The Toxic Action of Phosphine, Methyl Bromide, Methyl Chloroform, and Carbon Dioxide, Alone and as Mixtures, Against the Pupae of *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae)

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The toxicity of phosphine, methyl bromide, methyl chloroform, and carbon dioxide, and mixtures of phosphine/methyl bromide, methyl bromide/methyl chloroform, phosphine/carbon dioxide, and methyl bromide/carbon dioxide to 1–2 day old pupae of *Tribolium castaneum* Herbst was studied. Joint action ratios estimated at LD50 and LD90 for a 24 hour exposure indicated antagonism in the effect on the pupae of phosphine and methyl bromide (except at LD50 in a mixture of 0.01 mg/L concentration of phosphine and methyl bromide), and of methyl chloroform and methyl bromide (Table 1). Carbon dioxide up to 40% concentration enhanced the toxic action of phosphine as well as methyl bromide; when increased further, carbon dioxide failed to increase their toxicity proportionately. Carbon dioxide alone produced a maximum of 11% mortality of the pupae exposed to 20–80% concentrations for 24 hours. The order of toxicity of the fumigants at both LD50 and LD90 on a weight (mg/L) basis or molar per volume (moles/L) basis was phosphine > methyl bromide > methyl chloroform.

Table 1. Toxicity data on phosphine, methyl bromide, and methyl chloroform and joint action ratios of their mixtures in tests against 1–2 day old *Tribolium castaneum* pupae exposed for 24 hours at 26°±1°C and 60–70% relative humidity.

Fumigant/ fumigant mixture	LD50 (mg/L)	Fiducial limits	LD90 (mg/L)	Fiducial limits	Slope±SE	χ^2 (d.f.)	LD_{90}/LD_{50}	Joint action ratio at LD_{50}	Joint action ratio at LD_{90}
Phosphine (PH_3)	0.017	0.01 0.02	0.085	0.06 0.14	1.81±0.04	28.1(6)	5.1	–	–
Methyl bromide	2.852	2.77 2.93	3.708	3.61 3.83	11.23±0.06	6.8(6)	1.3	–	–
Methyl chloroform	208.400	175.50 240.70	391.500	324.80 546.70	4.68±0.07	12.4(5)	1.9	–	–
0.0025 mg/L PH_3 + methyl bromide	2.984	2.89 3.07	3.978	3.80 4.25	10.25±0.07	1.0(3)	1.3	0.81	0.82
0.01 mg/L PH_3 + methyl bromide	1.022	0.79 1.14	4.670	3.23 10.06	1.94±0.05	9.7(4)	4.6	1.06	0.82
2.5 mg/L methyl bromide + methyl chloroform	83.010	68.90 97.81	496.000	362.30 789.80	1.65±0.06	2.8(4)	6.0	0.76	0.65
3.0 mg/L methyl bromide + methyl chloroform	51.220	42.06 60.95	239.000	195.00 313.00	1.91±0.06	4.5(4)	4.7	0.76	0.65