EFFECT OF ETHYLENE DIBROMIDE FUMIGATION ON THE VIABILITY OF OIL SEEDS *

By

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INTRODUCTION

Any fumigant used in concentrations above a certain level is likely to injure the living seed. Hence the main factor influencing the choice of a fumigant for seeds in storage is the degree to which it impairs their viability. The best fumigant, therefore, is one which shows the widest margin between the minimum concentration lethal to insects and that likely to affect the seed adversely.

The possibility of using ethylene dibromide (EDB) as a fumigant was first tested by Plaut in 1942 at Rehovot. It has been used in Israel since World War II and has proved to be a very effective fumigant which fulfils the above requirements. Its characteristics and effectiveness have been summarized by Aman, *et al.* (1), who showed that in the concentrations lethal to insects, this fumigant did not impair the viability of the seeds investigated. Furthermore, EDB is distinguished from such fumigants as hydrocyanic acid and carbon disulfide by its delayed effect. Many fumigants merely stupify, and many of the insects, seemingly dead, may recover after some time in normal atmosphere. Insects exposed to EDB, on the other hand, though seemingly unaffected at the time, may die shortly afterward in the open air.

It has been shown by several workers (2, 5, 6) that there is some relation between the oil content of seeds and fruits and the amount of bromine they sorbed after exposure to EDB. However, the relation between bromine sorption and viability, and the effects of EDB on the viability of oil seeds in particular, have received little attention.

The cultivation of various oil crops is increasing in Israel, and satisfactory methods of storing such seeds for subsequent sowing must be developed. It seemed important, therefore, to investigate the effect of EDB on the oil seeds commonly used in Israel.

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This paper reports a study of the effects of various concentrations of EDB and various periods of post-fumigation airing on the viability of seeds with different oil contents. The relation between oil content and bromine sorption in oil seeds, and the effect of bromine sorption on their viability, is also reported.

A. Effect of Airing on Viability (under field conditions) of EDB–fumigated Sunflower Seeds

Sunflowers were selected for this trial because they are an important non-irrigated oil crop in Israel.

Three lots of seeds, each containing 2 kg, were used. From each lot, 1 kg was set aside for control, and 1 kg, in 6 replicates, was placed in open paper bags and fumigated for 7 days in a hermetically sealed container of 0.1 m^3 capacity; the amount of fumigant used was equivalent to 70 g of EDB per m^3.

Lot I was aired for 42 days before sowing; Lot II, for 11 days; and Lot III was sown immediately after fumigation. All seeds, including the controls, were sown on February 29 in 6 replicates. Plots were randomized according to the split block design, in a 4.0 × 1.2 m field plot. Seedlings were counted 7, 14, and 30 days after sowing; in addition, the general appearance of the plants was noted.

The effect of various periods of post-fumigation airing on viability and growth is shown in Table 1.

TABLE 1

EFFECT OF POST-FUMIGATION AIRING ON EMERGENCE-CAPACITY AND GROWTH OF SUNFLOWER SEEDS IN THE FIELD

(*Seedling counts from a block of* 70 *sown seeds*)

Post-fumigation Airing (days)	*Number of Seedlings**			*Number of Flowering Heads after 50 days*
	after 7 days	*after 14 days*	*after 30 days*	
Untreated	37	65	67	42
0	11	44	50	29
11	34	60	65	42
42	36	61	64	41
F	28.2**	16.4**	8.8**	9.07**
P=0.05	7.03	6.80	7.75	6.18
P=0.01	9.70	9.44	10.37	8.56

* Average of 6 replicates ** Very significant

With seeds sown immediately after fumigation, both viability and subsequent plant development in the field were seriously impaired, but seeds which had been aired for 11 days or more were not harmed. There were no differences between plants from fumigated and unfumigated seeds.

B. Effect of EDB Concentration and Airing on Viability in Seeds of Differing Oil Content

Seeds used in this trial, and their oil and water content before fumigation, were as follows:

Seed	*Variety*	*Oil Content* (*% dry matter*)	*Moisture* %
Sesame	Local-Israel	55.0	5.6
Flax	Concurrent	35.0	8.0
Sunflower	Local-Israel	26.5	7.6
Sorghum*	Martin	3.5	11.6

* Sorghum was included because on certain farms it was observed that the feeding of EDB-fumigated grain to hens was followed by a gradual diminuation in size of eggs, leading, in extreme cases, to complete cessation of egg production. Bondi and Olomutzki (2, 6) showed that the seeds had absorbed considerable amounts of the fumigant, which is harmful to hens and greatly reduces their egg-laying capacity. It was desired to determine whether these seeds, despite their low oil content, sorb significant amounts of bromine, and to check its effect on their viability.

The seeds were mixed and then divided into 3 lots of 1 kg each, half of which was used for the controls and half for experimental treatment. Fumigation was carried out in 4 replicates according to the method described above at concentrations equivalent to 70, 100 and 130 g/m³.

Tests of germination-capacity and seedling-emergence capacity were carried out directly after fumigation, and after 7, 15, and 30 days' airing. Seeds were germinated, in 4 replicates, under laboratory conditions at a con-controlled temperature of 25°C. Seedling-emergence capacity was tested in pots

There were no statistically significant differences between the two types of test; therefore only data of the emergence-capacity tests are given. Results are shown in Figs. 1—4 as relative percentages of the germination obtained with untreated seeds.

Both the effect of EDB itself, and the effects of various concentration-levels, differ considerably with the different seeds, as the following analysis demonstrates:

Sunflower: These seeds were not highly sensitive to EDB fumigation. Fig. 1 shows that after treatment either with 70 g/m³ and 7 days' airing, or with 100 or 130 g/m³ and 15 days' airing, germination-capacity was not significantly different from that in the untreated controls.

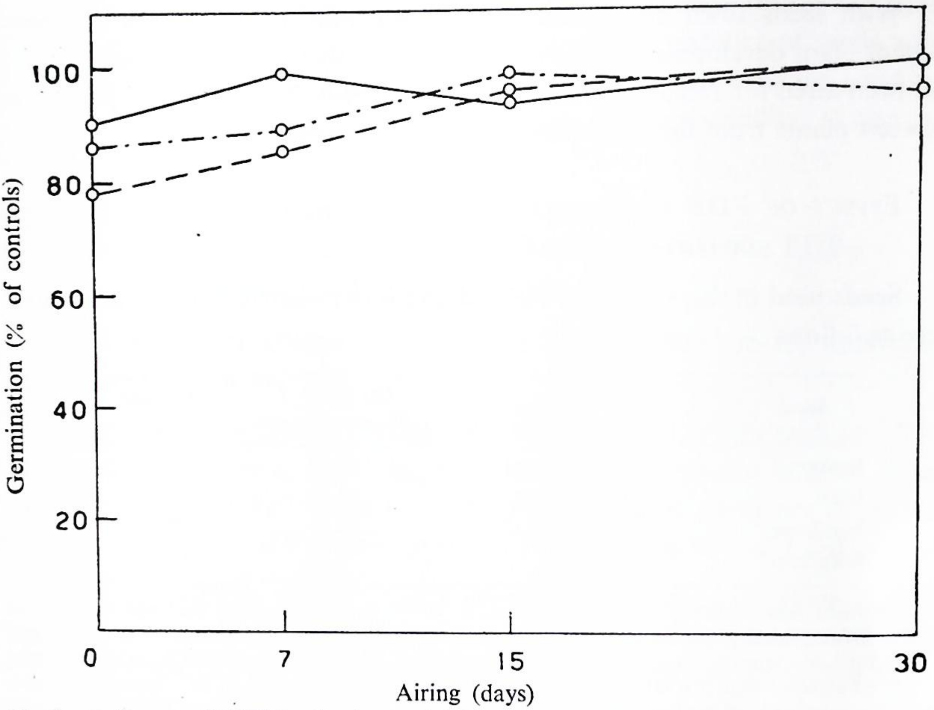

Fig. 1. Influence of EDB fumigation and airing on germination-capacity of sunflower seeds.

———	70 g / m3
— — —	100 g / m3
— · — · —	130 g / m3

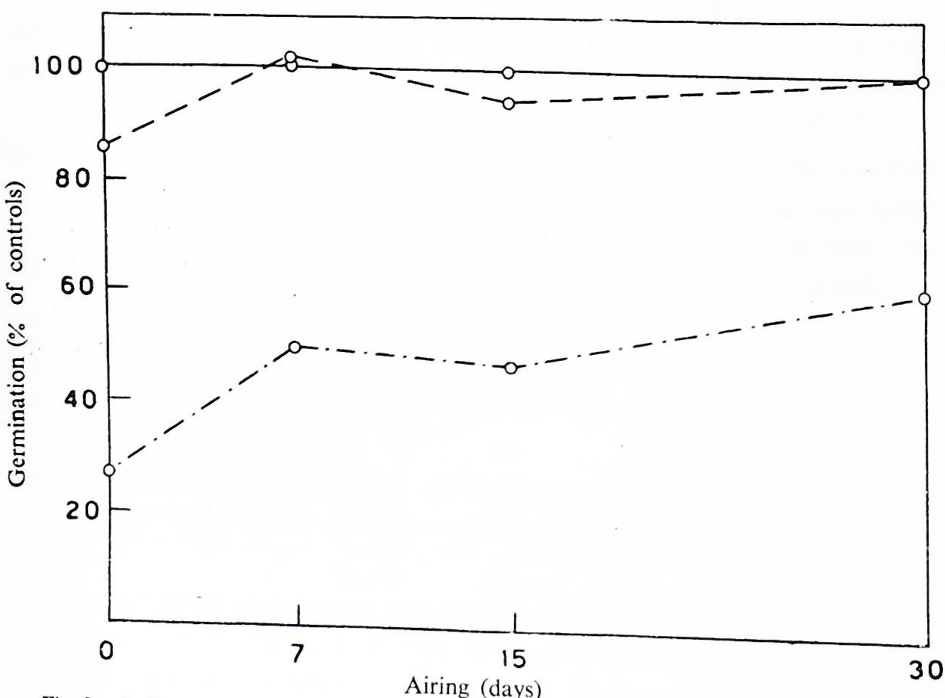

Fig. 2. Influence of EDB fumigation and airing on germination-capacity of flax seeds.

———	70 g / m3
— — —	100 g / m3
— · — · —	130 g / m3

Flax: Seeds of flax were sensitive only to high concentrations of the fumigant, as Fig. 2 shows. At 70 g, even without airing, and at 100 g with 7 days' airing, there was no significant difference between treated and untreated seeds. At 130 g/m³, however, even after 30 days' airing, there was a significant decrease in viability.

Sesame: Sesame seeds proved to be extremely sensitive to fumigation at all concentrations; germination-capacity after treatment at the 130 g level— even after 30 days' airing — was very significantly less than that in the untreated controls.

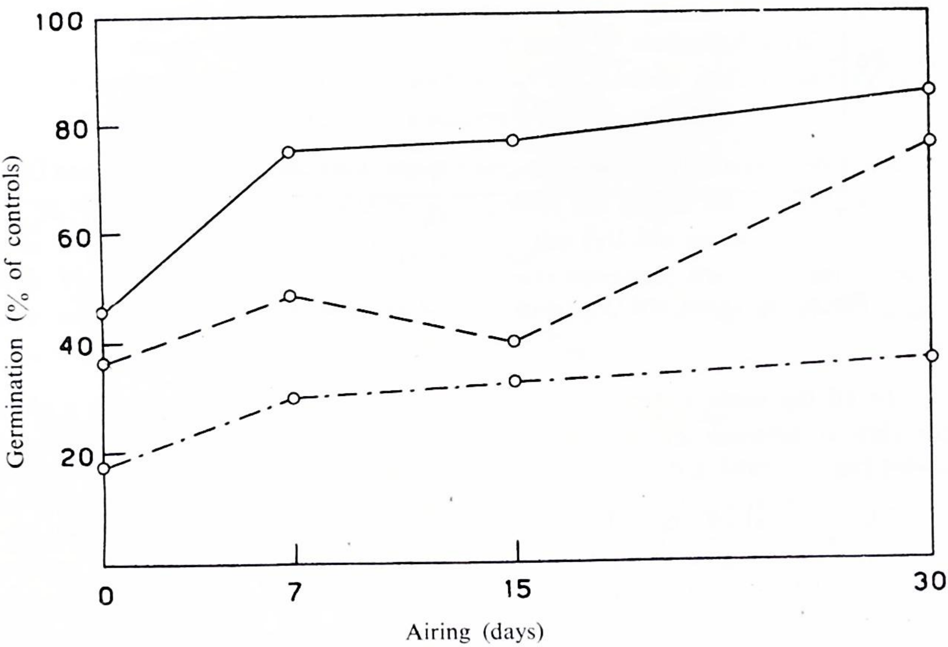

Fig. 3. Influence of EDB fumigation and airing on germination-capacity of sesame seeds.

———— 70 g/m³

— — — — 100 g/m³

— · — · — 130 g/m³

Sorghum: In spite of their very low oil content, sorghum seeds were the most sensitive to EDB fumigation. Fig. 4 shows the great influence, both of concentration-level and of airing, on viability in these seeds. At 70 g, even after 30 days' airing, viability was significantly lower than in the controls. The higher the concentration, more quickly were the seeds killed.

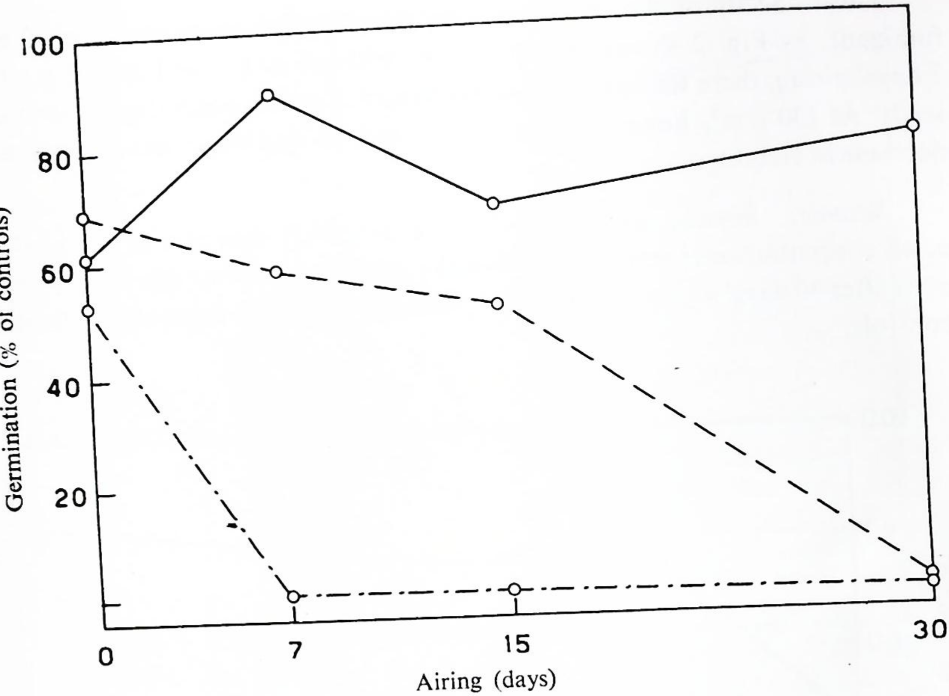

Fig. 4. Influence of EDB fumigation and airing on germination-capacity of sorghum seeds.

In all the seeds tested, with the exception of sorghum, there was a clear correlation between oil content and degree of sensitivity of grain treated with EDB.

The inimical effects of fumigation were also shown by morphological abnormalities in sesame and sorghum seedlings. Shoots from fumigated sesame seeds showed markedly stunted growth and necrosis of the cotyledons. Though the rootlets were not affected in sesame, root-development was strikingly abnormal in sorghum; only a single radicle appeared which instead of tapering to a point, was stumpy, as if cut off; the root hairs were poorly developed, and there was no normal branching of lateral rootlets.

Two subsidiary experiments were carried out — one to test the effect of fumigating in nearly empty containers, and the other to test the effect of airing on volatilization of bromine from the seeds.

1. *Empty vs. full fumigating containers*

In several instances, as mentioned above, certain lots of EDB fumigated sorghum seeds had been harmful to laying hens. Other lots, however, though fumigated at the same concentration, had produced no ill effects. This raised the suspicion that the harmful effects might have been due not only to the use of high concentrations of EDB or lack of airing but also from the use of almost empty containers — a circumstance which tends to increase the sorption of bromine. To clarify this point, one lot containing 0.5 kg each of sesame and sorghum seeds was placed in an empty bin of 0.1 m^3 capacity, while a second similar lot of these grains was placed in an identical bin which had been three-quarters filled with rye. All seeds were fumigated for 7 days, with the equivalent of 100 g/m^3 of EDB.

Viability tests were made immediately after fumigation, and after 7 days, airing. Indovina's method (3) was used for the bromine analyses in the treated seeds.

Sorghum seeds treated in the full bin sorbed 70.0 ppm of bromine, while those in the empty bin sorbed 135.5 ppm, or twice as much. With sesame, those in the empty bin sorbed four times as much as those in the full — 232.0 and 58.5 ppm, respectively. Of the seeds from the full bin, viability in sorghum was not impaired, while in sesame it was only slightly reduced.

These results confirm, to some extent, the relation between oil content and bromine sorption, since sesame seeds, with the higher oil content, sorbed twice as much bromine after fumigation in the full bin as did the sorghum seeds. However in the empty bin, the case was reversed: the sorghum sorbed more bromine than did the sesame seeds, thus indicating that another factor is involved in the bromine sorption of sorghum seeds.

2. *Effect of prolonged airing on volatilization of sorbed bromine*

Flax, sesame and sorghum seeds which had previously been treated with 130 g/m^3 of fumigant, were tested for bromine content after 4 months' airing. Sorghum was found to contain 28.8 ppm of bromine; sesame, 19.2, and flax, 27.7. Compared with bromine content immediately after fumigation in an empty barrel, sorghum had lost 59% of the bromine through volatilization, while the sesame seeds had lost 66%. However, although the amount of bromine retained in the seeds was small, their germination capacity was found to be considerably reduced.

C. Relationship Between Oil Content and Bromine Sorption.

Soybean, flax, peanut, and sesame seeds were fumigated as in the previous experiments, but at a concentration of 200 g/m^3, and at 20—25°C; amount of bromine sorbed was essayed immediately after fumigation. Results are presented in Table 2.

Table 2 shows that bromine sorption increases with oil content in the seeds. Here again, however, as with the sorghum seeds, it is evident that another factor is involved since the peanut shells, which contain only traces of oil, sorbed an enormous amount of bromine.

TABLE 2

RELATION BETWEEN OIL CONTENT AND BROMINE SORPTION IN OIL SEEDS

Seed	*Oil Content* (*% dry matter*)	*Bromine* (*ppm*)
Soybean	19.0	70.0
Flax	34.0	101.0
Peanuts (shelled)	47.0	168.0
Peanuts (unshelled)	—	28.0
Peanut shells (separately treated)	—	246.0
Sesame	56.0	191.0

DISCUSSION

Results of this investigation clearly show that in oil seeds there is a relationship between oil content and bromine sorption on the one hand, and oil content and seed sensitivity to fumigation (as shown by impaired viability), on the other. Nevertheless, the results with sorghum seeds and peanut shells indicate that the problem is complex, and that other factors are involved. Olomutzki and Bondi (6) assume that differences in seed structure influence its sorption of bromine.

This assumption may be confirmed by the fact that with peanuts almost all the bromine in the pods was sorbed by the shells. Furthermore, the morphology of the seed coat differs considerably in the seeds tested: soybean and flax seed coats are relatively impermeable as compared with those of sesame. This may underlie the difference in bromine sorption.

Lewis and Eccleston (4) and Shrader and Beshgetoor (8), investigating the chemical reaction between methyl bromide and various seeds, found that the methyl bromide is hydrolyzed, freeing the bromide, which is dissolved by the water contained in the seed. Olomutzki and Bondi (6) note that two bromine forms were present in fumigated grain: a volatile bromide formed by hydrolysis from free EDB and a non-volatile, water-soluble bromide. The physically absorbed bromine — EDB is likely to be liberated when the seeds are aired for some time, while the water-soluble portion that is chemically sorbed remains. This residual bromide resulted from the reaction of EDB with grain constituent and is likely to injure the seed viability. However, even seeds which germinate show morphological damage as a result of fumigation. Hence the mechanism of damage to germination cannot be explained solely on the basis of the chemical effect of the bromine.

On the other hand, Shaffer (7) has shown that various fumigants inhibit the enzymes which control respiration in insects. The damage caused by EDB may result from its effect on the enzymatic mechanism present during germination; damage apparently occurs at the beginning of germination, which is accompanied by increased enzymatic activity. Moreover, it is well known that the damage to seed-catalase, or a decrease in the amount, is inimical to seed viability.

This hypothesis explains the beneficial effects of airing, which allows the liberation of a considerable quantity of bromine which would otherwise be detrimental to the enzymatic mechanism involved in germination.

CONCLUSIONS AND SUMMARY

In reducing damage to the viability of oil seeds which have been fumigated with ethylene dibromide, the most important factor is post-fumigation airing. The higher the oil content of the seeds, the longer should they be aired after treatment.

A concentration equivalent to 70 g of EDB per cubic meter is least harmful. At this level, sunflower and flax seeds may be sown after 7 days' airing, while sesame and sorghum seeds, which are most sensitive to bromine-damage require 15 to 30 days' airing.

Peanuts should be left unshelled for fumigation, as the shell sorbs almost all the bromine and protects the viability of the seed from damage.

EDB is so abundantly used in Israel that further studies should be carried out to clarify those points not introduced in this paper.

CITATIONS

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