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The Relative Effectiveness of Five Candidate Fumigants to Stored-Product Insects

MARKET QUALITY RESEARCH DIVISION
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WARNING

To protect the ultimate consumer of food crops and animal products, the use of pesticides is regulated under the Federal Insecticide, Fungicide, and Rodenticide Act and the Federal Food, Drug, and Cosmetic Act. The rate and method of application and any resulting residues must comply with the requirements of these two Acts.

The chemical compounds discussed in this publication should not be used for fumigating food or feed on the basis of the work reported here. The results presented in this report are for scientific information only. Their publication should not be construed as a recommendation for the use of the compounds studied. If fumigants are handled or disposed of improperly, they may be injurious to humans, domestic animals, or desirable plants, and contaminate water supplies.

This report is part of a broad program of research to maintain high market quality of agricultural commodities through effective prevention and control of stored-product insects.

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THE RELATIVE EFFECTIVENESS OF FIVE CANDIDATE FUMIGANTS TO STORED-PRODUCT INSECTS

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SUMMARY

Fumigations were conducted in 19.5-liter bottles to determine the relative toxicity of certain fumigants to adult confused flour beetles, Tribolium confusum Duv.; adult saw-toothed grain beetles (Oryzaephilus surinamensis (L.); adult cigarette beetles, Lasioderma sericorne (F).; and black carpet beetle larvae, Attagenus piceus (Oliv.). The fumigants tested were acrylonitrile, CH_2CHCN; Wyandotte W-24, N-(alpha-methylacetonitrile)-morpholine; Substanz 215, acetate of dimethyl 2,2-dichloro-1-hydroxyvinylphosphonate; methylamine (30 percent aqueous), CH_3NH_2; diethylamine, $(C_2H_5)_2$ NH; and carbon tetrachloride, CCl_4. Exposures were 24 hours at 80° F. ± 4° and a relative humidity of 78 percent ± 18.

As indicated by their LD_{95} values, Substanz 215 was the most toxic chemical tested against confused flour beetles, Wyandotte W-24 against cigarette beetles, and acrylonitrile against black carpet beetles. Substanz 215 and Wyandotte W-24 were the most toxic to saw-toothed grain beetles, as indicated by minimum dosages giving 100-percent mortality.

INTRODUCTION

The evaluation of promising new fumigants for use on raw and processed agricultural commodities is part of a broad research program aimed at developing more specific insect control methods that are safer to the handler and to the consumer.

Lindgren and others[3] reported that acrylonitrile (CH_2CHCN) was the most effective of 10 fumigants tested against eight species of insects. Preliminary studies by the Wyandotte Chemical Corporation, Wyandotte, Mich., showed that Wyandotte W-24[4] (N-(alpha-methylacetonitrile)-morpholine) was effective against adult confused flour beetles, Tribolium confusum Duv. Speirs[5] noted that Substanz 215 (acetate of dimethyl 2, 2-dichloro-1-hydroxyvinylphosphonate) exhibited high vapor toxicity to adult flour beetles, Tribolium spp., and the black carpet beetle larvae, Attagenus piceus (Oliv.). Diethylamine ($(C_2H_5)_2NH$) and methylamine (30-percent aqueous) (CH_3NH_2) were selected for further testing because a report by Ferguson and Pirie[6] indicated that the fumigant action of several amines was greater than that of carbon disulfide to the granary weevil, Sitophilus granarius (L.). Carbon tetrachloride (CCl_4) was included in the tests as a standard for comparison.

This paper reports the relative effectiveness of acrylonitrile, Wyandotte W-24, Substanz 215, methylamine (30-percent aqueous), diethylamine, and carbon tetrachloride to four species of stored-product insects.[7]

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[2] This laboratory is a field station of the Stored-Product Insects Branch, Market Quality Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

[3] Lindgren, D. L., Vincent, L. E., and Krohne, H. E. Relative Effectiveness of Ten Fumigants to Adults of Eight Species of Stored-product Insects. Jour. Econ. Ent. 47(5): 923-6. 1954.

[4] Use of trade names is for identification purposes only. It does not constitute endorsement by the U.S. Department of Agriculture.

[5] Speirs, R. D. 1960. Stored-Product Insects Laboratory, Savannah, Ga. [Unpublished data.]

[6] Ferguson, J., and Pirie, H. The Toxicity of Vapours to the Grain Weevil. Ann. Appl. Biol. 35: 532-50. 1948.

[7] Wyandotte W-24 was supplied by the Wyandotte Chemicals Corporation, Wyandotte, Mich., and Substanz 215 by Norddeutsche Affinerie, Hamburg, Germany.

MATERIALS AND METHODS

Test insects and their respective ages when exposed to the fumigants were adults of the confused flour beetle and the saw-toothed grain beetle, Oryzaephilus surinamensis (L.), 14 days ± 3; adults of the cigarette beetle, Lasioderma serricorne (F.), 5 days ± 2; and larvae of the black carpet beetle, 4 months ± 1. The confused flour beetles and the cigarette beetles were reared in a 50:50 mixture of white flour and cornmeal, the saw-toothed grain beetles in rolled oats, and the black carpet beetles in Purina laboratory chow meal. All media were fortified with 5 percent of brewer's yeast. The insects were reared at a temperature of 80° F. ± 2° and a relative humidity of 60 percent ± 5.

Fumigations were conducted in 19.5-liter bottles, fitted with rubber stoppers. Two wire clips were attached to each stopper. A double-layered strip of blotting paper was fastened to one of the wire clips. During exposures, the insects were confined in cages 2-1/2 inches in length by 3/4 inch in diameter and constructed of 40- x 36- mesh Monel metal wire. Three cages, containing 10 insects each, were suspended in the center of each bottle with 8-inch copper wires attached to the second wire clip in the stopper. The bottles were then kept 24 hours at a temperature of 80° F. ± 4° and a relative humidity of 78 percent ± 18 to stabilize the atmosphere in the bottles and to allow the insects to become accustomed to the environment in which they would be fumigated. Results from preliminary "range finding" tests were used as a guide to estimate dosage increments and levels that would provide data for establishing dosage-mortality regression lines. The fumigants in a liquid phase were measured with a microsyringe[8] and were applied to the blotting paper in each bottle. Fumigations were replicated three times.

After a 24-hour exposure, the insects were transferred to clean chambers containing food and held at a temperature of 80° F. ± 5° and a relative humidity of 60 percent ± 10. Estimates of the toxicity to insects of the candidate fumigants were based on mortalities observed 3 weeks after exposure of confused flour beetles and saw-toothed grain beetles, 1 week after exposure of cigarette beetles, and 5 weeks after exposure of black carpet beetle larvae. Insects that did not move, even after being subjected to vibration, light, and mild heat, were classified as dead. Dosage-mortality analyses were calculated at the Cornell Computing Center, Cornell University, using the probit method of analysis of quantal response data. All statistical analyses were conducted at the 5-percent level of significance. The information obtained included LD_{50} and LD_{95} values with their respective fiducial limits. Minimum lethal dosages (MLD) were estimated from dosage-mortality regression lines or were based on minimum dosages giving 100-percent mortality.

RESULTS

Dosage-mortality regression lines for each insect species are presented in figures 1 through 4. Wyandotte W-24 and Substanz 215 were the most toxic to saw-toothed grain beetles, based on the fact that minimum dosages of 0.18 and 0.24 mg./liter, respectively, caused 100-percent mortality. The smallest measurable increments of these candidate fumigants did not provide an adequate range of mortalities of saw-toothed grain beetles to establish dosage-mortality regression lines. The MLD values given in tables 1 through 4 indicate the Substanz 215 was the most toxic to confused flour beetles, Wyandotte W-24 to saw-toothed grain beetles and cigarette beetles, and acrylonitrile to black carpet beetles. Based on their MLD values for each species, the decreasing order of toxicity for the chemicals was: First, acrylonitrile; then Substanz 215 and Wyandotte W-24; then diethylamine and methylamine (30-percent aqueous); and last, carbon tetrachloride.

[8] Pedersen, J. R. A Microsyringe for Laboratory Grain Fumigation. Jour. Kans. Ent. Soc. 32(4): 151-2. 1959.

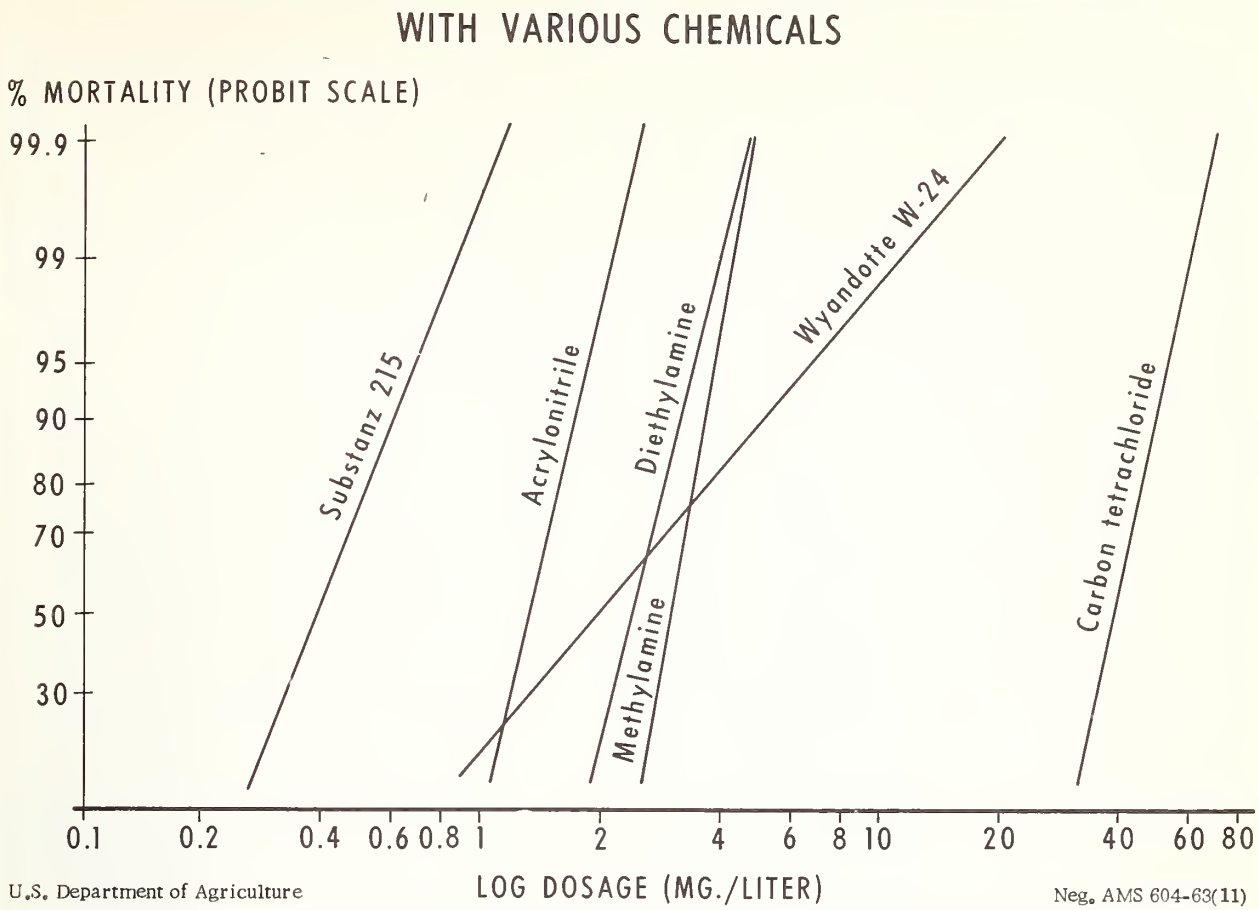

Figure 1.--Dosage-mortality regression lines for adult confused flour beetles fumigated 24 hours with various chemicals in 19.5-liter bottles at 80° F. ± 4°.

Table 1.--Dosages of six chemicals required to produce 50-percent (LD_{50}), 95-percent (LD_{95}), and 100-percent mortalities among adult confused flour beetles exposed 24 hours at 80° F.° ± 4° in 19.5-liter bottles

[Mortalities based on observation 3 weeks after exposure]

Fumigant	Dosage (Mg./liter)						
	LD_{50}	LD_{50} fiducial limits		LD_{95}	LD_{95} fiducial limits		MLD[1]
		Low	High		Low	High	
Substanz 215	0.38	0.35	0.42	0.66	0.58	0.78	1.08
Acrylonitrile	1.36	1.32	1.40	1.80	1.66	1.96	2.3
Diethylamine	2.36	2.29	2.42	3.31	3.16	3.47	4.5
Methylamine (30-percent aqueous)	2.9	2.7	3.1	3.7	3.2	4.4	4.8
Wyandotte W-24	1.89	1.69	2.11	6.42	5.18	7.97	18.4
Carbon tetrachloride	37.7	36.6	38.9	50.7	47.7	53.9	65.5

[1] Minimum dose producing 100-percent mortality.

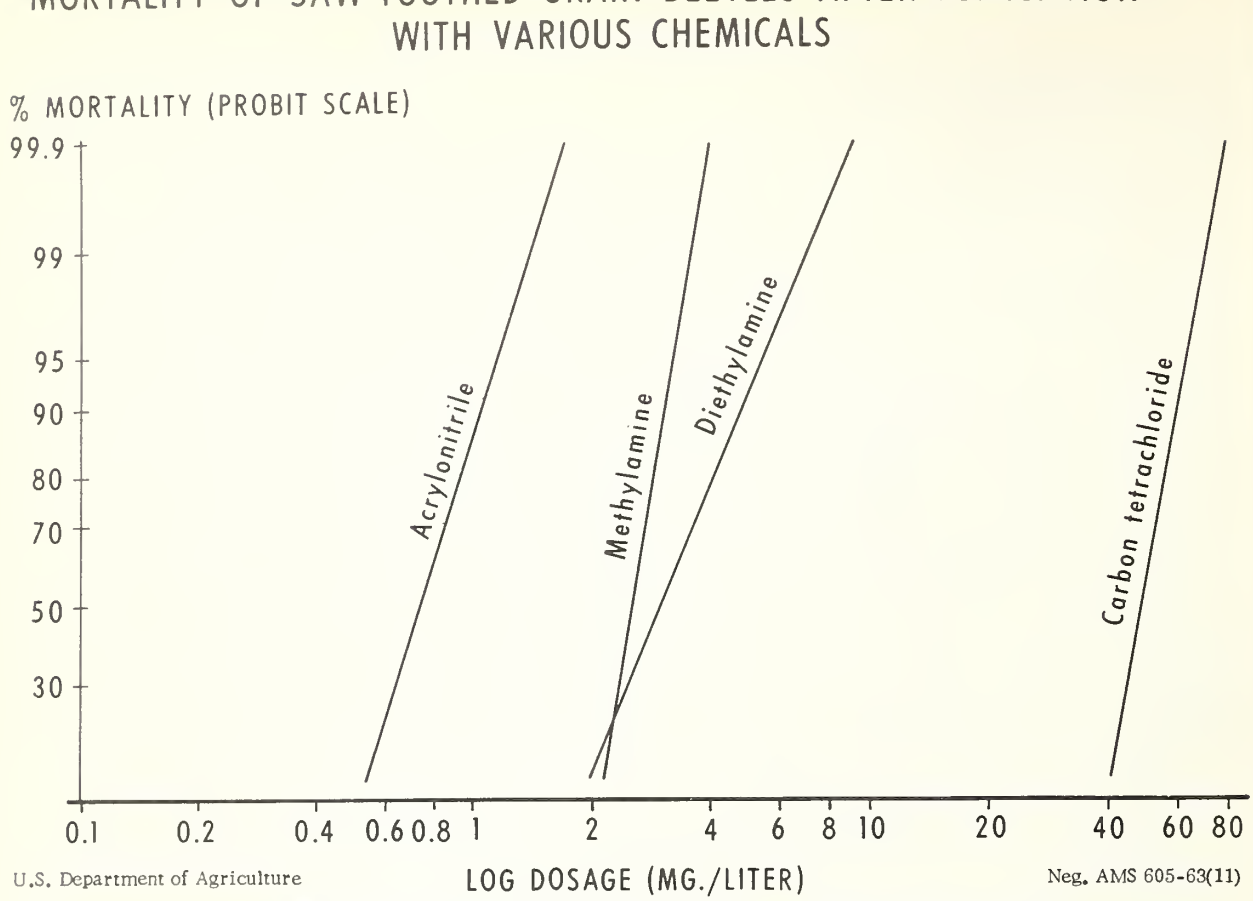

Figure 2.--Dosage-mortality regression lines for adult saw-toothed grain beetles fumigated 24 hours with various chemicals in 19.5-liter bottles at 80° F. ± 4° . Wyandotte W-24 and Substanz 215 were also tested, but the range in data was insufficient to establish regression lines.

Table 2.--Dosages of six chemicals required to produce 50-percent (LD_{50}), 95-percent (LD_{95}), and 100-percent mortalities among adult saw-toothed grain beetles exposed 24 hours at 80° F. ± 4° in 19.5-liter bottles

[Mortalities based on observation 3 weeks after exposure]

Fumigant[1]	Dosage (Mg./liter)						
	LD_{50}	LD_{50} fiducial limits		LD_{95}	LD_{95} fiducial limits		MLD[2]
		Low	High		Low	High	
Acrylonitrile	0.73	0.71	0.76	1.15	1.05	1.25	1.68
Methylamine (30-percent aqueous)	2.53	2.40	2.67	3.29	3.02	3.59	4.0
Diethylamine	2.94	2.78	3.10	5.39	4.60	6.31	9.2
Carbon tetrachloride	47.8	45.1	50.6	62.0	54.3	70.8	78.0

[1] Wyandotte W-24 and Substanz 215 were also tested, but LD_{50}, LD_{95}, and MLD data could not be ascertained because the smallest measurable dosages did not provide enough range in mortality to establish regression lines.

[2] Minimum dose producing 100-percent mortality.

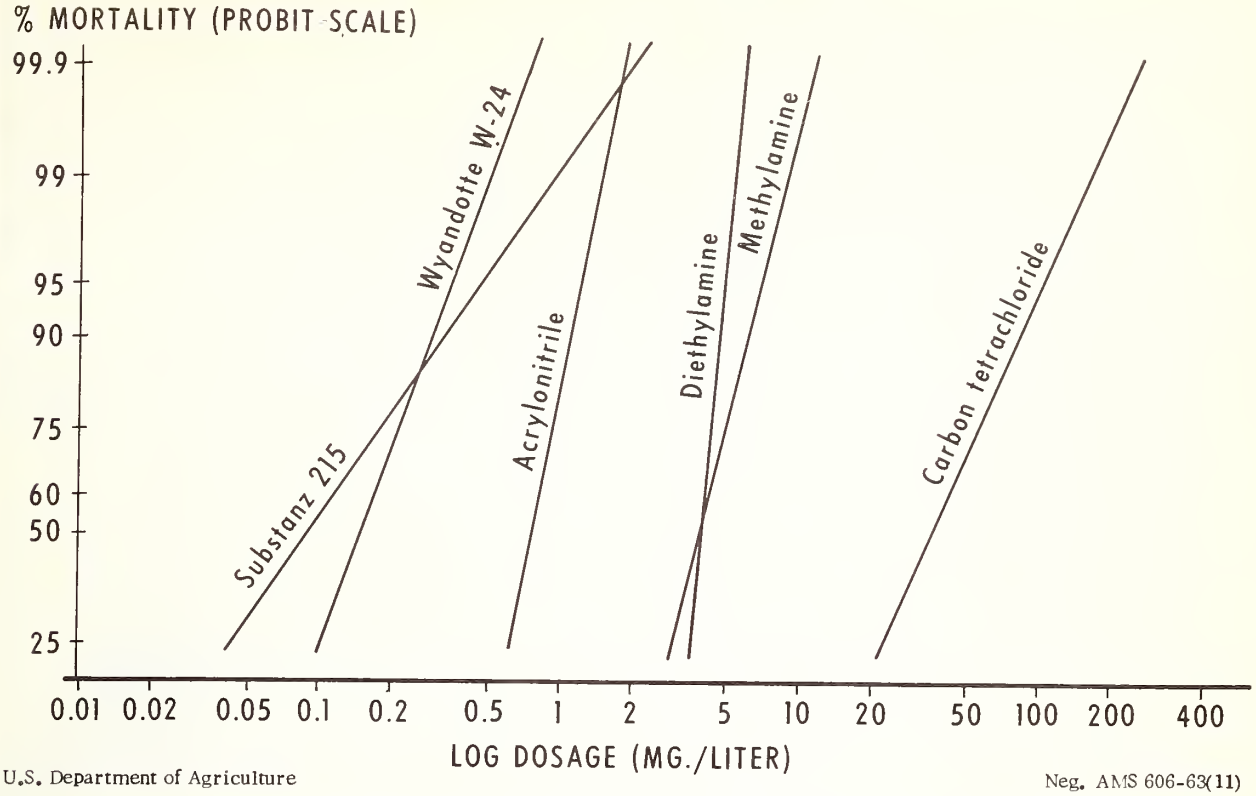

Figure 3.--Dosage-mortality regression lines for adult cigarette beetles fumigated 24 hours with various chemicals in 19.5-liter bottles at 80° F. ± 4°.

Table 3.--Dosages of six chemicals required to produce 50-percent (LD_{50}), 95-percent (LD_{95}), and 100-percent mortalities among adult cigarette beetles exposed 24 hours at 80° F. ± 4° in 19.5-liter bottles

[Mortalities based on observation 1 week after exposure]

Fumigant	Dosage (Mg./liter)						
	LD_{50}	LD_{50} fiducial limits		LD_{95}	LD_{95} fiducial limits		MLD [1]
		Low	High		Low	High	
Wyandotte W-24	0.15	0.08	0.27	0.36	0.12	1.11	0.77
Substanz 215	.09	.07	.13	.47	.25	.89	2.0
Acrylonitrile	.78	.73	.84	1.27	1.04	1.56	1.92
Diethylamine	3.99	3.89	4.10	5.0	4.77	5.24	6.10
Methylamine (30-percent aqueous)	3.96	3.65	4.30	7.13	5.98	8.51	12.0
Carbon tetrachloride	36.0	32.4	40.1	105.8	76.9	145.6	270.0

[1] Minimum dose producing 100-percent mortality.

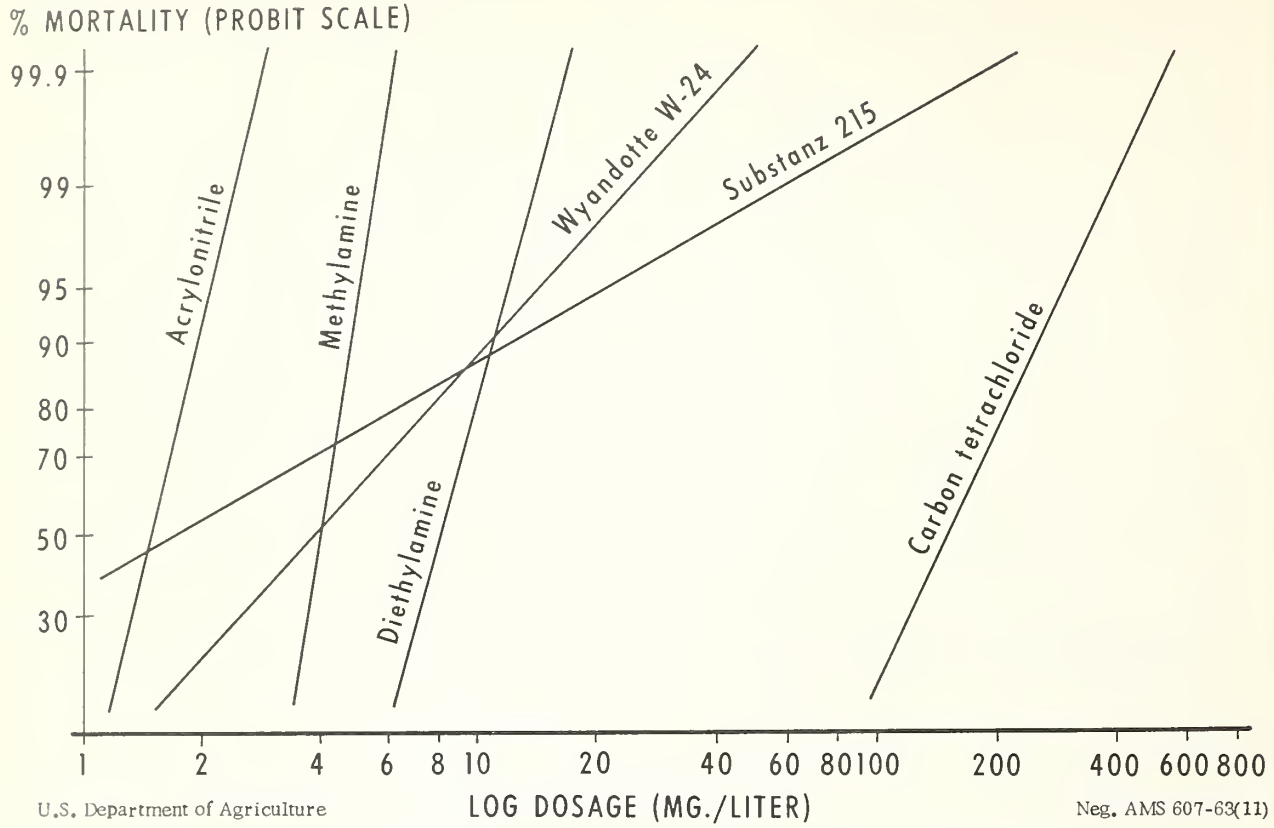

Figure 4.--Dosage-mortality regression lines for black carpet beetle larvae fumigated 24 hours with various chemicals in 19.5-liter bottles at 80° F. ± 4°.

Table 4.--Dosage of six chemicals required to produce 50-percent (LD_{50}), 95-percent (LD_{95}), and 100-percent mortalities among black carpet beetle larvae exposed 24 hours at 80° F. ± 4° in 19.5-liter bottles

[Mortalities based on observation 5 weeks after exposure]

Fumigant	Dosage (Mg./liter)						
	LD_{50}	LD_{50} fiducial limits		LD_{95}	LD_{95} fiducial limits		MLD[1]
		Low	High		Low	High	
Acrylonitrile	1.48	1.42	1.54	2.11	1.93	2.31	2.87
Methylamine (30-percent aqueous)	3.98	3.90	4.06	5.06	4.90	5.24	6.2
Diethylamine	8.0	7.75	8.35	11.8	10.8	13.0	16.6
Wyandotte W-24	3.80	3.32	4.34	14.29	11.50	17.75	46.7
Substanz 215	1.62	1.17	2.25	20.91	5.21	83.89	200.0
Carbon tetrachloride	150.8	140.5	162.0	298.1	261.7	339.6	545.0

[1] Minimum dose producing 100-percent mortality.