

Resistance of Stored Product Insects to Fumigants

by

E.J. Bond

Research Centre, Agriculture Canada, London, Ontario, Canada

When successive generations of insects are selected with a toxicant so that some survive and reproduce, an increased tolerance to the toxicant usually develops. This change, which is known as insect resistance, results from the process of selection of the more tolerant individuals to produce a resistant population. With stored product insects that are controlled with fumigants, resistance can develop just as it does with other insecticides. Laboratory experiments have shown with several species that appreciable resistance to fumigants can develop under appropriate selection pressure. Surveys of wild populations of insects that have been repeatedly treated for extended periods have also shown some indication of increased resistance. In a global survey, Champ and Dyte (1976) reported the occurrence of resistance to the two major fumigants, methyl bromide and phosphine, in several species of stored product insects. Prior to this time, occasional reports had suggested that resistance to fumigants might be appearing. Since that time, more reports have not only confirmed resistance but also have indicated its economic implications.

One of the most notable differences between insect resistance to fumigants and resistance to most other insecticides is the slowness with which it has developed. Fumigants have been used on a wide scale for many more years than most other pesticides, yet resistance has been very slow in appearing. Also the degree of resistance has been relatively low. This lack of resistance seems to have created a false sense of security against resistance. It seems to have given the impression that resistance to these chemicals might never develop. Consequently, the precautions that could be taken to avoid resistance have never been stressed.

The purpose of this communication is to review the practice of fumigation as it relates to resistance and to emphasize the need for developing appropriate procedures for avoiding or preventing resistance.

History of fumigant resistance

Since fumigants are one of the oldest groups of pesticides in use today, it would seem logical to expect that much would be known about their action and effects. Fumigants have been applied on a commercial scale for over 100 years. Carbon disulphide came into general use as a grain fumigant in 1879 and hydrogen cyanide followed soon after in 1886. Since that time a number of other compounds have developed and a few of these are still in use today.

The first recorded occurrence of resistance to fumigants, and indeed, one of the earliest indications that insects could acquire resistance to toxicants, was with hydrogen cyanide on citrus scale insects in California. In 1916, H.J. Quayle published an article entitled "Are

scale insects becoming resistant to fumigation". Hydrogen cyanide had been used for a number of years and then the treatment began to lose effectiveness. Entomologists suspected that insects were building up a resistance, but the nature of the change was not clear. Even by 1929 there was lack of agreement on whether or not insects could acquire resistance to toxic chemicals. Since then we have learned that insects can develop true resistance. We know that many species of insects have developed high levels of resistance to insecticides, particularly the synthetic organic insecticides. Now the process by which insects acquire resistance is reasonably well understood.

Amongst the stored product insects, resistance to any chemical has not developed rapidly. Even to contact insecticides it has not developed in this group as rapidly as it has with public health or other agricultural insects. The reason for this slow onset probably relates to methods of treatment and to the lack of intensive selection pressure. However, resistance of stored product insects to several contact insecticides has developed to economically important levels. In 1965 Parkin indicated that the future use of pyrethrins, lindane and malathion was seriously threatened by resistance and since that time the use of these compounds on stored product insects has drastically declined. Newer materials such as fenitrothion, bromophos and the synthetic pyrethroids have been used as replacements. However, resistance now threatens to nullify the effectiveness of these compounds.

Resistance to fumigants has not developed to economically important levels until recently. Even with methyl bromide, a material that has been applied extensively for over 50 years, little resistance is evident. The reason for lack of resistance to fumigants is probably due largely to the sporadic nature of the treatments. Seldom are the same populations treated repeatedly for prolonged periods of time. Also a number of different chemicals have been employed over the years.

The present trend to restrict fumigants to fewer and fewer compounds is producing the very conditions that favour resistance. Intensive and repeated use of the same insecticide on the same population is known to promote resistance. With the fumigant phosphine, the necessary factors for producing resistance are being applied with increasing frequency. Consequently, control failures are beginning to appear in several parts of the world and resistant insects are being selected at increasingly faster rates.

Standardization of Procedures for measuring resistance

Since resistance is emerging as an important economic factor, it seems essential that comprehensive methods for measuring resistance to fumigants should be established. If appropriate, standardized methods were developed, they would allow accurate comparisons of results from different sources as well as give a clear indication of the progress of resistance. Since the toxicity of fumigants is dependent on the amount of toxicant absorbed, it is important to have some reliable criteria that accurately reflect the toxic effect and give data that are amenable to comparative assessment.

This means that precise methods for treating the insects with known quantities of gas should be available. Efficient methods of analysis that will give accurate data on exposure concentrations are essential. With the use of gas chromatography such data can be readily obtained and thus resistance can be reliably described in terms that relate closely to effectiveness.

For a fumigant like methyl bromide, where response to concentration and time is reasonably uniform, this approach is quite satisfactory and methods already described (Anon 1975) may be adequate. Results can be based on accurate measurement of concentration and time to give reliable $C \times T$ products. However, for the fumigant phosphine, the influence of concentration is less important and the parameters involved are less thoroughly understood. Uptake of phosphine is quite variable amongst different species and stages of insects so that the influence of concentration is more variable (Fig. 1 and 2). Time is usually considered as

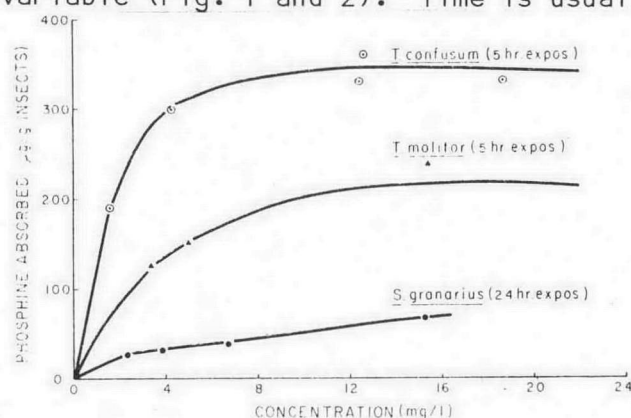


Fig. 1. Absorption of phosphine by three species of insects according to the average concentration to which they were exposed. (Bond et al. 1969).

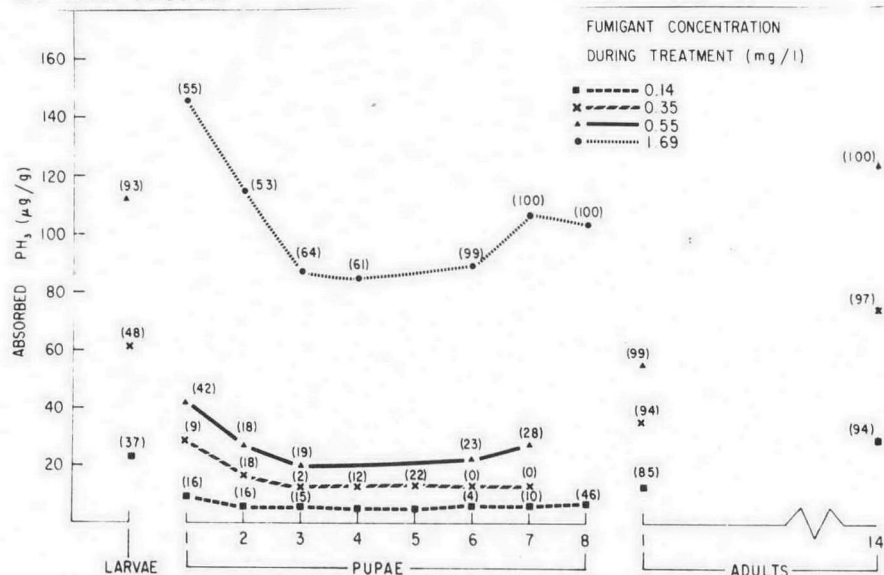


Fig. 2. Uptake of phosphine by larvae, pupae and adults of *T. castaneum* when exposed to various concentrations of the gas for 5 hr. (numbers in brackets indicate % mortality) (Bond 1980).

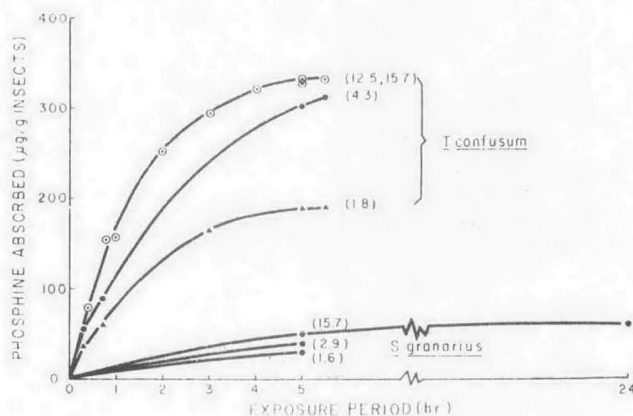


Fig. 3. Absorption of phosphine by *T. confusum* and *S. granarius* according to the length of the exposure period, (average conc. for each treatment is indicated in brackets. (Bond et al. 1969)

the more important factor, but even here considerable difference occurs amongst different species and stages of insects (Fig. 3). The underlying principles of the toxic action of phosphine are not sufficiently well known to understand the mechanism of resistance. Further information on dosage response of different species, strains and stages of insects is needed, along with information on uptake and mode of action, to understand its effects. For both of these fumigants considerably more data is required to give a working comprehension of the scope and the mechanism of resistance.

In conclusion it should be noted that in making assessments of fumigant resistance it seems inevitable that we should make mental comparisons with resistance to other insecticides. Often the levels of resistance for fumigants appear to be much lower and the onset of resistance much slower than with contact insecticides. The reasons for the apparent differences in response to the two groups of compounds may be more imaginary than real. If the actual quantities of toxicant required to reach the sites of action were known we might find that levels of resistance to fumigants were as great or sometimes greater than for other insecticides. We must remember that both the methods and the units used in expressing dosage to the two groups of compounds are quite different.

Nevertheless, the apparent differences in resistance levels between fumigants and contact insecticides plus the slow onset may well account for the disregard for fumigant resistance that has prevailed. There seems to be good evidence to suggest that the present upsurge in fumigant resistance is the result of a flagrant disregard for known facts about resistance. Furthermore there is a good possibility that much could be done to reduce the fumigant resistance problem if the proper approaches were taken. One of the most important questions on fumigant resistance that we must contend with is, do we have the necessary administrative and political capabilities to make use of the knowledge we have on resistance.

References

- Anon, (1975) Recommended methods for the detection and measurements of resistance of agricultural pests to pesticides. Tentative method for adults of some major beetle pests of stored cereals with methyl bromide and phosphine. FAO Method No. 16. Pl. Prot. Bull. FAO, Rome, 23:12-25.
- Bond, E.J. (1980) Sorption of tritiated phosphine by various stages of Tribolium castaneum (Herbst). J. stored Prod. Res. 16:27-31
- Bond, E.J., Robinson, J.R. and Buckland, C.T. (1969) The toxic action of phosphine - Absorption and symptoms of poisoning in insects. J. stored Prod. Res. 5:289-298
- Champ, B.R. and Dyte, C.E. (1976) Report of the FAO Global survey of pesticide susceptibility of stored grain pests. FAO Plant Production and Protection Series No. 5. F.A.O. Rome. 297 pp
- Parkin, E.A. (1965) The onset of insecticide resistance among field strains of stored product insects. Proc. X11 Int. Cong. Ent. London, 657-658
- Quayle, H.J. (1916) Are scales becoming resistant to fumigation. J. Agr. U. of Cal. 3:333
- Tyler, P.S., Taylor, R.W. and Rees, D.P. (1983) Insect resistance to phosphine fumigation in food warehouses in Bangladesh. Int. Pest Control 25:10-13