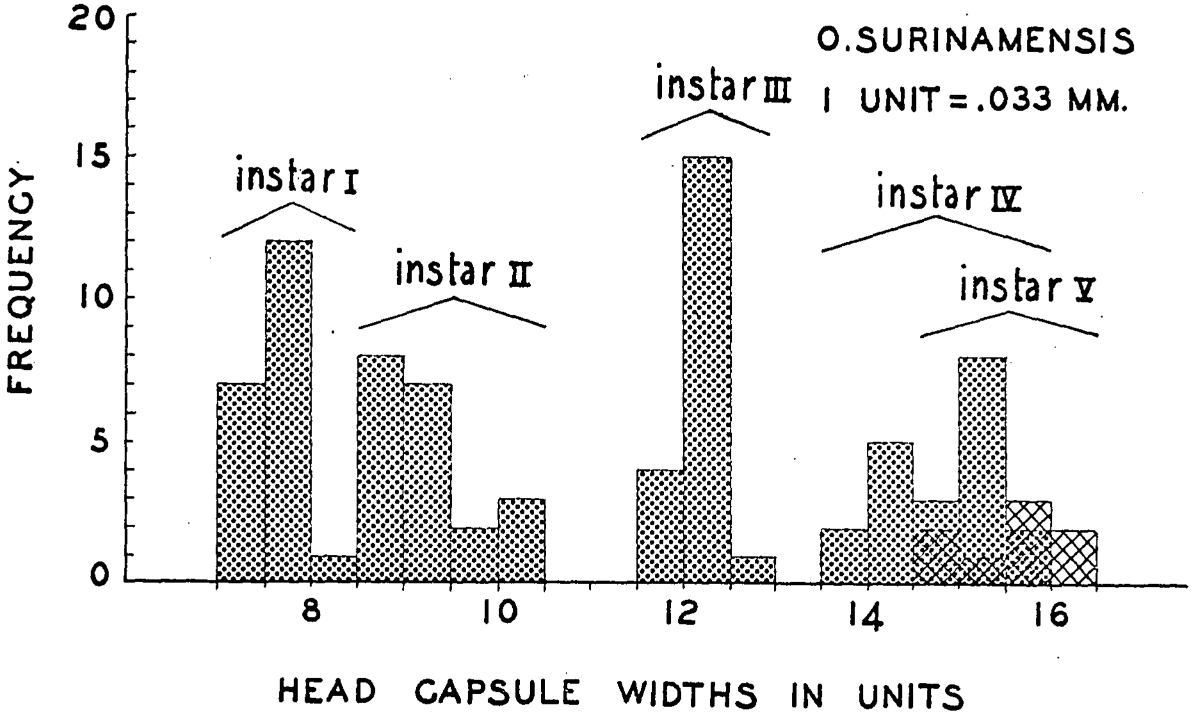



FIGURE 4

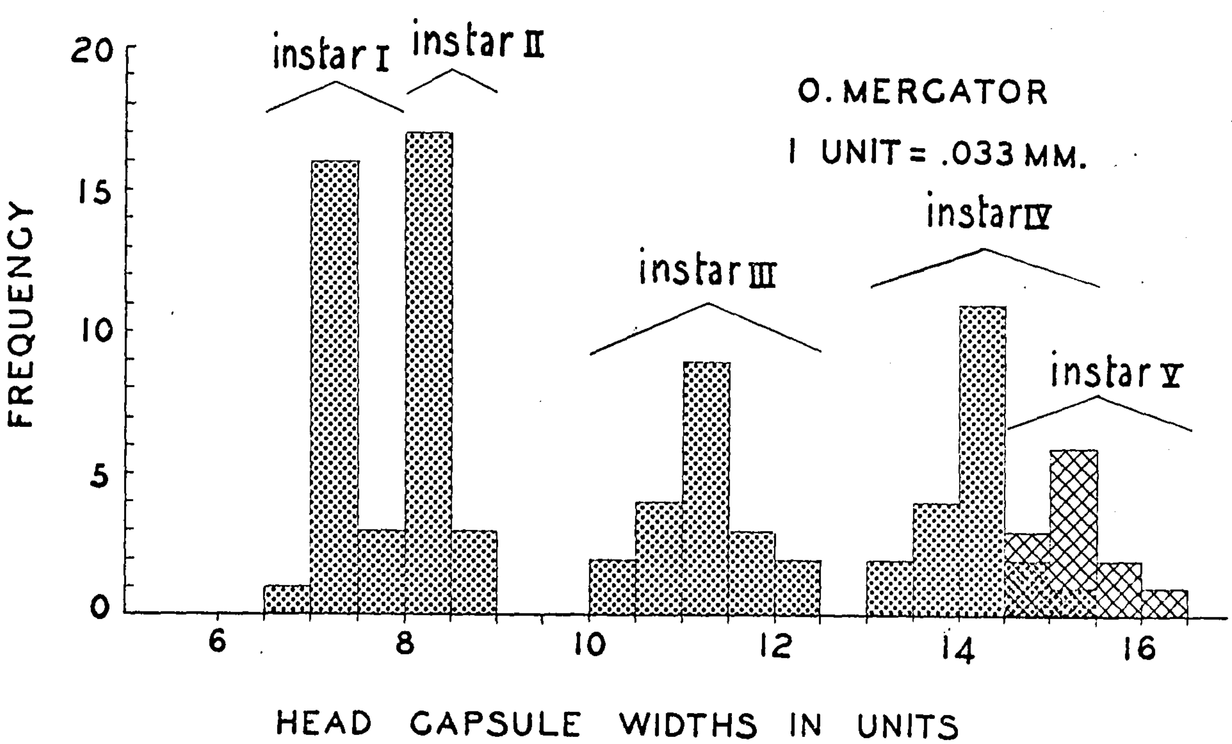
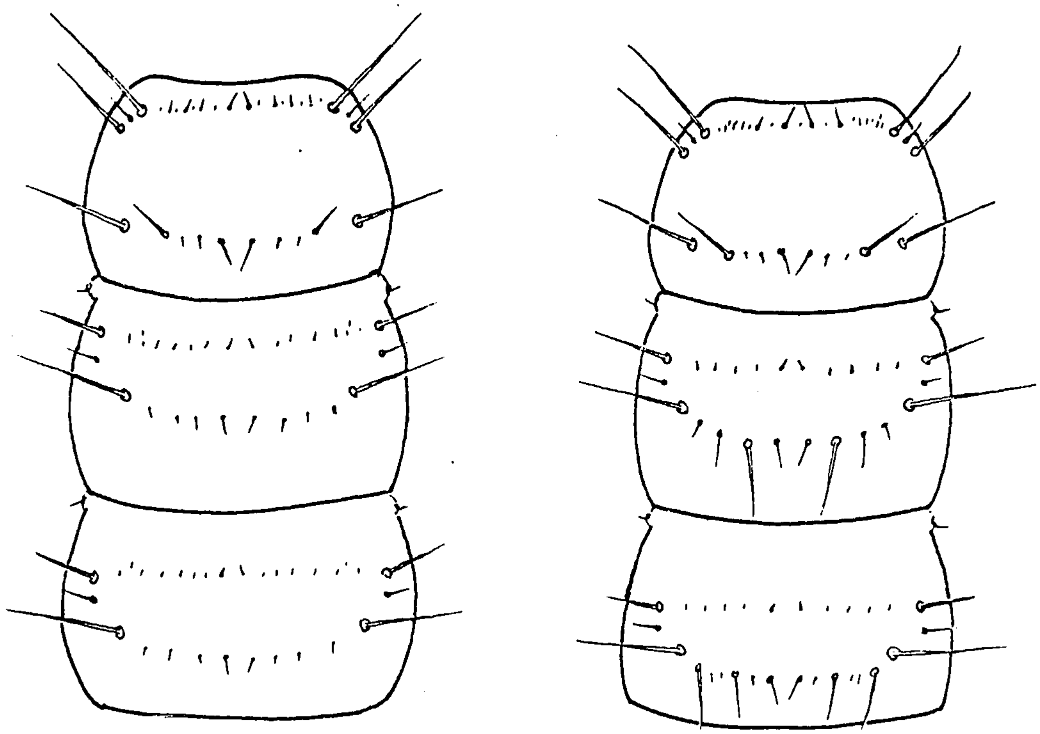



FIGURE 5

Fig.6 Dorsal aspect of thoracic segments of fourth instar larvae of *O.surinamensis* and *O.mercator* showing the distribution of setae (drawn from slides, x 68).

A, *O.surinamensis*,

B, *O.mercator*.



A B

FIGURE 6

## 3. Pupae

Pupae (Fig.7) of both species have similar morphological features. When first formed they have a white colour but turn yellowish within a few days. It is not possible to sex the pupae.

Pupal measurements are summarized in Table III. It is concluded that neither their morphological characters nor their sizes can be used to distinguish between the pupae of the two species.

## 4. Adults

### Body length

Length measurements of both species are summarized in Table IV, and histograms for both male and female showing the range of variation in measurements are shown in Figs. 10 and 16 respectively. It is concluded that body length is of no value in distinguishing between the two species.

### Adult weight

Twenty-five specimens of each sex of both species were weighed using a Mettler macro balance. On average O.mercator were heavier than O.surinamensis and females of both species were heavier than males. The average of adult weights is shown in Table V.

Fig.7 Ventral and lateral aspects of pupae of *O.mercator*.

A, ventral aspect;

B, lateral aspect.

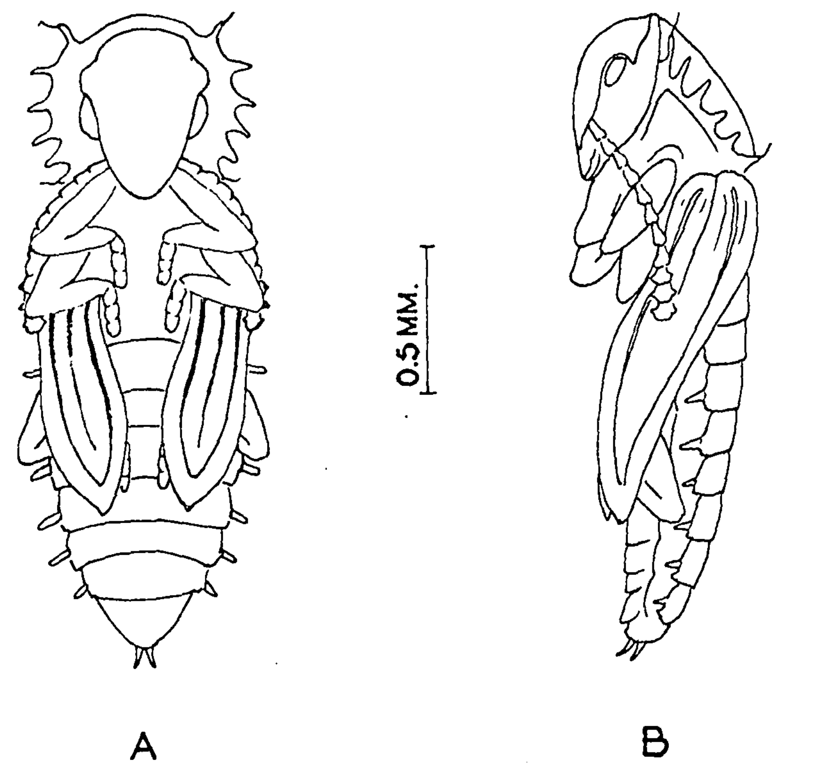



FIGURE 7

Table III Average length and width in mm. of pupae of *O. surinamensis* and *O. mercator*.

| Species | Number | Length: Average | Length: Standard deviation | Width: Average | Width: Standard deviation |
|---|---|---|---|---|---|
| *O. surinamensis* | 20 | 2.33 | ± .152 | .68 | ± .030 |
| *O. mercator* | 20 | 2.48 | ± .129 | .72 | ± .020 |

Table IV Average length in mm. of adults of *O. surinamensis* and *O. mercator*.

| Species | Number | Male Average | Male Standard deviation | Female Average | Female Standard deviation |
|---|---|---|---|---|---|
| *O. surinamensis* | 20 | 2.64 | ± .093 | 2.75 | ± .101 |
| *O. mercator* | 20 | 2.81 | ± .070 | 2.[illegible]2 | ± .107 |

Table V Average adult weight in mg. of *O. surinamensis* and *O. mercator*

| Species | Number | Male Average | Male Standard deviation | Female Average | Female Standard deviation |
|---|---|---|---|---|---|
| *O. surinamensis* | 25 | .43 | ± .094 | .52 | ± .069 |
| *O. mercator* | 25 | .65 | ± .024 | .76 | ± .070 |

Head

The head of O.surinamensis (Fig.8, A and Plate 4,B) is rather triangular in shape. It is broad at the temples, behind the eyes and is narrower anteriorly. The ratio of eye length/temple length is 1.40 in the males and 1.62 in the females (Table VI).

In O.mercator (Fig.8,B and Plate IV,A), the head is more parallel-sided than that of O.surinamensis. The ratio of eye length/temple length is 4.14 in the males and 3.74 in the females (Table VI).

These results have been found to coincide with those of Slow (1958). She measured the eye/temple ratio and found that it differed considerably in the two species.

Size ratios of external parts

Adults measurements were made on various parts of both species (Fig.9), using specimens reared under the same conditions. The measurements were made on 15 individuals of each sex and each species. The ratios are given in Table VI and the histograms showing the range of variation in measurements for male and female on various parts of both species are shown in Figs. 11-15 and 17-21 respectively. Measurements for all parts were made with a

Fig.8 Heads of A, O.surinamensis and B, O.mercator illustrating the differences in shape and eye/temple ratio.

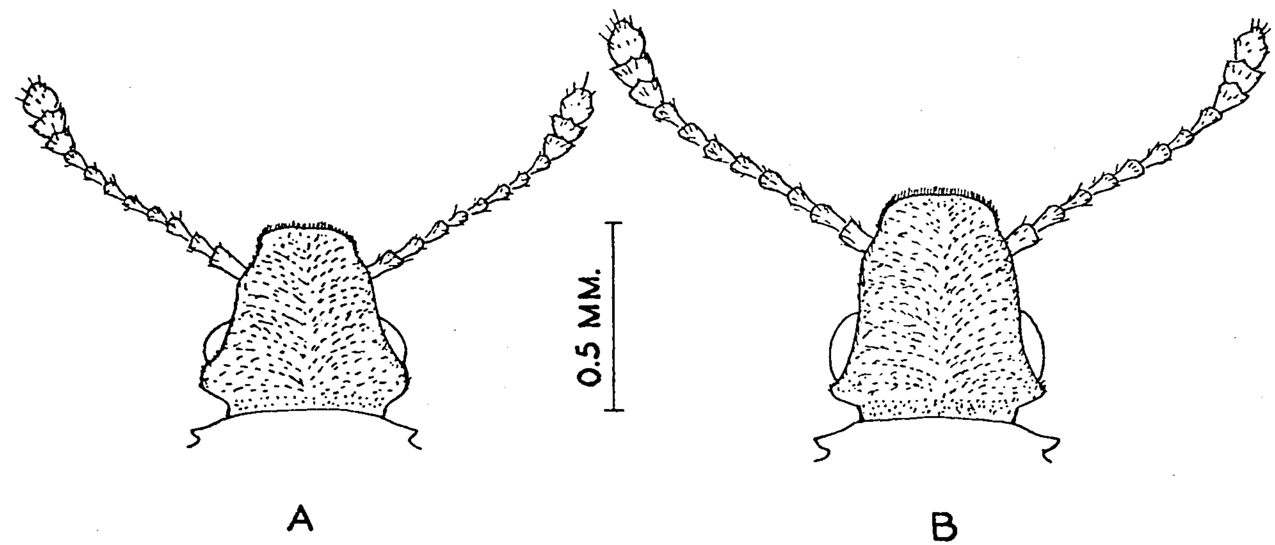



FIGURE 8

Plate IV   Adult of A, *O. mercator* (x 27) and B, *O. surinamensis* (x 27).

A

B

Table VI Size ratios of external parts of adults of <u>O.surinamensis</u> and <u>O.mercator</u>.

| | | *O.surinamensis* | | | | *O.mercator* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Male | | Female | |
| Ratio | Number | Average | Range | Average | Range | Average | Range | Average | Range |
| EL/TL | 15 | 1.40 | 1.22-1.86 | 1.62 | 1.44-1.75 | 4.14 | 3.60-5.67 | 3.74 | 3.20-4.75 |
| HWT/HWG | 15 | 2.00 | 1.88-2.33 | 2.00 | 1.93-2.07 | 1.81 | 1.64-2.00 | 1.82 | 1.73-1.92 |
| HWT/PW | 15 | .88 | .81- .91 | .87 | .84- .91 | .78 | .74- .83 | .78 | .75- .83 |
| HWT/WBT | 15 | 1.50 | 1.40-1.58 | 1.51 | 1.42-1.55 | 1.36 | 1.16-1.48 | 1.33 | 1.27-1.39 |
| HL/PW | 15 | 1.10 | .97-1.13 | 1.06 | 1.03-1.09 | 1.07 | .97-1.14 | 1.07 | 1.04-1.12 |

For lettering, see Fig.9.

Fig.9 Diagram of adult of O.mercator showing measurements recorded.

L, length of body; HWC, head width at clypeus;
EL, eye length; TL, temple length;
HWT, head width at temple; HL, head length;
WBT, head width behind temple; PW, pronotum width.

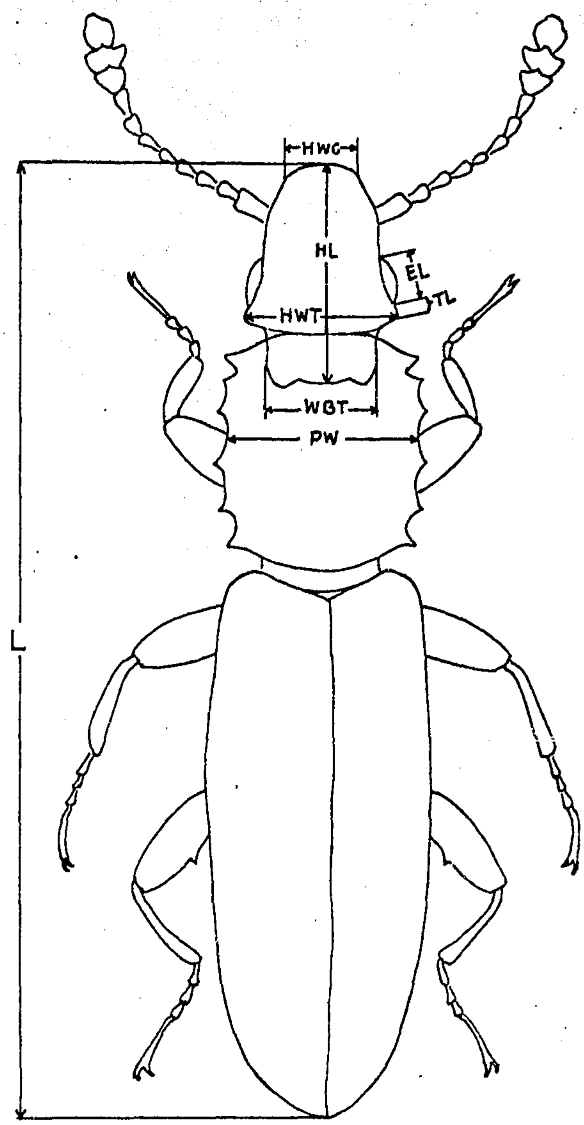



FIGURE 9

Fig.10 Body lengths of adult male O.*surinamensis* and O.*mercator*.

Fig.11 Ratios of eye length/temple length of adult male A, O.*surinamensis* and B, O.*mercator*.

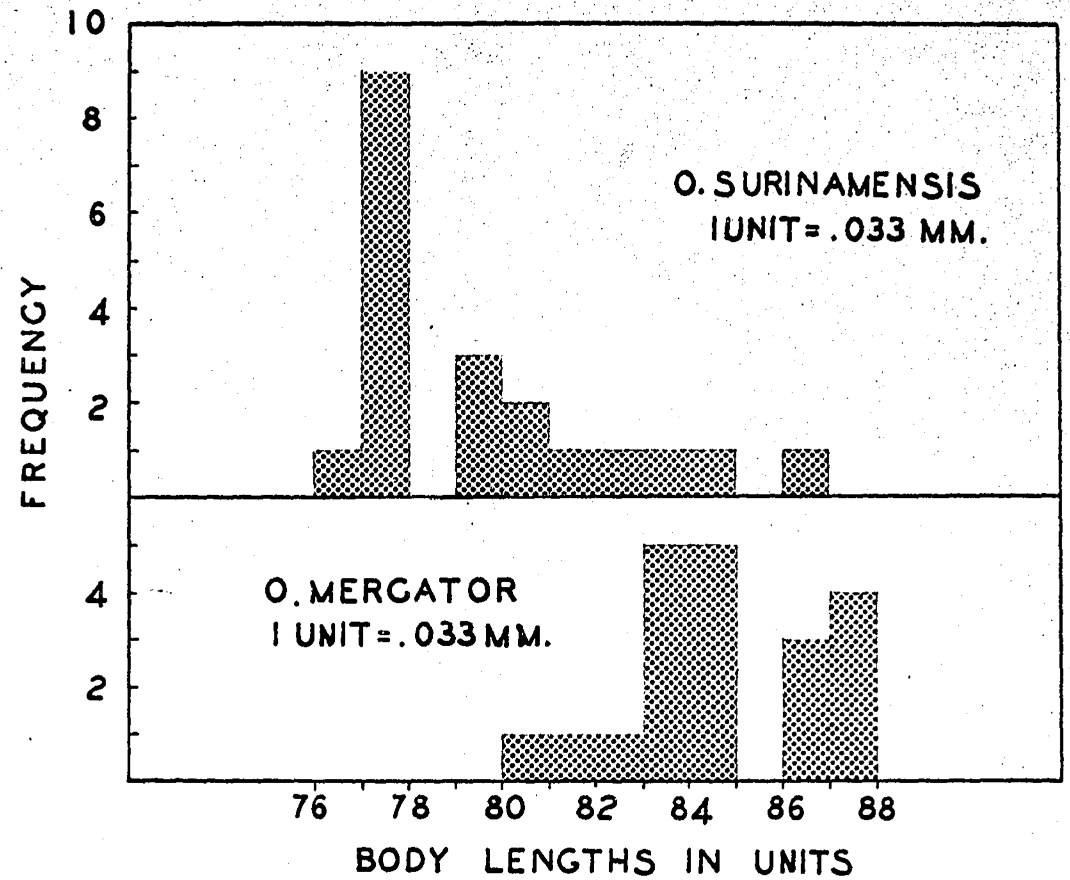



FIGURE 10

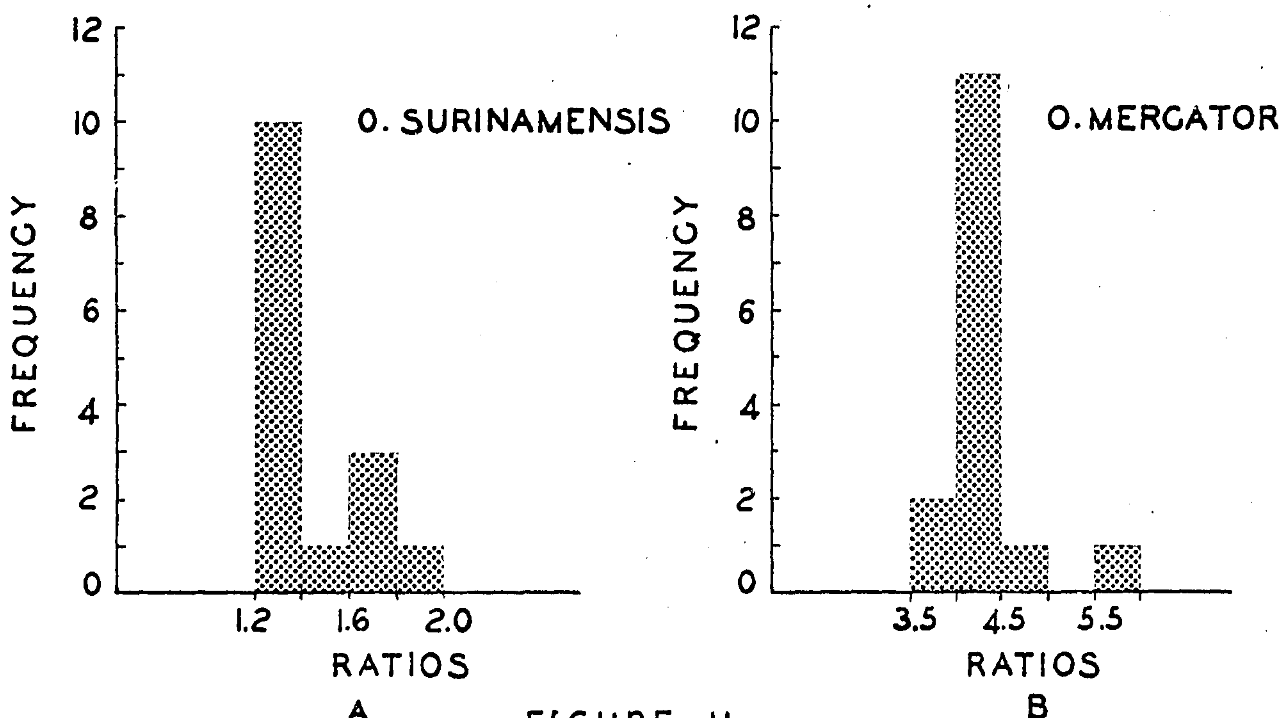



FIGURE 11

Fig.12 Ratios of head width at temple/head width at clypeus of adult male A, *O.surinamensis* and B, *O.mercator*.

Fig.13 Ratios of head width at temple/pronotum width of adult male A, *O.surinamensis* and B, *O.mercator*.

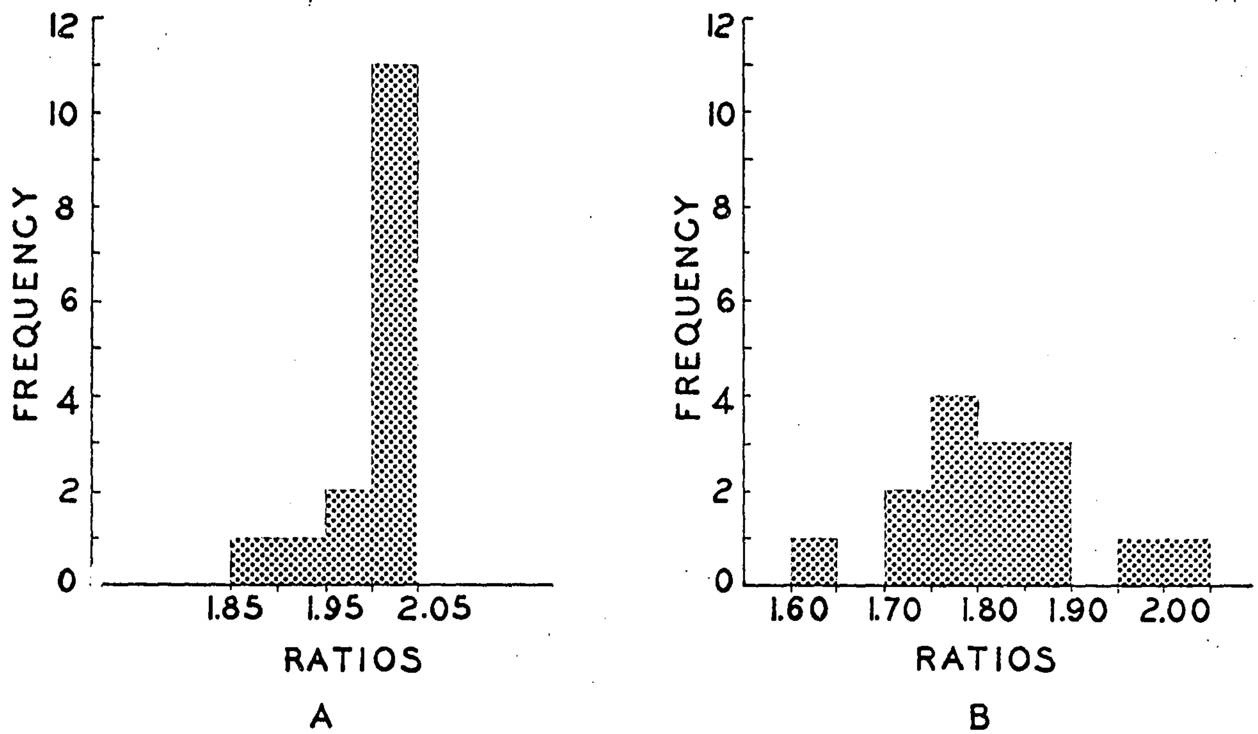



FIGURE 12

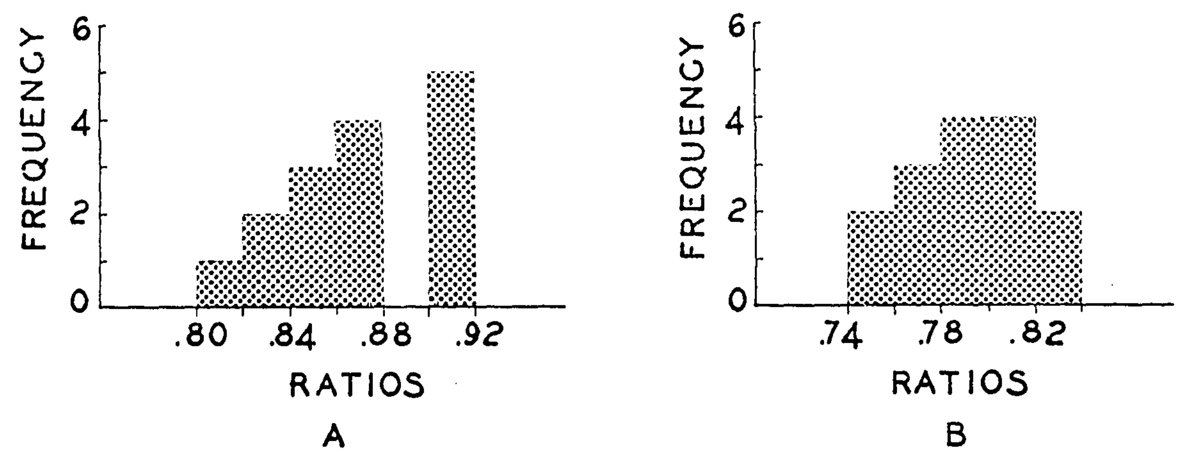



FIGURE 13

Fig.14 Ratios of head width at temple/width behind temple of adult male A, O.surinamensis and B, O.mercator.

Fig.15 Ratios of head length/pronotum width of adult male A, O.surinamensis and B, O. mercator.

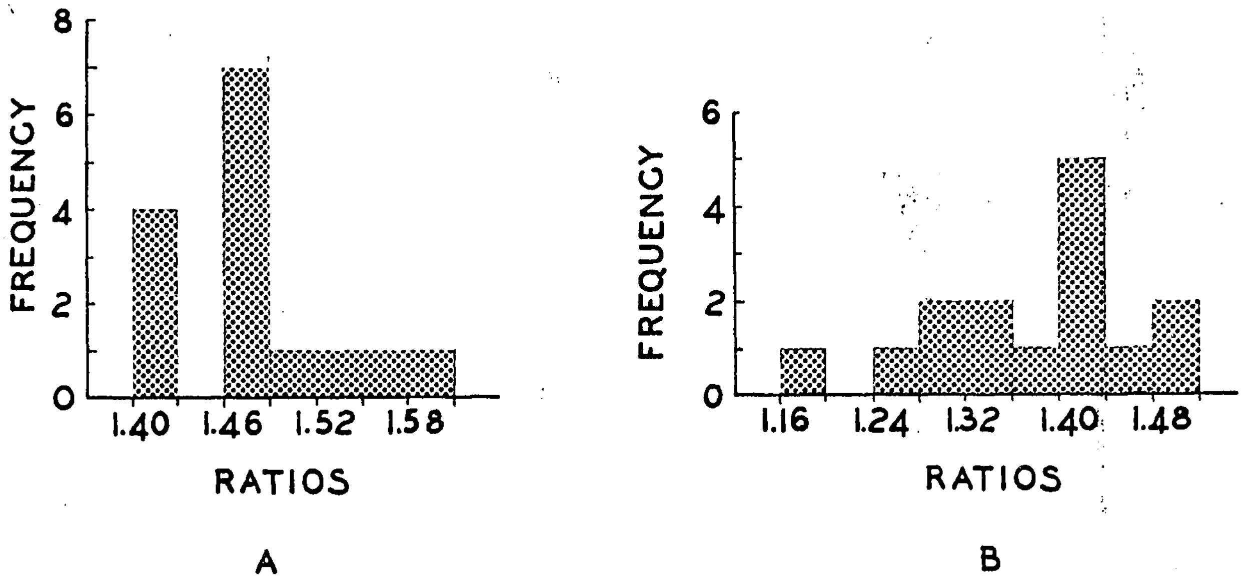



FIGURE 14

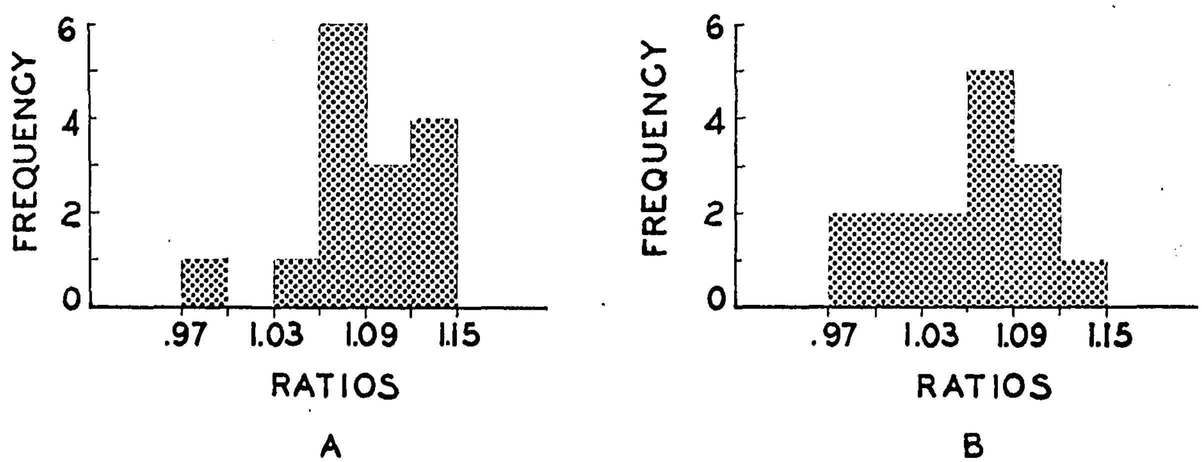



FIGURE 15

Fig.16 Body length of adult female *O.surinamensis* and *O.mercator*.

Fig.17 Ratios of eye length/temple length of adult female A, *O.surinamensis* and B, *O.mercator*.

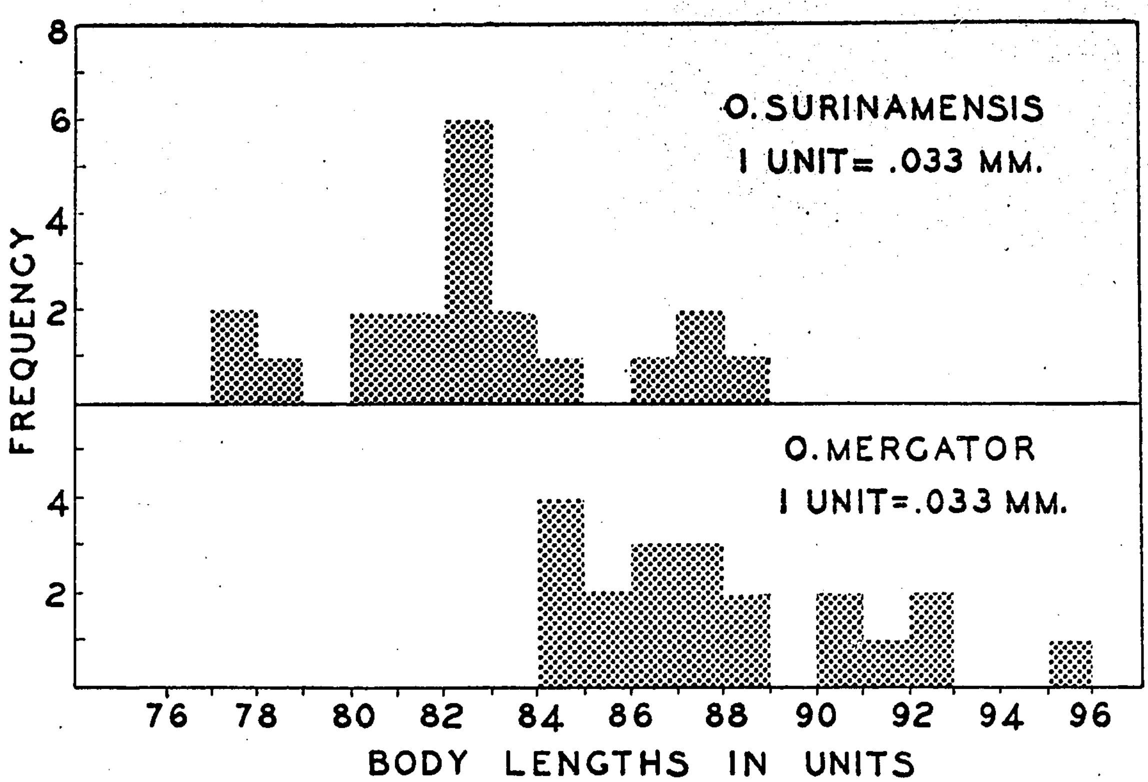



FIGURE 16

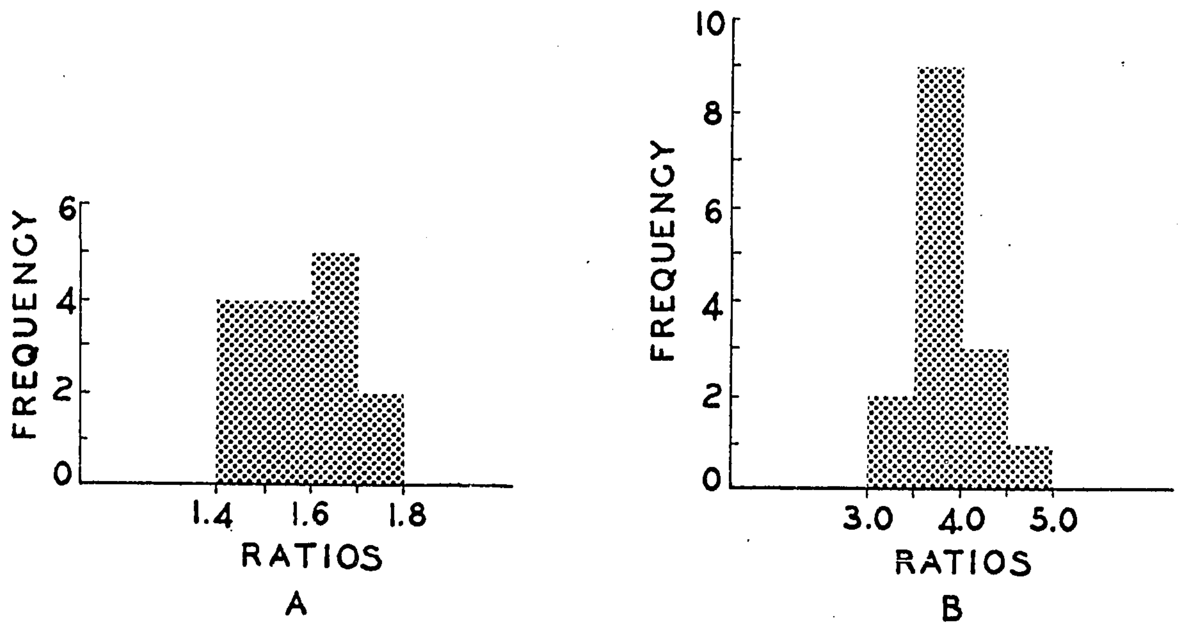
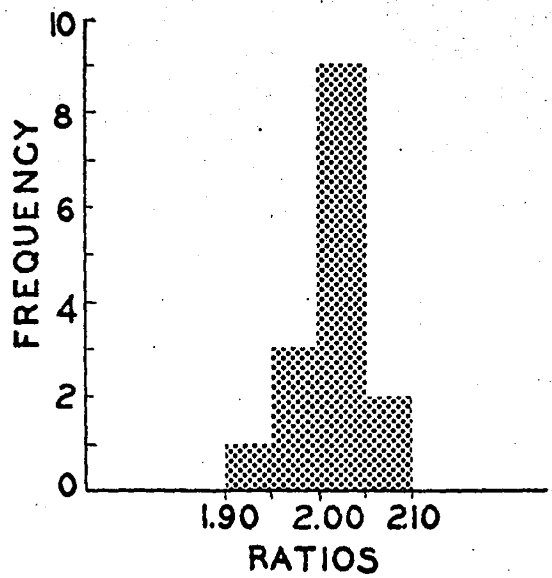


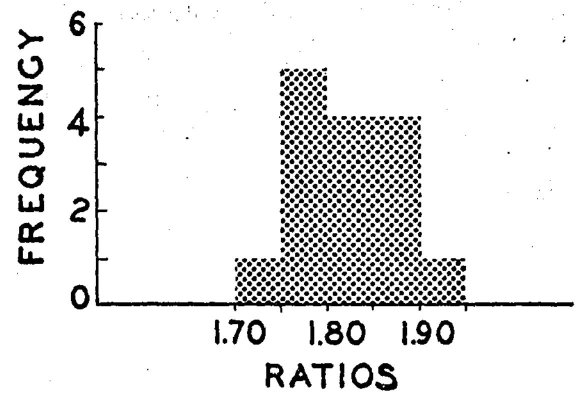

FIGURE 17

Fig.18 Ratios of head width at temple/head width at clypeus of adult female A, *O.surinamensis* and B, *O.mercator*.

Fig.19 Ratios of head width at temple/pronotum width of adult female, A, *O.surinamensis* and B, *O.mercator*.

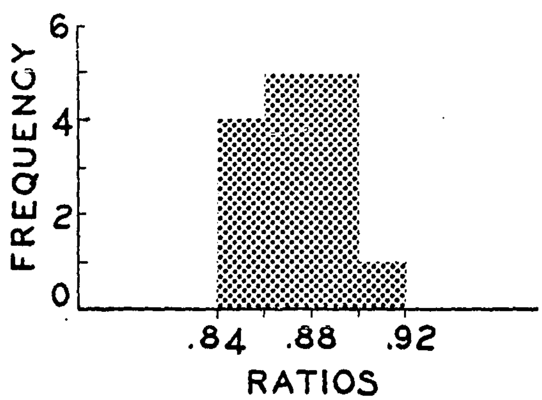



A

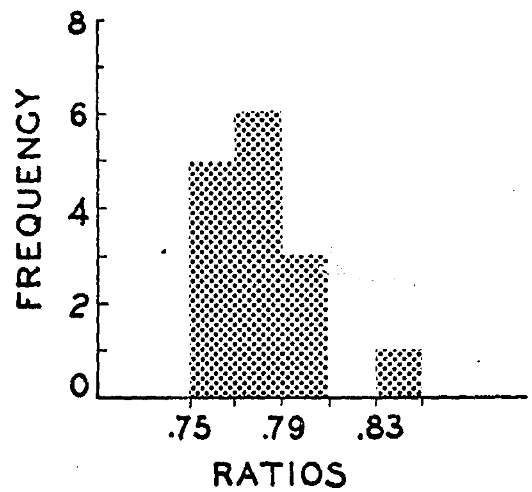



B

FIGURE 18




A




B

FIGURE 19

Fig.20 Ratios of head width at temple/width behind temple of adult female A, *O.surinamensis* and B, *O.mercator*.

Fig.21 Ratios of head length/pronotum width of adult female A, *O.surinamensis* and B, *O.mercator*.

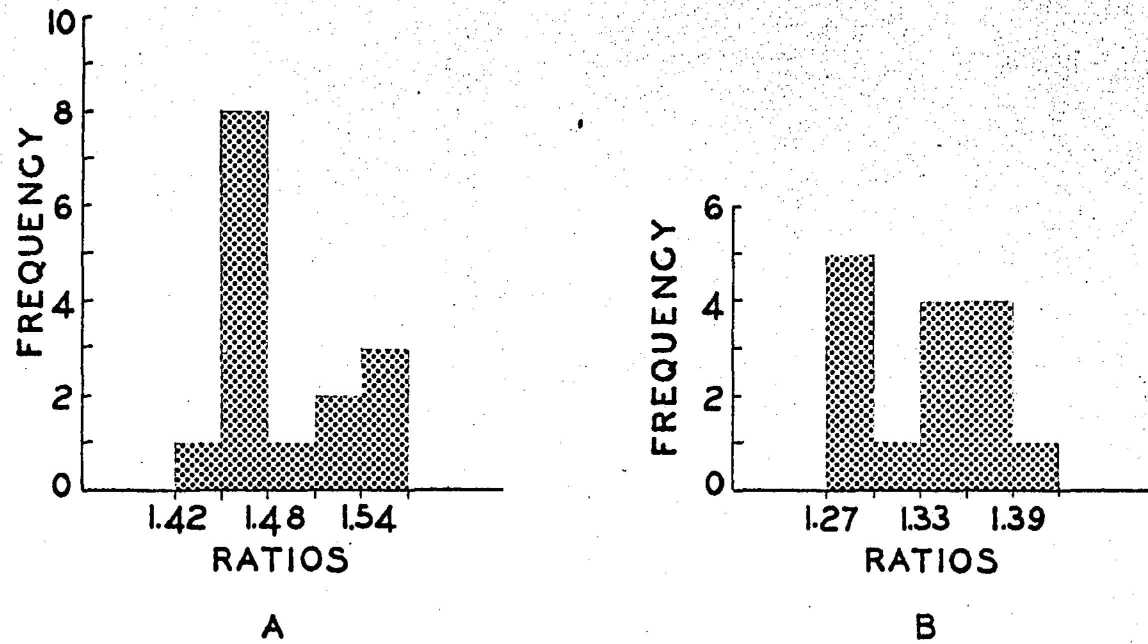



FIGURE 20

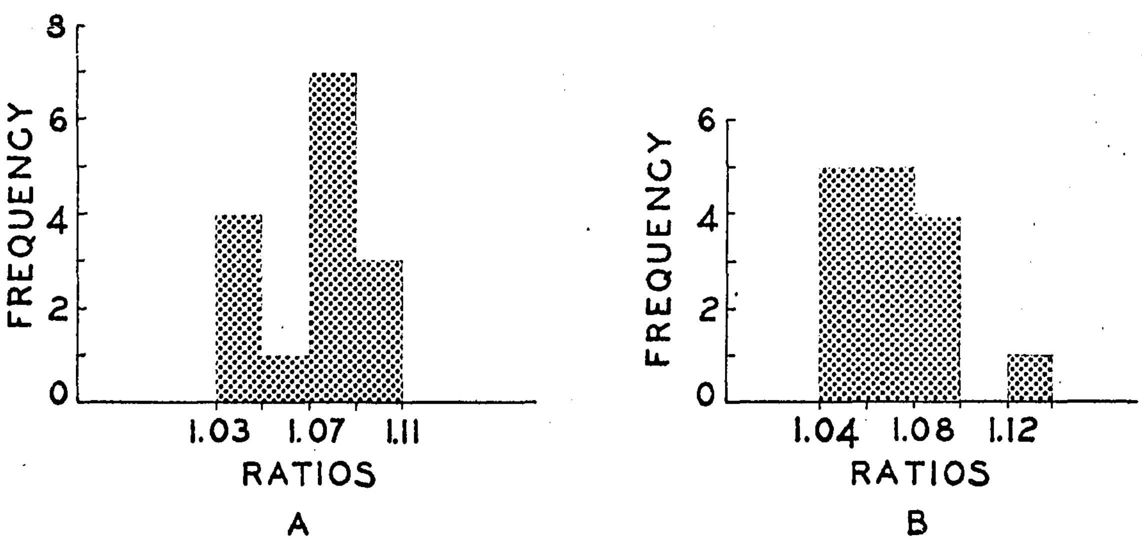



FIGURE 21

stereomicroscope, using 1 division of the ocular scale being equal to 0.033 mm., except the eye-temple ratio where an ocular micrometer of the moving hair type was used. Divisions on the latter were such that 100 were equal to 0.28 mm.

It can be concluded that among all of these measurements, only one, the ratio of eye length to temple length can be readily used to distinguish between the two species. The other although differing on average, overlap in range, and therefore cannot be used to positively identify these two species.

5. Male genitalia of adults

The differences in the male genitalia between the two species can be readily distinguished. They are shown in Figs. 22-27 and Plates V and VI. The aedeagus of both species consists of a tegmen and a median lobe (ml) (Figs.22 and 23). The tegmen consists of paired struts (tg), basal piece (bp), and lateral lobes (ll), and is connected to the median lobe by a membrane (cm).

The lateral lobes (Fig.24, A and B) are slender and flattened, carrying long setae at their rounded distal ends and attached to the basal piece ventrally. The whole structure assumes the shape of an inverted 'U'.

Fig.22 Male genitalia of O.surinamensis from the ventral aspect.

ej, ejaculatory duct; is, internal sac; ms, median strut, tg, paired struts, cm, connecting membrane; bp, basal piece; ml, median lobe; ll, lateral lobe; $st_9$, ninth sternite.

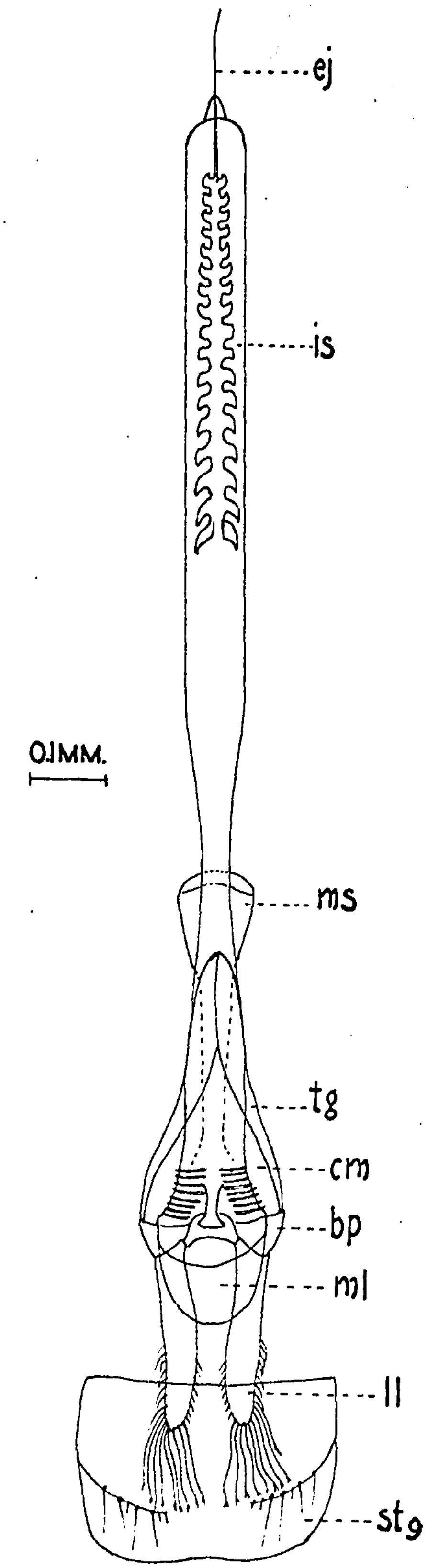



FIGURE 22

Fig.23 Male genitalia of *O.mercator* from the ventral aspect. Lettering as in Fig.22.

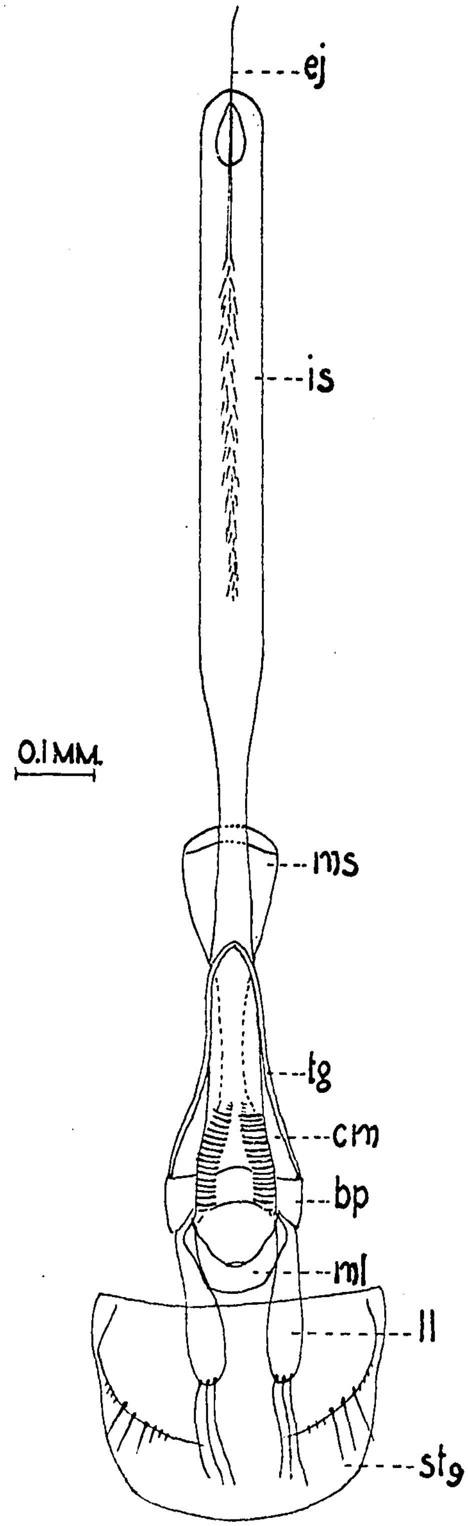



FIGURE 23

Fig.24 Male genitalia of A, O.surinamensis and B, O.mercator: tegmen and lateral lobes. Lettering as in Fig.22.

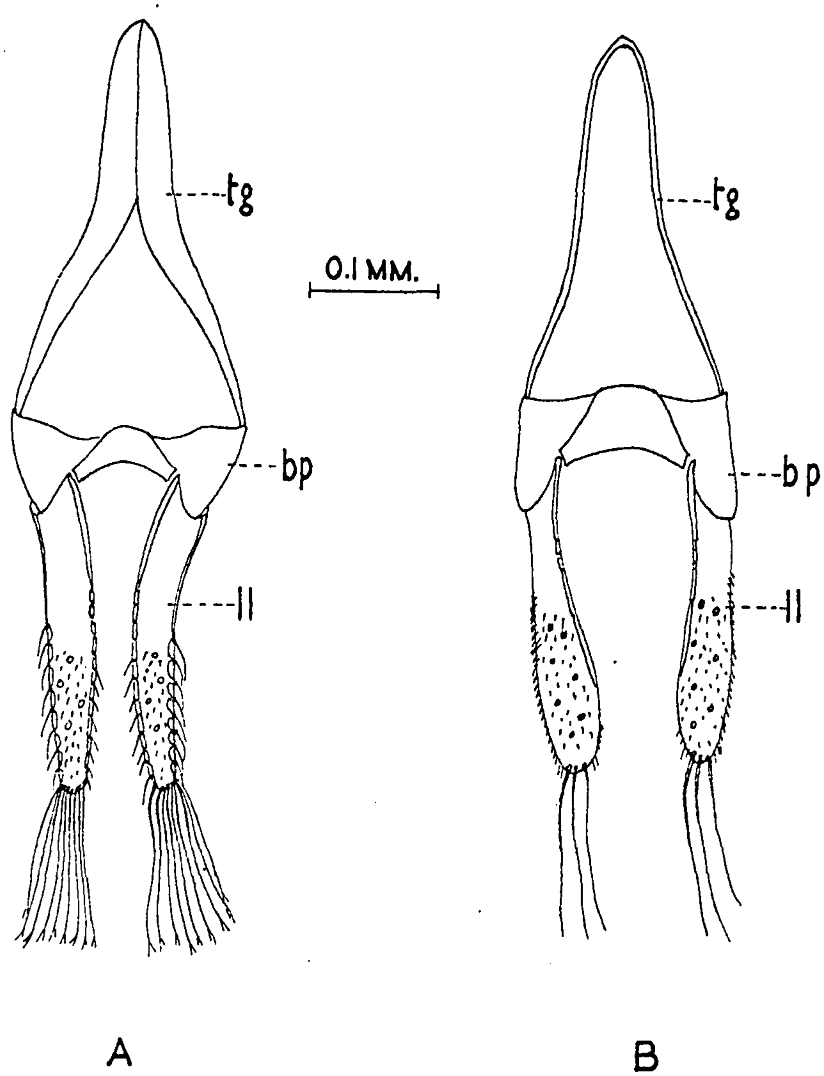



FIGURE 24

In *O.surinamensis*, the lateral lobes each bear 9 long branched setae at the distal end (Fig.24, A). In *O.mercator*, there are only 3 long and unbranched setae at the distal end of the lateral lobes (Fig.24,B). The setae on the outer sides of the lateral lobes of *O.surinamensis* are all longer than those of *O.mercator*. The surface of the lobes of both species is rough and covered with numerous small spines. The lobes in *O.surinamensis* are more parallel-sided than in *O.mercator*. The latter has them broad at the distal end.

The basal piece (bp) of *O.surinamensis* is more triangular in shape than that of *O.mercator* (Fig.24,A and B).

The median lobe (Fig.25, A and B) is long, tubular and rounded at the distal end. At the distal end is the median orifice (mo) through which the internal sac (is) is evaginated. The median orifice is bordered by chitinous rods (ct) of which there are about eight on each side in *O.surinamensis* (Fig.25,A), and about sixteen on each side in *O.mercator* (Fig.25,B).

The internal sac (is) (Figs.22 and 23) is long; about twice as long as the median lobe. In *O.surinamensis* the internal sac bears a saw-toothed structure internally (Fig.22), whereas in *O.mercator* there is no definite saw-toothed structure inside it (Fig.23).

Fig.25 Male genitalia of A, O.surinamensis and B, O.mercator: median lobe. ct, chitinous rods; mo, median orifice.

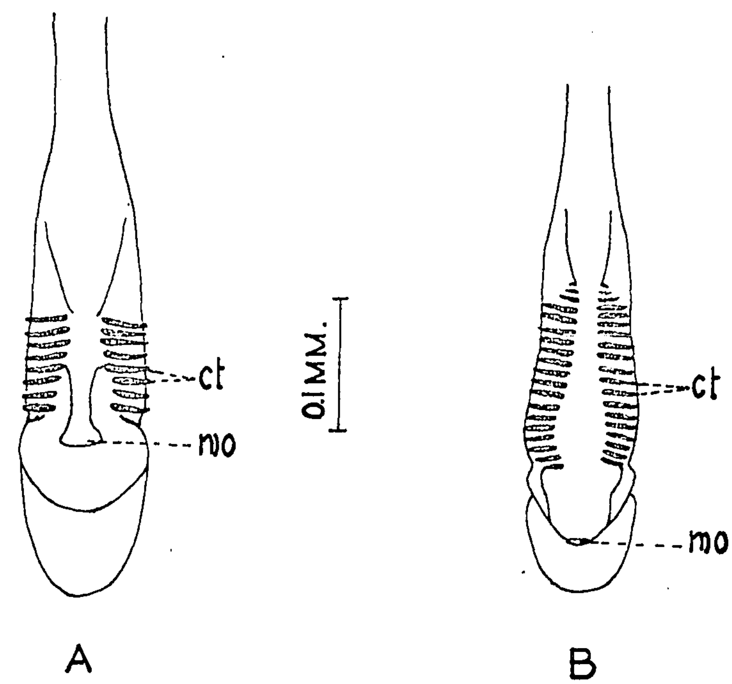



FIGURE 25

Protruding from the basal part of the median lobe is a median strut (ms) (Figs.22 and 23). The base of the median strut of O.mercator (Fig.26,B) is broader than that of O.surinamensis (Fig.26,A.)

The spiculum (sp) (Fig.27,A and B) is a thin sclerotized structure shaped like an inverted "Y" and is placed between the lateral lobes. This structure is omitted in Figs. 22 and 23. No specific differences have been found in this part.

The eighth sternite of O.surinamensis has four setae on each side near the lateral margin of its posterior edge (Fig.27,A), whereas there are only three in O.mercator (Fig.27,B).

A summary of some distinguishing features of the male genitalia is as follows:

| Character | O.surinamensis | O.mercator |
|---|---|---|
| Sternite 8 | Four setae on each side along posterior edge | Three setae only on each side along posterior edge |
| Lateral lobes | Parallel-sided About nine long branched setae at the tip and several shorter setae along the outer margin | Broadest at the distal part. Three unbranched setae at the tip only |
| Median orifice | About eight chitinous rods | About sixteen chitinous rods |
| Internal sac | Bearing a saw-toothed structure internally | No definite saw-toothed structure inside it |

Fig.26 Median strut from male genitalia of A, O.*surinamensis* and B, O.*mercator*.

Fig.27 Male genitalia of A, O.*surinamensis* and B, O.*mercator*: abdominal sternite eight and nine. sp, spiculum, $st_8$, eighth sternite; $st_9$, ninth sternite.

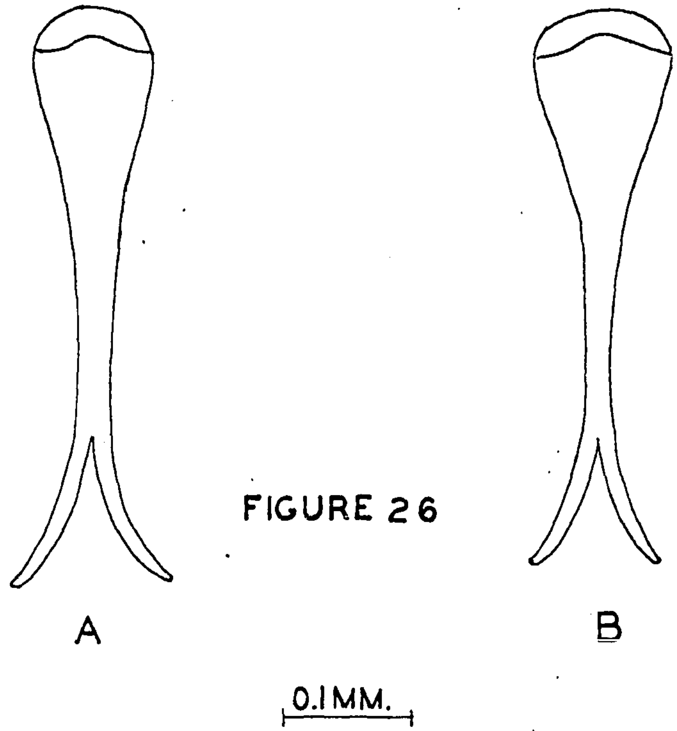



FIGURE 26

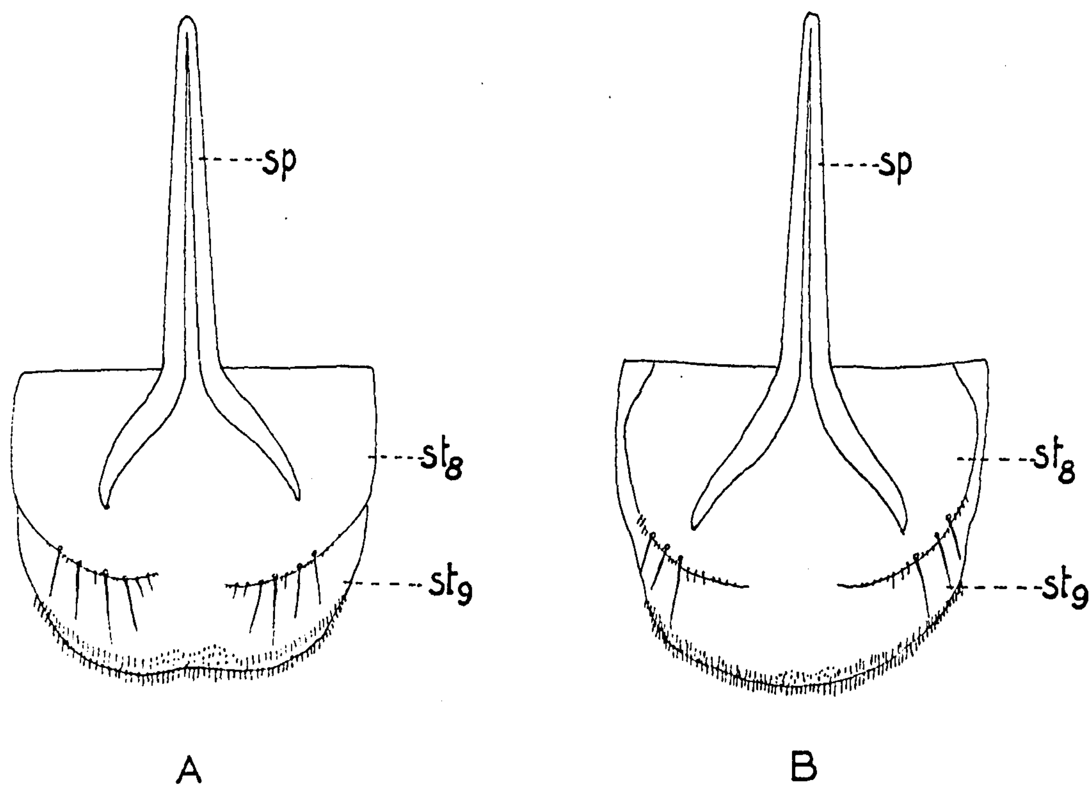
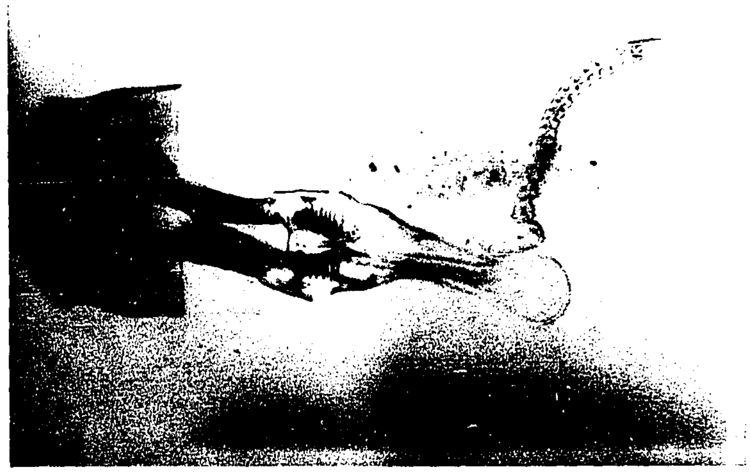



FIGURE 27

Plate V Male genitalia of *O. surinamensis* (x 95)

Plate VI Male genitalia of *O. mercator* (x 95)



## B. OVIPOSITION AND NUMBER OF EGGS

At a temperature of 32.5° C. and 75 to 80% R.H., the eggs were laid singly or in small clusters in the food supplied. Muslin used to cover the vials was also found to provide a suitable surface for the females to thrust their ovipositors into, and deposit their eggs through the mesh.

The preoviposition period ranged from 1 to 10 days in O.surinamensis and from 1 to 18 days in O. mercator, the average of 14 females of each species being about 6 and 5 days respectively. The average length of the preoviposition period is shown in Table VII.

The oviposition period lasted over 3 months for O.surinamensis and over 4 months for O.mercator. The average length of the oviposition period of both species is shown in Table VIII.

The results of oviposition rate studies are summarized in Fig.28. As indicated in Fig.28, O.surinamensis reached a peak of approximately 6 eggs, per female, per day, and O.mercator of 3 eggs, per female, per day. The rate of egg-laying of both species rapidly reached the maximum in about 4 weeks and after that the rate fell off gradually. Oviposition by O.surinamensis fell off more rapidly than O.mercator.

Table VII Average length of preoviposition period of O.surinamensis and O.mercator fed on Surtees' diet* at 32.5° C. and 75-80% R.H.

| Species | No.of individuals | Average (Days) | Range (Days) |
|---|---|---|---|
| O.surinamensis | 14 | 6 | 1-10 |
| O.mercator | 14 | 5 | 1-18 |

* - A diet of wheatfeed, rolled oats and dried yeast powder (4:4:1).

Table VIII Average length of oviposition period of O.surinamensis and O.mercator fed on Surtees' diet at 32.5° C and 75-80% R.H.

| Species | No. of individuals | Average (Days) | Range (Days) |
|---|---|---|---|
| O.surinamensis | 14 | 112 (3.74 months) | 72-156 |
| O.mercator | 14 | 124 (4.14 months) | 59-175 |

Fig.28 Oviposition rates of _O.surinamensis_ and _O.mercator_ fed on a diet of wheatfeed, rolled oats and dried yeast powder (4:4:1) at 32.5° C. and 75-80% R.H.

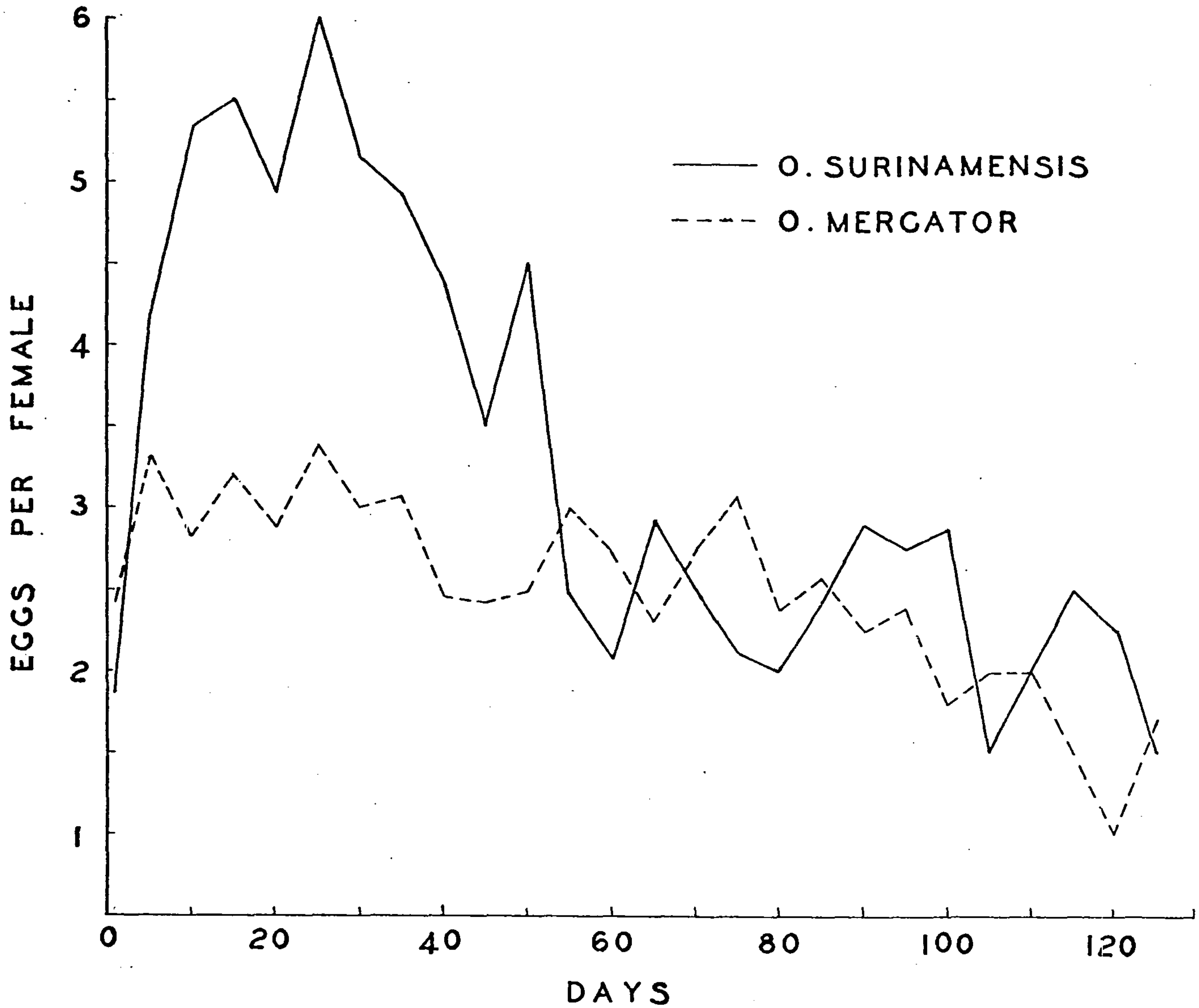

EGGS PER FEMALE
6
5
4
3
2
1
0
20
40
60
80
100
120
DAYS
O. SURINAMENSIS
O. MERGATOR

FIGURE 28

The average number of eggs laid by females of O.*surinamensis* was 334, ranging from 217 to 445 eggs. O.*mercator* laid an average of 285, ranging from 141 to 393 eggs. Egg-laying data for females of both species are summarized in Table IX. The average number of eggs obtained by Howe (1956) was about 375 for O. *surinamensis* and nearly 200 for O.*mercator*. Back and Cotton (1926) recorded 285 as the highest number of eggs laid by O.*surinamensis*.

Table IX Average number of eggs laid by *O.surinamensis* and *O.mercator* fed on Surtees' diet at 32.5° C. and 75-80% R.H.

| Species | No.of individuals | Average | Range |
|---|---|---|---|
| *O.surinamensis* | 14 | 334 | 217-445 |
| *O.mercator* | 14 | 285 | 141-393 |

## C. NUMBER OF INSTARS

Under a range of conditions of temperature and food, the number of larval moults of _O.surinamensis_ varied from 2 to 4. The majority of the larvae observed moulted 3 times, some moulted only twice and a very few moulted 4 times. Most larvae of _O.mercator_ moulted 3 times, a few moulted 4 times and none moulted twice.

Observations on moulting for each instar were carried out by examining both the exuviae and the appearance of the larvae. When first formed the larvae of each instar in both species has a whitish colour with a flattened body, and exhibits characteristic slow and uncertain movements. The body soon becomes rounded, the colour turns to pale yellowish, and its activity increases both in degree and coordination. The above observations were supplemented by size comparisons, as there is an increase in size after each moult.

As indicated in Table X and XI, in the case of _O.surinamensis_, only 12 individuals out of 177 had 4 moults whereas 56 had 2 moults. In _O.mercator_, out of 147 individuals, 13 larvae had 4 moults and none had 2 moults.

These results have been found to coincide with those of Back and Cotton (1926) and those of Howe (1956).

Table X Number of larval moults of *O.surinamensis* and *O.mercator* fed on Surtees' diet and reared at different temperatures and at 75-80% R.H.

| Species | Temperature (°C) | Number observed | Number of larval moults | | |
|---|---|---|---|---|---|
| | | | 2 | 3 | 4 |
| *O.surinamensis* | 22.5 | 31 | 13 | 18 | - |
| | 27.5 | 40 | 30 | 10 | - |
| | 32.5 | 29 | 1 | 28 | - |
| | 37.5 | 23 | - | 19 | 4 |
| *O.mercator* | 22.5 | 28 | - | 28 | - |
| | 27.5 | 39 | - | 39 | - |
| | 32.5 | 22 | - | 13 | 9 |

Table XI Number of larval moults of *O.surinamensis* and *O.mercator* fed on different foods at 32.5° C. and 75-80% R.H.

| Species | Food | Number observed | Number of larval moults 2 | 3 | 4 |
|---|---|---|---|---|---|
| *O.surinamensis* | Rolled oats | 31 | 12 | 19 | - |
| | Surtees' diet | 29 | 1 | 28 | - |
| | Crushed groundnut | 23 | - | 15 | 8 |
| *O.mercator* | Rolled oats | 32 | - | 31 | 1 |
| | Surtees' diet | 22 | - | 13 | 9 |
| | Crushed groundnut | 26 | - | 23 | 3 |

Back and Cotton stated that most larvae of O.surinamensis moulted 3 times, quite a number moulted twice and a few moulted 4 times. The number of larval moults for O.surinamensis obtained by Howe varied from 2 to 4, the usual number was 3 but a few individuals had 4 or 2. In O.mercator, Howe found that most larvae had 3 moults, a few had 4 but none had 2 moults.

## D. DEVELOPMENTAL STUDIES

### 1. The effect of temperatures on development

#### a. Eggs

Eggs of both species hatched at all temperatures from 17.5 to 37.5° C. Although some eggs hatched at 17.5° C., neither *O. surinamensis* nor *O. mercator* completed larval development at this temperature.

As shown in Table XII, egg mortality was highest for *O. surinamensis* at a temperature of 37.5° C. and for *O. mercator* at 17.5° C., the mortality 39.65 and 53.85 per cent respectively. Egg mortality of *O. mercator* was higher than that of *O. surinamensis* at all temperatures. The lowest mortality for the eggs of *O. surinamensis* was 4.44 per cent, and that for those of *O. mercator* was 11.11 per cent, both at 27.5° C.

The duration of the egg stage of both species varies with temperature. The incubation period data for eggs of *O. surinamensis* and *O. mercator* are summarized in Table XIII. As indicated in Table XIII, the shortest incubation period for *O. mercator* was at 32.5° C., the average being 2.73 and 3.45 days for male and female respectively. *O. surinamensis* had the shortest incubation period at 37.5° C. At a temperature of 22.5° C. more than 7 days were required for *O. mercator* eggs to hatch, whereas

Table XII Per cent mortality of the egg, larval and pupal stages of *O.surinamensis* and *O.mercator* fed on Surtees' diet at different temperatures and at 75-80% R.H.

| Species | Temperature (°C.) | Egg mortality | Larval mortality | Pupal mortality |
|---|---|---|---|---|
| *O.surinamensis* | 17.5 | 20.59 | 100* | - |
| | 22.5 | 20.51 | 0 | 0 |
| | 27.5 | 4.44 | 6.98 | 0 |
| | 32.5 | 8.33 | 12.12 | 0 |
| | 37.5 | 39.65 | 22.86 | 14.81 |
| *O.mercator* | 17.5 | 53.85 | 100* | - |
| | 22.5 | 28.57 | 6.67 | 0 |
| | 27.5 | 11.11 | 2.50 | 0 |
| | 32.5 | 18.92 | 26.67 | 0 |
| | 37.5 | 48.00 | 100** | - |

* - All died in less than a few days after hatching.

** - All failed to develop, 9 died after eclosion, 3 died after first moult, 1 died after fourth moult.

Table XIII Incubation period of eggs of *O. surinamensis* and *O. mercator* at different temperatures.

| Species | Temperature (°C.) | Number observed | | Average incubation period in days | | Range in days | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | Male | Female |
| *O. surinamensis* | 22.5 | 16 | 15 | 7.12 | 6.73 | 6-8 | 5-8 |
| | 27.5 | 19 | 21 | 4.47 | 4.48 | 4-5 | 4-5 |
| | 32.5 | 10 | 19 | 3.00 | 3.63 | 2-4 | 2-5 |
| | 37.5 | 11 | 12 | 3.00 | 3.00 | - | - |
| *O. mercator* | 22.5 | 14 | 14 | 7.64 | 7.36 | 6-9 | 5-9 |
| | 27.5 | 20 | 19 | 4.85 | 4.68 | 3-6 | 3-6 |
| | 32.5 | 11 | 11 | 2.73 | 3.45 | 2-3 | 3-4 |

about 7 days were required for O.surinamensis eggs. It can be seen that egg development for both species is more rapid at a higher temperature.

b. Larval development

Larvae of both species failed to develop at a temperature of 17.5° C. There was no larval mortality of O.surinamensis at 22.5° C. The lowest mortality of larvae of O.mercator was at 27.5° C. At 37.5° C, larvae of O.surinamensis completed development although mortality was high, whereas larvae of O.mercator failed to develop at this temperature (Table XII).

The duration of the larval stage varies with temperature. Data for the larval period of both species are summarized in Table XIV. Larval development of O. surinamensis was quickest at 32.5° C., whereas that of O.mercator was fastest at 27.5° C.

c. Pupal development

Since the larvae of O.mercator failed to develop at 37.5° C., no pupae were produced at this temperature. No pupal mortality of O.surinamensis was recorded at temperatures of 22.5, 27.5 and 32.5° C., but 14.81 per cent died at 37.5° C. (Table XII).

Duration of the pupal period of both species is shown in Table XV. The rate of pupal development of

Table XIV Duration of the larval period of <u>O.surinamensis</u> and <u>O.mercator</u> fed on Surtees' diet at different temperatures and at 75-80% R.H.

| Species | Temperature (°C.) | Number observed | | Average larval period in days | | Range in days | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | Male | Female |
| O.surinamensis | 22.5 | 16 | 15 | 24.37 | 25.13 | 22-30 | 21-28 |
| | 27.5 | 19 | 21 | 14.21 | 15.00 | 14-16 | 14-18 |
| | 32.5 | 10 | 19 | 13.30 | 13.79 | 13-14 | 13-16 |
| | 37.5 | 11 | 12 | 15.27 | 17.25 | 13-17 | 14-21 |
| O.mercator | 22.5 | 14 | 14 | 33.50 | 32.71 | 30-37 | 29-37 |
| | 27.5 | 20 | 19 | 19.10 | 19.26 | 18-20 | 17-23 |
| | 32.5 | 11 | 11 | 19.91 | 19.09 | 16-26 | 17-25 |

Table XV  Duration of the pupal period of *O.surinamensis* and *O.mercator* at different temperatures.

| Species | Temperature (°C.) | Number observed | | Average pupation period in days | | Range in days | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | Male | Female |
| *O.surinamensis* | 22.5 | 16 | 15 | 11.06 | 11.27 | 10-12 | 11-12 |
| | 27.5 | 19 | 21 | 6.89 | 6.80 | 6-7 | 6-7 |
| | 32.5 | 10 | 19 | 4.40 | 4.37 | 4-5 | 4-5 |
| | 37.5 | 11 | 12 | 4.64 | 4.42 | 4-5 | 4-5 |
| *O.mercator* | 22.5 | 14 | 14 | 11.00 | 10.86 | 10-12 | 10-12 |
| | 27.5 | 20 | 19 | 6.25 | 6.47 | 5-7 | 5-7 |
| | 32.5 | 11 | 11 | 4.64 | 4.54 | 4-5 | 4-5 |

both species varies with temperature. The minimum development period was at 32.5° C. for both species, being 4.40 days for male and 4.37 days for female O.surinamensis, and 4.64 and 4.54 days for male and female O.mercator respectively. The maximum period for both species was at 22.5° C., being a mean of 11.06 and 11.27 days for male and female O.surinamensis, and 11.00 and 10.86 days for male and female O.mercator respectively.

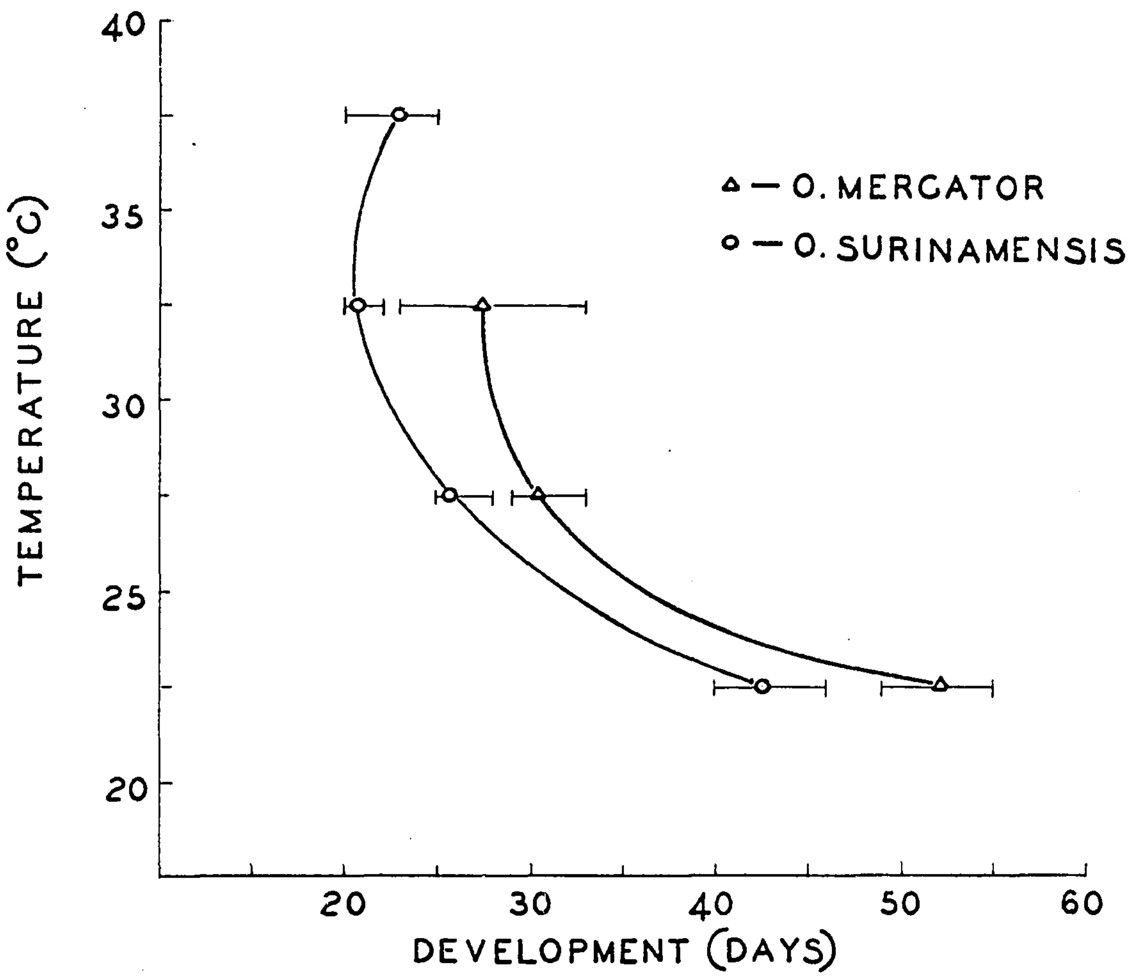
d. Total developmental period

The total developmental period of the two species for male and female is compared in Figs. 29 and 30 respectively.

The shortest mean total developmental period observed for both species was at 32.5° C., being 20.70 and 21.79 days for male and female O.surinamensis and 27.27 and 27.09 days for male and female O.mercator respectively. The longest mean total developmental period was 42.56 days for male and 43.13 days for female O.surinamensis , and 52.14 and 50.93 days for male and female O.mercator respectively, both species being kept at 22.5° C.

It is clear that O.mercator is more sensitive than O.surinamensis to temperature conditions. The comparison of the two species with respect to the time required for development from egg to adult shows O.surinamensis to be considerably faster than O.mercator in its

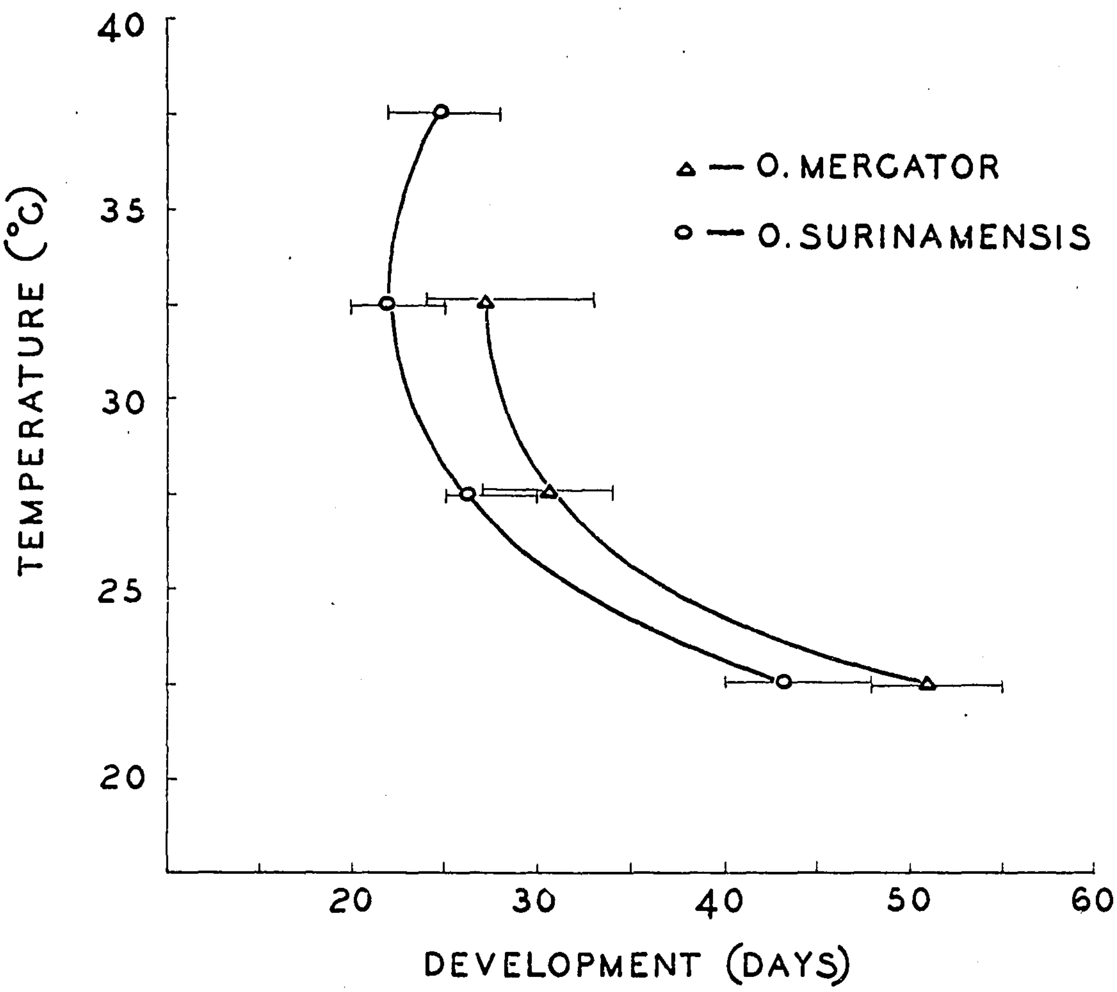
Fig.29 Comparison of the total developmental periods at different temperatures for the male of O.surinamensis and O.mercator fed on a diet of wheatfeed, rolled oats and dried yeast powder (4:4:1) at 75-80% R.H.



40
35
30
25
20
TEMPERATURE (°C)
△ — O. MERCATOR
○ — O. SURINAMENSIS
20
30
40
50
60
DEVELOPMENT (DAYS)


FIGURE 29

Fig.30 Comparison of the total developmental periods at different temperatures for the female of _O.surinamensis_ and _O. mercator_ fed on a diet of wheatfeed, rolled oats and dried yeast powder (4:4:1) at 75-80% R.H.



TEMPERATURE (°C)
40
35
30
25
20
△ — O. MERCATOR
○ — O. SURINAMENSIS
20
30
40
50
60
DEVELOPMENT (DAYS)


FIGURE 30

development. The effect of temperature was similar for both species, the longest development period being obtained at the lowest temperature used. Both had an optimum temperature of 32.5° C., as the mortality was not high and the shortest mean total development period occurred at this temperature. There was no definite differences between male and female of each species as to temperature response.

2. Development on different foodstuffs

a. Larval development

As shown in Table XVI, larval mortality of O.surinamensis was high on crushed groundnut as food, being 50.98%, whereas only 13.89% was obtained from O.mercator. The lowest larval mortality of both species occurred on rolled oats, being 6.06% for O.surinamensis and 5.71% for O.mercator.

The length of the larval period is affected by diet. Duration of the larval period of both species on various foodstuffs is shown in Table XVII. Larval development of both species was quickest on rolled oats. On crushed groundnut, the rate of larval development of O.surinamensis was found to be much slower than that of O.mercator. On the basis of the rate of development and

Table XVI Per cent mortality of the larval and pupal stages of *O.surinamensis* and *O.mercator* fed on different foods and reared at 32.5° C. and 75-80% R.H.

| Species | Food | Larval mortality | Pupal mortality | Adult died just after emergence % |
|---|---|---|---|---|
| *O.surinamensis* | Rolled oats | 6.06 | 0 | 0 |
| | Surtees' diet | 12.12 | 0 | 0 |
| | Crushed groundnut | 50.98 | 8 | 34.78 |
| *O.mercator* | Rolled oats | 5.71 | 3.03 | 0 |
| | Surtees' diet | 26.67 | 0 | 0 |
| | Crushed groundnut | 13.89 | 16.13 | 15.38 |

Table XVII Duration of the larval period of O.surinamensis and O.mercator fed on different foods and reared at 32.5° C. and 75-80% R.H.

| Species | Food | Number observed | | Average larval period in days | | Range in days | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | Male | Female |
| O.surinamensis | Rolled oats | 17 | 14 | 12.06 | 12.28 | 10-15 | 10-16 |
| | Surtees' diet | 10 | 19 | 13.30 | 13.79 | 13-14 | 13-16 |
| | Crushed groundnut | 11 | 12 | 26.45 | 25.25 | 19-33 | 19-32 |
| O.mercator | Rolled oats | 16 | 16 | 15.37 | 14.56 | 13-21 | 13-17 |
| | Surtees' diet | 11 | 11 | 19.91 | 19.09 | 16-26 | 17-25 |
| | Crushed groundnut | 12 | 14 | 18.75 | 19.07 | 16-23 | 14-22 |

larval mortality, rolled oats is superior to either Surtees' diet or crushed groundnut as food for these two species.

b. Pupal development

Diet has little effect on the length of the pupal period to both species. Duration period data for pupae of both species are summarized in Table XVIII. Pupal mortality, however, was found to be influenced by diet. When larvae were fed on crushed groundnut, 8% of O.surinamensis and 16.13% of O.mercator pupae died. When the diet was rolled oats, the pupal mortalities were 3.03% and 0% for O.mercator and O.surinamensis respectively. When the crushed groundnut diet was used, 34.78% of O.surinamensis adults died within a few days of adult emergence. Under the same conditions the per cent mortality in O.mercator was 15.38 (Table XVI). These figures would also indicate the superiority of rolled oats as a diet.

c. Total developmental period

Since foods have little or no effect on the rate of the development of the pupae and egg, the rate of development on various foods for the entire period from egg to adult is correlated with that of the larva. The total development period data for both species are

Table XVIII Duration of the pupal period of O.surinamensis and O.mercator fed on different foods at 32.5° C. and 75-80% R.H.

| Species | Food | Number observed | | Average pupation period in days | | Range in days | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | Male | Female |
| O.surinamensis | Rolled oats | 17 | 14 | 4.47 | 4.57 | 4-5 | 4-5 |
| | Surtees' diet | 10 | 19 | 4.40 | 4.37 | 4-5 | 4-5 |
| | Crushed groundnut | 11 | 12 | 5.18 | 5.42 | 5-6 | 5-6 |
| O.mercator | Rolled oats | 16 | 16 | 4.31 | 4.44 | 4-5 | 4-5 |
| | Surtees' diet | 11 | 11 | 4.64 | 4.54 | 4-5 | 4-5 |
| | Crushed ground-nut | 12 | 14 | 4.33 | 4.43 | 3-5 | 4-5 |

summarized in Table XIX. For both species, the total development period was quickest on rolled oats. On crushed groundnut *O.surinamensis* required the longer period to complete development. The longer time required to complete the life-cycle by *O.surinamensis* on crushed groundnut is probably due to food preference. *O.mercator* is principally associated with oilseeds, whereas *O.surinamensis* is associated with cereals (Howe,1956).

Table XIX The total developmental period of <u>O.surinamensis</u> and <u>O.mercator</u> fed on different foods at 32.5° C. and 75-80% R.H.

| Species | Food | Number observed | | Average in days | | Range in days | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | Male | Female | Male | Female |
| O.surinamensis | Rolled oats | 17 | 14 | 19.65 | 19.93 | 17-22 | 18-23 |
| | Surtees' diet | 10 | 19 | 20.70 | 21.79 | 20-22 | 20-25 |
| | Crushed groundnut | 11 | 12 | 34.90 | 33.67 | 28-41 | 27-40 |
| O.mercator | Rolled oats | 16 | 16 | 23.00 | 22.31 | 20-28 | 20-24 |
| | Surtees' diet | 11 | 11 | 27.27 | 27.09 | 23-33 | 24-33 |
| | Crushed groundnut | 12 | 14 | 26.50 | 26.57 | 24-30 | 21-30 |

## E. COLD HARDINESS OF ADULTS

The mortality of O.surinamensis and O.mercator was expressed both as a per cent and as a probit. The former was transformed to the latter by reference to the appropriate table from Finney (1947).

The results are summarized in Figs. 31-34. Fig. 31 shows the mortality-rate of O.surinamensis, in per cent, plotted against duration of exposure; Fig.32 shows the 50 per cent mortality plotted as probits. Figs. 33 and 34 show the same data for O.mercator.

There was a wide difference between the two species in the effect of low temperature on their adult stages. Adults of O.surinamensis were found to be much more resistant to low temperature than that of O.mercator. As shown in Fig.32, the exposure period necessary to kill 50 per cent of the adults of O.surinamensis was 14.35 days, whereas an exposure of only 1.7 days was required to kill 50 per cent of adults of O.mercator (Fig.34). These re-results confirm that O.surinamensis is cold hardy and O. mercator is not.

Fig.31 Sigmoid curve showing the mortality-rate for adults of <u>O.surinamensis</u> exposed to 2° C.

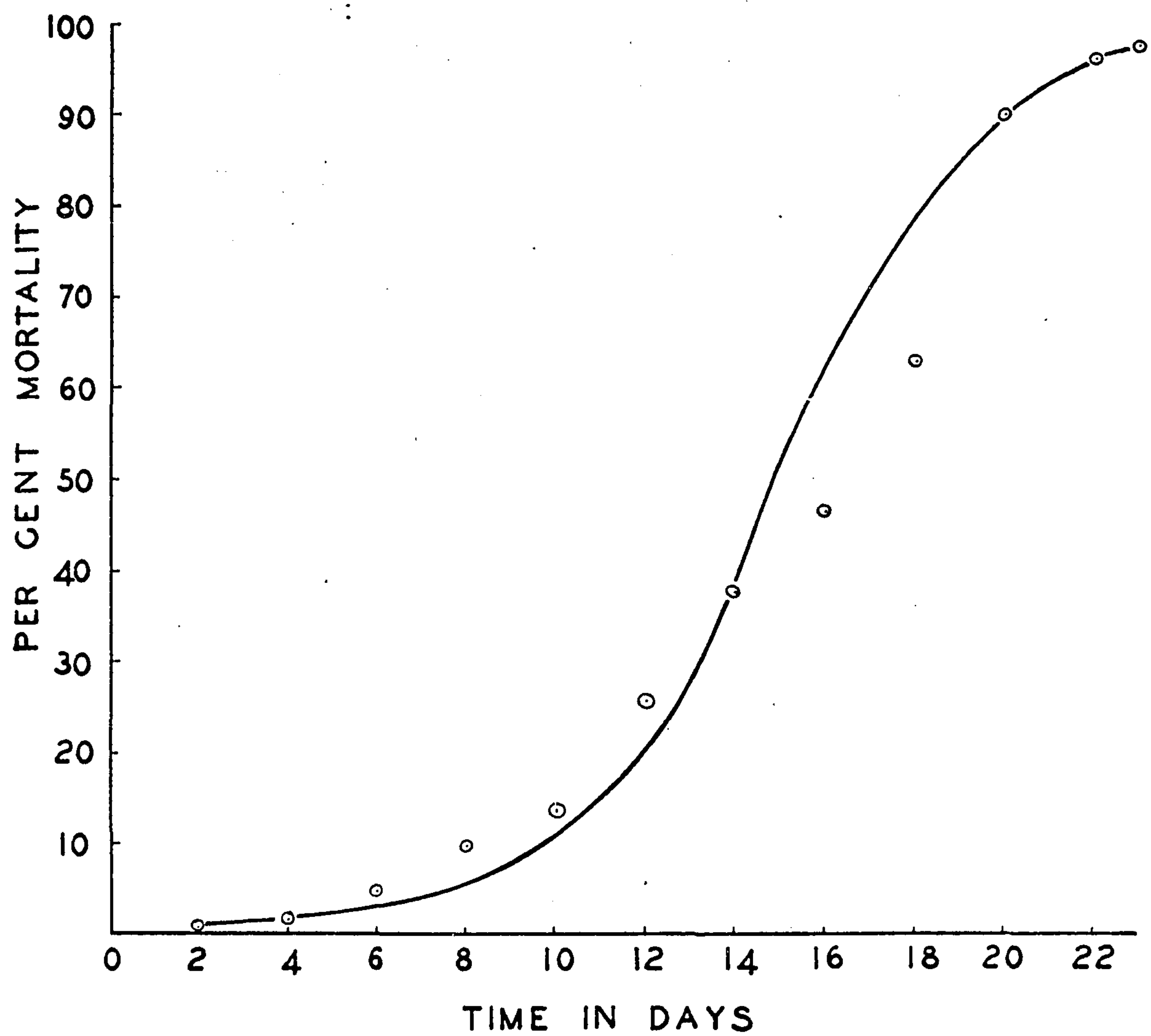

100
90
80
70
60
50
40
30
20
10
PER CENT MORTALITY
0
2
4
6
8
10
12
14
16
18
20
22
TIME IN DAYS

FIGURE 31

Fig.32 Probit regression line showing 50 per cent mortality for adults of <u>O.surinamensis</u> exposed to 2° C.

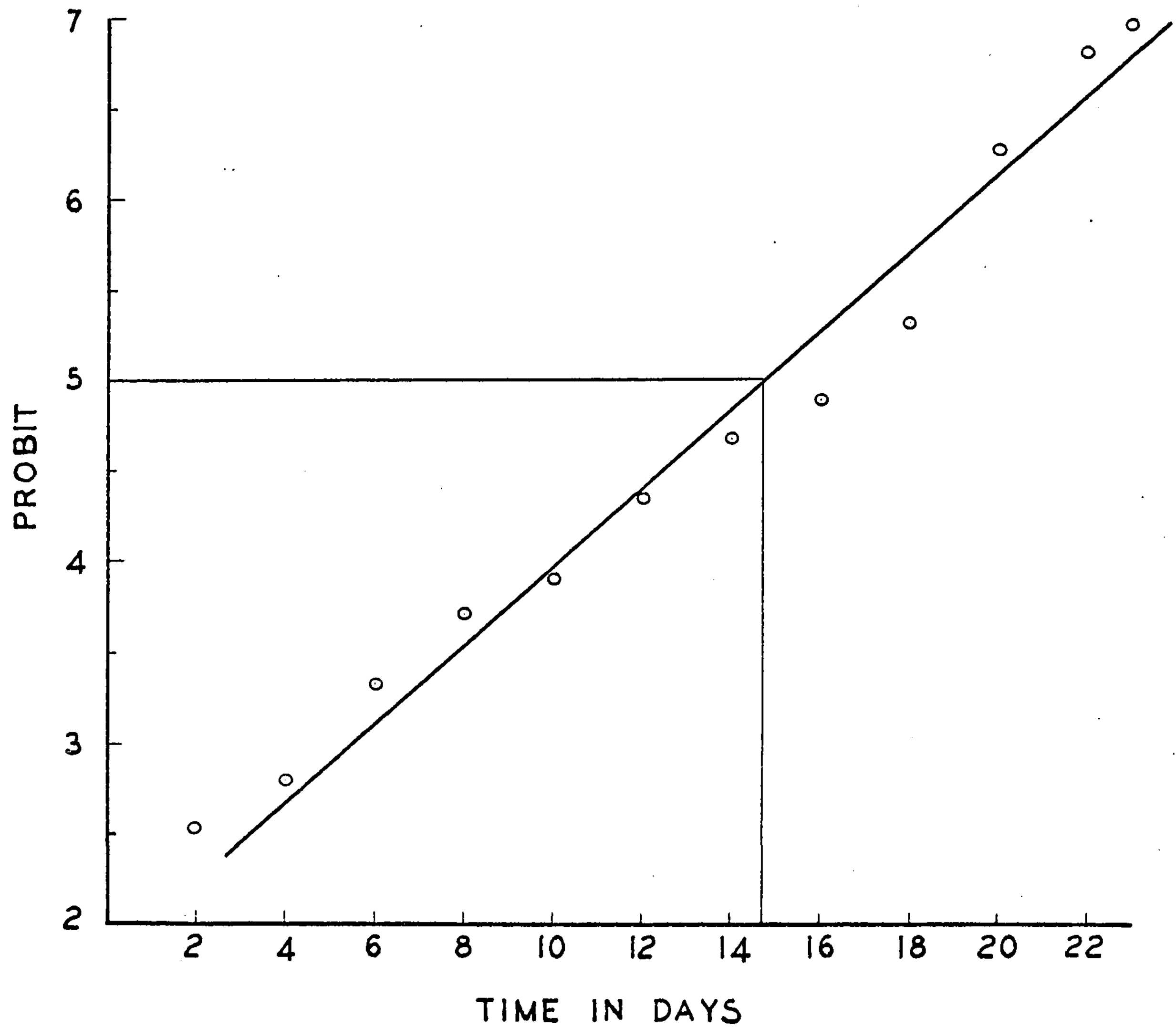



FIGURE 32

Fig.33 Sigmoid curve showing the mortality-rate for adults of O.*mercator* exposed to 2° C.

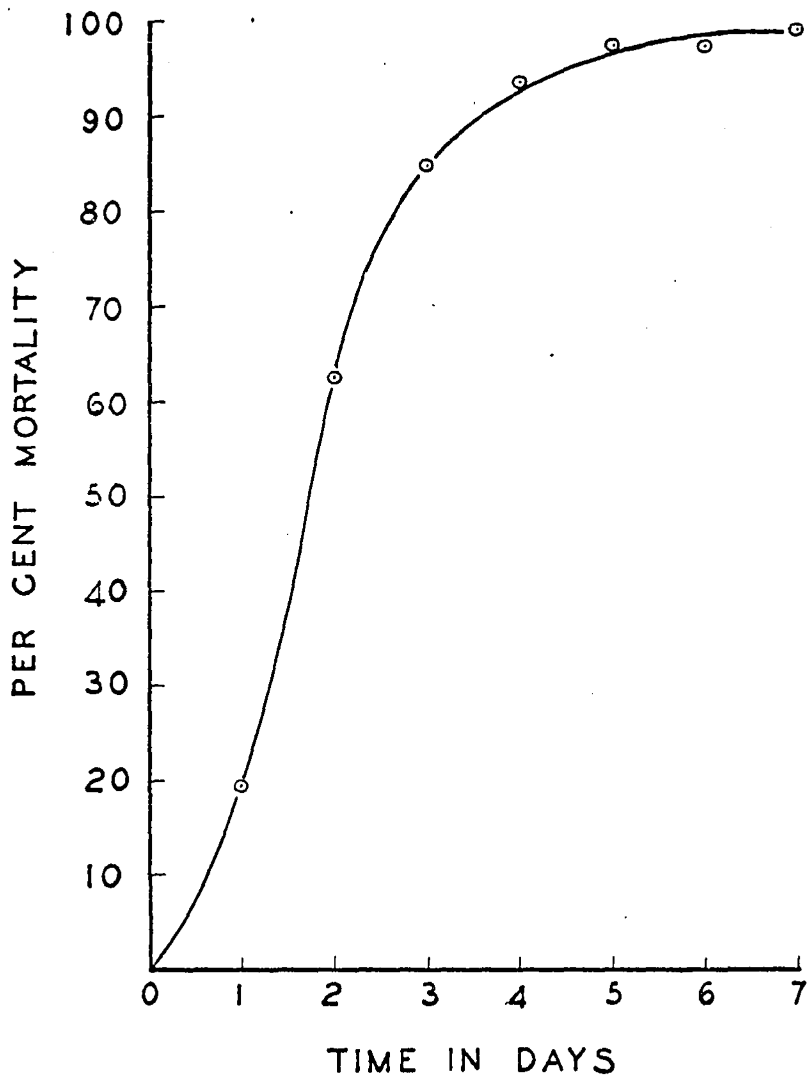

PER CENT MORTALITY
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
TIME IN DAYS

FIGURE 33

Fig.34 Probit regression line showing 50 per cent mortality for adults of _O.mercator_ exposed to 2° C.

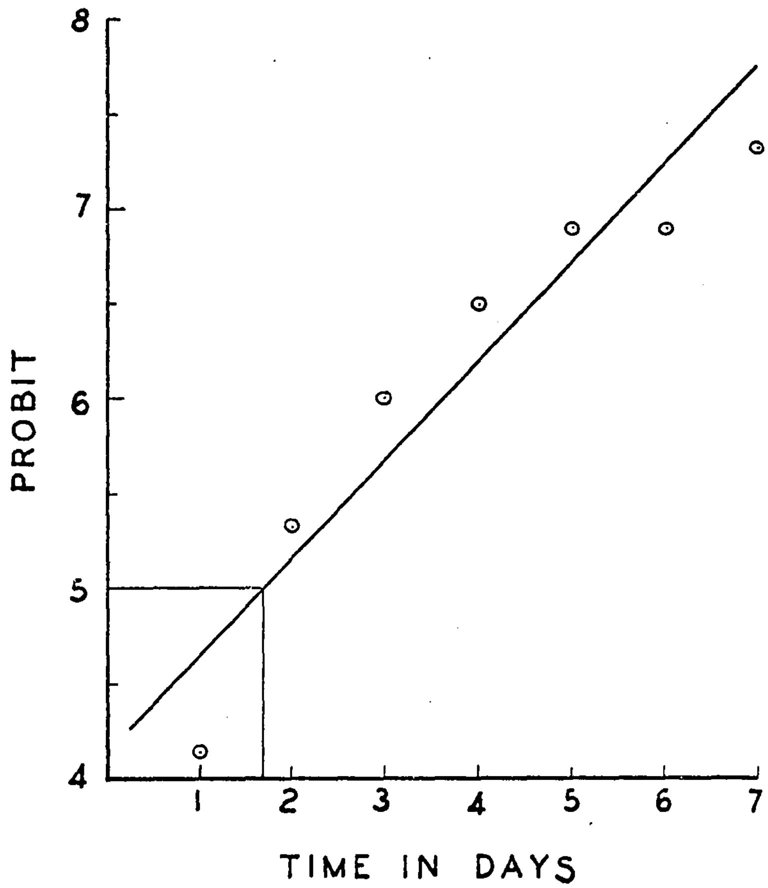



FIGURE 34

## V. CONCLUSION

The work reported here confirms the great morphological similarities between *Oryzaephilus surinamensis* and *O.mercator*. The eggs as well as the pupae are so similar morphologically that it is not possible to distinguish between the two species. However, the larvae of the specimens examined have distinct differences in chaetotaxy which allow them to be distinguished.

The adults are more readily separated by both body measurements and by differences in the male genitalia. These distinct differences confirm that *O.mercator* is a good species and not merely a variety of *O.surinamensis*.

From developmental studies, it is concluded that *O.mercator* is more sensitive than *O.surinamensis* to temperature conditions. The comparison of the two species with respect to development time from egg to adult shows *O.surinamensis* to be considerably faster than *O.mercator* at the same temperature.

*O.surinamensis* can be expected to multiply much more quickly than *O.mercator* when both are fed on a cereal foodstuff. On oilseed, i.e. crushed groundnut, the reverse is true. This may be the reason for the observed occurrence of *O.mercator* principally on oilseeds and *O. surinamensis* on cereals (Howe,1956).

In the adult stage, *O. surinamensis* shows much more resistance to low temperature than *O. mercator*. The principal reason for this difference is probably that the adults of *O. surinamensis* are more cold hardy than those of *O. mercator*.

In conclusion, therefore, it may be stated that *O. surinamensis* and *O. mercator* are distinct species. They can be readily distinguished by the relative lengths of eye and temple, by the male genitalia, and by the differences in their biology.

## VI. SUMMARY

The sizes and morphological characters of the immature stages have little or no taxonomic value; but the length of setae on the dorsum of the meso and metathorax of the larvae may be used in the identification of the two species of *Oryzaephilus*.

The eggs as well as the pupae cannot be separated.

It is not possible to determine the sex of the immature stages.

The usual number of larval moults before pupation for *O.surinamensis* is three, but a few individuals have four or two. Most larvae of *O.mercator* have three moults, a few have four but none have two moults.

The oviposition period of both species is quite long, lasting over three months for *O.surinamensis* and over four months for *O.mercator* when both are fed on Surtees' diet at 32.5° C. and 75-80% R.H.

*O.surinamensis* reaches a peak of 6 eggs laid per female per day and *O.mercator* a peak of about 3 eggs laid per female per day. The number of eggs laid by *O.surinamensis* is about 334 per female. *O.mercator* lays an average of 285 eggs. Both species reach the maximum rate of egg-laying in about 4 weeks, after that

the rate falls off gradually. O.surinamensis oviposition falls off more rapidly than O.mercator.

Adults of both species may be conveniently sexed by observing the spines on the trochanter and femur of the metathoracic leg in the male. These spines are absent in the female.

The size ratio of the lengths of the eye and temple between the two species is significantly different. In O.surinamensis, the length of the eyes is about one and a half times the length of temples, whereas the eye length is about four times temple length in O.mercator. This serves as an excellent character for distinguishing the two species.

Differences in the male genitalia between the two species can be readily observed. A brief summary of some distinguishing features of the male genitalia is as follows. The lateral lobes of O. surinamensis bear about nine long branched setae at the distal end and several shorter setae along the outer margin, whereas there are only three long unbranched setae at the tip in O.mercator. The shape of the lobes in O.surinamensis is more parallel-sided than that of O.mercator. In O.surinamensis, the median orifice is bordered by about eight chitinous rods on each side while there are about sixteen in *O.mercator*. The internal sac of *O.surinamensis* bears a saw-toothed structure internally, whereas in *O.mercator* there is no definite structure inside it. The eighth sternite of *O.surinamensis* has four setae on each side along the posterior edge while there are only three in *O. mercator*.

The development rate of the two species under various conditions of temperature and food is different. At 75 to 80% R.H., eggs of both species hatch at all temperatures to which they are exposed from 17.5 to 37.5° C. Egg mortality of *O.surinamensis* is highest at 37.5° C. whereas that of *O.mercator* is highest at 17.5° C. Although some eggs hatch at 17.5° C., neither *O.surinamensis* nor *O.mercator* completes larval development at this temperature. Larvae of *O.mercator* fail to develop at 37.5° C.

On Surtees' diet as food and at 75 to 80% R.H., the total life-cycle from egg to adult of *O. surinamensis* requires 42.56 days (male) and 43.13 days (female) at 22.5° C.; 25.58 days (male) and 26.28 days (female) at 27.5° C.; 20.70 days (male) and 27.79 days (female) at 32.5° C; and 22.90 days (male) and 24.67

days (female) at 37.5° C.

Under the same conditions O.mercator requires 52.14 days (male) and 50.93 days (female) at 22.5° C.; 30.20 days (male) and 30.42 days (female) at 27.5° C.; and 27.27 days (male) and 27.09 days (female) at 32.5° C.

The development is more rapid at the higher temperatures. The optimum temperature for both species is 32.5° C. On Surtees' diet and at 75 to 80 R.H., the shortest mean total developmental period for both species is at 32.5° C. O.mercator develops more slowly than O. surinamensis at this temperature.

On crushed groundnut at 32.5° C. and 75 to 80% R.H., O.mercator is considerably faster than O. surinamensis in its development. Larval development for both species is quickest on rolled oats, O.mercator grows more slowly than O.surinamensis on this food.

When adults of both species are exposed to 2° C. and 50 to 55% R.H., 50 per cent of O.surinamensis are killed in 14.35 days while only 1.7 days is required for 50 per cent mortality in O.mercator.

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