Presumption of Dosage-Response Curve obtained by the Treatment of Chemosterilant for Both Sexes of the Mexican Bean Weevil, *Zabrotes subfasciatus* Boheman (Coleoptera, Bruchidae)

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ブラジルマメゾウムシの雌雄に化学不妊剤を処理したときにえられる薬量一反応率曲線の推定

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Insect chemosterilant are divided into three groups from the sexual effective point of view. Some chemicals are effective only on female or male individuals ; others are effective on both sexes. The effectiveness of a chemical depends on the insect species, developmental stages of the insect, test methods, criterions for evaluation, etc. ; it is not always constant for a certain chemical. Now, in the case where a chemical is effective on both sexes, the results of cross fertilization between a treated female and treated male should correspond to the independent joint action with a correlation $r=0$. That is, since the site of chemosterilizing action is completely independent between sexes, the dosages for females and males are not additive. In order to get sterilized results, a dosage of chemosterilant must be enough to sterilize at least the female or the male. The expected response rate P for mating between a treated female and treated male could be written as :

$$P = P_{♀} + P_{♂}(1-P_{♀}).$$

Here, $P_{♀}$ and $P_{♂}$ are the response rates produced from the same amount of chemosterilant used in mating treated female×untreated male and untreated female× treated male, respectively. The object of this paper is to deal with this problem. Data are based on the chemosterilizing effect of metepa on female and male Mexican bean weevils.

Materials and Methods

The Mexican bean weevil, *Zabrotes subfasciatus* Boheman, used as the test organism for the present experiment was the progeny of a strain developed at the Agricultural

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Institute of Campinas, São Paulo, Brazil. It was successively reared on the bean, *Phaseolus vulgaris* L., in the Biological Inslitute of São Paulo, São Paulo. Adult weevils, just emerged from beans, were used for tests. Metepa, tris [1−(2−methyl) aziridinyl] phosphine oxide, was the technical grade sample provided by Cyanamid International, Princeton, New Jersey, U. S. A.

Ten concentrations of metepa were prepared with chemically pure acetone by a 1 : 1 serial dilution of 1.0 $\mu g/\mu l$ and 0.7 $\mu g/\mu l$. One microliter of test solution was topically applied to the newly emerged weevil with a Lang-Levy microliter pipette. A pair of weevils were confined with about 50 beans in a covered Petri dish 9.0 cm in diameter and 1.5 cm high. The number of offsprings from three combinations, treated female × untreated male, untreated female × treated male and treated female × treated male, were counted. Fifteen pairs of weevils were counted for each combination and for each level of dosage. The experiment was conducted under an insectary condition of ca 25°C and ca 60% R. H.

Results and Discussion

Results for each dosage level for three combinations are shown in Table 1. Following the probit estimation method of parameters of tolerance distribution proposed by Wadley[4] and generalized later by Finney[2], N was provisionally estimated as 31 for the first cycle of calculations. Calculations were then carried out for the regression lines drawn parallel each other for the data on the treated female × untreated male and untreated female × treated male series. The first cycle had given the revised estimates $N = 30.04$ and the parallel regression equations $Y = 5.506 + 1.9595x$ and $Y = 6.096 + 1.9595x$ for the treated female × untreated male and untreated female × treated male series, respectively, as approximations to the maximum likelihood estimates.

The second cycle of calculations using $N = 30.04$ was then carried out to get the revised regression equations :

$$Y'_{♀} = 5.4790 + 1.8919x,$$

$$Y'_{♂} = 6.0725 + 1.8919x.$$

The revised estimate of the N is

$$N' = 30.14.$$

The equations obtained by the second cycle of calculations are very close to those by the first cycle. The revised estimate of N is almost identical to the provisional value. Consequently, there may be no need to make further cycle of calculations.

The heterogeneity test shows

$$\chi^2_{[17]} = 4.10.$$

Clearly, there is no indication of heterogeneity. Empirical probits plotted against the logarithms of dosage applied and the calculated parallel regression lines are shown in Fig. 1.

The analysis of χ^2 in Table 2 shows that both the components for deviations from parallelism and for residual heterogeneity are small enough to be attributed to random

Table 1. Relation between topically applied dosage of metepa and average number of emerged adults per pair of treated Mexican bean weevils.

Dosage µg/weevil	Treatment Female	Male	Both
1	10.5	2.8	1.5
0.7	11.7	6.2	3.8
0.5	18.0	11.7	9.0
0.35	19.2	12.6	13.2
0.25	22.7	15.5	12.2
0.175	21.2	19.7	18.5
0.125	25.2	20.2	16.4
0.0875	29.0	24.2	21.8
0.0625	24.9	27.4	27.0
0.04375	31.5	32.5	31.1
Controls		31.2	

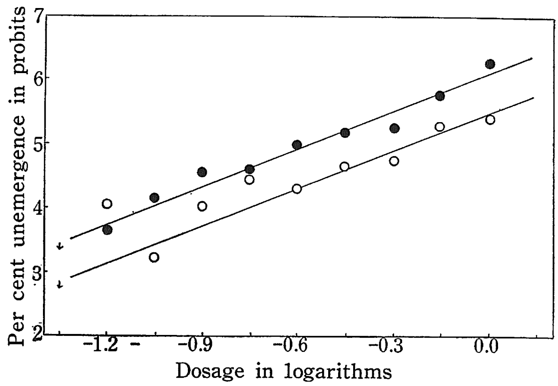

Fig. 1. Sterilizing effect of metepa on the Mexican bean weevil. The solid line with empty circles and solid line with solid circles represent treated female × untreated male and untreated female × treated male, respectively.

variation in the data.

The sizes of the standard errors calculated b and N', $b = 1.8919 \pm 0.451$ and $N' = 30.14 \pm 9.80$, again show further cycle of calculations to be unnecessary.

The log median effective dose of metepa inhibiting the emergence for female Mexican bean weevil is

$$m_{♀} = -0.2532.$$

Similarly

$$m_{♂} = -0.5669.$$

The logarithm of the relative susceptibility of female and male weevils to the inhibiting effect of metepa on emergence is

$$M = -0.3137.$$

For the 5% level of probability

$$g = 0.22$$

is too large to permit the assessment of fiducial limits to m or M by means of the standard error formulae. The complicated formulae given by Finney were used for calculating the fiducial limits to m or M.

The arithmetical values derived as the fiducial limits to $m_{♀}$ are -0.5811 and -0.0577. The antilogarithms of $m_{♀}$ and its limits give 0.558 µg/♀ as the estimated median effective dose, with 95% limits at 0.262 and 0.876 µg/♀. Similarly the fiducial limits to $m_{♂}$ were calculated as -0.9678 and -0.3674. The antilogarithms of $m_{♂}$ and its limits give 0.271 µg/♂ as the estimated median effective dose, with 95% limits at 0.108 and 0.429 µg/♂. Then, the fiducial limits to M are -0.6834 and -0.0130. The antilogarithms of M and its limits give 0.4856 at 0.2073 and 0.9698 as the relative susceptibility of female and male weevils, with 95% limits. The reciprocals of these values show the male is 2.059 times as susceptible as the female to the emergence

Table 2. Analysis of χ^2

Source of variation	Degrees of freedom	Sum of squares	Mean square
Parallelism of regressions	1	0.52	0.52
Residual heterogeneity	16	3.58	0.22
Total	17	4.10	—

Table 3. Presumption of dosage-response curve for treated female×treated male combination.

x	$Y_♀$	$Y_♂$	$P_♀$	$P_♂$	P	Expected probits	Observed probits	Weight	χ^2
0.00	5.4790	6.0725	0.684	0.858	0.955	6.6954	6.6449	6.2784	0.016
−0.15	5.1952	5.7887	0.577	0.785	0.909	6.3846	6.1455	9.2253	0.528
−0.30	4.9114	5.5049	0.465	0.693	0.836	5.9782	5.5244	13.3948	2.758
−0.45	4.6276	5.2211	0.355	0.588	0.734	5.6250	5.1535	16.5701	3.684
−0.60	4.3438	4.9373	0.256	0.475	0.609	5.2767	5.2378	18.5978	2.790
−0.75	4.0600	4.6535	0.173	0.364	0.474	4.9348	4.7050	19.0934	1.008
−0.90	3.7762	4.3697	0.111	0.264	0.346	4.6039	4.8844	18.0600	1.421
−1.05	3.4924	4.0859	0.066	0.180	0.234	4.2743	4.3992	15.7530	0.246
−1.20	3.2086	3.8021	0.036	0.115	0.147	3.9506	3.7241	12.6769	0.650

inhibitory effect of metepa, and the true value of relative susceptibility of the male as compared with the female is likely to lie between 4.824 and 1.031 times.

Nagasawa and Nakayama[3] reported that the egg deposition of the azuki bean weevil was not inhibited by the application of metepa at the adult stage. The hatchability of the deposited eggs and the emergence of adults, however, were affected with metepa in certain range of dosages. The male is 2.748 and 2.659 times as susceptible as the female to the inhibitory effect of metepa on the egg hatching and adult emergence, respectively. The effective dosage inhibiting the egg hatching was almost equal to that of adult emergence. They concluded that the main sterilizing effect of metepa is the inhibition of egg hatching. The relative susceptibility of male to female of the azuki bean weevil for metepa is substantially equal to that of the Mexican bean weevil obtained in the present experiment.

The type of independent action may occur with a mixture whose constituents produce their toxic effect in entirely different ways, as for example, a mixture of two insecticides of which one is a stomach poison and the other a contact poison (Bliss)[1]. Likewise, the site of chemosterilizing action is completely independent of sex. The results of cross fertilization between a treated female and treated male should correspond to the mathematical model of the independent joint action with a correlation $r = 0$. That is, the dosages for females and males are not additive. A dosage of chemosterilant must be enough to sterilize at least the female or the male. Consequently, the expected response rate P for mating between a treated female and treated male is written as

$$P = P_♀ + P_♂(1 - P_♀).$$

$P_♀$ and $P_♂$ are the response rates produced from the same amount of chemosterilant used in mating the treated female × untreated male and untreated female × treated male, respectively.

The steps of calculations for proving this assumption are shown in Table 3. The revised parallel dosage-response regression equations mentioned above were used to calculate expected probits, $Y_♀$ and $Y_♂$, for each dose. These were tabulated in columns 2 and 3.

Corresponding values of response proportions, $P_♀$ and $P_♂$, were read from a probit table and tabulated in columns 4 and 5. Expected response proportions from independent joint action, P, were then calculated and tabulated in column 6. Expected probits corresponding to P were read from table and tabulated in the next column.

Unemergence rates for the treated female × treated male series were calculated based on the average numbers of emerged adults in Table 1 using $N = 30.04$ and then transformed to probits. These were tabulated in column 8. The weighting coefficients, $w = Z^2/Q$, corresponding to each expected probit were calculated by linear interpolation in the table of weighting coefficients. Weights of column 9 were obtained by multiplying the weighting coefficient with N.

A test of the agreement between the hypothesis and observations can be made by finding the weight to be associated with the expected probits, multiplying these by the squares of the corresponding discrepancy between expected and observed probits, and summing to give χ^2 with degrees of freedom equal to the number of dosage levels. The result is

$$\chi^2_{[9]} = 13.101.$$

There is no evidence of any conflict with the hypothesis. This problem has already been discussed by Nagasawa and Nakayama[3] using the chemosterilizing data of allyl triphenyltin, N, N, N′, N′—tetramethyl—P—piperidinophosphoric diamide, and metepa on the ezuki bean weevil.

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Summary

The male of the Mexican bean weevil, *Zabrotes subfasciatus* Boheman, is 2.059 times as susceptible as the female with 95% limits at 4.824 and 1.031 times to the inhibitory effect of metepa on the adult emergence. The response rate P as the result of cross fertilization between a treated female and treated male was possible to presume by a mathematical model of the independent joint action with a correlation $r=0$. $P=P_{♀}+P_{♂}(1-P_{♀})$. Here, $P_{♀}$ and $P_{♂}$ are the response rates produced from the same amount of metepa used in mating treated female×untreated male and untreated female×treated male, respectively.

摘　　要

化学不妊剤を雌雄の両方に処理し，これらを交配してえられる結果は，同じ薬物であっても，作用点が雌と雄では全く独立した部分であるから，当然 independent の連合作用型を示すものと考えなければならない．すなわち雌雄いずれか一方に不妊性を誘発するに足る薬量があたえられないかぎり，その不妊性は期待できない．いいかえれば，雌雄のそれぞれに不妊剤を処理した後，無処理個体との交配によってえられる不妊率 P_1，P_2 をもたらす薬量を，雌雄おのおのに処理してそれらを交配したときえられる不妊率 P は，相関 r を0とする

$$P=P_1+P_2(1-P_1)$$

の数学的モデルにあてはまるはずである．ブラジルマメゾウムシを供試材料に，metepa を処理してこの推定を実験的に証明した．