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DIFFERENTIATION AND INCREASE IN SIZE OF NYMPHAL INSTARS OF MONISTRIA DISCREPANS (WALKER) (ORTHOPTERA: PYRGOMORPHIDAE)*

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SUMMARY

The width of the pronotum, length of metathoracic tibia and femur, total length, and number of antennal segments have been determined for all instars and adults of both sexes of *Monistria discrepans* (Walker). Total body length is the most useful measurement for the identification of the various instars. Growth of the pronotum, metathoracic tibia and femur, and body length conform to both Dyar's rule and Przibrum's principle.

I. INTRODUCTION

Monistria discrepans (Walker) has been considered one of the insects which shows promise as a biocontrol agent for green turkey bush (*Eremophila gilesii* F. Muell.) (Allsopp 1977). To assess the potential of this insect, detailed knowledge of both the life-cycle and reproductive potential of the species is necessary. However, before such studies can be completed adequate means to differentiate the various stages of the insect must be available.

This study was aimed at determining the size of the various nymphal instars of *M. discrepans* and, as an adjunct, at analysing their growth rates. Neither of these aspects has been studied in any Australian pyrgomorphid.

II. MATERIALS AND METHODS

Nymphs of *M. discrepans* were reared from laboratory-laid eggs obtained from adults collected 48 km north-west of Charleville in March 1973. Each nymph was maintained in a separate plastic tube, 80 mm high and 40 mm in diameter, at 27·5°C and 60% relative humidity and under a 12:12 photoperiod. Sprigs of fresh *E. gilesii* were added at least every second day. Tubes were examined daily and the presence of cast skins noted—this was considered a reliable indicator of moulting since nymphs of *M. discrepans* do not eat cast skins. Measurements of various parts were made using a binocular microscope fitted with a micrometer eyepiece after the individual had moulted and the cuticle had acquired the usual degree of rigidity.

Measurements were made of the following parts: width of pronotum at widest point (P); length of the right hind tibia (T); length of the right hind femur (F); and total length of the body excluding the antennae (L). In addition the number of antennal segments (A) was determined for each stage.

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The increase in size of *M. discrepans* nymphs was analysed to determine whether it conformed to either Dyar's rule (Dyar 1890) or to Przibrum's principle (Przibrum and Megusar 1912). Both analyses followed the pattern used by Duarte (1938) in his study of *Locusta migratoria* (L.).

III. RESULTS

The number of antennal segments, width of pronotum, length of metathoracic tibia and femur (both taken from the distal end, not including spines, to the tip of the lower lobe of the proximal end), and total length for each instar and sex are given in tables 1 and 2. Measurement of adults, except the male femur length, show no significant difference ($P < 0 \cdot 01$) from those of their field-collected parents (compare table 3 with tables 1 and 2).

The rates of increase for the various structures from instar to instar were obtained by dividing any of the values for length in tables 1 and 2 by the preceding one. The values of R then given in tables 4 and 5 are the means of these rates for each measurement. Using this average rate of increase for each parameter, values were calculated between the first and last nymphal instar in accordance with Dyar's rule. These are compared with the actual values in tables 4 and 5. In no instance was there a significant difference between the actual and calculated values ($P = 0 \cdot 01$).

The standard coefficient of $1 \cdot 26$ enabled calculated values to be obtained in an attempt to apply Przibrum's principle. An allowance was made for latent divisions and the calculated values were compared with the actual data (tables 6 and 7). There is no significant difference ($P = 0 \cdot 01$) between the two sets of data.

IV. DISCUSSION

Measurements of the width of pronotum, lengths of metathoracic tibia and femur, and total length were all helpful in determining nymphal instars since, in most instances, their ranges did not overlap in adjacent stages. The most useful measurement is probably that of total length as it is easier to measure than is the pronotal width and not as subject to damage or loss as are the hind tibia and femur. Overlap is present only between instar II and III of the male and these instars can easily be separated on the basis of reversal of the alar rudiments. Individual variation in the number of antennal segments added at each moult makes this character unacceptable for separation of instars.

Although cranial widths are normally used for the separation of instars in insects, other measurements were used in this study. In *M. discrepans* the dorsal part of the head is triangular and is capable of partial retraction into the pronotum. Hence establishing a common point on the head for measurements to be taken from many specimens would be difficult. Total length, hind tibial and femoral lengths, width of pronotum and number of antennal segments, among others, have been used successfully in the differentiation of orthopteran nymphs in numerous studies, e.g. Daurte (1938), Richards and Waloff (1954), and Valek and Coppel (1972).

Dyar (1890) showed that in lepidopterous larvae the relative increase in head width keeps practically constant throughout the instars. This value is obtained by means of a geometric progression, its terms being the relationship between successive values of the dimensions of the part or parts concerned. In the present study it can be concluded that Dyar's rule holds true for the growth of the pronotum, hind tibia and femur, and total body length of both sexes of *M. discrepans*.

TABLE 1

MEASUREMENTS (mm ± S.D.) OF THE WIDTH OF PRONOTUM, LENGTH OF METATHORACIC TIBIA AND FEMUR AND TOTAL LENGTH; AND THE NUMBER OF ANTENNAL SEGMENTS OF 29 MALE *Monistria discrepans*

Instar	No. of Antennal Segments	Width of Pronotum	Length of Metathoracic Tibia	Length of Metathoracic Femur	Total Length
I	8·00 ± 0·0	1·70 ± 0·08	2·68 ± 0·15	2·83 ± 0·10	5·80 ± 0·14
	(8)*	(1·6 – 1·8)	(2·5 – 2·8)	(2·7 – 2·9)	(5·6 – 5·9)
II	9·13 ± 1·26	2·18 ± 0·16	3·86 ± 0·41	4·00 ± 0·39	8·88 ± 0·83
	(8 – 12)	(1·9 – 2·4)	(3·2 – 4·4)	(3·6 – 4·5)	(7·5 – 9·9)
III	12·87 ± 1·42	2·70 ± 0·16	5·18 ± 0·23	5·45 ± 0·50	10·35 ± 0·54
	(10 – 14)	(2·4 – 3·0)	(4·7 – 5·7)	(4·5 – 6·1)	(9·9 – 11·1)
IV	13·90 ± 0·45	3·20 ± 0·13	6·67 ± 0·28	7·04 ± 0·33	15·30 ± 1·81
	(12 – 14)	(3·0 – 3·4)	(6·1 – 7·2)	(6·2 – 7·4)	(13·2 – 17·0)
Adult	15·68 ± 0·48	3·68 ± 0·21	8·43 ± 0·44	9·09 ± 0·48	19·16 ± 1·33
	(15 – 16)	(3·3 – 4·2)	(7·8 – 8·9)	(8·2 – 10·1)	(17·3 – 21·5)

* Numbers in parenthesis show range.

TABLE 2

MEASUREMENTS (mm ± S.D.) OF THE WIDTH OF PRONOTUM, LENGTH OF METATHORACIC TIBIA AND FEMUR AND TOTAL LENGTH; AND THE NUMBER OF ANTENNAL SEGMENTS OF 33 FEMALE *Monistria discrepans*

Instar	No. of Antennal Segments	Width of Pronotum	Length of Metathoracic Tibia	Length of Metathoracic Femur	Total Length
I	8·0 ± 0·0	1·70 ± 0·09	2·70 ± 0·12	2·82 ± 0·13	5·90 ± 0·14
	(8)*	(1·6 – 1·8)	(2·4 – 2·8)	(2·7 – 2·9)	(5·8 – 6·0)
II	9·29 ± 0·95	2·63 ± 0·05	4·13 ± 0·59	4·10 ± 0·55	8·60 ± 0·56
	(8 – 10)	(2·6 – 2·7)	(3·3 – 4·7)	(3·7 – 4·8)	(8·1 – 9·2)
III	12·10 ± 1·66	2·97 ± 0·18	5·19 ± 0·47	5·64 ± 0·54	10·13 ± 0·38
	(10 – 14)	(2·7 – 3·3)	(4·6 – 5·7)	(5·0 – 6·6)	(9·5 – 10·9)
IV	13·60 ± 0·70	3·49 ± 0·21	6·47 ± 0·51	7·00 ± 0·33	14·80 ± 1·06
	(12 – 14)	(3·3 – 4·0)	(5·9 – 6·7)	(6·5 – 7·4)	(14·0 – 16·0)
V	14·20 ± 0·42	4·51 ± 0·24	8·42 ± 0·45	8·96 ± 0·49	18·83 ± 1·32
	(14 – 15)	(4·1 – 4·9)	(7·8 – 9·1)	(8·1 – 9·7)	(17·1 – 20·5)
Adult	15·88 ± 0·33	6·19 ± 0·45	10·47 ± 0·48	11·70 ± 0·75	31·47 ± 3·60
	(15 – 16)	(5·1 – 7·0)	(9·6 – 11·2)	(9·5 – 13·2)	(23·4 – 36·0)

* Numbers in parenthesis show range.

TABLE 3

MEASUREMENTS (mm ± S.D.) OF THE WIDTH OF PRONOTUM, LENGTH OF METATHORACIC FEMUR AND TOTAL LENGTH WITH THE NUMBER OF ANTENNAL SEGMENTS OF FIELD-COLLECTED *Monistria discrepans*

Sex	Number Examined	No. of Antennal Segments	Width of Pronotum	Length of Metathoracic Femur	Total Length
Male	25	15·82 ± 0·67	3·56 ± 0·34	9·73 ± 0·65	20·13 ± 1·72
Female	42	15·93 ± 0·59	6·23 ± 0·67	11·67 ± 0·83	30·96 ± 3·71

TABLE 4

APPLICATION OF DYAR'S RULE TO THE GROWTH OF VARIOUS PARAMETERS OF MALE *Monistria discrepans* SHOWING ACTUAL AND CALCULATED VALUES (mm)

Instar	Pronotum Width		Tibia Length		Femur Length		Body Length	
	Actual	Calculated	Actual	Calculated	Actual	Calculated	Actual	Calculated
I	1·70	..	2·68	..	2·83	..	5·80	..
II	2·18	2·06	3·86	3·56	4·00	3·79	8·88	7·89
III	2·70	2·49	5·18	4·74	5·45	5·08	10·35	10·73
IV	3·20	3·01	6·67	6·31	7·04	6·81	15·30	14·59
Adult	3·68	..	8·43	..	9·09	..	19·16	..
R*	1·21		1·33		1·34		1·36	
χ^2 (2df)	0·0367 n.s.		0·0867 n.s.		0·0464 n.s.		0·1722 n.s.	

*R = average rate of increase between stadia.
n.s. = not significantly different at P = 0·01.

TABLE 5

APPLICATION OF DYAR'S RULE TO THE GROWTH OF VARIOUS PARAMETERS OF FEMALE *Monistria discrepans* SHOWING ACTUAL AND CALCULATED VALUES (mm)

Instar	Pronotum Width		Tibia Length		Femur Length		Body Length	
	Actual	Calculated	Actual	Calculated	Actual	Calculated	Actual	Calculated
I	1·70	..	2·70	..	2·82	..	5·90	..
II	2·63	2·21	4·13	3·56	4·10	3·75	8·60	8·32
III	2·97	2·87	5·19	4·70	5·64	4·99	10·13	11·73
IV	3·49	3·73	6·47	6·20	7·00	6·64	14·80	16·54
V	4·51	4·85	8·42	8·18	8·96	8·83	18·83	23·32
Adult	6·19	..	10·47	..	11·70	..	31·47	..
R*	1·30		1·32		1·33		1·41	
χ^2 (3df)	0·1226 n.s.		0·1611 n.s.		0·1388 n.s.		1·2752 n.s.	

*R = average rate of increase between stadia.
n.s. = not significantly different at P = 0·01.

TABLE 6

APPLICATION OF PRZIBRUM'S PRINCIPLE TO THE GROWTH OF VARIOUS PARAMETERS OF MALE *Monistria discrepans* SHOWING ACTUAL AND CALCULATED VALUES (mm)

Instar	Pronotum Width		Tibia Length		Femur Length		Body Length	
	Actual	Calculated	Actual	Calculated	Actual	Calculated	Actual	Calculated
I	1·70	1·46	2·68	2·65	2·83	2·86	5·80	6·03
				3·34		3·61		7·60
II	2·18	1·82	3·86	4·21	4·00	4·54	8·88	9·58
III	2·70	2·32	5·18	5·31	5·45	5·73	10·35	12·07
IV	3·20	2·92	6·67	6·69	7·04	7·21	15·30	15·21
Adult	3·68	..	8·43	..	9·09	..	19·16	..
χ^2 (3df)	0·1914 n.s.		0·0327 n.s.		0·0822 n.s.		0·3056 n.s.	

n.s. = not significantly different at P = 0·01.

TABLE 7

APPLICATION OF PRZIBRUM'S PRINCIPLE TO THE GROWTH OF VARIOUS PARAMETERS OF FEMALE *Monistria discrepans* SHOWING ACTUAL AND CALCULATED VALUES (mm)

Instar	Pronotum Width		Tibia Length		Femur Length		Body Length	
	Actual	Calculated	Actual	Calculated	Actual	Calculated	Actual	Calculated
I	1·70	1·55	2·70	2·62	2·82	2·92	5·90	6·24
	..	1·95	..	3·30	..	3·68	..	..
II	2·63	2·46	4·13	4·15	4·10	4·64	8·60	7·86
III	2·97	3·09	5·19	5·23	5·64	5·85	10·13	9·91
								12·49
IV	3·49	3·90	6·47	6·59	7·00	7·37	14·80	15·73
V	4·51	4·91	8·42	8·31	8·96	9·29	18·83	19·82
								24·98
Adult	6·19	..	10·47	..	11·70	..	31·47	..
χ^2 (4df)	0·1066 n.s.		0·0050 n.s.		0·1041 n.s.		0·1975 n.s.	

n.s. = not significantly different at P = 0·01.

In *M. discrepans*, the values for the increase in size of different parts (except the male pronotum) keep above 1·26, the value postulated by Przibrum and Megusar (1912) as the increase in size between moults. In such cases Bodenheimer (1927) suggested cell divisions may have occurred more than once in the same stadium, and he termed the extra divisions 'latent divisions'. With an allowance for such divisions the growth of the pronotum, hind tibia and femur, and total length of *M. discrepans* conforms to that postulated under Przibrum's principle. The presence of such latent cell divisions in some parts of both sexes would allow for extra instars without increasing the size of the resultant adult. In laboratory rearing the number of instars of both male and female *M. discrepans* does show some variation (Allsopp 1976). The very large value for the increase in body length between instar V and the adult of females is due to sexual development and the associated increase in the size of the ovaries and related structures.

As the above data do conform to both Dyar's rule and Przibrum's principle the question of which is the relevant law arises. Obviously when the rate of increase is much greater than 1·26, the observations in many cases can be made to conform to Przibrum's principle simply by the assumption of a latent instar in any position. However Wigglesworth (1965) presented evidence which shows that the assumption of latent divisions is incorrect in various larval flies. Thus Dyar's rule, in which the growth rate may vary between species and between parts of a single species, must be more relevant.

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