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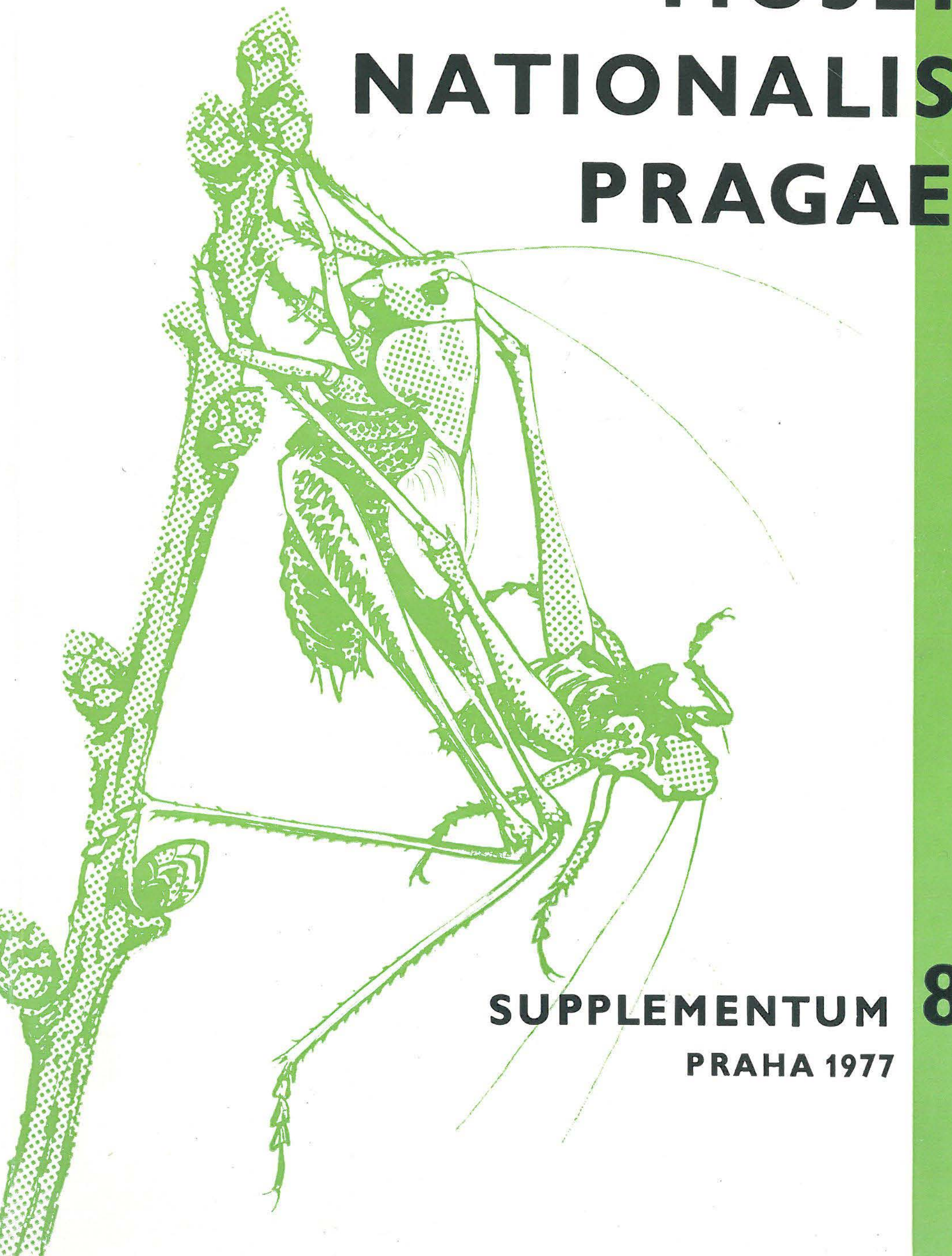

SUPPLEMENTUM 8
PRAHA 1977

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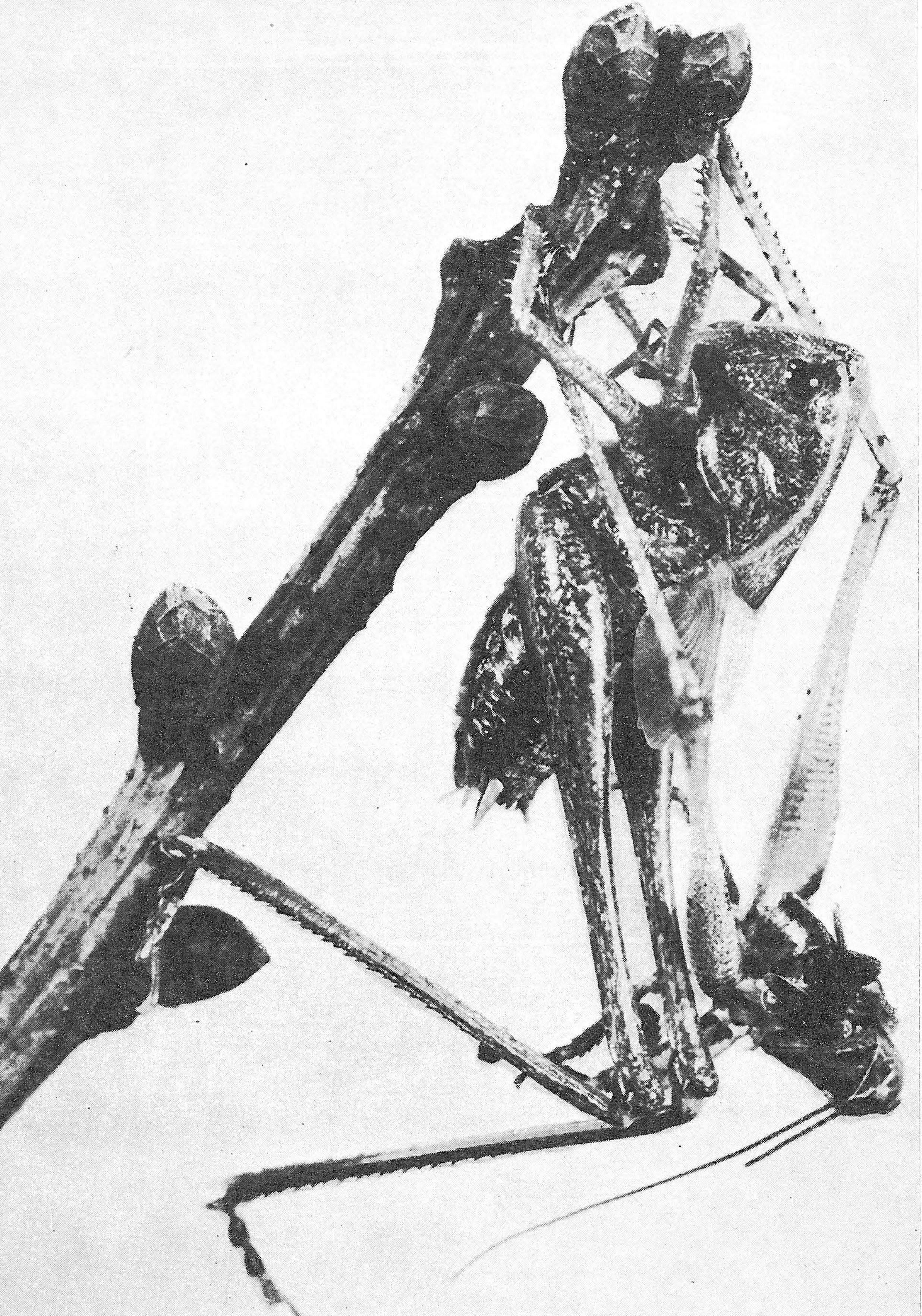

The postembryonic development of the bush crickets Tettigonia cantans (Fuessly), Decticus verrucivorus (L.) and Metrioptera brachyptera (L.) (Orthoptera: Tettigonioidea, Tettigoniidae)

By

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CONTENTS

I. Foreword and acknowledgements

Most of the present study was carried out and written in the Regional Museum at Hradec Králové and finished in the Entomology Department of the National Museum in Prague as a result of external postgraduate study at the Institute of Entomology of the Czechoslovak Academy of Sciences, supervised by V. Landa DSc. and Docent Dr. J. Mařan.

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II. Introduction

Three common species of bush crickets, *Tettigonia cantans* (Fuessly, 1775), *Decticus verrucivorus* (Linné, 1758) and *Metrioptera brachyptera* (Linné, 1761), whose postembryonic development had not yet been studied, were chosen for its investigation. The number of instars had been known in *Metrioptera brachyptera* only (Richards, 1958).

The main object of the present paper was to obtain basic bionomic information about the course of nymphal development, to determine, or rather verify, the number of instars in individual species, to ascertain their duration as well as the length of the whole nymphal life in the laboratory and in the field, and to concentrate on the moulting process, our knowledge of which in orthopteroid insects is incomplete and insufficient, particularly with representatives of the superfamily Tettigonioidea.

Another partial aim was to discover the course of growth in the individual bush cricket species during the postembryonic development. Growth was observed only from the second instar, because we did not succeed on rearing larvae from eggs (our cultures were set up with first instars collected in the field). The full duration of the first instars is not known.

It was necessary for practical reasons to classify individual instars of all three species according to their morphological characters, to describe them in detail, and to prepare original keys for their identification. The material for the morphological part of the present study was collected in the years 1957—1971, mostly in eastern Bohemia.

The papers, presenting classified bionomic-morphological information on the postembryonic development of the three bush crickets, obtained under almost constant laboratory conditions and supplemented, or confronted, with field observations, can serve as a basis for further ecological-physiological studies or other detailed research.

III. Survey of literature

Postembryonic development has only been studied in very few species of orthopteroid insects, mainly in some pests of the superfamily Acridoidea. The most detailed study of the postembryonic development in the suborder Acridomorpha has recently been published by Dirsh (1968). His paper includes an almost complete bibliography of the ontogeny of grasshoppers of the suborder Acridomorpha.

The postembryonic development of only a few species of bush crickets (Tettigonioidea) has been studied in detail. Most authors confined themselves to brief notes on the mechanism of moulting and to determination of the number of instars. About 800 genera of the Tettigonioidea, comprising over three thousand species, are known from all over the world. However, the number of instars is known in 33 species only. The postembryonic development of a mere 12 species of bush crickets has been closely examined.

Bekker (1932) studied the postembryonic development of *Tylopsis liliifolia* (Fabr.). He concentrated on the growth of the male subgenital plate and came to the conclusion that it was a part of the eighth abdominal tergite, secondarily of instars. The sexes of *T. liliifolia* can be distinguished by external morphological characters as early as in the first instar.

Bérenguier (1908 a) determined the number of instars in *Isophya pyrenea* Serv. Unfortunately, he included neither detailed morphological descriptions nor a key. Kalandadze and Tulashvili (1940) ascertained the number of instars in *Poecilimon geoktschaicus* Stshelk. Concise data on the number of instars in *Ephippiger bitterensis* (Marg.), *Tettigonia viridissima* L. and *Saga pedo* (Pall.), mostly without further references and other details, have been given by Chopard (1938) and Beier (1955). Stolyarov (1966) and Chetyrkina (1966) determined the number of instars in *Isophya redtenbacheri* Adel. and *I. taurica* Br.—W. and described their morphology. Dobosh (1969) discovered the number of instars in *Phaneroptera falcata* (Poda), briefly described individual instars and constructed a key for their identification. Achverdiev (1967) determined the number of instars in *Paradrymadusa viridipennis* Stshelk., *P. pastuchovi* Uv., *Isophya caspica stshelkanovtzevi* Mir. and *Euconocerus iris* B. — Bienko.

Richards (1958) wrote an interesting paper containing the results of his observation of nymphs of seven species of bush crickets of the families Tettigoniidae, Meconematidae, Conocephalidae and Phaneropteridae. He determined the number of moults in five species (*Metrioptera brachyptera, Platycleis denticulata, Leptophyes punctatissima, Tettigonia viridissima* and *Conocephalus dorsalis*) and thus also the number of instars. An approximate number of moults (6 or 7) has been given for another species, *Pholidoptera griseoaptera*. A survey of the most important morphological changes occurring after individual moults in five species of bush crickets has been given in Table I. A simple key enabling identification of the five species by their first instars has also been included (unfortunately, there are no keys to individual instars). Valuable are data on the morphology of the first instars of *Platycleis denticulata* and *Conocephalus dorsalis* immediately after hatching from eggs. The descriptions of nymphal development in individual species are incomplete and not very uniform; more details have been given only for *Platycleis denticulata* and *Conocephalus dorsalis*. Data on the duration of individual instars and on intervals between ecdyses are interesting. The author has also described the mechanism of moulting (in fact only the second ecdysial phase in my conception has been discussed — see the chapter on the moulting process). The last chapter contains brief descriptions of the properties of individual species and their food (some plants are listed on which feed the nymphs of *Pholidoptera griseoaptera, Platycleis denticulata* and *Leptophyes punctatissima*).

In the same year appeared a paper by Can (1958) containing data on the number of instars in three species of the genus *Isophya* Br.-W. (*I. amplipennis* Br.-W., *I. paveli* Br.-W. and *I. speciosa* Friv. = *tenuicerca* Ramme) and their morphological descriptions. In these species also can the sexes be distinguished in the first instar.

A more detailed paper on the postembryonic development and growth of *Metrioptera (Roeseliana) roeselii* (Hgb.) has been published by Čejchan (1960) who determined the number of instars, classified them by external morphological characters, prepared an original key to both sexes, observed the duration of individual instars, mechanism of moulting, growth during the nymphal life, and for the first time pointed out that the growth of the ovipositor proceeds almost in geometric progression. Mc E. Kevan, Le Roux and D'Ornellas (1962) studied the postembryonic development of the same species in Quebec, Canada.

As for studies on crickets (Grylloidea), two detailed papers on the postembryonic development of the house cricket, *Gryllus domesticus* (L.), and the common black field cricket, *Gryllus assimilis* (Fabr.), deserve special attention. Hrdý (1956), who studied the postembryonic development of the house cricket, stated 11 instars. The sexes can be distinguished by external morphological characters only in the fifth instar. A detailed study of the postembryonic development of the common black field cricket, *Gryllus assimilis* (Fabr.), has been published by Severin (1935). He determined the number of instars (9), described their morphology in detail, and determined the duration of individual instars as well as the total length of the nymphal development.

The postembryonic development of only a few species of Tettigonioidea has been studied. The number of instars is known in only 33 species of bush crickets; 27 of these occur in the Palaearctic region.

Nymphs of the superfamily Tettigonioidea have been found to undergo 5—9 instars differing in the body size, degree of wing development, shape and size of external genitalia, etc. The nymphs of later instars of brachypterous and especially apterous forms do not differ very much from the imago.

Species of the superfamily Tettigonioidea whose number of instars is known (after Ramsay, 1964; supplemented - !)

Family, species	♂	Sex not stated	♀	Author
Mecopodidae				
Sexava nubila (Stol)		5		Leefmans, 1927
Tettigoniidae				
Anabrus longipes Caudell	7		7	Criddle, 1926
Anabrus simplex Hald.	7		7	Cowan, 1929
Anabrus simplex Hald.		6		Criddle (unpublished)
Metrioptera brachyptera (L.)	6		6	Richards, 1958
Metrioptera roeselii (Hgb.)	6		6	Čejchan, 1957, 1960
Paradrymadusa viridipennis Stshelk.		6		Achverdiev, 1967 (!)
Paradrymadusa pastuchovi Uv.		6		Achverdiev, 1967 (!)
Paranabrus scabricollis (Thom.)		7		Melander Yothers, 1917
Pholidoptera femorata (Fieb.)	5		5	Chopard, 1920
Phol. griseoaptera (De Geer) (= *cinerea* Gmel.)		c. 6—7		Richards, 1958
Platycleis denticulata Panz.	7		7	Graber, 1868, Richards, 1958
Saga pedo (Pall.)		8—9		Bérenguier, 1908 b, Beier, 1955
Tettigonia viridissima (L.)		6—7		Beier, 1955, Chopard, 1958
Tettigonia viridissima (L.)	7		7	Richards, 1958
Meconematidae				
Meconema thalassinum De Geer (= *varium* Fabr.)		c. 5		Richards, 1958
Conocephalidae				
Conocephalus dorsalis (Latr.)	5		5	Richards, 1958
Conocephalus saltans (Scud.)		5		Criddle (unpublished)
Phaneropteridae				
Barbitistes berenguieri V. Mayet		5		Bérenguier, 1908 b
Eurycorypha (= *Myrmecophana*) *fallax* (Brun.)		6		Vosseler, 1908
Leptophyes punctatissima (Bosc.)		5		Bérenguier, 1908 b
Leptophyes punctatissima (Bosc.)	6		6	Richards, 1958
Orophus retinervis (Burm.)		4		Packard, 1897
Poecilimon geoktshaicus Stshelk.		7		Kalandadze, Tulashvili, 1940
Tylopsis liliifolia Fabr.		5		Bekker, 1932
Isophya pyrenea (Serv.)		5		Bérenguier, 1908 b
Isophya redtenbacheri Adel.		5		Stolyarov, 1966 (!)
Isophya taurica Br.-W.	5		5	Chetyrkina, 1966 (!)
Isophya caspica stshelkanovtzevi Mir.		5		Achverdiev, 1967 (!)
Isophya amplipennis Br.-W.	5		5	Can, 1958 (!)
Isophya paveli Br.-W.	5		5	Can, 1958 (!)
Isophya speciosa (Friv.) (= *tenuicerca* Rme.)	5		5	Can, 1958 (!)
Phaneroptera falcata Poda	6		6	Dobosh, 1969 (!)
Euconocercus iris B.-Bienko		5		Achverdiev, 1967 (!)
Ephippigeridae				
Ephippiger bitterensis Mar.		5		Bérenguier, 1908 b, Beier, 1955
Ephippiger terrestris Yersin		5		Bérenguier, 1908 b

The Palaearctic species of the family Phaneropteridae usually go through 5 to 6 instars, the family Tettigoniidae through 6—7 instars (Chopard's finding of 5 instars in Pholidoptera femorata seems to be doubtful). The instars of only a few species are known in other families.

The nymphs of crickets (superfamily Grylloidea) undergo 5—15 ecdyses during their postembryonic development (only 4 moults in *Brachytrypes membranaceus* [Drury]).

The greatest number of moults has been found in representatives of the family Gryllidae, the smallest in representatives of the family Oecanthidae (only 5 in all species known so far).

On the average 5—6 moults have been ascertained in nymphs of the superfamily Acridoidea (only 4 in some small species, but 7—8 ecdyses in some large tropical species). Patanga succincta (L.) is known to have as many as 9 instars (Ramsay, 1964).

IV. Material and methods

a) Material

Nymphs for the laboratory culture were collected in the years 1970—1971 at the following localities in northeastern Bohemia:

Tettigonia cantans — 23. 5. 1970, Pavlišov near Náchod (Ist instar nymphs), 28. 5. 1970, Zdobnice, Orlické Mountains (Ist instar nymphs), 4. 6. 1970, Hostinné v Podkrkonoší (IInd and IIIrd instar nymphs), 20. 6. 1970, Zdobnice, Orlické Mountains (IIIrd and IVth instar nymphs), 4. 7. 1970, Zdobnice, Orlické Mts (IVth and Vth instar nymphs).

Decticus verrucivorus — 28. 5. 1970, Zdobnice, Orlické Mts (Ist instar nymphs), 17. 6. 1970, Zdobnice, Orlické Mts (IIIrd and IVth instars), 20. 6. 1970, Zdobnice, Orlické Mts (IVth and Vth instars), 4. 6. 1970, Zdobnice, Orlické Mts (Vth and VIth instars).

Metrioptera brachyptera — 28. 5. 1970, Zdobnice, Orlické Mts (Ist instar nymphs), 20. 6. 1970, Zdobnice, Orlické Mts (IIIrd instar). 10. 7. 1970, Hronov nad Metují (Vth instar), 21. 5. 1971, Hronov n. Met. (Ist instar), 26. 5. 1971, Zdobnice, Orlické Mts (Ist instar).

Further material of nymphs of individual instars and adults for morphological examination, fixed in 90 % alcohol, was collected during several years at the following localities in northeastern Bohemia:

Tettigonia cantans — 3. 6. 1957, Hronov n. Met. (1 specimen); 26. 6. 1957, Hronov n. Met. (1 specimen); 4. 7. 1957, Hronov n. Met. (3 specimens); 31. 5. 1958, Hronov n. Met. (7 specimens); 3. 6. 1958, Hronov n. Met. (17 specimens); 21. 5. 1960, Hronov n. Met. (20 specimens); 5. 6. 1960, Hronov n. Met. (11 specimens); 12. 6. 1960, Hronov n. Met. (9 specimens); 18. 6. 1960, Hronov n. Met. (13 specimens); 26. 6. 1960, Hronov n. Met. (13 specimens); 3. 7. 1960, Hronov n. Met. (14 specimens); 9. 7. 1960, Hronov n. Met. (29 specimens); 16. 7. 1960, Hronov n. Met. (15 specimens); 31. 7. 1960, Hronov n. Met. (3 specimens); 26. 5. 1971, Zdobnice, Orlické Mts (6 specimens).

Decticus verrucivorus — 25. 5. 1958, Hronov n. Met. (4 specimens); 31. 5. 1958, Hronov n. Met. (14 specimens); 8. 6. 1958, Hronov n. Met. (4 specimens); 22. 6. 1958, Hronov n. Met. (7 specimens); 1. 7. 1958, Hronov n. Met. (10 specimens); 15. 5. 1960, Hronov n. Met. (6 specimens); 21. 5. 1960, Hronov n. Met. (8 specimens); 28. 5. 1960, Hronov n. Met. (6 specimens); 5. 6. 1960, Hronov n. Met. (6 specimens); 12. 6. 1960, Hronov n. Met. (7 specimens); 18. 6. 1960, Hronov n. Met. (7 specimens); 3. 7. 1960, Hronov n. Met. (10 specimens); 9. 7. 1960, Hronov n. Met. (8 specimens); 10. 7. 1960, Hronov n. Met. (9 specimens); 16. 7. 1960, Hronov n. Met. (10 specimens); 31. 7. 1960, Hronov n. Met. (6 specimens); 12. 7. 1963, Zvičina near Dvůr Králové n. L. (4 specimens); 26. 5. 1971, Zdobnice, Orlické Mts (9 specimens); 30. 5. 1971, Zdobnice, Orlické Mts (7 specimens).

Metrioptera brachyptera — 26. 6. 1957, Hronov n. Met. (16 specimens); 29. 6. 1957, Hronov n. Met. (9 specimens); 30. 6. 1957, Hronov n. Met. (10 specimens); 4. 7. 1957, Hronov n. Met. (13 specimens); 11. 5. 1958, Hronov n. Met. (11 specimens); 3. 6. 1958, Hronov n. Met. (32 specimens); 21. 5. 1960, Hronov n. Met. (11 specimens); 26. 5. 1960, Hronov n. Met. (8 specimens); 5. 6. 1960, Hronov n. Met. (9 specimens); 12. 6. 1960, Hronov n. Met. (3 specimens); 12. 6. 1960, Zábrodí at Náchod (7 specimens); 18. 6. 1960, Hronov n. Met. (13 specimens); 26. 6. 1960, Hronov n. Met. (10 specimens); 3. 7. 1960, Hronov n. Met. (35 specimens); 9. 7. 1960, Hronov n. Met. (45 specimens); 16. 7. 1960, Hronov n. Met. (15 specimens); 31. 7. 1960, Hronov n. Met. (13 specimens); 12. 7. 1963, Zvičina near Dvůr Králové n. L. (1 specimen); 21. 5. 1971, Hronov n. Met. (5 specimens); 26. 5. 1971, Zdobnice, Orlické Mts (11 specimens); 5. 6. 1971, Zdobnice, Orlické Mts (6 specimens); 8. 6. 1971, Zdobnice, Orlické Mts (8 specimens).

The material is deposited in the Regional Museum at Hradec Králové.

Rearing equipment

The nymphs of *Tettigonia cantans, Decticus verrucivorus* and *Metrioptera brachyptera* were reared in small cages of two sizes. They were of a very simple construction, but meeting all requirements of my research, i. e. sufficient light, permanent circulation of air and easy access to the nymphs. They were also easily disassembled for photography.

The cage consisted of a solid wooden bottom (in two sizes for two types of cages). In its corners were fixed stanchions with clefts for three glass walls and for a wooden frame with nylon netting which was the fourth wall. The lid, a wooden frame with nylon netting, was detachable.

One type of the cage (undivided) had the following measurements: bottom 23 × × 18 cm, height 22 cm. The other type, with a glass wall in the middle, had a 38 × × 18 cm bottom, height 22 cm.

The bottom of the cage was covered with dry river sand; a watchglass with food and a thick-walled test tube containing drinking water and stoppered with a piece of cottonwool to prevent direct contact of the larvae with water were placed on the sand. A dry twig was fixed in each cage to give support to moulting nymphs.

On the whole 26 specimens of *Tettigonia cantans*, 18 specimens of *Decticus verrucivorus* and 34 specimens of *Metrioptera brachyptera* were reared in the laboratory in the course of two years. The rearing of the latter species was not very successful in 1970, so that it was repeated in 1971. Individual cages were marked with letters and a detailed record was kept on each nymph, with all basic data taken down twice a day, at 8 a. m. and 4 p. m. (e. g. temperature, relative humidity, date of ecdysis, behaviour during the moulting, death, etc.).

The nymphs in the laboratory culture were observed for the total length of nymphal development, number of moults in individual species, intervals between ecdyses, number and duration of individual instars, moulting process, etc.

Food

The nymphs were fed on a dry mixture of oats, bread crumbs, dried pupae of ants and dried water fleas as well as vegetables, mainly fresh lettuce and grated carrots. This staple food was supplemented with dog food containing dried blood plasm. Control insects were occasionally given boiled beef (finely chopped), raw liver and cottage cheese.

Fresh vegetables were supplied every day, the dry mixture approximately once in a fortnight; tap water was replenished every day, changed approximately every three weeks.

Rearing conditions

The nymphs were kept in a small room (length 210 cm, width 110 cm, height 220 cm) lighted 12 hours a day (7 a. m. to 7 p. m.) with a 200 W bulb. The cages were placed on shelves

Temperature in the rearing room was not quite constant and the relative humidity also varied, as follows:

May 1970	relative humidity 82—90 %	temperature 16—18 °C
June 1970	82—90 %	16—18 °C
July 1970	75—90 %	20—23 °C
August 1970	85—90 %	20—22 °C
May 1971	77—90 %	16—20 °C
June 1971	75—93 %	17—22 °C
July 1971	70—86 %	20—24 °C

b) Methods

Measurement

The growth of all three species was observed by measuring individual instars and the imago with an ocular micrometer under a stereoscopic microscope.

The body length, length of the pronotum and abdomen, width of the vertex (the widest space between the eyes was measured), length and width of the hind femur, length of the ovipositor and male cerci were measured, always in 10 males and 10 females of each instar and the imago. In total 3360 measurements were taken.

Drawing and photography

Figures were drawn after dead specimens with a drawing apparatus (Meopta 59613) under the stereoscopic microscope.

Photographic documentation of the moulting process was made throughout the laboratory rearing of the bush crickets, including evenings, in the year 1970 with the following equipment: Pentacon-six 6×6, Asahi Pentax 24×36. Films ORWO 20 DIN, 3 Teslafot lamps in reflectors, tripods, extension tubes. The same cameras were used for photographing the localities.

Mathematical evaluation

The arithmetical mean ($\bar{x}$) of ten measurements was determined. The mean values were used for calculation of the length and width growth coefficients, according to the formula:

$$\mathrm{l.coeff.} = \frac{\bar{x}_n}{\bar{x}(n-1)}$$

The results have been arranged in tables; minimum and maximum values are given along with the arithmetical means and the length or width growth coefficients (the coefficient being a ratio of corresponding values in two successive instars).

Growth from the second instar has been expressed in graphs by curves of growth (dashed curve for males, unbroken for females). Size (in millimeters) is indicated on the ordinate, days on the abscissa. The average duration of individual instars (see Tables C—E) in days is indicated on the curves of growth with crosses for males and solid circles for females. Standard deviations are expressed in abscissae (dashed for males, unbroken for females).

c) Characterization of the Tettigonioids under study, their geographic distribution and occurrence in Czechoslovakia

The three species studied belong to the family Tettigoniidae. *Tettigonia cantans* (Fuessly) is a representative of the subfamily Tettigoniinae; *Decticus verrucivorus* (L.) and *Metrioptera brachyptera* (L.) are members of the subfamily Decticinae.

All three species belong to the fauna of deciduous forests of the Eurosiberian subregion. *Metrioptera brachyptera* does not occur in the warm lowlands of Central Europe, but in the north its range reaches to the polar zone of the Eurosiberian subregion. *Decticus verrucivorus* lives mainly in the mountainous areas of the zone of deciduous forests, where it is found in considerably high altitudes. Its wide ecological range even includes the Mediterranean subregion, but there the species lives in mountains only. *Tettigonia cantans* occurs almost everywhere in the submontane and montane areas of the zone of deciduous forests of the Eurosiberian subregion, up to the river Amur in the east.

The three bush crickets are abundant in Czechoslovakia. *Tettigonia cantans* and *Decticus verrucivorus* live in mountain and submontane meadows, clearings in woods, in pastures and on grassy slopes (Photograph 1). *Tettigonia cantans* moves during the sixth instar and as an adult to higher herbs and then to shrubs and deciduous trees. *Decticus verrucivorus* lives at the beginning of its postembryonic development at localities with sparse and low vegetation, in later instars moves to places with a higher and thicker herbaceous cover. The third species, *Metrioptera brachyptera,* lives mostly on degraded earth-sand soils overgrown with heather (Photograph 2), almost always occuring together with the grasshoppers *Omocestus viridulus* (L.) and *Tetrix bipunctata* (L.).

V. Postembryonic development

Life cycle and seasonal cycle

All three bush crickets under study, as most of the orthopteroid insects occuring in Czechoslovakia, have only one generation in a year. Nymphs hatch from eggs in spring, rarely at the end of April, more often from the second half of May onwards. At that time first larvae of the three species can be found in the field. The first adults of *Metrioptera brachyptera* begin to occur about the middle of July (the earliest occurrence recorded by me were 2 males on 11 June 1971 at Zdobnice, Orlické Mts). Males usually reach the adult stage a few days earlier than females. The nymphal development of *Tettigonia cantans* and *Decticus verrucivorus* takes a little more time, so that under natural conditions adults begin to appear 10—15 days later (sometimes only at the end of July). Mating and oviposition in *Metrioptera brachyptera* take place in the second half of August, in *Tettigonia cantans* and *Decticus verrucivorus* from the end of August until the end of September (the last case observed was *Tettigonia cantans,* 28. 9. 1969, Zdobnice, Orlické Mts). In single cases, adult *T. cantans* and *D. verrucivorus* can still be found, under optimal weather conditions, at the beginning of October.

The females of all three species lay eggs in soil.

The males, which have reached maturity sooner than the females, begin to die after mating, the females usually live until the first strong frost which kills them. It seems that not all females have time enough in the mountain climate to lay their eggs; early frost makes it impossible. Two adult females of *Tettigonia cantans* found on 3 October 1969 at Plasnice, Orlické Mts, had many mature eggs in their ovaries; considering the time of the year it was improbable that they would have laid them. Also one female of *Tettigonia cantans,* found dead at the same locality on the same day, had large ovaries full of mature eggs. I presume that this might explain the varying number of individuals of the same species in a certain habitat in individual years. Overpopulation of a certain species may occur under optimal weather conditions, when all eggs have been laid and favourable weather enables eclosion and undisturbed nymphal development.

The eggs hibernate in soil from the second half of August (more often from September) until the end of April or first half of May of the next year. The nymphal life of *Metrioptera brachyptera* takes place approximately from the middle of May to the middle of July, of *Tettigonia cantans* and *Decticus verrucivorus* from the end of April in extreme cases, but usually from the middle of May until almost the end of July. The adult life is comparatively short, lasting approximately two — two and a half months. Mating and oviposition occur when gonads have matured, and the life as well as seasonal cycles are thus completed.

Table A

Metrioptera brachyptera

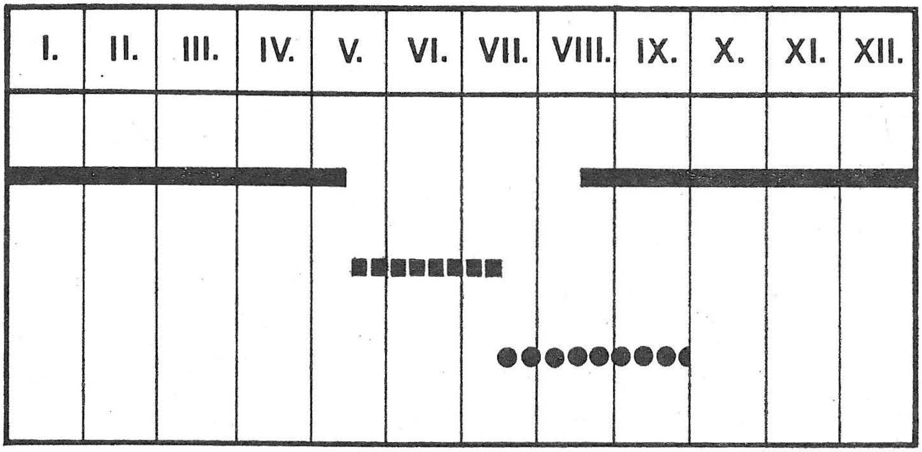
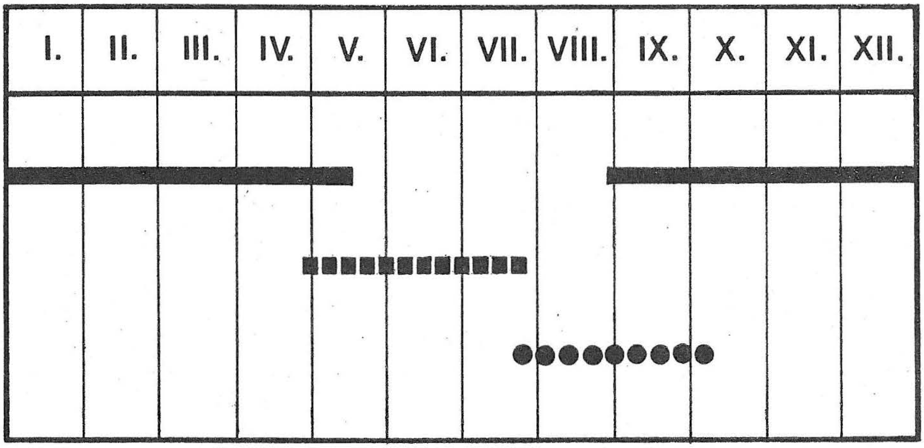


Table B

Tettigonia cantans and **Decticus verrucivorus**



Roman numbers = months
Number 1 = overwintering eggs
Number 2 = nymphal life
Number 3 = adult life

The above tables show that nymphal life in the field is approximately as long as the adult life. In *Metrioptera brachyptera* it takes about two months, in *Tettigonia cantans* and *Decticus verrucivorus* over two and a half months. The adult *Metrioptera brachyptera* lives at most two and a half months, the other two bush crickets a little less long. The egg stage is the longest, lasting about 8—9 months.

A concise description of the reared bush crickets and a summary of my experience of their rearing in the laboratory

Almost 80 nymphs of the three species were reared in the laboratory in 1970 and 1971. The following observations seem to be worth mentioning:

All three species are omnivorous, so that they can be reared on vegetable as well as animal food. Fresh lettuce has proved to be the best of the first kind of food, dried water fleas and ant pupae of the latter.

All three species, in particular *Tettigonia cantans,* are prone to cannibalism. Therefore it is necessary to keep the nymphs separated, especially those of different species; the same applies to different instars of one species (nymphs of advanced instars attacked younger ones). Only an adult couple can be safely kept in one cage.

The nymphs of all three species are very sensitive to light, and even more to heat. This is easy to verify: if a strong reflector is switched on in the rearing room, the nymphs become markedly active, particulary in the evening.

They move quickly about the cage, with antennae extended forward and rapidly moving up and down as well as laterally. The nymphs concentrate in the direction of the source of light, so that we can say that they are positively phototactic. Their activity ceases when the light is switched off. The nymphs do not respond to light before ecdysis (on the contrary, they seek shaded places in the cage). The nymphs refuse food prior to ecdysis (sometimes as early as 24 hours before the moult), but water intake continues almost until the ecdysis. Perhaps also in the bush crickets water, along with the swallowed air, by distending the digestive tract contributes to the increase in the inner pressure of haemolymph, which is necessary to the splitting of cuticle along ecdysial lines.

The nymphs find food with their long antennae, always extended forward when the insects are in motion, and rapidly moving in all directions. Exuviae are also felt for with the antennae and palps after ecdysis. Several times I placed older exuviae within the reach of antennae of a recently moulted nymph, which always responded when its antennae touched the exuviae and began to eat them, even though they were several hours old. Once a sixth instar nymph of *Metrioptera brachyptera* even consumed the exuviae of another species. In a few atypical cases the exuviae were not consumed (usually when the nymph moved after ecdysis far from the cast skin). However, no macroscopically detectable negative effects on the nymphs have been observed. Sclerotisation and coloration of the new cuticle proceeded quite normally.

It has been suggested that eating of the cast skin perhaps helps to maintain the increased bulk of the insect body (Wigglesworth, 1965: 44). I have noted that the nymphs of *Tettigonia cantans* ate exuviae 2—3 days after ecdysis, i. e. at a time when it was not necessary to maintain the increased bulk. Hill & Goldsworthy (1968) have recently found on *Locusta migratoria migratorioides* that all chitin and most of protein are obtained from the old cuticle.

Eggs

Postembryonic development begins with the hatching of the nymph from the egg. Therefore a brief note on the size, shape and colour of eggs of the bush crickets under study seems necessary.

The eggs of *Tettigonia cantans* are blackish, with a very fine surface sculpture consisting of tiny hexagonal depressions (the sculpture resembles a miniature honeycomb). The egg is cylindrical; its dorsal side is slightly concave, the other sides are moderately convex; the poles are broadly rounded (Photograph 3). Size of the eggs: length 4.95—5.34 mm, width 1.5—2.00 mm.

The eggs of *Decticus verrucivorus* are pale, some with a honey-brown tinge, with a very fine surface sculpture of hexagonal depressions. The eggs are broadly cylindrical, with all sides distinctly convex; the poles are broadly rounded (Photograph 4). Size of the eggs: length 5.34—5.75 mm, width 1.50—2.25 mm.

The eggs of *Metrioptera brachyptera* are brown black to black, with a very fine surface sculpture of tiny dots. The egg is narrow, cylindrical, the dorsal side moderately concave, the others distinctly convex; the poles are narrowly rounded (Photograph 5). Size of the eggs: length 4.04—4.33 mm, width 1.17—1.18 mm.

The ventral side of the eggs of all three species is always more convex than the dorsal one (Photographs 3, 4, 5). Mycropyles are on the ventral side.

Nymphal development

The most profound morphological changes occur in the orthopteroid insects during the development of the vermiform larva into the first instar, and then during the last (imaginal) moult when the larva becomes the imago. This change is particularly conspicuous in species with fully developed wings.

Since I did not succeed in rearing nymphs from eggs, the vermiform larva has not been described, nor do I know the full duration of the first instar in the three species. The vermiform larva of *Isophya taurica* Br.-W., a representative of the superfamily Tettigonioidea, has been described in detail by Chetyrkina (1966). Many more bionomical and morphological details are known about this first stage of the nymphal life in the related superfamily Acridoidea, in which it is much easier to rear the vermiform larva from the egg (Dirsh, 1968).

Other conspicuous morphological changes occur at the ultimate ecdysis when the nymph becomes the imago. During the imaginal ecdysis wings are inverted by 180°, so that the tegmina reaches its normal position in front of the hind wing. Articulation of wing rudiments and their first inversion were observed in all three Tettigonioids at the fourth moult. The wing rudiments of fifth and sixth instar nymphs are in the inverse position (Figs. 5, 6, 28, 29, 51, 52). The mechanism of this remarkable phenomenon, also known in Odonata besides the orthopteroid insects, has not yet been sufficiently explained.

The wing rudiments of the three bush cricket species under study develop in approximately the same way. They are absent from nymphs of the first and second instars. In the third and fourth instars the lateral margins of the meso- and metanotum are projected and elongated, developing into so-called tegminal and alar lobes

(e. g. Figs. 3 and 4), with detectable venation. The wing rudiments are articulated at the fourth moult, so that the fifth and sixth instar nymphs have wings already separated from the meso- and metanotum. Venation of the tegmina as well as wing is distinct. Also the coloration of the wing becomes apparent (Figs. 28, 29). The most conspicuous change in the development of the wings occurs after the final ecdysis, as has already been mentioned above (this can be best observed during the third ecdysial phase). Immediately after the moult the wings are tightly folded, parachute-like, in a very small form, but after a short time, under the inner pressure of haemolymph, they are gradually unfolded, expanded, and under the influence of air oxygen they darken and harden.

From the viewpoint of the wing development, the nymphs of the three bush crickets can be divided into three groups:

Group I Wing rudiments absent. Nymphs of the first and second instars.
Group II Wing rudiments developed as the so-called tegminal and alar lobes. Nymphs of the third and fourth instars.
Group III Wing rudiments separated from the meso- and metanotum in inverse position (inverted by 180°). Nymphs of the fifth and sixth instars.

The sex of the nymphs of all three species under study can already be morphologically distinguished in the first instar. The rudiments of the Ist pair of valvulae of the ovipositor (= fore valvulae, ventral valvulae, or gonapophyses) are on the eighth abdominal segment. Two other pairs of valvulae (IInd and IIIrd pairs) develop on the ninth abdominal segment. The ovipositor does not develop in the same manner in all three species. In the first two instars of *Tettigonia cantans* and *Metrioptera brachyptera* the rudiments of the ovipositor are formed by three pairs of valvulae which are well visible under a high magnification (Figs. 19, 20, 65, 66). In the third instar have the IInd valvulae already been enclosed by the Ist and IIIrd pairs (Figs. 21, 67). The ovipositor of *Decticus verrucivorus* develops more rapidly. All three pairs of valvulae are detectable in the first instar only; the IInd valvulae are enclosed in the subsequent instars by the Ist and IIIrd pairs (Figs. 42, 43).

Number and duration of nymphal instars

I have ascertained six instars in all three Tettigonioids under laboratory conditions. The number was always constant in both sexes. According to my observations the number is the same in the field. The number of instars has been known so far only in *Metrioptera brachyptera* (L.) (Richards, 1958).

It has been found that the number of instars may not always be constant in representatives of the superfamily Acridoidea. Females of some grasshoppers undergo one or two instars more than males. In such cases the females are always much larger than the males, and some authors have concluded that the number of instars depends on the body size (Dirsh, 1968).

The number of instars may be influenced by various factors. E. g. Parker (1930) has found that the grasshopper *Melanoplus mexicanus* Sauss. has five instars at the temperature of 32—37 °C, and six instars at 22—27 °C.

No similar cases have been found in Tettigonioidea, since the study of their postembryonic development is only beginning.

Duration of the nymphal instars

Tettigonia cantans

Ist instar	9 – 23 days (plus t time)*
IInd instar	7 – 13 days
IIIrd instar	7 – 11.5 days
IVth instar	8 – 12 days
Vth instar	7 – 13.5 days
VIth instar	10 – 16.5 days

Decticus verrucivorus

Ist instar	7 – 19 days (plus t time)*
IInd instar	10 – 14 days
IIIrd instar	8 – 15 days
IVth instar	9 – 12 days
Vth instar	11 – 16 days
VIth instar	15.5 – 23 days

Metrioptera brachyptera

Ist instar	1 – 16 days (plus t time)*
IInd instar	9 – 15 days
IIIrd instar	9 – 18 days
IVth instar	10.5 – 18.5 days
Vth instar	8.5 – 14.5 days
VIth instar	9 – 15 days

The average duration of the IInd – VIth instar (in days) in individual species

Table C

Tettigonia cantans

Instar	II	III	IV	V	VI	Days
♂♂	10	8.5	9.5	9.5	14	51.5
♀♀	9.5	10	10.5	12	14.5	56.5

*) Time for which the first instar nymphs lived in the field after eclosion (t) should be added to the time given here. However, it should be taken into consideration that the development of the first instar nymphs was retarted by the transfer into the laboratory (they needed several days to adapt themselves to the new conditions). This would partly explain the relatively long duration of the first instars in all three Tettigonioids.

Table D

Decticus verrucivorus

Instar	II	III	IV	V	VI	Days
♂♂	11	9	9	13.5	19	61.5
♀♀	11	10	11	13.5	19	64.5

Table E

Metrioptera brachyptera

Instar	II	III	IV	V	VI	Days
♂♂	12.5	12	15.5	11.5	11.5	63
♀♀	13.5	14.5	14.5	11.5	11	65

Tables C—E show that in both sexes of *Tettigonia cantans* and *Decticus verrucivorus* the longest period is that between the penultimate and last moults. On the contrary, the same period in *Metrioptera brachyptera* does not substantially differ from the previous one, being even shorter. Also the average length of the nymphal development between the second and sixth instars is shorter in males than in females (this finding is in agreement with observations in the field where the male post-embryonic development is also shorter).

I presume that particularly the degree of development of the wings of the adult bush cricket is decisive for the duration of the ultimate instar of the species (relative length of wings is meant).

In the year 1970, when for the first time I had sixth instar nymphs of *Tettigonia cantans* and *Decticus verrucivorus* in the cultures, I expected that a seventh nstar would develop, considering their relatively short wing rudiments. It did not happen, but the duration of the sixth instar was very much prolonged (most conspicuously in *Decticus verrucivorus,* in some females being almost twice as long as the fifth instar). The wings were rapidly developing during the prolonged period between the penultime and last ecdyses.

In *Metrioptera brachyptera* the period between the penultimate and last (sith) moults was never prolonged. On the contrary, on average it was the shortest one. *M. brachyptera* is a relatively small species with markedly abbreviated wings (a brachypterous form, as suggested by the specific name). *Tettigonia cantans* has fully developed wings of the mesopterous type, distinctly exceeding the abdomen, but on average they are shorter than in *Decticus verrucivorus* (length of tegmina

24—27 mm in males, 24—27 mm in females). The sixth instar of this species lasts distinctly longer than the previous instars. The bush cricket *Decticus verrucivorus* also has fully developed wings of the mesopterous type, which are somewhat longer in the female (length of tegmina 24—32 mm in males, 24—37 mm in females). The interval between the penultimate and last moults is conspicuously long in this species, the sixth instar lasting on average 19 days in both sexes. The sixth instar of several females lasted almost twice as long as the fifth (e. g. in female nymph marked L the fifth instar lasted 13 days, sixth 21 days; in another female, marked Jb, the fifth instar lasted 14 days, sixth 23 days).

My opinion that the final degree of wing development in a given species of the superfamily Tettigonioidea is decisive for the duration of the last instar seems to be substantiated by the account given above.

Duration of the nymphal life

The postembryonic development under laboratory conditions took 55*—71 days in the males of *Tettigonia cantans*, 63*—81 days in the females. In *Metrioptera brachyptera* it lasted 63.5*—68 days in the males, 67*—84 days in the females. In *Metrioptera brachyptera* the postembryonic development was completed in 47** to 65 days in the males and 59*—73.5 days in the females.

The postembryonic development of the males of all three bush crickets took a few days less; this is in agreement with observations in the field where males also reach maturity several days earlier than females.

We can conclude that the postembryonic development under laboratory conditions was completed within 8—10 weeks in the males of *Tettigonia cantans*, within 9 to 11 weeks in the females. It took approximately 9 weeks in the males of *Decticus verrucivorus* and 9—12 weeks in the females; approximately 7—9 weeks in the males of *Metrioptera brachyptera* and 8—10 weeks in the females. According to my observations in the years 1970—1971 at Zdobnice in the Orlické Mountains, the postembryonic development of these species in the field was shorter by 7—15 days.

Moulting process

Moulting is a complex physiological process affecting all functions of the insect body. It begins in many species as early as in the first half of each instar with the separation and gradual dissolving of the lower layers of the old cuticle (endocuticle). The moulting proper (= ecdysis), in my conception the IInd phase during which the old cuticle is shed, is only a mechanical termination of one stage of the moulting proces.

Deposition of the lowest cuticular layers continues long after the exuviae have been shed, and is usually finished not long before the beginning of the next ecdysis (Wigglesworth, 1965).

The moulting proces and the whole matamorphosis of insects are regulated by metamorphic hormones which are not species-specific. The first of them, the activat-

*) plus the time for which the first instar larvae had lived in the field after eclosion.

**) the first instar larva moulted after 1 day in the cage, so that the time for which it had lived in the field after eclosion must be added to the 47 days.

ing hormone, is produced in neurosecretory cells of the protocerebral region of the brain and accumulated in the paired corpora cardiaca which are situated immediately behind the brain. Ecdysis is induced by the moulting hormone, ecdysone, secreted by prothoracic glands in the prothorax (Novák, 1969).

During the ecdysis is shed not only cuticle from the entire body surface, but also the intima of the anterior and posterior parts of the digestive tract (stomodaeum and proctodaeum), outlets of various glands, and of the tracheal system.

Both sexes of all three Tettigonioids under study regularly moulted six times. The imago emerged after the sixth ecdysis.

Whenever the terms "moulting process" or "ecdysial process" are mentioned below, its last stage is meant which can be macroscopically observed. The preceding phases of the moulting process can be reliably determined only by microscopic anatomical examination.

a) Description of individual phases of the moulting process

The moulting process, which can be macroscopically observed took, in the studied bush crickets, about 24—26 hours. The moulting of nymphs of all three species proceeded in distinct, regularly repeated periods, mostly interrupted by pauses of rest, so that the whole process can be divided into the following four phases:

Phase I The nymph stops feeding (sometimes as early as 24 hours before ecdysis proper), but water intake continues almost until ecdysis. The nymph is often motionless for a long time, seeking shaded places in the cage (does not respond to light). The abdomen is gradually distended with swallowed air; the old cuticle is separated in a rapid sequence of contractions of dorsoventral abdominal muscles (this can be observed on abdominal tergites, rugose and slightly translucent in lateral view). The cuticle loses its lustre and becomes dull before the ecdysis proper.

Phase II begins with the nymph taking a firm hold of a suitable support. In the cage it was most often a twig sometimes the top (ceiling) net, sometimes the net walls, but in a few cases also the vertical glass wall. The nymph firmly grasps the support with all six legs, either in the vertical position, head downwards, or horizontally, the dorsal side of the body always being in the direction of gravitation. The dorsal side of the thorax is highly arched and cuticle is split along the so-called ecdysial line under the inner pressure of haemolymph. The nymph gradually crawls out through the rupture. This moulting proper always consists of two distinct stages between which there is an interval of rest:

a) In the first stage, the cuticle of the whole fore part of the body is relatively quickly shed including all legs and antennae, up to the apical region of the abdomen (Photographs 20—31, 36—42).

b) The second stage begins with a prolonged period of rest, during which the moulting nymph is motionless, suspended head downwards (the apex of the abdomen, in females including the ovipositor, is still inside the old cuticle (Photographs 32, 43). In this stage the hind legs, which immediately after the shedding of the old cuticle are quite immobile, become sclerotised from the bases of femora. The second stage usually ends with the nymph grasping the support with its fore and middle legs and drawing itself out of the exuviae in a forward movement.

Phase III After leaving the old cuticle exuviae the nymph again remains motionless for some time. The new, still wrinkled cuticle expands with swallowed air, and oxygen in the air gives it the normal coloration and hardness. In this phase of the last (imaginal) ecdysis wings are unfolded and stretched (Photographs 14—17).

Phase IV After the resting pause, typical of the whole Phase III, the moulted nymph finds the exuviae with antennae and palps and in most cases eats them, leaving no remnants (Photographs 18—19, 33—35). The process of sclerotisation and coloration is completed in this last phase. The fourth phase and the entire process of ecdysis are over when feeding is resumed.

The length of individual phases of the ecdysial process in the bush crickets under study is, as follows:

Phase I up to 24 hours.

Phase II 13—32 minutes. The length of the second phase depends on the instar (in early instars it is shorter than in advanced ones).

Phase III 27 to 53 minutes.

Phase IV begins with the ingestion of the exuviae, which takes 12 to 34 minutes. Feeding usually follows shortly afterwards, but may begin only 2—3 hours later.

This shows that Phase I is the longest. It can be described as a preparatory period, during which the whole metabolism slows down. Blood pressure is increased by the swallowing of air and perhaps also by water intake, and is further increased by undulating, forward movements of the abdomen. The moulting proper (ecdysis), i. e. the shedding of old cuticle, takes place in the second phase, in which two stages can be distinguished. Sclerotisation occurs in the third phase, during which the new cuticle gradually darkens and hardens. In this phase the nymphs again swallow air, thus increasing the inner pressure of haemolymph, which in necessary for expansion of the new cuticle. The exuviae which are the main source of chitin and protein (Hill and Goldsworthy, 1968), are consumed in the fourth and last phase. Sclerotisation and coloration are completed. The entire process of ecdysis is finished in this consumptive phase.

b) Description of phase II with notes on its stages

The second phase of ecdysis begins with the nymph getting hold of a suitable support. The dorsal side of the thorax of the moulting nymph is arched high at the beginning of this stage. The cuticle of the pronotum, mesonotum and metanotum is split along the median line (the first abdominal segment is intact) and along a Y-shaped ecdysial line in the middle of the occipital region of the head. The cuticle of the entire frontal region of the head including eyes is shed forward in one piece, and when the dorsal side of the thorax has been freed, the old cuticle is gradually shed over the ventral side of the thorax under the abdomen. The fore and middle legs (Photographs 8—9, 23—26, 36—38) (femora first, then tibiae and tarsi) and the basal part of hind femora are gradually drawn out along with the dorsal side of the thorax. When the fore and middle legs and most of abdominal segments have been drawn out from the old cuticle, the hind femur is often bent, usually at a right angle (Photographs 11, 27—29, 39). The nymph gradually releases its tibiae by lateral movements of the body, the hind femora remain bent (Photographs 12—13, 30, 40—41); the hind femora are gradually straightened while hind tibiae are being drawn out. When the hind tibiae have been released, the apical part of antennae is gradually drawn out with the aid of mandibles, palps and often also fore legs (Photograph 42). Hind tarsi are usually the last to be rid of the old cuticle (Photograph 31). Afterwards the nymph draws its hind tibiae up to the hind femora and for some time remains motionless, head downwards, suspended by the apex of the abdomen (Photographs 32 and 43) which is still inside the old cuticle. The second stage of ecdysial phase II, characterized by a period of rest necessary for sclerotisation of the hind legs, begins at the moment of their release from the old cuticle. This resting pause takes 5—11 minutes in individual instars. The second stage ends with the disengagement of the apical part of the abdomen. Usually the nymph seizes the support with its fore and middle legs and crawls from the exuviae (the ovipositor of females is usually also released at this moment). Sometimes, at the end of the resting period, the nymph suddenly violently contracts its abdomen and falls out from the exuviae. This happened only when the nymph could not grasp a support (e. g. when it was freely suspended, head downwards, from the upper net, without any support within its reach).

Such is the macroscopic picture of moulting in individual stages of phase II. It is more or less the same in all Tettigonioids under study, with negligible modifications (i. e. sometimes femora are bent more than at the right angle, sometimes less, or the tarsi of hind legs are drawn out from the old cuticle prior to antennae, etc.).

The following record of the moulting of a third instar female of *Metrioptera brachyptera* (marked 0) on 23 June 1971 will illustrate at what intervals are individual parts of the body released from the old cuticle.

14.30 Ecdysis is beginning. The nymph holds to a branchlet.
14.32 The dorsal side of the thorax is arched high.
14.37 The thorax, head, a larger part of the fore and middle femora have been drawn out and the basal part of the hind femora and first abdominal segments begin to appear.
14.38.30″ The fore and middle femora have been released, fore and middle tibiae are being drawn out.
14.39 The fore and middle tibiae have been disengaged, tarsi begin to be drawn out.
14.40 Complete disengagement of the fore and middle legs, the hind femur is bent at right angles. The nymph moves the body from side to side, thus freeining the apical part of the bent hind femur.
14.41 The hind femora have been released and remain bent at a lesser angle, hind tibiae are drawn out.
14.42 The hind tibiae have been released up to the tarsi.
The femora are almost straight.
14.42.30″ The hind femora are quite straight.
14.45 After a short interval the nymph begins to draw out its long antennae with the aid of mandibles, palps and fore legs.

14.46 The antennae have been released almost at the same time as the hind tarsi. (End of the first stage of phase II).
14.47 The nymph is suspended by the apical part of the abdomen, head downwards.
14.55 The nymph grasped the branchlet with the fore and middle legs and in a forward movement has drawn out the apex of the abdomen and the ovipositor (the ovipositor is pale green, translucent). (End of the second stage).
14.56 The nymph is motionless, suspended from the branchlet beside the exuviae (phase III).
15.25 First movement — the nymph touches its exuviae with the antennae.
15.25.30″ The nymph begins to eat the exuviae from the thoracic region (beginning of phase IV).
15.27 The nymph begins to consume the right hind femur of the exuviae.
15.31 The hind femur has been eaten.
15.31.3″ The ingestion of the hind tibia begins.
15.31.33″ The hind tibia and tarsus have been eaten.

The ingestion of the whole exuviae took 22 minutes.

c) Length of ecdysial phase II and its individual stages

Table F

Metrioptera brachyptera

Instar	1st stage (mins)	2nd stage (mins)	Length of phase II
Ist instar	9′	5′	14′
IInd instar	13–14′	7–8′	20–22′
IIIrd instar	16–17′	8′	24–25′
IVth instar	16′	7′	23′
Vth instar	18–19′	9–10′	27–29′
VIth instar	19′	9′	28′

Table G

Tettigonia cantans

Instar	1st stage (mins)	2nd stage (mins)	Length of phase II
Ist instar	8′	5′	13′
IInd instar	12′	5′	17′
IIIrd instar	14–15′	5–6′	19–21′
IVth instar	18′	6′	24′
Vth instar	18′	11′	29′
VIth instar	19′	8′	27′

Table H

Decticus verrucivorus*)

Instar	1st stage (mins)	2nd stage (mins)	Length of phase II
IInd instar	11′	9′	20′
IIIrd instar	18′	10′	28′
Vth instar	19′	13′	32′
VIth instar	21′	11′	32′

It was not easy to record the timing of the moulting process. Ecdysis often took place early in the morning (between 5 and 7 a. m.), then about 1—3 p. m., and another period of most frequent moulting was from 4 to 9 p. m. In the year 1970 when photographic documentation was made throughout the laboratory rearing of the insects, the cultures were watched nonstop from 6 a. m. to 8 p. m. and sometimes to 10 p. m. Most of the data on the mechanism of moulting and its timing were collected at that time. Nevertheless, I have relatively few data at my disposal on the timing of the stages of phase II in individual instars (in most cases I have only one or two for a given instar).

Data on the length of phase II and its stages in *Decticus verrucivorus* are incomplete (none on the Ist and IVth instars).

VI. The growth of nymphal instars during the postembryonic development

Growth is commonly expressed in data on the changing length of various parts of the body in individual instars during the postembryonic development. The increase in these parameters in insects largely depends on ecdysis. The growth of the body in length is characterized in the three Tettigonioids under study by the following mean coefficients: Tettigonia cantans ♂ 1.29, ♀ 1.32; *Decticus verrucivorus* ♂ 1.26, ♀ 1.30; *Metrioptera brachyptera* ♂ 1.24, ♀ 1.30. The mean growth coefficient is higher in the females of all three species than in the males. The growth of the body was affected in all three species by the range of variation in the length of the abdomen, which is shown in Graphs 3, 11 and 19. Yet the body length increased in *Tettigonia cantans* more or less continuously from the second instar to the sixth. After the last (imaginal) moult the growth rate increased (Graph 1), and the greatest increase in length was recorded particulary in the females. In the first and second instars the males were somewhat larger than the females. The differences in length were probably due to varying degrees of the stretching of abdominal intersegmental membranes. In the males of *Decticus verrucivorus* (Graph 9) the body length increased almost continuously, in the females the growth rate increased after the third moult, with the greatest increment after the final ecdysis. In the third and fourth instars values found in the males were higher than in the females. Deviations were

*) Data on the length of phase II and its stages in the Ist and IVth instars are not included.

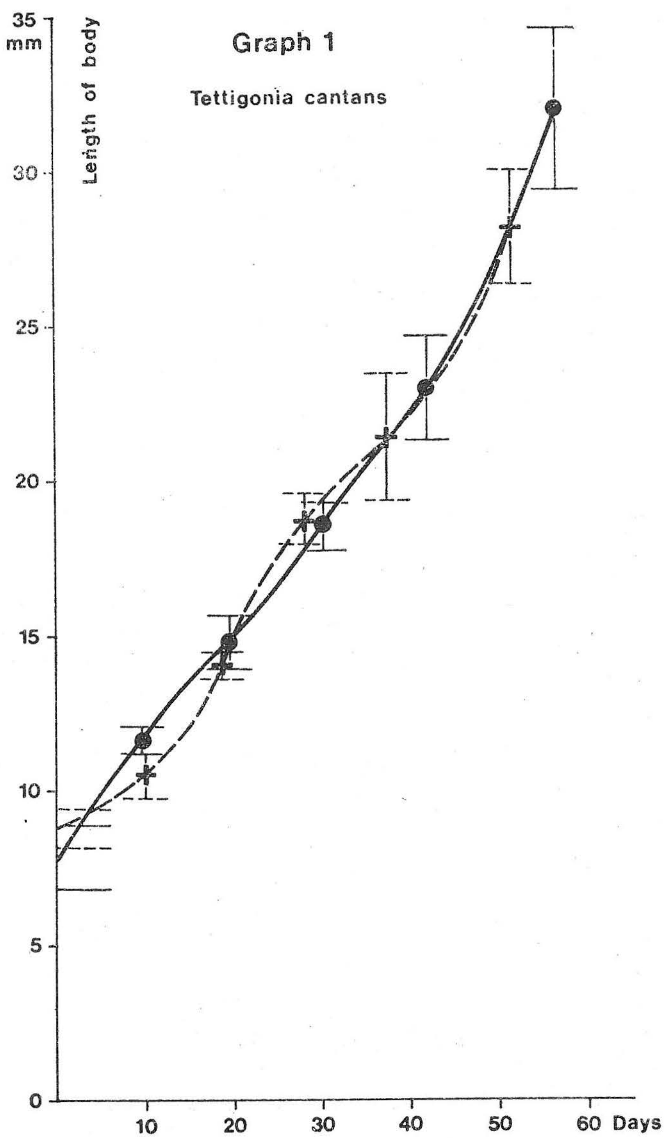
due to the variation range of the length of the abdomen (Graph 11). The body length of the males of *Metrioptera brachyptera* (Graph 17) increased almost continuously, whereas in the females it increased very unevenly owing to the variation range of the length of the abdomen (Graph 19), particularly in the fourth instar. Growth was more intensive after the fourth moult, when the greatest increase in length took place (the extreme increment was influenced by the varying length of the abdomen — see Graph 19).

The growth of the pronotum in length during the postembryonic development can be characterized by mean coefficients of growth, which in the studied bush crickets are, as follows: *T. cantans* ♂ 1.34, ♀ 1.36; *D. verrucivorus* ♂ 1.28, ♀ 1.29; *M. brachyptera* ♂ 1.27, ♀ 1.26. In only one case *(M. brachyptera)* was the mean growth coefficient slightly higher in the males than in the females. The growth of the pronotum in length is shown in Graphs 2, 10 and 18. In all three Tettigonioids the pronotum grew almost continuously from the second to fourth instar; growth was more rapid in the fifth instar, and then markedly slowed down after the final moult (with the exception of the females of *M. brachyptera* — see Graph 18) when the increments in length were smallest (growth coefficients were very low, 1.02 in *T. cantans* ♂, 1.01, ♀; *D. verrucivorus* ♂ 1.07, ♀ 1.02; *M. brachyptera* ♂ 1.03, ♀ 1.12 — see Table 2). All this indicates that the growth of the pronotum in *T. cantans, D. verrucivorus* and in the males of *M. brachyptera* was almost completed in the sixth instar.

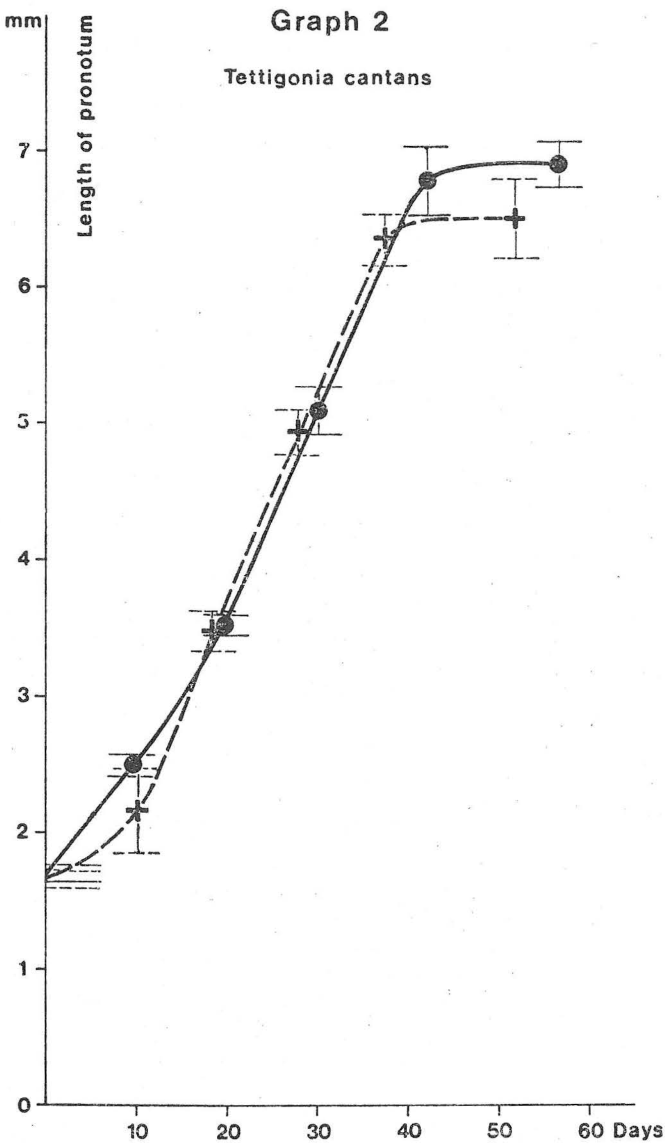
The abdomen grew in length very unevenly during the postembryonic development of all three Tettigonioids, so that the rules of its growth could not be determined. Graphs 3, 11 and 19 show that the curves of growth of both sexes of all three species intersect, mainly as a result of the variation of values. Also standard deviations are unusually great and overlapping in many cases. Values obtained by measurement of the length of the abdomen considerably varied with individual specimens of the same instar. The differences in length are due to varying degrees of expansion of the intersegmental membranes of the abdomen. The abdomen is short immediately after ecdysis, but it is substantially elongated within a few hours (mostly owing to food intake). The abdomen of the imago is also elongated, largely owing to the growth of gonads (particularly ovaries). Also great differences in mean coefficients in both sexes indicate an uneven growth (*T. cantans* ♂ 1.30, ♀ 1.34; *D. verrucivorus* ♂ 1.27, ♀ 1.35; *M. brachyptera* ♂ 1.26, ♀ 1.33).

The growth of the hind femur in length is characterized by mean growth coefficients, which in the individual Tettigonioids were, as follows: *T. cantans* ♂ 1.31, ♀ 1.32; *D. verrucivorus* ♂ 1.30, ♀ 1.32; *M. brachyptera* ♂ 1.30, ♀ 1.33. The mean growth coefficients were higher in the females than in the males of all three species. The growth of the hind femur in length from the second instar is shown in Graphs 4, 12 and 20. The hind femur grew almost continuously until the fourth instar, then the growth rate increased almost uniformly in all three species (growth was slower in *T. cantans* after the final moult).

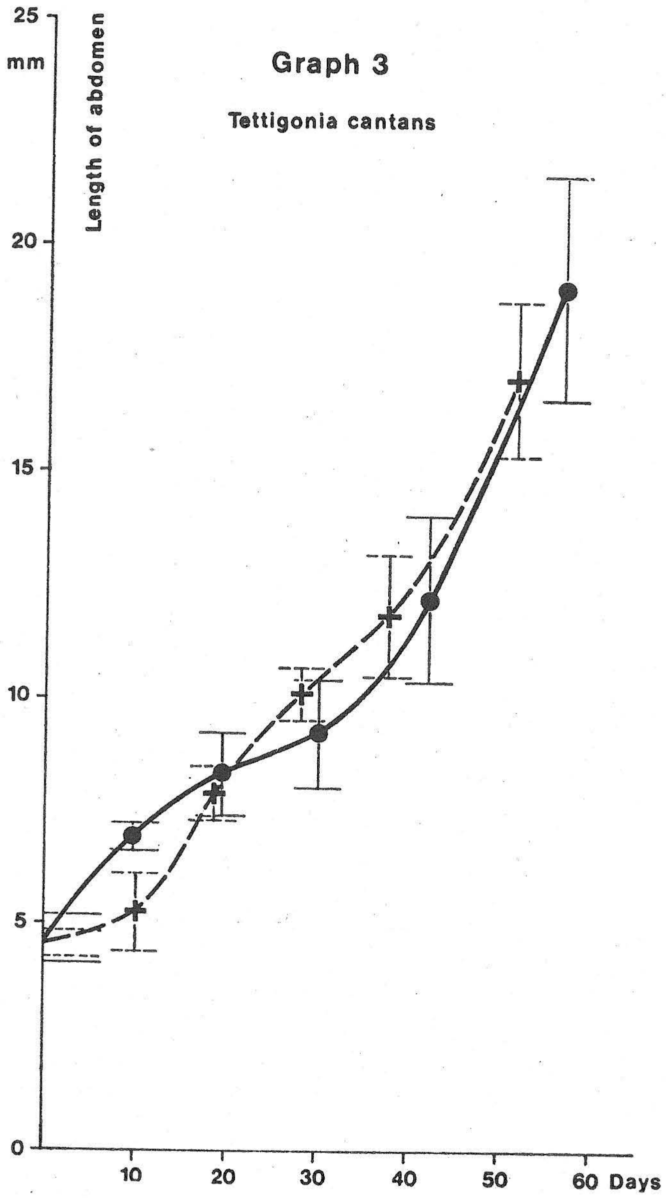
Also the growth of the hind femur in width (Graphs 5, 13 and 21) was almost continuous in all three Tettigonioids. The growth rate increased after the fourth moult; *T. cantans* the growth rate was reduced after the final ecdysis (the increment was smaller than in the previous instar). The growth of the hind femur in width can be characterized by the following mean growth coefficients: *T. cantans* ♂ 1.22, ♀ 1.24; *D. verrucivorus* ♂ 1.25, ♀ 1.27; *M. brachyptera* ♂ 1.24, ♀ 1.27. The mean growth coefficients of the female of all three species were higher than in the males.



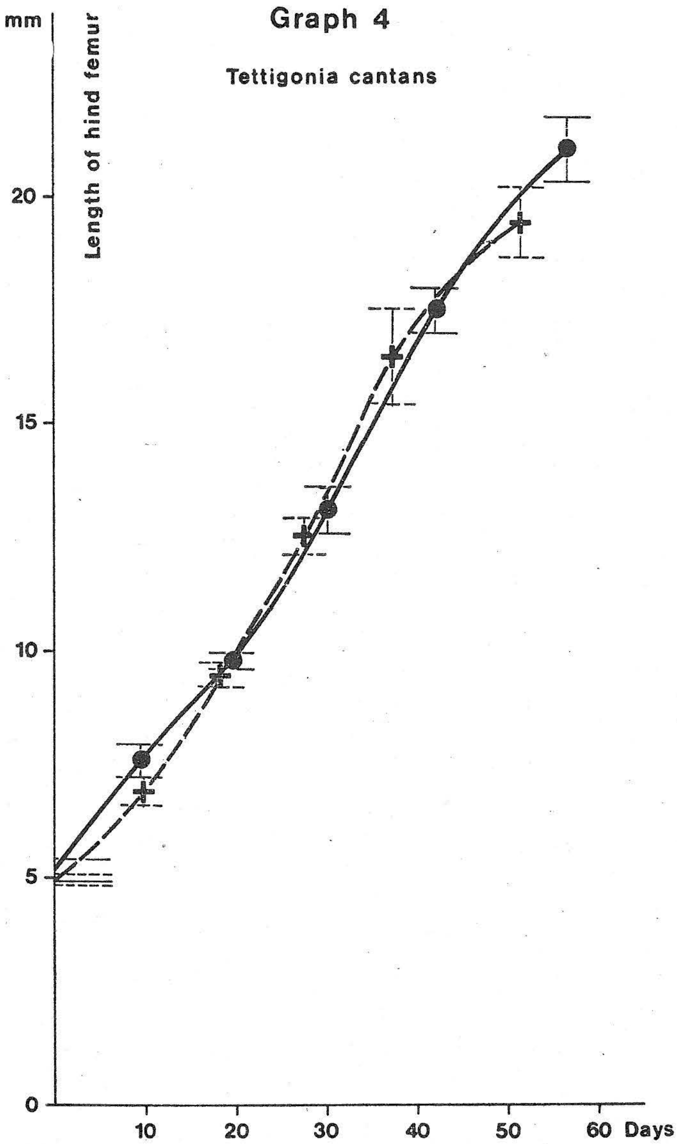
Graph 1: Average body length of the IInd—VIth instar nymphs and imago. Length (in mm) is indicated on the ordinate, average duration (in days) of postembryonic development from the IInd instar to imago on the abscissa. Dashed growth curve = male, unbroken = female. Average duration of individual instars (see Tables C—E) is indicated on the growth curve with a cross for the male and solid circle for the female. Standard deviations are represented by abscissae (dashed for the male, unbroken for the female).



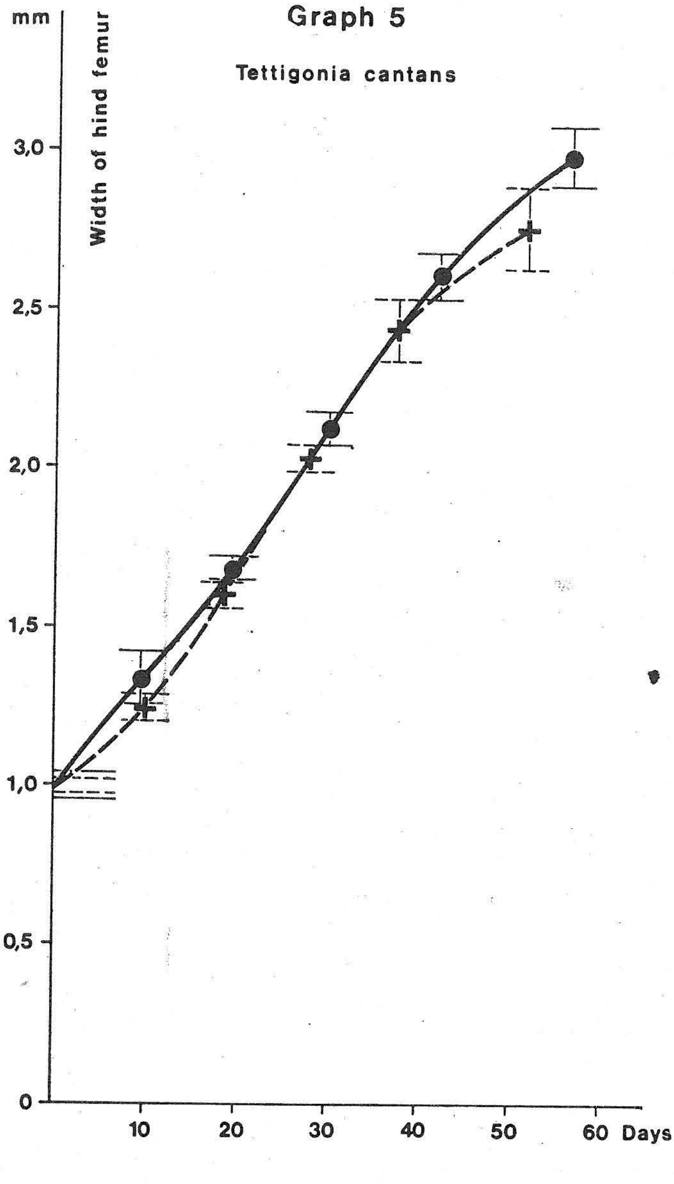
Graph 2: Average length of the pronotum of the IInd—VIth instar nymphs and imago.



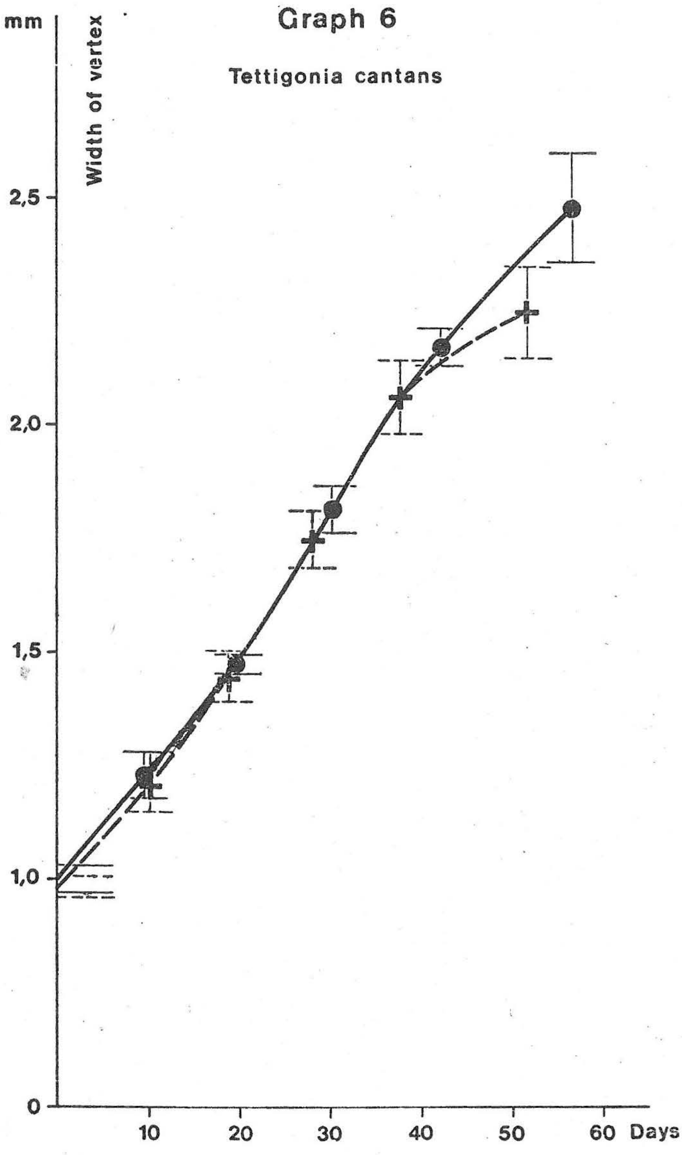
Graph 3: Average length of the abdomen of the IInd—VIth instar nymphs and imago.



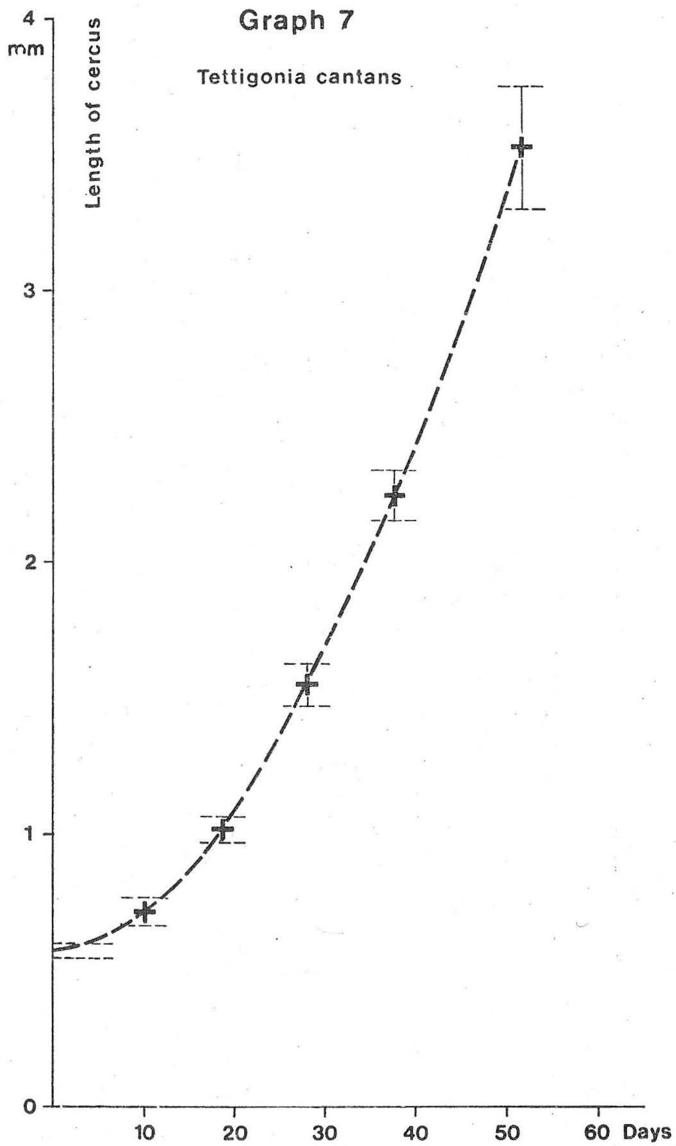
Graph 4: Average length of the femur of the IInd—VIth instar nymphs and imago.



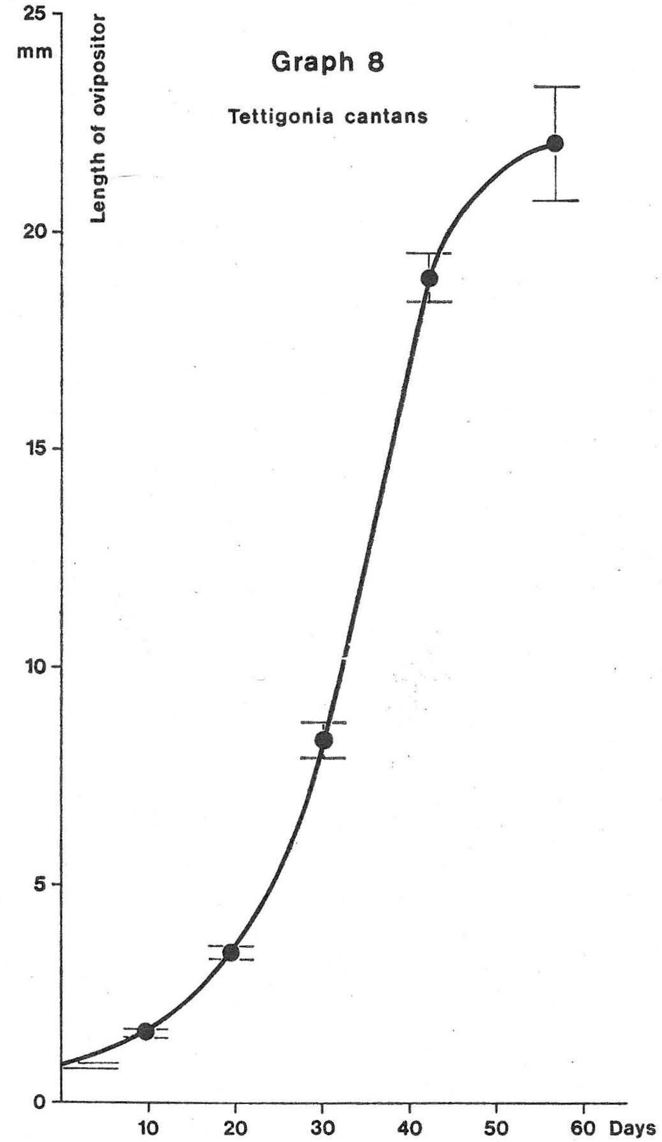
Graph 5: Average width of the hind femur of the IInd—VIth instar nymphs and imago.



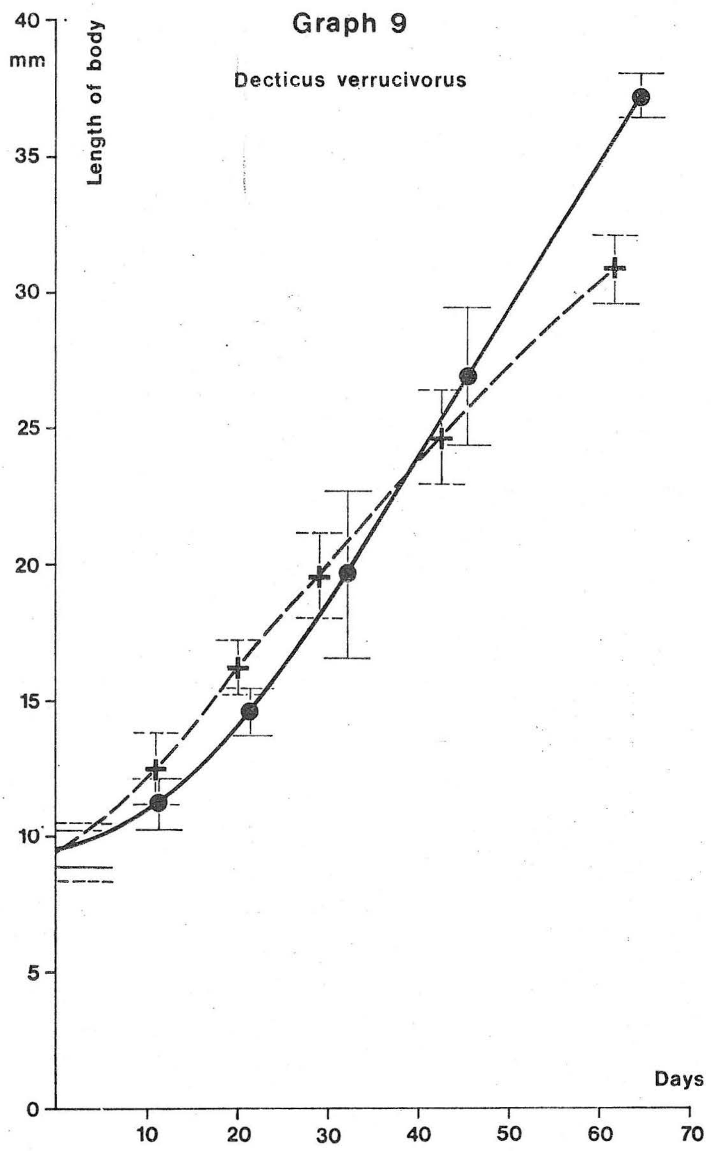
Graph 6: Average width of the vertex of the IInd–VIth instar nymphs and imago.



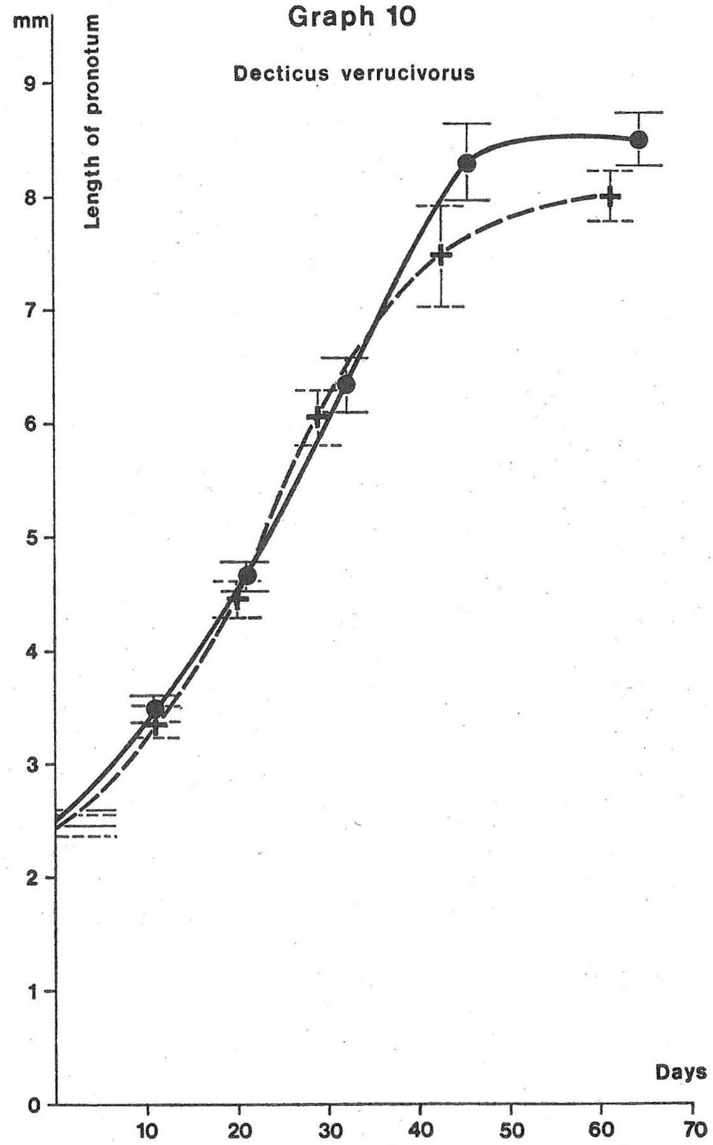
Graph 7: Average length of the cerci of the IInd—VIth instar male nymphs and imago.



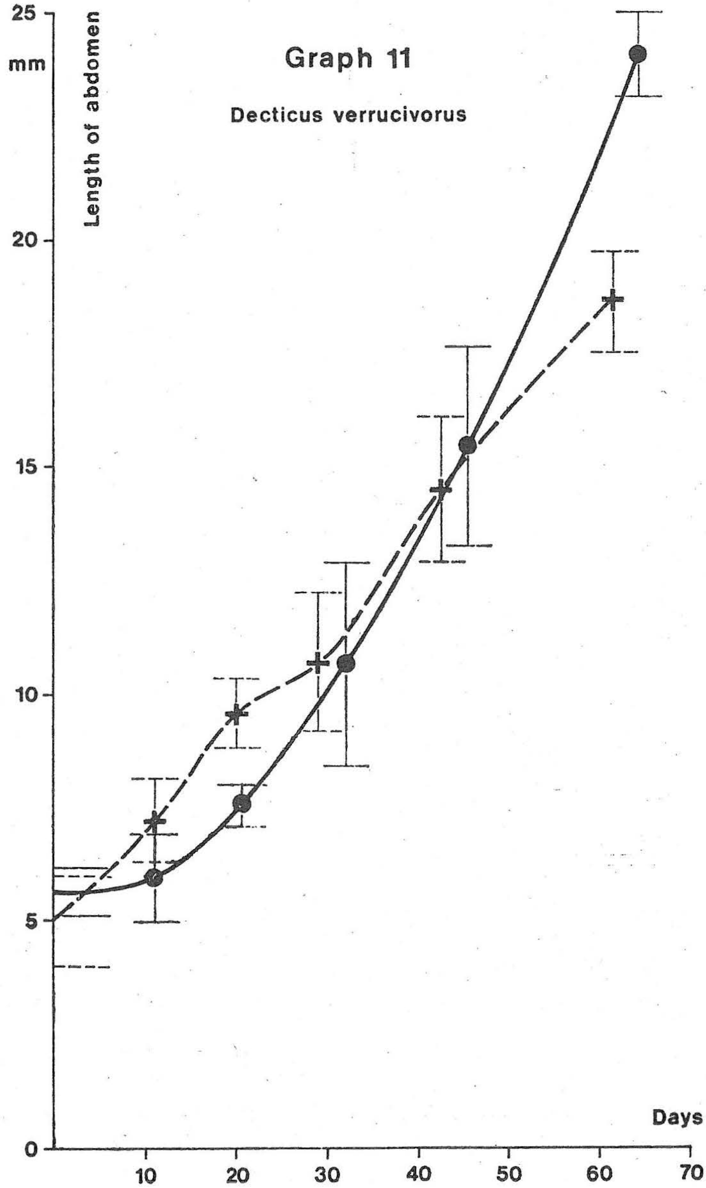
Graph 8: Average length of the ovipositor of the IInd—VIth instar nymphs and imago.



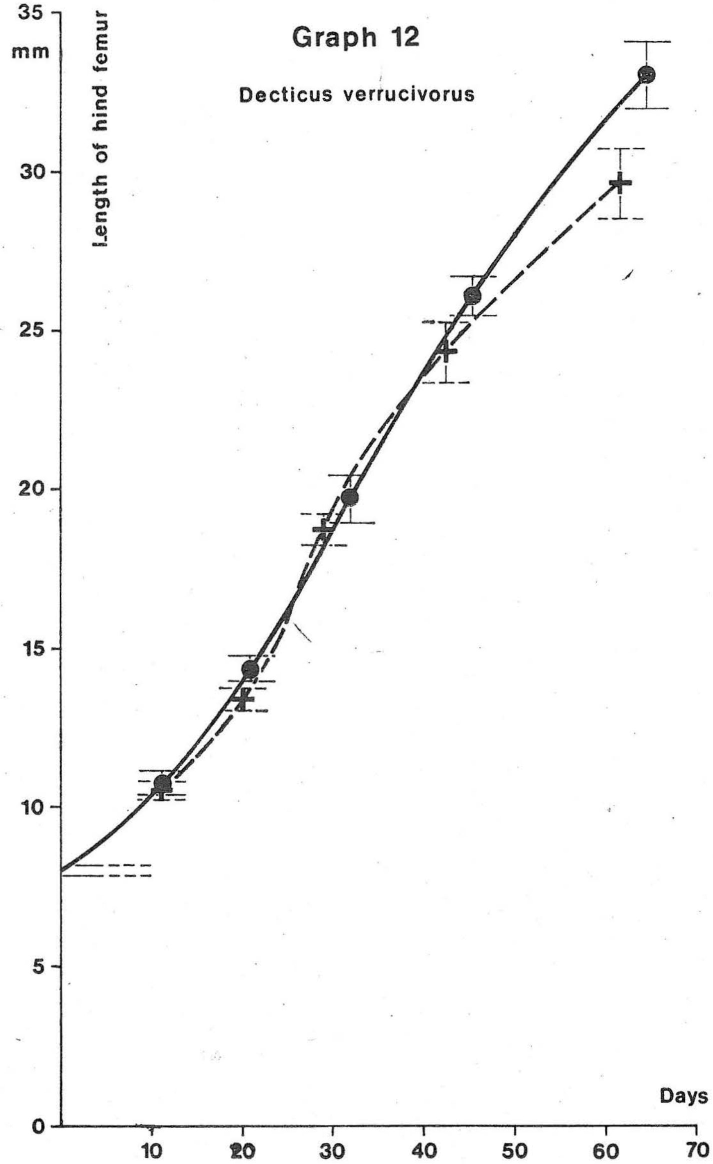
Graph 9: Average body length of the IInd—VIth instar nymphs and imago.



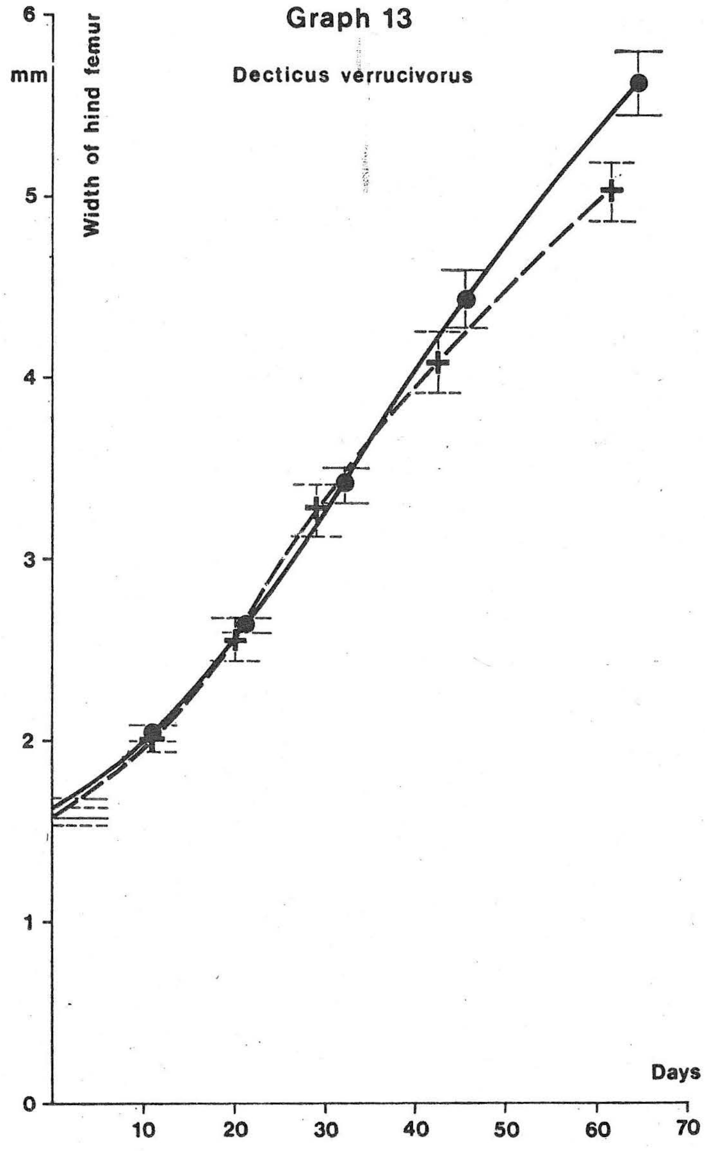
Graph 10: Average length of the pronotum of the IInd—VIth instar nymphs and imago.



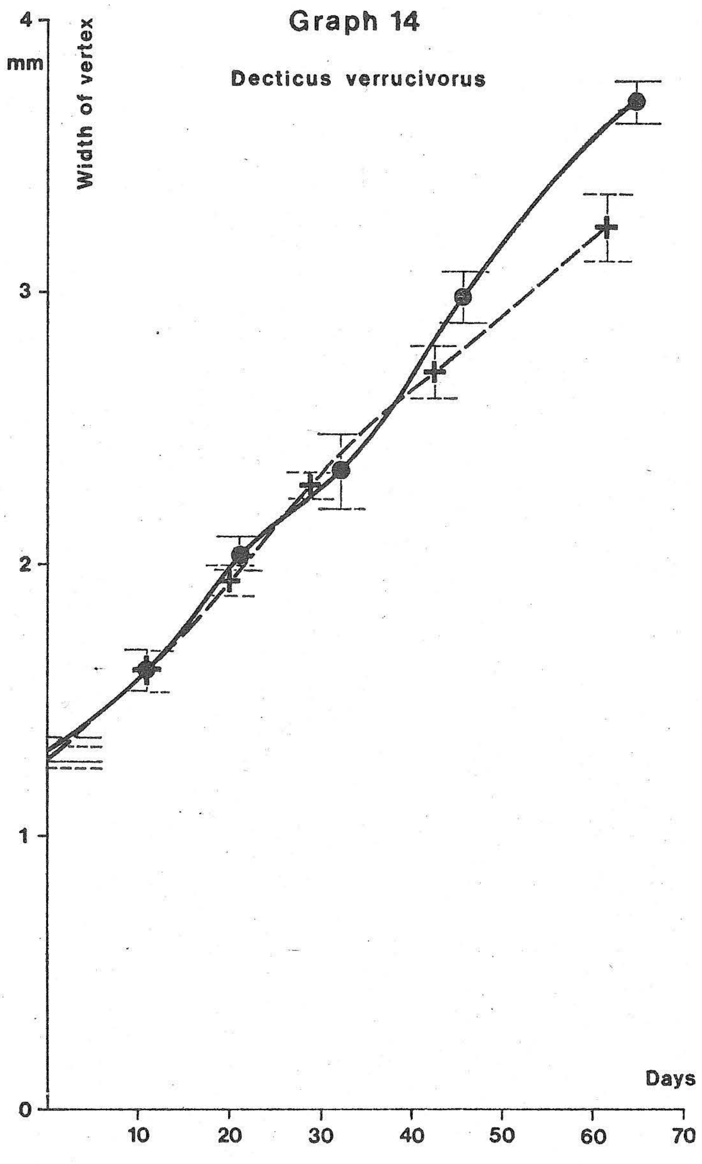
Graph 11: Average length of the abdomen of the IInd—VIth instar nymphs and imago.



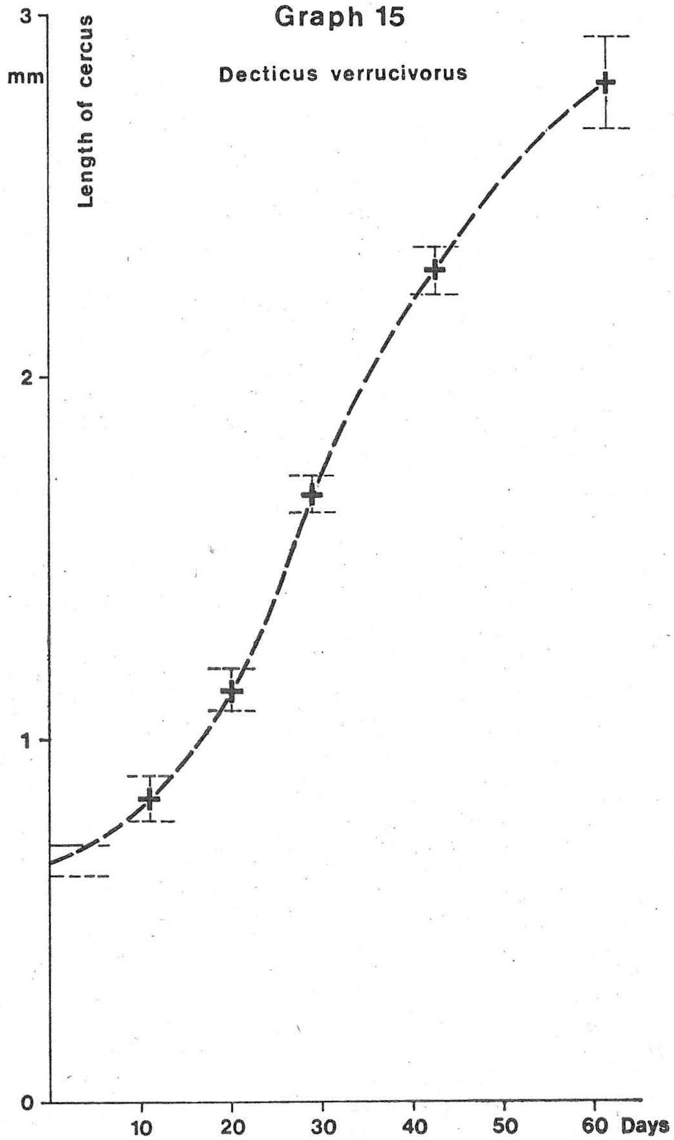
Graph 12: Average length of the hind femur of the IInd—VIth instar nymphs and imago.



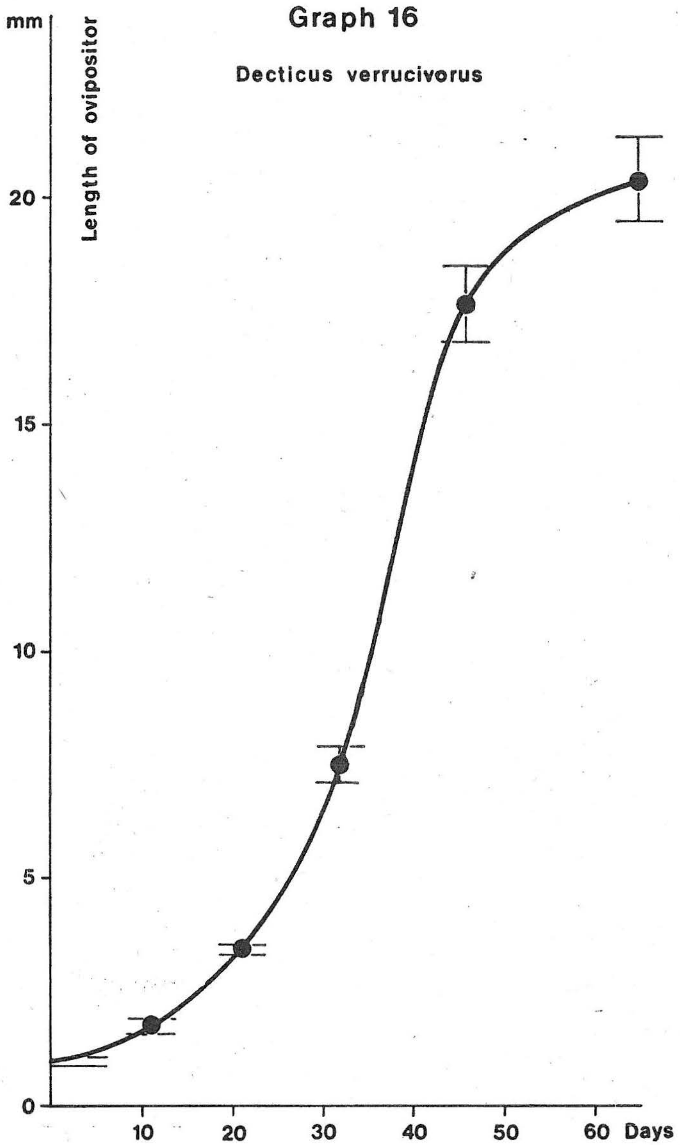
Graph 13: Average width of the femur of the IInd—VIth instar nymphs and imago.



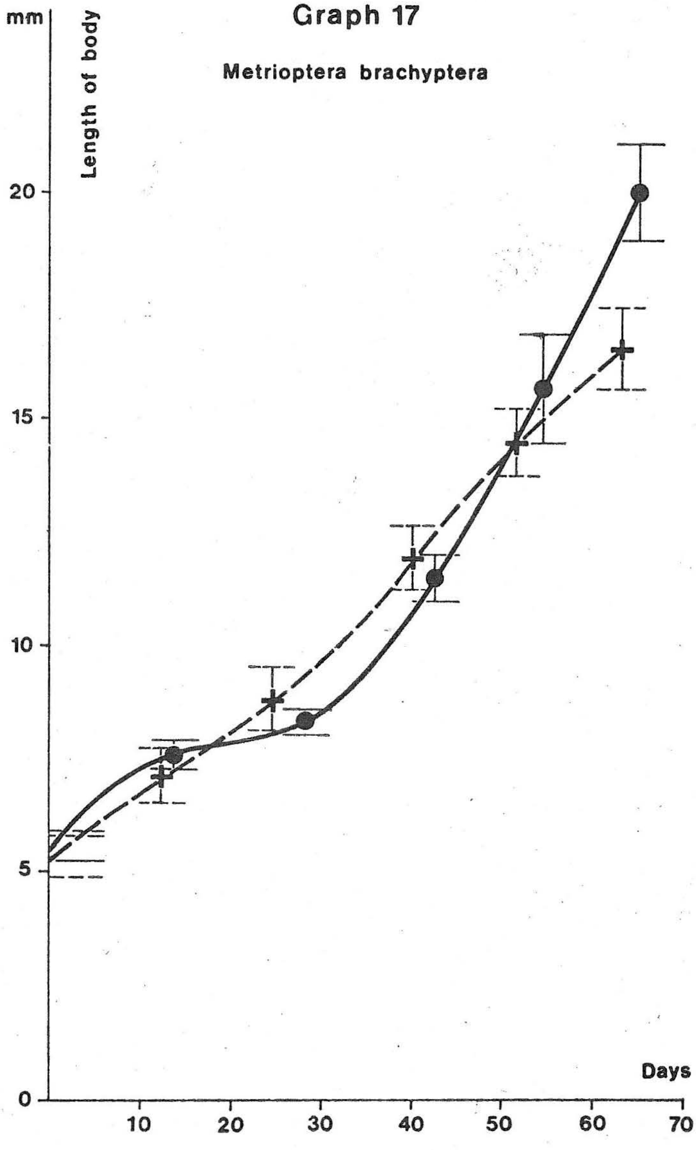
Graph 14: Average width of the vertex of the IInd—VIth instar nymphs and imago.



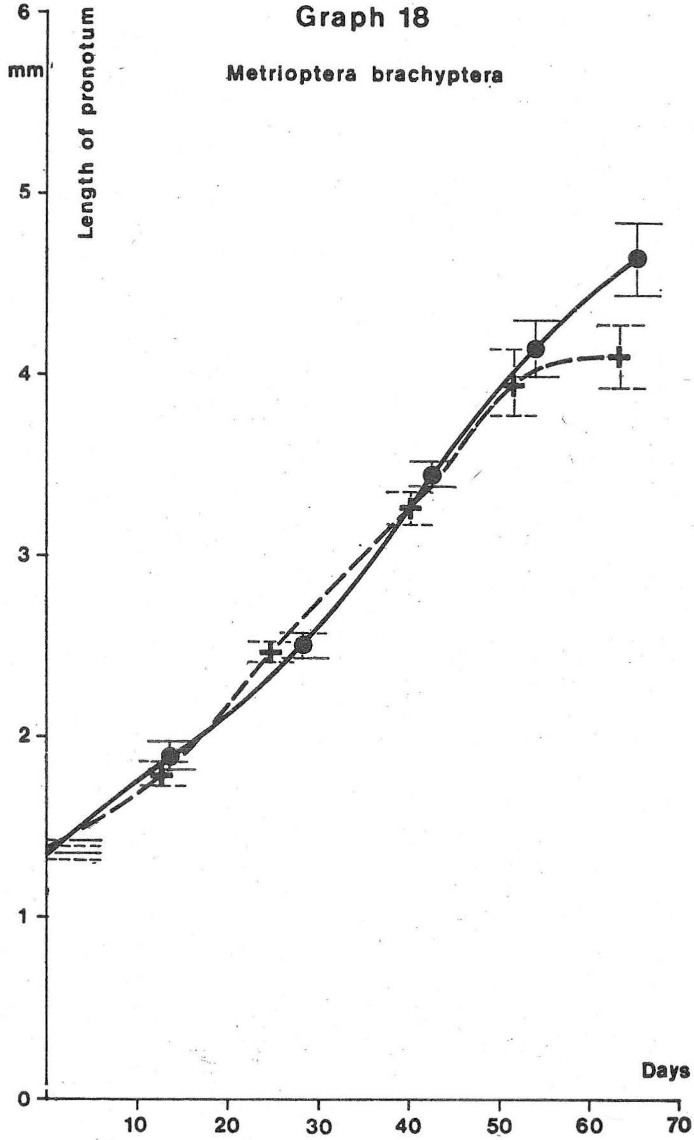
Graph 15: Average length of the cerci of the IInd—VIth instar male nymphs and imago.



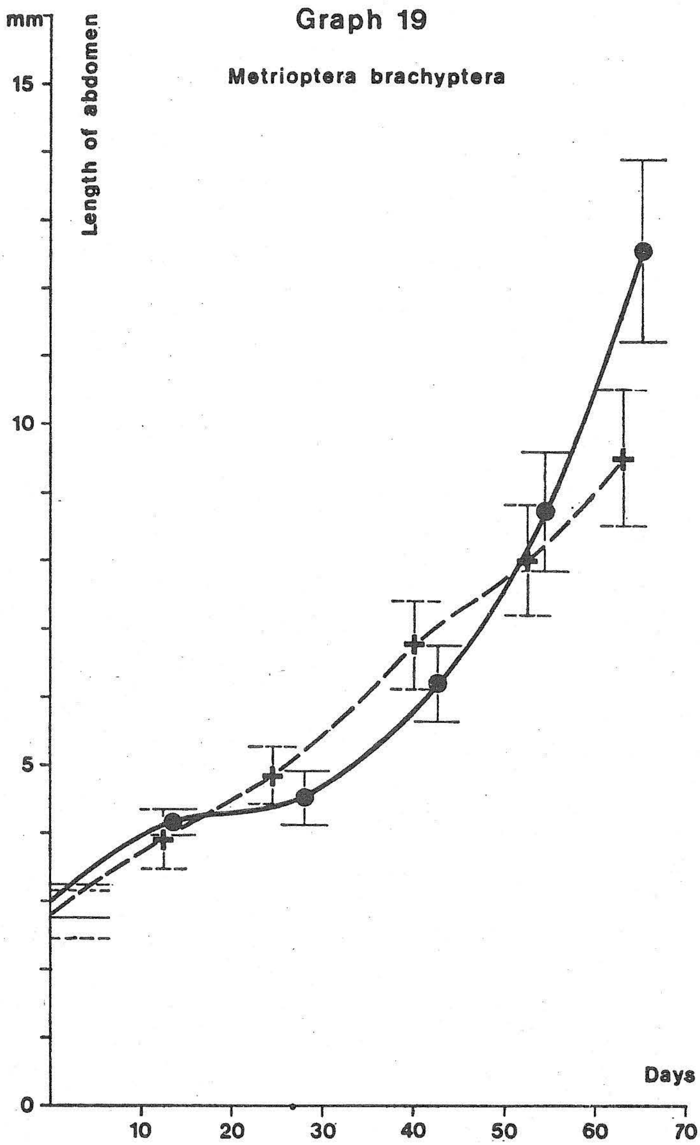
Graph 16: Average length of the ovipositor of the IInd—VIth instar nymphs and imago.



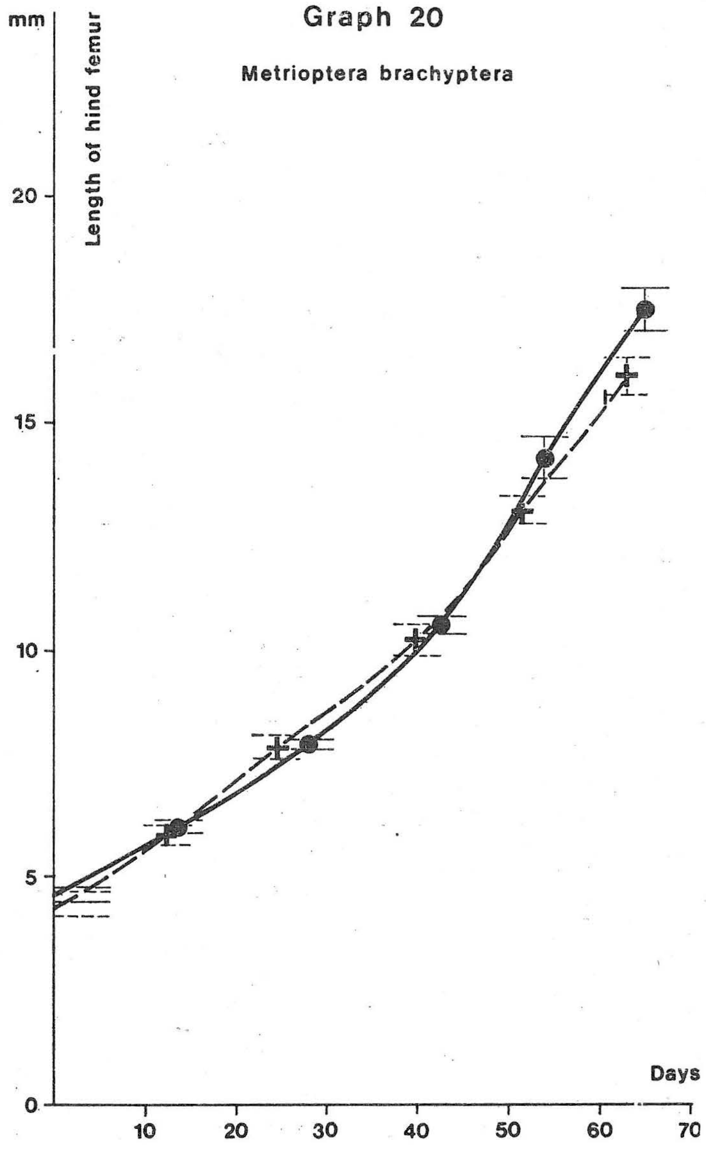
Graph 17: Average body length of the IInd—VIth instar nymphs and imago.



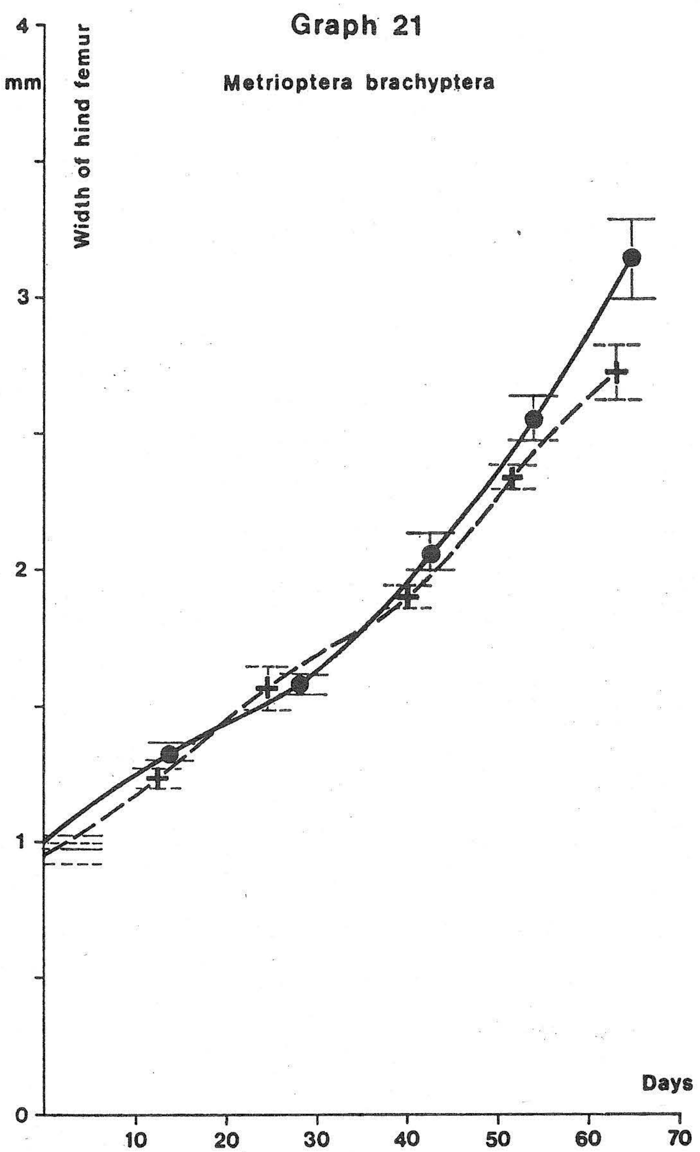
Graph 18: Average length of the pronotum of the IInd—VIth instar nymphs and imago.



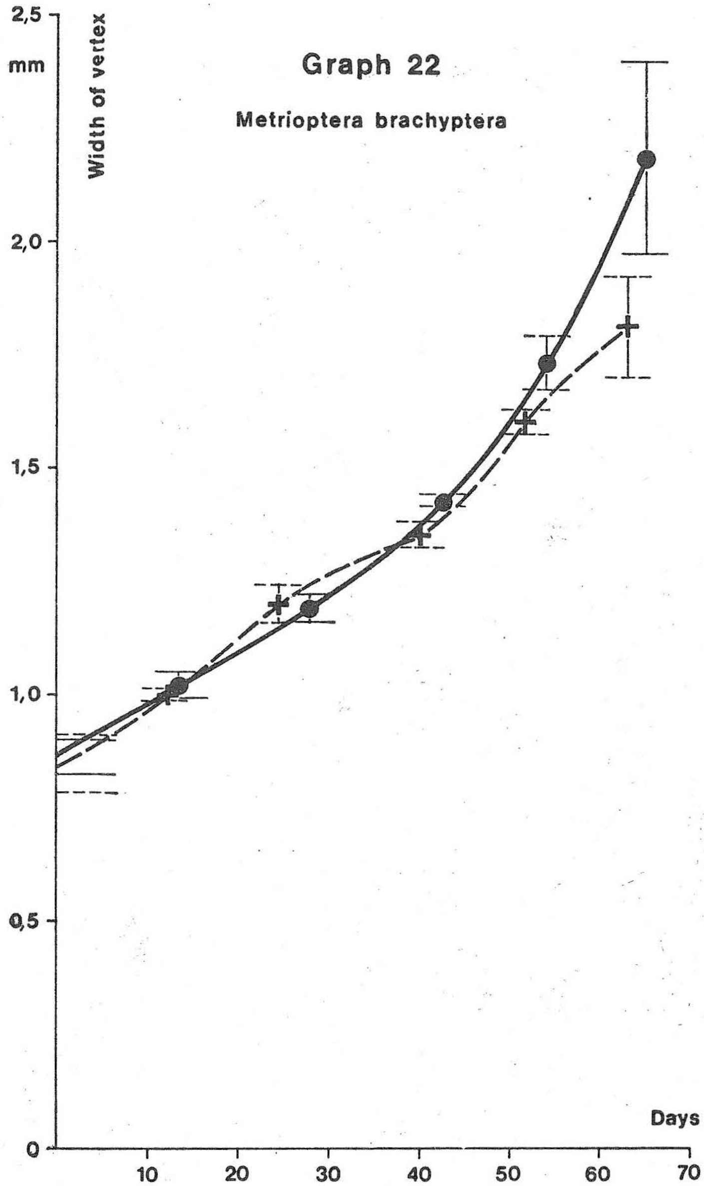
Graph 19: Average length of the abdomen of the IInd—VIth instar nymphs and imago.



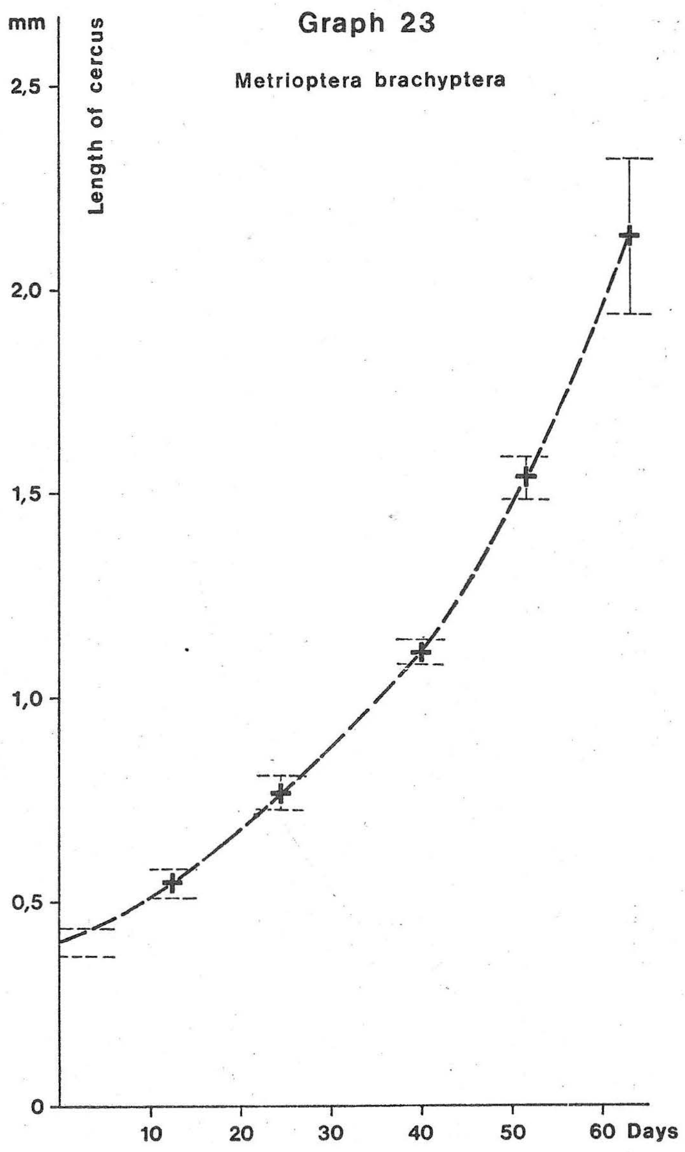
Graph 20: Average length of the hind femur of the IInd—VIth instar nymphs and imago.



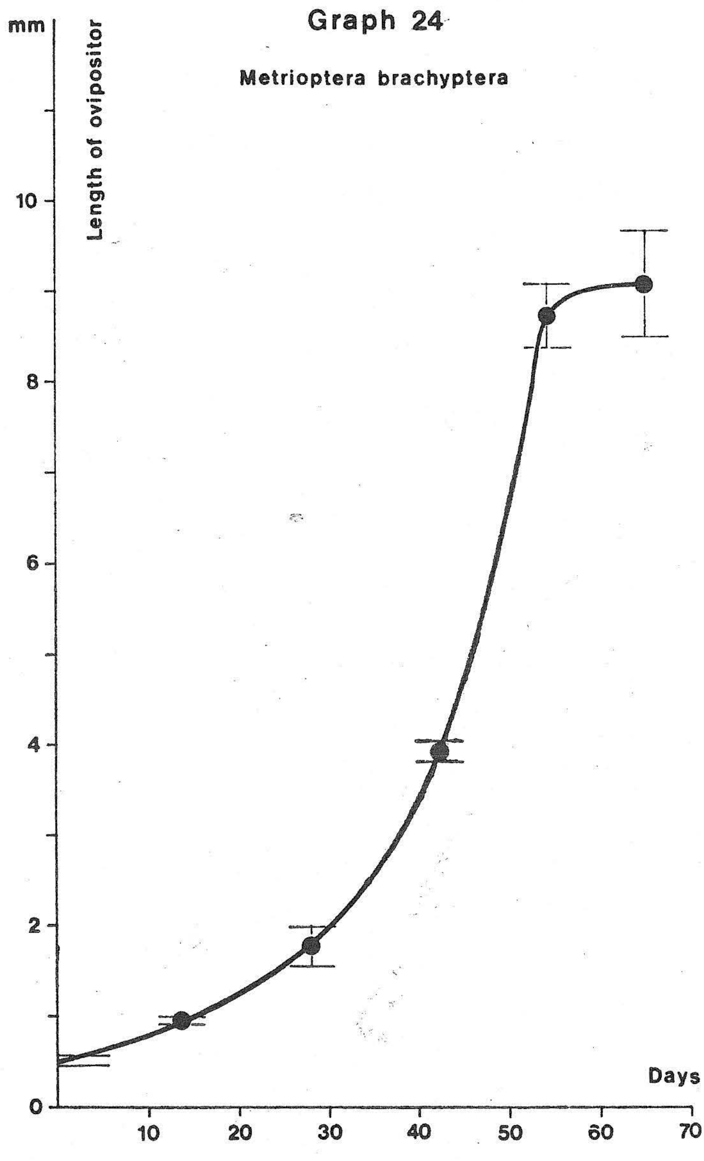
Graph 21: Average width of the hind femur of the IInd—VIth instar nymphs and imago.



Graph 22: Average width of the vertex of the IInd—VIth instar nymphs and imago.



Graph 23: Average length of the cerci of the IInd–VIth instar male nymphs and imago.



Graph 24: Average length of the ovipositor of the IInd—VIth instar nymphs and imago.

The growth of the vertex in width is characterized by the following mean coefficients of growth: *T. cantans* ♂ 1.17, ♀ 1.21. The mean coefficients were higher in the females than in the males. The growth of the vertex in width is shown in Graphs 6, 14 and 22. In *T. cantans* the vertex grew in width almost continuously (Graph 6); after the final moult the growth rate was reduced in both sexes (more conspicuously in the males). The growth coefficients were 1.09 in the males and 1.14 in the females (Tab. 6). Also in *D. verrucivorus* (Graph 14) the vertex grew in width almost continuously (the rate of growth did not decrease after the final moult). In the males of *M. brachyptera* the vertex grew almost continuously, whereas in the females the growth rate increased after the final ecdysis, culminating in the imago (growth coefficient 1.26, while only 1.13 in the males). Minor deviations in the width of the vertex might be due to inaccurate measurement (measurement from a different angle).

The growth of male cerci in length during the postembryonic development was characterized by the following mean coefficients of growth: *T. cantans* 1.44; *D. verrucivorus* 1.33; *M. brachyptera* 1.35. The growth of the cerci is shown in Graphs 7, 15 and 23; in *T. cantans* the rate of growth was increasing after the third moult (Graph 7) until the adult stage in which the greatest increment in length was recorded. Growth proceeded more rapidly after the third moult also in *D. verrucivorus* (Graph 15), but, in contrast to *T. cantans,* the growth rate decreased after the final ecdysis. The cerci of *M. brachyptera* grew in le ıgth (Graph 23) almost continuously between the second and fourth instars. After the fourth moult the rate of growth increased, culminating in the imago (the greatest increment in length).

The growth of the ovipositor in length during the postembryonic development can be characterized by the following average coefficients of growth: *T. cantans* 1.95, *D. verrucivorus* 1.85 and *M. brachyptera* 1.86. The growth of the ovipositor in length, shown in Graphs 8, 16 and 24, was of a typical exponential character. The rate of growth was increasing in all three Tettigonioids from the third instar, when the curve of growth began to rise steeply, particularly in *T. cantans* and *D. verrucivorus.* The maximum rate of growth ended in the sixth instar (point of inflexion), and after the final moult the rate of growth greatly decreased, most conspicuously in *M. brachyptera* (Graph 24). Apparently the growth of the ovipositor is almost completed in the sixth instar; its size increases very slightly in the adult stage. Increments in the length of the ovipositor of all three Tettigonioids almost make up a geometric progression.

On the whole we can say that the overall growth of the body in length proceeds more or less continuously in all three Tettigonioids (the rate of growth markedly increases in *T. cantans* and in the females of *D. verrucivorus* after the final moult). The length of the abdomen also increases in the adult insect, mainly as a result of feeding and growth of reproductive organs. The pronotum of all three species grows almost continuously from the second instar to the fourth. The rate of its growth increases in the fifth instar, but is greatly reduced after the final ecdysis (with the exception of the females of *M. brachyptera*). The abdomen grows in length very unevenly in all three species, so that the rules of its growth cannot be determined. The hind femur grows almost continuously until the fourth instar, then the rate of its growth almost uniformly increases (only in *T. cantans* the growth rate decreases after the final ecdysis). The hind femur also grows in width almost continuously in all three species. The rate of growth increases after the fourth moult (in *T. cantans*

Table I

Mean coefficients of growth

	T. cantans		D. verrucivorus		M. brachyptera	
	♂	♀	♂	♀	♂	♀
Length of body	1.29	1.32	1.26	1.30	1.24	1.30
Length of pronotum	1.34	1.36	1.28	1.29	1.27	1.26
Length of abdomen	1.30	1.34	1.27	1.35	1.26	1.33
Length of hind femur	1.31	1.32	1.30	1.32	1.30	1.33
Width of hind femur	1.22	1.24	1.25	1.27	1.24	1.27
Width of vertex	1.17	1.19	1.21	1.22	1.17	1.21
Length of male cerci	1.44	—	1.33	—	1.35	—
Length of ovipositor	—	1.95	—	1.85	—	1.86

the rate of growth decreases after the final moult). There are differences in the growth in width of the vertex of the Tettigonioids under study. In *T. cantans* it grows almost continuously in both sexes, the growth rate is reduced after the final moult. The vertex of *D. verrucivorus* grows in width similarly, but its growth rate does not decrease after the final ecdysis. In *M. brachyptera* the vertex grows almost continuously in the males, in the females its growth rate increases in the sixth instar and culminates in the imago. The male cerci do not grow in length in a uniform manner. In *T. cantans* the rate of growth increases after the third moult until the adult stage. In *D. verrucivorus* the rate of growth also increases after the third moult, but in contrast to *T. cantans* it decreases after the final ecdysis. The cerci of male *M. brachyptera* grow almost continuously between the second and fourth instars. After the fourth moult the rate of growth increases and culminates in the adult stage. The ovipositor grows in almost the same way in all three species and is of an exponential character. The maximum rate of growth occurs in the sixth instar. The increase in size in the imago is negligible. Increments in the length of the ovipositor almost make up a geometric progression. Čejchan (1957, 1960) made a similar finding in *Metrioptera (Roeseliana) roeselii* (Hgb.).

No changes occur in the size of compact sclerotised structures (e. g. width of the vertex, length of the pronotum, length and width of the hind femur, length of the ovipositor, length of the cerci) during an instar. Minor changes in the size of these sclerotised structures can take place only immediately after ecdysis, when the new cuticle is still soft and pliant. The abdomen grows very unevenly and, consequently, the total body length varies greatly. The relative (allometric) growth was not therefore observed.

VII. The morphology of instars

Descriptions of individual instars of Tettigonia cantans, Decticus verrucivorus and Metrioptera brachyptera

Tettigonia cantans

Ist instar

Male: 4.84—7.00 mm. Wing rudiments absent (Fig. 1). Scape twice as wide as fastigium. Subgenital plate short, its posterior margin with a deep notch exceeding the middle of the plate (Fig. 13). Styli practically absent or minute (Fig. 13). Cerci short, conical, twice as long as wide (Fig. 7). Pronotum not covering meso- and metanotum.

Female: 4.92—7.08 mm. Wing rudiments absent (Fig. 1). Scape twice as wide as fastigium. The rudiment of ovipositor formed by Ist, IInd and IIIrd pairs of valvulae, well visible under high magnification (Fig. 19). Pronotum not covering meso- and metanotum.

IInd instar

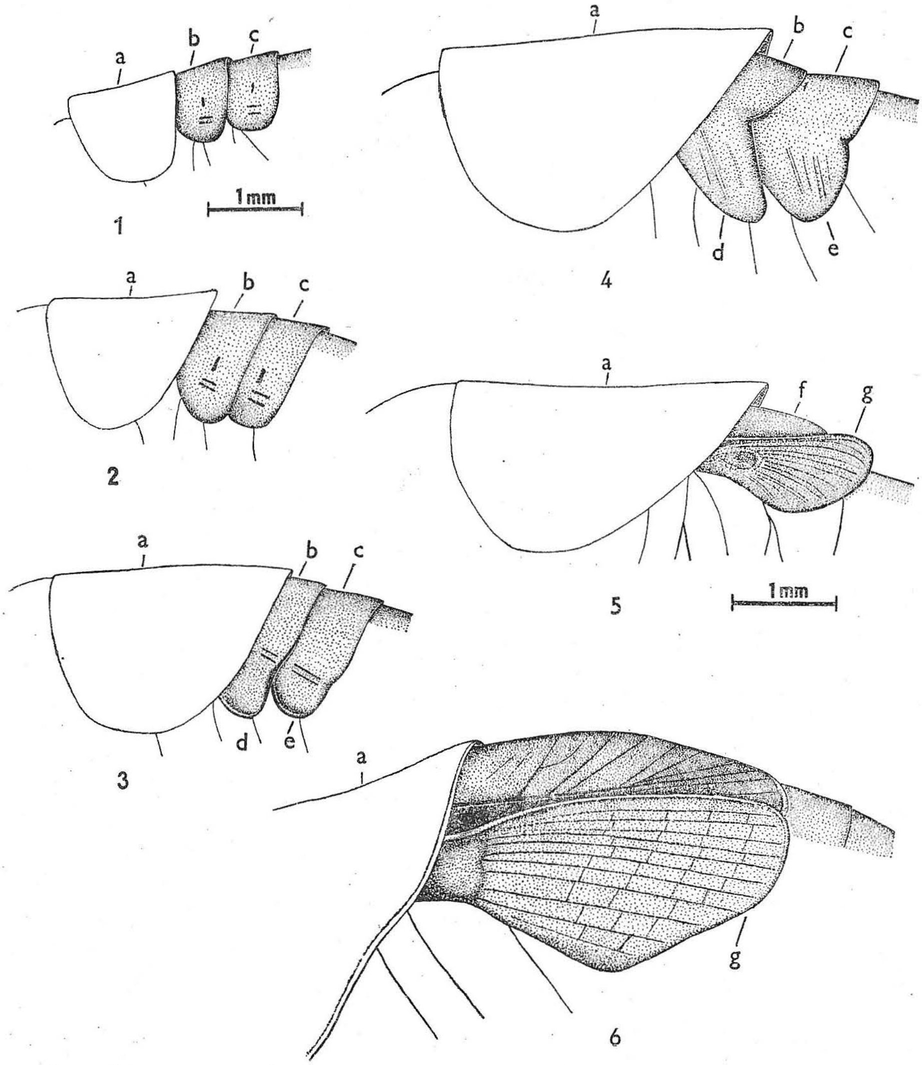
Male: 7.50—9.70 mm. Wing rudiments absent (Fig. 2). Scape twice as wide as fastigium. Subgenital plate (Fig. 14) notched almost to the middle. Styli short, as long as wide. Cerci short, conical, 2.3—2.6 times longer than wide (Fig. 8). Pronotum not covering meso- and metanotum.

Female: 7.17—10.00 mm. Wing rudiments absent (Fig. 2). Scape twice as wide as fastigium. Ovipositor very short, straight, IInd pair of valvulae almost enclosed by Ist and IIIrd pairs (Fig. 20). Pronotum not covering meso- and metanotum.

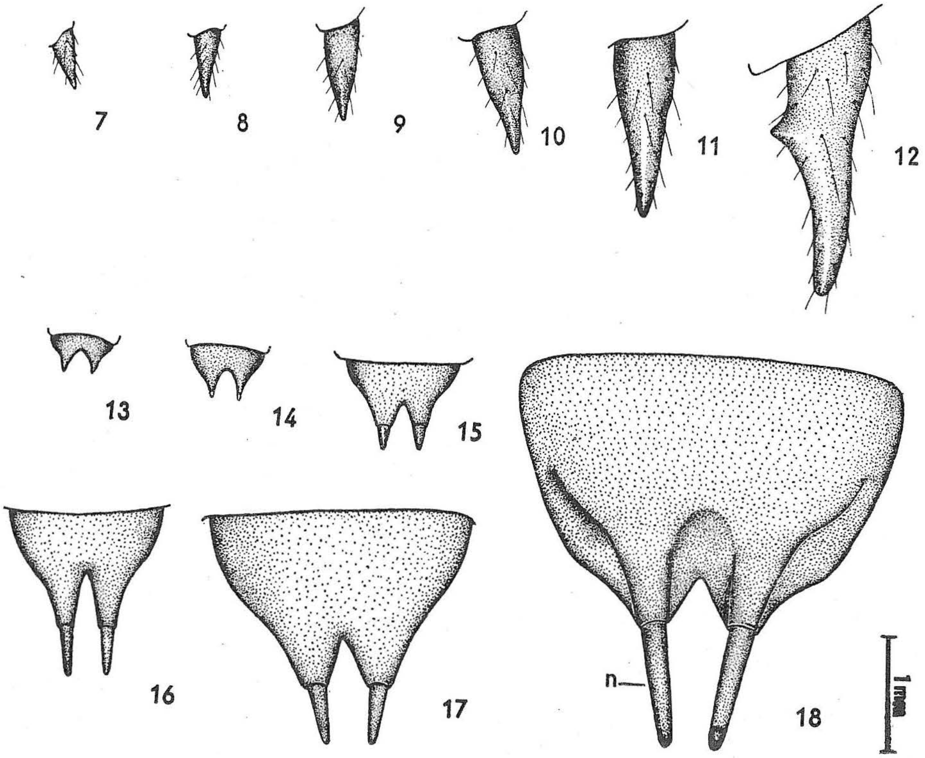
IIIrd instar

Male: 9.17—12.00 mm. Wing rudiments developed in the shape of slightly elongate and rounded lateral lobes of meso- and metanotum (so-called alar and tegminal lobes) (Fig. 3). Notches in the posterior margins of alar and tegminal lobes minute. Scape 1.5 times wider than fastigium. Subgenital plate (Fig. 15) with an acutangular indentation reaching almost to its middle. Styli short, cylindrical, 1.6 to twice as long as wide (Fig. 15). Pronotum extending over one half of mesonotum. Cerci short, conical, 2.2—2.5 times as long as wide (Fig. 9).

Female: 11.00—12.00 mm. Wing rudiments the same as in the male. Scape 1.6 times as wide as fastigium. Ovipositor short, straight, reaching to the apex of abdomen or slightly longer; Ist pair of valvulae reaching to the end of IIIrd pair (Fig. 21). Pronotum covering one half of mesonotum.



Figs. 1—6. Wing development in male *Tettigonia cantans*. Lateral view. Fig. 1. Pronotum, mesonotum and metanotum in Ist instar. Fig. 2. The same in IInd instar. Fig. 3. The same in IIIrd instar. Fig. 4. The same in IVth instar. Fig. 5. Separated wing rudiments in Vth instar. Fig. 6. The same in VIth instar. a = pronotum, b = mesonotum, c = metanotum, d = tegminal lobe, e = alar lobe, f = tegmina, g = wing. Figs. 1—4 and 5—6 drawn under the same magnification.



Figs. 7—18. Development of cerci and subgenital plate in male *Tettigonia cantans*. Figs. 7—12 dorsal view, Figs. 13—18. ventral view. Fig. 7. Right cercus in Ist instar. Fig. 8. The same in IInd instar. Fig. 9. The same in IIIrd instar. Fig. 10. The same in IVth instar. Fig. 13. Subgenital plate in Ist instar. Fig. 14. The same in IInd instar. Fig. 15. The same in IIIrd instar. Fig. 16. The same in IVth instar. Fig. 17. The same in Vth instar. Fig. 18. The same in VIth instar. n = stylus. All figures drawn under the same magnification.

IVth instar

Male: 13.00—15.00 mm. Wing rudiments developed in the shape of alar and tegminal lobes (Fig. 4); indentations in the posterior margin of the lobes deeper than in the previous instar. Venation of both tegminal and alar lobes distinct. Scape 1.4 times wider than fastigium. Subgenital plate (Fig. 16) very sharply notched almost to the middle. Styli narrow, cylindrical, 3.1—3.6 times as long as wide. Cerci longer, conical, 2.6—3 times longer than wide (Fig. 10). Pronotum covering more than one half of mesonotum.

Female: 13.00—16.00 mm. The bases of wings developed similar to the male. Scape 1.3 times wider than fastigium. Ovipositor (Fig. 22) longer than in the previous instar, straight, protruding beyond the apex of abdomen by almost one half. Pronotum covering more than one half of mesonotum.

Vth instar

Male: 17.00—20.00 mm. Wing rudiments already separated from meso- and metanotum and situated dorsolaterally (Fig. 5). Wing markedly longer than tegmina (Fig. 5), situated in front of tegmina in inverse position. Tegminae not in contact by their posterior margins. Wing venation distinct, less so in tegmina. Scape only 1.1—1.2 times wider than fastigium. Subgenital plate (Fig. 17) with an acutangular notch reaching to $^1/_4$ of its length. Styli long, cylindrical, 3.3—4 times as long as wide. Cerci longer, conical, 2.9—3 times as long as wide. Pronotum covering mesonotum.

Female: 18.00—20.00 mm. Wing rudiments developed as in the male. Scape only 1.1—1.2 times as wide as fastigium. Ovipositor longer, almost straight, protruding beyond the apex of abdomen by more than $^2/_3$ (sometimes almost $^3/_4$). Pronotum covering mesonotum.

VIth instar

Male: 17.00—25.00 mm. Wings more developed than in the previous instar (Fig. 6). Tegmina as long as or somewhat longer than wing, reaching to the posterior margin of IInd abdominal tergite. Wing broad, situated in front of tegmina in inverse position. Venation of wing and tegmina well visible. Tegminae in contact by their posterior margins. Scape only 1.2 times wider than fastigium. Subgenital plate (Fig. 18) almost fully developed. Styli long, cylindrical, 4.3—5 times as long as wide. Cerci long, their outer side concave in the middle, the inner side with an obtuse denticle in the basal third (Fig. 12). Pronotum covering mesonotum.

Female: 21.00—26.00 mm. Wing development similar to the male. Scape 1.1—1.2 times as wide as fastigium. Ovipositor long, slightly curved, its apex pointed. It differs from the ovipositor of the imago only by smaller size. Pronotum covering mesonotum.

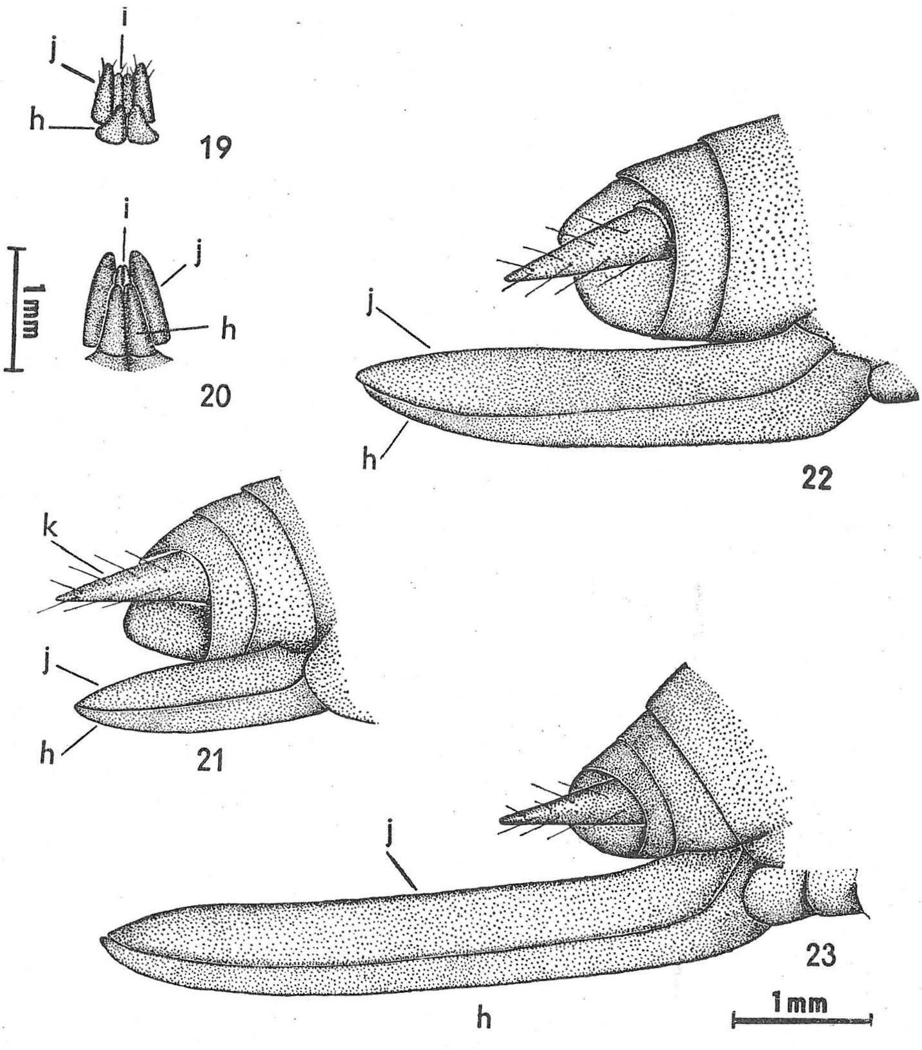
The basic coloration of all instar of both sexes is light green. A very narrow, pale yellow median on the dorsal side of the body, beginning posteriorly of fastigium, runs through occiput, pronotum, meso- and metanotum and abdominal tergites to anal plate.

Decticus verrucivorus

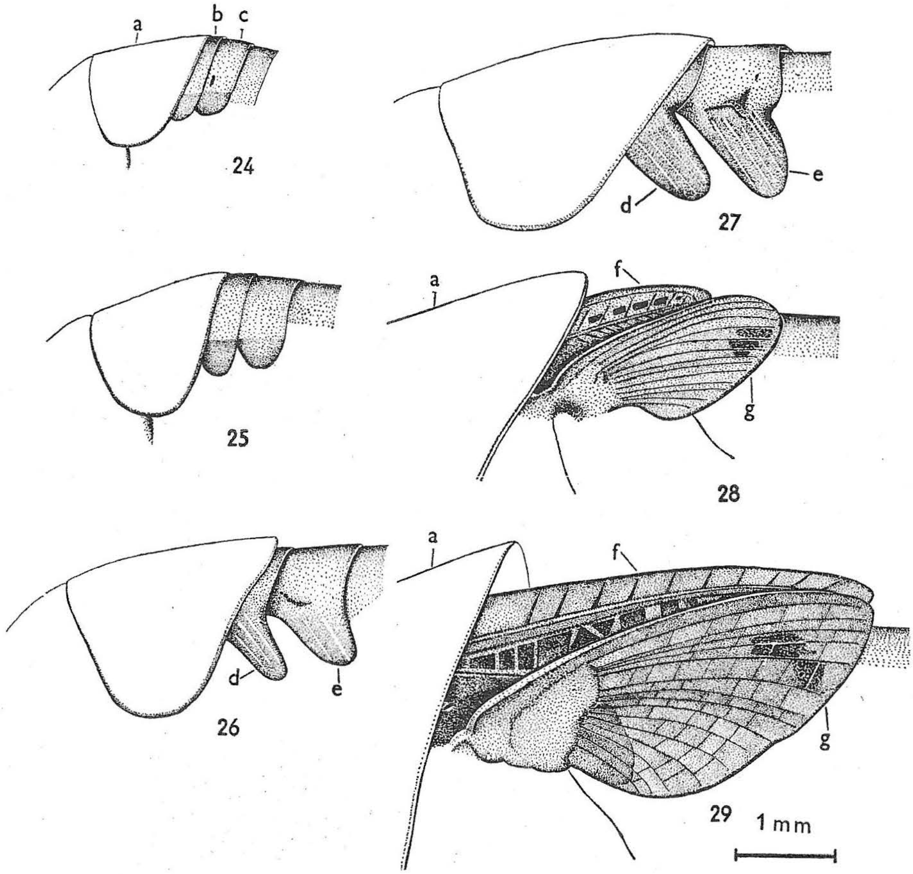
Ist instar

Male: 7.25—8.17 mm. Wing rudiments absent (Fig. 24). Fastigium 1.7—1.8 times as wide as scape. Subgenital plate (Fig. 36) short, notched almost to half its length. Styli very short, as long as wide or shorter than wide. Cerci (Fig. 30) short, conical, 1.8—2 times as long as wide, with pointed apices. Pronotum covering $^1/_3$ of mesonotum.

Female: 6.92—8.50 mm. Wing rudiments absent. Fastigium 1.8—1.9 times as wide as scape. The rudiments of ovipositor formed by Ist, IInd and IIIrd pairs of valvulae, visible under high magnification. The rudiments of Ist valvulae



Figs. 19—23. Development of ovipositor in female *Tettigonia cantans*. Figs. 19—20 ventral view, Figs. 21—23. lateral view. Fig. 19. Rudiments of ovipositor in Ist instar. Fig. 20. The same in IInd instar. Fig. 21. Apical part of abdomen and rudiment of ovipositor in IIIrd instar. Fig. 22. The same in IVth instar. Fig. 23. The same in Vth instar. h = Ist pair of valvulae, i = IInd pair of valvulae, j = IIIrd pair of valvulae, k = cercus. Figs. 19—20 and 21—23 drawn under the same magnification.



Figs. 24—29. Wing development in male *Decticus verrucivorus*. Lateral view. Fig. 24. Pronotum, mesonotum and metanotum in Ist instar. Fig. 25. The same in IInd instar. Fig. 26. The same in IIIrd instar. Fig. 27. The same in IVth instar. Fig. 28. Separated wing rudiments in Vth instar. Fig. 29. The same in VIth instar. a = pronotum, b = mesonotum, c = metanotum, d = tegminal lobe, e = alar lobe, f = tegmina, g = wing. All figures drawn under the same magnification.

divergent, strong, with rounded apices. The rudiments of IInd valvulae cylindrical, in contact by their inner margins; not reaching to the apices of IIIrd valvulae. Pronotum reaching to the middle of mesonotum or slightly beyond it.

IInd instar

Male: 8.00—11.00 mm. Wing rudiments absent (Fig. 25). Fastigium 1.8—1.9 times as wide as scape. Subgenital plate (Fig. 37) with an acutangular notch reaching to its third. Styli very short, almost as long as wide or very slightly longer than wide. Cerci short (Fig. 31), conical, 1.8—2.5 times as long as wide; their apices pointed. Pronotum covering half the mesonotum.

Female: 8.50—11.00 mm. Wing rudiments absent (Fig. 25). Fastigium 2.0—2.1 times wider than scape. Ovipositor short, straight; IInd valvulae enclosed by Ist and IIIrd pairs (Fig. 43). Ist valvulae narrower than IIIrd and not reaching to their apices. Pronotum covering $^1/_2$ to $^2/_3$ of mesonotum.

IIIrd instar

Male: 10.20—14.90 mm. Wing rudiments developed in the shape of posteriorly elongated, rounded alar and tegminal lobes (Fig. 26). Tegminal lobes markedly narrower than alar ones. Venation detectable in both lobes. Indentations in the posterior margins of tegminal and alar lobes rounded. Fastigium 2.1—2.3 times wider than scape. Subgenital plate (Fig. 38), narrowly notched up to $^1/_6$ of its length. Styli short, cylindrical, 2.2 to 2.5 times as long as wide. Cerci short, conical, 2.7—3 times longer than wide (Fig. 32), with pointed apices. Pronotum covering at least half the mesonotum (sometimes whole).

Female: 9.59—13.00 mm. Wing rudiments developed as in the male. Fastigium 2.3 times wider than scape. Ovipositor short, protruding very slightly beyond the apex of abdomen (Fig. 44). Ist pair of valvulae reaching (or almost reaching) to the apices of IIIrd valvulae. Pronotum covering almost the whole mesonotum.

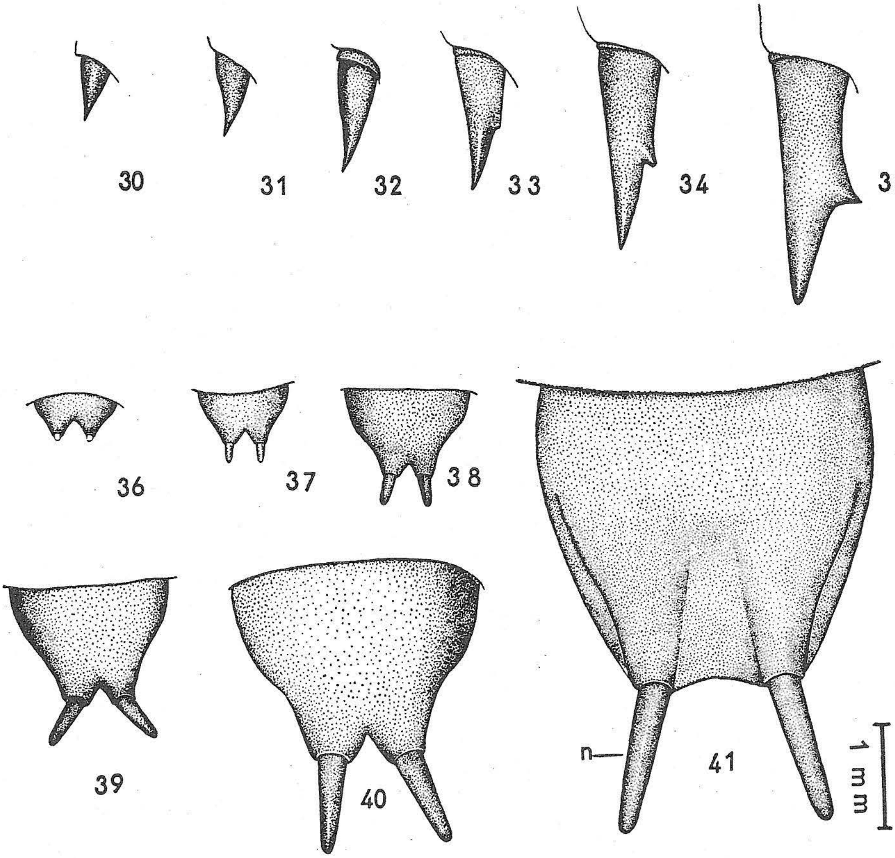
IVth instar

Male: 14.40—17.50 mm. Wing rudiments developed in the shape of posteriorly elongated and rounded tegminal and alar lobes (Fig. 27). Tegminal lobes markedly narrower than alar ones; notches in their posterior margins deeper and sharper, venation more distinct than in the previous instar. Fastigium 2.3—2.6 times wider than scape. Subgenital plate (Fig. 39) with a very short indentation. Styli short, cylindrical, 2.9—3.2 times longer than wide. Cerci longer, conical, 2.9—3.3 times as long as wide, a small obtuse denticle developing on their inner side posteriorly to the middle (Fig. 33). Pronotum covering more than $^2/_3$ mesonotum (sometimes up to one half only).

Female: 13.50—16.00 mm. Wing rudiments developed similarly to the male. Fastigium 2.5 times as wide as scape. Ovipositor (Fig. 45) longer than in the previous instar, slightly curved in lateral view, protruding at least by one half beyond the apex of abdomen (note: the apex of abdomen in Fig. 45 was pushed in a fixation, so that the ovipositor protrudes beyond the abdomen by more than a half). Pronotum in most cases covering the whole mesonotum and sometimes even half the metanotum.

Vth instar

Male: 17.00—22.00 mm. Wing rudiments already separated from meso- and metanotum, in dorsolateral position (Fig. 28). Wing noticeably longer than tegmina, in inverse position in front of it and reaching to the posterior



Figs. 30—41. Development of cerci and subgenital plate in male *Decticus verrucivorus*. Figs. 30—35. dorsal view. Figs. 36—41. ventral view. Fig. 30. Left cercus in Ist instar. Fig. 31. The same in IInd instar. Fig. 32. The same in IIIrd instar. Fig. 33. The same in IVth instar. Fig. 34. The same in Vth instar. Fig. 35. The same in VIth instar. Fig. 36. Subgenital plate in Ist instar. Fig. 37. The same in IInd instar. Fig. 38. The same in IIIrd instar. Fig. 39. The same in IVth instar. Fig. 40. The same in Vth instar. Fig. 41. The same in VIth instar. n = stylus. All figures drawn under the same magnification.

margin of IInd abdominal tergite. Tegminae not in contact by their posterior margins. Venation of tegmina and wing well visible (more distinct in the latter). A typical pattern distinct in tegmina. Fastigium 2.6—2.9 times wider than scape. Subgenital plate (Fig. 40) very slightly notched. Styli longer, cylindrical, 3.3—3.8 times as long as wide. Cerci longer, conical, 3.1—3.8 times as long as wide (Fig. 34), with a small obtuse denticle posteriorly to the middle of their inner side (Fig. 34). Pronotum covering half the metanotum.

Female: 14.00—24.00 mm. Wing rudiments developed similarly to the male. Wing at least twice as broad as tegmina. Fastigium 2.6—2.7 times wider than scape. Ovipositor longer, slightly curved, at least $^3/_4$ of its length protruding beyond the apex of abdomen (Fig. 46). Pronotum covering almost the whole metanotum.

VIth instar

Male: 20.00—27.00 mm. Development of wings very advanced. Wing as long as tegmina (Fig. 29), reaching to the posterior margin of IVth abdominal tergite. Venation of wing and tegmina well visible, the typical pattern distinct, particularly in tegmina. Tegminae in contact by their posterior margins. Fastigium 2.9—3.1 times wider than scape. Subgenital plate (Fig. 41) almost fully developed. Styli long, cylindrical, 4—4.4 times as long as wide. Cerci cylindrical in the basal half, conical in the apical region, 3.2—3.6 times longer than wide; with a bigger and sharper denticle posterior to the middle of the inner side (Fig. 35). Pronotum covering metanotum.

Female: 22.00—31.00 mm. Wing broad, somewhat longer than tegmina. The degree of development similar to the male. Fastigium 2.8—3 times wider than scape. Ovipositor long (16—19 mm), slightly curved upwards. Pronotum covering metanotum.

The basic coloration of all instars of both sexes is light brown, the posterior margins of the pronotum, mesonotum and metanotum as well as of all abdominal tergites are dotted in dark brown to black. Both lateral sides of the abdomen with a dark brown, longitudinal stripe. Lateral lobes of the pronotum and lateral lobes of the meso- and metanotum with dark brown to black spots. Hind femora with a dark brown spot in the basal part of the outer side. The disc of the pronotum and the middle of abdominal tergites green in some specimens (this coloration may extend to the occiput and vertex).

Metrioptera brachyptera

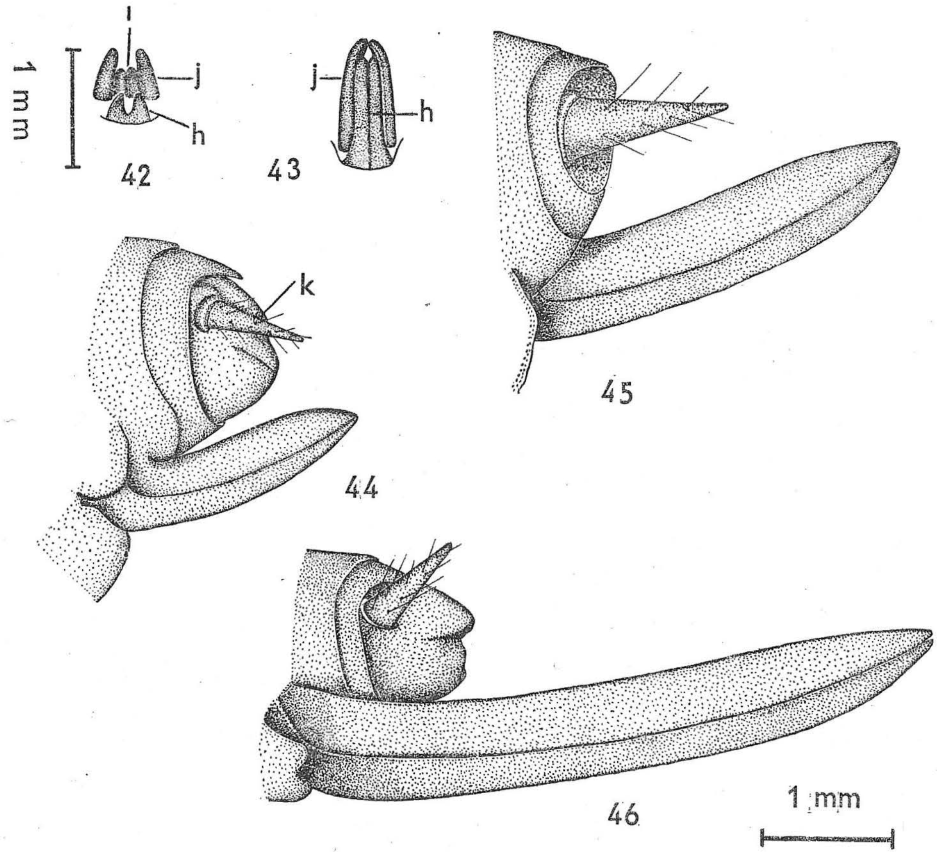
Ist instar

Male: 3.92—4.75 mm. Wing rudiments absent (Fig. 47). Fastigium 1.3—1.5 times as wide as scape. Subgenital plate (Fig. 59) short, indented at least to the middle (sometimes more). Styli absent (Fig. 59). Cerci short, conical, twice as long as wide (Fig. 53). Pronotum covering $^1/_4$ to $^1/_2$ of mesonotum.

Female: 3.08—5.08 mm. Wing rudiments absent. Fastigium 1.6—1.8 times wider than scape. The rudiment of ovipositor formed by Ist, IInd and IIIrd pairs of valvulae (Fig. 65) noticeable under high magnification. Ist valvulae shaped as minute protuberances on VIIIth abdominal segment, IInd valvulae as small tubercles between IIIrd valvulae. IIIrd pair of valvulae largest, usually triangular with rounded apices. Ist valvulae usually dark brown to black, behind them is a shallow depression of the same colour. Pronotum covering about $^1/_4$ of mesonotum.

IInd instar

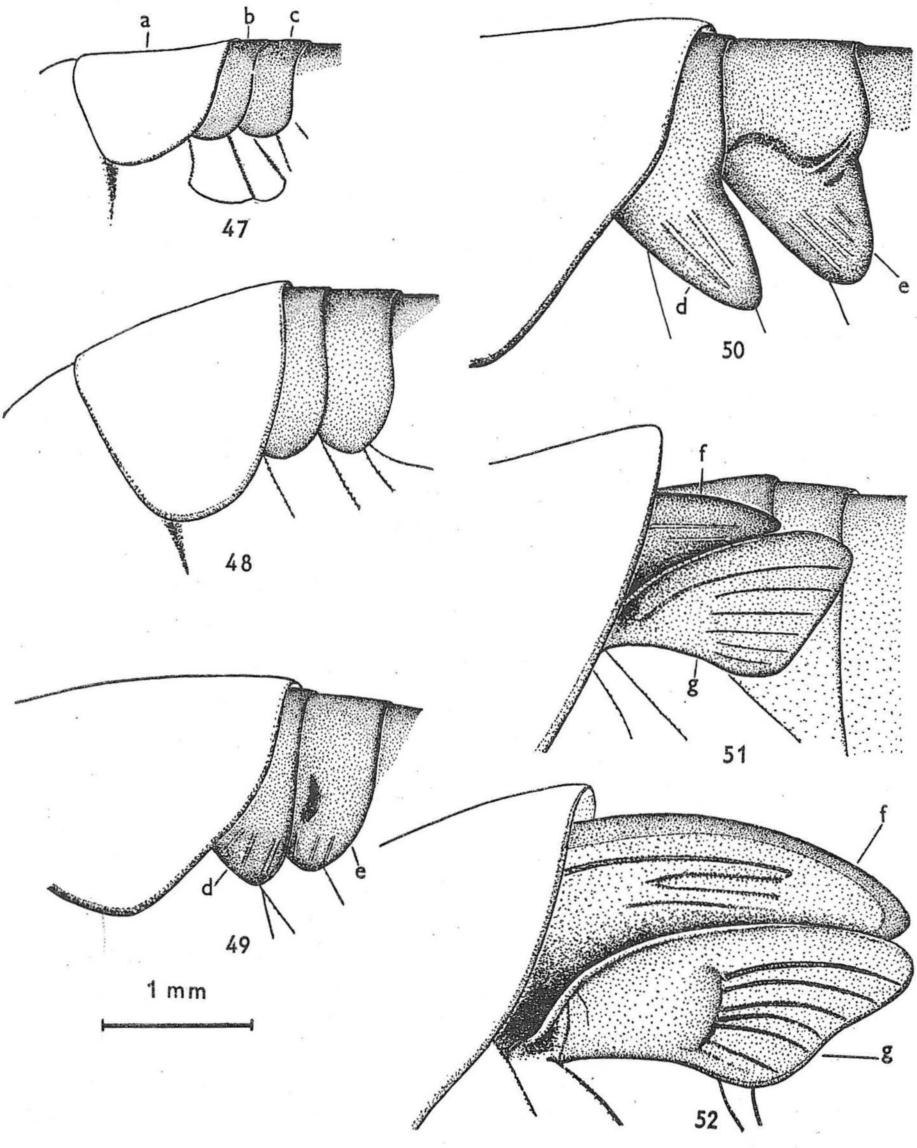
Male: 4.67—6.34 mm. Wing rudiments absent (Fig. 48). Fastigium 1.6—1.7 times longer than scape. Subgenital plate (Fig. 60) short, with an arch-like



Figs. 42—46. Development of ovipositor in female *Decticus verrucivorus*. Figs. 42—43. ventral view. Figs. 44—46. lateral view. Fig. 42.Rudiments of ovipositor in Ist instar. Fig. 43. The same in IInd instar. Fig. 44. Apical part of abdomen and rudiment of ovipositor in IIIrd instar. Fig. 45. The same in IVth instar. Fig. 46. The same in Vth instar. h = Ist pair of valvulae, i = IInd pair of valvulae, j = IIIrd pair of valvulae, k = cercus .Figs. 42—45. drawn under the same magnification.

indentation reaching almost to half its length. Styli very small, as long as wide (Fig. 60). Cerci short, conical, 2.5—2.7 times as long as wide (Fig. 54). Pronotum covering $^1/_4$ to $^1/_2$ of mesonotum.

Female: 5.00—6.00 mm. Wing rudiments absent. Fastigium 1.5—1.7 times wider than scape. The rudiment of ovipositor formed by detectable Ist, IInd and IIIrd valvulae (Fig. 66). Ist valvulae triangular with rounded apices, IInd valvulae cylindrical, markedly narrower and shorter than IIIrd valvulae, which are strong, cylindrical, with rounded apices. Pronotum covering almost half the mesonotum.



Figs. 47—52. Wing development in male *Metrioptera brachyptera*. Lateral view. Fig. 47. Pronotum, mesonotum and metanotum in Ist instar. Fig. 48. The same in IInd instar. Fig. 49. The same in IIIrd instar. Fig. 50. The same in IVth instar. Fig. 51. Separated wing rudiments in Vth instar. Fig. 52. The same in VIth instar. a = pronotum, b = mesonotum, c = metanotum, d = tegminal lobe, e = alar lobe, f = tegmina, g = wing. All figures drawn under the same magnification.

IIIrd instar

Male: 6.25—8.42 mm. Wing rudiments developed in the shape of slightly elongate and rounded tegminal and alar lobes (Fig. 49). Venation detectable. Fastigium 1.8—1.9 times wider than scape. Subgenital plate (Fig. 61) notched to $^1/_3$ of its length. Styli short, cylindrical, very slightly longer than wide. Cerci longer, conical, 2.6—2.8 times as long as wide (Fig. 55). Pronotum covering or almost covering mesonotum.

Female: 7.08—8.40 mm. Wing rudiments developed similarly to the male. Fastigium 1.8—2 times wider than scape. Ovipositor short, narrow, straight (in lateral view), reaching or almost reaching to the apex of abdomen (Fig. 67). IInd pair of valvulae completely enclosed by Ist and IIIrd valvulae. Ist valvulae shorter than IIIrd. Pronotum overlapping the middle of mesonotum.

IVth instar

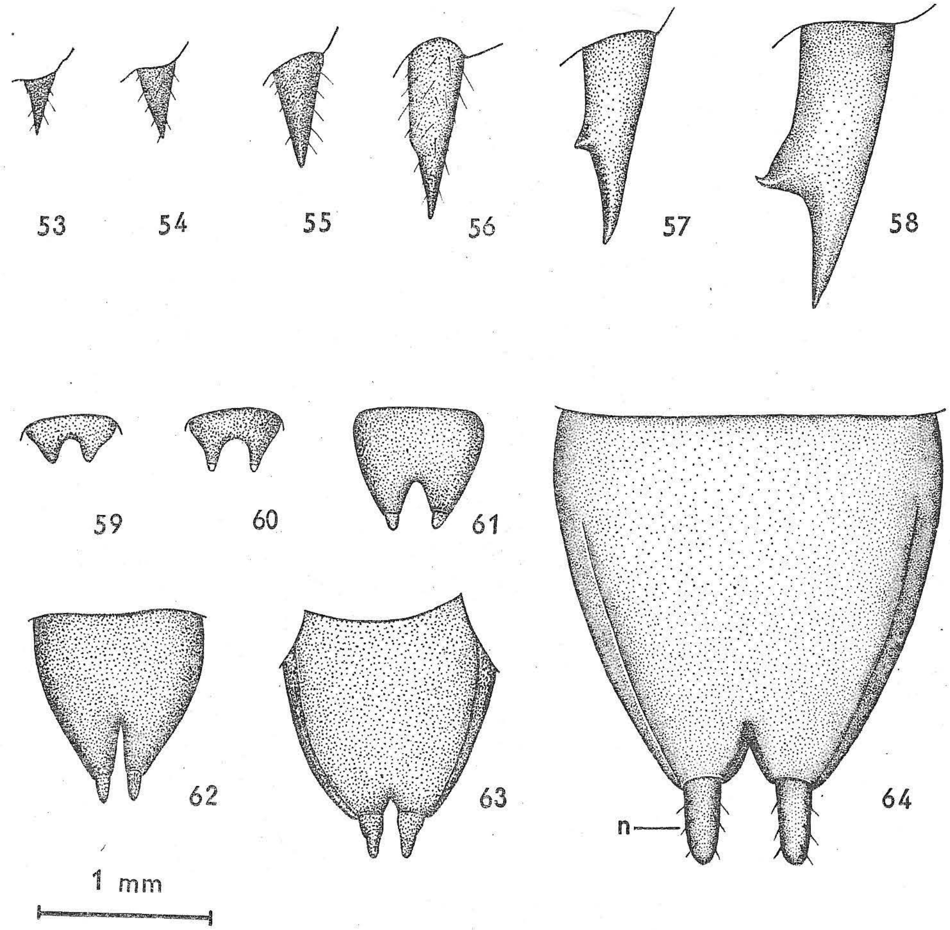
Male: 7.66—10.17 mm. Wing rudiments developed in the shape of posteriorly elongated and rounded tegminal and alar lobes (Fig. 50). Notch in the posterior margin of tegminal and alar lobes distinct, also venation more pronounced than in IIIrd instar. Fastigium 2.1—2.3 times as wide as scape. Subgenital plate (Fig. 62) with a very narrow notch reaching to $^1/_4$ or $^1/_3$ of its length. Styli short, cylindrical, twice as long as wide. Cerci short, conical, with a small obtuse denticle on the inner side posterior to its middle (Fig. 56), 2.5—2.8 times as long as wide. Pronotum covering or almost covering mesonotum.

Female: 7.25—9.40 mm. Wing rudiments developed as in the male. Fastigium 2—2.2 times wider than scape. Ovipositor slightly curved in lateral view, protruding beyond the apex of abdomen by almost half its length (Fig. 68). Pronotum covering half the mesonotum (in some cases the whole mesonotum).

Vth instar

Male: 11.00—12.50 mm. Wing rudiments already separated from meso- and metanotum, situated dorsolaterally (Fig. 51). Wing broad (almost twice as wide as tegmina), distinctly longer than tegmina, very slightly overlapping Ist abdominal tergite, in inverse position in front of tegmina. Tegminae not in contact by their hind margins. Venation of tegmina and wing distinct. Fastigium 2—2.3 times as wide as scape. Subgenital plate (Fig. 63) very slightly notched. Styli thicker, cylindrical, 2.2—2.5 times as long as wide. Cerci longer, conical, 2.6—3.2 times as long as wide, with a larger and sharper denticle on the inner side (Fig. 57). Pronotum covering half the metanotum.

Female: 11.00—12.00 mm. Wing rudiments developed similarly to the male. Tegmina short, overlapping the middle of wing. Fastigium 2.3—2.4 times wider than scape. Ovipositor (in lateral view) slightly curved upwards, almost $^2/_3$ of its length protruding beyond the apex of abdomen (Fig. 69). Pronotum covering $^1/_3$ to $^1/_2$ of metanotum.



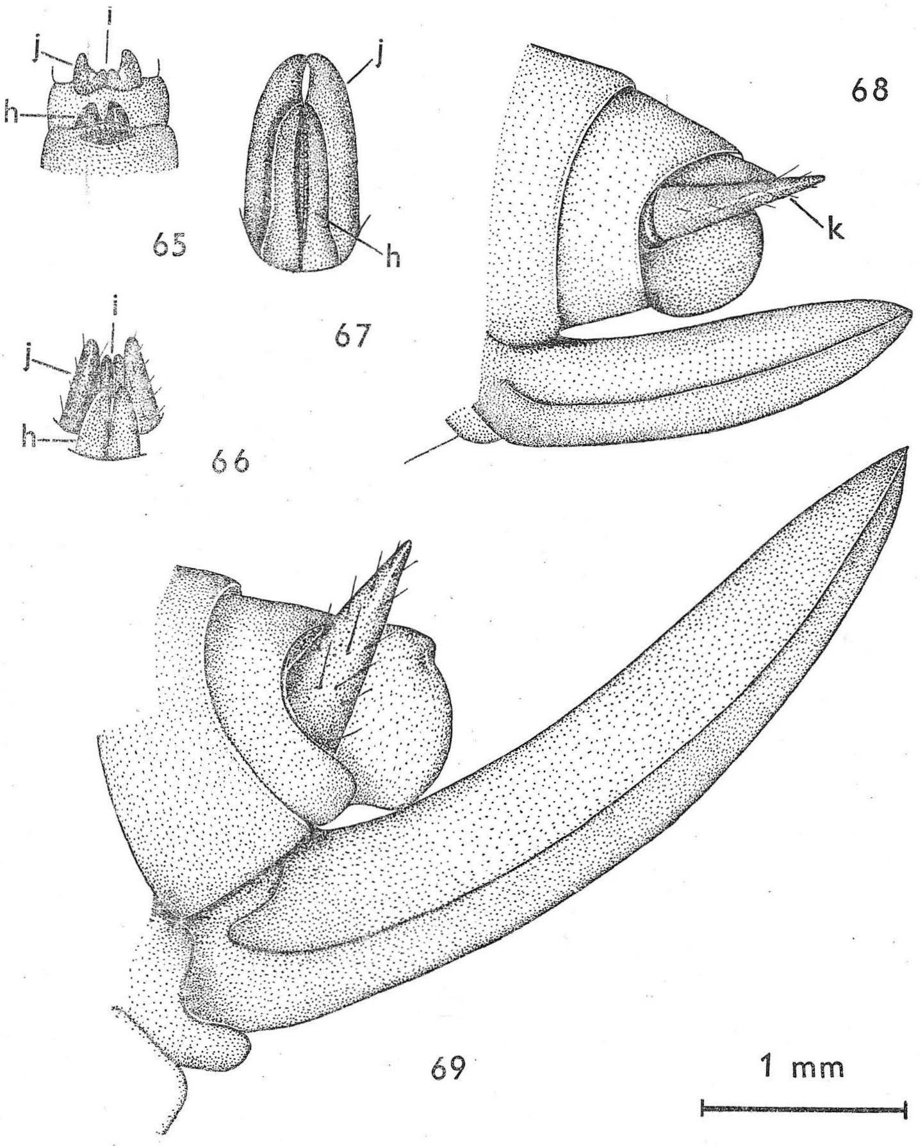
Figs. 53–64. Development of cerci and subgenital plate in male *Metrioptera brachyptera*. Figs. 53–58. dorsal view. Figs. 59–64. ventral view. Fig. 53. Right cercus in Ist instar. Fig. 54. The same in IInd instar. Fig. 55. The same in IIIrd instar. Fig. 56. The same in IVth instar. Fig. 57. The same in Vth instar. Fig. 58. The same in VIth instar. Fig. 59. Subgenital plate in Ist instar. Fig. 60. The same in IInd instar. Fig. 61. The same in IIIrd instar. Fig. 62. The same in IVth instar. Fig. 63. The same in Vth instar. Fig. 64. The same in VIth instar. n = stylus. All figures drawn under the same magnification.

VIth instar

Male: 13.00—16.00 mm. Wing rudiments separated from meso- and metanotum (Fig. 52), their development more advanced. Tegmina as long as or longer than wing, reaching to the posterior margin of IInd abdominal tergite. Wing still inversely situated in front of tegmina. Tegminae in contact by their posterior margins. Venation of tegmina as well as wing distinct. Fastigium 2.4—2.5 times as wide as scape. Subgenital plate (Fig. 64) almost fully developed. Styli longer, thick, cylindrical, 2.3—2.6 times as long as wide. Cerci cylindrical in the basal half, apical part conical, with a larger sharp denticle posterior to the middle of the inner side (Fig. 58); they are 3.2—3.4 times as long as wide. Pronotum covering metanotum.

Female: 14.00—18.000 mm. Wing rudiments developed as in the male. Tegmina as long as or longer than wing, reaching to the posterior margin of IInd abdominal tergite. Fastigium 2.4—2.8 times wider than scape. Ovipositor longer, slightly curved upwards, almost fully developed, only a little shorter than in the adult stage. Pronotum covering matanotum.

Basic coloration brown. A pale grey median running from fastigium on head through occiput, pronotum, meso- and metanotum and abdominal tergites to anal plate. The lateral side of abdomen dark brown to black brown, lateral lobes of pronotum dark brown. A conspicuous, narrow, white stripe running caudad along the lower side of lateral lobes. Hind femora with a longitudinal dark brown stripe on the outer side. Eyes black in early instars, later dark brown.



Figs. 65—69. Development of ovipositor in female *Metrioptera brachyptera*. Figs. 65—67. ventral view. Figs. 68—69. lateral view. Fig. 65. Rudiments of ovipositor in Ist instar. Fig. 66. The same in IInd instar. Fig. 67. The same in IIIrd instar. Fig. 68. Apical part of abdomen and rudiment of ovipositor in IVth instar. Fig. 69. The same in Vth instar. h = Ist pair of valvulae, i = IInd pair of valvulae, j = IIIrd pair of valvulae, k = cercus. All figures drawn under the same magnification.

Key to the instars

Tettigonia cantans

Male:

1/4 Wing rudiments absent (Figs. 1, 2). Scape twice as wide as fastigium. Length of hind femur: 3.67—5.34 mm.

2/3 Subgenital plate (Fig. 13) very small, indented to more than half its length, styli absent (or very little developed). Length of hind femur: 3.67—4.10 mm. .... Ist instar

3/2 Subgenital plate (Fig. 14) larger, indented to less than half its length, styli short, as long as wide (Fig. 14). Length of hind femur: 4.59—5.34 mm...... .... IInd instar

4/1 Wing rudiments developed as alar and tegminal lobes (Figs. 3, 4), or already separated from meso- and metanotum (Figs. 5, 6). Scape 1.1—1.5 times as wide as fastigium. Length of hind femur: 5.90—19.80 mm.

5/8 Wing rudiments developed as tegminal and alar lobes (Figs. 3, 4). Length of hind femur: 5.90—9.80 mm.

6/7 Tegminal and alar lobes less developed (Fig. 3), venation hardly detectable. Styli short, 1.6—2 times as long as wide. Length of hind femur: 5.90—7.33 mm. .... IIIrd instar

7/6 Tegminal and alar lobes more developed (notch in their posterior margins distinct) (Fig. 4), venation distinct. Styli longer, 3.1—3.6 times as long as wide. Length of hind femur: 9.00—9.80 mm........................ IVth instar

8/5 Wing rudiments separated from meso- and metanotum (Figs. 5, 6). Length of hind femur: 12.00—19.80 mm.

9/10 Wing distinctly longer than tegmina (Fig. 5), tegminae not in contact by their posterior margins. Cerci shorter, without denticle on the inner side (Fig. 11). Length of hind femur: 12.00—13.20 mm .... Vth instar

10/9 Wing as long as or a little shorter than tegmina (Fig. 6), tegminae in contact by their posterior margins. Cerci longer, with an obtuse denticle in the basal half of the inner side (Fig. 12). Length of hind femur: 15.10—19.80 mm. .... VIth instar

Female:

1/4 Wing rudiments absent (Figs. 1, 2). Length of hind femur: 3.67—5.40 mm. Scape twice as wide as fastigium. All three pairs of valvulae of ovipositor detectable (Figs. 19, 20).

2/3 First valvulae of ovipositor short, as long as wide (Fig. 19). Length of hind femur: 3.67—4.16 mm.................................... Ist instar

3/2 First valvulae of ovipositor longer, twice as long as wide (Fig. 20), in ventral view covering almost the whole IInd pair. Length of hind femur: 4.65 to 5.40 mm.. IInd instar

4/1 Wing rudiments developed as tegminal and alar lobes (Figs. 3, 4) or separated from meso- and metanotum (Figs. 5, 6). Length of hind femur: 7.00—18.20 mm. Scape 1.1—1.6 times as wide as fastigium. Only Ist and IIIrd valvulae of ovipositor detectable (Figs. 21—23).

5/8 Wing rudiments developed as tegminal and alar lobes (Figs. 3, 4). Length of hind femur: 7.00—10.00 mm.

6/7 Ovipositor short, straight, reaching to or protruding somewhat beyond the apex of abdomen (Fig. 21). Scape 1.5—1.6 times as wide as fastigium. Length of hind femur: 7.00—8.10 mm .... IIIrd instar

7/6 Ovipositor longer, straight, protruding beyond the apex of abdomen by half its length (Fig. 22). Scape 1.3 times wider than fastigium. Length of hind femur: 9.40—10.00 mm .... IVth instar

8/5 Wing rudiments separated from meso- and metanotum (Figs. 5, 6). Length of hind femur: 12.00—18.20 mm.

9/10 Wing distinctly longer than tegmina (Fig. 5); tegminae not in contact by their posterior margins. Ovipositor straight, protruding beyond the apex of abdomen by more than $^2/_3$ (sometimes by nearly $^3/_4$) (Fig. 23). Length of hind femur: 12.00—14.20 mm .... Vth instar

10/9 Wing as long as or somewhat shorter than tegmina (Fig. 6); tegminae in contact by their posterior margins. Ovipositor much longer (18.00—20.00 mm), slightly curved, its apex pointed. Length of hind femur: 16.50—18.20 mm .... VIth instar

Decticus verrucivorus

Male:

1/4 Wing rudiments absent (Figs. 24, 25). Length of hind femur: 5.42—8.10 mm.

2/3 Subgenital plate (Fig. 36) short, notched to almost half its length. Length of hind femur: 5.42—6.34 mm .... Ist instar

3/2 Subgenital plate (Fig. 37) longer, notched to $^1/_3$ only. Length of hind femur: 7.80—8.10 mm .... IInd instar

4/1 Wing rudiments developed as tegminal and alar lobes (Figs. 26, 27) or separated from meso- and metanotum (Figs. 28, 29). Length of hind femur: 10.20—26.00 mm.

5/8 Wing rudiments developed as alar and tegminal lobes (Figs. 26, 27). Length of hind femur: 10.20—14.00 mm.

6/7 Tegminal and alar lobes (Fig. 26) with posterior margins slightly indented, wing venation less developed. Cerci short, conical (Fig. 32), without denticle on the inner side. Length of hind femur: 10.20—11.00 mm .... IIIrd instar

7/6 Tegminal and alar lobes (Fig. 27) with posterior margins sharply notched, venation of alar and tegminal lobes distinct. Cerci longer, conical (Fig. 33), with a small obtuse denticle on the inner side behind the middle. Length of hind femur: 13.00—14.00 mm .... IVth instar

8/5 Wing rudiments separated from meso- and metanotum (Figs. 28, 29). Length of hind femur: 17.90—26.00 mm.

9/10 Wing distinctly longer than tegmina (Fig. 28), tegminae not in contact by their posterior margins. Wing reaching to the posterior margin of IInd abdominal tergite. Denticle on the inner side of cercus shorter, more obtuse (Fig. 34). Length of hind femur: 17.90—19.40 mm.............Vth instar

10/9 Wing almost as long as tegmina (Fig. 29), reaching to the posterior margin of IVth abdominal tergite. Tegminae in contact by their posterior margins. Denticle on the inner side of cercus longer, sharper (Fig. 35). Length of hind femur: 22.50—26.00 mm................................VIth instar

Female:

1/4 Wing rudiments absent (Figs. 24, 25). Length of hind femur: 6.08—8.20 mm.

2/3 All three pairs of valvulae of ovipositor detectable (Fig. 42). Length of hind femur: 6.08—6.40 mm.................................... Ist instar

3/2 Only Ist and IIIrd valvulae of ovipositor detectable (Fig. 43) (rudiment of ovipositor: 0.92—1.00 mm). Length of hind femur: 7.60—8.20 mm.......... .... IInd instar

4/1 Wing rudiments developed as tegminal and alar lobes (Figs. 26, 27) or separated from meso- and metanotum (Figs. 28, 29). Length of hind femur: 10.00—27.00 mm.

5/8 Wing rudiments developed as tegminal and alar lobes (Figs. 26, 27). Length of hind femur: 10.00—15.00 mm.

6/7 Ovipositor short, very slightly protruding beyond the apex of abdomen (Fig. 44). Length of hind femur: 10.00—11.40 mm...............IIIrd instar

7/6 Ovipositor longer, protruding beyond abdomen by half its length (Fig. 45). Length of hind femur: 13.70—15.00 mm.....................IVth instar

8/5 Wing rudiments separated from meso- and metanotum (Figs. 28, 29). Length of hind femur: 18.20—27.00 mm.

9/10 Wing distinctly longer than tegmina (Fig. 28); tegminae not in contact by their posterior margins. Hind wing reaching to the posterior margin of IInd abdominal tergite. Ovipositor shorter (7.00—8.00 mm). Length of hind femur: 18.20—20.70 mm.....................................Vth instar

10/9 Wing as long as, or almost as long as tegmina (Fig. 29); tegminae in contact by their posterior margins. Wing reaching to the posterior margin of IVth abdominal tergite. Ovipositor longer (16.00—19.00 mm). Length of hind femur: 24.00—27.00 mm................................VIth instar

Metrioptera brachyptera

Male:

1/4 Wing rudiments absent (Figs. 47, 48). Length of hind femur: 3.17—4.59 mm.

2/3 Subgenital plate short (Fig. 59), indented to at least half its length. Styli absent (Fig. 59). Length of hind femur: 3.17—3.32 mm............Ist instar

3/2 Subgenital plate longer (Fig. 60), indented not quite to half its length. Styli small, as long as wide (Fig. 60). Length of hind femur: 4.13—4.59 mm. ....IInd instar

4/1 Wing rudiments developed as tegminal and alar lobes (Figs. 49, 50) or separated from meso- and metanotum (Figs. 51, 52). Length of hind femur: 5.75 to 13.50 mm.

5/8 Wing rudiments developed as tegminal and alar lobes (Figs. 49,50). Length of hind femur: 5.75—8.20 nem.

6/7 Cerci without denticle on the inner side (Fig. 55). Styli short, cylindrical, very slightly longer than wide (Fig. 61). Length of hind femur: 5.75—6.17 mm .... IIIrd instar

7/6 Cerci with a small obtuse denticle behind the middle of the inner side (Fig. 56). Styli longer, cylindrical, twice as long as wide (Fig. 62). Length of hind femur: 7.60—8.20 mm.. IVth instar

8/5 Wing rudiments separated from meso- and metanotum (Figs. 51, 52). Length of hind femur: 9.60—13.50 mm.

9/10 Tegmina short, not reaching to the apex of wing (Fig. 51). Tegminae not in contact by their posterior margins. The inner side of cercus with a small obtuse denticle posteriorly of the middle (Fig. 57). Length of hind femur: 9.60—10.50 mm..Vth instar

10/9 Tegmina longer, as long or, more often, somewhat longer than wing (Fig. 52). Tegminae in contact by their posterior margins. The inner side of cercus with a large sharp denticle posteriorly of the middle (Fig. 58). Length of hind femur: 12.50—13.50 mm.................................VIth instar

Female:

1/4 Wing rudiments absent (Figs. 47, 48). All three pairs of valvulae of ovipositor detectable (Figs. 65, 66). Length of hind femur: 3.08—4.67 mm.

2/3 Rudiment of ovipositor (Fig. 65). First valvulae almost as long as wide (Fig. 65). Length of hind femur: 3.08—3.34 mm.................Ist instar

3/2 Rudiment of ovipositor (Fig. 66). First valvulae at least twice as long as wide (Fig. 66). Length of hind femur: 4.25—4.67 mm................IInd instar

4/1 Wing rudiments developed as tegminal and alar lobes (Figs. 49, 50) or separated from meso- and metanotum (Figs. 51, 52). Only Ist and IIIrd valvulae of ovipositor detectable (Figs. 67—69). Length of hind femur: 5.92—15.00 mm.

5/8 Wing rudiments developed as tegminal and alar lobes (Figs. 49, 50). Length of hind femur: 5.92—8.00 mm.

6/7 Ovipositor short, straight (Fig. 67), reaching almost to the apex of abdomen. Length of hind femur: 5.92—6.42 mm .... IIIrd instar

7/6 Ovipositor longer, slightly curved (Fig. 68), protruding beyond abdomen by half its length. Length of hind femur: 7.60—8.00 mm............ IVth instar

8/5 Wing rudiments separated from meso- and metanotum (Figs. 51, 52). Length of hind femur: 10.20—15.00 mm.

9/10 Tegmina shorter, distinctly not reaching to the apex of wing (Fig. 51); tegminae not in contact by their posterior margins. Ovipositor shorter, slightly curved upwards, protruding beyond the apex of abdomen by $^2/_3$ (Fig. 69). Length of hind femur: 10.20—11.00 mm...................... Vth instar

10/9 Tegmina longer, reaching to the apex of wing or slightly exceeding it (Fig. 52); tegminae in contact by their posterior margins. Ovipositor longer, slightly curved upwards, protruding beyond the apex of abdomen by $^5/_6$. Length of hind femur: 13.50—15.00 mm.............................. VIth instar

Key to the species of six busch crickets by their instar nymphs.

So far it has practically been impossible to identify most Tettigonioids by their instar nymphs.

Detailed descriptions of individual instars of the Tettigonioids under study and keys for their identification are given in the previous two chapters. However, it was necessary to prepare an original key to the species by their nymphs. Three other bush crickets, namely *Pholidoptera griseoaptera* (De Geer) (= *P. cinerea* Gmel.), *Metrioptera (Roeseliana) roeselii* (Hgb) and *Isophya pyrenea* Serv., have been included in the key for practical reasons, since they live in the same habitats in the submontane and montane areas of Bohemia and Moravia as the bush crickets under study.

The instar nymphs of all these six species occur in the mountains of the Bohemian Massif from the end of April to the second decade of May. The key to the species of the six Tettigonioids by their instar nymphs can be safely used only for identification of material collected in the submontane and montane areas of Bohemia and Moravia. In lowlands occur other species which might be mistaken for those included in the key.

A bush cricket nymph can be easily distinguished from a grasshopper nymph, as follows:

a/b Tarsi three-segmented, antennae much shorter than body (rarely exceeding the posterior margin of pronotum)........................... Acridoidea

b/a Tarsi four-segmented, antennae distinctly longer than body (antennae often twice as long as body).................................. Tettigonioidea

Key

1/4 Basic coloration light green (body and legs with tiny brown dots).

2/3 Anterior and posterior margins of pronotum convex (anterior margin more than posterior), disc of pronotum vaulted. Pronotum without lateral longitudinal pale strip.................................. *Tettigonia cantans*

3/2 Anterior and posterior margins of pronotum straight or slightly concave, disc of pronotum flat. Pronotum laterally bordered by a longitudinal pale yellow strip .... *Isophya pyrenea*

4/1 Basic coloration light brown to dark brown (sometimes grey brown).

5/8 Lateral lobes of pronotum without a conspicuous pale strip (or spot) on the ventral margin.

6/7 Larger, more robust, lateral lobes of meso- and metanotum dark brown, sharply delimited from the dorsal side of lateral lobes. Pronotum with markedly protruding lateral lobes; pronotum wider than long in dorsal view. .... *Decticus verrucivorus*

7/6 Smaller, more slender, lateral lobes of meso- and metanotum brown, not differing in colour from the dorsal side of lateral lobes. Pronotum with slightly protruding lateral lobes; pronotum longer than wide in dorsal view.......... .... *Pholidoptera griseoaptera*

8/5 Lateral lobes of pronotum with a conspicuous pale strip (or spot) along the ventral margin.

9/10 Lateral lobes of pronotum brown in upper $^2/_3$, lower part bordered by a pale yellow strip (or bearing a distinct, pale yellow spot). The outer side of hind femora brown with tiny dark brown dots.................................. .... *Metrioptera roeselii*

10/9 Lateral lobes of pronotum dark brown to black brown in upper $^2/_3$, lower part bordered by a conspicuous, narrow, white strip towards the posterior margin. The outer side of hind femora brown black (often with a reddish tinge). .... *Metrioptera brachyptera*

The chapter on morphology includes detailed descriptions of all six instars of the bush crickets under study *(Tettigonia cantans, Decticus verrucivorus* and *Metrioptera brachyptera)*. With nymphs of both sexes attention was focused on the development of wings, with females on the development of the ovipositor, and with males on the development of the subgenital plate, styli and cerci (Figs. 1—69).

Original keys enable identification of individual instars of both sexes of all three Tettigonioids studied.

Another key has been prepared for practical purpose, enabling identification of the three species of bush crickets by their instar nymphs, as well as of three other Tettigonioids *(Pholidoptera griseoaptera, Metrioptera roeselii* and *Isophya pyrenea)* living in the same habitats.

VIII. Tables

Table 1. Tettigonia cantans. Length of body

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	4.84	7.00	6.17	1.42	4.92	7.08	5.97	1.31
II.	7.50	9.70	8.75	1.20	7.17	10.00	7.80	1.50
III.	9.17	12.00	10.50	1.34	11.00	12.60	11.70	1.26
IV.	13.00	15.00	14.10	1.33	13.00	16.00	14.80	1.26
V.	17.00	20.00	18.70	1.14	18.00	20.00	18.70	1.23
VI.	17.00	25.00	21.30	1.32	21.00	26.00	23.00	1.39
Im.	25.00	32.00	28.20		26.00	37.00	32.00	

Table 2. Tettigonia cantans. Length of pronotum

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	1.08	1.25	1.17	1.44	1.08	1.17	1.14	1.49
II.	1.51	1.79	1.68	1.29	1.58	1.83	1.70	1.47
III.	1.83	2.52	2.17	1.61	2.29	2.75	2.50	1.41
IV.	3.21	3.84	3.49	1.42	3.34	3.67	3.52	1.45
V.	4.59	5.17	4.94	1.29	4.67	5.42	5.12	1.33
VI.	6.08	6.83	6.38	1.02	6.08	7.17	6.80	1.01
Im.	6.00	7.10	6.50		6.40	7.00	6.90	

Table 3. Tettigonia cantans. Length of abdomen

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	2.50	4.16	3.54	1.29	2.42	4.16	3.36	1.38
II.	4.16	5.25	4.58	1.15	3.84	5.50	4.65	1.48
III.	4.84	7.00	5.27	1.50	6.00	7.40	6.90	1.20
IV.	6.20	9.10	7.90	1.28	7.00	10.00	8.30	1.11
V.	8.80	11.00	10.10	1.17	9.00	12.00	9.20	1.33
VI.	9.00	14.00	11.80	1.44	10.00	15.00	12.20	1.56
Im.	14.00	21.00	17.00		15.00	25.00	19.00	

Table 4. Tettigonia cantans. Length of hind femur

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	3.67	4.10	3.86	1.30	3.67	4.16	3.90	1.33
II.	4.59	5.34	5.00	1.39	4.67	5.40	5.19	1.46
III.	5.90	7.33	6.94	1.37	7.00	8.10	7.60	1.29
IV.	9.00	9.80	9.50	1.32	9.40	10.00	9.80	1.34
V.	12.00	13.20	12.55	1.31	12.00	14.20	13.10	1.34
VI.	15.10	19.80	16.50	1.18	16.50	18.20	17.50	1.20
Im.	17.70	21.00	19.50		20.00	23.00	21.00	

Table 5. Tettigonia cantans. Width of hind femur

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	0.77	0.83	0.81	1.23	0.75	0.85	0.80	1.25
II.	0.85	1.03	1.00	1.25	0.83	1.08	1.00	1.34
III.	1.05	1.33	1.25	1.29	1.17	1.67	1.34	1.25
IV.	1.50	1.67	1.61	1.26	1.58	1.75	1.67	1.28
V.	2.00	2.08	2.03	1.21	2.08	2.25	2.13	1.23
VI.	2.33	2.58	2.45	1.13	2.46	2.67	2.61	1.14
Im.	2.42	3.04	2.76		2.83	3.17	2.98	

Table 6. Tettigonia cantans. Width of vertex

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	0.79	0.92	0.85	1.15	0.79	0.90	0.86	1.16
II.	0.94	1.00	0.98	1.24	0.92	1.08	1.00	1.24
III.	1.00	1.33	1.21	1.20	1.17	1.35	1.24	1.19
IV.	1.38	1.58	1.45	1.21	1.43	1.50	1.48	1.23
V.	1.58	1.86	1.75	1.18	1.75	1.92	1.82	1.19
VI.	1.92	2.25	2.07	1.09	2.08	2.25	2.17	1.14
Im.	2.00	2.38	2.25		2.17	2.67	2.48	

Table 7. Tettigonia cantans. Length of cercus (♂), length of ovipositor (♀)

Instar	Male				Female			
	min.	max.	$\bar{x}$	growth coeff.	min.	max.	$\bar{x}$	growth coeff.
I.	0.33	0.46	0.40	1.43	0.41	0.54	0.47	1.64
II.	0.50	0.60	0.57	1.26	0.80	0.92	0.77	2.10
III.	0.58	0.83	0.72	1.43	1.43	1.75	1.62	2.13
IV.	1.00	1.17	1.03	1.52	2.97	3.75	3.45	2.41
V.	1.43	1.67	1.56	1.44	7.50	9.00	8.32	2.28
VI.	2.08	2.42	2.24	1.57	18.00	20.00	19.00	1.16
Im.	3.08	3.84	3.52		20.00	25.00	22.00	

Table 1. Decticus verrucivorus. Length of body

Instar	Male				Female			
	min.	max.	$\bar{x}$	growth coeff.	min.	max.	$\bar{x}$	growth coeff.
I.	7.25	8.17	7.71	1.22	6.92	8.50	7.75	1.24
II.	8.00	11.00	9.40	1.32	8.50	11.00	9.60	1.17
III.	10.20	14.90	12.40	1.31	9.59	13.00	11.25	1.30
IV.	14.40	17.50	16.30	1.20	13.50	16.00	14.60	1.35
V.	17.00	22.00	19.60	1.26	14.00	24.00	19.70	1.37
VI.	20.00	27.00	24.70	1.26	22.00	31.00	26.90	1.38
Im.	29.00	34.00	31.00		36.00	38.00	37.20	

Table 2. Decticus verrucivorus. Length of pronotum

Instar	Male				Female			
	min.	max.	$\bar{x}$	growth coeff.	min.	max.	$\bar{x}$	growth coeff.
I.	1.58	1.92	1.79	1.37	1.67	2.00	1.86	1.34
II.	2.29	2.54	2.45	1.38	2.33	2.58	2.50	1.38
III.	3.17	3.58	3.39	1.32	3.25	3.75	3.45	1.35
IV.	4.16	4.67	4.47	1.35	4.25	4.84	4.66	1.36
V.	5.50	6.50	6.04	1.24	6.00	6.83	6.34	1.31
VI.	6.25	8.00	7.50	1.07	8.00	9.00	8.30	1.02
Im.	7.50	8.50	8.00		7.90	9.00	8.50	

Table 3. Decticus verrucivorus. Length of abdomen

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	4.00	4.75	4.44	1.13	3.42	4.59	4.11	1.36
II.	3.00	6.58	5.00	1.42	4.84	6.34	5.59	1.04
III.	5.17	8.50	7.11	1.34	4.59	7.50	5.81	1.29
IV.	8.34	10.60	9.52	1.11	6.42	8.50	7.52	1.42
V.	9.00	13.00	10.60	1.37	7.00	14.50	10.65	1.45
VI.	10.00	17.00	14.50	1.28	11.00	20.00	15.40	1.56
Im.	16.00	20.00	18.60		21.00	25.00	24.00	

Table 4. Decticus verrucivorus. Length of hind femur

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	5.42	6.34	6.02	1.33	6.08	6.40	6.21	1.29
II.	7.80	8.10	8.00	1.32	7.60	8.20	8.00	1.33
III.	10.20	11.00	10.58	1.27	10.00	11.40	10.63	1.35
IV.	13.00	14.00	13.44	1.39	13.70	15.00	14.33	1.37
V.	17.90	19.40	18.70	1.30	18.20	20.70	19.68	1.32
VI.	22.50	26.00	24.40	1.21	24.00	27.00	26.00	1.27
Im.	28.00	31.00	29.60		31.00	35.00	33.00	

Table 5. Decticus verrucivorus. Width of hind femur

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	1.17	1.33	1.28	1.23	1.25	1.33	1.30	1.26
II.	1.42	1.71	1.58	1.27	1.58	1.75	1.64	1.24
III.	1.92	2.12	2.00	1.28	1.83	2.17	2.03	1.31
IV.	2.33	2.75	2.56	1.29	2.58	2.75	2.65	1.30
V.	2.92	3.50	3.28	1.25	3.17	3.67	3.44	1.29
VI.	3.67	4.50	4.10	1.23	4.16	4.70	4.44	1.27
Im.	4.75	5.34	5.05		5.25	5.92	5.64	

Table 6. Decticus verrucivorus. Width of vertex

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	1.00	1.08	1.03	1.25	1.03	1.25	1.10	1.19
II.	1.21	1.33	1.29	1.26	1.17	1.35	1.31	1.23
III.	1.50	1.83	1.62	1.20	1.50	1.75	1.61	1.27
IV.	1.83	2.00	1.94	1.19	1.92	2.17	2.04	1.15
V.	2.25	2.42	2.30	1.18	1.88	2.50	2.34	1.28
VI.	2.56	2.88	2.71	1.20	2.83	3.17	2.99	1.24
Im.	3.00	3.58	3.24		3.58	3.84	3.70	

Table 7. Decticus verrucivorus. Length of cercus (♂), length of ovipositor (♀)

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	0.50	0.50	0.50	1.32	0.50	0.58	0.57	1.68
II.	0.54	0.75	0.66	1.27	0.92	1.00	0.96	1.83
III.	0.75	0.92	0.84	1.35	1.58	2.00	1.76	2.00
IV.	1.08	1.25	1.13	1.48	3.08	3.92	3.52	2.14
V.	1.50	1.75	1.67	1.37	7.00	8.00	7.55	2.33
VI.	2.17	2.42	2.29	1.22	16.00	19.00	17.60	1.16
Im.	2.50	3.00	2.80		17.50	22.00	20.40	

Table 1. Metrioptera brachyptera. Length of body

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	3.92	4.75	4.42	1.20	3.08	5.08	4.18	1.30
II.	4.67	6.34	5.32	1.33	5.00	6.00	5.45	1.39
III.	6.25	8.42	7.10	1.24	7.08	8.40	7.57	1.09
IV.	7.66	10.17	8.77	1.36	7.25	9.40	8.26	1.39
V.	11.00	12.50	11.90	1.21	11.00	12.00	11.50	1.36
VI.	13.00	16.00	14.45	1.14	14.00	18.00	15.60	1.28
Im.	12.00	18.00	16.50		17.60	22.00	19.96	

Table 2. Metrioptera brachyptera. Length of pronotum

Instar	Male				Female			
	min.	max.	$\bar{x}$	growth coeff.	min.	max.	$\bar{x}$	growth coeff.
I.	0.92	1.08	1.00	1.38	0.94	1.08	1.14	1.18
II.	1.33	1.42	1.38	1.30	1.25	1.42	1.35	1.40
III.	1.71	1.92	1.80	1.37	1.75	2.00	1.89	1.32
IV.	2.33	2.58	2.46	1.33	2.33	2.67	2.50	1.38
V.	3.08	3.47	3.26	1.22	3.32	3.54	3.44	1.20
VI.	3.67	4.25	3.97	1.03	3.67	4.49	4.13	1.12
Im.	3.75	4.59	4.08		4.33	5.00	4.63	

Table 3. Metrioptera brachyptera. Length of abdomen

Instar	Male				Female			
	min.	max.	$\bar{x}$	growth coeff.	min.	max.	$\bar{x}$	growth coeff.
I.	1.92	2.67	2.33	1.18	1.42	2.75	2.17	1.37
II.	2.17	3.34	2.76	1.42	2.58	3.25	2.97	1.40
III.	3.08	4.75	3.93	1.23	3.84	4.42	4.17	1.08
IV.	4.00	5.83	4.85	1.40	3.67	5.25	4.49	1.38
V.	6.00	9.00	6.80	1.16	5.00	7.00	6.20	1.40
VI.	6.00	9.20	7.89	1.20	7.00	10.20	8.70	1.44
Im.	6.00	11.00	9.50		10.00	14.00	12.55	

Table 4. Metrioptera brachyptera. Length of hind femur

Instar	Male				Female			
	min.	max.	$\bar{x}$	growth coeff.	min.	max.	$\bar{x}$	growth coeff.
I.	3.17	3.32	3.26	1.34	3.08	3.34	3.18	1.42
II.	4.13	4.59	4.37	1.36	4.25	4.67	4.51	1.35
III.	5.75	6.17	5.94	1.33	5.92	6.42	6.09	1.30
IV.	7.60	8.20	7.89	1.30	7.60	8.00	7.93	1.34
V.	9.60	10.50	10.25	1.28	10.20	11.00	10.61	1.34
VI.	12.50	13.50	13.09	1.22	13.50	15.00	14.23	1.23
Im.	14.40	17.00	15.98		17.00	18.40	17.51	

Table 5 Metrioptera brachyptera. Width of hind femur

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	0.67	0.80	0.74	1.28	0.67	0.75	0.73	1.37
II.	0.89	1.00	0.95	1.31	0.98	1.03	1.00	1.33
III.	1.17	1.29	1.24	1.27	1.25	1.38	1.33	1.19
IV.	1.42	1.71	1.58	1.20	1.50	1.67	1.58	1.30
V.	1.83	2.00	1.90	1.24	1.83	2.17	2.06	1.24
VI.	2.25	2.50	2.35	1.16	2.33	2.67	2.55	1.24
Im.	2.50	2.88	2.72		2.92	3.34	3.15	

Table 6. Metrioptera brachyptera. Width of vertex

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	0.67	0.75	0.69	1.22	0.63	0.75	0.69	1.25
II.	0.79	0.96	0.84	1.19	0.75	0.92	0.86	1.19
III.	0.96	1.04	1.00	1.20	0.96	1.08	1.02	1.17
IV.	1.12	1.25	1.20	1.13	1.12	1.25	1.19	1.19
V.	1.33	1.42	1.36	1.18	1.40	1.46	1.42	1.22
VI.	1.58	1.67	1.60	1.13	1.67	1.89	1.73	1.26
Im.	1.58	2.29	1.81		2.00	2.67	2.18	

Table 7. Metrioptera brachyptera. Length of cercus (♂), length of ovipositor (♀)

Instar	Male				Female			
	min.	max.	x̄	growth coeff.	min.	max.	x̄	growth coeff.
I.	0.30	0.42	0.35	1.14	0.25	0.28	0.26	1.96
II.	0.33	0.42	0.40	1.38	0.50	0.58	0.51	1.90
III.	0.50	0.58	0.55	1.40	0.92	1.08	0.97	1.83
IV.	0.67	0.83	0.77	1.44	1.33	2.00	1.77	2.22
V.	1.08	1.17	1.11	1.39	3.75	4.16	3.93	2.22
VI.	1.42	1.63	1.54	1.38	8.00	9.10	8.72	1.04
Im.	2.00	2.92	2.13		7.40	10.00	9.06	

IX. Summary

1. The three species of bush crickets under study are omnivorous, with a pronounced tendency to cannibalism which is particularly distinct in *Tettigonia cantans* (nymphs must be kept in separate cages). The nymphs of all three species are strongly positively phototactic (they do not respond to light immediately before ecdysis only).

2. All three Tettigonioids have only one generation in a year. Eclosion occurs in the spring, rarely at the end of April, more often beginning in the second half of May. The first adults of *Metrioptera brachyptera* emerge about the middle of July (usually males, which reach maturity earlier than females). The nymphal development of *Tettigonia cantans* and *Decticus verrucivorus* is longer, the adults emerge 10—15 days later. Mating and oviposition occur in the second half of August in *M. brachyptera,* and in *T. cantans* and *D. verrucivorus* from the end of August to the end of September. The famales of the three bush crickets lay eggs in soil. The nymphal development of *M. brachyptera* takes place from the middle of May to the middle of July, of *T. cantans* and *D. verrucivorus* usually from the middle of May until the end of July. The adult life is short, lasting approximately two to two and a half months. The egg stage is the longest, lasting 8—9 months.

3. The postembryonic development of male *T. cantans* under laboratory conditions was completed within 8—10 weeks, of females within 9—11 weeks; male *D. verrucivorus* within approximately 9 weeks, females 9—12 weeks; *M. brachyptera* within 7—9 weeks, females 8—10 weeks. The postembryonic development in the field in 1970—1971 was shorter by 7—15 days.

4. The eggs of all three bush crickets are described and their measurements given. The ventral side of the eggs of all three species is more convex than the dorsal one on which are micropyles.

5. Six instars constantly occur in all three species. The average duration of the second to sixth instar is given in Tables C—E (in days). In both sexes of *Tettigonia cantans* and *Decticus verrucivorus* the longest period is that between the penultimate and ultimate moults. In contrast, it is the shortest one in *M. brachyptera.* It is proposed that the longer are the wings of a species of the superfamily Tettigonioidea (relative wing length is meant) the longer lasts its ultimate instar. The average length of the nymphal development between the second and sixth instars is shorter in males than in females. This finding is in agreement with field observations.

6. The moulting process which can be macroscopically observed is divided into four phases:

Phase I — preparation. Overall metabolism of the nymph is decreasing. Food is refused, but water intake continues almost until ecdysis. The nymph is motionless for long periods, swallowing air which increases the inner pressure of haemolymph. This phase lasts up to 24 hours.

Phase II — ecdysis. The old cuticla (exuviae) is shed in this phase which has two stages:

a) The first stage begins with the nymph taking firm hold of a support, and ends with the shedding of the old skin from the whole fore part of the body, antennae and all legs.

b) The second stage is characterized by an interval of rest, during which hind legs become sclerotised. The nymph is suspended, head downwards, by the apex of abdomen which is still inside the old cuticle. The stage is over when the abdomen

(in females also the ovipositor) is drawn out from the exuviae. The whole phase II takes 13—32 minutes (its length depends on the instar).

Phase III — sclerotisation. Under the influence of air oxygen the new cuticle gradually darkens and hardens. The moulted individual is motionless during this phase. Again it swallows air, thus increasing the inner pressure of haemolymph, which in necessary for the stretching of all folds in the new cuticle and for the unfolding and expansion of wings (after the imaginal moult). This phase lasts 27—53 minutes. Phase IV — consumption. The cast skin is felt for with the long antennae and eaten; food intake is resumed. Sclerotisation of the new cuticle is completed. This ultimate phase lasts up to 3 hours.

The macroscopic picture of moulting in both stages of Phase II (= ecdysis) is described in detail in a separate chapter. The duration of both stages in individual instars and the total length of Phase II are given in Tables F—H.

7. No substantial changes in the size of compact sclerotised structures (e. g. in the width of the vertex, length of the pronotum and male cerci, length and width of the hind femur, etc.) occur during an instar. Minor changes in the size of these sclerotised structures may occur only immediately after ecdysis when the new cuticle is still soft and pliant. Changes in the size of the abdomen occur very unevenly, which is reflected in the total body length. The overall growth of the body in length is more less continuous in all three species (the growth rate increases in *T. cantans* and female *D. verrucivorus* after the imaginal moult). Also the abdomen of the imago and, consequently, the whole body grow in length as a result of feeding and growth of reproductive organs. The pronotum of all three species grows almost continuously between the second and fourth instars. The growth rate increases after the fourth moult, but substantially decreases after the imaginal ecdysis (with the exception of female *M. brachyptera*). The abdomen of all three species grows very unevenly, so that the rules of its growth cannot be determined. The hind femur grows in length and width almost continuously in all three bush crickets; the rate of its growth uniformly increases after the fourth moult (only in *T. cantans* the growth slows down after the last ecdysis). The growth of the vertex in width is not uniform in the bush crickets studied. It proceeds almost continuously, in both sexes of *T. cantans,* but its rate decreases after the imaginal moult. The same is true of *D. verrucivorus*, but there is no decrease in the growth rate after the ultimate ecdysis. The vertex of male *M. brachyptera* grows in width almost continuously, but in the female the rate of its growth increases after the fifth moult, culminating in the imago. Growth of the male cerci in length is not uniform in the three species; the growth rate increases in *T. cantans* and *D. verrucivorus* after the third moult, in *T. cantans* it keeps increasing until the adult stage, in *D. verrucivorus* it decreases after the last moult. The cerci of *M. brachyptera* grow almost continuously until the fourth instar; the growth rate increases after the fourth moult and culminates in the imago. The growth of the ovipositor is almost the same in all three species and is of exponential character. The growth rate reaches its maximum in the sixth instar and is almost negligible after the imaginal moult. Increments in the length of the ovipositor almost make a geometric progression.

8. Essential morphological changes occuring after the ultimate moult are described. Wing rudiments of all three Tettigonioids become articulated at the fourth moult. Nymphs of the fifth and sixth instars have wing rudiments in inverse position

(turned by 180°). The nymphs of the species under study are divided into three groups according to the development of the wing rudiments:

Group I — wing rudiments absent (first and second instars).

Group II — wing rudiments developed as so-called alar and tegminal lobes (third and fourth instars).

Group III — wing rudiments separated from the meso- and metanotum in inverse position (fifth and sixth instars).

The morphology of individual instars (both sexes) of the three species is described in detail; measurements and coefficients of growth are given in tables. Attention is focused on development of the wings (see above), the ovipositor of females, and the subgenital plate, styli and cerci od males (Figs. 1—69). Original keys enable identification of individual instars of both sexes of the species. A key to species of the three bush crickets under study and three other species by their instar nymphs is included for practical reasons, proving that genera or species can be identified by their first instars.

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Photo 1: Zdobnice in the Orlické hory (Mountains). A habitat of *Tettigonia cantans* and *Decticus verrucivorus*.

Photo 2: Hronov n. Met. A habitat of *Metrioptera brachyptera* (the car stands right at the locality).

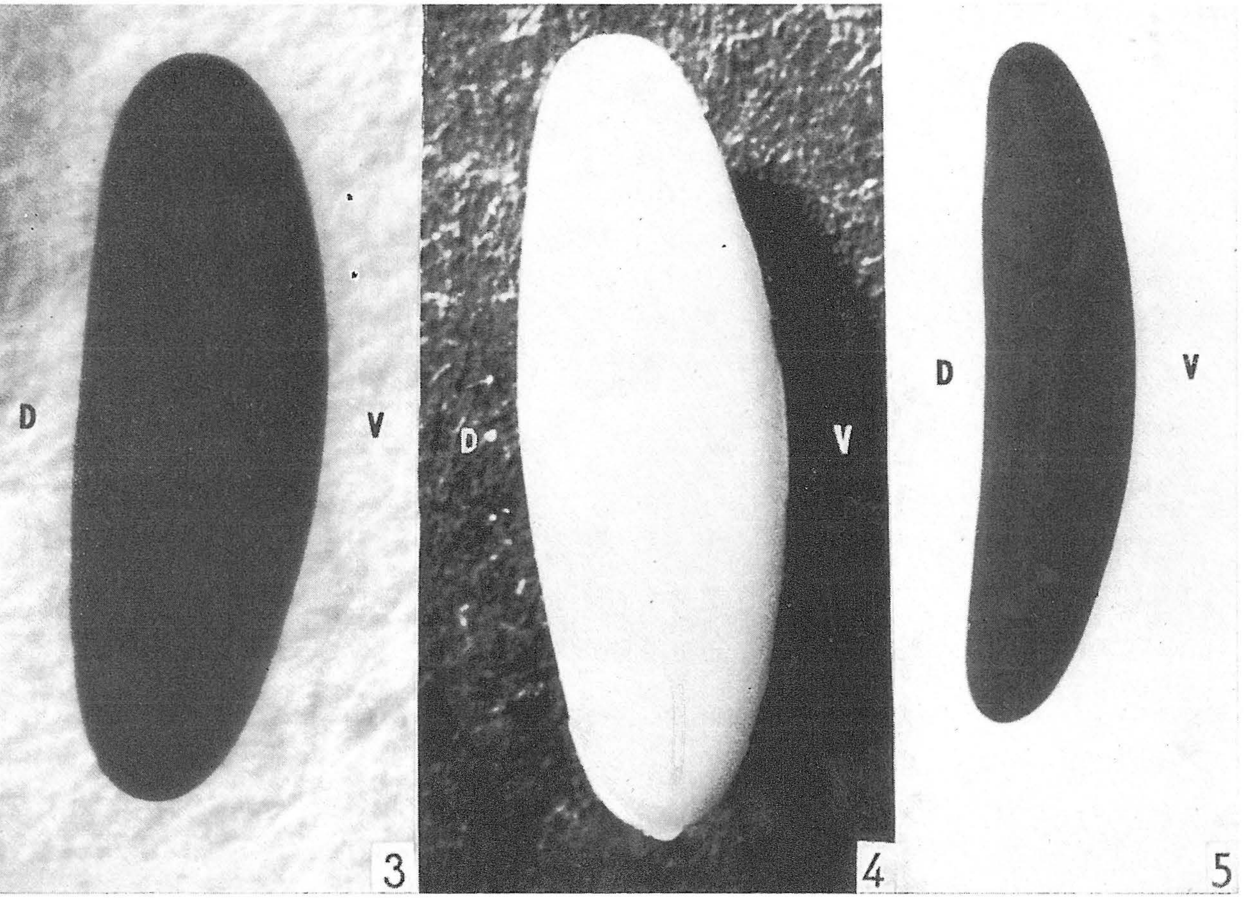
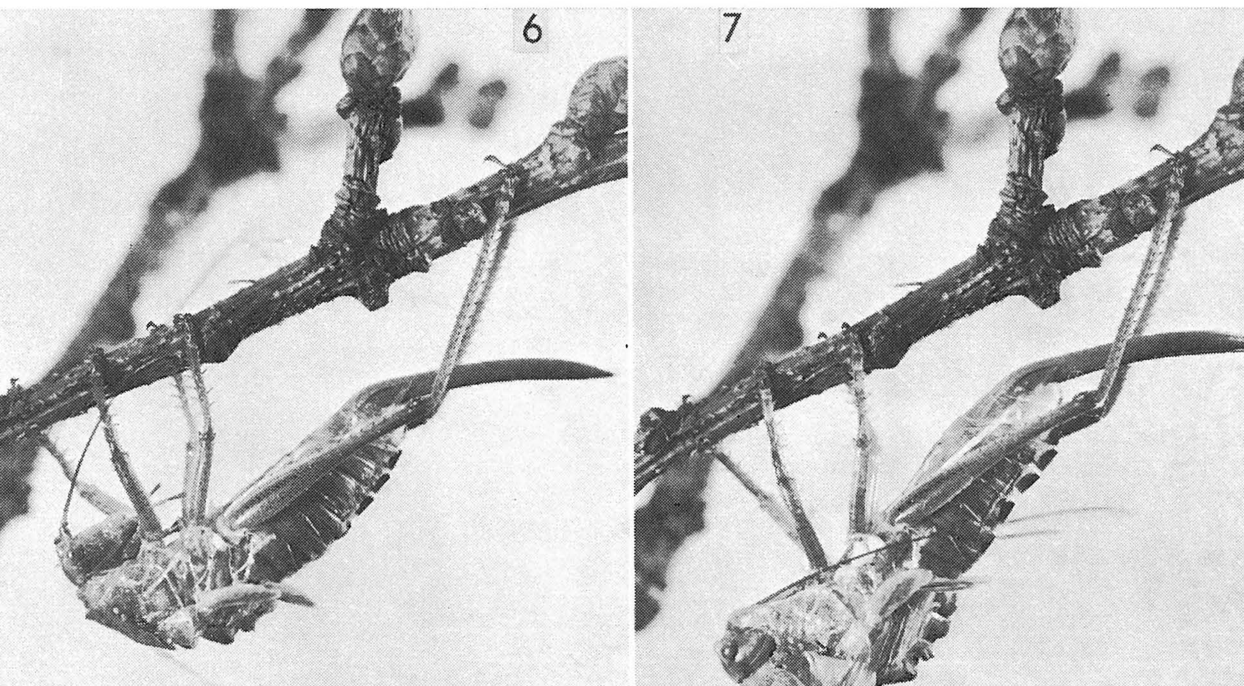
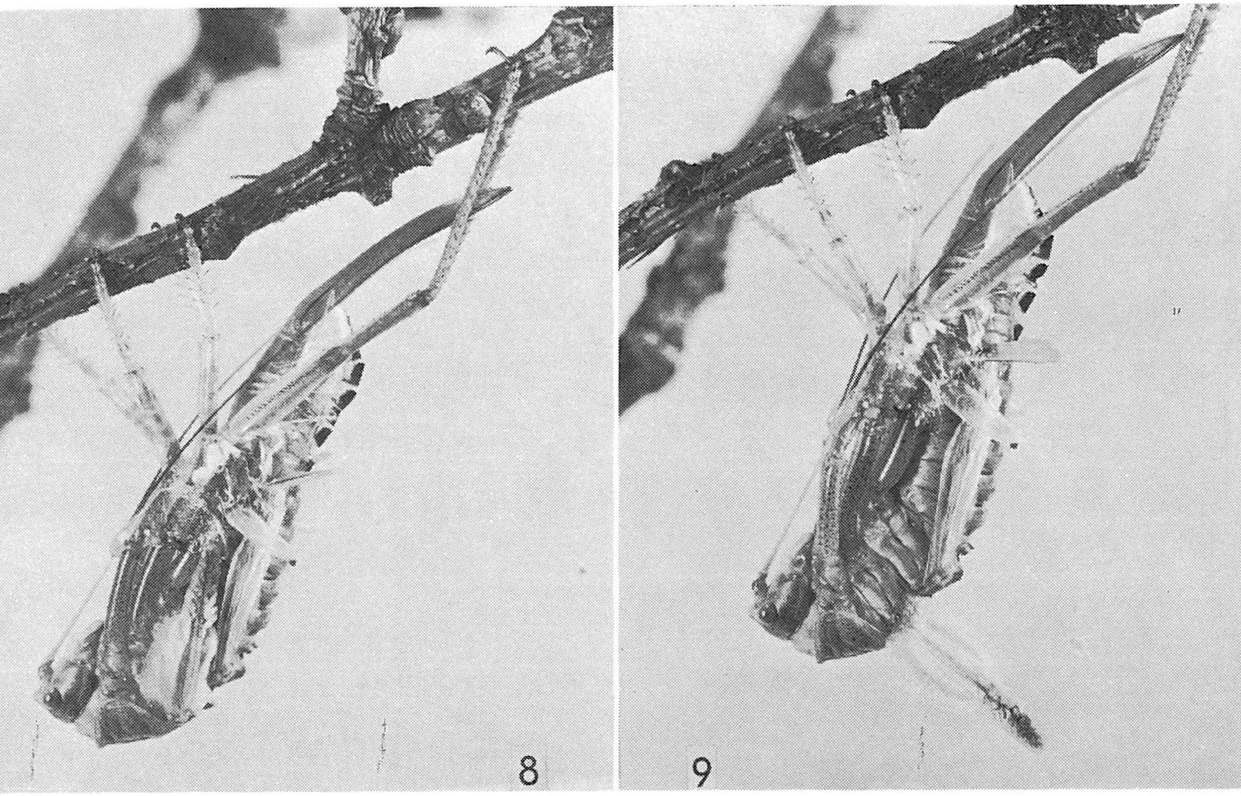


Photo 3: The eggs of *Tettigonia cantans*, — Photo 4: The egg of *Decticus verrucivorus*. Photo 5: The egg of *Metrioptera brachyptera*. D = Dorsal side, V = ventral side.

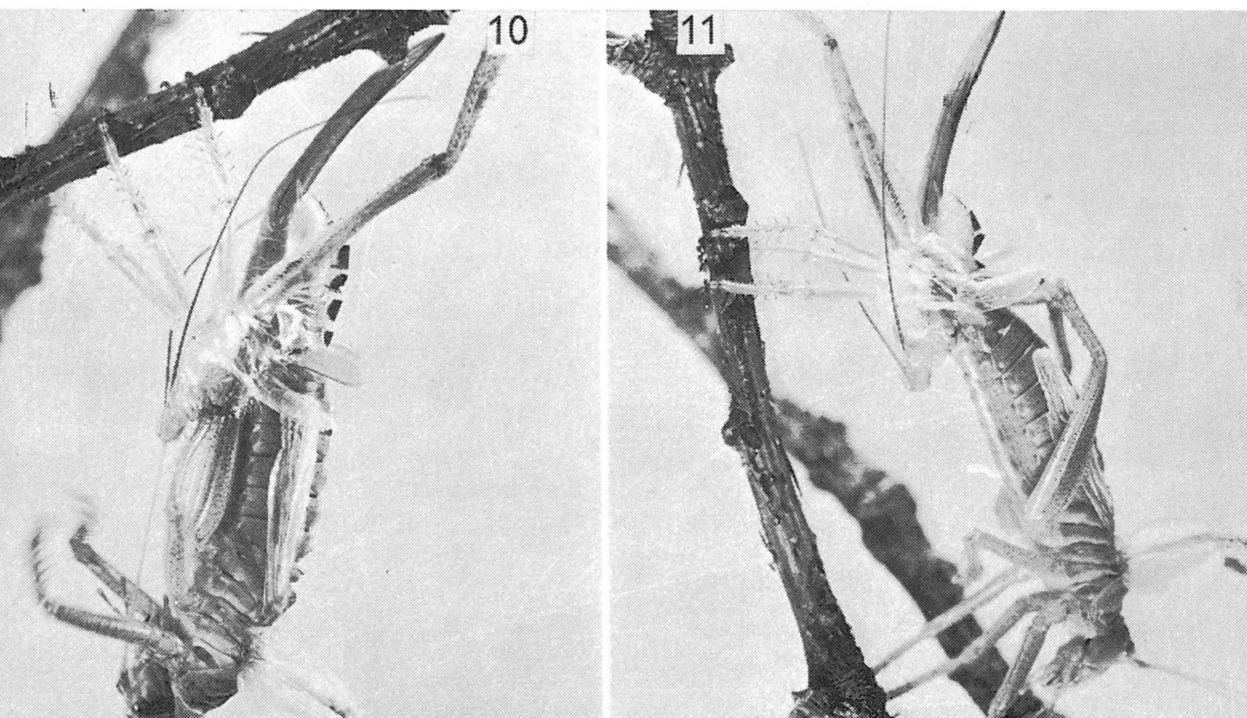
Photos 6—7: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Ecdysis — first stage of phase II.

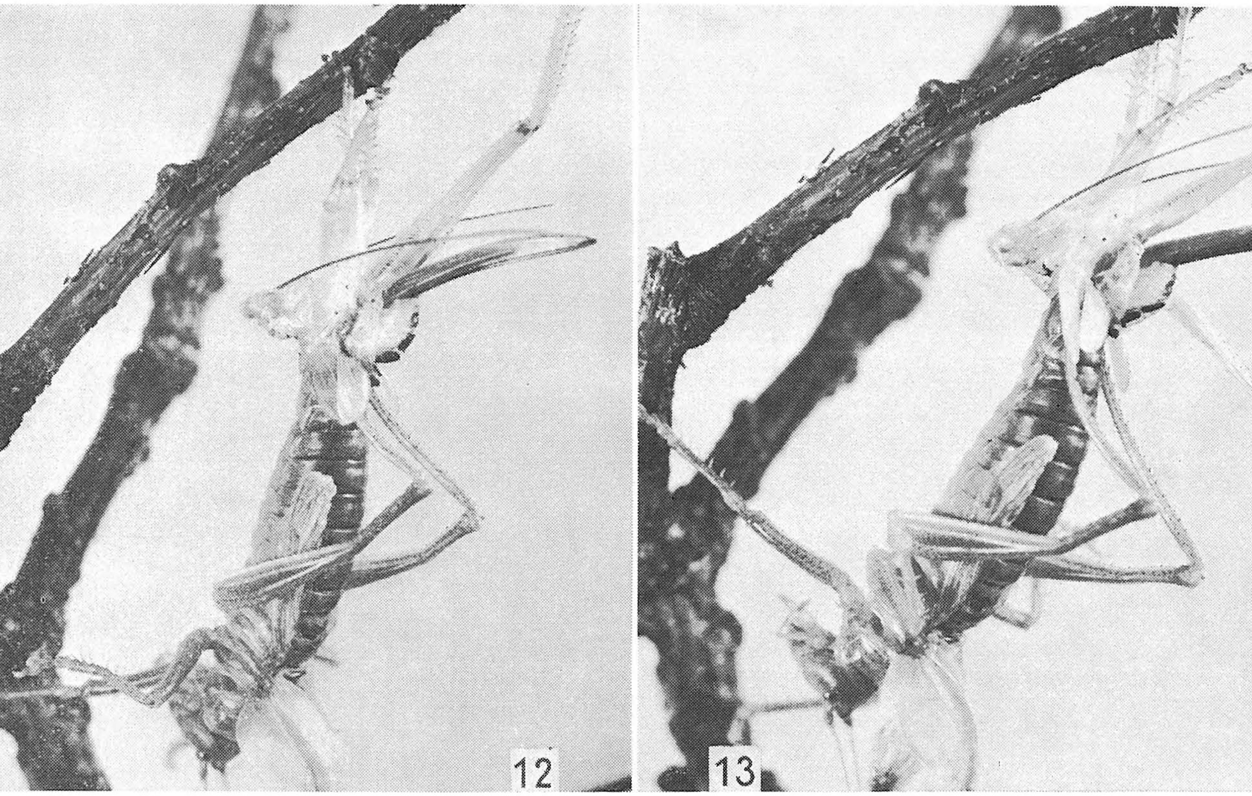




Photos 8—9: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Ecdysis — first stage of phase II.

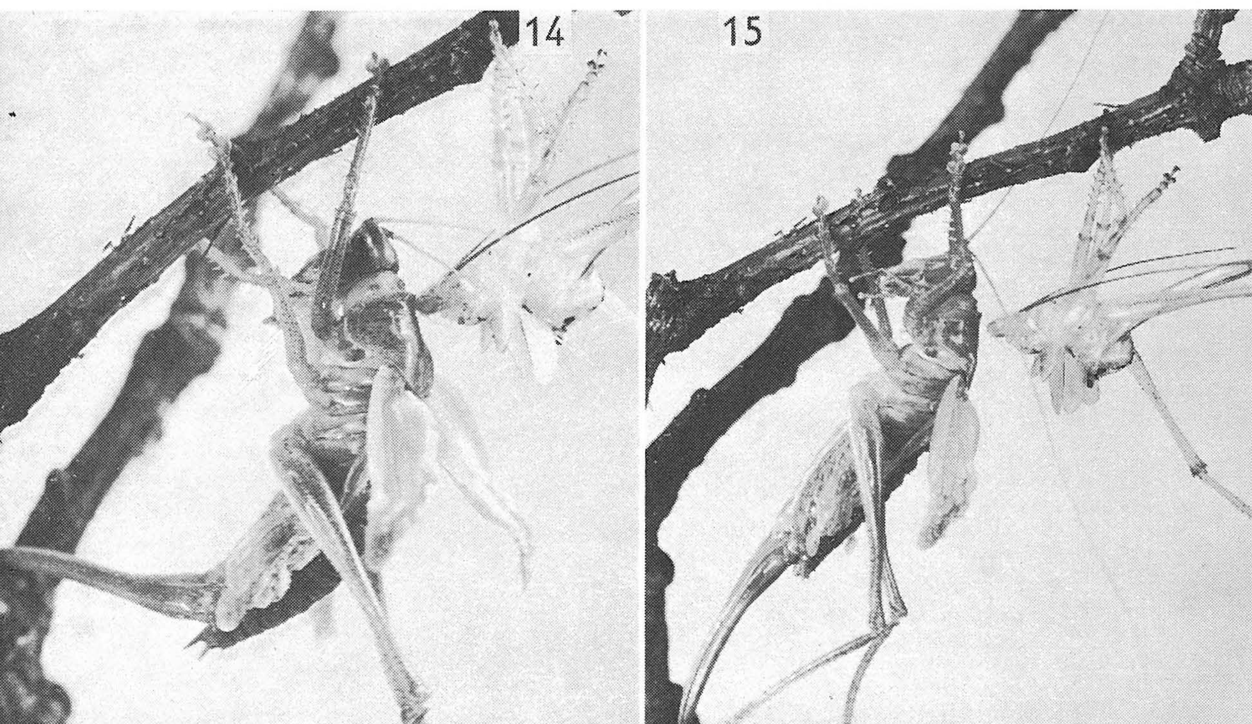
Photos 10—11: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Ecdysis — first stage of phase II.

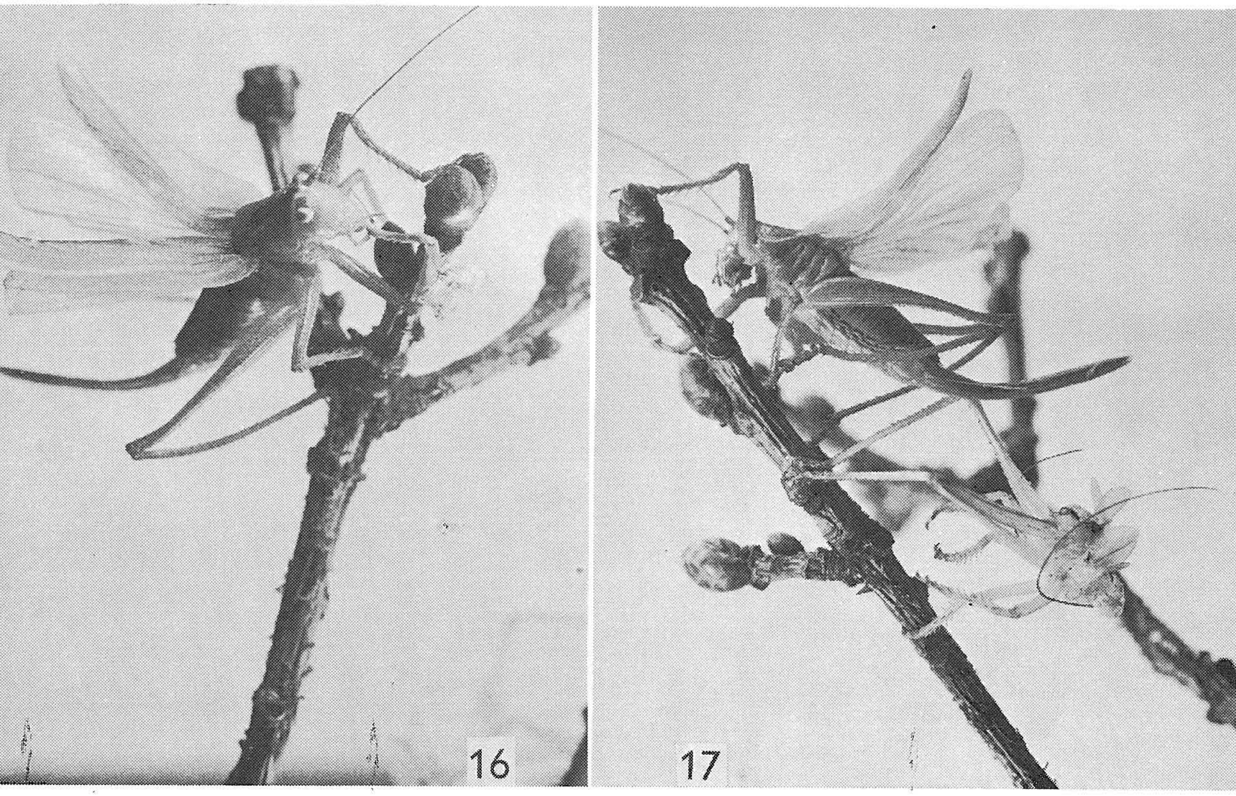




Photos 12—13: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Ecdysis — first stage of phase II.

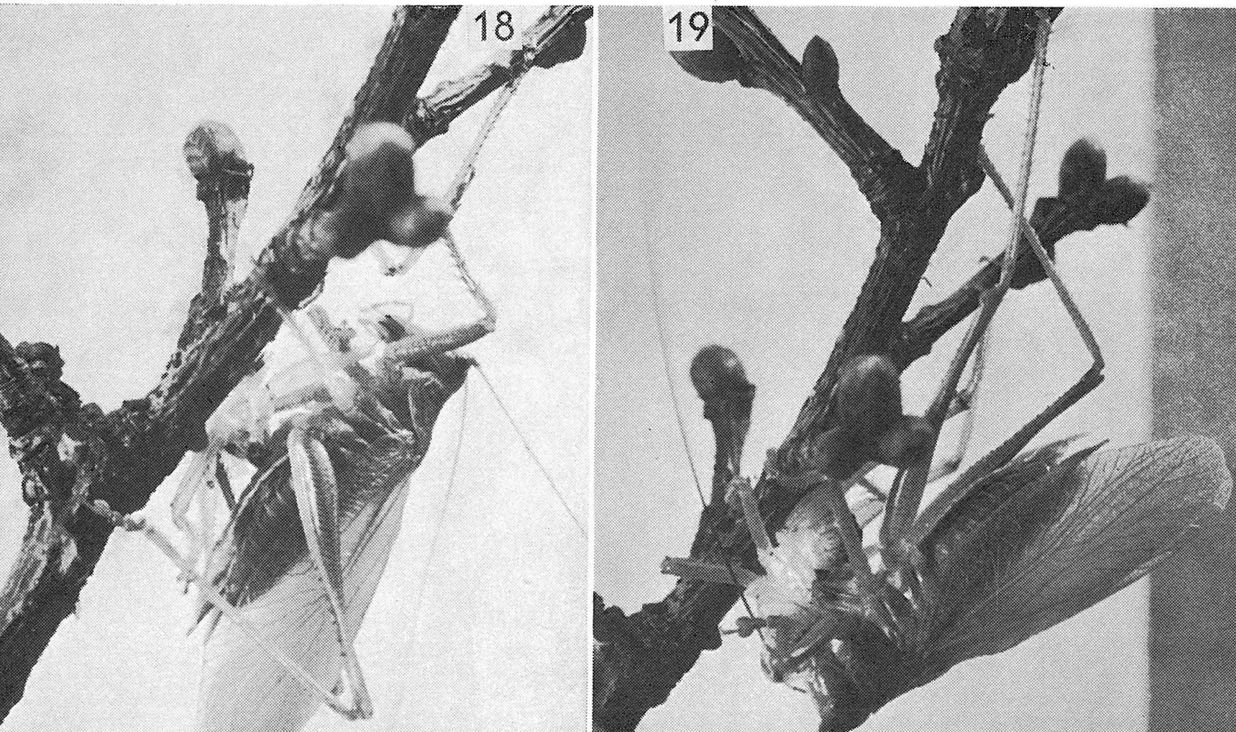
Photos 14—15: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Ecdysis — first stage of phase III.

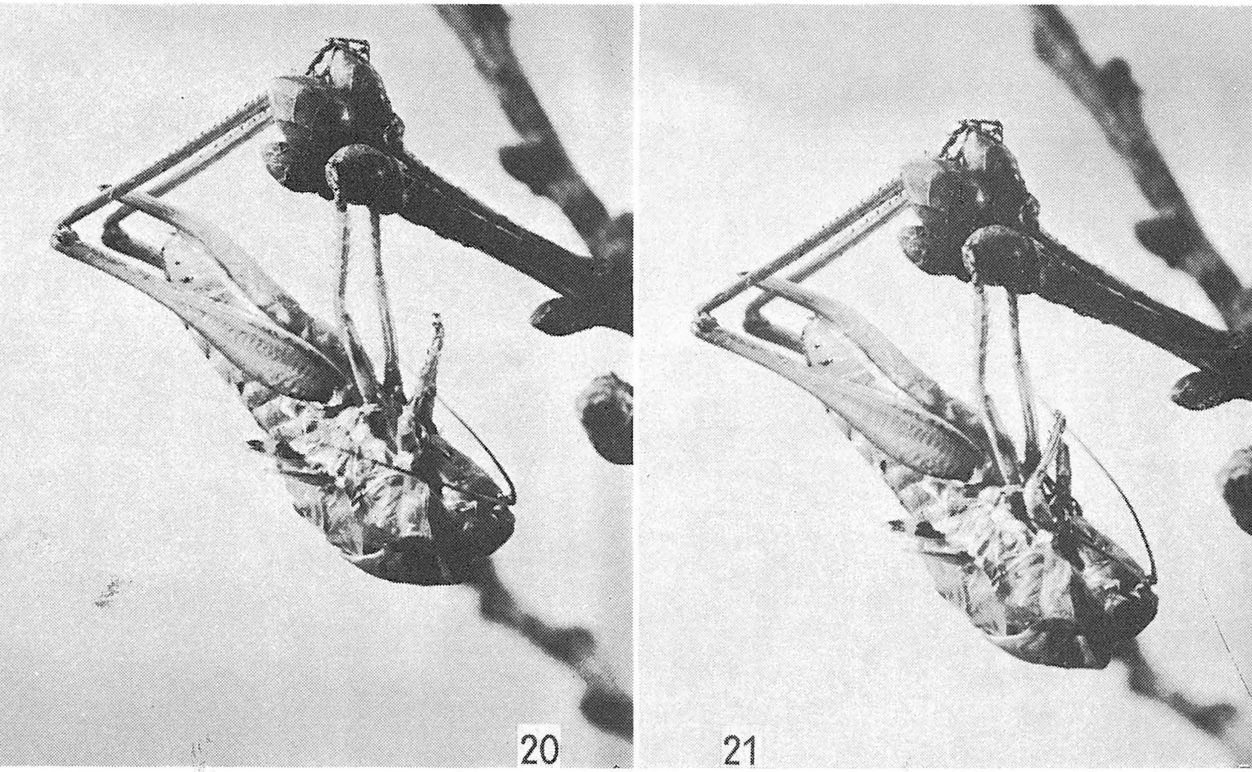




Photos 16—17: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Phase III. — unfolding and expansion of wings.

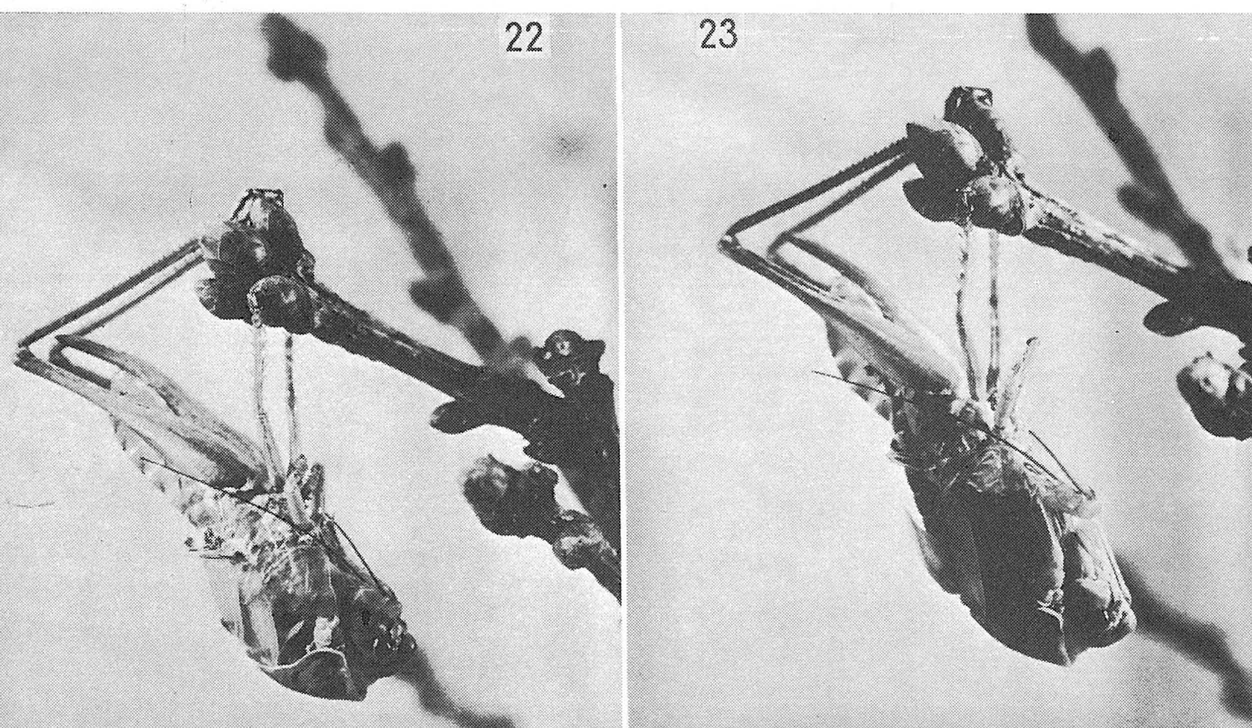
Photos 18—19: Details of the imaginal moulting process in the sixth instar female nymph of *Tettigonia cantans*. Details of phase IV.

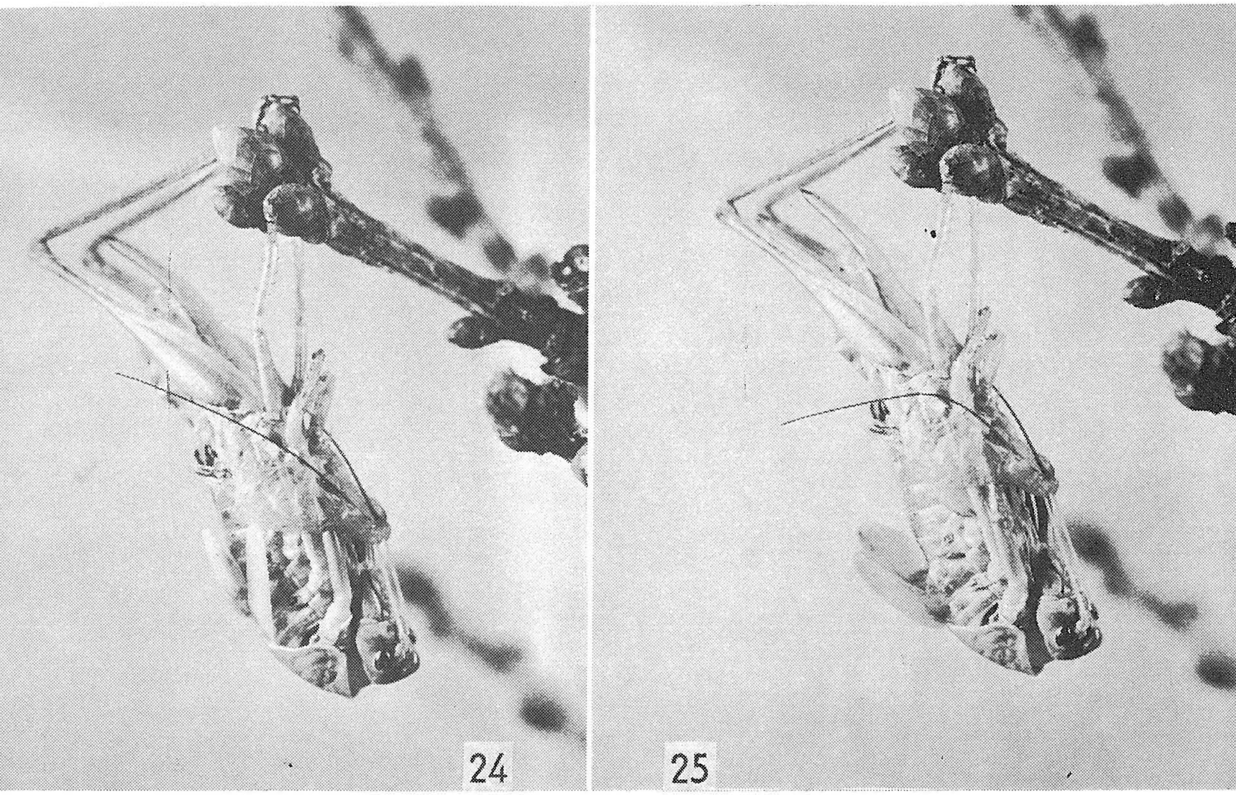




Photos 20—21: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Ecdysis during the first stage of phase II.

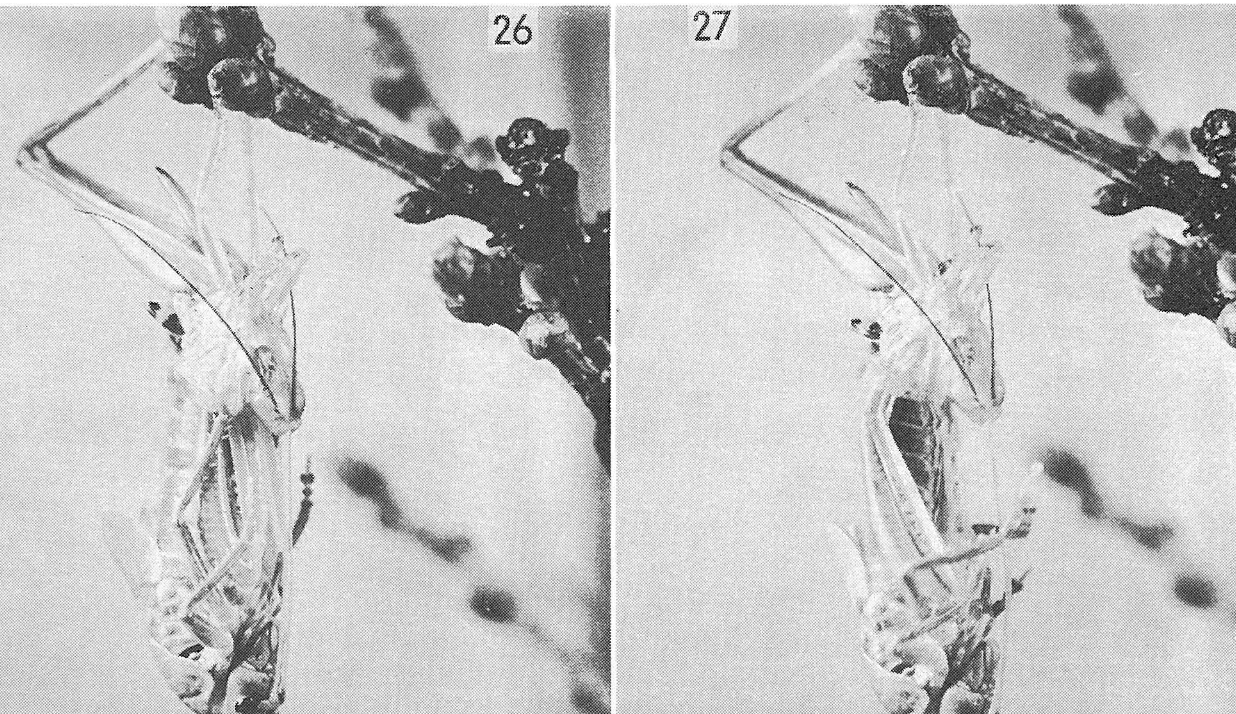
Photos 22—23: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Ecdysis during the first stage of phase II.

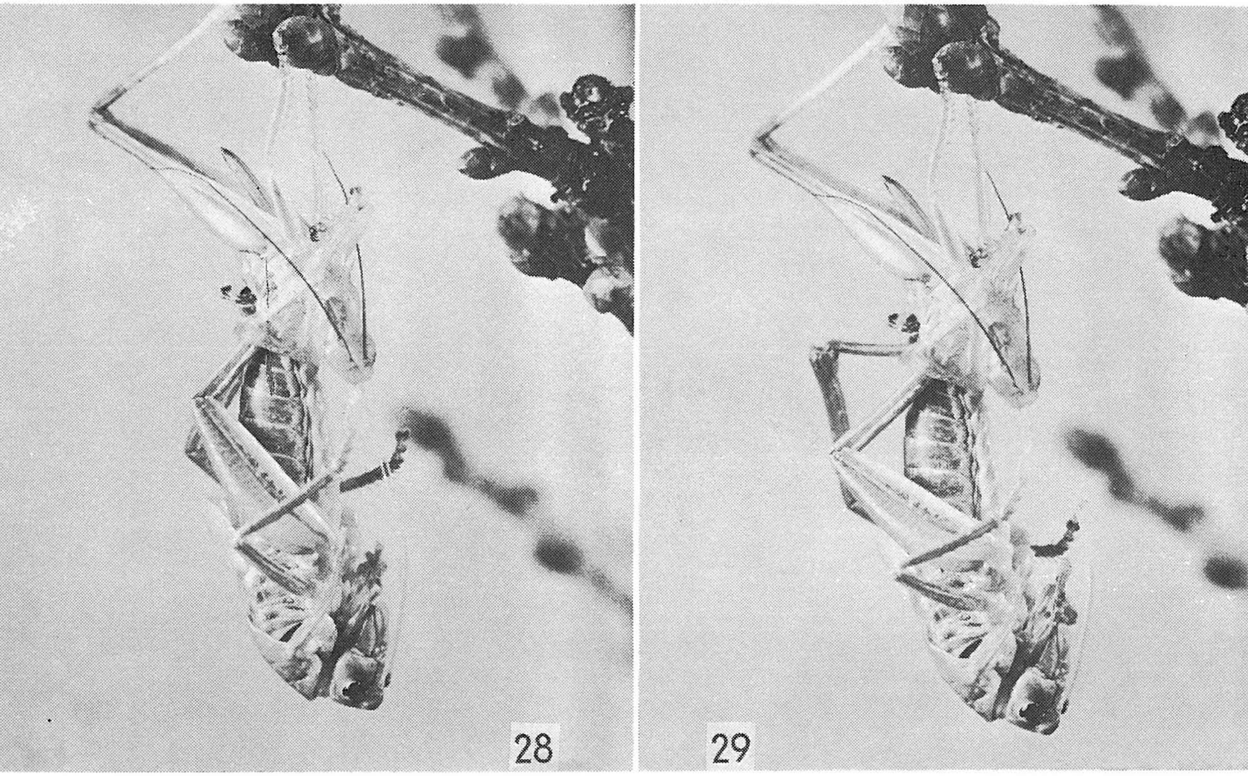




Photos 24—25: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Ecdysis during the first stage of phase II.

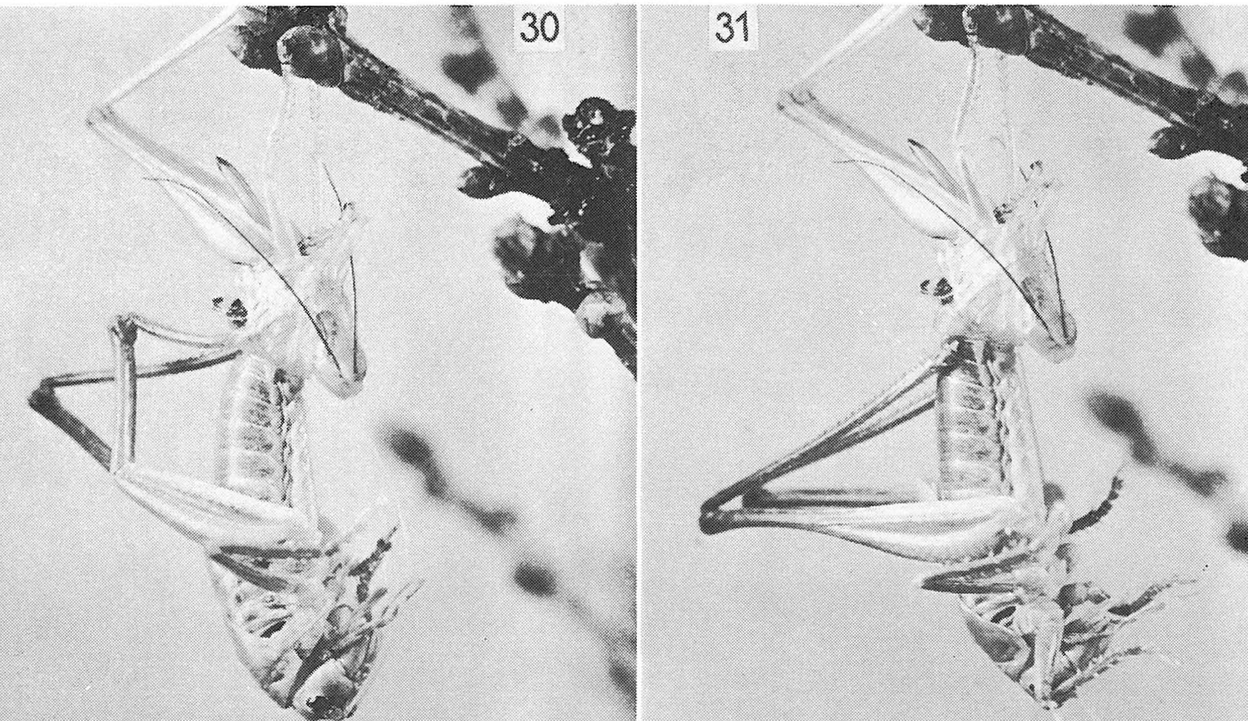
Photos: 26—27: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Ecdysis during the first stage of phase II.

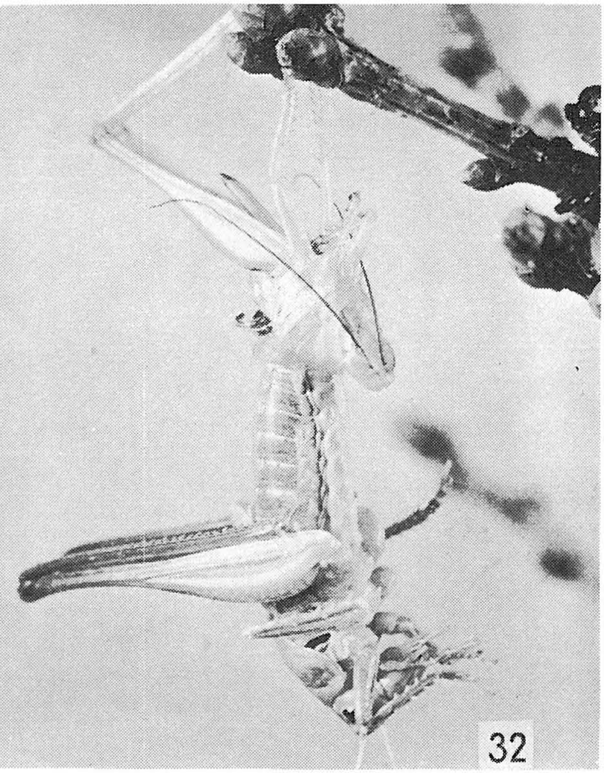


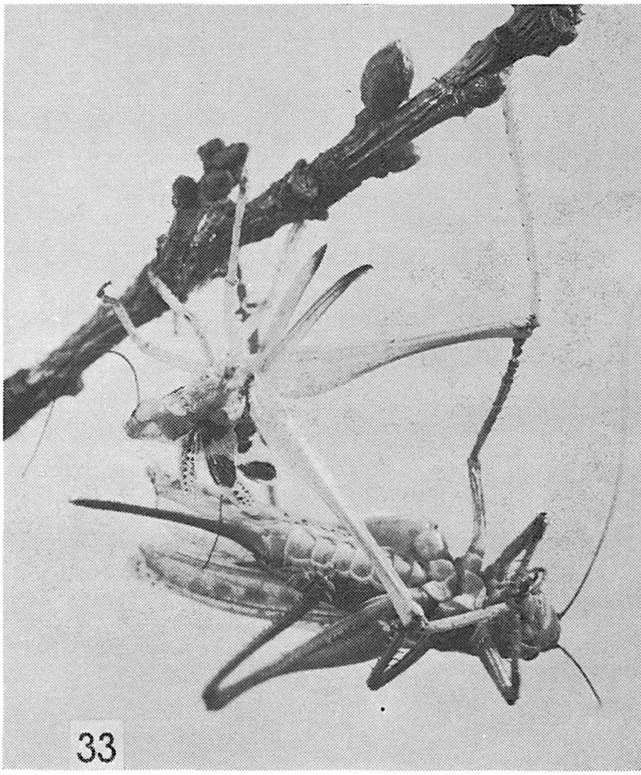


Photos 28 – 29: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Ecdysis during the first stage of phase II.

Photos 30 – 31: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Ecdysis during the first stage of phase II.

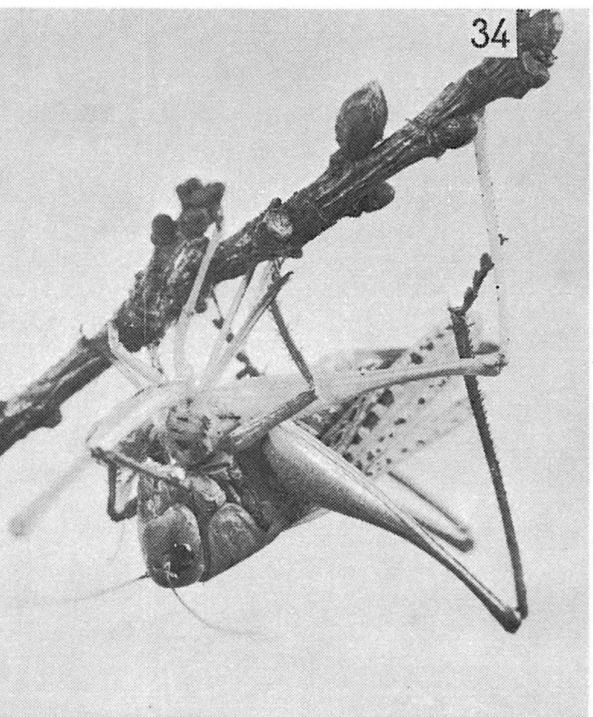


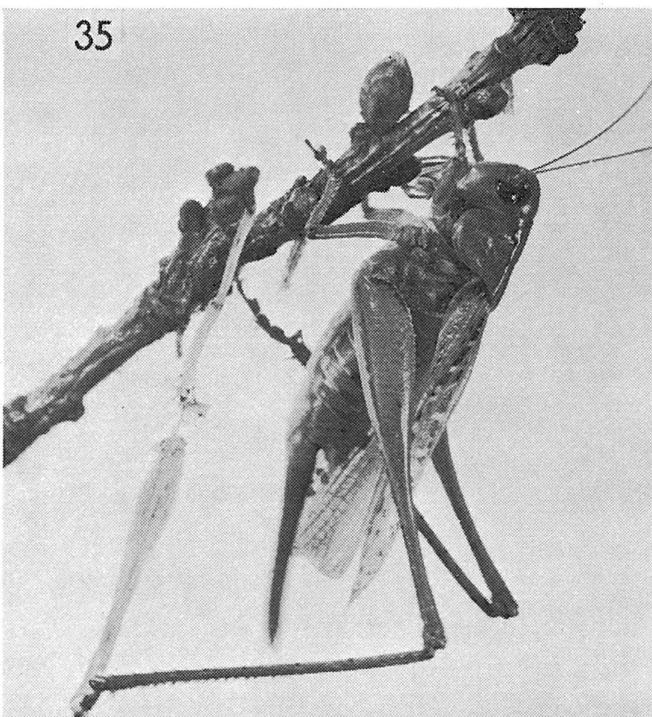


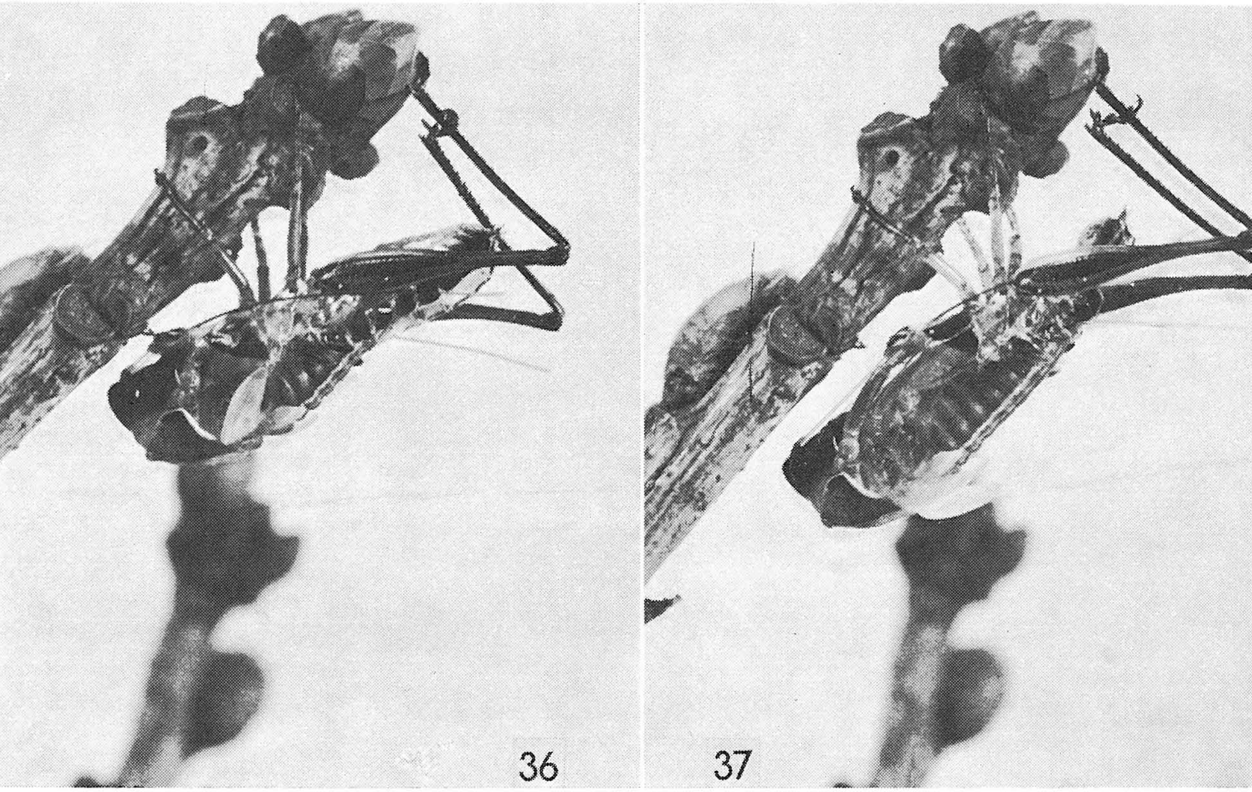


Photos 32–33: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. 32: Detail of the beginning of the second stage of phase II. 33: Detail of phase IV. of the moulting process. Consumption of exuviae after the ultimate moult.

Photos 34–35: Details of the moulting process in the fifth instar female nymph of *Decticus verrucivorus*. Detail of phase IV. of the moulting process. Consumption of exuviae after the ultimate moult.

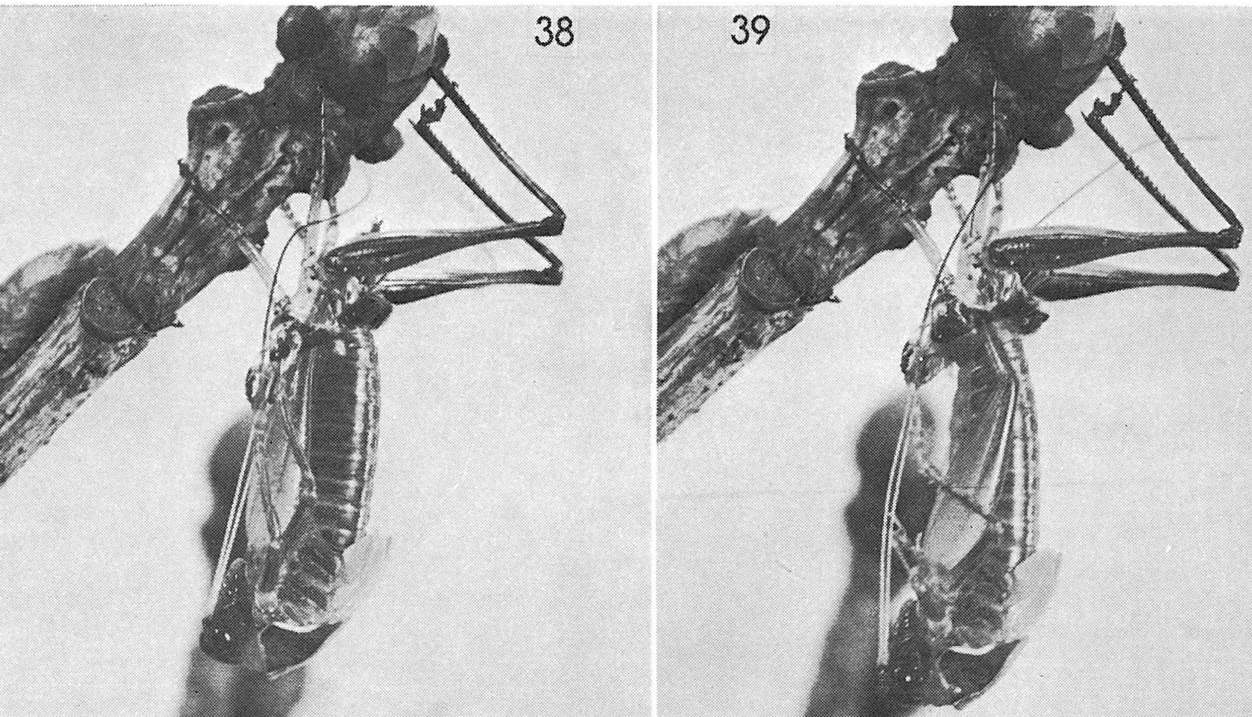


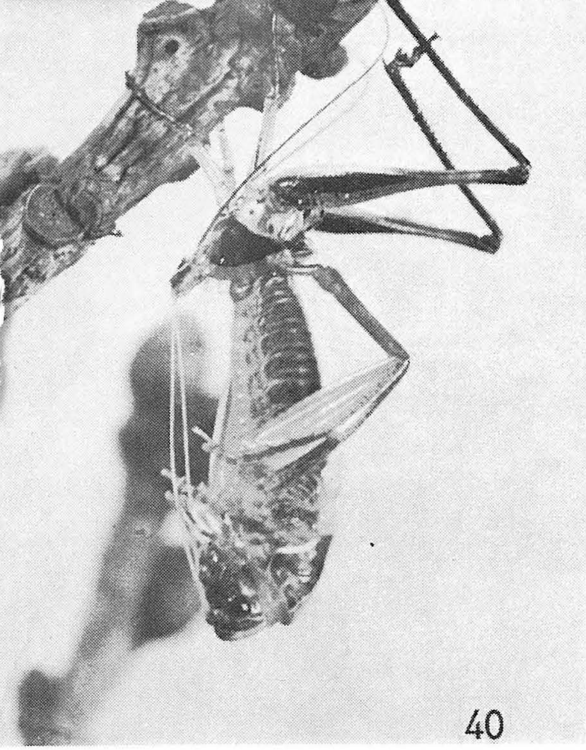


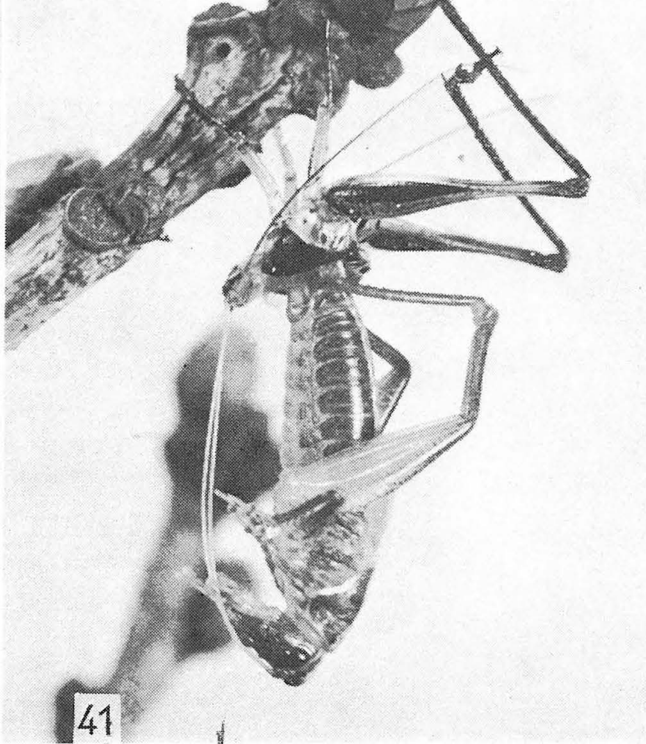


Photos 36—37: Details of the imaginal moulting process in the sixth instar male nymph of *Metrioptera brachyptera*. First stage of phase II.

Photos 38—39: Details of the imaginal moulting process in the sixth instar male nymph of *Metrioptera brachyptera*. First stage of phase II.







Photos 40–41: Details of the imaginal moulting process in the sixth instar male nymph of *Metrioptera brachyptera*. First stage of phase II.

Photos 42–43: Details of the imaginal moulting process in the sixth instar male nymph of *Metrioptera brachyptera*. 42: First stage of phase II. 43: Atypical course of the second stage.

The moulted adult male clings to the twig basides its exuviae. (All photos, with the exception of Nos 3–5, were taken by Mr. Jan Lebeda, Nos 3–5 by Dr. Petr Bílek.)