THE RESIDUAL EFFECTS OF INSECTICIDES AGAINST STORED-GRAIN INSECTS

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by

HARI CHARAN AGARWAL

AN ABSTRACT

Submitted to the College of Science and Arts
Michigan State University of Agriculture and
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HARI CHARAN AGARWAL ABSTRACT

Experiments were conducted to evaluate the residual effects of Dowfume-75, Dow Grain Fumigant (80-20 Mixture), Dowfume EB-5, Serafume, malathion and DOW-ET-14 against five common grain pests. The five test insects were: saw-toothed grain beetle, Oryzaephilus surinamensis (L.); confused flour beetle, Tribolium confusum (Duv.); granary weevil, Sitophilus granarius (L.); cadelle, Tenebroides mauritanicus (L.); and larvae of the Indian meal moth, Plodia interpunctella (Hbn.).

The fumigation of two bushel samples of wheat and corn, according to commercial recommendations, did not provide any noticeable residual effects against the above insects. In order to duplicate as closely as possible the conditions which exist on the surface of large grain bins, wheat was dipped in the fumigants and the phosphate emulsions of malathion and DOW-ET-14.

Wheat dipped in emulsions of malathion and DOW-ET-14 at a concentration of 200 ppm (30 ppm of actual material was deposited on the wheat) provided effective residual action against saw-toothed grain beetles, granary weevils and confused flour beetles for seven to ten weeks. DOW-ET-14 residues were also effective against Indian meal moth larvae. Residues of malathion at ten ppm (1.5 ppm of actual material was deposited on the wheat) were effective against saw-toothed grain beetles and granary weevils for

a period of three weeks. DOW-ET-14 residues at the same concentration were not effective against any of the above test insects.

Residues on wheat dipped in Serafume gave 70 to 100 percent control of saw-toothed grain beetles and granary weevils for eight and four weeks, respectively. Dowfume EB-5 residues were less effective than the Serafume treatment, while Dowfume-75 and 80-20 Mixture did not show any significant residual activity.

Fumigation at the normal dosages did not reduce the germination of wheat, corn, barley, oat, rye, and kidney bean seeds.

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INTRODUCTION

Man has been fighting insects since time immemorial in one way or another. Insects are so numerous and diversified that they are present in almost every type of habitat. Stored grain and stored products are no exception to this. About ten percent of the world's production of cereals, pulses and oil seeds are destroyed annually by various pests, mainly insects. In the United States the losses from insects to cereal grains and their products have been variously estimated to be from 200 million to 600 million dollars annually. With the increase in the amount of stored products we are faced with a serious problem of saving our grain from insects.

Many studies have been conducted in the past half century regarding the protection of stored products. At the present time fumigation is considered one of the most successful means of combating insect infestations. Methyl bromide is one of the most recent fumigants to be used successfully for grain fumigation. Recent problems associated with the residues resulting from the application of methyl bromide and other fumigants have increased the interest in some of the older formulations. The increase in surface infestations of the Indian meal moth, Plodia in-

terpunctella (Hbn.), in many grain storages has also focused attention to the residual activity of various fumigants.

The objective of this study was the evaluation of the residual effectiveness of various formulations of fumigants against the following five stored grain pests: confused flour beetle, Tribolium confusum (Duv.); saw-toothed grain beetle, Oryzaephilus surinamensis (L.); granary weevil, Sitophilus granarius (L.); Indian meal moth, Plodia interpunctella (Hbn.), and cadelle, Tenebroides mauritanicus (L.).

LITERATURE REVIEW

One of the oldest fumigants known was the fumes of burning sulfur. It had been used for the fumigation of houses for thousands of years and was a common practice as early as the 12th century B. C. Hydrocyanic acid (prussic acid) was known by Egyptians as a poison derived from extracts of the peach and other plants. The Romans acquired this knowledge and used the poison for suicidal purposes (Blyth, 1895). Its use as an insect fumigant to kill museum pests in insect collections was recorded by Bell (1877). Coquillett (1888) used hydrocyanic acid for control of the cottony cushion scale, Icerya purchasi Mask. In 1922 a mixture of liquid hydrocyanic acid and chloropicrin absorbed on diatomaceous earth was developed in Germany for general fumigation work. It was used by Metzger (1926) to a limited extent for local fumigation work in flour mills. The great development of fumigants for insecticidal purposes has taken place during the past fifty years.

The use of carbon disulfide as an insect fumigant was discovered by Garreau (1854) for control of the granary weevil. His results indicated that carbon disulfide was the most satisfactory material for control of this

pest. Since about 1880 the use of carbon disulfide has steadily increased, chiefly as a soil insecticide for the control of rats, gophers and ants. Chittenden (1897) recommended its use in general fumigations of stored products in warehouses. Hinds (1909) and Hinds and Turner (1910) extended the use of carbon disulfide to the control of insects in stored corn.

The mixture of carbon disulfide vapors and air is a highly flammable mixture and for this reason it is considered unsafe for use as a fumigant. In order to reduce the fire hazard associated with the use of carbon disulfide many mixtures with non-flammable chemicals such as carbon tetrachloride have been proposed (Cotton, 1956b). Mixtures containing about 15 percent carbon tetrachloride together with other ingredients are relatively stable and can be used safely.

Chloropicrin was important in chemical warfare during World War I as one of the tear gases known commonly as "vomiting gas." According to Roark (1934) it was first prepared by Stenhous in 1848. According to Cotton (1956b) the insecticidal use of chloropicrin was first proposed in 1907 by Fabricwerke of Austria. Moore (1918) discovered its value as an efficient insect fumigant. Piutti and Bernadini (1917) in Italy, and Bertrand (1919) in France published papers on the effect of chloropicrin on stored product insects. Chapman and Johnson (1925) reviewed the

history of chloropicrin research and determined some of the limitations for its use in cereal fumigation. It is extremely toxic to insects and non-flammable, but is disagreeable to handle because of its lachrymatory and nauseating effects. Its vapors cling to fumigated commodities and seriously decrease the germination of seeds when moisture content is high or if used in heavy dosages for long exposures (Cotton, 1956b).

Morse (1910) employed carbon tetrachloride for the first time as a fumigant for control of insect pests in stored grain and grain products. Chittenden and Popenoe (1911) tested it as a substitute for carbon disulfide for fumigating stored grain and published an account of its effectiveness. Doane (1919) reported the successful use of carbon tetrachloride for controlling Sitophilus oryza (L.) and Sitophilus granarius (L.) at the rate of two gallons per 1000 bushels of wheat. It was recognized shortly after the discovery of its use as a fumigant that carbon tetrachloride is not as effective as carbon disulfide and at the present time it is more frequently used in combination with other chemicals more toxic to insects. These combinations reduce the fire hazard and aid in the distribution of the fumigant by increasing the volume of the mixture.

Neifert et al (1925) found that ethylene dibromide mixed with carbon tetrachloride was a promising fumigant

for stored grain. Ethylene dichloride mixed with carbon tetrachloride was employed in the fumigation of stored products by Cotton and Roark in 1927. Later, Cotton and Wagner (1941) recommended a mixture of ethylene dichloride and carbon tetrachloride (75:25) for the fumigation of wheat. Farrar and Flint (1942) extended its use to corn. Cotton and Roark (1928), in an effort to find an acceptable substitute for carbon disulfide as a grain fumigant, discovered the insecticidal properties of ethylene oxide. Cotton and Young (1929) reported that by mixing carbon dioxide with ethylene oxide the insecticidal action of ethylene oxide was increased while the fire hazard was reduced.

Methyl bromide is one of the most recent additions to the list of the fumigants. Le Goupil (1932) used it to eliminate the fire hazard of ethylene oxide and he discovered it to be even more effective than the compound with which it was mixed. Vayssière (1934), de Francolini (1936) and Lepigre (1936) in France reported on the insecticidal uses of methyl bromide and noted its effectiveness against grain-infesting insects.

Hicks and Dabney (1897) reported that field corn is one of the seeds most susceptible to injury by gas treatment. In their experiments, the germination of corn treated for 48 hours with a standard atmosphere of gas was

reduced 40 percent. A 24-hour treatment resulted in no injury.

Hinds in 1909 conducted tests to find the effect of carbon disulfide on the germination of seed corn. He used carbon disulfide at the rate of 75 pounds per 1000 cubic feet. The seeds, soaked with water before exposure of 40 and 72 hours, were all killed. Others which were soaked in water and then aired showed an injury of about 27 percent. He concluded that the proportion of water in the seeds at the time of treatment has much to do with the possibility of gas injury.

Moore (1918) reported that small doses of chloropicrin, such as one-half pound per 1000 cubic feet of space, did not injure the germination of certain grain seeds. Higher concentrations did reduce the germination when it was attempted before the grain was aired thoroughly. He further noted that pure chloropicrin did not change the color or baking properties of flour.

Willard (1923) working with carbon disulfide found that, in practice, no aeration of storages was necessary after fumigation with carbon disulfide, unless they were air tight. Bins and similar storages for seeds seldom are air tight and the carbon disulfide would diffuse out of the bin. It required large concentrations of carbon disulfide for an extended period of time to have any marked effect on the germination of seeds used in the experiment.

The injury slowly became greater as the time and the rate increased but was not directly proportional to either variable. The first effect of the treatment was to delay germination one or more days later than the check. Willard also observed that when liquid carbon disulfide was poured directly on most seeds during fumigation it did not cause serious injury.

Roark and Cotton (1928) during their tests of various aliphatic chlorides as fumigants for stored grains indicated that these compounds when used at normal dosages do not injure the germinating qualities of the grain.

Shepard and Buzicky (1939) found that ethylene dichloride, unlike many other fumigants, produced a delayed mortality for the first ten days after fumigation. Richardson and Casanges (1942) working along the same line found that this delayed effect continued beyond ten days. In some of their tests 40 to 60 percent of the confused flour beetles were killed between the tenth and twentieth days. There was only slight increase in mortality between the twentieth and fortieth days. The mixture of ethylene dichloride with carbon tetrachloride was found to have a similar latent effect, while carbon tetrachloride alone did not produce this delayed mortality.

Cotton (1944) working with methyl bromide and chloropicrin reported that these materials may cause severe losses in germination of wheat with low moisture con-

tent. Smith and Staton (1942) pointed out that damage to the germ of wheat by fumigants may impair the baking value. Cotton further noted that with many fumigants germination injury increased if grain moisture is above 12 percent, if the concentration is excessive, or the exposure period prolonged. A three to one mixture of ethylene dichloride and carbon tetrachloride did not retard germination of grain, regardless of the above factors.

Richardson and Walkden (1945) obtained 100 percent mortality of rust red flour beetle, saw-toothed grain beetle and rice weevil with the use of 20 percent β-methylallyl chloride at the rate of two gallons per 1000 bushels of shelled corn stored in steel bins. The germination was not reduced in corn and wheat treated as above and containing 9.1 percent moisture. Injury to germination increased with the increase in dosage or moisture content of the grain. They also observed no reduction in the germination of corn and wheat fumigated with the ethylene dichloride-carbon tetrachloride mixture (25:75).

Fisher (1945) found that when methyl bromide was applied at the rate of two pounds per 1000 cubic feet for a period of 24 hours, there was a retention of 2.6 ppm (expressed as bromide) in raisins, 1.6 ppm in dried peaches, 2.8 ppm in dried apricots and a trace in prunes. Rolled oats had a residue of 130 ppm and raw cashew nutmeats 148 ppm, 48 hours after fumigation. Oil-bearing

foods tend to absorb more of the oil soluble methyl bromide. Farrar and Wright in 1946 found that the use of DDT at the normal rates had no deleterious effect on the germination of wheat, barley and oats.

Richardson (1946), while comparing the efficiency of the carbon tetrachloride-ethylene dichloride mixture on shelled corn, found that the effective dosages of carbon tetrachloride (two gallons per 1000 bushels for 24 hours) did not injure the germination of seed corn even when the fumigant was poured directly on the corn.

Grayson (1948), while testing the effect of chloropicrin on the germination of shelled peanuts at rates up to ten pounds and for exposures of 24 hours, found that at a moisture content below ten percent very little reduction in germination occurred. At moisture contents greater than 14 percent slight reduction in germination resulted from a two pound rate and the germination reduced considerably at higher rates.

Glass and Crosier (1949) tested the effects of acrylonitrile-carbon tetrachloride mixture (50:50) on germination of bean, beet, cabbage, carrot, corn, cucumber, lettuce, lima bean, oat, onion, pea, pumpkin, radish, squash, tomato and wheat seeds. The fumigant was used at dosages varying from one to 25 pounds per 1000 cubic feet. No evidence was found of immediate or delayed deleterious effect on germination of any of the seeds.

Smallman (1949), in an effort to find a fumigant with long residual action for use in milling machinery, tested compounds with low vapor pressure. He found that fumigants with low vapor pressure and high toxicity have a longer residual life. Ethylene dibromide with a vapor pressure as low as 13.5 mm. of mercury at 25°C. gave 100 percent mortality for 20 days.

Gerhardt, Lindgren and Sinclair (1951) pointed out that when whole walnuts stored in sealed, double-walled cellophane bags were vacuum-fumigated with two pounds of methyl bromide per 1000 cubic feet, the methyl bromide persisted over a period of one hour to 21 days within the bags and the nuts absorbed 0.41 to 4.84 mg. bromide per 100 gms.

Walkden and Schwitzgebel (1951) noted that carbon tetrachloride, when applied to 1000 bushels of wheat in a steel bin at the rate of two gallons per 1000 bushels, was retained in lethal concentrations from two to three weeks. An increased rate of application extended the time of retention of the fumigant in lethal concentrations. The mixture of carbon disulfide-carbon tetrachloride (1:4), when applied to 1000 bushels of wheat at the rate of two gallons per 1000 bushels, was retained in lethal concentrations for two to four weeks. Increased rate also prolonged the time of its retention on the wheat. A mixture of ethylene dichloride and carbon tetrachloride (3:1) was retained in

lethal concentrations for four to five weeks when three gallons of this formulation was applied to 1000 bushels of wheat. It was retained for 24 to 32 weeks when 5000 bushels of wheat were treated at the same rate.

Lindgren, Krohne and Vincent (1954) observed that rice weevils, granary weevils and lesser grain borers, when exposed to malathion-treated grain, were killed at dosages as low as two ppm. After storage for three months the kill of these insects was relatively high, especially when the malathion was applied to the grain as a dust. Concentrations of eight and 16 ppm were still effective six to seven months after application. The insects oviposited normally prior to their death in the treated wheat. In cases where 100 percent mortality occurred there was no evidence of breeding four months after treatment. The same workers also reported that the tests under progress indicate that the residual effectiveness of the malathion treatment may be affected by the moisture content of the grain.

Berck (1956) recently pointed out that fumigant containing ethylene dibromide and carbon tetrachloride showed greater insecticidal effectiveness than a fumigant containing ethylene dibromide and methyl bromide. He explained this phenomenon by the improved downward distribution and persistence of ethylene dibromide when carbon tetrachloride is present. When ethylene dibromide and

methyl bromide mixture was applied to wheat, bromide residues were found on the fumigated wheat.

PROCEDURE

Field run samples of corn and wheat were place in fiber drums. Ten drums contained two bushel samples of corn and ten additional drums were used for two bushels of wheat. The fiber drums had a diameter of 20 inches and a height of 31 inches. The drums were filled to a depth of 12 and 14 inches with two bushels of corn and wheat, respectively. The exposed surface area of the grain was 314.2 square inches. Ten drums, five of corn and five of wheat, were kept in a storage room in the Natural Science building. The remaining ten drums were placed in a screened insectary where they were exposed to outside temperatures but protected from rain. During storage, drums in the Natural Science building were covered with a metal cover and those at the insectary remained open. The conditions of storage in the drums in the Natural Science building were very similar to those in tightly closed grain storage. The grain at the insectary was exposed to conditions representative of those in open farm storage.

Small cages, 2.5 inches long and 0.75 inch in diameter, were filled with 150 insects. Each cage contained 50 saw-toothed grain beetles, Oryzaephilus surinamensis (L.); 50 confused flour beetles, Tribolium confusum (Duv.)

and 50 granary weevils, Sitophilus granarius (L.). Larger screen cages, 4 inches long and 0.75 inch in diameter, were filled with wheat flour containing eggs, larvae and pupae of the confused flour beetle. The cages were then fastened together in pairs with rubber bands. Each pair consisted of one small and one large cage. In each drum two such pairs of cages were inserted in the grain in an upright position, one pair at the bottom and the other pair near the surface. A small cheese-cloth sack containing more than 100 seeds each of wheat, corn, rye, barley, oats and kidney beans was placed at the bottom of each drum.

The drums were fumigated on July 9, 1956. The fumigant was evenly distributed over the surface of the grain by means of a small sprinkler consisting of a rubber ball of 30 cubic centimeter capacity, attached to a narrow glass tube which tapered to a fine opening. The fumigants used were all commercially prepared materials. They were: Dowfume-75, consisting of 70.2 percent ethylene dichloride and 29.8 percent carbon tetrachloride; Dow Grain Fumigant (80-20 Mixture), consisting of 83.5 percent carbon tetrachloride and 16.5 percent carbon bisulfide; Dowfume EB-5, consisting of 7.2 percent ethylene dibromide, 29.2 percent ethylene dichloride and 63.6 percent carbon tetrachloride; and Serafume, consisting of 3.5 percent ethylene dibromide, 10.0 percent carbon disulfide, 10.0 percent ethylene di-

chloride and 76.5 percent carbon tetrachloride. Slightly more than the recommended dosages were used, because of the small amount of the grain fumigated.

Four drums, two at the Natural Science building and two at the insectary, were fumigated with each material. One drum of corn and one of wheat were treated at each location. The remaining drums were left untreated as checks.

All drums were covered immediately after fumigation and opened after 24 hours for aeration of the grain, and all of the cages were removed. Thirty-six hours after fumigation the drums stored at the Natural Science building were covered. The small cages were transferred to a constant temperature and humidity rearing room maintained at 80° F. and 50 percent humidity. Each large cage containing infested wheat flour was emptied into a one-half pint, wide mouth glass jar and covered with white muslin. These samples were placed in the rearing room for future observations. The mortality of the insects in the small cages was determined after 72 hours. Twenty-four hours after removing the first series of cages a second series was placed in the grain. These cages were taken out after 48 hours and the same process as above was followed.

Forty-eight hours after fumigation approximately one-half pint of grain was taken from both the surface and the bottom of the grain in each drum. Two samples of 50 gms. each were taken from the surface, and one from the

bottom of the grain in each drum, and placed in one-half pint, wide mouth glass jars and covered with muslin, Ten Indian meal moth larvae, Plodia interpunctella (Hbn.), about one-half inch long, were placed in one of the surface samples, and in the second as well as the bottom sample 50 adults each of confused flour beetle, saw-toothed grain beetle and granary weevil. Ten adult cadelle, Tenebroides mauritanicus (L.), were placed in 50-gram samples of the fumigated and unfumigated wheat stored at the Natural Science building. The jars containing these samples were placed in the rearing room. After one week the number of dead insects and the number of Indian meal moth adults that had emerged was recorded. The number of adult confused flour beetles emerging in the flour was noted. The sampling procedure as outlined above was continued for four weeks. Mortality counts and observations were continued until the second generation adults appeared.

A second series of experiments was established by actually dipping samples of wheat into the fumigant. Approximately five pounds of wheat was dipped in a fumigant for one minute, after which it was spread on a sheet of paper to dry. The materials used were Dowfume-75, Dow Grain Fumigant (80-20 Mixture), Dowfume EB-5, Serafume, DOW-ET-14 (four pounds DOW-ET-14 per gallon), and Malathion (premium grade, five pounds per gallon). Malathion and

DOW-ET-14 were used at the concentrations of ten and 200 ppm. Since about 256 cubic centimeters of the emulsion were retained by the grain, calculation shows there was approximately 1.5 ppm (10 ppm) and 30 ppm (200 ppm) of actual malathion and of DOW-ET-14 deposited on the wheat.

The dipped grain was allowed to dry for 12 hours and then divided into two lots of 2.5 pounds each. Each lot was placed in a wide mouth gallon jar. This resulted in 18 jars, eight containing grain dipped in fumigants, eight with grain dipped in DOW-ET-14 and malathion emulsions, and two containing untreated wheat. Nine jars were stored in the Natural Science building and the other nine were kept at the insectary as in the previous case. The jars in the Natural Science building were covered and those at the insectary remained open.

Two samples of 50 grams each were removed from each jar weekly. Ten Indian meal moth larvae were introduced in one sample. In the other sample 50 adults each of saw-toothed grain beetle, confused flour beetle and granary weevil were introduced. These cultures were maintained in the rearing room at the temperature and humidity as above. The number of dead insects and the number of the Indian meal moth that had emerged were recorded each week. This sampling procedure was continued for eight weeks.

Seed germination tests were conducted before and after the fumigation. Before fumigation 200 seeds each of

wheat, corn, rye, barley, oat, and kidney bean were tested by the upright paper towel method. The number of seeds germinated after six days was recorded. The sacks containing the seeds for germination studies were removed from the drums five weeks after fumigation. Germination studies of these seeds were conducted as above.

PRESENTATION OF DATA

The exposure of confused flour beetle, saw-toothed grain beetle and granary weevil adults to the normal dosages of Dowfume-75, 80-20 Mixture, Dowfume EB-5 and Serafume normal fumigation procedure for twenty-four hours in wheat and corn resulted in the mortality shown in Table 1. The mortality of the three species of insects approached 100 percent. In the case of Dowfume-75 all of the insects were killed both at the bottom and near the surface of the grain except in one drum of wheat located at the insectary. In this drum 34 percent of the granary weevils were killed in the cage near the surface of the wheat. In the same wheat 94 percent of the confused flour beetles and ten percent of the granary weevils were killed in the cage at the bottom of the drum.

With the exception of one drum of wheat fumigated with Serafume, 100 percent mortality of the insects located both at the bottom and near the surface of the grain was obtained by fumigation with 80-20 Mixture, Dowfume EB-5 and Serafume. In one drum of wheat treated with Serafume and located at the insectary, 38 percent of the granary weevils were killed in the bottom cage. In the checks the mortality was low, the highest being in the

TABLE 1

PERCENT MORTALITY OF INSECTS EXPOSED TO FUMIGATION FOR 24 HOURS IN GRAIN STORED IN FIBER DRUMS

Material	Grain	Type of storage	Position of insect cage in grain	Percent of dead insects		
				Oryzaephilus surinamensis	Tribolium confusum	Sitophilus granarius
Dowfume EB-5	Wheat	Closed	Surface	100	100	100
	"	"	Bottom	100	100	100
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
	Wheat	Open	Surface	100	100	100
	"	"	Bottom	100	100	100
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
Serafume	Wheat	Closed	Surface	100	100	100
	"	"	Bottom	100	100	100
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
	Wheat	Open	Surface	100	100	100
	"	"	Bottom	100	100	98
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
80-20 Mixture	Wheat	Closed	Surface	100	100	100
	"	"	Bottom	100	100	100
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
	Wheat	Open	Surface	100	100	100
	"	"	Bottom	100	100	100
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
Dowfume-75	Wheat	Closed	Surface	100	100	100
	"	"	Bottom	100	100	100
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	98
	Wheat	Open	Surface	100	100	34
	"	"	Bottom	94	100	10
	Corn	"	Surface	100	100	100
	"	"	Bottom	100	100	100
Check	Wheat	Closed	Surface	0	0	4
	"	"	Bottom	6	0	20
	Corn	"	Surface	2	2	8
	"	"	Bottom	6	2	2
	Wheat	Open	Surface	0	0	16
	"	"	Bottom	6	0	6
	Corn	"	Surface	10	0	18
	"	"	Bottom	8	2	20

case of the granary weevils, where 20 percent of the insects were dead. Mortality was zero to ten percent in the case of the saw-toothed grain beetles, zero to two percent with the confused flour beetles and two to 20 percent in the case of granary weevils.

The second set of insects was exposed to the fumigated wheat and corn, 48 hours after fumigation, for a period of 48 hours to obtain data on residues from normal fumigation. The data in Table 2 indicates that the highest kill was obtained with Dowfume EB-5. In the covered drums the mortality of saw-toothed grain beetles (Table 2) placed on fumigated grain 48 hours after aeration varied from 60 to 94 percent, granary weevils from 48 to 76 percent and confused flour beetles 18 to 78 percent. The mortality was less in the samples stored in the open drums. In these drums the mortality of saw-toothed grain beetles varied from 12 to 30 percent, granary weevils 34 to 46 percent and the confused flour beetles zero to two percent. The mortality resulting from the various fumigants decreased in effectiveness in the following order: Dowfume EB-5, Serafume, Dowfume-75 and 80-20 Mixture. A mortality of zero to 12 percent for the saw-toothed grain beetles, six to 38 percent of the granary weevils and zero to four percent in case of the confused flour beetles was noted in the checks. In all cases higher mortality was observed in closed drums than in open drums. It was appar-

TABLE 2

PERCENT MORTALITY OF INSECTS EXPOSED FOR 48 HOURS TO FUMIGATED GRAIN 48 HOURS AFTER FUMIGATION IN FIBER DRUMS

Material	Grain	Type of storage	Position of insect cage in grain	Percent of dead insects		
				Oryzaephilus surinamensis	Tribolium confusum	Sitophilus granarius
Dowfume EB-5	Wheat	Closed	Surface	82	40	76
	"	"	Bottom	60	18	54
	Corn	"	Surface	66	30	60
	"	"	Bottom	94	78	48
	Wheat	Open	Surface	12	2	42
	"	"	Bottom	26	2	46
	Corn	"	Surface	16	0	42
	"	"	Bottom	30	0	34
Serafume	Wheat	Closed	Surface	0	6	42
	"	"	Bottom	14	0	60
	Corn	"	Surface	62	16	80
	"	"	Bottom	64	24	76
	Wheat	Open	Surface	8	2	54
	"	"	Bottom	10	4	42
	Corn	"	Surface	2	2	50
	"	"	Bottom	6	2	42
80-20 Mixture	Wheat	Closed	Surface	6	0	28
	"	"	Bottom	6	2	54
	Corn	"	Surface	4	0	48
	"	"	Bottom	4	4	38
	Wheat	Open	Surface	2	0	44
	"	"	Bottom	14	0	38
	Corn	"	Surface	0	0	26
	"	"	Bottom	2	4	14
Dowfume-75	Wheat	Closed	Surface	8	86	36
	"	"	Bottom	26	96	30
	Corn	"	Surface	2	18	30
	"	"	Bottom	8	70	26
	Wheat	Open	Surface	4	6	36
	"	"	Bottom	2	6	26
	Corn	"	Surface	0	4	32
	"	"	Bottom	0	0	16
Check	Wheat	Closed	Surface	6	0	28
	"	"	Bottom	6	0	26
	Corn	"	Surface	12	0	38
	"	"	Bottom	4	0	6
	Wheat	Open	Surface	0	0	14
	"	"	Bottom	4	0	32
	Corn	"	Surface	0	0	34
	"	"	Bottom	2	4	20

ent that the fumigants were retained for a longer time in the closed storage conditions. There was no emergence of adult confused flour beetles from the rearing of its eggs, larvae and pupae in flour exposed to fumigants in the first and second sets of cages. The checks also showed the same results.

The residual effect of the fumigants on the mortality of adult saw-toothed grain beetles, confused flour beetles, confused flour beetles and granary weevils exposed to the samples of fumigated wheat and corn are recorded in Tables 3 to 9. The first three tables present the results of one week's exposure of the above three species of insects. Little residual effect was observed in the case of saw-toothed grain beetles during the one-week exposure. The data in Table 3 indicate that the mortality in the checks and treatments were comparable. This same trend was present in the case of confused flour beetles (Table 4) and granary weevils (Table 5). The data in Tables 6 to 9 indicate that there was also no residual effect to these three insects when they were continuously reared on the fumigated wheat and corn.

When adult cadelles were maintained on samples of fumigated wheat, there was some indication of residual action. The fumigants ranked in the following order of decreasing effectiveness: Dowfume-75, 80-20 Mixture, Dowfume EB-5 and Serafume. In the samples taken two days

TABLE 3

PERCENT MORTALITY OF SAW-TOOTHED GRAIN BEETLES EXPOSED TO FUMIGATED GRAIN FOR SEVEN DAYS AT VARIOUS INTERVALS AFTER FUMIGATION OF THE GRAIN

Material	Grain	Type of storage	Sample position	Percent of dead insects			
				Days after fumigation			
				9	16	23	30
Dowfume EB-5	Wheat	Closed	Surface	2	10	0	2
	"	"	Bottom	0	4	2	2
	"	Open	Surface	4	2	0	2
	"	"	Bottom	4	40	0	4
	Corn	Closed	Surface	0	0	4	4
	"	"	Bottom	0	2	0	2
	"	Open	Surface	0	2	4	4
	"	"	Bottom	0	8	6	2
Serafume	Wheat	Closed	Surface	0	2	2	8
	"	"	Bottom	0	2	0	4
	"	Open	Surface	0	6	0	2
	"	"	Bottom	0	76	2	8
	Corn	Closed	Surface	0	6	0	4
	"	"	Bottom	0	16	12	2
	"	Open	Surface	0	8	4	4
	"	"	Bottom	0	4	6	6
80-20 Mixture	Wheat	Closed	Surface	0	2	4	2
	"	"	Bottom	0	0	2	2
	"	Open	Surface	2	12	4	0
	"	"	Bottom	2	12	4	0
	Corn	Closed	Surface	2	2	4	2
	"	"	Bottom	0	8	0	0
	"	Open	Surface	0	2	6	2
	"	"	Bottom	2	4	2	0
Dowfume-75	Wheat	Closed	Surface	0	10	12	2
	"	"	Bottom	2	0	0	6
	"	Open	Surface	4	2	2	0
	"	"	Bottom	0	8	4	2
	Corn	Closed	Surface	0	2	6	0
	"	"	Bottom	0	0	0	0
	"	Open	Surface	0	0	0	2
	"	"	Bottom	0	10	2	0
Check	Wheat	Closed	Surface	2	2	0	2
	"	"	Bottom	0	0	4	2
	"	Open	Surface	2	6	0	0
	"	"	Bottom	0	2	0	0
	Corn	Closed	Surface	2	4	0	0
	"	"	Bottom	2	4	4	2
	"	Open	Surface	2	4	0	0
	"	"	Bottom	0	4	6	0

TABLE 4

PERCENT MORTALITY OF CONFUSED FLOUR BEETLES EXPOSED TO FUMIGATED GRAIN FOR SEVEN DAYS AT VARIOUS INTERVALS AFTER FUMIGATION OF THE GRAIN

Material	Grain	Type of storage	Sample position	Percent of dead insects			
				Days after fumigation			
				9	16	23	30
Dowfume EB-5	Wheat	Closed	Surface	10	30	4	0
	"	"	Bottom	30	6	0	0
	"	Open	Surface	0	2	0	0
	"	"	Bottom	2	4	6	0
	Corn	Closed	Surface	24	2	4	0
	"	"	Bottom	20	0	0	0
	"	Open	Surface	2	8	0	0
	"	"	Bottom	0	4	0	0
Serafume	Wheat	Closed	Surface	40	18	0	0
	"	"	Bottom	26	12	4	2
	"	Open	Surface	2	4	0	0
	"	"	Bottom	0	18	0	2
	Corn	Closed	Surface	14	2	0	0
	"	"	Bottom	26	18	0	0
	"	Open	Surface	0	2	0	0
	"	"	Bottom	0	2	0	2
80-20 Mixture	Wheat	Closed	Surface	0	16	2	0
	"	"	Bottom	22	16	4	0
	"	Open	Surface	4	8	0	0
	"	"	Bottom	0	24	4	0
	Corn	Closed	Surface	22	14	0	0
	"	"	Bottom	30	12	2	0
	"	Open	Surface	0	2	0	0
	"	"	Bottom	0	8	0	0
Dowfume	Wheat	Closed	Surface	4	34	0	2
	"	"	Bottom	36	28	2	0
	"	Open	Surface	2	6	2	0
	"	"	Bottom	0	6	0	2
	Corn	Closed	Surface	22	18	2	0
	"	"	Bottom	18	6	0	0
	"	Open	Surface	0	2	0	0
	"	"	Bottom	10	8	0	0
Check	Wheat	Closed	Surface	40	14	2	0
	"	"	Bottom	34	8	0	0
	"	Open	Surface	0	4	0	0
	"	"	Bottom	0	12	2	0
	Corn	Closed	Surface	26	0	0	0
	"	"	Bottom	38	8	6	0
	"	Open	Surface	0	10	0	0
	"	"	Bottom	0	12	0	0

TABLE 5

PERCENT MORTALITY OF GRANARY WEEVILS EXPOSED TO FUMIGATED GRAIN FOR SEVEN DAYS AT VARIOUS INTERVALS AFTER FUMIGATION OF THE GRAIN

Material	Grain	Type of storage	Sample position	Percent of dead insects			
				Days after fumigation			
				9	16	23	30
Dowfume EB-5	Wheat	Closed	Surface	10	0	0	4
	"	"	Bottom	6	2	0	8
	"	Open	Surface	14	2	0	4
	"	"	Bottom	10	12	0	2
	Corn	Closed	Surface	8	2	0	0
	"	"	Bottom	6	0	4	0
	"	Open	Surface	0	0	0	8
	"	"	Bottom	2	2	0	2
Serafume	Wheat	Closed	Surface	8	0	0	2
	"	"	Bottom	8	2	2	0
	"	Open	Surface	16	2	0	2
	"	"	Bottom	8	0	0	4
	Corn	Closed	Surface	4	0	0	6
	"	"	Bottom	0	0	2	0
	"	Open	Surface	2	0	0	2
	"	"	Bottom	6	4	0	2
80-20 Mixture	Wheat	Closed	Surface	2	6	0	0
	"	"	Bottom	2	2	0	0
	"	Open	Surface	4	4	2	0
	"	"	Bottom	14	0	0	0
	Corn	Closed	Surface	2	0	2	0
	"	"	Bottom	2	0	0	0
	"	Open	Surface	6	2	2	2
	"	"	Bottom	8	0	0	0
Dowfume-75	Wheat	Closed	Surface	10	0	2	4
	"	"	Bottom	10	2	2	0
	"	Open	Surface	12	6	0	0
	"	"	Bottom	14	6	2	0
	Corn	Closed	Surface	12	2	2	2
	"	"	Bottom	2	2	0	4
	"	Open	Surface	4	4	0	0
	"	"	Bottom	10	0	0	0
Check	Wheat	Closed	Surface	6	0	0	2
	"	"	Bottom	4	4	0	0
	"	Open	Surface	8	0	0	2
	"	"	Bottom	20	2	0	4
	Corn	Closed	Surface	4	6	2	0
	"	"	Bottom	4	0	0	4
	"	Open	Surface	2	0	0	0
	"	"	Bottom	6	0	2	0

TABLE 6

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON FUMIGATED GRAIN
TWO DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Grain	Type of storage	Sample position	Percent of dead insects												Total mortality of insects		
				Days after fumigation														
				9			16			23			30					
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume EB-5	Wheat	Closed	Surface	2	10	10	0	4	6	0	0	2	0	2	2	2	16	20
	"	"	Bottom	0	30	6	0	6	4	0	6	8	0	4	2	0	46	20
	"	Open	Surface	4	0	14	0	0	2	0	0	8	0	0	4	4	0	28
	"	"	Bottom	4	2	10	2	0	6	0	0	2	0	0	2	6	2	20
	Corn	Closed	Surface	0	24	8	4	2	8	2	16	12	2	4	4	8	46	32
	"	"	Bottom	0	20	6	2	4	0	0	8	6	0	4	2	2	36	14
	"	Open	Surface	0	2	0	0	0	4	0	0	0	0	0	2	0	2	6
	"	"	Bottom	0	0	2	2	0	2	0	2	6	0	0	4	2	2	7
Serafume	Wheat	Closed	Surface	0	40	8	0	6	2	0	4	6	2	0	4	2	50	20
	"	"	Bottom	0	26	8	2	4	4	0	14	12	0	4	4	2	48	28
	"	Open	Surface	0	2	16	4	0	2	2	0	6	0	0	4	6	2	28
	"	"	Bottom	0	0	8	0	0	10	0	0	2	0	0	2	0	0	22
	Corn	Closed	Surface	0	14	4	2	4	2	4	10	6	2	4	4	8	32	16
	"	"	Bottom	0	26	0	2	10	14	0	2	4	0	4	2	2	42	20
	"	Open	Surface	0	0	2	0	0	2	4	0	0	2	0	0	6	0	4
	"	"	Bottom	0	0	6	2	0	2	0	0	4	4	0	2	6	0	14

TABLE 6 (continued)

Material	Grain	Type of storage	Sample position	Percent of dead insects: Days after fumigation: 9			16			23			30			Total mortality of insects		
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
80-20 Mixture	Wheat	Closed	Surface	0	0	2	6	2	2	8	0	6	4	2	4	18	4	14
	"	"	Bottom	0	22	2	4	2	2	12	6	6	6	2	2	22	32	12
	"	Open	Surface	2	4	4	0	2	4	4	0	12	2	0	4	8	6	24
	"	"	Bottom	2	0	14	0	0	4	2	0	10	0	0	4	4	0	32
	Corn	Closed	Surface	2	22	2	0	2	12	0	6	4	0	2	2	2	32	20
	"	"	Bottom	0	30	2	4	14	6	0	4	12	0	2	6	4	50	26
	"	Open	Surface	0	0	6	2	2	8	0	0	10	0	0	4	2	2	28
	"	"	Bottom	2	0	8	2	0	4	2	0	2	0	0	2	6	0	16
Dowfume	Wheat	Closed	Surface	0	4	10	4	0	6	2	0	4	2	2	0	8	6	20
	"	"	Bottom	2	36	10	0	4	4	2	4	6	0	2	4	4	46	24
	"	Open	Surface	4	2	12	2	0	6	2	0	2	2	4	0	10	6	20
	"	"	Bottom	0	0	14	2	0	6	0	0	8	0	2	6	2	2	34
	Corn	Closed	Surface	0	22	12	0	2	2	0	6	6	0	4	2	0	34	22
	"	"	Bottom	0	18	2	2	2	2	0	8	6	2	6	6	4	34	16
	"	Open	Surface	0	0	4	4	2	4	2	0	6	0	0	4	6	2	18
	"	"	Bottom	0	10	10	4	40	6	0	32	8	0	6	4	4	88	28
Check	Wheat	Closed	Surface	2	40	6	0	4	2	0	2	8	0	0	4	2	46	20
	"	"	Bottom	0	34	4	2	6	10	0	8	6	0	4	4	2	52	24
	"	Open	Surface	2	0	8	2	0	4	0	0	0	0	2	0	4	2	12
	"	"	Bottom	0	0	20	0	0	2	0	2	8	0	2	4	0	4	34
	Corn	Closed	Surface	2	26	4	12	4	2	6	2	8	4	0	6	24	32	20
	"	"	Bottom	2	38	4	4	4	2	0	14	0	0	6	0	6	62	6
	"	Open	Surface	2	0	2	0	0	4	0	0	2	2	0	2	4	0	10
	"	"	Bottom	0	0	6	0	0	6	0	0	4	0	0	2	0	0	18

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

TABLE 7

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON FUMIGATED GRAIN NINE DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Grain	Type of storage	Sample position	Percent of dead insects												Total mortality of insects		
				Days after fumigation														
				16			23			30			37					
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume EB-5	Wheat	Closed	Surface	10	30	0	8	4	6	10	6	4	6	4	2	34	44	12
	"	"	Bottom	4	6	2	4	6	4	6	10	6	4	4	4	18	26	16
	"	Open	Surface	2	2	2	4	2	6	8	0	4	4	0	2	18	4	14
	"	"	Bottom	40	4	12	2	4	2	8	10	4	6	4	4	56	22	22
	Corn	Closed	Surface	0	2	2	6	4	0	2	4	2	2	0	2	10	10	6
	"	"	Bottom	2	0	0	6	6	4	10	12	2	6	4	2	24	22	8
	"	Open	Surface	2	8	0	2	4	4	4	4	0	4	0	0	12	16	4
	"	"	Bottom	8	4	2	6	2	0	2	10	6	0	4	2	16	20	10
Serafume	Wheat	Closed	Surface	2	18	0	4	4	0	4	12	0	2	6	0	12	40	0
	"	"	Bottom	2	12	2	8	14	2	2	4	2	0	0	2	12	30	8
	"	Open	Surface	6	4	2	10	2	0	2	0	6	0	2	4	18	8	12
	"	"	Bottom	76	18	0	2	28	8	10	16	4	6	4	0	94	66	12
	Corn	Closed	Surface	6	2	0	2	8	0	2	4	0	4	2	2	14	16	2
	"	"	Bottom	16	18	0	6	14	6	12	14	6	6	16	4	40	62	16
	"	Open	Surface	8	2	0	0	8	4	6	10	6	6	8	4	20	28	14
	"	"	Bottom	4	2	4	12	6	10	2	2	2	2	4	2	20	14	18

TABLE 7 (continued)

Material	Grain	Type of storage	Sample position	Percent of dead insects: Days after fumigation: 16			23			30			37			Total mortality of insects		
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
80-20 Mixture	Wheat	Closed	Surface	2	16	6	6	8	4	2	4	4	0	4	2	10	32	16
	"	"	Bottom	0	16	2	2	4	6	2	12	0	0	8	0	4	40	8
	"	Open	Surface	12	8	4	6	2	2	4	0	2	4	2	0	26	12	8
	"	"	Bottom	12	24	0	8	12	6	2	8	2	2	6	0	24	50	8
	Corn	Closed	Surface	2	14	0	0	10	2	4	12	6	4	14	4	10	50	12
	"	"	Bottom	8	12	0	0	0	4	4	0	2	4	0	0	16	12	6
	"	Open	Surface	2	2	2	4	14	0	10	0	6	6	0	4	22	16	12
	"	"	Bottom	4	8	0	2	6	2	0	6	0	0	4	2	6	24	4
Dowfume-75	Wheat	Closed	Surface	10	34	0	2	4	0	4	6	2	2	4	0	18	48	2
	"	"	Bottom	0	28	2	4	8	4	10	8	2	6	4	0	20	48	8
	"	Open	Surface	2	6	6	4	0	4	0	0	8	0	0	4	6	6	22
	"	"	Bottom	8	6	6	0	14	2	0	8	4	0	4	2	8	32	14
	Corn	Closed	Surface	2	18	2	0	6	4	4	12	0	4	6	2	10	42	8
	"	"	Bottom	0	6	2	2	6	2	2	2	0	0	2	0	4	16	4
	"	Open	Surface	0	2	4	4	0	4	8	0	4	4	0	2	16	2	14
	"	"	Bottom	10	8	0	0	6	2	4	8	2	6	4	0	20	26	4
Check	Wheat	Closed	Surface	2	14	0	0	6	4	2	4	0	4	0	2	8	24	6
	"	"	Bottom	0	8	4	14	14	4	8	8	10	6	6	4	28	36	22
	"	Open	Surface	6	4	0	4	2	4	8	8	2	6	4	2	24	18	8
	"	"	Bottom	2	12	2	0	6	6	4	22	0	4	14	8	10	54	16
	Corn	Closed	Surface	4	0	6	2	2	4	6	6	2	8	6	0	20	14	12
	"	"	Bottom	4	8	0	0	12	2	2	4	2	2	0	2	8	24	6
	"	Open	Surface	4	10	0	4	6	2	2	4	8	4	2	6	14	22	16
	"	"	Bottom	4	12	0	18	24	4	12	10	6	8	6	6	42	52	16

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

TABLE 8

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON FUMIGATED GRAIN
16 DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Grain	Type of storage	Sample position	Percent of dead insects												Total mortality of insects		
				Days after fumigation														
				23			30			37			44					
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume EB-5	Wheat	Closed	Surface	0	4	0	2	0	2	0	0	2	4	0	0	6	4	4
	"	"	Bottom	2	0	0	8	0	0	4	0	0	2	0	0	16	0	0
	"	Open	Surface	0	0	0	2	0	0	2	0	2	2	2	4	6	2	6
	"	"	Bottom	0	6	0	2	2	0	2	2	2	4	2	6	8	12	8
	Corn	Closed	Surface	4	4	0	2	4	2	4	2	0	6	0	0	16	10	2
	"	"	Bottom	0	0	4	2	0	0	0	2	2	0	0	0	2	2	6
	"	Open	Surface	4	0	0	12	0	0	6	0	0	2	0	0	24	0	0
	"	"	Bottom	6	0	0	8	0	0	4	0	0	0	2	0	18	2	0
Serafume	Wheat	Closed	Surface	2	0	0	2	0	0	0	2	0	2	0	2	6	2	2
	"	"	Bottom	0	4	2	2	0	2	2	2	2	2	4	2	6	10	8
	"	Open	Surface	0	0	0	0	0	0	0	0	2	0	2	0	0	2	2
	"	"	Bottom	2	0	0	0	0	0	0	0	2	2	0	2	4	0	4
	Corn	Closed	Surface	0	0	0	4	0	0	2	0	0	2	0	2	8	0	2
	"	"	Bottom	12	0	2	4	0	0	4	0	2	2	4	0	22	4	4
	"	Open	Surface	4	0	0	2	0	2	2	0	0	6	6	2	14	6	4
	"	"	Bottom	6	0	0	4	0	0	2	0	0	4	0	4	16	0	4

TABLE 8 (continued)

Material	Grain	Type of storage	Sample position	Percent of dead insects												Total mortality of insects		
				Days after fumigation														
				23			30			37			44					
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
80-20 Mixture	Wheat	Closed	Surface	4	2	0	4	2	0	2	2	2	2	4	4	12	10	6
	"	"	Bottom	2	4	0	4	0	0	4	0	2	4	0	2	14	4	4
	"	Open	Surface	4	0	2	0	0	2	0	2	0	2	0	0	6	2	4
	"	"	Bottom	4	4	0	0	0	2	0	0	0	0	0	4	4	4	6
	Corn	Closed	Surface	4	0	2	2	0	0	4	0	2	6	4	0	16	4	4
	"	"	Bottom	0	2	0	0	6	2	0	4	2	2	2	0	2	14	4
	"	Open	Surface	6	0	2	2	0	0	2	2	0	2	0	2	12	2	4
	"	"	Bottom	2	0	0	0	0	0	0	2	0	0	0	2	2	2	2
Dowfume-75	Wheat	Closed	Surface	12	0	2	8	0	0	8	2	0	6	2	0	34	4	2
	"	"	Bottom	0	2	2	2	2	0	2	4	0	2	2	0	6	10	2
	"	Open	Surface	2	2	0	0	2	0	0	0	2	2	0	0	4	4	2
	"	"	Bottom	4	0	2	2	8	2	4	2	2	2	4	2	12	14	8
	Corn	Closed	Surface	6	2	2	2	2	0	0	2	0	0	0	0	8	6	2
	"	"	Bottom	0	0	0	4	0	0	0	4	0	2	0	2	6	4	2
	"	Open	Surface	0	0	0	0	0	0	0	2	2	2	2	2	2	4	4
	"	"	Bottom	2	0	0	2	0	0	2	0	2	4	2	0	10	2	2
Check	Wheat	Closed	Surface	0	2	0	4	2	0	4	0	2	2	2	2	10	6	4
	"	"	Bottom	4	0	0	8	0	2	6	2	4	6	4	4	24	6	10
	"	Open	Surface	0	0	0	2	0	0	2	0	2	8	4	10	12	4	12
	"	"	Bottom	0	2	0	2	2	0	2	4	0	4	0	0	8	8	0
	Corn	Closed	Surface	0	0	2	2	0	0	2	0	2	6	2	2	10	2	6
	"	"	Bottom	4	6	0	8	8	0	6	14	4	6	4	0	24	32	4
	"	Open	Surface	0	0	0	2	0	0	4	2	4	4	4	4	10	6	8
	"	"	Bottom	6	0	2	2	0	2	4	2	2	2	0	4	14	2	10

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

TABLE 9

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON FUMIGATED GRAIN
23 DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Grain	Type of storage	Sample position	Percent of dead insects												Total mortality of insects		
				Days after fumigation														
				30			37			44			51					
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume EB-5	Wheat	Closed	Surface	2	0	4	4	0	2	0	0	4	2	2	4	8	2	14
	"	"	Bottom	2	0	8	0	0	4	2	2	2	0	0	2	4	2	16
	"	Open	Surface	2	0	4	0	0	2	0	0	0	0	0	0	2	0	6
	"	"	Bottom	4	0	2	2	2	2	0	0	2	2	0	0	8	2	6
	Corn	Closed	Surface	4	0	0	2	0	2	6	0	4	0	0	0	12	0	6
	"	"	Bottom	2	0	0	8	0	0	4	0	4	2	2	6	16	2	10
	"	Open	Surface	4	0	8	4	0	2	2	4	6	0	0	0	10	4	16
	"	"	Bottom	2	0	2	2	4	2	0	0	0	0	0	0	4	4	4
Serafume	Wheat	Closed	Surface	8	0	2	0	2	4	6	4	4	2	0	6	16	6	16
	"	"	Bottom	4	2	0	2	0	0	2	2	0	0	2	4	8	6	4
	"	Open	Surface	2	0	2	0	0	0	0	0	0	4	2	4	6	2	6
	"	"	Bottom	8	2	4	0	0	2	2	4	0	4	4	6	14	10	12
	Corn	Closed	Surface	4	0	6	2	2	0	4	0	6	0	2	2	10	4	14
	"	"	Bottom	2	0	0	0	0	0	6	2	2	0	0	0	8	2	2
	"	Open	Surface	4	0	2	2	4	4	0	0	0	6	2	4	12	6	10
	"	"	Bottom	6	2	2	6	4	4	2	0	0	2	2	2	16	8	8

TABLE 9 (continued)

Material	Grain	Type of storage	Sample Position	Percent of dead insects												Total mortality of insects		
				Days after fumigation														
				30			37			44			51					
				S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
80-20 Mixture	Wheat	Closed	Surface	1	0	0	0	0	2	0	0	0	0	2	2	2	2	4
	"	"	Bottom	2	0	0	4	2	0	4	4	4	2	0	0	12	6	4
	"	Open	Surface	0	0	0	0	0	2	2	0	0	0	0	0	2	0	2
	"	"	Bottom	0	0	0	0	0	0	0	0	6	2	4	2	2	4	8
	Corn	Closed	Surface	2	0	0	0	0	0	0	0	0	2	0	2	4	0	2
	"	"	Bottom	0	0	0	2	0	0	0	2	2	4	2	6	6	4	8
	"	Open	Surface	2	0	2	0	2	2	4	2	6	0	0	0	6	4	10
	"	"	Bottom	0	0	0	0	0	2	0	4	0	10	2	8	10	6	10
Dowfume	Wheat	Closed	Surface	2	2	4	2	0	2	0	0	0	2	4	4	6	6	10
	"	"	Bottom	6	0	0	0	4	2	0	0	2	4	0	0	10	4	4
	"	Open	Surface	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0
	"	"	Bottom	2	2	0	0	0	0	0	0	0	2	0	0	4	2	0
	Corn	Closed	Surface	0	0	2	4	0	0	0	2	2	4	2	4	8	4	8
	"	"	Bottom	0	0	4	0	0	2	4	0	0	0	0	2	4	0	8
	"	Open	Surface	2	0	0	0	0	4	2	2	0	0	0	0	4	2	4
	"	"	Bottom	0	0	0	0	0	2	6	0	0	2	4	6	8	4	8
Check	Wheat	Closed	Surface	2	0	2	0	2	4	4	2	4	4	4	8	10	8	18
	"	"	Bottom	2	0	0	4	0	4	0	2	0	4	2	6	10	4	10
	"	Open	Surface	0	0	2	0	0	0	0	0	0	6	2	4	6	2	6
	"	"	Bottom	0	0	4	4	0	6	2	2	2	0	0	0	6	2	12
	Corn	Closed	Surface	0	0	0	0	0	2	4	0	2	2	2	4	6	2	8
	"	"	Bottom	2	0	4	4	0	0	0	0	4	4	2	4	10	2	12
	"	Open	Surface	0	0	0	0	0	0	0	0	6	6	2	2	6	2	8
	"	"	Bottom	0	0	0	0	0	6	0	0	0	4	0	0	4	0	6

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

after fumigation the total mortality ranged from 80 to 100 percent and 70 percent in the checks (Table 10). In samples after 9 days (Table 11) it was from 90 to 100 percent with the checks remaining constant. In the samples 16 days after fumigation a mortality of 80 to 90 percent was recorded in the treatments and 60 percent in the checks (Table 12). Table 13 shows that there were no noticeable residual effects on Indian meal moth larvae reared on samples of fumigated wheat and corn.

In the second experiment, when wheat was dipped in emulsions of malathion and DOW-ET-14 at the concentrations of ten and 200 ppm, approximately 256 cubic centimeters of the emulsion was retained by the wheat. The actual amount of malathion and DOW-ET-14 deposited on the grain was 1.5 ppm (emulsion 10 ppm) and 30 ppm (emulsion 200 ppm). The average amount of fumigants retained by the wheat, from the dipping treatments, was 250 cubic centimeters.

The residual effects of various materials on adult saw-toothed grain beetles, confused flour beetles, and granary weevils reared on wheat dipped in the insecticides are shown in Tables 14 to 25. The exposure of saw-toothed grain beetles for one week to samples of wheat dipped in DOW-ET-14 (200 ppm) gave a 100 percent mortality through nine weeks after treatment (Table 14). In the tenth week the kill dropped to 98 percent. No difference was observed between the effects of samples drawn from the closed

TABLE 10

WEEKLY PERCENT MORTALITY OF CADELLES PLACED ON FUMIGATED WHEAT TWO DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Percent of dead cadelles						Total mortality of cadelles
	Days after fumigation						
	9	16	23	30	37	44	
Dowfume-75	10	20	40	10	20	0	100
80-20 Mixture	10	10	10	30	20	10	90
Dowfume EB-5	0	10	20	20	20	10	80
Serafume	10	10	50	10	0	0	80
Check	0	10	30	30	0	0	70

TABLE 11

WEEKLY PERCENT MORTALITY OF CADELLES PLACED ON FUMIGATED WHEAT NINE DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Percent of dead cadelles						Total mortality of cadelles
	Days after fumigation						
	16	23	30	37	44	51	
Dowfume-75	40	10	30	10	10	0	100
80-20 Mixture	10	30	10	20	30	0	100
Dowfume EB-5	10	20	20	30	10	0	90
Serafume	0	30	10	20	20	10	90
Check	0	0	0	30	20	20	70

TABLE 12

WEEKLY PERCENT MORTALITY OF CADELLES PLACED ON FUMIGATED WHEAT 16 DAYS AFTER FUMIGATION AND CONTINUOUSLY REARED

Material	Percent of dead cadelles						Total mortality of cadelles
	Days after fumigation						
	23	30	37	44	51	58	
Dowfume-75	30	20	10	20	10	0	90
80-20 Mixture	10	30	20	20	0	10	90
Dowfume EB-5	20	40	0	10	0	10	80
Serafume	0	20	30	20	10	0	80
Check	0	10	0	20	20	10	60

TABLE 13

PERCENT EMERGENCE OF INDIAN MEAL MOTH ADULTS FROM CULTURES OF LARVAE EXPOSED TO FUMIGATED WHEAT FOR FIVE WEEKS

Material	Grain	Type of storage	Total percentage of adults emerged			
			Days after fumigation			
			37	44	51	58
Dowfume-75	Wheat	Closed	40	30	80	80
	"	Open	40	90	30	80
	Corn	Closed	30	30	60	70
	"	Open	10	90	40	20
80-20 Mixture	Wheat	Closed	30	90	30	40
	"	Open	20	90	50	40
	Corn	Closed	0	60	30	30
	"	Open	20	50	80	60
Dowfume EB-5	Wheat	Closed	40	70	90	70
	"	Open	30	90	60	30
	Corn	Closed	50	60	20	40
	"	Open	10	80	30	60
Serafume	Wheat	Closed	20	40	60	50
	"	Open	30	90	40	50
	Corn	Closed	20	50	50	40
	"	Open	20	40	60	40
Check	Wheat	Closed	40	30	80	20
	"	Open	50	20	40	0
	Corn	Closed	20	40	40	60
	"	Open	30	50	60	40

TABLE 14

PERCENT MORTALITY OF SAW-TOOTHED GRAIN BEETLES EXPOSED FOR SEVEN DAYS TO WHEAT DIPPED IN INSECTICIDES AT VARIOUS INTERVALS AFTER TREATMENT OF THE GRAIN

Material	Type of storage	Percent of dead insects								
		Days after treatment								
		14	21	28	35	42	49	56	63	70
Dowfume-75	Closed	64	94	76	18	8	10	10	4	2
"	Open	56	38	20	14	6	0	2	2	0
80-20 Mixture	Closed	42	48	6	2	8	12	4	2	0
"	Open	60	30	4	4	4	0	2	2	0
Dowfume EB-5	Closed	78	80	58	16	12	12	8	2	2
"	Open	16	54	18	0	16	0	10	2	0
Serafume	Closed	82	100	94	94	80	70	88	48	10
"	Open	84	100	100	94	98	68	72	46	6
DOW-ET-14 (200 ppm)	Closed	100	100	100	100	100	100	100	100	98
"	Open	100	100	100	100	100	100	100	100	98
Malathion (200 ppm)	Closed	100	100	100	100	100	100	-	-	-
"	Open	100	100	100	100	100	100	-	-	-
DOW-ET-14 (10 ppm)	Closed	18	2	14	6	2	-	-	-	-
"	Open	90	12	16	14	0	-	-	-	-
Malathion (10 ppm)	Closed	96	74	90	34	8	-	-	-	-
"	Open	100	90	100	52	12	-	-	-	-
Check	Closed	8	4	6	2	2	0	0	2	2
"	Open	10	10	2	0	2	0	2	4	2

TABLE 14

PERCENT MORTALITY OF SAW-TOOTHED GRAIN BEETLES EXPOSED FOR SEVEN DAYS TO WHEAT DIPPED IN INSECTICIDES AT VARIOUS INTERVALS AFTER TREATMENT OF THE GRAIN

Material	Type of storage	Percent of dead insects								
		Days after treatment								
		14	21	28	35	42	49	56	63	70
Dowfume-75	Closed	64	94	76	18	8	10	10	4	2
"	Open	56	38	20	14	6	0	2	2	0
80-20 Mixture	Closed	42	48	6	2	8	12	4	2	0
"	Open	60	30	4	4	4	0	2	2	0
Dowfume EB-5	Closed	78	80	58	16	12	12	8	2	2
"	Open	16	54	18	0	16	0	10	2	0
Serafume	Closed	82	100	94	94	80	70	88	48	10
"	Open	84	100	100	94	98	68	72	46	6
DOW-ET-14 (200 ppm)	Closed	100	100	100	100	100	100	100	100	98
"	Open	100	100	100	100	100	100	100	100	98
Malathion (200 ppm)	Closed	100	100	100	100	100	100	-	-	-
"	Open	100	100	100	100	100	100	-	-	-
DOW-ET-14 (10 ppm)	Closed	18	2	14	6	2	-	-	-	-
"	Open	90	12	16	14	0	-	-	-	-
Malathion (10 ppm)	Closed	96	74	90	34	8	-	-	-	-
"	Open	100	90	100	52	12	-	-	-	-
Check	Closed	8	4	6	2	2	0	0	2	2
"	Open	10	10	2	0	2	0	2	4	2

TABLE 15

PERCENT MORTALITY OF GRANARY WEEVILS EXPOSED FOR SEVEN DAYS TO WHEAT DIPPED IN INSECTICIDES AT VARIOUS INTERVALS AFTER TREATMENT OF THE GRAIN

Material	Type of storage	Percent of dead insects								
		Days after treatment								
		14	21	28	35	42	49	56	63	70
Dowfume-75	Closed	12	34	88	6	32	6	44	18	0
"	Open	22	32	60	8	32	20	38	20	10
80-20 Mixture	Closed	42	32	72	20	50	16	14	28	0
"	Open	34	32	76	16	48	16	34	22	2
Dowfume EB-5	Closed	68	62	80	24	76	28	32	28	2
"	Open	44	52	72	10	70	6	72	28	4
Serafume	Closed	98	100	100	60	98	60	90	56	6
"	Open	100	100	100	44	98	52	86	54	4
DOW-ET-14 (200 ppm)	Closed	100	100	100	100	100	100	100	100	100
"	Open	100	100	100	100	100	100	100	100	100
Malathion (200 ppm)	Closed	100	100	100	100	100	98	-	-	-
"	Open	100	100	100	100	100	92	-	-	-
DOW-ET-14 (10 ppm)	Closed	12	12	10	10	2	-	-	-	-
"	Open	2	16	4	12	20	-	-	-	-
Malathion (10 ppm)	Closed	70	60	58	40	0	-	-	-	-
"	Open	98	80	52	42	6	-	-	-	-
Check	Closed	0	2	16	22	0	8	2	2	2
"	Open	2	32	4	10	10	4	0	10	2

TABLE 16

PERCENT MORTALITY OF CONFUSED FLOUR BEETLES EXPOSED FOR SEVEN DAYS TO WHEAT DIPPED IN INSECTICIDES AT VARIOUS INTERVALS AFTER TREATMENT OF THE GRAIN

Material	Type of storage	Percent of dead insects								
		Days after treatment								
		14	21	28	35	42	49	56	63	70
Dowfume-75	Closed	4	4	10	2	20	14	8	2	0
"	Open	4	22	6	6	22	14	8	6	0
80-20 Mixture	Closed	8	2	16	2	28	14	6	8	2
"	Open	8	4	22	2	28	4	4	4	0
Dowfume EB-5	Closed	34	4	14	0	38	20	10	10	0
"	Open	18	4	6	0	22	6	8	10	4
Serafume	Closed	28	4	22	6	46	16	12	6	2
"	Open	44	2	6	2	22	4	16	6	0
DOW-ET-14 (200 ppm)	Closed	86	100	100	76	100	100	98	96	84
"	Open	96	100	100	92	100	100	100	94	94
Malathion (200 ppm)	Closed	100	100	100	100	100	30	-	-	-
"	Open	100	100	100	100	100	20	-	-	-
DOW-ET-14 (10 ppm)	Closed	14	16	14	2	0	-	-	-	-
"	Open	8	20	14	6	0	-	-	-	-
Malathion (10 ppm)	Closed	26	20	16	8	0	-	-	-	-
"	Open	44	24	10	6	0	-	-	-	-
Check	Closed	0	0	4	0	6	8	8	6	0
"	Open	0	0	6	0	14	8	2	4	2

TABLE 17

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES SEVEN DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects															Total mortality of insects after five weeks		
		Days after treatment																	
		14			21			28			35			42					
		S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	64	4	12	26	8	78	0	38	6	0	4	0	0	2	0	90	56	96
"	Open	56	4	22	24	4	74	2	18	2	2	8	0	0	6	0	84	40	98
80-20 Mix-	Closed	42	8	42	12	22	58	2	52	0	2	6	0	6	6	0	64	94	100
ture	Open	60	8	34	16	26	64	0	54	2	0	4	0	0	4	0	76	96	100
Dowfume	Closed	78	34	68	18	26	32	4	32	0	0	6	0	0	2	0	100	100	100
EB-5	Open	16	18	44	10	26	54	60	52	2	8	4	0	6	0	0	100	100	100
Serafume	Closed	82	28	98	16	22	2	2	20	0	0	6	0	0	8	0	100	84	100
"	Open	84	44	100	14	24	0	0	14	0	0	6	0	2	6	0	100	94	100
DOW-ET-14	Closed	100	86	100	0	14	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	96	100	0	4	0	0	0	0	0	0	0	0	0	0	100	100	100
Malathion	Closed	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
DOW-ET-14	Closed	18	14	12	8	16	14	4	14	8	10	6	12	6	4	10	46	54	56
(10 ppm)	Open	90	8	2	2	18	8	6	8	6	2	4	20	0	2	16	100	40	52
Malathion	Closed	96	26	70	2	10	14	2	8	10	0	6	4	0	4	0	100	54	98
(10 ppm)	Open	100	44	98	0	4	2	0	0	0	0	6	0	0	4	0	100	58	100
Check	Closed	8	0	0	0	0	6	2	10	4	4	2	4	12	16	10	26	28	24
"	Open	10	0	2	0	2	6	4	2	4	2	2	8	6	4	4	22	10	24

*S = Saw-toothed grain beetle; C = Confused flour beetle; G = Granary weevil.

TABLE 18

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 14 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects															Total mortality of insects after five weeks		
		Days after treatment																	
		21			28			35			42			49					
		S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	94	4	34	4	38	62	2	14	2	0	10	0	0	4	0	100	70	98
"	Open	38	22	32	8	8	30	2	22	2	6	2	4	4	2	4	58	56	72
80-20 Mix-	Closed	48	2	32	4	60	62	2	26	2	2	8	0	2	0	0	58	96	96
ture	Open	30	4	32	4	64	66	6	20	2	6	8	0	4	4	0	50	100	100
Dowfume	Closed	80	4	62	14	88	34	4	8	0	0	0	0	0	0	0	98	100	100
EB-5	Open	54	4	52	12	52	48	4	32	0	0	4	0	2	4	0	72	96	100
Serafume	Closed	100	42	100	0	52	0	0	4	0	0	2	0	0	0	0	100	100	100
"	Open	100	2	100	0	18	0	0	8	0	0	4	0	0	2	0	100	34	100
DOW-ET-14	Closed	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
Malathion	Closed	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
DOW-ET-14	Closed	2	16	12	0	20	20	18	4	16	14	2	8	-	-	-	34	42	56
(10 ppm)	Open	12	20	16	4	14	14	18	2	6	8	2	2	-	-	-	42	38	38
Malathion	Closed	74	20	60	6	4	16	6	4	6	4	0	2	-	-	-	90	28	84
(10 ppm)	Open	90	24	80	10	6	6	0	2	4	0	0	4	-	-	-	100	32	94
Check	Closed	4	0	2	2	4	2	6	4	0	14	0	4	12	4	4	38	12	12
"	Open	10	0	32	4	8	4	6	4	12	8	2	4	12	6	4	40	20	56

*S = Saw-toothed grain beetle; C = Confused flour beetle; G = Granary weevil.

TABLE 19

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 21 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects															Total mortality of insects after five weeks		
		Days after treatment																	
		28			35			42			49			56					
		S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	76	10	88	2	2	2	10	32	8	0	0	0	0	0	0	88	44	98
"	Open	20	6	60	2	16	14	2	16	14	4	4	2	0	8	0	28	50	90
80-20 Mix-	Closed	6	16	72	0	28	26	0	36	2	8	6	0	12	4	0	26	90	100
ture	Open	4	22	76	2	34	18	6	12	6	4	14	0	2	8	0	18	90	100
Dowfume	Closed	58	14	80	8	42	12	4	34	8	2	2	0	0	0	0	72	92	100
EB-5	Open	18	6	72	2	30	22	2	30	2	4	14	0	0	6	0	26	86	96
Serafume	Closed	94	22	100	6	16	0	0	24	0	0	8	0	0	2	0	100	72	100
"	Open	100	6	100	0	4	0	0	10	0	0	0	0	0	0	0	100	20	100
DOW-ET-14	Closed	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
Malathion	Closed	100	100	100	0	0	0	0	0	0	0	0	0	-	-	-	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	0	0	0	-	-	-	100	100	100
DOW-ET-14	Closed	14	14	10	10	4	12	6	2	8	-	-	-	-	-	-	30	20	30
(10 ppm)	Open	16	14	4	8	2	12	4	0	8	-	-	-	-	-	-	28	16	24
Malathion	Closed	90	16	58	4	4	8	2	2	6	-	-	-	-	-	-	96	22	72
(10 ppm)	Open	100	10	52	0	2	6	0	0	4	-	-	-	-	-	-	100	12	62
Check	Closed	6	4	16	4	6	4	2	0	2	12	2	4	4	0	0	28	12	26
"	Open	2	6	4	4	6	4	6	2	0	10	6	0	6	2	0	28	22	8

*S = Saw-toothed grain beetle; C = Confused flour beetle; G = Granary weevil.

TABLE 20

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 28 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects															Total mortality of insects after five weeks		
		Days after treatment																	
		35			42			49			56			63					
		S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	18	2	6	28	18	86	4	20	2	6	12	2	6	8	0	62	60	96
"	Open	14	6	8	4	26	72	4	12	6	2	6	10	8	4	4	32	54	100
80-20 Mix-	Closed	2	2	20	0	52	78	20	12	2	16	10	0	12	6	0	50	82	100
ture	Open	4	2	16	0	42	80	8	24	4	6	14	0	16	4	0	34	86	100
Dowfume	Closed	16	0	24	14	28	72	4	34	4	2	18	0	16	10	0	52	90	100
EB-5	Open	0	0	10	10	44	84	2	22	4	0	18	2	2	8	0	14	92	100
Serafume	Closed	94	6	60	0	30	32	4	2	4	2	4	4	0	4	0	100	46	100
"	Open	94	2	44	6	30	38	0	18	10	0	14	8	0	2	0	100	66	100
DOW-ET-14	Closed	100	76	100	0	24	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	92	100	0	8	0	0	0	0	0	0	0	0	0	0	100	100	100
Malathion	Closed	100	100	100	0	0	0	0	0	0	-	-	-	-	-	-	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	-	-	-	-	-	-	100	100	100
DOW-ET-14	Closed	6	2	10	2	2	8	-	-	-	-	-	-	-	-	-	8	4	18
(10 ppm)	Open	14	6	12	10	6	8	-	-	-	-	-	-	-	-	-	24	12	20
Malathion	Closed	34	8	40	6	4	12	-	-	-	-	-	-	-	-	-	40	12	52
(10 ppm)	Open	52	6	42	12	4	10	-	-	-	-	-	-	-	-	-	64	10	52
Check	Closed	2	0	22	4	6	8	8	12	14	10	10	4	8	0	12	32	28	60
"	Open	0	0	10	4	4	8	18	22	4	8	24	4	8	2	10	38	52	36

*S = Saw-toothed grain beetle; C = Confused flour beetle; G = Granary weevil.

TABLE 21

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 35 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects															Total mortality of insects after five weeks		
		Days after treatment																	
		42			49			56			63			70					
		S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	8	20	32	12	18	20	6	20	42	12	8	2	8	4	0	46	70	96
"	Open	6	22	32	4	18	26	8	22	16	12	2	6	4	0	2	34	64	82
80-20 Mix-	Closed	8	28	50	6	24	24	8	18	16	4	12	2	2	6	0	28	88	92
ture	Open	4	28	48	4	22	20	2	20	20	6	4	4	2	2	2	18	76	94
Dowfume	Closed	12	38	76	18	30	4	10	12	16	12	6	2	8	2	2	60	88	100
EB-5	Open	16	22	70	0	16	16	0	18	10	14	12	2	6	8	0	36	76	98
Serafume	Closed	80	46	98	12	4	2	8	4	0	0	4	0	0	2	0	100	60	100
"	Open	98	22	98	2	16	0	0	8	2	0	4	0	0	2	0	100	52	100
DOW-ET-14	Closed	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
Malathion	Closed	100	100	100	0	0	0	-	-	-	-	-	-	-	-	-	100	100	100
(200 ppm)	Open	100	100	100	0	0	0	-	-	-	-	-	-	-	-	-	100	100	100
DOW-ET-14	Closed	2	0	2	-	-	-	-	-	-	-	-	-	-	-	-	2	0	2
(10 ppm)	Open	0	0	20	-	-	-	-	-	-	-	-	-	-	-	-	0	0	20
Malathion	Closed	8	0	0	-	-	-	-	-	-	-	-	-	-	-	-	8	0	0
(10 ppm)	Open	12	0	6	-	-	-	-	-	-	-	-	-	-	-	-	12	0	6
Check	Closed	2	6	0	6	20	6	2	14	6	4	6	12	2	4	8	16	50	32
"	Open	2	14	10	0	18	2	0	10	0	6	2	12	6	4	6	14	48	30

*S = Saw-toothed grain beetle; C = Confused flour beetle; G = Granary weevil.

TABLE 22

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 42 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects												Total mortality of insects after four weeks		
		Days after treatment														
		49			56			63			70					
		S*	C*	G*	S	C	G	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	10	14	6	10	34	86	6	4	4	4	4	2	30	56	98
"	Open	0	14	20	2	24	32	2	6	18	2	4	8	6	48	78
80-20 Mixture	Closed	12	14	16	4	20	72	8	18	4	4	14	2	28	66	94
"	Open	0	4	16	0	42	60	6	16	6	2	10	4	8	72	86
Dowfume EB-5	Closed	12	20	28	10	28	72	4	16	0	2	8	0	28	72	100
"	Open	0	6	6	0	26	60	2	14	16	0	10	6	2	56	88
Serafume	Closed	70	16	60	12	32	38	6	4	2	4	2	0	92	54	100
"	Open	68	4	52	16	30	48	6	0	0	4	0	0	94	34	100
DOW-ET-14 (200 ppm)	Closed	100	100	100	0	0	0	0	0	0	0	0	0	100	100	100
"	Open	100	100	100	0	0	0	0	0	0	0	0	0	100	100	100
Malathion (200 ppm)	Closed	100	30	98	-	-	-	-	-	-	-	-	-	100	30	98
"	Open	100	20	92	-	-	-	-	-	-	-	-	-	100	20	92
Check	Closed	0	8	8	0	4	10	10	4	6	6	2	4	16	18	28
"	Open	0	8	4	2	12	6	0	6	6	0	4	6	2	30	22

*S = Saw-toothed grain beetle; C = Confused flour beetle; G = Granary weevil.

TABLE 23

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 49 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects									Total mortality of insects after three weeks		
		Days after treatment											
		56			63			70					
		S*	C*	G*	S	C	G	S	C	G	S	C	G
Dowfume-75	Closed	10	8	44	2	8	20	2	6	12	14	22	76
"	Open	2	8	38	2	8	22	2	6	16	6	22	76
80-20 Mixture	Closed	4	6	14	2	8	28	2	6	24	8	20	66
"	Open	2	4	34	4	12	28	2	8	14	8	24	76
Dowfume EB-5	Closed	8	10	72	4	18	8	4	12	6	16	40	86
"	Open	10	8	72	2	36	12	0	14	8	12	58	92
Serafume	Closed	88	12	90	6	2	4	2	2	2	96	16	96
"	Open	72	16	86	12	8	8	6	6	2	90	30	96
DCW-ET-14 (200 ppm)	Closed	100	98	100	0	2	0	0	0	0	100	100	100
"	Open	100	100	100	0	0	0	0	0	0	100	100	100
Check	Closed	0	8	2	2	4	2	2	2	0	4	14	4
"	Open	2	2	0	2	4	6	2	2	4	6	8	10

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

TABLE 24

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 56 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects						Total mortality of insects after two weeks		
		Days after treatment								
		63			70					
		S*	C*	G*	S	C	G	S	C	G
Dowfume-75	Closed	4	2	18	2	0	18	6	2	36
"	Open	2	6	20	0	4	16	2	10	36
80-20 Mixture	Closed	2	8	28	0	8	16	2	16	44
"	Open	2	4	22	2	2	18	4	6	40
Dowfume EB-5	Closed	2	10	28	2	8	24	4	18	52
"	Open	2	10	28	0	6	20	2	16	48
Serafume	Closed	48	6	56	12	4	16	60	10	72
"	Open	46	6	54	10	2	14	56	8	68
DOW-ET-14 (200 ppm)	Closed	100	96	100	0	4	0	100	100	100
"	Open	100	94	100	0	6	0	100	100	100
Check	Closed	2	6	2	0	4	2	2	10	4
"	Open	4	4	10	2	4	6	6	8	16

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

TABLE 25

WEEKLY PERCENT MORTALITY OF INSECTS PLACED ON WHEAT DIPPED IN INSECTICIDES 63 DAYS AFTER TREATMENT AND CONTINUOUSLY REARED

Material	Type of storage	Percent of dead insects		
		Days after treatment		
		70		
		S*	C*	G
Dowfume-75	Closed	2	0	0
"	Open	0	0	10
80-20 Mixture	Closed	0	2	0
"	Open	0	0	2
Dowfume EB-5	Closed	2	0	2
"	Open	0	4	4
Serafume	Closed	10	2	6
"	Open	6	0	4
DOW-ET-14	Closed	98	84	100
"	Open	98	94	100
Check	Closed	2	0	2
"	Open	2	2	2

*S = Saw-toothed grain beetle; C = Confused flour beetle; and G = Granary weevil.

and open type of storage. DOW-ET-14 at a concentration of ten ppm accounted for 90 percent mortality in the first samples from open storage, after which the mortality dropped rapidly. In the first samples taken from the closed storage the kill of saw-toothed grain beetles was only 18 percent. This dropped gradually as the interval after treatment increased.

There was a 100 percent mortality of all insects exposed to malathion (200 ppm) dipped wheat for seven weeks after treatment. There was no indication of a decline in effectiveness at the end of this period. A ten ppm concentration of malathion was responsible for 100 percent mortality in the first samples from open storage. Consistently high residual activity was maintained for four weeks, after which it declined. In the samples from closed storage the mortality was 96 percent for the first samples, but this also declined after being maintained close to this level for four weeks.

Among the fumigants the highest mortality of saw-toothed grain beetles resulted from the Serafume dippings. The mortality ranged from 70 to 100 percent, gradually declining during the eight weeks. This was followed by a sharp drop after the eighth week. No noticeable difference was observed between the open and closed storage samples. Dowfume-75, Dowfume EB-5 and 80-20 Mixture were slightly less effective than the Serafume treatments. In

all cases the mortality gradually declined as the interval between the treatment and exposure increased. There was no appreciable difference between the samples drawn from open and closed storages. Mortality in the checks varied from zero to ten percent.

In case of granary weevils the DOW-ET-14 (200 ppm) dipping treatment provided 100 percent mortality for ten weeks without any signs of decline at the end of this period (Table 15). The maximum kill with DOW-ET-14 at ten ppm was 20 percent.

Granary weevils exposed to malathion (200 ppm) dipped wheat showed 100 percent mortality for six weeks after treatment. This was followed by a decline. Malathion at ten ppm accounted for 98 percent kill in the first samples from open storage, and 70 percent in samples from closed storage. The effectiveness gradually declined after the second week. Other materials arranged in order of their decreasing effectiveness are: Serafume, Dowfume EB-5, Dowfume-75 and finally 80-20 Mixture. The mortality in the checks varied from zero to 32 percent.

The mortality of confused flour beetles reared on grain dipped in DOW-ET-14 (200 ppm) varied from 76 to 100 percent over a period of ten weeks (Table 16). This was true in samples both from closed and open storage. DOW-ET-14 (ten ppm) killed none to 20 percent of the confused flour beetles with the efficiency decreasing with

the passage of time. Malathion (200 ppm) accounted for 100 percent mortality for six weeks after treatment, followed by a sharp drop in mortality. Malathion at a concentration of ten ppm killed 44 percent of the beetles in the second week in the open storage samples. The mortality gradually diminished during six weeks. Serafume, Dowfume EB-5, 80-20 Mixture and Dowfume-75 also showed a slight residual effect on the confused flour beetles. Serafume accounted for the greatest kill, while Dowfume-75 was the least effective. The mortality in the checks ranged from zero to 14 percent.

When the insects were continuously reared on the wheat dipped in the insecticides, it was observed that the highest mortality occurred in the first week of exposure, and it gradually declined until the study was terminated. When the total kill in the samples of each week is considered (Tables 17 to 25) it was apparent that the mortality was highest in the first samples followed by a gradual decline. In the last samples there was an almost negligible mortality except in cases of DOW-ET-14 and malathion at a concentration of 200 ppm, which still killed as high as 100 percent of the insects.

Tables 26 and 27 present the emergence of Indian meal moth adults from samples in which the larvae were reared on wheat dipped in insecticides. When the total number of moths emerging from each week's samples was con-

TABLE 26

PERCENT EMERGENCE OF INDIAN MEAL MOTH ADULTS FROM CULTURES OF LARVAE EXPOSED FOR FIVE WEEKS TO WHEAT DIPPED IN INSECTICIDES

Material	Type of storage	Total percent of adults emerged							
		Days after treatment							
		42	49	56	63	70	79	86	93
Dowfume-75	Closed	60	90	70	60	60	0	0	0
"	Open	70	80	90	80	60	30	0	0
80-20 Mixture	Closed	70	50	90	100	60	10	0	0
"	Open	70	70	40	100	60	0	0	0
Dowfume EB-5	Closed	40	0	80	90	70	0	0	0
"	Open	70	40	50	70	50	0	0	0
Serafume	Closed	50	80	80	60	50	0	0	0
"	Open	70	70	30	60	40	10	0	0
DOW-ET-14 (200 ppm)	Closed	0	0	20	60	50	10	0	0
"	Open	20	10	30	50	30	0	0	0
Malathion (200 ppm)	Closed	60	50	10	0	0	-	-	-
"	Open	20	10	0	0	0	-	-	-
DOW-ET-14 (10 ppm)	Closed	40	0	0	0	-	-	-	-
"	Open	50	0	0	0	-	-	-	-
Malathion (10 ppm)	Closed	50	0	0	0	-	-	-	-
"	Open	40	0	0	0	-	-	-	-
Check	Closed	40	90	70	100	100	0	0	0
"	Open	50	70	70	80	50	0	0	0

TABLE 27

PERCENT EMERGENCE OF INDIAN MEAL MOTH ADULTS AFTER THREE WEEK EXPOSURE OF LARVAE TO WHEAT DIPPED IN INSECTICIDES

Material	Type of storage	Percent of adults emerged						
		Days after treatment						
		28	35	42	49	56	63	70
Dowfume-75	Closed	40	80	30	0	20	0	0
"	Open	30	40	20	10	20	20	0
80-20 Mixture	Closed	60	10	10	50	20	10	0
"	Open	30	40	20	20	20	0	0
Dowfume EB-5	Closed	30	0	60	10	30	0	0
"	Open	50	10	40	20	10	0	0
Serafume	Closed	30	60	30	30	0	0	0
"	Open	20	50	10	20	10	10	0
DOW-ET-14 (200 ppm)	Closed	0	0	20	40	20	10	0
"	Open	10	10	30	10	0	0	0
Malathion (200 ppm)	Closed	20	0	10	0	-	-	-
"	Open	10	10	0	0	-	-	-
DOW-ET-14 (10 ppm)	Closed	20	0	0	-	-	-	-
"	Open	20	0	0	-	-	-	-
Malathion (10 ppm)	Closed	10	0	0	-	-	-	-
"	Open	10	0	0	-	-	-	-
Check	Closed	20	50	40	40	10	0	0
"	Open	30	40	10	30	20	0	0

sidered, it was observed that the least number emerged from the wheat samples treated with DOW-ET-14 (200 ppm). In the first samples from open storage, only 20 percent of the moths emerged and none emerged from the first two samples from closed storage. The total number of moths that emerged gradually increased, followed by a sudden drop in the samples taken during the seventh week. None of the adults emerged in the later weeks. The data in Table 26 indicate that DOW-ET-14 (200 ppm) was the only material that caused any appreciable reduction in the emergence of the moth adults.

Results of the tests conducted to ascertain the effect of fumigants on the germination of oats, barley, corn, kidney beans, wheat and rye seeds are recorded in Table 28. The fumigation had no deleterious effect on the germination of the above seeds. It required five weeks to complete the germination tests. In the case of rye and kidney beans, the germination of the seeds continuously decreased during the five-week period. Rye germination was reduced more than half during this period. This trend was also evident with the seeds of kidney beans.

TABLE 28

PERCENT GERMINATION OF SEEDS BEFORE AND AFTER GERMINATION

Material	Type of storage		Percent germination					
	Grain	Exposure	Wheat	Corn	Rye	Barley	Oats	Kidney Beans
Before fumigation			83	99	54	99	99	95
After fumigation: Dowfume-75	Wheat	Closed	77	99	46	99	99	94
	"	Open	72	98	41	98	100	93
	Corn	Closed	68	99	40	98	99	85
	"	Open	68	100	37	98	100	87
80-20 Mixture	Wheat	Closed	72	100	33	95	100	91
	"	Open	79	97	31	99	98	85
	Corn	Closed	73	100	32	95	99	87
	"	Open	72	100	33	97	98	90
Dowfume EB-5	Wheat	Closed	73	99	43	99	100	84
	"	Open	68	99	36	99	100	87
	Corn	Closed	65	100	30	97	100	86
	"	Open	70	97	37	97	100	94
Serafume	Wheat	Closed	74	100	35	96	100	90
	"	Open	70	95	28	98	100	91
	Corn	Closed	54	100	17	97	100	76
	"	Open	66	97	20	96	100	79
Check	Wheat	Closed	66	98	15	99	99	77
	"	Open	72	98	23	99	100	78
	Corn	Closed	72	100	23	94	100	83
	"	Open	70	98	20	95	100	76

DISCUSSION OF RESULTS

Results from the fumigation of wheat and corn by Dowfume-75, 80-20 Mixture, Dowfume EB-5 and Serafume indicated that these materials are effective grain fumigants for the control of saw-toothed grain beetles, granary weevils and confused flour beetles. The lack of complete kill of granary weevils and saw-toothed grain beetles in one drum of wheat fumigated with Dowfume-75, as pointed out in the previous section, was probably due to the lack of penetration of the fumigant in sufficient quantities to kill all of the test insects. With the exception of this one replication the mortality was one hundred percent. Other investigators have reported similar results. Cotton and Roark (1927) noted the efficiency of ethylene dichloride and carbon tetrachloride mixture for the fumigation of stored products. Later, similar observations were made by Cotton and Wagner (1941), Farrar and Flint (1942), and Walkden and Schwitzgebel (1951), when they used a 3:1 mixture of ethylene dichloride and carbon tetrachloride. Walkden and Schwitzgebel (1951) also reported that the 4:1 mixture of carbon tetrachloride and carbon disulfide, which is comparable with 80-20 mixture, was a satisfactory fumigant used at the rate of two gallons per 1000 bushels.

The mortality resulting from the exposure of the second set of insects to the fumigated wheat and corn indicated that some of the vapors of the fumigants were retained in the grain, though not in high concentration. In the drums which were left open the retention of the fumigant vapors were less than in the closed drums. Dowfume EB-5 was retained in the highest concentration, while Dowfume-75 and 80-20 Mixture dissipated most rapidly.

This retention of fumigant vapors in the fumigated grains was also noticed by Walkden and Schwitzgebel (1951). They observed that the 1:4 mixture of carbon disulfide and carbon tetrachloride (similar to 80-20 Mixture) was retained in lethal concentrations for two to four weeks in 1000 bushels of wheat. Similar results were obtained when a 3:1 mixture of ethylene dichloride and carbon tetrachloride was used. The time of retention increased with the increase in the amount of wheat. The short period of retention in this study was possibly due to the small quantity of grain fumigated.

The reason for the total absence of the emergence of adult confused flour beetles from the wheat flour containing its eggs, larvae and pupae, could not be ascertained. The conditions to which these insects were exposed were the same as those of the stock cultures and there was no sign of a mass mortality of the immature or adult stages. No parasites were found and no exposure of checks to any harmful vapors was recorded.

When saw-toothed grain beetles, confused flour beetles and granary weevils were fed on fumigated wheat and corn, little mortality occurred. Results were similar when Indian meal moth larvae were reared on the fumigated grains. Slight residual action was indicated in the case of adult cadelles which were exposed to grain fumigated with Dowfume-75.

When large quantities of grain are fumigated, the grain at the exposed surface becomes saturated with the fumigant. It is in this grain that the greatest concentration of insects occur. In this experiment only two bushels of wheat and corn were used in each drum and the amount of fumigant used was not sufficient to wet the surface layer of grain as in the normal fumigations. To overcome this difference a second series of experiments was set up, in which wheat was dipped in the fumigants. This time, DOW-ET-14 and malathion were also used at the concentrations of ten and 200 ppm.

When saw-toothed grain beetle, confused flour beetle and granary weevil adults were reared on the wheat treated in this manner, residues of the insecticides were noted in the wheat. Lethal concentrations of DOW-ET-14 (200 ppm, actual DOW-ET-14 deposited on the wheat was 30 ppm) were retained for ten weeks after treatment. At the concentration of ten ppm (actual DOW-ET-14 retained by the

wheat was 1.5 ppm) it did not leave enough residues to be of any practical value.

Malathion (200 ppm, actual amount of malathion deposited on the wheat was 30 ppm) residues were responsible for 100 percent mortality of saw-toothed grain beetles for seven weeks after the treatment, at which time the study was terminated. Malathion residues did not show any signs of decline at the end of this same period. Residues left from the ten ppm (actual malathion deposited on the wheat was 1.5 ppm) treatments were effective against saw-toothed grain beetles for the first three weeks, with the mortality gradually declining.

Serafume dipping treatments gave the highest residual effects among the fumigants used, when evaluated for the control of the saw-toothed grain beetle. This material provided a high mortality for the first three weeks. Dowfume-75 and Dowfume EB-5 provided residual activity to a lesser degree.

In the case of granary weevils, malathion and DOW-ET-14 (200 ppm) treatments were effective for a period of six and ten weeks, respectively. DOW-ET-14 at the concentration of ten ppm was not satisfactory, while malathion at the same concentration was effective for at least two weeks. Lindgren, Krohne and Vincent (1954) also obtained residual effects from the malathion treatments at concentrations as low as two ppm. They reported that this

residual activity lasted for about three months. They also observed that there was no reproduction of rice weevils, granary weevils and the lesser grain borer in the treatments. These treatments killed all of the adults for a period of four months. In this investigation no reproduction of saw-toothed grain beetles, confused flour beetles and granary weevils was noted. Serafume and Dowfume EB-5 were effective against the granary weevils for about three weeks.

Malathion and DOW-ET-14 (200 ppm), when evaluated against the confused flour beetles, were retained in lethal concentrations for six and nine weeks respectively. The same chemicals at the concentration of ten ppm were not effective in their residual action. Serafume, Dowfume-75, Dowfume EB-5 and 80-20 Mixture provided little residual activity in the case of confused flour beetles. It was observed that as the time passed the effectiveness of the various insecticide residues gradually declined and vanished completely after a certain period of time.

Emergence of the Indian meal moth adults from larvae reared on the wheat treated with DOW-ET-14 (200 ppm) indicated a residual activity for three weeks from this treatment. None of the other materials showed residual action of practical importance against this pest.

Certain irregularities in the data may be due to experimental errors. In Table 15, which gives the mortal-

ity of granary weevils exposed to dipped wheat for seven days, it is seen that the mortality of the weevils declined gradually with the passage of time. However, in the samples taken 35 days after dipping and counted 42 days after the treatment, a sudden rise in the mortality was noted. In the next week's samples the mortality declined as usual. Similar observations were made in Table 16 in the samples taken 35 days after dipping; here the checks also showed an upward trend in mortality. In Table 14 this rise of mortality occurred in the samples taken 49 days after dipping and mortality recorded 56 days after the treatment. Again it was noted that the emergence of Indian meal moth adults, from samples taken 35 days after dipping and later, started declining and finally no adults emerged.

Various possibilities were considered, in order to discover the reasons for this irregularity. One possibility which may have caused this irregularity appeared to be an Aramite treatment made six weeks after dipping treatment to clean up a mite infestation in the rearing room. Care was taken to air the room thoroughly before the cultures were returned to the room, but apparently toxic vapors were still retained in sufficient quantities to affect the mortality of the insects. Saw-toothed grain beetles were the least affected, while the granary weevils were most susceptible. It also had an adverse effect on

the Indian meal moth larvae. A second Aramite treatment in the beginning of the third week of September (two weeks later than the first) likewise accounted for the second rise in the mortality of insects. The Indian meal moth was especially susceptible, as all of the larvae were killed.

From the germination studies of wheat, corn, rye, barley, oats, and kidney beans, before and after the fumigation, no harmful effects were observed on the seed germination from the treatments. Roark and Cotton (1928) also presented the same results when they tested various aliphatic chlorides. Cotton (1944) observed that a 3:1 mixture of ethylene dichloride and carbon tetrachloride did not affect germination of grain, regardless of its dosage, period of exposure and the moisture content of the seeds.

SUMMARY AND CONCLUSIONS

This study was established to investigate the residual activity of some of the common commercial fumigant mixtures. Two bushel samples of wheat and corn were fumigated and stored under conditions comparable with those in open and closed farm storages. Saw-toothed grain beetles, confused flour beetles, granary weevils and cadelle adults, as well as Indian meal moth larvae were exposed to samples of fumigated grain weekly and the resulting mortality observed. The initial results indicated that, when small samples were fumigated, the results were not comparable with those that exist on the surface of large quantities of fumigated grain. In order to simulate these conditions as closely as possible, samples of wheat were dipped directly in fumigants, as well as in emulsions of malathion and DOW-ET-14. Again, adult saw-toothed grain beetles, confused flour beetles and granary weevils, and Indian meal moth larvae were exposed to the samples of the wheat.

The results from these studies are outlined as follows:

1. Dowfume-75, 80-20 Mixture, Dowfume EB-5 and Serafume proved to be highly efficient fumigants for control of saw-toothed grain beetles, confused flour beetles and granary weevils.

2. Little residual activity was apparent when these fumigants were used to fumigate two bushel samples of wheat and corn at recommended rates.

3. When wheat was dipped directly into the emulsions of malathion and DOW-ET-14 at a concentration of 200 ppm (30 ppm actual residue on the grain), effective residual action was evident for seven to ten weeks against saw-toothed grain beetles, confused flour beetles and granary weevils. DOW-ET-14 was also effective against Indian meal moth larvae.

4. Malathion at ten ppm (1.5 ppm actual residue on the grain) had an effective residual period of three weeks against saw-toothed grain beetles and granary weevils, but provided little control of the confused flour beetles. DOW-ET-14 at ten ppm was not effective against these same pests.

5. When wheat was dipped directly in the commercial formulation of Serafume, its residues were effective for the control of saw-toothed grain beetles and granary weevils for three to five weeks, but had very little effect on confused flour beetles.

6. Dowfume EB-5 was slightly less effective than Serafume in its residual action on the above insects.

7. Dowfume-75 and 80-20 Mixture had little residual activity against the insects tested.

8. None of the materials used in this study, with the exception of DOW-ET-14 (200 ppm), provided significant residual action against Indian meal moth larvae.

9. Germination of wheat, corn, barley, oats, rye and kidney beans was not affected by the fumigation with the recommended dosages of Dowfume-75, 80-20 Mixture, Dowfume EB-5 and Serafume.

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