Soybeans: Fumigation with Phosphine[1,2]

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ABSTRACT

Eggs and larvae of *Plodia interpunctella* (Hübner), adult *Tribolium castaneum* (Herbst), and immature *Sitophilus oryzae* (L.) were used to evaluate phosphine as a fumigant for control of insects in stored soybeans. The insects were used to determine toxicity and penetration and were not necessarily relevant to soybean storage. Fumigation with phosphine (90 tablets/1000 bu placed in various patterns) failed to produce 100% mortality of the test insects at all locations in the treated bins.

In 1970, when Agricultural Stabilization and Conservation Service (ASCS) reported finding insects in stored soybeans owned by Commodity Credit Corporation (CCC), the Midwest Grain Insects Investigations Laboratory at Manhattan, Kans., was asked for recommendations. However, no procedure or fumigant has been cleared for use on soybeans by the Food and Drug Administration. Phosphine was therefore selected for a test of feasibility because aluminum phosphide tablets (Phostoxin®) had been tested in corn (McGregor 1961) and processed commodities (McGregor 1966). Also, ASCS personnel were using this fumigant on other commodities.

Three tests were made at the Nevada, Iowa, ASCS bin-site in 1970. In each test, five 3250-bu circular metal bins each containing ca. 3000 bu of soybeans were fumigated, and 5 bins were held as controls.

MATERIALS AND METHODS.—*Test 1.*—The temperature of the stored soybeans was taken at the door and center of the bins at consecutive depths of 18 in. beginning at the surface. (A hygrothermograph was placed in one of the 5 bins held as controls.) Eggs (less than 24 h old) and larvae of the Indian meal moth, *Plodia interpunctella* (Hübner), and the red flour beetle, *Tribolium castaneum* (Herbst), in cages were placed in each quadrant of each bin and at the center just under the surface of the beans. Also, caged immature rice weevils, *Sitophilus oryzae* (L.), were placed near the surface of the beans, at 5 and 10 ft below the surface, and at the bottom of the bins at each of 3 horizontal locations, i.e., at the door, ½ way between the door and the center of the bins, and at the center. The test insects were used to evaluate the fumigation and to determine toxicity, penetration, and distribution and were not necessarily relevant to insect infestation in soybeans.

The procedure used in fumigating the 5 bins of soybeans on Aug. 6 was as follows: 30 aluminum phosphide tablets (rate of 90 tablets/1000 bu) were inserted with a fumigation probe as near the bottom as possible in each bin of soybeans at each of 9 locations, 8 around the perimeter, and 1 at the center. The gas was sampled 24, 48, 72, and 96 h later at the 12 locations in each bin where the immature rice weevils had been placed. At 96 h, exposed insects were recovered, and counts were made of the dead adult red flour beetles and Indian meal moth larvae. All insects were returned to the Manhattan laboratory and placed in the rearing room. The Indian meal moth larvae were examined after 1 week to verify the 1st mortality count. The medium in which the Indian meal moth eggs was held was examined after 5 weeks for the presence or absence of adults. Wheat containing the immature rice weevils was examined after 5 weeks, and the number of adults was recorded.

Test 2.—The same procedure was used on Sept. 4, except that only ⅓ the dose was placed near the bottom of the bins, ⅓ was placed at the middle, and ⅓ at 2 ft below the surface of the beans.

Test 3.—Test 3 (Sept 29) was similar to Test 1 except that all tablets were placed 4–5 ft below the surface of the beans.

RESULTS.—*Test 1.*—At the time of fumigation, the temperature of the beans ranged between 76–82°F at the center of the bins and between 75–83°F near the side walls. During the 96 h fumigation, the air temperature in the bins ranged between 66–90°F. The RH was 88% at the time the fumigant was inserted and ranged between 55–92% during the 96-h exposure.

All Indian meal moth larvae and red flour beetle adults were killed by the treatment but Indian meal moth adults developed from eggs placed in the quadrant nearest the door in each of the 5 bins. All immature rice weevils at all surface locations were killed as were all weevils placed at 5 and 10 ft and at the bottom locations at the center of the bins. Table 1 shows the locations of the caged immature rice weevils that subsequently emerged and the numbers that emerged.

In contrast, only one of the Indian meal moth larvae died of those placed in the 5 check bins, and adult moths developed from eggs placed at all locations. No red flour beetles died that were exposed in the control bins and an average 12.5 rice weevils emerged from infested grain exposed at all locations in the 5 control bins.

Table 1 shows the range of concentrations of phosphine as determined by gas chromatography (GC).

Test 2.—The temperature of the beans ranged between 74–84°F at the center of the bins and between 78–85°F near the bin walls. At the time the fumigant was applied, the air temperature in the bins ranged between 70–90°F. During the fumigation temperatures ranged between 52–101°F. The RH was 86% at the time the 1st bin of beans was fumigated but dropped to 40% by the time the fumigant was applied to the 5th bin. During the exposure, the RH ranged between 25–90%.

All Indian meal moth larvae and red flour beetle adults in all the fumigated bins were killed. Also, the only Indian meal moth adults that developed from eggs were obtained from eggs placed in the quadrant nearest the door in 1 bin. All immature rice weevils were killed in 1 bin; in 2 bins, these weevils survived at 2 locations; and in the other 2 bins, they survived at 1 location. Table 2 shows the locations from which rice weevils emerged and the numbers that emerged.

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[2] Mention of proprietary product does not constitute a recommendation or an endorsement by the USDA.
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Table 1.—Concentration of phosphine found in 5 bins of soybeans fumigated with 90 aluminum phosphide tablets/1000 bu placed at the bottom of the bin and the total number of rice weevils that emerged from the various locations, Nevada, Iowa, Test 1, Aug. 6, 1970.

Location of tablets in grain	Concn (ppm) of phosphine measured at indicated h after application				Total no. rice weevils emerging	
	24	48	72	96	Test bins	Control bins
At door:						
Surface	12– 41	<10– 55	<10–32	<10–28	0	66
5 ft	<10– 21	<10– 37	<10	<10–28	23	65
10 ft	<10– 10	<10– 32	<10	<10–28	32	75
Bottom	<10	<10	<10	<10	53	67
One-half door to center:						
Surface	14–101	<10– 78	<10–23	<10–32	0	58
5 ft	<10–198	<10–129	<10–32	<10	6	66
10 ft	<10– 46	<10– 55	<10	<10	22	49
Bottom	<10– 32	<10– 46	<10	<10	36	59
At center:						
Surface	78–179	46–110	14–18	<10–28	0	66
5 ft	55–202	69–179	<10–37	<10–18	0	56
10 ft	129–340	74–483	23–37	23–37	0	65
Bottom	32–538	16–331	<10–64	<10–37	0	60

In the 5 control bins, 4% of the Indian meal moth larvae died, but adult moths developed from the eggs placed at all test locations. All red flour beetle adults survived in the control bins, and an average of 36 rice weevils emerged from those placed at each test location.

Table 2 shows the ranges of concentration of phosphine determined by GC.

Test 3.—The temperature of the beans ranged between 66–74°F at the center of the bins and between 67–73°F near the bin walls. The air temperature ranged between 60–88°F. During the 96 h exposure, it ranged between 42–92°F. The RH was 98% at the time the 1st bin was fumigated, but it had dropped to 30% by the time the fumigant was applied to the last bin. During the fumigation the RH ranged between 22–98%.

All immature rice weevils and red flour beetles in all fumigated bins were killed. The only Indian meal moth larva that survived was exposed in the quadrant nearest the door. Indian meal moth adults developed from eggs exposed at all locations in all bins.

In the control bins, 2 Indian meal moth larvae died; adult moths developed from eggs at all test locations. All red flour beetles survived. An average of 85 rice weevils emerged from the eggs placed at each test location.

Table 3 shows the range of concentration of phosphine determined by GC and the numbers of rice weevils that emerged.

DISCUSSION.—Gas concentrations determined by GC were lower than anticipated. The high reading found over a 4-day period was less than 10 ppm at some locations. The dose of 90 aluminum phosphide tablets/1000

Table 2.—Concentration of phosphine found in 5 bins of soybeans fumigated with 90 aluminum phosphide tablets/1000 bu placed one-third near the bottom of the bin, one-third at the middle, and one-third 2 ft below the surface, and the total number of rice weevils that emerged from the various locations, Nevada, Iowa, Test 2, Sept. 4, 1970.

Location of tablets in grain	Concn (ppm) of phosphine measured at indicated h after application				Total no. rice weevils emerging	
	24	48	72	96	Test bins	Control bins
At door:						
Surface	<10– 87	<10– 64	<10	<10	0	186
5 ft	<10	<10– 10	<10	<10	2	186
10 ft	<10	<10	<10	<10	62	171
Bottom	<10–570	<10–373	<10–515	<10–161	21	146
One-half door to center:						
Surface	28–244	32–101	<10– 41	<10– 28	0	180
5 ft	<10–124	<10–106	<10–147	<10	0	201
10 ft	<10– 64	<10–129	<10–152	<10	0	173
Bottom	28–294	120–244	55–359	<10– 51	0	219
At center:						
Surface	92–285	28–124	18– 74	14– 37	0	164
5 ft	23–423	23–239	23–244	<10– 55	0	176
10 ft	69–373	51–166	55–244	10–124	0	163
Bottom	166–478	120–492	166–423	28–235	0	198

Table 3.—Concentration of phosphine found in 5 bins of soybeans fumigated with 90 aluminum phosphide tablets/1000 bu placed 4–5 ft below surface of beans, and the total number of immature rice weevils that emerged from the various locations, Nevada, Iowa, Test 3, Sept. 29, 1970.

Location of tablets in grain	Concn (ppm) of phosphine measured at indicated h after application				Total no. rice weevils emerging	
	24	48	72	96	Test bins	Control bins
At door:						
Surface	246–742	48–576	130–490	34–370	0	394
5 ft	<10–322	<10–154	<10–110	<10	0	456
10 ft	<10–178	<10	<10	<10	0	444
Bottom	<10– 10	<10	<10	<10	0	414
One-half door to center:						
Surface	24–154	53–336	29–163	<10– 62	0	405
5 ft	<10–187	<10– 67	<10– 77	<10	0	440
10 ft	<10–120	<10	<10– 14	<10	0	451
Bottom	<10– 10	<10	<10	<10	0	421
At center:						
Surface	48–178	43–427	77–192	<10–120	0	420
5 ft	20–202	10–216	24–312	<10– 34	0	431
10 ft	<10–120	<10– 77	14–144	<10– 19	0	422
Bottom	<10–139	<10–125	<10–134	<10– 38	0	433

bu was not adequate for complete disinfestation as all test insects were not killed in any of the 3 tests.

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