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The Determination of Larval Instars and Stadia of Some Wireworms (Elateridæ)

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The Determination of Larval Instars and Stadia of Some Wireworms (Elateridæ).

By W. A. McDOUGALL, Assistant Entomologist.

SOME three years ago the writer visited Mackay in order to undertake a comprehensive investigation of the wireworm pests of sugar-cane in Central Queensland. This investigation had not proceeded far before it was realised that it was necessary to have more exact information than was available on methods of determining the larval instars of wireworms, as a means to determining, in turn, the larval stadia. Considerable attention was accordingly given to this work. In the course of the past three years, over thirty different species of Elaterid larvæ have been collected in the area embraced by the investigation. Of these species, one was taken from the rotted wood on the damp lee-side of a tree stump, another from under bark, but the remainder were soil inhabitants. The wood-inhabiting species, and three of the soil species, were of the brown cylindrical type of larva with the ninth abdominal segment either simply rounded at the apex or gradually tapering to a point. Of the remaining species, all were of the yellowish semi-flattened Elaterid larval type with specifically shaped ninth abdominal segments with processes. Included in this latter group is *Lacon variabilis* Cand.; as this species is considered (9) to be the most serious wireworm pest of sugar-cane in the areas mentioned, its life cycle and habits have been observed in as much detail as possible. At the same time, the methods employed in the study of its life cycle and habits have been applied to those of other Elateridæ (mainly, but not exclusively, species of the same larval type that inhabit cultivated fields) for the purpose of checking the reliability of these methods, and also for comparing and contrasting the larval periods and general behaviour of these species with *L. variabilis*.

A. HISTORICAL.

Although the larvæ of a number of Elateridæ of economic importance have been studied, there are few published accounts of a detailed nature dealing with the length of the complete larval period or with larval instars and their stadia. Many of the workers, such as Graf (6) and Ford (5), have had to deal with pest species of wireworms which evidently require two to five or more years from egg to pupation, according to the particular species. The lengths of the larval periods have usually been estimated from observations, chiefly on the sizes of the larvæ found in the field at different times of the year, and the observed rates of growth of some of the different sized larvæ in captivity. The number of larval instars of any species has never been accurately ascertained, and very few species have been taken through from egg stage to adult.

From a survey of literature relevant to this phase of "wireworm" work, it appears that larval length is the usual criterion upon which the larvæ of any species are differentiated into groups, and this grouping is as far as most investigators have proceeded. Ford (5), after working with *Agriotes obscurus* Linnaeus, stated that many of the smaller stages taken in one year, from July to October, varied much in size, and it was found that after about two months a number of these apparently small specimens were really of medium size. It therefore appeared to him that the breadth might be a safer criterion of age than length. Graf (6), although not successful in working out the number of larval instars of *Limonius californicus* Mannh. on account of the unsuitability of the available rearing apparatus, found the increase in the width of the head to be the best indication of an ecdysis.

Various authors have made observations on the growth rates of some species of Elaterid larvæ at different stages during larval life. Graf (6) found there were indications that *L. californicus* moulted five or six times during a larval life calculated to extend a trifle over three years. Larvæ grew rapidly during the first two or three weeks after emerging from the eggs, but this was the only time during their long larval period when growth was apparent. To Veitch (17), the moults of *Simodactylus cinnamoneus* Boisd. appeared to be of frequent occurrence and, in the older wireworms in the laboratory, they might be expected to occur once every eight to twelve weeks. The complete larval life was considered to extend over two or three years; growth rate of the young wireworms was found to be very slow. Ford (5) thought the larvæ of *Agriotes obscurus* passed through three stages, limited by three moults, and were full grown at the end of three years. There is then a period of active feeding, followed by a quiescent condition and terminating in pupation; total length of larval period was computed at four years. The rate of growth was found to be so uniform as to suggest that the curve of growth would be fairly continuous rather than irregular. Roberts (15) found *Agriotes* spp. to moult twice a year, and the rate of growth of the first stage larvæ to be very slow. The earlier estimate of five years for the larval stage of *A. obscurus* is considered to be approximately correct. Mesnil (11), who studied a number of wireworms in France, found that all seemed to have lengthy larval stages, and the larval period of *A. sputator* L. was calculated to be three years. The growth rate of the earlier instars was found to be extremely slow. Fenton (4) found that the growth of two species of *Melanotus* was very slow during the first year of larval life and that, during that time, one moult took place. Conradi and Eagerton (3) give the average periods occupied by the different stages of *Monocrepidius vespertinus* Fab. as twelve days for the egg, 305 for the larval, and thirteen for the pupal stages. In Hawaii (16) *Monocrepidius exsul* is thought to have a larval period of one year or more. Unfortunately no references are made to the growth rates of any of the larval instars of these two *Monocrepidius* species.

B. DETERMINING LARVAL INSTARS.

Various possible criteria for the grouping of larvæ of *Lacon variabilis* were investigated during the course of the rearing work with a view to enabling definite determination of instars. These included the following:—

1. Length of larvæ.
2. Greatest width of ventral mouth parts.
3. Antennal segment ratios, and other mouth part measurements.
4. Width of head capsule.

5. Time of feeding of an instar.
6. Appearance of an instar prior to an ecdysis.
7. A peculiarity in the shape of the first instar.

The results which were obtained are discussed under these headings, and this is followed by a brief discussion of Dyar's Law in its application to the larvæ of *L. variabilis*. A short account is also given of similar work which was carried out to some extent with the other species found.

During the last three quarters of 1931 approximately 1,200 larval specimens of *L. variabilis* were taken from cane fields; of these 306 were used for rearing purposes, and 219 adults were obtained from them between October and the end of that year.

Length of Larvæ.

Numerous measurements of length were taken at monthly intervals during the rearing of the larvæ (Table I.), but apart from serving as a general guide to the probable stage of development they were of little value. The chief result accruing from this rearing work was the correlation of the larva with its correct adult. After length measurements had failed to provide a method for the working out of the details of the larval life with the degree of precision desired, further search was made for criteria suitable for the purpose, as outlined.

Greatest Width of Ventral Mouth Parts.

The ventral portion of the mouth parts of an Elaterid larva is a conspicuous structure situated in a large depression on the venter of the head Plate 1, figs. A and B).

This structure is formed by the fusion of the stipites of the maxillæ with the mentum (Plate 1, fig. E [a]). In some genera (e.g., B. sp.) the mentum is quadrilateral and much longer than wide; in these instances more of the cardines are visible when the whole of the ventral mouth parts is retracted than is so with *Lacon* spp. and *Heteroderes* spp., each of these possessing a triangular mentum. A total of 229 larvæ of different sizes was examined, and it was found that these could be grouped according to the greatest width of the ventral mouth parts, i.e., the measurement (A-B) illustrated in fig. A of Plate 1. In a number of instances this grouping (Table II.) disagreed with the grouping as obtained when the same larvæ were separated on the basis of length. The groups obtained by this means were well defined, there being no individuals with intermediate measurements which might equally well be placed in two groups. During 1931 several larvæ, which had just shed their skins, had been preserved with the exuviæ which had been found near them. The (A-B) [b] measurements of the mouth parts of these larvæ and their respective exuviæ were taken, in the manner described above. Each exuvium measurement was within the limits of the group immediately preceding that into which a similar measurement of the correctly-related larva fell.

(*a*) This drawing represents one section of a complete serial section of a sixth instar. The block was prepared by the double embedding in celloidin and paraffin (adapted from Guyer: Animal Micrology, Revised Edition, p. 64) of the instar immediately after ecdysis; the larva was completely white with the exception of the tips of the mandibles, which were brown.

(*b*) For the sake of convenience the greatest width of the ventral mouth parts is termed the (A-B) measurement both in the text and tables.

TABLE I.

Lengths of Larvæ in Centimetres; Data based on the Recorded Observations on 306 Larvæ and 3 Pupæ, made during Rearing Work, 1931.

Lab. No. of Larva and Pupa.	Dates of Observations.										
	14th May	8th June	22nd June.	6th July.	5th Aug.	9th Sept.	28th Sept.	Oct.	Nov.	Dec.	Jan. (1932).
P. 2 ..	P.f.		Adult 19th May.								
L. 2 ..	Length ·58 cm.	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	e. Ex. f. ·9 cm.	e. Ex. f. 1·2 cm.	..	Adult (17th)	..	..
L. 19 ..	1·45	p.n.c. n.e.	1·7	e.h. 1·6	n.e. 1·7	e.h. 1·9	n.e.	n.e.	P.f. (17th) Adult (29th)	..	..
L. 23 ..	1·1	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	n.e. Ex. f. 1·1	e.h.	e.h. Ex. f. 1·5	n.e. 1·7	P.f. (17th) Adult (24th)	..	..
L. 31 ..	1·0	n.e. Ex. f. 1·4	p.n.c. e.h.	n.e.	n.e.	e.h. Ex. f. 1·5	n.e.	n.e.	P. f. (17th) Adult (30th)	..	..
L. 40 ..	1·5	e.h. 1·6	p.n.c. n.e. 1·74	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.c.	P.f. (12th) Adult (21st)	..	..	..
L. 47 ..	1·9	p.n.c. e.h. ..	p.n.c. n.e.	p.n.c. n.e.	Just changed Ex. f.	e.v.h. 1·86	e.h. Ex. f. 1·94	..	P. f. (17th) Adult (22nd)	..	..
L. 52 ..	1·1 ..	p.n.c. n.e.	p.n.c. n.e.	..	p.n.c. n.e. 1·1	e.v.h. 1·4	p.n.c. 1·5	e.h. Ex. f. 1·7	P.f. (17th) Adult (21st)	..	..
L 70 ..	·77	e.	..	..	Ex.f.	e.h. 1·2	e.h. 1·3	e.h. 1·6	p.n.c. n.e.	P.f. (27th)	Adult (8th)
L. 81 ..	1·9	e.v.h. Ex.f.	n.e. p.n.c. 1·9	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	In a cell	P.f. (12th) Adult (17th)	..	..	..
L. 87 ..	·83	h.e. Ex.f. 1·0	p.n.c. n.e.	n.e.	n.e.	e.v.h. 1·6	1·7	e.v.h.	P.f. (17th) Adult (29th)	..	..
L. 88 ..	1·9	Just changed Ex.f.	e.v.h. 1·9	n.e.	n.e.	n.e.	n.e.	1·8	..	P.f. (8th) Adult (10th)	..
L. 95 ..	1·7	e.v.h. Ex.f. 1·9	1·9	n.e.	Just changed n.e. Ex.f.	e.v.h.	2·0	..	P.f. 2nd Adult (15th)	..	..
L. 120 ..	Taken from field 27th May 1·6	..	e.v.h. Ex.f. 1·6	1·9	..	Nearing an ecdysis	e.v.h. 1·9	..	..	P.f. (3rd) Adult (8th)	..
Ls. 140 to 145		..	.. ..	Taken 10th July 1·7	p.n.c. n.e.	.. ..	..	1·6 to 1·7	..	P.f. (17th) Adults (20th to 25th)	..
L. 152 ..	..	..	..	1·3	Ex.f. 1·5	e.v.h.	Ex.f. 1·6	e.v.h.	..	P.f. (10th) Adult (21st)	..
L. 161 ..	..	..	..	1·9	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	P.f. (2nd Adult (10th)	..	..
L. 205 ..	.. ..	..	..	1·9	p.n.c. n.e.	e.v.h. Ex.f. 2·0	..	..	P.f. (2nd) Adult (10th)	..	..
L. 230 ..	..	..	..	2·1	p.n.c. n.e.	p.n.c. n.e.	p.n.c. n.e.	..	Adult (17th)	..	..
L. 255 ..	..	..	..	Taken 27th July very small	e.h.	1·3	e.	e. 1·6	e.v.h. Ex.f. 1·6	e.v.h.	P.f. (8th) Adult (10th)
L. 256 ..	..	..	..	Very small	e.h.	1·0	e.	e.v.h. 1·45	e.v.h.	P.f. (18th) Adult (20th)	..
Ls. 295 to 301	..	..	..	..	..		..	Taken 14th Oct. 1·6—2·1	Adults (17th-28th)	..	..

p.n.c. = probably no change; n.e., e., e.h., e.v.h. = not eaten, eaten, eaten heavily, or eaten very heavily, of potato tuber since last inspection (fresh potato tuber supplied after every inspection). Ex.f. = exuvium found; P.f. = pupa found.

TABLE II.—MOUTH PART MEASUREMENTS OF SIX GROUPS OF LARVÆ.

Group.	Number of Larvae Measured.	Greatest Width of Ventral Mouth Parts. (in mm.)		
		Minimum.	Mean.	Maximum.
A	5	·35	·38	·40
B	10	·47	·52	·54
C	68	·63	·68	·70
D	60	·79	·83	·86
E	29	·96	·99	1·03
F	57	1·12	1·15	1·24
Total	229	..	..	..

In December, 1931, and January, 1932, approximately 1,000 eggs of *L. variabilis* were obtained from adults bred from larvæ during 1931 and from other adults collected in the field. From these eggs many larvæ emerged and were used for rearing purposes. With the rearing apparatus in use at that time the majority of the exuviæ from the younger instars could not be recovered from the soil in the rearing jars. However, the (A-B) measurements of 179 small instars were taken; at the time of measurement some of those larvæ had just emerged from eggs. Again, grouping could be effected, and the details are given in Table III.; obviously groups J and K contain larvæ similar to those represented by groups A and B respectively of Table II. It would seem, therefore, that any larva of *L. variabilis* can be placed, according to its (A-B) measurement, into one of eight groups.

TABLE III.—MOUTH PART MEASUREMENTS OF FOUR GROUPS OF LARVÆ.

Group.	Number of Larvae Measured.	Greatest Width of Ventral Mouth Parts. (in mm.)		
		Minimum.	Mean.	Maximum.
G	89	·161	·163	·167
H	50	·21	·23	·28
J	27	·35	·38	·40
K	13	·47	·53	·54
Total	179	..	..	..

The percentage loss by death in rearing young larvæ up to the fourth group (Group K of Table III.) was exceptionally heavy during 1932. Varying environmental conditions were tried, and when a suitable set of conditions was found, 134 larvæ were reared from eggs to

TABLE IV.

(A–B) MEASUREMENTS AS DETERMINED FROM THE RECORDED OBSERVATIONS OF 134 LARVÆ.

Laboratory No. of Larva.	Egg Laid.	First Instar. Date of Emergence.	First Instar. (A–B) Measurement.	Remarks on any Intermediate (A–B) Measurements and Ecdyses.	Ecdyses Observed. Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	Date of Appearance of Adult.	Length of Complete Larval Period (in days).
L1. 1	8 i.	16 i.	·163	Larvæ with (A–B) measurement of ·65 on 8 iii.	..	..	..	12 iii.	·65	·79	29 iv.	·79	·98	1 vi.	·98	1·14	1 x.	1·14	16 x.	259
L1. 3	8 i.	16 i.	·162	Larvæ with (A–B) measurement of ·54 on 16 ii.	20 ii.	·54	·67	8 iii.	·67	·84	1 v.	·84	1·03	21 vi.	1·03	1·24	30 x.	1·24	14 x.	288
L1. 6	8 i.	16 i	·166	Found on 24 ii. an exuvium with (A–B) measurement of ·35; on 27 ii. (A–B) measurement of larvæ was ·47	2 iii.	·47	·63	10 iv.	·63	·79	25 v.	·79	·98	29 vii.	·98	1·20	1 xi.	1·2	16 xi.	290
L2. 2	10 i.	18 i.	·167	..	..	..	..	25 iv.	·65	·82	6 vi.	·81	·98	4 vii.	·98	1·16	23 xi.	1·16	7 xii.	310
L2. 3	10 i.	18 i.	·161	Larvæ with (A–B) measurement of ·53 on 18 ii.	19 ii.	·53	·67	4 iii.	·67	·84	15 iii.	·84	(Pupa)	..	..	..	..	..	29 iii. ♂	57
L2. 5	10 i.	18 i.	·163	..	..	..	..	24 ii.	·65	·80	4 iii.	·81	·98	..	..	..	26 iii.	1·16	9 iv. ♀	68
L2. A1	28 i.	6 ii.	·167	Two ecdyses recorded. (A–B) measurement 12 iii. (Ex. ·26) (L. 39); 28 iii. (Ex. ·39) (L. 51)	30 iv.	·51	·65	4 vi.	·66	·81	26 viii.	·81	·98	7 x.	·98	1·12	24 xi.	1·12	10 xii.	292
L2. 26	1 ii.	9 i.	·161	Ecdyses recorded on 12 iii. (Ex. ·237) (L. ·373)	..	..	..	1 v.	·63	·82	1 vi.	·82	1·02	28 vii.	1·02	1·25	14 xi.	1·25	29 xi.	279
L22. 11	29 i.	7 ii.	·164	Larvæ with (A–B) measurement of ·51 on 28 iv.	5 v.	·51	·63	18 vi.	·63	·79	1 ix.	·79	·98	1 x.	·98	1·15	12 xii.	1·15	Found Adult, 8 ii. 1933	..
L22. 17	29 i.	7 ii.	·164	Larvæ with (A–B) measurement of ·51 on 8 iii.	20 iii.	·50	·65	10 v.	·65	·86	5 vi.	·86	1·03	20 vii.	1·03	1·20	9 i. 1933	1·20	24 i., 1933	337
L22. 18	29 i.	7 ii.	·165	Recorded an ecdysis on 20 iii. (Ex. ·25) (L. ·39)	24 ii.	·51	·65	1 v.	·65	·84	1 vi.	·84	·98	30 vii.	·98	1·16	26 x.	1·16	10 xi.	262
L22. 22	30 i.	8 ii.	·163	Larvæ with (A–B) measurement of ·49 on 15 v.	25 v.	·49	·65	26 vi.	·65	·86	24 viii.	·86	·98	26 x.	·98	1·20	25 xi.	1·20	9 xii.	291
L22. 23	30 i.	8 ii	·163	Larvæ with (A–B) measurement of ·49 on 1 v.	14 iv.	·49	·63	5 v.	·63	·81	6 vi.	·81	1·03	24 vi.	1·03	1·20	26 x.	1·20	9 xi.	261
L22. 26	8 ii.	16 ii.	·161	Larvæ with (A–B) measurement of ·65 on 29 iii.	..	..	..	5 iv.	·65	·82	24 v.	·82	1·03	1 vii.	1·03	1·17	28 x.	1·17	11 xi.	255
L7. A	1 ii.	9 ii.	·161	Recorded the ecdysis (Ex. ·25) (L. ·37)	..	..	..	4 iii.	·67	·82	30 iv.	·82	·98	1 vii.	·98	1·14	14 xi.	1·14	30 xi.	279

L1. 1, L1. 3, and L1. 6 are larvæ from eggs of adult L1. L22 only, represents more than one female confined in the one cage.

* ±) 2 days; in many instances the date is exact.

TABLE V.

(A–B) Measurements in Millimetres as Determined from the Recorded Observations on 117 Larvæ.

Laboratory No. of Larvæ.	Ecdyses Recorded.																	Date of Appearance of Adult.
	Date when Collected from Field.	(A–B) Measurement on Date of Collection.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.*	(A–B) Measurement of Exuvium.	Pupa.	
128	19 April	·96	..	..	..	..	..	..	..	..	..	15 May	·96	1·16	19 Dec.	1·16	..	..
169	19 April	1·17	..	..	..	..	..	..	..	..	..	..	..	..	10 May	1·17	..	25 May
132	19 April	·65	..	..	..	27 April	·65	·86	21 July	·86	1·03	21 Oct.	1·03	1·21	1 Dec.	1·21	..	17 Dec.
134	19 April	1·17	..	..	..	..	..	..	..	..	..	..	..	..	8 May	1·17	..	22 May
135	19 April	1·03	..	..	..	..	..	..	..	..	..	1 June	1·03	1·16	1 Nov.	1·16	..	16 Nov.
146	19 April	·51	25 April	·51	·70	15 May	·70	·86	1 June	·86	·98	1 July	·98	1·16	25 Oct.	1·16	..	9 Nov.
150	19 April	1·16	..	..	..	..	..	..	..	..	..	..	..	..	?	1·16	..	Found Adult, 2 June
158	19 April	·47	20 May	·47	·67	1 July	·67	·82	15 Sept.	·82	·98	15 Oct.	·98	1·15	28 Nov.	1·15	..	12 Dec.
169	24 May	·65	..	..	..	20 June	·65	·82	21 July	·82	1·00	20 Aug.	1·00	1·16	25 Oct.	1·16	..	10 Nov.
182	1 June	†·39	28 Aug.	·51	·65	12 Oct.	·65	·82	30 Oct.	·82	·98	14 Nov.	·98	1·15	28 Nov.	1·15	..	13 Dec.
183	10 June	·96	..	..	..	..	..	..	..	..	..	15 June	·96	1·14	14 Nov.	1·14	..	30 Nov.
184	22 June	1·00	..	..	..	..	..	..	..	..	..	24 June	1·00	1·26	25 Oct.	1·26	..	9 Nov.
185	22 June	1·15	..	..	..	..	..	..	..	..	..	..	..	..	5 Nov.	1·15	..	20 Nov.
186	22 June	·98	..	..	..	..	..	..	..	..	..	20 July	·98	1·16	14 Nov.	1·16	..	29 Nov.
187	22 June	·96	..	..	..	..	..	..	..	..	..	20 Aug.	·96	1·12	14 Nov.	1·12	..	28 Nov.
190	22 June	1·26	..	..	..	..	..	..	..	..	..	..	..	..	1 Oct.	1·26	..	16 Oct.
191	22 June	1·26	..	..	..	..	..	..	..	..	..	..	..	..	14 Nov.	1·26	..	28 Nov.
192	22 July	·81	..	..	..	..	..	..	1 Aug.	·81	·98	12 Oct.	·98	1·14	14 Nov.	1·14	..	29 Nov.
198	15 Aug.	·51	28 Aug.	·51	·68	15 Oct.	·68	·84	28 Nov	·84	(Pupa)	..	..	..	..	..	..	12 Dec.
199	15 Aug.	·67	..	..	..	15 Sept.	·67	·86	11 Oct.	·86	1·00	20 Nov.	1·00	1·19	12 Dec.	1·19	..	..

* (±) 2 days ; in many instances the date is exact.

† Ecdysis recorded on 9 June, (A–B) measurement of exuvium being ·39 and that of larva ·51.

adults. Each larva was watched carefully, and the necessary measurements of both larva and exuvium were taken after all the later ecdyses (Table IV.). It now seems apparent that at least the last five larval instars of *L. variabilis* can be recognised by referring the measurements of the greatest widths of their ventral mouth parts to Table II. During this year (1932) larvæ in different stages were taken from the fields at intervals and reared to adults (Table V.). This was done mainly for two purposes—firstly, to obtain additional evidence along the lines utilised in Table IV.; and secondly, to compare the development of the larvæ reared in the laboratory, from eggs to adults, with those living under field conditions during various portions of their existence.

Between December, 1932, and November, 1933, with a better knowledge of the environmental conditions desired by the smaller instars, and with more suitable rearing apparatus, 107 larvæ were taken through from eggs to adults. In 49 instances a complete set of eight larval exuviæ for each specimen under observation was obtained and the larval and exuvial (A-B) measurements were recorded as in Table VIA. In other instances an occasional exuvium was missed out; however (A-B) measurements taken of all exuviæ found, and also of the related larvæ, were in accord with what would be expected after a study of the recorded observations of which a portion are set out in Table VIA. There now seems to be no doubt that there are normally eight instars in the larval life of *L. variabilis,* and that any larval specimen of this species can be given its correct "instar number" by referring the measurement, in millimetres, of the greatest width of its ventral mouth parts to the eight distinct groups of Tables II. and III.

As in previous years a small proportion of the larvæ behaved in a manner similar to No. L2.3. of Table IV., i.e., pupation was reached after less than eight larval moults, and in four instances a complete set of six larval exuviæ for each specimen was recovered. In each instance the (A-B) measurement of the final larval exuvium corresponded to that of a larva in its sixth instar. When there are only six instars during the life of a larva, any resulting adult is invariably a small male. As in 1932 observations were made on numerous specimens collected in the field; records of such are very similar to those recorded in Table V.

In compiling the tables for this article from records of observations on larvæ reared from eggs in the laboratory, no references have been made to those instances when only one or two ecdyses (with necessary measurements) were recorded of any larvæ which, for some reason or other, were not taken through to pupation. The inclusion of such records would easily double the "ecdysal" measurements similar to those of Tables IV.-VIA., and it would be merely added evidence in favour of the points which these tables already demonstrate.

Antennal Segment Ratios and Other Mouth Part Measurements.

Roberts (16), when describing the first larval instar of an *Agriotes* sp., points out that the third, or supplementary segment in an antenna is longer than the conical ventral process at the apex of the second, but that this difference is much less in the mature larvæ. At this stage it is also much longer in proportion to the whole antenna than in the older larvæ. When working with *L. variabilis* it was found to be very difficult to measure accurately the true lengths of the segments of the antennæ (see Plate 1, fig. D.). Each segment can be withdrawn,

TABLE VIa.

(A–B) Measurements in Millimetres as Determined from the Recorded Observations on 49 Larvæ.

Laboratory No. of Larva.	Egg Laid.	First Instar. Date of Emergence.	First Instar. (A–B) Measurement.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.
4	20 Nov., 32	28 Nov., 32	·162	5 Dec., 32	·162	·233	19 Dec., 32	·23	·39	12 Jan., 33	·39	·52	11 Feb., 33	·52	·65
5	20 Nov., 32	28 Nov., 32	·162	6 Dec., 32	·162	·237	18 Dec., 32	·24	·38	15 Jan., 33	·38	·52	24 Jan., 33	·52	·66
12	5 Dec., 32	12 Dec., 32	·161	24 Dec., 32	·161	·233	13 Jan., 33	·234	·40	16 Feb., 33	·40	·54	3 Mar., 33	·54	·70
26	21 Nov., 32	28 Nov., 32	·167	4 Dec., 32	·167	·235	11 Dec., 32	·24	·39	19 Dec., 32	·39	·53	1 Jan., 33	·53	·69
30	8 Dec., 32	15 Dec., 32	·165	24 Dec., 32	·165	·233	3 Jan., 33	·23	·38	20 Jan., 33	·38	·52	3 Feb., 33	·52	·67
33	5 Dec., 32	13 Dec., 32	·163	24 Dec., 32	·163	·234	13 Jan., 33	·234	·36	4 Feb., 33	·36	·52	20 Feb., 33	·52	·68
35	5 Dec., 32	12 Dec., 32	·163	19 Dec., 32	·163	·236	26 Dec., 32	·236	·38	10 Jan., 33	·38	·52	15 Feb., 33	·52	·69
37	13 Dec., 32	21 Dec., 32	·163	3 Jan., 33	·163	·233	24 Jan., 33	·233	·37	4 Feb., 33	·37	·53	21 Feb., 33	·53	·68
39	3 Jan., 33	10 Jan., 33	·163	24 Jan., 33	·163	·234	4 Feb., 33	·235	·37	21 Feb., 33	·37	·51	23 Mar., 33	·51	·66
41	3 Dec., 32	12 Dec., 32	·163	19 Dec., 32	·163	·233	25 Jan., 33	·233	·39	14 Feb., 33	·39	·53	16 Mar., 33	·53	·67
62	5 Jan., 33	12 Jan., 33	·162	24 Jan., 33	·162	·235	13 Feb., 33	·235	·38	24 Feb., 33	·38	·53	9 Mar., 33	·53	·67

TABLE VIa.—*continued.*

(A–B) Measurements in Millimetres as Determined from the Recorded Observations on 49 Larvæ—*continued.*

Laboratory No. of Larva.	Egg Laid.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.	(A–B) Measurement of Exuvium.	(A–B) Measurement of Larva.	Date.	(A–B) Measurement of Exuvium.	Pupa.	Date of Appearance of Adult.	Length of Complete Larval Period (in days).
4	20 Nov., 32	15 Mar. ..	·65	·82	7 May ..	·82	·98	27 May ..	·98	1·15	7 Nov. ..	1·15	..	21 Nov., 33	344
5	20 Nov., 32	18 Feb. ..	·66	·85	10 Apr. ..	·85	1·00	30 May ..	1·00	1·20	1 Nov. ..	1·20	..	15 Nov., 33	338
12	5 Dec., 32	3 Apr. ..	·69	·86	7 May ..	·86	1·00	15 June ..	1·00	1·16	10 Nov. ..	1·16	..	24 Nov., 33	333
26	21 Nov., 32	23 Jan. ..	·69	·84	4 Feb. ..	·84	·98	20 Mar. ..	·98	1·12	26 Apr. ..	1·12	..	11 May, 33	149
30	8 Dec., 32	1 Mar. ..	·67	·82	29 Mar. ..	·82	·98	11 May ..	·98	1·15	26 Oct. ..	1·15	..	7 Nov., 33	315
33	5 Dec., 32	16 Mar. ..	·68	·85	5 Apr. ..	·85	1·00	13 May ..	1·00	1·20	9 Nov. ..	1·20	..	23 Nov., 33	331
35	5 Dec., 32	12 Mar. ..	·69	·85	1 Apr. ..	·85	1·00	9 June ..	1·00	1·16	14 Nov. ..	1·16	..	28 Nov., 33	337
37	13 Dec., 32	23 Mar. ..	·68	·82	1 May ..	·82	·98	9 June ..	·98	1·16	14 Oct. ..	1·16	..	29 Oct., 33	297
39	3 Jan., 33	1 May ..	·66	·81	9 June ..	·81	·98	4 July ..	·98	1·12	4 Nov. ..	1·12	..	19 Nov., 33	298
41	3 Dec., 32	19 Apr. ..	·67	·84	10 May ..	·84	1·00	21 June ..	1·00	1·21	10 Nov. ..	1·21	..	24 Nov., 33	333
62	5 Jan., 33	25 Mar. ..	·67	·82	29 Apr. ..	·82	1·00	30 May ..	1·00	1·21	15 Nov. ..	1·21	..	30 Nov., 33	307

TABLE VIb.

Laboratory No. of Larva.	(A–B) Measurements of Instars (in mm.).														
	1st	A	2nd	B	3rd	C	4th	D	5th	E	6th	F	7th	G	8th
4	·162	·071	·233	·157	·39	·13	·52	·13	·65	·17	·82	·16	·98	·17	1·15
5	·162	·075	·237	·143	·38	·14	·52	·14	·66	·19	·85	·15	1·00	·20	1·20
12	·161	·072	·233	·167	·40	·14	·54	·16	·70	·16	·86	·14	1·00	·16	1·16
26	·167	·068	·235	·155	·39	·14	·53	·16	·69	·15	·84	·14	·98	·14	1·12
30	·165	·068	·233	·147	·38	·14	·52	·15	·67	·15	·82	·16	·98	·17	1·15
33	·163	·071	·234	·126	·36	·16	·52	·16	·68	·17	·85	·15	1·00	·20	1·20
35	·163	·073	·236	·144	·38	·14	·52	·17	·69	·16	·85	·15	1·00	·16	1·16
37	·163	·070	·233	·137	·37	·16	·53	·15	·68	·14	·82	·16	·98	·18	1·16
39	·163	·071	·234	·136	·37	·14	·51	·15	·66	·15	·81	·17	·98	·14	1·12
41	·163	·070	·233	·157	·39	·14	·53	·14	·67	·17	·84	·16	1·00	·21	1·21
62	·162	·073	·235	·145	·38	·15	·53	·14	·67	·15	·82	·18	1·00	·21	1·21
L1. 1	..	..	..	..	..	..	..	..	..	..	·79	·19	·98	·16	1·14
L1. 3	..	..	..	..	..	..	·54	·13	·67	·17	·84	·19	1·03	·21	1·24
L 22. 11 ..	..	..	..	..	..	..	·51	·12	·63	·16	·79	·19	·98	·17	1·15
L2. A1 ..	..	..	·26	·13	·39	·12	·51	·14	·65	·16	·81	·17	·98	·14	1·12
L22. 26 ..	..	..	..	..	..	..	..	..	·65	·17	·82	·21	1·03	·14	1·17
L7. A8 ..	..	..	..	..	..	..	..	..	..	..	·82	·16	·98	·16	1·14
132	..	..	..	..	..	..	..	..	·65	·11	·86	·17	1·03	·18	1·21
146	..	..	..	..	..	..	·51	·19	·70	·16	·86	·12	·98	·18	1·16
158	..	..	..	..	..	..	·47	·20	·67	·15	·82	·16	·98	·17	1·15
169	..	..	..	..	..	..	..	..	·65	·17	·82	·18	1·00	·16	1·16
182	..	..	..	..	·39	·12	·51	·16	·65	·17	·82	·16	·98	·17	1·15
192	..	..	..	..	..	..	..	..	..	..	·81	·17	·98	·16	1·14
198	..	..	..	..	..	..	·51	·17	·68	·16	·84	..	..	..	..
199	..	..	..	..	..	..	..	..	·67	·19	·86	·14	1·00	·19	1·19

Columns headed by ordinates give (A–B) measurements of instars, whilst columns headed by the letters A, B, C, &c., give differences in (A–B) measurements of larvæ in successive instars. All measurements in millimetres.

wholly or partly, into the one preceding it and the whole antenna may be withdrawn into the head capsule. The same difficulty is encountered when attempting to measure some of the mouth parts and their appendages. The maxillary palps may telescope wholly or partly and the dististipites (Plate 1. fig. A., *dis.*) and appendages connected with them may be withdrawn into the stipites; the mentum may house the prementum. It is considered that the use of antennal segment ratios for distinguishing the different instars is attended by too many difficulties. Table VII. gives the ratios, obtained after many measurements, of the lengths of the antennal segments for all larval instars; all measurements having been brought to a common denominator.

Measurements were made of the distance from the tips of the mandible to the condyles, but quite often when the larger instars are nearing the completion of stadia, the tips of the mandibles become worn, as also do the processes of the nasale.

TABLE VII.—Antennal Segment Ratios. In the Column dealing with the Second Segments the Upper Figures represent the Lengths of the Segments while the Lower Figures relate to the Conical Processes at the Apices of the Segments.

Instar.	Segments of Antenna.		
	First.	Second.	Third.
First	6	9 10	14
Second	16	15 12	16
Third	26	20 15	20
Fourth	40	28 18	24
Fifth	54	38 19	27
Sixth	70	46 20	30
Seventh	90	58 21	34
Eighth	110	68 22	40

Description of Plate 1.

Lacon variabilis Cand.

A.* Ventral mouth parts: *dis.*, dististipes; *st.*, stipes; *m.*, mentum; *c.*, cardo × 24.

B. Ventral view of head showing ventral mouth parts *in situ* × 24.

C. Dorsal view of full-grown larva × 3.

D.* Antenna of sixth larval instar × 60.

E.* Transverse section through head region showing mentum fused with the stipes of the maxillæ: *m.*, mentum; *st.*, stipes; *ma.*, mandible; *a.*, antenna × 60.

* Drawn from permanent mounts.

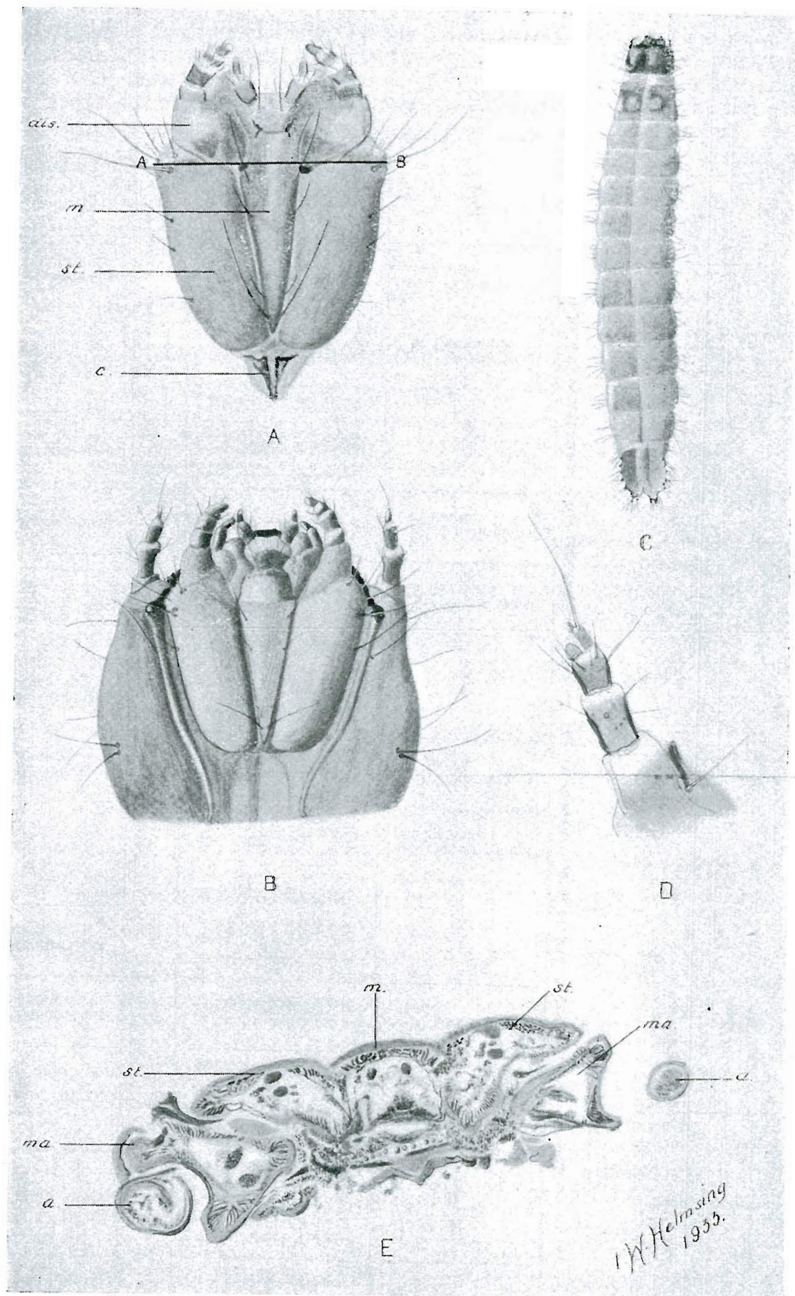


Plate 1.

Width of the Head Capsule.

In all probability this measurement could have been utilised in determining the instars of *L. variabilis* had no other criterion been of outstanding value. Measurements of the widths of the head capsules are not as accurate as those of the ventral mouth parts, as the capsules may be ruptured during ecdyses. Furthermore, the comparatively compact nature of the ventral mouth parts (see Plate 1, figs. B. and E.) does not allow of their losing shape when being measured in exuviæ, whereas the empty moulted head capsules tend to flatten, with consequent increase of width. When dealing with living specimens, the accurate measurement of the ventral mouth parts is much more easily carried out than that of the head capsules. Measurements of the head capsules of each instar are such that, where v = greatest width of the ventral mouth parts, and h = width of head capsule, v = kh, k being a constant which closely approximates to ·60 for any specimen of any larval instar of *L. variabilis*.

Time of Feeding of an Instar.

During 1931, when length measurements only were determined, it was apparent that feeding was not continuous (see Table I.). Later it was observed that, in the continued presence of vegetable material and suitable soil moisture, a *L. variabilis* instar feeds voraciously for a short period immediately after an ecdysis and does not feed again during that stadium. As examples Nos. 4, 5, 30, and 33 of Table VIA. may be cited. Nos. 30 and 33 were in the final larval instar by the middle of May, Nos. 4 and 5 by the end of May; Nos. 30 and 33 pupated in late October and early November respectively, but both had finished feeding by the first week in June while Nos. 4 and 5 had finished feeding by the third week in June. At all times, from May to November, vegetable material and suitable soil moisture conditions were present in the jars containing the larvæ in order to encourage the feeding of this particular instar. If either of the two environmental factors governing feeding is unfavourable immediately after an ecdysis the larva will ingest soil, but if suitable conditions are provided at a later stage during the stadium, the one large feed of vegetable material will be taken. In addition to the effect on the time of feeding, variations in these environmental conditions have an effect on the measurable length of an instar.

Appearance of an Instar Prior to Ecdysis.

Prior to ecdyses all instars become torpid, their general shape and colouring changes, and in many instances the measurable length is increased. The body segments may assume the appearance of a short string of tightly-strung broad-ended beads, with indentations here and there in the lateral and ventral regions. The general colour is paler than that of the normal active larvæ. In this pre-ecdysal state a larva may exist for periods ranging from two days (smaller instars), to as long as two months (last larval instar). This distinctive appearance of the instars before ecdyses, and their heavy feeding immediately after ecdyses, when conditions are at all suitable, were of considerable help during the rearing work of 1932-33 in enabling us to place within a few days the dates of some of the ecdyses of the smaller and moderately-sized instars.

A Peculiarity in Shape of the First Larval Instar.

It was found that the larvæ of *L. variabilis* do not assume the specific shape of the ninth abdominal segment until the second instar (see Plate 2, figs. C, D, and E), and as a result the first instar can be separated from all other larval instars on the basis of the shape of the ninth abdominal segment alone.

Discussion.

Concerning the use of head width measurements Imms (7) states:—"Dyar has shown from observations on the larval instars of twenty-eight species of Lepidoptera that the head-width follows a regular geometric progression in successive instars. Since the head is not subject to growth during a stadium it is possible, by means of accurate measurements, to determine whether ecdysis has been overlooked during life-history studies." During the past few years some workers ([a]) have attempted to apply Dyar's Law to other orders of insects, not only as a means of determining whether an ecdysis has been overlooked or not during life-history studies, but also in some instances for the purpose of estimating the number of instars in some particular species. The procedure usually adopted is to measure accurately the widths of the head capsules of a sufficiently large random population and then arrange the measurements in an ascending order of magnitude. Measurements are next divided into well-defined groups, if possible, and the mean of each group calculated. The possibility of these means advancing in geometrical progression is then investigated and as much rearing work as possible is carried out.

This procedure has been followed in dealing with *L. variabilis* with this exception, that for greater convenience and accuracy, the greatest widths of the ventral mouth parts (v) were measured instead of the widths of the head capsules (h) ($v = 0{\cdot}60 \times h$, see page 56). In Table VIII. are set out eight groups, together with means, &c., and it is demonstrated by the measurements taken during the rearing of larvæ from eggs to adults, that each group represents an instar. In compiling this table all data as shown in Tables II. and III. are used in conjunction

(*a*) Metcalfe (12) found that the head measurements of 887 specimens of a random population of *Sitodrepa panicea* L. fell into two sets of groups, the growth ratios of which approximated to two geometric series; it is suggested that these two sets represent sexes. No satisfactory conclusions with regard to the number of early instars could be reached owing to the inadequate number of larvæ obtained.

Miles (13) found that in the Tenthredinidæ studied by him growth and development appear to be more complicated than in the larvæ of Lepidoptera first reported by Dyar. Sex differentiation is considered to render the larval growth of the later instars irregular.

Prebble (14) found that the larval growth rate of three bark-beetles conformed satisfactorily with Dyar's Law. One species has four larval instars and the other two species three.

Andrewartha (1) measured the head widths of 147 larvæ of *Otiorrhyncus cribricollis* Gyll. It was considered that the grouping of these measurements, together with some relevant circumstantial evidence, demonstrated that there are ten instars in the larval life of *O. cribricollis*. For this species Dyar's Law was found to hold good when applied to the average head width of an instar. From this work Andrewartha concludes that "we now have a reliable method for determining the number of instars in the life of soil-inhabiting, leaf-mining, and other inaccessible larvæ." The actual application of the method together with direct evidence shows that, so far as *L. variabilis* and several other species of Elateridæ are concerned, the above conclusion is not altogether correct. The application of Dyar's Law, in its entirety, to the average head width of successive instars seems to have some limitations.

with similar measurements of the larvæ represented in Tables IV., V., and VIA. From Table VIII. it will be seen that the means of the groups representing the last seven larval instars are very approximately in regular arithmetical progression with a common difference of ·15 to ·16 (theoretically ·153).

TABLE VIII.

Groups Representing the Larval Instars.	Observed. A-B Measurements in mm. Minimum.	Observed. A-B Measurements in mm. Mean.	Observed. A-B Measurements in mm. Maximum.	Observed. Common Difference.	Calculated.* Mean.	Calculated.* Common Difference.
1	·161	·163	·167		..	
2	·21	·23	·28	·067	·23	..
3	·35	·38	·40	·15	·383	·153
4	·47	·53	·55	·15	·537	·153
5	·63	·68	·70	·15	·690	·153
6	·79	·84	·86	·16	·843	·153
7	·96	·99	1·03	·15	·997	·153
8	1·12	1·15	1·26	·16	1·15	·153

* ·23 has been taken as the first term and 1·15 as the last.

Table VIB. indicates that the (A-B) measurements of the last seven larval instars of a single larva are also approximately in regular arithmetical progression; for this table the same examples of larval records as given in Table VIA. are used, together with some from Tables IV. and V. The first larval instar is well separated from all other instars, both on the shape of its ninth abdominal segment and on the isolation of its (A-B) measurement when those of all instars are placed in a regular series.

Other Species of Elateridæ.

By the method of grouping the (A-B) measurements of a random larval population, and then using the information as a guide in rearing

DESCRIPTION OF PLATE 2.

Lacon assus Cand.

A.* First larval instar; dorsal view of ninth abdominal segment × 60.
B. Full-grown larva; dorsal view of ninth abdominal segment × 12.

Lacon variabilis Cand.

C.* First larval instar; dorsal view of ninth abdominal segment × 60.
D.* Second larval instar; dorsal view of ninth abdominal segment × 60.
E. Full-grown larva; dorsal view of ninth abdominal segment × 15.

* Drawn from permanent mounts.

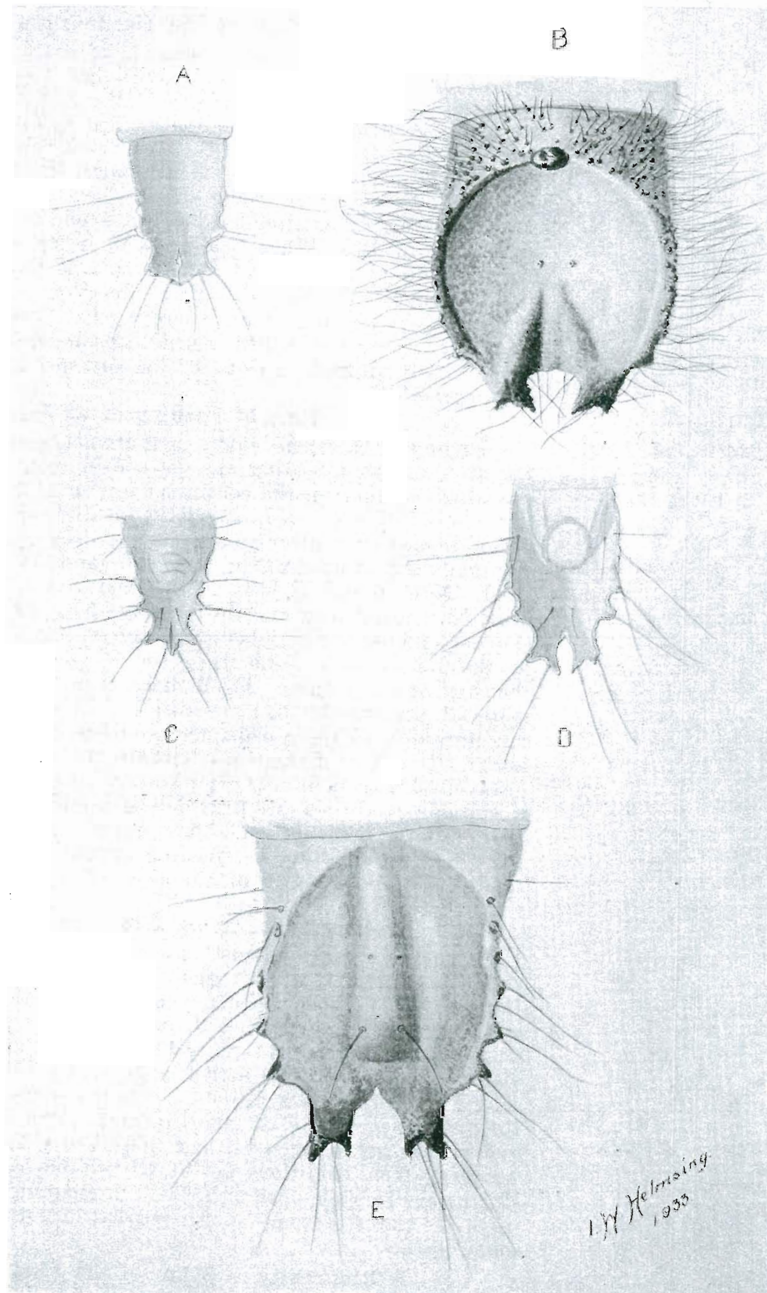


PLATE 2.

work, it was found that with *Heteroderes carinatus* Blbn. [(a)], *Heteroderes cairnsensis* Blbn., five other *Heteroderes* species, *Lacon humilis* Er., *Lacon lateralis* Schw., and seven other *Lacon* species, each group represents an instar. Further, the means of the groups (with the exception of those representing the first larval instars) for each species advance approximately in arithmetical progression. As with *L. variabilis*, so with all the above-mentioned species, the specific shapes of the ninth abdominal segments are not assumed until the second larval instars. The ninth abdominal segments of *L. lateralis, H. carinatus,* and *H. cairnsensis* are illustrated in Plate 3 (figs. A to F), while *L. assus* Cand. is similarly treated in Plate 2 (figs. A and B). This species has been reared from the egg up to the third larval instar and over the last two larval instars, and there is every indication that the larval growth of *L. assus,* as expressed by the increase of the (A-B) measurements of successive instars, is similar to that of the other *Lacon* species with which more complete rearing work has been carried out.

Hyslop (2) in his drawings of the first and last larval instars of *Monocrepidius lividus* illustrates and draws attention to a difference in shape of the ninth abdominal segments which is similar to that found in many of the species mentioned in this article.

Some observations have been made on two species of larvæ (of the yellowish semi-flattened type) the adults of which have not been even generically identified. One here termed B sp. [(b)] and the other Y sp. (commonly found when chipping in some of the hillside country around Mackay) behave, in so far as growth of the last five larval instars are concerned, in a manner similar to the *Lacon* species, and *Heteroderes* species. The smaller instars of B sp. and Y sp. have not been studied.

No species with the cylindrical type of larva have been studied in detail. The (A-B) measurements of twenty-four cylindrical larvæ of the same species taken from rotted wood could be placed into four distinct groups; the means of these groups approximated very closely to an arithmetic progression. Exuvial measurements taken as the larvæ were reared to adults (four obtained) indicate that each group represents an instar.

Times of feeding of all the *Lacon* species, all the *Heteroderes* species and B sp. are similar to that of *L. variabilis* as described on page 56.

C. LARVAL STADIA.

Lacon variabilis.

As climatic conditions play a great part, both in the variation of the larval stadia of *L. variabilis* and in the incidence of this pest in

(*a*) The writer is indebted to the British Museum for the identification of *H. carinatus, H. cairnsensis, L. variabilis, L. assus, L. lateralis,* and *L. humilis*. *H. carinatus* is listed as *Monocrepidius* in Master's Catalogue (1886) (according to a communication from H. Hacker, Queensland Museum), and specimens of *H. cairnsensis* are labelled *Monocrepidius cairnsensis* in the Bureau collection at Meringa. In *Coleoptera of North America* (1883) Leconte and Horn state: "The genus *Heteroderes*, adopted by Candeze, appears to be untenable and heterogeneous; our species are therefore referred to *Monocrepidius*."

(*b*) The British Museum authorities identify this species as Gen. (?) (near Athous).

different years (10), fig. 1 has been inserted for the purpose of giving some idea of the climatic conditions prevailing in the Mackay district. Although there are large variations in rainfall in different years, the usual climatic sequence is a wet season of varying intensity between December and March, moderate winter rains, and a comparatively dry spring followed by thunderstorms in early November.

Many field observations made during 1932-33 indicated that, in general, the behaviour of the larvæ of *L. variabilis* in the rearing jars in the laboratory during those years, very closely resembled that of the larvæ under natural field conditions. For the purpose of discussing the stadia of larvæ under natural conditions, the larvæ may be divided into three classes according to the period of the year during which pupation takes place, together with the period of oviposition of the eggs, from which the larvæ emerge. These three classes are—(*a*) Those which emerge from eggs deposited during the period November-February and which pupate in the following October to January; (*b*) Those which emerge from eggs deposited in November-January and which pupate in the following March to April; (*c*) Those which emerge from eggs laid by adults from "*b*" class larvæ and which pupate in the following November to January.

Tables IX. and X. present a record of the larval stadia of forty-eight "*a*" class larvæ reared during 1933. It is considered that these tables illustrate the normal growth rate of the larvæ under the usual climatic conditions of the Mackay district (see fig. 1). The true average length

TABLE IX.—STADIA OF LARVAL INSTARS DETERMINED FROM THE RECORDED OBSERVATIONS ON 53 LARVÆ, 48 BEING "a" CLASS AND 5 "b" CLASS.

Laboratory Number of Larva.	Stadia (in Days) of the Larval Instars.								Complete Larval Period.
	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	
4	7	14	24	30	32	53	20	164	344
5	8	12	28	9	25	51	50	155	338
12	12	20	34	15	31	34	39	148	333
26	6	7	8	13	22	12	44	37	149
30	9	10	17	14	26	28	43	168	315
33	11	20	22	16	24	20	38	180	331
35	7	7	15	36	25	20	69	158	337
37	13	21	11	17	30	39	39	127	297
39	14	11	17	30	39	39	25	123	298
41	7	37	20	30	34	21	42	142	333
62	12	20	11	13	16	35	31	169	307

TABLE X.—LARVAL STADIA DETERMINED FROM THE RECORDED OBSERVATIONS ON 48 "*a*" CLASS LARVÆ REARED FROM EGGS TO ADULTS DURING 1933.

Larval Instar.	Stadia (in Days).			
	Minimum.	Mean.	Maximum.	Standard Deviation.
1st	5	9·5	14	2·73
2nd	7	14·9	37	6·16
3rd	11	18·9	34	4·82
4th	13	20·2	31	8·48
5th	16	28·2	39	7·16
6th	20	32·8	53	9·78
7th	20	38·2	69	12·11
8th	119	152·0	180	16·67

of the larval period of these forty-eight specimens was 314·8 days. During 1933 a total of 102 "*a*" class larvæ reared from eggs to pupæ spent an average of 302·2 days in the larval state. The forty-eight larvæ of Table X. are included in this number, some of which hatched from eggs deposited fairly late during the November-February period. During 1932, 128 "*a*" class larvæ spent a true average of 279·4 days in the larval state but, as Tables IV. and VIA. indicate, in 1932 a greater proportion of the observed larvæ were hatched from eggs deposited in January or early February than was the case in 1933, when many of the eggs used for rearing purposes were obtained in November and December.

In 1932, six out of 134 larvæ reared from eggs oviposited during November-January pupated during the following March and April, while in 1933, five out of 107 behaved similarly. During the two years, the minimum larval periods of these "*b*" class larvæ were fifty-seven days for those passing through six larval stadia only before pupation, and sixty-eight days for those with eight larval instars. Another "six larval instar" specimen required 161 days to complete its larval life. When the stadia of these "*b*" class larvæ are compared with those of

DESCRIPTION OF PLATE 3.

Lacon lateralis Schwarz.

A. Full-rown larva; dorsal view of ninth abdominal segment × 15.
B.* First larval instar; dorsal view of ninth abdominal segment × 60.

Heteroderes carinatus Blbn.

C. Full-grown larva; dorsal view of ninth abdominal segment × 15.
D.* First larval instar; dorso-lateral view of ninth abdominal segment × 60.

Heteroderes cairnsensis Blbn.

E. Full-grown larva; dorsal view of ninth abdominal segment × 15.
F.* First larval instar; dorso-lateral view of ninth abdominal segment × 60.

* Drawn from permanent mounts.

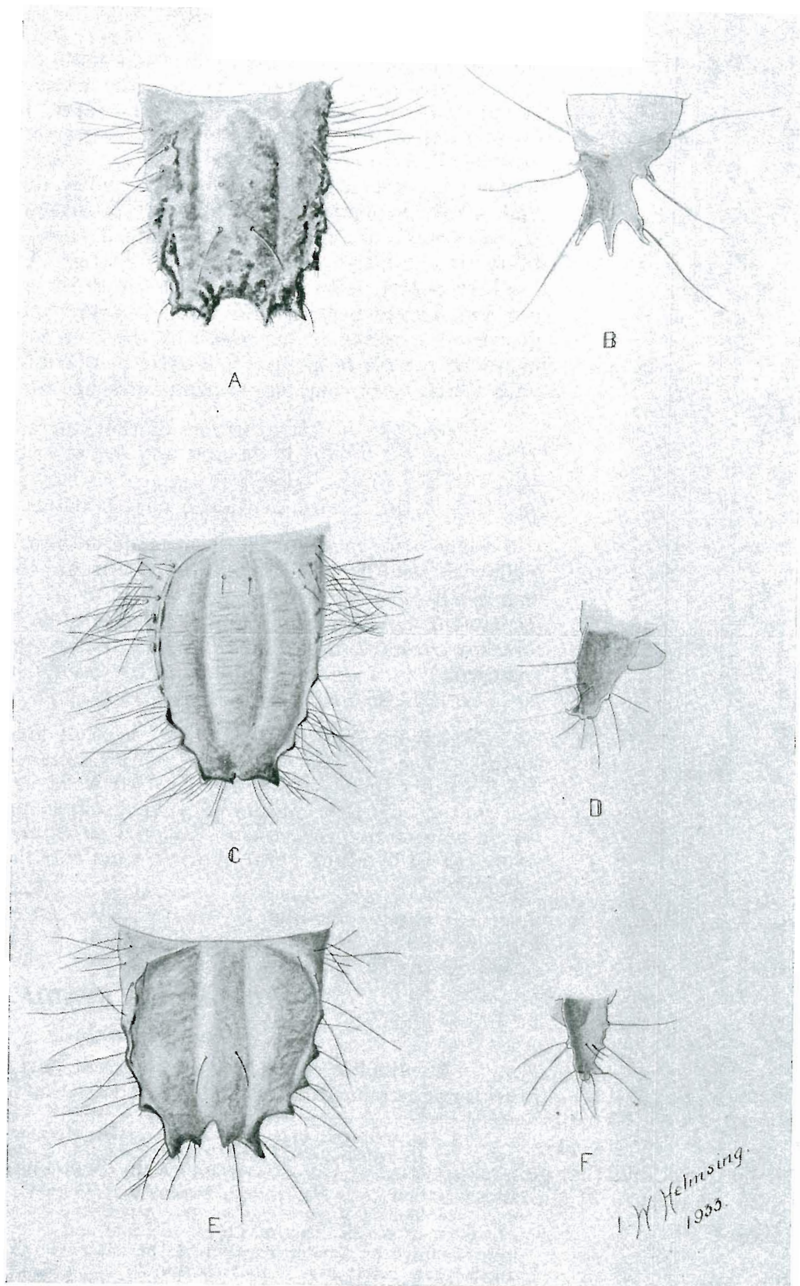


PLATE 3.

"*a*" class, as in Tables IX. and X., a shortening of some of the stadia is evident. Of course the last two stadia exhibit the greatest actual reductions, but not always the greatest proportional reductions.

The "*c*" class larvæ are considered to be even more rare in the field than are the "*b*" class larvæ. This is to be expected (see Section D and fig. 1) as the normal climatic conditions militate against the survival of the smaller instars. In the laboratory many of the adults from

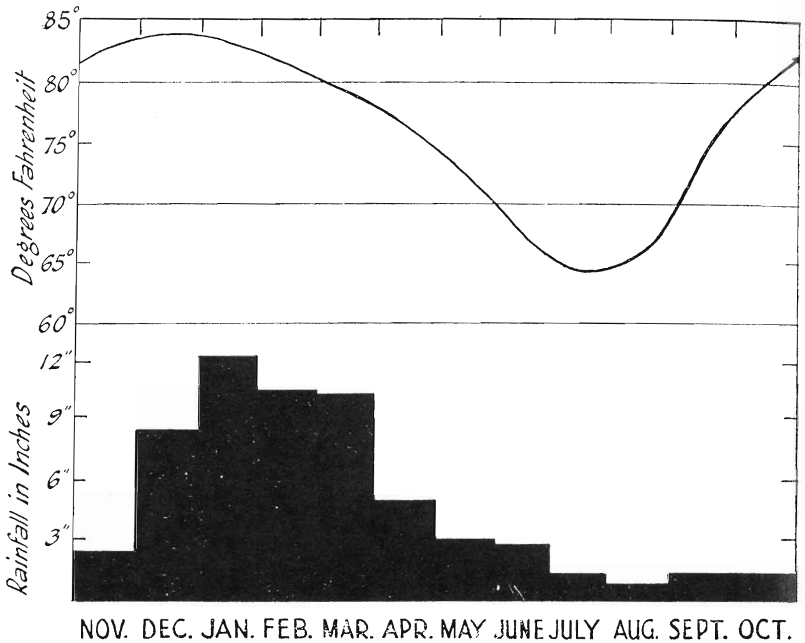


PLATE 4.

Mean monthly rainfall, in inches, and mean 9 a.m. shade temperatures at the Mackay Sugar Experiment Station for the twenty years 1910-1930, both inclusive, but with 1918—an abnormal cyclone year—excluded.

"*b*" class larvæ do not oviposit except under such an artificial condition as increased temperature. It is an easy matter to take the larvæ which emerge from eggs so obtained over the first four or five larval instars, provided the temperature is kept up and suitable soil moisture is provided; under normal environmental conditions the mortality percentage is very high, although once a larva reaches its fourth or fifth larval stadium it will survive under normal conditions. Comparing the stadia of "*c*" class larvæ with those represented in Tables IX. and X. it will be found that generally speaking the earlier stadia are considerably lengthened at the expense of a very noticeable shortening of the later ones.

It is impossible to state definitely whether a small larva found in the field in August or September is in the "*a*" or "*c*" classes as it may be an "*a*" class larva from an egg deposited in late January or February,

which during its early larval life experienced unfavourable environmental conditions. As "*c*" class larvæ are considered to be so rare, it is usual to place any small larvæ found in the field during August and September into the "*a*" class, but this classification may be proven to be incorrect if the larvæ are reared to pupation. As in the "*b*" class so some "*c*" class larvæ pupate at the end of the sixth larval instar, but this has never been found to occur when dealing with any larvæ known to belong to the "*a*" class. If "*a*" class larvæ are kept over the winter in soil with suitable moisture and at the mean shade temperature for October (79·7 deg. F., see fig. 1) they pupate as early as June and never later than August; there are always eight larval stadia.

On the 27th July, 1933, thirty larvæ in their eighth instars were taken from the field. Fifteen were placed in a chamber kept at approximately the mean shade temperature for October, and all had pupated by the 20th August. The second fifteen were reared under normal conditions (i.e., similar to the conditions experienced by the other fifteen except for the increased temperature), and these pupated in late October and November.

Adults of *L. variabilis* have, collectively and sometimes singly, a rather lengthy laying period—collectively from October to February for the majority, and from March to April, for a very few. The vast majority of adults appear in November and early December; the pupal stage is approximately fourteen days and the adults do not remain long in the pupal cells. The first oviposition usually takes place at about three to four weeks after the emergence of the female adult. Irrespective of the exact time of oviposition within the November-February period, and the environmental conditions subsequently encountered by the larvæ, pupation takes place either in the following May-April or October-January. There is no "hang-over," and even all "*c*" class larvæ pupate not later than the January following the May-April during which they had emerged from eggs.

In addition to environmental conditions, some physiological difference in their make-up may be responsible for the fact that some larvæ pupate at the end of their sixth larval stadia and some pupate before the winter, after passing through eight larval stadia.

Other Species of Wireworms.

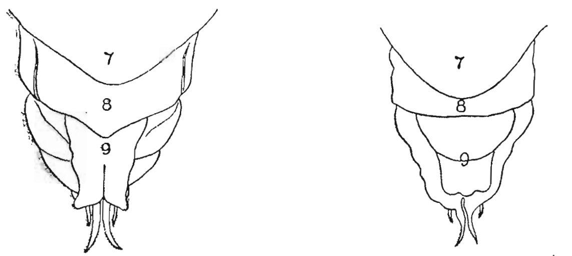
Under Mackay conditions the following species normally have egg, pupal, and larval periods of very similar length to those of *L. variabilis,* viz.—*Heteroderes carinatus, H. cairnsensis,* five other *Heteroderes* species, *Lacon humilis, L. lateralis,* seven other *Lacon* species and B. sp. These species also pass through larval stadia in a manner similar to *L. variabilis,* i.e., the earlier stadia are short compared to the last one or two, especially the final one. Many specimens of all these species are to be found in the fields or in grass lands in either of their last two larval stadia by July-August, although they do not pupate until September-February. The majority of adults of *L. variabilis* are to be found in suitable places in the field in November and early December. However, this is not so for some of the other species; B sp. is found in the adult stage in largest numbers as early as the middle of October. Adults of *H. cairnsensis* are often found in large numbers with any early appearing *L. variabilis* adults. Adults of *H. carinatus,* the other *Heteroderes* species, *L. humilis, L. lateralis,* and other *Lacon* species are to be found in greatest numbers during the wet season (January and/or February). *L. lateralis* is usually the species of Elaterid adult most common during the latter end of the wet season; *L. assus* also appears in greatest numbers during the wet season. The earlier larval stadia of this species are also short as compared to the final one. Specimens of two of the unidentified *Lacon* species have pupated leaving exuviæ with (A-B) measurements corresponding to those of larvæ which have not reached their second last larval instars.

D. TECHNIQUE.

Obtaining and Hatching the Eggs.

From most species eggs were obtained by placing female adults in glass jars (see below) which were two-thirds filled with soil of moisture of about one-half that of the "sticky point" (a). Potato tuber was sometimes supplied as *Lacon variabilis* adults and those of some of the other species gnaw it. Eggs were hatched either in the soil in the jars in which the females had been confined, or singly in soil in the receptacles to be used for rearing the larvæ during the smaller instars.

In the matter of distinguishing the female adults from males, size is often of considerable help; for all species with which the writer dealt the smaller specimens were invariably males and the larger ones were females. Adults of *L. variabilis* were examined in more detail than those of other species, and in this species the very small adults are males, the large ones are females, and those of medium size may be either male or female. External sex differences are more definite in the pupal than in any other stage; they are manifest on the venters of the



♀ ♂

PLATE 5.

Ventral views of eighth and ninth abdominal segments of *Lacon variabilis* pupæ: ♀ and ♂ × 15.

ninth abdominal segments. The sex difference in *L. variabilis* pupæ as illustrated in fig. 2 is similar to that for all *Heteroderes* species and *Lacon* species examined by the writer.

(a) E. S. West defines the "sticky point" as the moisture content of the soil expressed as per cent. oven-dried soil, when the kneaded soil mass just fails to adhere to external objects. (Observations on Soil Moisture and Water Tables in an irrigated soil at Griffith, New South Wales, 1933.)

When any of the soils used in all of the wireworm work was considered to be in a state of good tilth, it was found that the moisture content was at about one-half the "sticky point."

Rearing the Larvæ.

Four-ounce glass jars with metal screw caps were used as cages in general rearing work with most of the species, but for some of the species with larger larvæ (e.g., *Agrypnus mastersi* Macl.) larger jars of the same type were found to be necessary. Each larva was kept separately in a jar two-thirds filled with soil on which was placed, cut surface downwards, a piece of potato tuber; for larvæ known to be carnivorous, scarabæid larvæ were supplied instead of potato tuber. When dealing with the larger larval instars of all species, the soil moisture in the rearing jars was kept at a little under one-half the "sticky point" for the soil used. The older larval instars of all species can withstand considerable drying out of the soil.

Some writers (8 and 11) have pointed out that it is a relatively easy matter for the older wireworms of the species studied by them to adjust themselves to most unfavourable conditions and still survive, but the smaller instars are very susceptible to changes in environmental conditions. Lane (8) used this fact in formulating a control for *Ludius pruininus* Horn, var. *noxius* Hyslop.

The writer found it impossible to rear the wireworms, with which he was concerned, from eggs to adults without a knowledge of the environmental conditions desired by the younger instars of the different species. Younger instars of the different species might need very different conditions for their survival and normal development. For example, take the case of *L. variabilis* and *H. carinatus*. The larvæ of the former species, if they are to survive and develop normally, must have excessive soil moisture during the lives of the small instars. On the other hand, at the same room temperature, and under similar conditions, the small instars of *H. carinatus* cannot live; a moderately moist soil environment is needed in this instance. Ordinary drain pipes, sunk into the ground to a depth of 2 feet 6 inches and with brass gauze fixed to the lower ends, were at times also used as cages. These were filled with soil up to the level of the ground surrounding the pipes and, as far as practicable, the soil conditions inside the pipes were made similar to those of the surrounding soil. These pipes were placed in well-drained land and as a result it was found that they could not be used for rearing *L. variabilis* from eggs to adults under natural weather conditions, whereas they were, under similar conditions, quite suitable for this purpose so far as *H. carinatus* was concerned.(a) Larvæ of these two species are the wireworms most commonly found in cultivated cane fields in the Central Queensland mill areas.

During 1932, by dint of keeping the soil in the rearing jars at approximately its "sticky point" during the lives of the younger instars, the rearing of *L. variabilis* from eggs to adults was found to be a comparatively easy matter. Also, by providing the necessary conditions for the younger instars of most of the species of the genera *Heteroderes* and *Lacon*, and B sp., fairly satisfactory data concerning their larval lives were obtained. During this year (1932), however, very

(a) A preventive control (9) of *L. variabilis* has been developed, and has proved very satisfactory where topographical and economic conditions are such that the necessary drainage can be done efficiently. This control is based on field observations and the fact that, more so than any other species of wireworm inhabiting cultivated cane fields in the Central Queensland sugar areas, the young instars of *L. variabilis* needs excessive soil moisture for their survival.

few of the smaller exuviæ were recovered from the soil in the rearing jars. Attempts to rear the young wireworms between pieces of damp filter paper, or in small pellets of soil between pieces of damp filter paper, were not successful; under these conditions no larvæ survived. During December, 1932, and during 1933, very small instars were successfully reared by using small salve tins (1 inch in diameter by ⅝ inch deep) as cages. By the help of the facts reported in Section B. (pp. 44-60) and inspections every second day, it was possible to recover most of the small exuviæ from the soil in these "salve tin" cages (for *L. variabilis* see Table VIA.). When larvæ were in the fourth or fifth stadium they were removed from these small cages to the 4-oz. jars.

Pupæ were seldom affected if removed from their pupal cells. When a pupa was found it was placed in a depression in the surface of the soil (after it had been pressed down) in its rearing jar. The final larval exuvium was very often found attached to the posterior end of a pupa from a larva of the semi-flattened yellowish type. Attachment is usually made by strings (mostly intima of the tracheæ) which have become entangled with the barbed spines at the extremity of the pupal abdomen.

As mentioned in Section B, four adults were obtained from twenty-four larvæ taken from rotted woods. Whilst collecting these larvæ it was observed that some were feeding on the internals of larvæ of the tenebrionid *Uloma westwoodi* Pasc.; when in captivity for six months their environment consisted of broken-up rotted wood, kept damp. As food they were provided with any wood-inhabiting tenebrionid larvæ available.

Measuring the Greatest Width of the Ventral Mouth Parts.

For this purpose use was made of a micrometer eye-piece and objectives of three different powers. Calibration was such that with objective (*a*) 4·25 divisions on the eye-piece scale equalled 0·2 mm., with objective (*b*) 3·0 divisions equalled 0·7 mm., and with (*c*) the measurements were in millimetres direct. When working with *L. variabilis* objective (*b*) was used for all instars, while for specimens of first instars set in slides, objective (*a*) was also used.

Whilst being measured the living larvæ were held on the microscope stage between two glass slides (for the larger instars) or between a glass slide and a cover glass (for the very small instars).

Summary.

1. The reliability of larval length, antennal segment ratios, head width, and the greatest width of the ventral mouth parts ((A-B) measurements), as criteria for determining larval instars of *Lacon variabilis* are discussed. Evidence collected during the rearing of this species from eggs to pupæ demonstrates that any of its larval instars can be recognised by the greatest width of its ventral mouth parts. The application of Dyar's Law to this species is discussed. The (A-B) measurements of a random larval population can be divided into well-defined groups of which each represents an instar. When the means of the groups representing the last seven larval instars are arranged in order of magnitude, it will be seen that they advance in arithmetical progression. The (A-B) measurements of the last seven larval instars of a single larva are also approximately in arithmetical progression.

There are normally eight larval instars in the life of *L. variabilis*, but a small percentage of the larvæ of this species pupates at the end of six larval stadia. The first larval instar is distinguished from all other instars, both by the shape of its ninth abdominal segment and the isolation of its (A-B) measurement when such measurements of all instars are placed in a regular series.

2. By the procedure of grouping the (A-B) measurements of a random larval population, calculating the means of the groups, and using the information as a guide during rearing work, it was found that for seven species of *Heteroderes* and for nine other *Lacon* species, each group represents an instar. Further, the means of the groups (with the exception of those representing the first larval instars) for each species advance approximately in arithmetical progression. As in *L. variabilis* so in all these species the first larval instars are easily distinguished from any other instars.

3. The distinctive appearance of any instar prior to ecdysis and the feeding habits of the larvæ under certain conditions were of practical help in placing to within a few days the dates of some of the ecdyses of the smaller and moderately-sized larvæ.

4. The larval stadia for *L. variabilis* are given; under Mackay conditions larval growth is usually more rapid during the earlier stadia. The larval growth rates of several other species of *Lacon* and several species of *Heteroderes* are similar to that of *L. variabilis*.

5. Technique used by the writer in rearing some wireworms is described. In this connection it should be noted that the critical point in the larval period of all the species with which the writer had to deal is the early instars. In the rearing of the larvæ from first larval instars to final larval instars, success was dependent upon providing the small instars with suitable environmental conditions. The early instars of different species may require, for their survival, quite different environments.

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