Pennisetum japonicum Trin., *Alopeculus aequalis* Sobol.

Anoecia corni Fab.: *Oryza sativa* L., *Hordeum vulgare* L., *Triticum* spp., *Panicum Crusgalli* L., *Miscanthus sinensis* Anderss., *Imperata cylindrica* Beaw. var. *Koenigii* Dur. et Schinz., *Agropyrum semicostatum* Ness., *Digitaria ciliaris* Pers.

Brysocrypta ulmi L.: *Oryza sativa* L., *Hordeum vulgare* L., *Triticum* spp., *Panicum Crusgalli* L., *Agropyrum semicostatum* Ness., *Setaria viridis* Beauv., *S. lutescens* Hubbard, *Digittaria ciliaris* Pers., *Eleusine indica* Gaertn., *Pennisetum japonicum* Trin., *Imperata cylindrica* Beauv., *Zoysia japonica* Steud., *Alopeculus japonicus* Steud., *Phleum pratense* L., *Agrostis Matsumurae* Hack., *Eragrostis ferruginea* Beauv., *E. Niwahokori* Honda.

Forda harukawai Tanaka: *Oryza sativa* L., *Hordeum vulgare* L.

On the Increment of Size of Faecal Pellets following the Growth in Larva of the Gypsy Moth, *Lymantria dispar* L. Problems on the Breeding of Insects for Biological Assay of Insecticides. XVI*. Sumio Nagasawa (Takei Laboratory, Institute for Chemical Research, Kyoto University, Takatsuki, Ohsaka). Received Nov. 23, 1956. *Botyu-Kagaku*, **22**, 176-182, 1957.

28. マイマイガ幼虫の成長にともなう糞形の増大について 殺虫剤の生物試験用昆虫の飼育にかんする諸問題 第16報

長沢純夫（京都大学 化学研究所 武居研究室） 31. 11. 23 受理

春川先生は，この学問の道に生涯をゆだねようとしたわたくしを，最初の日から今日にいたるまでの長い年月，つねに正しいしるべをあたえてあたたかくお導き下さつた．このたび古稀の賀を迎えられるにあたり，この小文をささげて心からなるお祝いと感謝を申上げる次第である．

札幌産マイマイガの雄の成虫を，一定の環境条件下でケヤキの葉をあたえて飼育し，排泄された糞の最大幅を測定，その結果にもとづいて糞形の日間，および令期間における増大様相を検討した．測定値の対数値の日間の増大様相はひとつの曲線関係をしめしたが，令期間における増大過程は頭幅のそれと相対的に全くひとしい2分された直線関係をしめした．少くとも1日間に排泄された糞の大きさの平均値をもつてするならば，その糞の属する令期の決定は可能である．

So-called "Koprometrie" which aims at the estimation of the rate of development of noxious insects or that of the damage by utilizing various figures obtained from the faecal pellets such as weight, size, shape, colour or number per time and area has been especially developed in the field of forest entomology where direct observation of the development of noxious insects or the damages due to them are relatively difficult to perform. In order to furnish fundamental knowledges on the problems of breeding of insects for biological assay of insecticides, the writer[11-15] carried out the measurements of width of head capsule of some Lepidopterous insects, and tried in a previous paper to represent the relation of log-width of head capsule to instar numbers by the linear equation of Dyar[2] or the quadratic equation of Gaines and Campbell[4]. In the present paper, the writer wishes to describe the result of an experiment which was conducted to study whether the relation found in the growth of the sclerotized head capsule is also observable in the increment of width of faecal pellets and to discuss on the possibility of determination of instar by the size of faecal pellets. Here, the writer wishes to express his sincere thanks to Prof. S. Takei and Prof. M. Ohno for their helpful encouragement. He is also indebted to Prof. C. Harukawa for the revision of this manuscript.

Material and Method

The material used in this experiment was the faecal pellets of a male larva of the gypsy moth

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hatched out on May 5 from an egg collected at Sapporo in the early spring of 1956. Under the constant environmental condition of 25° and 89% relative humidity the larva was reared on leaves of the zelkova-tree, *Zelkova serrata* Makino, in a pair of petri dishes measuring 1.5 cm high 6.0 cm in diameter. This larva moulted five times in its larval period of 34 days; namely, it had six larval instars. When the food leaves were renewed at every 9 o'clock of morning, the faecal pellets were collected into a parchment envelope from the petri dishes and preserved in a desiccator containing amorphous calcium chloride. Later, the width of faecal pellets, i. e., the maximum diameter which meets the longitudinal axis at right angle, was measured by the scale on the glass plate of the projector.

Result and Discussion

The result of measurement is shown in Table 1 together with the mean width of faecal pellets excreted daily. No faecal pellets were obtained on the 4, 8, 13, 18, and 24th days after hatching on which the larva moulted.

1. Increment of width of faecal pellets on successive days: In the first place, the writer wishes to discuss on the increment of mean width of faecal pellets which were collected every 24

Table 1. Mean width of faecal pellets excreted daily by a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Days after hatching	Number of faecal pellets	Mean	Standard deviation	Variation coefficient
		mm	mm	%
1	42	0.180±0.003	0.019	1.05
2	93	0.221±0.002	0.016	7.31
3	127	0.247±0.002	0.017	6.71
5	85	0.336±0.003	0.031	9.18
6	113	0.387±0.003	0.028	7.21
7	118	0.462±0.005	0.050	10.81
9	70	0.683±0.008	0.069	10.14
10	90	0.694±0.006	0.061	8.71
11	90	0.692±0.007	0.065	9.32
12	63	0.662±0.007	0.053	7.98
14	69	0.928±0.008	0.065	6.98
15	100	1.007±0.006	0.063	6.26
16	106	1.005±0.005	0.050	5.01
17	105	1.027±0.005	0.054	5.26
19	53	1.311±0.014	0.103	7.85
20	94	1.206±0.011	0.104	8.62
21	103	1.588±0.013	0.130	8.16
22	93	1.213±0.008	0.087	5.32
23	65	1.643±0.014	0.112	6.82
25	19	1.967±0.025	0.110	5.61
26	58	1.864±0.017	0.127	6.81
27	64	2.151±0.027	0.218	10.11
28	57	2.135±0.013	0.094	4.40
29	74	2.071±0.010	0.088	4.23
30	67	2.089±0.012	0.094	4.49
31	76	2.185±0.010	0.088	4.01
32	73	2.271±0.013	0.107	4.69
33	74	2.465±0.016	0.139	5.62
34	29	2.561±0.030	0.162	6.32

hours. Heretofore, the growth of various parts of insect larvae such as width or length of head capsule, diameter of spiracle, length of mandible, etc., has been studied in relation to the instar numbers using the logarithms of measurements, and the relation has been expressed either by Dyar's linear equation or by the quadratic equation of Gaines and Campbell in almost all cases. In the present study, the writer also adopted the figures of measurement of width in logarithms (mm) plus 1, y_f, for the ordinate and the number of days after hatching, X', for the abscissa, and plotted the relation of these two variables on a graph. Unity has been added to the logarithm of measurement for the sake of convenience in computation by avoiding the negative values of logarithmic values. The subscript letter f of y means the faecal pellet. As is seen Fig. 1, a curvilinear relation has been found between these two variables. It is clear that Gaines and Campbell's quadratic equation should be adopted to express

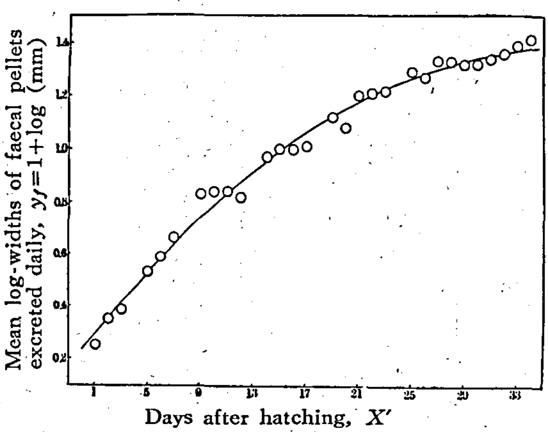

Fig. 1. Relation of mean log-widths of faecal pellets excreted daily, $y_f=1+\log$ (mm), to number of days after hatching, X', of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

the relation between the rate of increment of the mean log-width of faecal pellets on successive days and the number of days after hatching. The equation computed based on the figures of Table 1 is

$$y_f=0.234-0.0637X'-0.000886X'^2$$

The figures shown in Table 2 are result of test of significance for the departure from linear regression between the mean log-width of faecal pellets excreted daily and the days after hatching. The mean square for the quadratic term is highly significant as is seen from the figure of the last row of Table 2.

Table 2. Test of significance of departure from linear regression between mean log-widths of faecal pellets excreted daily and days after hatching of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Deviation from linear regression	27	0.1066	
Deviation from curved regression	26	0.0333	0.0013
Curvilinearity of regression	1	0.0733	0.0733**
F	56.38		

2. Increment of width of faecal pellets in successive instars : In the preceding paragraph, it has been proved that the gradual increment of mean log-width of faecal pellets excreted daily proceeds curvilinearly and it can be roughly expressed by the quadratic equation of Gaines and Campbell which is widely applied for the expression of relation between the mean log-values of various body dimensions and the number of larval instars. As is seen in Fig. 1., however, there are some points which are far apart from the curve; besides, all the durations of instars are not equal. Accordingly, the writer wishes to examine the increment of mean log-width of faecal pellets in successive instars. Mean values of widths of faecal pellets grouped by each instar are shown in Table 3. It is at once evident that the increment ratioes in the last column of Table 3 can be divided into two different groups, that is, the one comprising the values for the 1st～3rd instars and the other, the values for the 3rd～6th instars. They are approximately the same within a group, but they are quite different between the two groups. This fact suggests that the application of a linear equation for expressing the relation

Table 3. Mean width of faecal pellets grouped by each instar of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Instar	Number of faecal pellets	Mean	Standard deviation	Variation coefficient	Increment ratio
		mm	mm	%	
I	262	0.227±0.002	0.029	12.90	—
II	316	0.402±0.004	0.064	9.18	1.77
III	313	0.685±0.004	0.064	9.39	1.70
IV	380	0.998±0.004	0.068	6.83	1.46
V	408	1.482±0.011	0.213	14.34	1.48
VI	591	2.177±0.009	0.227	10.14	1.47

between the mean log-width of faecal pellets, $y_f=1+\log$ (mm), and the instar numbers, X, is possible within each group, but the relation does not hold good when all the instars are taken into consideration. According to this conception, the equations were calculated using the figures of Table 3. The result is shown in Table 4. And the relation between these two variables is shown in Fig. 2.

Table 4. Equation for the increment of mean log-widths of faecal pellets, $y_f=1+\log$ (mm), in succesive instars, X, of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Instar	$y_f=a+bX$	$\log^{-1} b$
I—III	$y_f=0.1187+0.2400X$	1.74
III—IV	$y_f=0.3309+0.1678X$	1.47

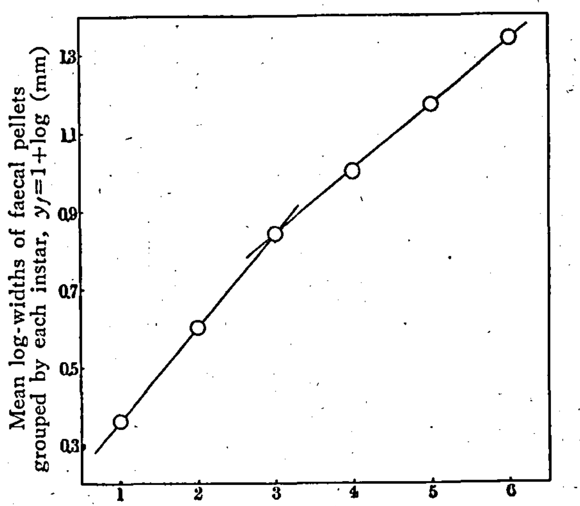

Fig. 2. Relation of mean log-widths of faecal pellets grouped by each instar, $y_f=1+\log$ (mm), to instar numbers, X, of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Up to date, there have been considerable papers[1,3,6,8,9] in which the increment of weight of faecal pellets in successive instars has been dealt with, but the papers reporting on the increment of size of faecal pellets are rather scanty. Yamanouchi[19] reported that the increment of length of faecal pellets of six Orthopterous insects in successive instars could be roughly expressed by an exponential curve. And, in some cases, he got the values of increment ratio of approximately 1.26. The figure $1.26=\sqrt[3]{2}$ is Przibram and Megusar's constant[16] which was found in the growth in various dimensioms of the preying mantis, *Sphodromantis bioculata* Burm. As is seen in the last column of Table 4, however, the two increment ratioes calculated from writer's data are somewhat apart from the figure 1.26.

3. Growth of width of head capsule in successive instars: In order to know whether the rate of increment of width of faecal pellets in successive instars is similar to the growth of head capsule, the writer conducted the measurement of width of the exuviae of head cepsule simultaneously. The result of measurement is shown in Table 5. The figures of growth ratio shown in the last column of Table 5 can also be classified into two different groups, within each of the growth ratioes are almost the same. It is obvious that a linear equation can be applied respectively to each of these two groups of figures representing the relations between log-width of exuviae of head capsule, $y_h=1+\log$ (mm), and

Table 5. Width of exuviae of head capsule of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Instar	Width	Growth ratio
I	0.62	—
II	1.10	1.77
III	1.78	1.62
IV	2.50	1.40
V	3.45	1.38
VI	4.80	1.39

Table 6. Equation for the growth of log-width of exuviae of head capsule, $y_h=1+\log$ (mm), in successive instars, X, of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

Instar	$y_h=a+bX$	$\log^{-1} b$
I—III	$y_h=0.5697+0.2290X$	1.69
III—VI	$y_h=0.8219+0.1433X$	1.39

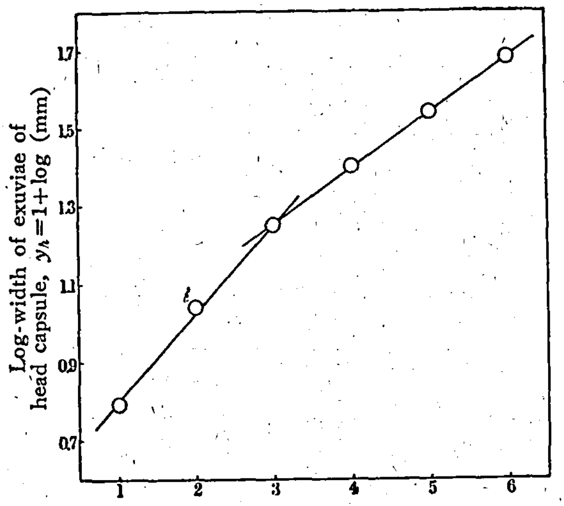

Fig. 3. Relation of log-width of exuviae of head capsule, $y_h=1+\log$ (mm), to instar number, X, of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

instar numbers, X. Here, the subscript letter h of y means head capsule. The result of calculation is shown in Table 6. It will be seen that antilogarithms of b, viz., Dyar's constant, in Table 6 may be considered nearly the same as those given in Table 4. This agreement means that we can safely estimate the rate of growth of head capsule in successive instars by that of increment in the mean width of faecal pellets grouped by each instar. The relation between these two variables is shown in Fig. 3.

4. Determination of instar by width of faecal pellets : As has been already pointed out by Goldschmidt[5], the number of instars of the larvae of the gypsy moth varies according to the localities where they grow, and sexes and also even within the same sex. Consequently it is beyond doubt that it is impossible to determine the instar by simply measuring the head capsules of larvae captured in the field. This has been already pointed out by Mitamura[10] in regard to the rice-plant skipper, *Paranara gutata* Bremer et Grey.

Now, let us suppose for the moment that all the larvae of the gypsy moth have the same number of moultings and also the same growth ratio under a constant environmental condition just as it is the case with the common cabbage butterfly[11,12,13,18], *Pieris rapae curucivora* Boisduval, and the cabbage moth[7,14,15,17], *Barathra brassicae* L. Then, would it be possible to determine the instar by measuring the width of faecal pellets?

Since it can be expected that the growth of the hind intestine proceeds stepwise with each moulting just as the growth of the sclerotized head capsule does, it seems to be impossible to group the measurements of widths of faecal pellets definitely so as the grouping corresponds to the instar to which they belong. Still, a clue to determination of instar might be found, if there exist definite gaps in the frequency distribution of size of faecal pellets. As a matter of fact, the histograms as shown in Fig. 4 are obtained when the frequency distribution of the results of measurements are graphically shown. As is seen in Fig. 4., there are considerable overlapping areas between instars. Therefore, even if it be assumed that all larvae of the gypsy moth have the same number of instars and the same rate of growth under the constant environmental condition, it must be concluded that we shall fail in determining the instar number if we happen to measure the faecal pellets which are found in these overlapping areas. The fact that there are

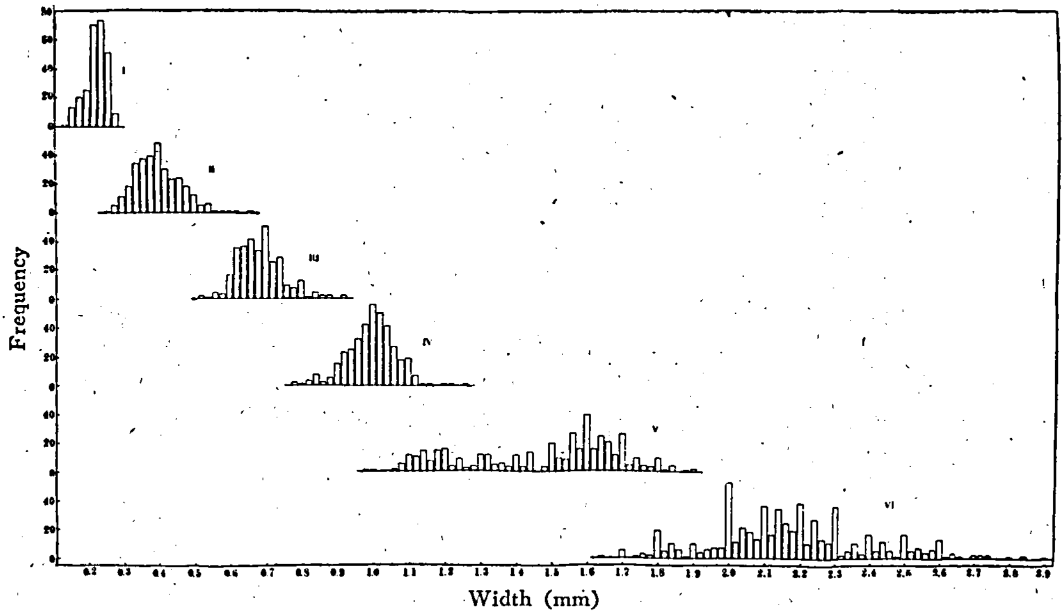

Fig. 4. Histogram representing frequency distribution of width of faecal pellets of a male larva of the gypsy moth, *Lymantria dispar* L., which moulted five times.

overlapping areas between successive instars in the frequency distribution of different sizes of faecal pellets means that the growth of the hind intestine proceeds gradually, and not stepwise, being different from the growth of the head capsule. This gradual growth of intestine is also apparent from the increment of width of daily faecal pellets shown in Fig. 1. Sometimes contradiction in the orders of the mean width of faecal pellets excreted daily may appear within an instar, but no contradictory orders have been observed between instars. It means that if we collect and measure all the faecal pellets excreted by a larva on a day and conclude the mean width we can determine correctly the instar to which the larva belongs by the mean width.

Summary

1) Under the constant environmental condition of 25° and 89% relative humidity, a male larva of the gypsy moth, *Lymantria dispar* L., was reared on the leaves of the zelkova tree, *Zelkova serrata* Makino. The width of faecal pellets, i.e., the maximum diameter that meets the longitudinal axis at right angle, was measured.

2) A curvilinear relation was obtained between the mean log-widths of daily faecal pellets and days after hatching, and this relation could be expressed by a quadratic equation.

3) The relation between mean log-widths of faecal pellets grouped by each instar and number of instars was found to be represented by two intersecting straight lines.

4) The relation of log-width of exuviae of head capsule to instar number agreed quite well with that of mean log-width of faecal pellets grouped by each instar to the number of instars. Therefore, we may estimate the rate of growth of head capsule in successive instars from the rate of increment in mean width of faecal pellets grouped by instar.

5) The width of faecal pellets does not increase stepwise as the width of head capsule does. However, if we collect and measure all the faecal pellets excreted by a larva on a day, we shall be able to determine correctly the instar to which the larva belongs by the mean width of the faecal pellets.

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Effects of the Larval Density of the Azuki Bean Weevil on Some Adult Characters.
Ryoichi ISHIKAWA, Yuzo MIYAMOTO and Hiroshi MATSUZAWA (Laboratory of Applied Entomology, Dept. of Agriculture, Kagawa University, Miki-cho, Kagawa Pref.). Received Dec. 1, 1956, *Botyu-Kagaku*, **22**, 182-185, 1957, (with English résumé, 185).

29. アズキゾウムシの小豆粒内喰入密度が，発育，生存率，羽化成虫の大きさおよび生存日数におよぼす影響*

石川良一・宮本裕三・松沢寛（香川大学 農学部 応用昆虫学研究室）31. 12. 1受理

謹んで春川忠吉博士の古稀を祝賀し奉る．

アズキゾウムシを実験材料として，幼虫期の棲息密度が発育，生存率，羽化成虫の性比，体の大きさ，生存期間，産卵力などに及ぼす影響について調べた．

昆虫の棲息密度効果については多数の研究者によつて実験的な研究が進められて来ているが，これらは供試昆虫の生活空間を一定にして供試虫数をいろいろにかえ，あるいは生活空間の大きさをいろいろにかえることにより，その棲息密度をかえて爾後の諸現象を観察しようと試みたものである．ある研究者は産卵面積の広狭を考慮に入れたり，真の利用空間を全棲息空間と区別して研究を進め，棲息密度なるものをより厳密に規定しようと試みてもいる．しかしながらわれわれが棲息密度あるいは密度効果なるものを考える場合に，たとえば アズキゾウムシ *Callosobruchus chinensis* の場合で考えられる如く，はじめ成虫の密度をいろいろにかえて実験を行うとその影響は直接には成虫の産卵の過程にのみ現われて，爾後の孵化幼虫や羽化する成虫等には直接には及ぼされない．直接の影響は厳密にはそれぞれのアズキ粒に産下された卵の数または孵化喰入したアズキ1粒中の棲息幼虫数などによつてもたらされると考えられる．

斯様な見地から筆者らはアズキ1粒内の幼虫の棲息密度が発育，生存率，羽化成虫の性比，体の大きさ，生存期間，産卵力に及ぼす影響を調査した．ここに概要を述べて大方の参考に供し度い．

本文に入るに先だつて常に協力をねがつた本学応用昆虫学研究室諸彦，ならびに供試アズキゾウムシの提供をたまわつた京都大学農学部昆虫学研究室に対して厚く謝意を表する．

実験材料及び方法

本実験に使用したアズキゾウムシは京都大学農学部昆虫学研究室に於いて長年累代飼育された系統である．30° に調整した電気定温器内で直径 12cm，深さ 3cm のシャーレにアズキ 300 粒を重ならぬ様に並べ，これに 10, 30, 50 対ずつの親虫を放つて 8 時間産卵せしめた．同時にまた直径 9cm，深さ 2cm のシャーレを使用して同様に親虫の数を 10, 20, 30, 90, 100, 120 対として12時間産卵を行わしめた．使用アズキの含水量は 15% で，粒の大きさをなるべく均一ならしめる如くした．産卵の行われたアズキは1粒当りの産卵数または喰入虫数毎に 1～6 の密度区に分け，さらにそれらはガラス管（1×4cm）に1粒宛収めて爾後

* 香川大学農学部応用昆虫学研究室業績．No. 30