The influence of temperature and modified atmosphere on effectiveness of *Lavandula angustifolia* Mill. oil for controlling *Tyrophagus putrescentiae*

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Abstract

A design of orthogonal conic substitution of 4 factors and 5 levels was adopted to study the influences of temperature (X_1), CO_2 concentration (X_2), O_2 concentration (X_3) and the concentration of oil of *Lavandula angustifolia* (X_4) on the mortality of female adults of *Tyrophagus putrescentiae* (Schrank) (Y). A regression was established as:

$$Y = 55.833 + 1.823X_1 + 10.781X_2 - 10.052X_3 + 13.281X_4 - 1.172X_1X_2 + 6.328X_1X_3 - 1.328X_1X_4 + 5.234X_2X_3 + 4.14X_2X_4 + 2.578X_3X_4 + 6.289X_1^2 + 3.945X_2^2 - 1.055X_3^2 - 3.086X_4^2$$

The coefficients of each item in the model indicate that the major factors affecting mite mortality were: plant oil concentration >CO_2 concentration >O_2 concentration. The interaction between temperature and O_2 concentration appeared to be the highest in the study, though it was not statistically significant.

Materials and Methods

The mites used in the experiments were from Stored–pests Ecological Research group cultures fed on a mixture of wheat flour and yeast powder (3:1). Oil from *Lavandula angustifolia* Mill was provided by the Sichuan Daily Used Chemical–Industrial Products Institute.

Temperature and CO_2, and O_2, and oil concentration were combined according to an orthogonal conic substitution. Each factor's level and code are given in Table 1. A bottle (1000 mL) was filled with four small plastic boxes (height = 1 cm, diameter = 3 cm), covered with 1600 mesh nylon net, and containing 10 adult female mites and some feed. Each bottle was filled with a different concentration according to the schedule in Table 1. Pieces of filter paper (length = 10 cm), (width = 2 cm) on which different concentrations of oil had been dropped were put immediately into the bottles. Each test was repeated three times at 28°C and 75 ± 5% r.h.. The bottles were opened after 48 hours treatment and mite mortality recorded after 12 hours.

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Table 1. Levels and codes for the four experimental factors.

Factor	Factor code				
	-2	-1	0	1	2
Temperature (X_1) °C	15	20	25	30	35
CO_2 (X_2) %	0	10	20	30	40
O_2 (X_3) %	4	8	12	16	20
Plant oil (X_4) ppm	5	15	20	35	45

Results and Analysis

By multivariate analysis, the mathematical model of relation between four factors and mite mortality was obtained:

$$Y = 55.833 + 1.823X_1 + 10.781X_2 - 10.052X_3 + 13.281X_4 - 1.172X_1X_2 + 6.328X_1X_3 - 1.328X_1X_4 + 5.234X_2X_3 + 4.14X_2X_4 + 2.578X_3X_4 + 6.289X_1^2 + 3.945X_2^2 - 1.055X_3^2 - 3.086X_4^2$$

The regression equation reached the most significant level through F test. Table 2 indicates that the model's theoretical values were close to the observed values, showing that the model could relatively accurately imitate actual values. The t test of regression coefficients showed that the coefficients that reached or approached 0.1 significance level included b2, b3, b4, b1, 3, b2, 3, b1, 1, b2, 2 among those, b1, 1 reached 0.05 level, b2, b3, b4 reached 0.01 level.

The comparison between each regression coefficient's absolute value showed that the most important factor affecting mite mortality was plant oil concentration, the second was CO_2 concentration, the third was O_2 concentration, and finally temperature. Apart from O_2 concentration, all factors caused increasing mite mortality as their levels rose.

Since the experiment was orthogonal, there were absolute relations between each coefficient. Once three factors' levels were all 0, another equation could be calculated as follows:

$$Y_1 = 55.833 + 1.823X_1 + 6.289X_1^2$$
$$Y_2 = 55.833 + 10.78X_2 + 3.946X_2^2$$
$$Y_3 = 55.833 - 10.52X_3 - 1.055X_3^2$$
$$Y_4 = 55.833 + 10.281X_4 - 3.086X_4^2$$

Figure 1 plots the relations between the functions. It shows that the relation between temperature (X_1) and mite mortality (Y_1) is an upward parabola indicating that higher or lower temperatures increase mite mortality. CO_2 has little effect on mite mortality at concentrations below 10%, but mortality rises significantly at higher concentrations. Mite mortality rises significantly with falling O_2 levels, but the effect decreases at low O_2 levels. The relation between plant oil concentration and mite mortality was positive, but the increase in mite mortality became slower when oil concentration reached 35 ppm. The increase in mortality was only 4% when oil concentration was increased from level 1 to level 2. This indicated

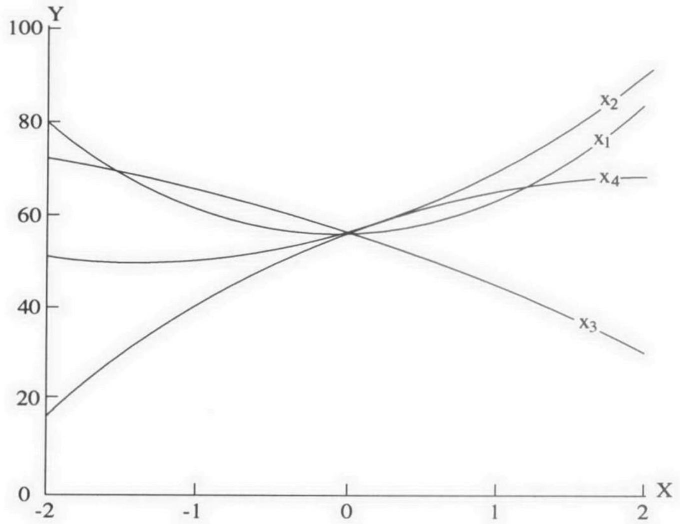

Fig. 1. Influence of four factors on mite mortality (Y): X_1 = temperature; X_2 = CO_2 concentration; X_3 = O_2 concentration; and X_4 = plant oil concentration.

that the relation between them was not linear. Oil level increases could not significantly improved mite mortality after oil concentration reached certain level.

The interaction (X_1 X_3) between temperature and O_2 concentration and that between CO_2 concentration and O_2 concentration appeared to have a relatively high effect on mite mortality. As in Table 2, at different temperatures, only O_2 concentration was decreased, the mortality would rise generally. The modified atmosphere of high CO_2 and low O_2 has a significant effect on efficacy of the plant fumigant. For example, the mortality of No. 12 treatment was higher 40% than that of No. 10.

Discussion

Some mites were only in a stupour during the 48-hour fumigation period, some of them recovering after 12 hours contact with fresh air. This phenomenon was more obvious when the CO_2 level was low. Because CO_2 anaesthesia decreased the mite respiration rate and reduced the dosage of fumigant. So increasing CO_2 level or lengthening fumigation time could both enhance the effects of plant fumigant in controlling *Tyrophagus putrescentiae*.

References

Zhangxing et al. 1983 Preliminary studies in controlling rice weevil and maize weevil with plant insecticides. Grain Storage 12(1): 1–8.

Table 2. The experimental structure matrix and results

Test number	X_1	X_2	X_3	X_4	Mortality	
					Experimental	Theoretical
1	1	1	1	1	97.50	93.54
2	1	1	1	-1	37.50	56.20
3	1	1	-1	1	85.50	85.36
4	1	1	-1	-1	67.50	58.33
5	1	-1	1	1	55.50	55.57
6	1	-1	1	-1	22.50	34.79
7	1	-1	-1	1	73.75	68.33
8	1	-1	-1	-1	55.00	57.86
9	-1	1	1	1	86.25	82.24
10	-1	1	1	-1	22.50	39.58
11	-1	1	-1	1	100.0	99.38
12	-1	1	-1	-1	68.75	67.03
13	-1	-1	1	1	18.75	39.58
14	-1	-1	1	-1	15.00	13.49
15	-1	-1	-1	1	97.50	77.66
16	-1	-1	-1	-1	46.25	61.88
17	2	0	0	0	87.50	84.64
18	-2	0	0	0	85.00	77.34
19	0	2	0	0	96.25	93.18
20	0	-2	0	0	57.50	50.05
21	0	0	2	0	56.25	31.51
22	0	0	-2	0	57.50	71.72
23	0	0	0	2	58.75	70.05
24	0	0	0	-2	38.75	16.93
25	0	0	0	0	50.00	58.83
26	0	0	0	0	65.00	58.83
27	0	0	0	0	62.50	58.83
28	0	0	0	0	45.00	58.83
29	0	0	0	0	65.00	58.83
30	0	0	0	0	62.50	58.83
31	0	0	0	0	57.50	58.83
32	0	0	0	0	52.50	58.83
33	0	0	0	0	52.50	58.83
34	0	0	0	0	57.50	58.83
35	0	0	0	0	45.00	58.83
36	0	0	0	0	55.00	58.83