# OPENING ADDRESS

by The President, Dr. H. G. Sanders

Ministry of Agriculture, Fisheries and Food

Before we plunge into the highly technical matters we are to discuss I have been given the chance to say a brief word of welcome. It is certainly very encouraging to those who have organised this Conference that we have so large and representative a gathering, which will ensure that this will be an Event of great importance to agriculture and to the chemical industry. Year by year farming comes to rely more and more on chemical controls and it must be very right that we should get together for discussion of the position reached and of the hopes and ideas germinating in the minds of research workers. We are, of course, going to be a bit scientific but we include advisory people whose job it is to interpret science to practical men, to pick out the knowledge which is ripe for application and to pass it on to farmers.

Many here today have been at the B. W. C. C. Conferences. I have to confess that at those I've often found myself out of my depth. Here I can hardly expect to have my foot on the bottom at all for the problems confronting us now are more complex and, indeed, are fraught with greater hazard. There are always exceptions, but generally speaking herbicides are relatively harmless to man and to animals and are non-persistent. One of the first things we hear of when we start learning biology is seed dispersal; nevertheless weeds tend to stay put or to spread slowly. The position is very different with insects and fungi. They are more mobile and hence the need for chemicals which will see the protected plant through the period when it is at risk. Some of the chemicals with considerable biological efficiency against insects and fungi unfortunately have high mammalian toxicity. This has led to considerable unease in the public mind. Part of this arises from the really surprising ignorance which exists of the safeguards which protect the public from harm, and we ought to do all we can to remedy this state of affairs. There are some pretty high hurdles that have to be cleared before a new chemical gets into common use and that these are effective is shown by the lack of evidence of any harm suffered by consumers of crops which have had chemicals applied to them. The same, indeed, can be said in regard to those who apply the chemicals; it is true that very occasional tragedies have occurred but they have been due to carelessness and their numbers have been infinitesimal compared to the fatalities and injuries suffered through carelessness with hazards other than chemical ones. Concern over dangers to wild life is widespread and I think we can understand it, but the idea which some people have, that indiscriminate slaughter is going on all the time, is very wide of the mark. When it was established that some very efficient seed dressings were causing deaths to birds the Government and Industry agreed on restrictions which, there is every reason to hope, will stop these deaths. It is easy enough to argue that if proper precautions had been taken earlier no deaths would have occurred at all but laboratory tests and field trials cannot reveal every hazard that could arise under any farming conditions to the almost infinite variety of wild life. The Notification Scheme now requires data on wild life and ensures that every possible care will be taken in the future, but only the general use of a new chemical can show whether or not it presents any hazard at all to wild life. No irreparable harm has been, or is likely to be, done but there is clearly a need for unceasing vigilance and this will be forthcoming. It is quite silly to accuse the scientist of heartless disregard for any other organism in his efforts to control a particular pest. He must in addition to wild life always give careful thought to beneficial organisms such as pollinators and predators.

The complexity of this Conference's subject is evident from a glance at the title of the papers we are to hear. The field they cover is very wide but no-one would claim that every conceivable aspect is included. We have here representatives of industry, government departments, research institutes and universities, and I am quite sure that getting all you people together is, in itself, a very good thing. It is a happy state of affairs that in this field there is a spirit of cooperation, of which this Conference is a manifestation. I had another example of this spirit earlier this year. A Research Study Group, of which some of you may have heard, wanted to know what acreage of the U.K. was sprayed with chemicals which are generally recognised to be toxic - don't ask me to define "toxic" because I defy anyone to produce a satisfactory definition. I wrote to all the companies in the country which manufacture, formulate or import pesticides and I asked a good deal of them. What I asked was, in terms of "acres sprayed", the amounts of certain specified chemicals they sold in 1955 and in 1960. Needless to say I would not have done this unless Mr. Mellor and Mr. Williams had first prepared the ground for me and naturally I regard the information I got as highly confidential; no-one, apart from my secretary and myself, has seen the replies and all that will see the light of day are four totals from which it is quite impossible to deduce what any one firm sold of any chemical. I had a reply from every single firm to whom I wrote and, where they were concerned with the particular chemicals, the figures for which I asked. It really is something to get 100 per cent replies from a round robin but what particularly impressed me was the care taken, by correspondence between themselves, to ensure that there was no duplication in the figures. I gladly seize the chance, here and now, publicly to thank all my correspondents for the considerable trouble they took and in particular the President, Secretary and all in ABMAC who made this little enquiry possible. The results were interesting and I felt they justified the whole exercise. They showed that the acreage sprayed with these toxic chemicals had more than doubled in the 5-year period but that there had been a very marked shift towards the less toxic materials. This is very encouraging because it is so clearly the way we must go. Research workers in this field do not need to be told that we want effective chemicals of lower mammalian toxicity; they are straining every nerve to this end and the figures I collected show that they are achieving considerable success.

Much effort has gone to organising this Conference and the attendance shows that this preliminary work has been well done. I am entirely confident that our meeting is going to prove interesting and useful.

# THE EELWORM PROBLEM

by F. G. W. Jones

Rothamsted Experimental Station

Although infested glasshouses and nurseries can be successfully treated with soil fumigants, only exceptionally are treatments for controlling nematodes in field crops in Great Britain economic. In the U.S.A., many thousands of acres of land are treated annually, mainly in the S.E. coastal plain, but the cash value of the crops concerned is greater and the soil temperatures appreciably higher. Although much screening and many *ad hoc* experiments are done each year, the results of which present a conflicting mixture of science and sales pressure, only three soil nematicides have stood the test of time: bromomethane, dibromoethane and dichloropropene. Dibromochloropropane and some of the dithiocarbamates and their relatives and one or two phosphorus compounds related to parathion show promise. The chemicals listed in Tables 1 and 2 are all "broad band" toxicants, harmful to plants and to mammals. Their undesirable properties are mitigated to some extent where field dosage rates are low as for mercury and dibromochloropropane (Table 1). With the exception of (3) in Table 3, all chemicals in the parathion group are highly toxic to mammals though usually of low toxicity to plants.

Effective chemicals are few partly because of the rather intractable problems posed by nematode control. Nematodes are rarely exposed as are many insects. No thorough and concerted attempts have been made to employ chemicals against species of *Ditylenchus* (stem and bulb eelworms), *Aphelenchoides* (bud and foliar nematodes) or *Anguina* (seed gall nematodes) although the difficulties are less than in the control of nematodes in soil, where most noxious nematodes occur.

For annual field crops the aim is to reduce the eelworm population in the soil occupied by plant roots below the level that does economic damage. Eradication is out of the question for vast amounts of chemical would be necessary and reinfection would probably occur from deep down below. Highly phytotoxic chemicals can be used in the interval between crops, provided they do not persist too long, and control has to be exerted to a depth which is equal to, or perhaps slightly below plough depth. Some economy can sometimes be achieved for crops with wide row spacing by confining treatment to the actual row. For perennial crops or plantations, phytotoxic compounds can be used only before planting and in the intervals between replacement. Tree roots often penetrate deeply and, in porous soils, as in the citrus orchards of Florida, nematodes may be more abundant six feet down than in the surface. The problem of disinfestation to that depth is so formidable that an entirely different approach seems necessary. Even for arable land the weight of soil to be treated to plough depth is of the order of 1,000 tons per acre including some 200 tons of water.

Because of the great mass of soil to be treated and the difficulties of mixing materials intimately with it, all the successful nematicides used so far possess appreciable vapour pressures and so are self-dispersing in treated soils. Spot or strip injections are commonly used and spaced so as to give confluent zones of adequate kill within the soil. Nematicides formulated as granules, as drenches or mixed directly into the soil attempt the same object in a different way. The situation after they are introduced is illustrated in Fig. 1. For most ordinary soils in reasonable tilth there is no difficulty in securing diffusion through the major pores. The main resistance arises in the smallest pores and channels leading to the interior of aggregates and crumbs and some of the losses occurring en route are depicted.

Many factors affect fumigation of field soils. Soil temperature greatly influences vaporisation and rate of diffusion. High temperatures assist fumigation but may lead to too rapid loss of gas from the surface. Fumigants with low boiling points and low vapour pressures are unsuitable for cold soils which, especially when wet, may retain gas partly in solution and lead to enhanced and long continued phytotoxicity. Soil type also influences fumigation because it influences pore size distribution. An excess of fine particles or of organic matter also favours sorption which lowers the effective concentration of the fumigant. Tilth also affects the issue, for a "clotty" soil with many gross air spaces cannot retain vapour. Excess moisture decreases porosity, increases the amount of nematicide held in solution and causes thick water films slowing down the last stages of diffusion which lead to contact with the nematode to be killed (Fig. 1). In contrast, fumigation of a very dry soil leads to rapid gas escape, increased sorption on to clay particles and inactivity of the nematicide. For highly volatile nematicides such as bromomethane an impervious surface seal is essential in the form of gas tight sheeting. Dichloropropene, trichloronitromethane, and methylisothiocyanate would also perform better if the surface were sealed by polythene, impervious paper or heavy watering (1,000 galls/acre = 1.1 cm.), operations economic with seedbeds or expensive crops but, agriculturally, only heavy rolling is economic and is always beneficial even though not fully effective. Quite apart from the physical aspects of fumigation, micro-organisms or other components of the soil may hasten breakdown. Where nematicide precursors such as the dithiocarbamates, (Table 2.) mercury compounds or halogen liberators are used, breakdown is an essential part of the operation.

There are many difficulties in attempting to measure the nematicidal activity of chemicals in the laboratory and in assessing their performance in the field. The field dosages given in Table 1. in no way reflect the activity of the compounds listed because of the confounding effect of the many variables already discussed. Assessing mortality is almost always much more laborious and time consuming than for insects or fungi. In streamlined screening tests these difficulties tend to be glossed over. It is often hard to decide when a nematode is dead. Dead larvae within eggs cannot be distinguished from living until gross changes have had time to occur. Discriminative staining has not proved reliable with eggs, larvae or adults and, although it is a simple matter to separate active from passive larvae and adults by suitable filters, inactivity does not always indicate death. These difficulties are greatest for cyst-forming nematodes, the closely related root-knot nematodes and for those forms which invade roots. The problem for cyst forming nematodes is analysed in Table 4. Root-knot nematodes are often used for screening and kill is estimated by counts of primary galls formed on indicator plants. As with cyst-nematodes, delayed hatch might delay invasion so giving an over-estimate of kill; larvae that invade may be unable to develop completely and counts of galls formed by these would under-estimate the kill. Effects of this kind may not greatly upset a screening programme but are important in research where more precise estimates of toxicity are required. The difficulties outlined have been emphasised by the work of Hague and his colleagues at Imperial College Field Station. Working mainly with potato root eelworm (Heterodera rostochiensis), they have plotted probits of kill against dosage and obtain the median lethal doses for bromomethane, dibromoethane and dibromochloropropane. For this work they have found the final cyst count the most reliable criterion.

Dosage of nematodes by exposure to varying concentrations of a toxicant for a standard time or a standard concentration for varying times brings in the concept of concentration-time-product (C. T. P.). Over middle ranges of concentration and time the C. T. P. is usually regarded as a constant if measured under similar conditions. Recent work on free living and migratory soil nematodes using methyl bromide has shown that the C. T. P. law breaks down (Table 5.). Very low concentrations of chemical give extremely high kills with long exposure time (Hague in litt). The lower field dosages of dibromochloropropane required compared with bromomethane or dibromoethane (Table 1) may reflect greater persistence arising from low volatility rather than greater inherent toxicity. The advantages of low volatility, if real, cannot be pushed too far or the self dispersing properties of the compound are lost. Greater quantities may then be necessary to achieve the desired kill or recourse must be had to special methods of cultivation to ensure thorough mixing with the soil as with mercury compounds.

In field trials, yield is often no criterion of kill because other effects are confounded with it. The final cyst population too is available only after harvest and long after application of treatments. Unrelated events might well influence cyst production in the interim. For this reason my colleague Dr. Peachey has attempted to use root invasion as a criterion because it can be obtained much sooner after treatment, either using root samples taken from the field plots or pot plants grown in representative soil samples under standardised conditions. Although density of larvae/g root is not directly related to the final kill and there are difficulties in deciding just when the samples should be taken, this criterion is useful in that it enables more plots to be handled and tests to be repeated within the compass of a single season. It may also be argued that injury is related to invasion and that delay in invasion is part of the beneficial action of the nematicide.

So far I have spoken only of the problems associated with the use and testing of general nematicides. These are broadly toxic to insects, fungi and plants. Sometimes their phytotoxic properties also help to suppress weeds. The grower accepts these useful side effects and the increased growth from nutrients released by so-called soil amendment, all of which help to make soil treatment more attractive. One problem which remains is the development of nematicides to free bulbs, tubers, corms, transplants and nursery stock from parasitic or adhering nematodes, for noxious species are often carried to new areas by this means and virgin land becomes infested when first planted. For this purpose more specialised nematicides are needed with high nematicidal power yet low toxicity to plants and to mammals.

Another problem is the exploration of ideas gained from a study of host-parasite inter-relationships and of toxic principles obtained from plants after the manner of nicotine, rotenone and pyrethrum.

Peacock, in a recent address to the Association of Applied Biologists, listed the ways in which systemic compounds moving down to the roots might give protection. They might be toxic to nematodes entering or feeding upon the roots as is $\alpha$-terthienyl in the roots of Tagetes. They might inhibit some host response to invasion which neamtodes depend on for survival, as in the suppression of giant cell formation by maleic hydrazide, or inhibit the formation of the hatching factors as with maleic hydrazide, sodium fluoracetate, and fluoracetamide. Finally they might diffuse out from the roots and exert a toxic, repellent or anti-hatching effect in the rhizosphere.

The Tagetes nematicide was isolated in Holland by Uhlenbroek and Bijloo who have already tested some related thienyls. At least two other compounds in this class are known to be nematicidal (Table 6). Toxic principles also occur in Asparagus roots and possibly in Crotalaria. The former is an unidentified glycoside which is said to decrease Trichodorus populations in soil when applied as a drench or sprayed on to leaves. Tarjan injected toxic compounds into citrus trees affected by spreading decline in Florida without success, but Peacock found he could introduce into tomatoes by means of a woollen wick many substances that were translocated downwards and inhibited nematodes in the roots. When sprayed on the leaves, however, most did not penetrate or were too phytotoxic. The finding of compounds to fill the roles listed by Peacock will not be easy but there is always the chance that someone will succeed.

Once it was thought that characterisation of the hatching factor for potato root eelworm would lead to its synthesis and use in control. Work in the interim on hatching makes this seem unlikely. Hatching factors, although active at great dilution, are also highly unstable and quite unfit for application to soil. Here again, when characterised and substituted in various ways to increase persistence, something usable may perhaps arise.

In many countries nematode problems remain to be recognized, surveyed and assessed. As this is done more outlets will arise for nematicides. In the developed countries mechanisation is tending to force growers to concentrate on a few crops so that expensive machinery can be used to the full and, consequently, traditional methods of control such as crop rotation are often difficult or inconvenient to apply. For these and other reasons the development of positive methods of chemical control at economic prices is an increasingly desirable pursuit.

Table 1

Properties and field dosages of some nematicides

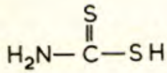
| | BP °C | VP 20-25°C | % Water solubility | Minimum soil temperature for use °C | °F | Approximate field dosage range lb/acre |
|---|---|---|---|---|---|---|
| Bromomethane | 5 | 1420 | 1.3 | 5 | 40 | 400-800 |
| Carbon disulphide | 46 | 357 | 0.3 | | | 1000? |
| 1,3-dichloropropene | 104-112 | 31 | 0.1 | 7 | 45 | 100-400 |
| trichloronitromethane | 112 | 24 | 0.2 | 10 | 50 | 400-800 |
| methyl isothiocyanate | 119 | 21 | 0.8 | | | 150-250* |
| 1,2-dibromoethane | 132 | 11 | 0.4 | 16 | 60 | 50-250 |
| 1,2-dibromo-3-chloropropane | 196 | $<1$ | 0.1 | 18 | 65 | 20-60 |
| Trans1,4-dibromobutene-2 | 205 | $<1$ | | | | 75-100 |
| Mercury | 357 | $<0.01$ | $\rightarrow 0$ | | | 5** |

* as methylisothiocyanate or derived from a dithiocarbamate precursor, claimed effective at low temperatures.

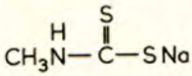
** as grey powder, mercuric oxide, calomel etc.

## The formulae of some dithiocarbamates and related sulphur compounds precursors of nematicidal isothiocyanates.

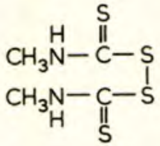
Dithiocarbamic acid



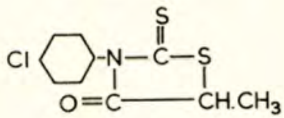
Sodium methyl dithiocarbamate



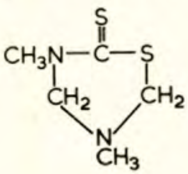
Dimethyl thiuram disulphide



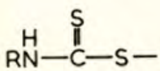
Parachlorphenyl methyl rhodanine



Dimethyl tetrahydro thiadiazinethione



General formula



Probable nematicidal and fungicidal breakdown product; isothiocyanate $RN{=}C{=}S$

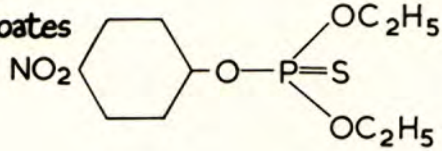
Methyl isothiocyanate $CH_3N{=}C{=}S$

**Characteristics.**

Low volatility,
Water solubility varies with chemical configuration,
Phytotoxic, Irritant.

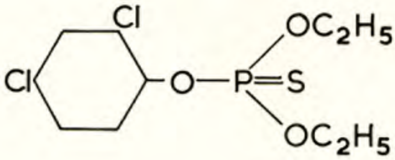
## Some parathion like substances with nematicidal activity

Diethyl phosphorothioates
Nitrophenyl



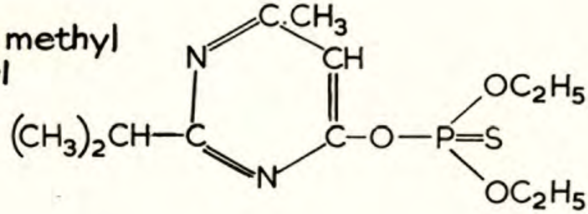
(1)

Dichlorophenyl



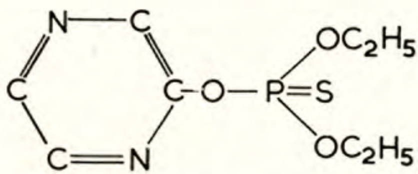
(2)

Isopropyl methyl
pyrimidyl



(3)

Pyrazinyl



(4)

### Characteristics

Breakdown in soil to potent cholinesterase inhibitors.
All derivatives of diethylthiophosphoric acid.
High BP, Low VP, Low water solubility.
High mammalian toxicity (except 3).
Low phytotoxicity.

Table 4. The effects of nematicides in soil: cyst forming nematodes

| Dosage of soil containing encysted eggs | Population after dosage | | | Invasion, development and reproduction on host plant after dosage | | |
|---|---|---|---|---|---|---|
| | Immediate | Intermediate | Final | Root population* | Cyst population | Egg population |
| Immediate Kill | Dead eggs not obvious | Dead eggs more obvious | Dead eggs disintergrated | Some invading larvae may be incapable of development or reproduction. | Confounded with mortality in roots due to competition or other causes. | Confounded with mortality in roots during cyst development and with all those factors which influence ovulation and egg nourishment. |
| Final kill | | Hatching may be delayed. Some moribund eggs may hatch. | Mortality complete but may include that from other sources and may be confused with spontaneous hatch. | Larvae/g root not directly related to survival; number successful in invading varies with soil conditions. | New cysts formed represent the number of female invasions that successfully complete development under the conditions of the trial. | Final egg populations affected by many factors besides nematicidal treatment and separated in time by months. |
| Availability of results | Shortly after dosage | Some time after dosage | Only after considerable delay | Results available shortly after planting | Results available only after completion of experiment | |
| | For hatching tests in addition to egg estimates, add 5 weeks. | | | | | |

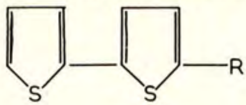
* Estimates can be obtained from root, from samples, separately from plants grown in representative soil samples under standardised conditions, or from extracted cysts added to pots of sterilised soil.

Table 5. The inconstancy of the time-concentration product at extremes of time and concentration.
Methyl bromide used against migratory and free living nematodes

| Hours Exposure | Concentration mg. | CTP | % Mortality |
|---|---|---|---|
| 1 | 100 | 100 | 0 |
| 10 | 10 | 100 | 50 |
| 100 | 1 | 100 | 100 |

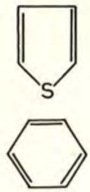
**Table 6** Some thienyl and similar compounds with nematicidal properties.

Experimental stage only



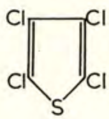
— (1)

Where R =



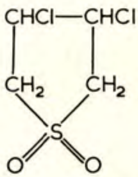
Derivatives of dithienyl.

$CH_3$
Cl
$NO_2$
$COC_2H_5$



— (2)

Tetrachlorothiophene.



— (3)

Dichlorotetrahydrothiophene-
-dioxide.

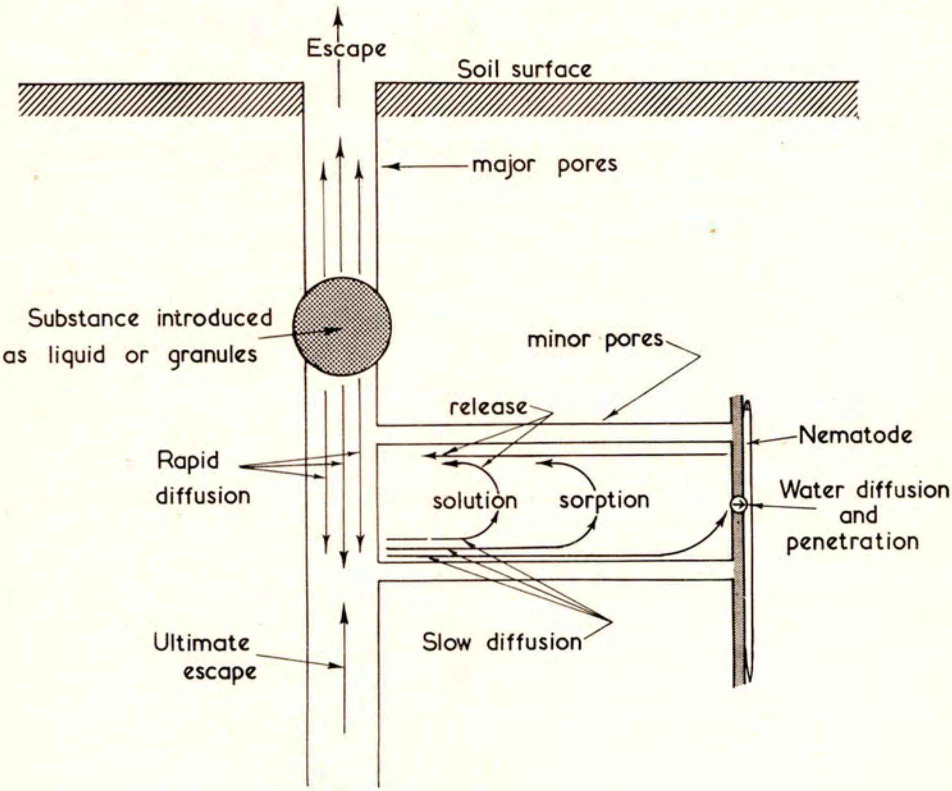
Characteristics

Low volatility. Low water solubility.

(3) somewhat phytotoxic.

(2) & (3) dosages suggested 20-60 lb./acre.

Diagrammatic representation of the processes concerned in soil fumigation.



# FIELD EXPERIMENTS WITH A NEW ORGANO-PHOSPHORUS NEMATOCIDE AGAINST POTATO ROOT EELWORM

by W. D. Fraser (Field Station, Wisbech) and C. D. Lindley
(Cyanamid of Great Britain Limited)

## Summary

Work is described with E. N. 18,133, a new organo-phosphorus nematocide, applied as a granular formulation for the control of potato root eelworm (Heterodera rostochiensis).

When applied immediately before planting to land infested with potato root eelworm, it significantly increased the yield of ware potatoes by amounts ranging from 15% to 60% in field experiments carried out over three seasons. It was more effective as a band application in the furrow than when broadcast and admixed by rotovation.

Lower rates of use were required on silty loam soils than on peat fen soils to give similar increases of yield. Furrow application on silt soils of 2 lb a. i. per acre was as effective as 4 lb, whereas on peat soils 6 lb was more effective than 3 lb.

It caused a decrease of yield in two experiments on eelworm-free soil.

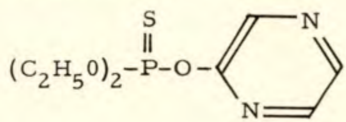
E. N. 18133 reduced the number of aphids on the leaves during the season by systemic action.

No detectable residues of E. N. 18,133 ( $< 0.02$ p. p. m. ) were found in the tubers in August or at harvest following furrow application of 8 or 12 lb.

## Introduction

Experimental Nematocide 18, 133 (E. N. 18, 133) OO-diethyl O-2 pyrazinyl phosphorothioate was discovered at Cyanamid's Stamford Laboratories in 1956.

The structural formula is:-




It is a liquid with a solubility in water of 0.1%.

Preliminary trials in the United States showed it to be active against several species of free living plant parasitic nematode. Trials were begun in the United Kingdom in 1959 against potato root eelworm (Heterodera rostochiensis).

## Materials and Methods

In 1959 and 1960 attapulgite granules containing 5% E.N. 18,133 were used in the trials and in 1961 the formulation consisted of 10% E.N. 18,133 on attapulgite granules (30-60 mesh).

In 1959 a randomized block design with 4 replicates was used, the plot size being 5 rows 15' long. The layout in 1960 and 1961 consisted of 5 x 5 Latin squares. The plot size in 1960 was 5 rows x $16\frac{1}{2}$', and in 1961, 3 rows x 15' with an untreated guard row between plots.

Two experiments were carried out in 1961 on clean soil to test the effect of the chemical in the absence of eelworm. One was a split plot trial with the varieties Majestic and King Edward as the main treatments and rates of application of E.N. 18,133 as the sub-treatments. The other was a randomized block with four-fold replication. The plot size was 5 rows x 15' in both trials.

Broadcast applications of E.N. 18,133 granules were made after preparation of the land and the chemical was incorporated into the soil by rotovating or harrowing. Ridging and planting of the seed took place on the same day. Furrow applications of granules were made immediately before planting. The tubers were planted 18" apart in the rows.

Soil samples were taken for eelworm counts before laying down the trial and again after harvesting. Twenty soil cores 6 to 8" deep were taken with a $1\frac{1}{4}$" auger from each plot and the samples bulked.

After drying and thorough mixing, 100g of soil was washed through a Fenwick can. The cysts were extracted from the residue by filtration and counted. In 1960 to assess viability 50 cysts were withdrawn at random from each sample and placed singly in a small drop of water on a glass slide. Each cyst was squashed with a glass rod and assessed for viability of eggs and larvae. Cysts containing 50 or more full eggs and larvae were classified as full, and under 50 as half-full. It was felt that a more accurate classification could be achieved by precise counts of eggs and larvae and this procedure was used in 1961. Again 50 cysts were taken at random from each sample and moistened and squashed with a glass rod. The squashed sample was washed into a boiling tube and made up to 30 ml with water. The suspension was agitated with an electric stirrer for 10 seconds to separate the eggs from the shells of the cysts. To obtain a uniform distribution of eggs and larvae air was bubbled into the suspension for a few seconds and 1 ml samples withdrawn and examined in a Fenwick counting slide. Counts were made of the total number of eggs and larvae, and they have been expressed together as eggs per gram of dried soil.

All results have been statistically analysed. An asterisk (*) signifies that the difference from the control is statistically significant at $P < 0.05$, and two asterisks (**) at $P < 0.01$.

## Results

### 1959 Trial:

This experiment was carried out on a light silt site near Holbeach, Lincs. The previous crop of early potatoes in 1956 had been severely attacked by eelworm. The plots were treated with E.N. 18,133 and planted with Majestic seed on 12th May. The results are shown in Table 1.

Table 1. Effect of E.N. 18,133 Granules on Shoot Emergence, Yield of Potatoes and Eelworm counts at Holbeach Site, 1959

| Treatment (lb a.i./acre) | No. shoots as % of control | Yield of Ware potatoes as % of control | No. of eggs/g dried soil | |
|---|---|---|---|---|
| | | | Pretreatment | Postcropping |
| 1 lb Furrow | 93.6 | 98.1 | 76 | 193 |
| 2 lb " | 89.8 | 121.9 | 96 | 232 |
| 4 lb " | 93.8 | 129.8 | 82 | 129 |
| 8 lb " | 81.2 | 98.9 | 78 | 169 |
| 16 lb " | 80.8 | 85.3 | 61 | 146 |
| Control | 100.0 | 100.0 | 90 | 252 |
| Control yield (Tons/Acre) | | 4.1 tons | | |

All rates of E.N. 18,133 caused a non-significant reduction in the number of shoots as shown by counts on 30th June. The 2 and 4 lb rates increased the yield of ware potatoes, but 16 lb caused a decrease indicating phytotoxicity. The low yields were probably partially due to the late planting date and the drought conditions of 1959.

The eelworm count as eggs per g of soil was higher after cropping than before treatment in all treatments. However, the increase with the 4, 8 and 16 lb treatments was not as great as with the others.

Counts of aphids on the leaves in July showed that E.N. 18,133 at 4, 8 and 16 lb had given a statistically significant ($P < 0.01$) reduction over the untreated.

### 1960 Trials:

In the light of the preliminary findings with E.N. 18,133, three experiments were laid down comparing two methods of application on two soil types. Details of the trials are given in Table 2 and results in Table 3.

Table 2. Details of 1960 Experiments

| Site Number | 2 | 3 |
|---|---|---|
| Location: | Sutterton, Lincs. | Holme, Hunts. |
| Soil type: | Silty Loam | Peat Fen |
| Date of treatment and planting: | 11th April | 8th April |
| Variety of potato: | Majestic | Majestic |
| Row width: | 28 ins. | 30 ins. |
| Method of mixing broadcast treatments: | Harrowing | Rotovating |
| Date of emergence count: | 15th June | 8th June |

Table 3. Effect of E.N. 18,133 Granules on Plant Emergence and Yield of Potatoes

| Treatment | No. plants as % of control | | Yield ware potatoes as % of control | |
|---|---|---|---|---|
| (lb a.i. /acre) | Site 2 | Site 3 | Site 2 | Site 3 |
| 4 lb Furrow | 101.9 | 102.0 | 133.1 | 126.4** |
| 4 lb Broadcast | 101.9 | 108.2 | 129.8 | 115.4* |
| 8 lb " | 100.0 | 106.1 | 145.8* | 118.8* |
| 16 lb " | 100.0 | 106.1 | 136.6 | 135.7** |
| Control | 100.0 | 100.0 | 100.0 | 100.0 |
| Control yield (Tons/acre) | | | 6.3 | 7.5 |

Counts of the number of plants at both sites showed that E.N. 18,133 did not affect germination.

E.N. 18,133 gave marked increases of yield over the untreated. The greatest increase at Site 2 was with 8 lb broadcast and at Site 3 with 16 lb broadcast, but 4 lb furrow increased the yield at both sites by 2 tons per acre. At Site 2, 16 lb broadcast gave a lower yield than the 8 lb rate, indicating some degree of phytotoxicity.

These results suggested that the peat fen soil required a higher rate of application than silt soils for a comparable effect on yield.

Table 4. Effect of E.N. 18,133 Granules on Eelworm Cyst Counts

| Treatment (lb a.i./acre) | No. of full cysts per 100 gm. dried soil | | | |
|---|---|---|---|---|
| | Site 2 | | Site 3 | |
| | Pretreatment | Postcropping | Pretreatment | Postcropping |
| 4 lb Furrow | 11.6 | 22.6 | 56.2 | 84.6 |
| 4 lb Broadcast | 8.4 | 30.2 | 40.6 | 107.8 |
| 8 lb " | 13.8 | 26.4 | 53.0 | 120.8 |
| 16 lb " | 13.0 | 37.4 | 47.2 | 45.4** |
| Control | 10.2 | 26.2 | 61.8 | 115.2 |

The eelworm counts expressed as full cysts per 100 g. of soil were higher after cropping than before treatment at both sites, with the exception of the 16 lb broadcast treatment at Site 3.

No detectable residues ( $< 0.02$ p.p.m.) of E.N. 18,133 were found by the Laws and Webley (1961) method in tubers taken from the highest rates of treatment at harvest.

1961 Trials:

Further experiments were laid down in 1961. These included two trials to determine the influence of E.N. 18,133 on potatoes in the absence of eelworm and ten trials on infested areas. The rates of E.N. 18,133 were 50% higher on the peat fen sites than on the silt sites.

a) Trials on eelworm-free soil:

Table 5. Details of 1961 Experiments

| Site Number | 4 | 5 |
|---|---|---|
| Soil type: | Silt | Peat |
| Location: | Wisbech, Cambs. | Methwold Hythe, Norfolk |
| Date of treatment & planting: | 11th April | 13th April |
| Variety: | Majestic & King Edward | Majestic |
| Fertiliser: | 10 cwt/acre 10-10-18 | 4 cwt/acre $K_2O$<br>3 cwt/acre Triple Supers |
| Row width: | 28 " | 28" |
| Date of emergence count: | 23rd May | - - |
| Previous potato crop: | 1953 | Pre 1941 |

The absence of eelworm at Site 4 was established by the examination of soil samples. Site 5 had been a grass field for twenty years.

The number of shoots from 10 plants were counted at Site 4 on 23rd May and the mean values, expressed as a percentage of the control, are shown below in Table 6.

Table 6. Effect of E.N. 18,133 Granules on Shoot Production of Majestic and King Edward potatoes

| Treatment (lb a.i./acre) | No. of shoots as % of control |
|---|---|
| 2 lb Furrow | 100.7 |
| 4 lb " | 93.2 |
| 8 lb " | 85.4 |
| 4 lb Broadcast | 89.9 |
| 8 lb " | 96.3 |
| Control | 100.0 |

There was an indication that the treatments reduced the number of shoots and this effect was most marked at the 8 lb furrow level. Visual assessment scores also indicated a small reduction in vigour associated with the plant in the 8 lb furrow treatment, and both observations suggested that this rate was mildly phytotoxic. As the season progressed the differences disappeared and in the late stages of growth it was impossible to distinguish one treatment from the other.

The effect of the chemical on yield is shown in Table 7 for both sites.

Table 7. Effect of E.N. 18,133 Granules on Yield of Ware Potatoes on Eelworm Free Soils

| Treatment (lb a.i./acre) | Yield of ware potatoes as % of control | | Treatment (lb a.i./acre) |
|---|---|---|---|
| Site 4 | Site 4 | Site 5 | Site 5 |
| 2 lb Furrow | 89.4 | 105.2 | 3 lb Furrow |
| 4 lb " | 84.1* | 92.1 | 6 lb " |
| 8 lb " | 85.6* | 95.8 | 12 lb " |
| 4 lb Broadcast | 91.3 | | |
| 8 lb " | 96.7 | | |
| Control | 100.0 | 100.0 | Control |
| Control yield (Tons/acre) | 20.8 | 16.5 | |

On the silt soil the treatments were associated with lower yields and the reductions were greater from furrow applications than from broadcasting. The yield differences between 4 or 8 lb furrow and the control were statistically significant. Slight yield reductions occurred with the high rates on the fen soil but they were not as marked as on the silt soil.

The results suggest that the rates tended to depress yield and in view of this the observed yield response in previous trials may be attributed to the nematocidal property of E.N. 18,133 and not to any side effects from the chemical.

b) Trials on eelworm-infested soil

Details of the sites are tabulated below.

Table 8. Details of 1961 Experiments

(i) Peat Fen Soil

| Site Number | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|
| Location: | Thorney, Cambs | Holme, Hunts | Farcet, Hunts | Methwold, Hythe, Norfolk | Methwold, Hythe, Norfolk |
| Date of treatment & planting: | 24th April | 18th April | 29th March | 13th April | 14th April |
| Variety: | King Edward | Majestic | Majestic | King Edward | Record |
| Fertiliser: | 10 cwt/acre 12-12-18 | 12 cwt/acre 6-15-15 | 10 cwt/acre 8-10-8 | 4 cwt/acre $K_2O$ 3 cwt/acre triple supers | 1 cwt/acre sulph. of ammonium 3 cwt/acre triple supers |
| Row width: | 28" | 30" | 28" | 28" | 30" |
| Date of emergence count: | 6th June | - - | - - | 1st June | - - |
| Previous potato crop: | 1957 | 1952 | 1955 | 1957 | 1957 |
| Mean pre-treatment count (egg/gm): | 55.3 | 42.5 | 149.3 | 106.5 | 25.8 |
| N.A.A.S. category of P.R.E. infestation: | Fairly high | Fairly high | High | High | Moderate |

## Table 8. Details of 1961 Experiments (Cont'd)

(ii) Silt Soil

| Site Number | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|
| Location: | Fosdyke, Lincs | Swineshead, Lincs | Christchurch, Cambs | Christchurch, Cambs | Kings Lynn, Norfolk |
| Date of treatment & planting: | 16th March | 28th March | 17th March | 24th March | 12th April |
| Variety: | Majestic | Majestic | Majestic | King Edward | Majestic |
| Fertiliser: | 10 cwt/acre 8-10-8 | 10 cwt/acre 8-10-8 | 10 cwt/acre 8-10-8 | 12 cwt/acre 10-10-18 | 10 cwt/acre 8-10-8 |
| Row width: | 28" | 28" | 28" | 28" | 28" |
| Date of emergence count: | 10th May | - - | - - | 24th May | - - |
| Previous potato crop: | 1957 | 1956 | 1960 (Earlies) | 1960 | 1959 |
| Mean pre-treatment count (egg/gm): | 68.7 | 74.8 | 40.8 | 76.6 | 7.3 |
| N.A.A.S. category of P.R.E. infestation: | Fairly high | Fairly high | Fairly high | Fairly high | Low |

To assess the influence of E N. 18,133 on emergence, counts of the number of shoots per plot were made at Sites 6, 9, 11 and 14. Analysis of the results showed that none of the rates tested affected the number of emerged shoots.

The results from the peat soils are given in Table 9.

## Table 9. Effect of E.N. 18,133 Granules on Yield of Ware Potatoes on Peat Soils

| Treatment (lb a.i./acre) | Yield of ware potatoes as % of control | | | | | |
|---|---|---|---|---|---|---|
| | Site 6 | Site 7 | Site 8 | Site 9 | Site 10 | Weighted Mean |
| 3 lb Furrow | 108.5 | 101.0 | 141.8 | 98.6 | 111.8 | 104.9 |
| 6 lb " | 120.8 | 104.7 | 158.2 | 101.2 | 118.5** | 109.7** |
| 6 lb Broadcast | 102.3 | 103.2 | 114.3 | 79.6 | 112.9* | 103.8 |
| 12 lb " | 105.5 | 113.8** | 123.9 | 103.1 | 121.3** | 115.0** |
| Control | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Control yield (Tons/Acre) | 3.6 | 8.5 | 3.1 | 8.5 | 7.3 | |

The nematocide exerted a response at all sites with the exception of site 9, and at sites 7 and 10 the increases were statistically significant at certain levels. The higher rates were an improvement over the lower rates for each method of application and this effect was consistently observed at all centres.

At site 8 there were apparently large responses, of the order of 50%, to furrow application, but the differences failed to reach significance. There was high variability here arising from frost damage. Severe frost in late May affected the growth of the plants at all sites and this probably is one cause of the low yields.

The use of the weighted mean instead of an arithmetic mean has been made because of the varying accuracy of the five experiments, after statistical tests had shown that the treatment effect did not differ from experiment to experiment. The means weight the more accurate experiments proportionately higher and they are largely determined from Experiments 7 and 10.

Analysis has shown that over all five experiments 6 lb furrow and 12 lb broadcast treatments have given statistically significant increases of 9.7% and 15.0% respectively.

Attempts have been made to find a relationship between eelworm population and yield increases but there was no consistent trend and responses of equal size were obtained at centres with "moderate" and "severe" categories of infestation.

The results from the silt soils are summarized in Table 10.

Table 10. Effect of E.N. 18,133 Granules on Yield of Ware Potatoes on Silt Soils

| Treatment (lb a.i./acre) | Yield of ware potatoes as % of control | | | |
|---|---|---|---|---|
| | Site 11 | Site 12 | Site 13 | Mean |
| 2 lb Furrow | 99.6 | 155.1** | 159.3 | 138.0 |
| 4 lb " | 113.5 | 150.3** | 153.4 | 139.1 |
| 4 lb Broadcast | 93.9 | 130.6** | 144.2 | 122.9 |
| 8 lb " | 98.5 | 118.0* | 148.8 | 121.8 |
| Control | 100.0 | 100.0 | 100.0 | 100.0 |
| Control yield (Tons/acre) | 7.5 | 5.0 | 4.2 (Estimated) | |

Analysis has shown that the treatment effect varies significantly from experiment to experiment and therefore the use of a weighted mean cannot be made. Experiment 12 was considerably more accurate than either 11 or 13.

At site 11 the only observed response was derived from 4 lb furrow and this was not statistically significant. There is no explanation for the general lack of response here since the plots were classified in the "fairly heavy" category of infestation. The results from site 12 are in sharp contrast to those from site 11 and all rates showed significant increases over the control. Furrow application was superior to broadcasting and the mean difference was represented by a 24% increase in yield.

The viability of the tubers planted at site 13 was low and only 49% to 67% of the tubers planted survived to produce mature plants. In an attempt to equate the plant numbers for yield estimates it has been assumed that yield was a function of the number of tubers. On this basis the yield responses obtained are of the same order as at site 12.

Increases of yield of the order of 300% were obtained with E.N. 18,133 at site 14 but the control yielded only 5 cwt of ware potatoes per acre. Symptoms of severe eelworm attack were evident on all treatments in July.

Aphid counts on the leaves were made at sites 4, 5 and 11 at intervals during June and July. E.N 18,133 was relatively ineffective on the peat fen site (No. 5), but it gave a significant reduction of aphids with 4 and 8 lb furrow treatments on the silt sites in mid-June. Differences were less marked in early July except at 8 lb furrow.

Residues of the order of 0.1 p.p.m. were found in the tubers in mid-July. No detectable residues ( $< 0.02$ p.p.m.) were found in mid-August samples.

## Discussion

The results with E.N. 18,133 in field trials in East Anglia over three seasons have shown that the yield of ware potatoes has been increased by amounts ranging from 15% to 60%. That these increases have been derived directly from the nematocidal effect of E N. 18,133 has been substantiated by two trials in eelworm-free soil where the nematocide tended to depress yields.

The extent of yield response has varied with soil type, dosage and method of application. The chemical was generally more efficient on silt soils than on peat fens, though a high application rate in 1960 on fen soil gave a substantial yield increase and the eelworm population remained at the same level as observed before cropping.

On both soil types the application of the nematocide to the furrow was superior to broadcasting. On the fen soils, a furrow application of 6 lb per acre was more effective than 3 lb. The same difference was not observed on the silt soils, 2 lb giving the same response as 4 lb.

In 1961 efforts were made to select sites with a varying population of eelworm to represent the N.A A.S. "low" to "severe" categories of infestation. Of the ten sites, 1 was "low", 1 "moderate", 6 "fairly high" and 2 "high". The results from the "low" site are not yet available. It will be seen that the majority of trials have been carried out on "fairly high" categories showing that the nematocide has been exposed to a rather thorough test of its properties.

Insufficient data is available at present to demonstrate the effect of E.N. 18,133 treatment on the eelworm population. This will be reported at a later date after examination of the samples from each site used in 1961. The 1959 and 1960 trials indicated that the post cropping populations had increased with E.N. 18,133 but that this increase was not as great as that in the untreated controls.

The yields of potatoes in the 1961 trials were comparatively low in certain instances. This was caused by a number of factors other than the effect of the nematodes. For example, at two sites there was a low percentage emergence of tubers and severe frosts in late May caused extensive damage on most of the peat fen sites. A planting distance of 18 inches in the row, regardless of seed size, was used in the majority of the trials, resulting in a low weight of seed per acre being set.

The yields from the two eelworm-free sites were very high, and more than double the best of the trials on infested soil. Neither of these sites had grown potatoes for many year, and in both cases large seed was planted. No frost damage occurred.

During 1960 a pot test was carried out to supplement the field experiments, in which potatoes were grown in John Innes compost inoculated with cysts of potato root eelworm. The best control of eelworm was given by thorough mixing of the nematocide with the soil, and was superior to the control given by placing E N. 18,133 under the tuber at planting. This suggests that the reason for the broadcast treatments of E N. 18,133 in the field being inferior to the furrow treatments was the inadequate mixing of nematocide in the soil. This conclusion is supported by the work of Staniland (1961) with fluorescent tracing materials which has shown that rotovating a dust broadcast on the surface gives an uneven mix in the top six inches of soil.

The furrow treatment has the advantage of ease of application over the broadcasting and machines will shortly be available commercially to apply granular insecticides to potatoes at planting time.

It has been shown in the field that E.N. 18,133 possesses systemic aphicidal properties but it is not clear if there is any systemic nematocidal action. Experiments are in progress to determine the mod of action and this knowledge will considerably help in devising methods of application in the field.

Further work is required to evaluate the effect of E.N. 18,133 on potatoes in soils containing "low" to "moderate" infestations of eelworm (i.e. under 39 eggs/g) in the different regions of the United Kingdom where this disease constitutes a problem.

## References

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Staniland, L.N. (1961). Plant Pathology, 10, 78.

## Acknowledgements

We wish to thank Mr. F.G W. Jones and members of the Nematology Department, Rothamsted Experimental Station, and many members of Eastern Region National Agricultural Advisory Service, particularly Mr. E. Brown, for their very valuable help with certain aspects of this work. Especial thanks are due to Mrs. C. Atkins (née Mason) formerly of the Eastern Region N.A.A.S. for carrying out the nematode counts in the 1959 trial.

The co-operation of many farmers, too numerous to mention by name, who provided the experimental sites is also gratefully acknowledged.

## DETAILS OF DISCUSSION

### SESSION I. THE EELWORM PROBLEM

Q. Mr. P. de Pietri-Tonelli.

What is the pH of the soils where the experiments have been carried out?

A. Mr. C.D. Lindley

Roughly neutral, if anything, on the alkaline side.

Mr. J.E. Peachey stated:

I would like to make the point that because we are using several poisons as nematicides it does not make impossible the study of subtle effects of kill. It is known that methylisothiocyanate has a pickling effect on eggs in treated cysts. Dichloropropene shrivels *Xiphinema* sp. in a different way from methyl isothiocyanate and dibromochloropropene appears to immobilise populations before kill takes place. Physiological studies following up these differences may lead to further advances.

Q. Mr. P. Everest-Todd

Have Messrs. Lindley and Fraser considered the value of soil incorporation of the organo-phosphorus compound by a machine such as the unit developed by Dr. J. Grainger?

A technique such as Grainger's would reduce the initial crop set-back and therefore enhance the yield response.

A. Mr. C. D. Lindley

I think it well might. We have given some thought to this use of the machine. Our thoughts are that it is a fairly costly machine, it is a fairly difficult machine to operate. It is necessary, I think, to keep the method of treatment as simple as possible and that is why we have been so interested in the possibility of putting material in the furrow. The other thing is to keep the rate of application down as low as possible and the results show that with broadcast application the rate would have to be probably in the region of 8 lb active per acre, whereas with furrow application a rate somewhere around 2 or 4 would appear to be sufficient. What we really need to do is to get local mixing in a band in the furrow and see whether it is possible to do this. It is something we are going to look at.

Q. Mr. T. E T. Trought

Would the mammalian toxicity of E. N. 18, 133 affect its use in agriculture?

A. Mr. C. D. Lindley

It looks pretty horrible 12 mg/kg acute oral toxicity. As I explained, we have been using granular formulations and it is known that granular formulations of toxic compounds are very much safer to handle because the risk of dermal absorption is reduced. If there is a need for this type of chemical I think operators would be prepared to wear a small amount of protective clothing to apply it.

# INSECTICIDES, FUNGICIDES AND THE SOIL

A review of a symposium held on 28th February 1961 to discuss the effects of chemicals on soil-inhabiting organisms and other aspects of such treatments

By Hubert Martin

The ecological complexities of the soil flora and fauna are a sufficient excuse for our comparative ignorance of the consequences of any modification of the soil, whether by cultivation or, in the present case, the application of pesticides. Rarely has research on this subject got beyond descriptional stages and the interpretation of the results has given rise more to polemics than to further experiment. Consider, for example, the decades of discussion on reasons for the beneficial effects of partial sterilisation on crop growth, or the controversies over the role of antibiotics in soil ecology. Each new addition to the list of chemicals applied as pesticides to soil brings its problems, some specific to the chemical but most involving the whole ecological complex. Hence why ABMAC organised, on February 28th, 1961, a symposium to which some forty-five workers in the subject were invited.

The morning session was devoted mainly to the uses and consequences of the use of chlorinated hydrocarbons against root pests, in particular, root fly control. Dieldrin, for instance, is nowadays widely used for carrot fly control; H. C. Gough estimated that over half of the larger carrot growers followed the practice. Another extensive use is on potato and surveys by the Potato Marketing Board in association with the Plant Pathology Laboratory have revealed that, in 1957, about a quarter of the potato acreage is aldrin-treated for the control of wireworm. Apparently there is needless concern for the surveys found that wireworm infestation is significant on only about 5 per cent of the potato acreage.

Intensive work on the fate and action of aldrin, dieldrin and lindane in soils has been carried out, since 1955, at the National Vegetable Research Station. D. W. Wright, of that Station, reviewed the results on the persistence of these chemicals in fen and mineral soils. Persistence was assessed by the degree of carrot fly control obtained in the years following the incorporation of the insecticide by rotovation of the top four inches of soil; the plots were ploughed to eight-inch depth in succeeding years. Lindane, applied at $\frac{3}{4}$ lb/acre to medium loam soil at Wellesbourne, gave a partial control in the second and third year but none in the fourth year after application, though, at 2 lb/acre, a partial control was obtained in the fifth year. In fen soil at Mepal, Isle of Ely, the 2 lb/acre application gave partial control in the second year but none in the third year after application, though at 4 lb/acre effects persisted for four years. Aldrin and dieldrin persisted in the soil for much longer for the 4 lb/acre aldrin application gave complete control for six years in the Wellesbourne soil. In the fen soil, aldrin at 2 lb/acre gave no control in the third year but the higher rate of 4 lb/acre persisted for over five years and partial control was shown in the fifth year. Dieldrin has a similar persistence for, at Wellesbourne, complete control was still obtained in the fifth year following application at 2 lb/acre and, at Mepal, a high level of control was obtained five years after a like application.

G.A. Wheatley, of Wellesbourne, has examined the persistence of these insecticides, used for the control of lettuce root aphid, by a bioassay technique using Drosophila melanogaster as test subject. A sandy loam soil treated with 1, 2 and 3 lb/acre was estimated to have retained 0.48, 1.1 and 1.9 lb/acre respectively after four years - about two-thirds in the case of the 3 lb/acre application. Similarly, a block of soil treated, in April 1956, with 2 and 4 lb/acre dieldrin apparently retained 1.4 and 2.3 lb/acre respectively in January 1960.

The results obtained at Wellesbourne confirmed the conclusions of American work that soil residues of these insecticides tend to an exponential decay and Wheatley gave estimates of their half-life based on the Wellesbourne work. That of dieldrin in black fen soil is 5 - 7 years, and, in sandy loam, 3.5 - 4.5 years. In the latter soil, both aldrin and heptachlor have half-lives of 3 - 4 years, endrin 2. - 2.5 years. On the basis of carrot fly control, the half-life of lindane in sandy loam is 2 - 3 years whereas that of DDT, based on analyses by Dr. J. T. Martin of the Wellesbourne soil, is 4 - 5 years. The apparent anamoly of the greater half-life of dieldrin in the fen soil and its lesser persistence as judged by carrot fly control is explainable if the insecticide is immobilised by adsorption or solution in soil lipids.

The practical implications of this work are at once apparent. The annual application of dieldrin at the rate of 1 lb/acre should lead to a maximum residue of 2.5 lb/acre over the years. Hence the amount of dieldrin applied for carrot fly control should be reduced on a sliding scale after the first year (see Plant Pathology, 1960, 9, 146). Wright estimated that the ideal half-life of a soil insecticide was about 100 days in the absence of any method of reducing the persistence of compounds of longer half-life. S. E. Jacobs was not hopeful of the selection of soil organisms able to metabolise these highly chlorinated compounds.

The use of bioassay techniques for the assessment of these insecticides in soil is indicative of the lack of suitable methods of residue analysis. This deficiency has, in part at least, been made good by the development of methods based on gas-liquid chromatography. J. G. Reynolds, of the Woodstock Agricultural Research Centre, described the technique employed for the detection and determination of the chlorinated hydrocarbons in soil. He discussed the advantages and limitations of the argon ionization and electron capture techniques. The latter is especially suitable for it has permitted the determination of amounts of aldrin and dieldrin less than 0.1 p.p.m. without the need for any time-consuming "clean-up" processes.

The wide use and high persistence of the chlorinated hydrocarbons has already created the experimental problem of finding suitable untreated areas for critical work on the responses of the soil flora and fauna to insecticide treatment. The effects of aldrin and DDT treatments on soil fauna were reported on by C. A. Edwards and E. B. Dennis from plots treated with 3 cwt 1.25% aldrin dust or 2 cwt 5% DDT dust per acre. The soil organisms were extracted with a modified Salt and Hollick apparatus and an initial decrease in numbers was found with all groups examined, a result of cultivation from which recovery took about three months. Both insecticide treatments led to a fall in the number of Acarina. Collembola became scarce in the aldrin-treated soil but increased in number in the DDT-treated plots to a maximum nine months after treatment, after which numbers fell to a level slightly above that of the untreated plots. Dipterous and coleopterous larvae and pupae, thrips and symphilids were markedly suppressed by both treatments, root aphid numbers were sharply reduced by aldrin but not by DDT. Neither insecticide affected the numbers of parasitic nematodes, earthworms or enchytraeid worms.

These results are in general agreement with those of earlier work reported by J. G. Sheals, now of the British Museum. He had found a marked reduction of the saprophagous species by either DDT or BHC treatment and was concerned by the possibility of adverse effects on soil fertility which might result. He confirmed that DDT treatment caused an increase in collembola, though BHC had the opposite effect, and considered that this increase was due to a reduction of predatory species including mites.

T. H. Coaker spoke on the specific problem of the effects of predators on the survival of the cabbage root fly. The natural mortality of the fly at Wellesbourne was estimated to be as high as 95 per cent and about 60 per cent of this natural control was thought to be egg loss due to predatory beetles. Serological tests indicated that about fifteen species of beetle were responsible for the inverse correlation, observed over the three years of experiment, between egg survivors and beetle density. The application of insecticides at rates rather lower than required to control cabbage root fly has resulted in predator mortality to a degree which makes likely serious pest damage to brassica grown on land containing insecticide residues.

The long use of Bordeaux mixture for the control of apple scab in the Wisbech area provided F. Raw, of Rothamsted, with rich experimental material for the study of the effects of this practice on the earthworm population. In most other apple orchards this population is of the order of 2-3,000 lb fresh weight per acre; in two Wisbech orchards the only earthworms found were a few Lumbricus castaneus representing a population of only a few lb/acre. These orchards had received, over the period 1926-57, about 430 lb copper per acre, of which about 300 lb/acre had been applied since the orchards were grassed down in 1945-6. Analysis revealed about 2,000 p.p.m. copper in the surface mat, about 200 p.p.m. in the top two inches of soil and, below that, about 30 p.p.m. copper. The leaf litter decomposes slowly and the soil profile had developed typical "mor" characteristics. This drastic change in earthworm population and soil properties had had no apparent effect on apple yield but no answer was possible to the question of the effect of copper buildup on infection by Gloeosporium.

The general problems arising through the use of soil nematicides were discussed by J.E Peachey of Rothamsted. He described the various ways of assessing nematode control and referred to the increase in yield which often follows treatment both in the absence of nematodes and when no effect on the nematode population was apparent. R.S. Pitcher, of East Malling, made special reference to the "replant" problem which arises through the frequent failure of stone fruit, in particular peaches, to thrive in soil previously planted to stone fruit, a failure not seen on soil previously bearing pip fruit. The deleterious effect was overcome by heat treatment or the use of nematicides such as DD mixture even in the absence of nematodes or other pathogens. That virus was not responsible had been shown by the normal growth of affected trees when transferred to normal soil. A likely explanation is that residues of the previous planting gave rise to substances inhibitory to the growth of the young replants.

Contrasts between the biological activities of the dithiocarbamates, metham-sodium and nabam, were brought out in the discussion of a contribution by D. Tyson of Pan Britannica Industries Ltd. Nabam is used mainly as a soil fungicide but its use is reported to increase eelworm attack; metham-sodium is used as a nematicide but virus infection is increased, sometimes doubled, in tomatoes grown in the treated soil. The following explanations were offered; nabam is a good general fungicide and may kill fungi predaceous on eelworms; metham-sodium is a more specific fungicide which may, by delaying the breakdown of plant residues, prolong exposure to the virus. On the other hand, nabam may so improve root growth that the chance of eelworm attack is increased. None of these explanations is satisfying, nor was any explanation forthcoming of the control of "docking" disease by DD mixture but the etiology of this disease is still unknown. The complexity of these problems was emphasised by W. H. Read, of the Glasshouse Crops Research Institute, where he had developed methods, both laboratory and field, for the estimation of methyl isothiocyanate, the effective nematicide and phytocide produced in soil from metham-sodium. The laboratory method is sensitive to as low as 0.02 p.p.m.

J. Grainger, of the West of Scotland Agricultural College, stressed the importance of intimate distribution in the effective use of a soil pesticide and gave an account of the appliances he had tested and the results he had obtained in the particular case of the use of yellow oxide of mercury for the control of potato root eelworm. He had found that successful control was dependent on the initial pest population which, if too high, defied success by a single application. In the case of his Auchincruive trials, the critical figure for potato root eelworm was 1.2 cysts per gram of soil; for club root, a population producing about 40 per cent disease on untreated soil. High populations can be reduced to treatable level by consecutive applications.

The thesis that the success of a soil pesticide is due indirectly to biological control was first developed by the late D.E. Bliss on the basis of his work on the control of <u>Armillaria mellea</u> by soil fumigation with carbon disulphide. He considered that the <u>Armillaria</u> was killed, not by the fumigant, but by the action of the soil fungus Trichoderma viride which becomes dominant in the treated soil. S.E. Garrett, of Cambridge, had re-examined Bliss's work and concluded that he had underestimated the fungicidal action of carbon disulphide. For instance, Garrett found that the dosage of fungicide needed to produce a dominance of T. viride in soil is four times that needed to kill A. mellea in small woody inocula. Nevertheless it is likely that T. viride can supplement the direct action of the fungicide and advantage may well be taken, in soil fumigation, of the high growth rate of this fungus which enables it to overtake in recolonization the more numerous surviving propagules of those fungi, chiefly Aspergilli and Penicillia, that have a higher degree of fumigant tolerance but are slower growers. He pointed out that proposals to combat soil pathogens by direct soil inoculation with antagonistic fungi were doomed to failure for the soil is a most selective habitat which must first be rendered suitable for the survival of the biological control agent. This contention was reinforced by E. Evans, of Chesterford Park Research Station, who outlined studies on the influence of formaldehyde on soil bacteria which he and his wife had made at Cambridge. T. viride again appeared as the most tolerant fungus and, among bacteria, species of Anthrobacter were the most resistant. Strains of both of these organisms were capable, in pure culture, of decomposing and perhaps utilizing formaldehyde. But in addition to the changed pattern of the soil flora brought about by formalin treatment, there was an improvement in nutritional status generally associated with an increased ammonia content. The Evans had found that this increase could be detected long before any increase in bacterial population, an observation which indicates that the phenomenon is of chemical rather than biological origin.

S.E. Jacobs, of the Imperial College, spoke briefly of the remarkable ability of bacteria to break down a wide range of exotic chemicals added, in small amount, to soil. Unfortunately, as had been emphasized earlier in the symposium, many soil pesticides were highly chlorinated and defy bacterial decomposition. The paradox that bacteria can attack compounds in the soil which would kill them in vitro is perhaps explained by the sorption of the toxicant by soil particles; generally speaking basic compounds were more strongly absorbed than neutral or acidic compounds. Some of his results gave support to the suggestion that, although killed, organisms can release enzymes capable of catalyzing the breakdown of certain compounds.

In answer to a specific request, C. Potter, of Rothamsted, gave an account of the changes in flavour produced in potatoes by soil treatment with chlorinated hydrocarbons. This work, sponsored by the Agricultural Improvement Council, was carried out at the Gleadthorpe, High Mowthorpe and Rosemaund Experimental Husbandry Farms and organoleptic tests were carried out under the direction of J.M. Harries of M.A.F.F. The insecticides were applied in the first year and their effects examined in that and the two following years. The rotations used were potatoes in all three years, cereals in the first year followed twice by potatoes, cereals for the first two years and then potatoes. The soils were a light sand, a calcereous loam and a heavy clay. Aldrin, at 4 lb/acre, gave no change in flavour in any test; dieldrin, at 4 lb/acre, produced a slight, not unpleasant, change in the crop from the light sand; lindane, at $\frac{3}{4}$ and $1\frac{1}{2}$ lb/acre, produced unpleasant flavours under nearly all conditions.

# FUNGICIDE SEED DRESSINGS

by Mary J. M. Noble,

Department of Agriculture and Fisheries for Scotland

In speaking of the control of soil-borne diseases of agricultural crops by the use of seed dressings, I would like to begin by attempting some definitions. First of all I have often protested against the use of the word 'dressings' in circumstances where 'treatment' is the more appropriate one but this time I have to speak about 'dressings' so I shall try to keep myself to that subject as I understand it and would like to define it. Again, I think now that I may be defined as a Seed Pathologist, that is one who studies all diseases transmitted by seeds and all injuries and diseases of the seed itself. It appears therefore that what you are about to hear is a dissertation upon seed dressings by a Seed Pathologist but may I first discuss this question of dressings as against treatment. The term 'dressing' means different things to different people dealing with different crops in different parts of the country! When potatoes are dressed out of the clamp or pit the operation consists of grading for size and removing the damaged and diseased onces and there is usually no question at all of chemical treatment. In the new Seeds Regulations, in fact, the terms 'dressing' and 'treating' for seed potatoes are used quite separately. Similarly in Scotland the term 'granary dressed' can be applied to cereal seed which has been sized or graded, had impurities removed, sometimes been polished mechanically, sometimes even has had its colour changed chemically, but it may have had no treatment or chemical dressing applied to it and there is the point where I think my objection is valid. Treatment and dressing are used as if they were synonymous and seed described as "granary dressed" has been given a second dose in England with resulting danger of phytotoxicity not perhaps so much when straight mercury is used each time but when the combined insecticide fungicide treatments are involved. Yet another point is that treated seed arriving in Scotland from "abroad" has been re-treated before sowing because the farmer considered it has not been "dressed" sufficiently. At least we who are present here should understand when seed is being treated to disinfect it and when a chemical is applied to seed to protect it from soil-borne fungi, from insects and other organisms entering through damaged seed. I know it's sometimes difficult and perhaps impracticable always to use the words in these rather restricted senses but I think we should at least try, and in saying this I have in mind recent press releases on seed "dressings", whereas in the new Seeds Regulations the operative word is "treated". Perhaps you'll say this is all too pedantic but we Scots are pedantic and I was assured by a recent visitor from Canada that I would be quite "in step" over there!

Now to get down to my title then. Let's seek for some good example of soil-borne diseases controlled by seed dressings and discuss them. In our common cereals it is usually considered that seed dressing does control both soil and seed-borne organisms. In the last year or two, however, I have come to doubt very much if many soil-borne fungus disease of our common cereals are controlled either by seed dressing or by treatment. I expect some of you are thinking now, "what about Fusarium Foot Rot"? A few years ago we in Scotland carried out a survey of the seed in samples passing in commercial trade circles. We tested them not only in the laboratory, but in the field to determine the exact cause of some of the diseases such as foot rot, leaf spot, etc. We were surprised to find a very high proportion of seed infected with Fusarium nivale, commonly known as the snow mould, and recognised in countries such as Finland and Sweden as a major cause of foot rotting in most of the cereals but scarcely recorded in Britain. We hadn't realised until then that this fungus was so common in seed and when we isolated from some brown foot rot plants in the field we again found F.nivale. Sometimes other species were present as well but the evidence indicated that in Scotland these are quite often secondary invaders which come along after F.nivale has caused the rot. One of these, F. culmorum, has been described by Chesters and Parkinson as a normal inhabitant of the soil around the roots of oat plants, only becoming active as the plants die off. However, Jamalainen in Finland has found that seed dressed with mercury and thiram is protected against F.nivale. What do we know of F.nivale as a soil-borne organism in the United Kingdom? I would suggest that, as a parasite of oats, wheat and barley, this fungus should be more closely studied in this country especially its relationship to soil-inhabiting Fusarium spp.

There is, however, one cereal now grown here which provides a good example of control of soil-borne disease by seed dressings. Maize is now grown extensively in England and there's some in Scotland. I've no personal experience of this crop but the exchange of views with my colleagues, especially in America, and a study of the literature, shows that of all the cereals the seed coat of maize can be most frequently cracked and broken. Now if this seed is sown without a protectant it will almost invariably fail but with a protectant such as thiram or captan, or a mixture, excellent control is obtained so that the cracked seed is just as good as seed with a complete testa. This does not seem to apply in the case of wheat and oats and barley. In these cereals the cracked seed coat seems to allow other fungi to penetrate before the protectant can really become effective but we've discussed often enough before the question of micro-cracking in wheat and in barley and I think we are all quite well aware of these literally hidden dangers.

Peas are now grown as an agricultural crop in both England and Scotland. There is still a bit of damping-off and here the use of protectant is definitely good practice. Thiram and spergon are both effective but now we have another factor coming in because thiram has proved also to control seed-borne Ascochyta disease; something which I for one had not suspected. Another very big problem, of course, in peas is the question of seed weakness. This may be a question of age, of harvesting damage or, as we have recently recognised, a condition called "hollow heart" which results in rather weakened seedlings. Now, if this rather weak seed is sown under ideal conditions it will do perfectly well but in Scotland at least, and I understand in some of the eastern England areas such as Cambridge, the soil conditions in early spring at sowing time may be anything but ideal and here a protectant such as thiram gives very good results apart from its disinfecting action on the seed. Peas in the field are also attacked by Fusarium sp. from the soil as well as fungi such as Pythium, the frequent cause of "damping-off", and protective dressing certainly reduces this risk. There is, of course, another classic example of a soil-borne disease controlled by seed dressings, that is the white rot of onions caused by Sclerotium cepivorum where a paste applied to the seed goes into the soil, acts as a local sterilant and wards off the fungus but that's from the horticultural field so we'd better leave it aside and conclude that in fact there are not nearly so many good examples of the control of soil-borne fungus diseases by seed dressings as you might think!

These observations I have so far made apply equally to the liquids and the dusts in the mercurial range. I understand from my chemical friends, of course, that once the mercurials reach the soil they break down fairly quickly so this protective effect of seed dressings is usually accepted to be in fact local sterilisation of the soil around the seed. If I might mention a few more points about the liquids as against the dust treatments, as we have found them in our work and without prejudice; the close adherence of the liquids as against the dusts is quite important. Once that liquid treatment is put on it is there to stay and the appearance of the seed is definitely better. There is a shine on seed treated with a mist or liquid as against the rather dusty look when it is treated with powder. The presence of the dye which so clearly indicates that the seed has had chemical treatment is a good thing, whereas the original powder disinfectants were usually made to blend with the seed because farmers apparently did not want a conspicuous label on the seed to the effect that it had been treated. However, as you know, you cannot wash off this treatment so that the practice which exists, at least in theory, of washing off the mercury from unwanted seed and then using it for feeding stuffs is out! A curious thing, however, is that I've never come across any merchant who definitely does wash off the mercury when it is in the powder form. I have a shrewd suspicion that one just "takes a chance", mixes a lot of untreated seed with a little of the treated and hopes that no harm will be done and probably in most cases it's not done. Last year when there was a good deal of talk about the killing of birds by certain poisonous seed treatments we were sent one sample of the "seed" which had caused trouble. Our report was that if anyone was using this as seed they were wasting good soil because it was a mixture of cereals and broken grain. It also included some which had been treated with a liquid mercurial, at least it had the red dye and therefore, of course, should not have been in any feeding stuff at all. We heard no more about that case.

Now I have been dealing with seed in this context as if it were a launching vehicle for the chemical which probably is fair enough but a rocket launching vehicle may properly be expendable in fulfilling its function. Seed must not be destroyed in this way or even injured because it is the source of food for the seedling. Not only that, it is the source of the complex enzyme system governing its growth and I wonder just how much we know about the effect of chemical treatment on that, let alone the interaction of beneficial organisms as well as harmful organisms which are naturally present in and on the seed and the seedlings. It was shown a few years ago that the fungus Chaetomium, generally regarded as an insignificant saprophyte on cereal seed, is a natural antibiotic against Fusarium nivale which I mentioned earlier as a primary parasite. Chaetomium globosum had also proved to be antagonistic to the very serious disease of oats in America caused by Helminthosporium victoriae. Compared with our knowledge of the interaction of beneficial and other organisms present in the soil I think we know too little yet about these on seed and seedlings. Toxins developed by the parasites and antibiotics by seedlings are also part of this picture. Ludwig and his co-workers, for instance, found that an aqueous extract of young oat coleoptiles has high anti-fungal activity and that this disappears with age. Sometimes, to treat seed correctly we need accurate knowledge not only of the crop concerned but the particular lot or parcel of seed and you might even have to know the soil conditions into which it is to be sown. In this connection the observations made by Gibson in Tanganyika and Purss in Queensland on crown rot of groundnuts are significant. Gibson found that crown rot could be reduced by 50% using thiram on the seed where mercury failed not because of phytotoxicity but because of the selective action of mercury on the flora of the soil. Mercury-tolerant strains of the parasitic fungus were present and able to attack more effectively because of suppression of other soil-borne fungi. Again Purss in Queensland found that under certain conditions organomercurials actually increased the incidence of crown rot caused by Aspergillus niger. Here then is "local sterilisation" working in the wrong way. However, taking pre-emergence rot into account the organo-mercurials and captan gave most consistently good results so a combination is now used to give control both over pre-emergence rot and crown rot. Another similar interesting observation made by my colleague in Edinburgh, Hughes, is that dieldrin stimulates brassica seedlings so that they can be grown in soil infected with club root and although diseased yet give quite a good crop not so much because of the control of the disease but because of stimulation by the dieldrin. Again Roth, in Germany, working with beet found that mercury had a stimulatory effect apart from disease control. Concerning the practise of using the seed simply to carry chemicals into the soil I've sometimes wondered if a pellet of some inert substance or even dead seed carrying the fungicide or insecticide would not be a practicable method of getting them into the soil very near the living seed but without using the seed itself as the launching vehicle.

I referred to myself in the first instance as a Seed Pathologist and I am sorry to say that there are still so very, very few of us studying seed pathology in this country while there is so much to find out. The rate of progress in our study in Great Britain I'm afraid I can only call 'dead slow'. On the home front in the new Seeds Regulations we've managed to introduce one seed-borne disease of one horticultural crop. I understand, of course, that there are many administrative difficulties but we in this country had better hurry up if we are to keep pace with international progress. I was recently in Paris at the Fourth International Meeting organised by the International Seed Testing Association's Plant disease Committee. We are studying methods of assessing the sowing value of seed, treated and untreated, in laboratory, glasshouse and field tests; work of considerable interest to all of you who are involved in the development and official approval of crop protection products. I know that in the very big screening programmes which you in the commercial world have to carry out you must restrict the number of your "guinea-pig" diseases and crops, but I would plead that you should not just use one sample of seed for this work and perhaps even just one disease. There are many seed-borne diseases still waiting for effective control. Of course through the new approval scheme which is a very great improvement on the original one, there will be opportunity for much wider testing of the new chemicals and it is through members of A. B. M. A. C. supporting the scheme and working with the advisory and official services such as the seed testing stations that we will eventually, and I hope a bit more quickly, come to a better understanding of the problems not only of those soil-borne diseases which may be controlled by seed dressings but of seed pathology.

# INSECTICIDAL SEED DRESSINGS AND SOIL INSECTICIDES

by M.J. Way

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In 1945 Gough's classical review on soil insecticides was published in which the need for good soil insecticides was contrasted with the ineffectiveness or unreliability of existing chemicals. The 144 pages of the review included one paragraph on the use of calomel seed dressings against the onion fly, Delia antiqua (Wright, 1938, 1939) which at the time was the only evidence of insect control by seed dressings. Gough's survey makes interesting comparison with the present position (Lilly, 1956; Lange, 1959; Reynolds, 1958; Way 1959). Thus, in 1958 about 2 out of the 9 million acres of arable crops in Great Britain received insecticidal seed dressings, greatly exceeding the combined acreage of crops treated by all other methods of application. Furthermore, insecticides applied to the soil and to seeds are not only being widely used against many species of soil insects but some which act systemically are proving invaluable against insects attacking the aerial parts of plants.

These recent developments were initiated by Jameson, Thomas and Woodward's discovery (1947) that γ BHC seed dressings and soil insecticides could protect the young cereal plant from wireworm attack. γ BHC and other chlorinated hydrocarbons, notably aldrin, dieldrin and heptachlor have since proved outstanding against many other soil insect species whereas organophosphorus insecticides such as phorate, thiodemeton, dimethoate and menazon are being used as systemics against leaf and shoot feeders. The practical use of systemically acting soil insecticides is a comparatively recent development which has followed rather slowly from the original laboratory and field demonstrations of their efficiency and of their advantages over normal foliar applications for protecting the shoot of the young plant which is particularly vulnerable to insects and to insect transmitted diseases (Schrader, 1951; Ivy, Iglinsky & Rainwater, 1950; Ripper, Greenslade & Hartley, 1950; Jancke, 1951; David & Gardiner, 1951; Ashdown & Cordner, 1952; Way & Needham, 1957).

I will use the term seed dressing to include any pre-sowing application of dust or liquid insecticides to the outside of the seed. This includes soaking the seed in liquids as well as applying liquids as mists, sprays, large drops or slurries. Seed treatment should be regarded as a special method of applying a soil insecticide (Gough & Woods, 1954) though there are important differences. Besides being easy to apply, seed dressings are obviously well placed to protect the germinating seed and the young seedling plant. Thus, newly hatched larvae of the onion fly, (Delia antiqua) invariably enter the base of the shoot close to the position of the treated seed so that almost all are killed by contact with the seed dressing before they reach the plant (Way, 1959a). Similarly, against wheat bulb fly (Leptohylemyia coarctata) aldrin, dieldrin and heptachlor dressings at 3 oz active ingredient/acre can control the newly hatched larvae better than aldrin or dieldrin combine;drilled with the seed at 24 oz/acre (Bardner, 1959); also for systemic action, seed dressings are immediately absorbed by the germinating seed or through the newly emerged root (David & Gardiner, 1955: Way, 1959a) in time to protect the emerging shoot, whereas a conventional soil application may sometimes fail to protect during the time taken for the roots to reach the insecticide in the soil (c./f. Burt, Broadbent & Heathcote, 1960).

The third advantage of seed dressings is the minute doses required for effective control. In the U.S A. 0.0062 mg of $\gamma$ BHC per cereal seed (about $\frac{1}{4}$ oz per acre) is effective against wireworms (Lange, 1959) and rates as low as 1/100 oz per acre are apparently effective with other crops sown at lower seed rates. In Britain, Carden (1960) recommends dieldrin seed dressings at 3 oz on 6 lb seed per acre or about 0.1 mg per seed against the onion fly. This makes interesting comparison with recommended rates of dieldrin for wheat bulb fly control - about 3 oz dieldrin on 150 lb seed per acre or about 0.07 mg per seed. In view of the importance of the relationship between the insecticide and the seed it would seem that the common practice of giving the amount of insecticide as weight per weight of seed or as weight per acre is a less useful criterion of efficiency than weight per seed.

Seed dressing rates of 0.25 - 3 oz active ingredient per acre contrast with rates of 1 - 2 lb per acre required for control by conventional soil insecticides. Consequently seed dressings are cheap and, as they are so easily applied, it is not surprising that they have been widely used as a routine treatment.

Further advantages of seed dressings follow from the minute amounts needed for effective control. Thus there is no evidence that they do harm to beneficial insects unlike broadcast applications which can enhance Cabbage Root Fly (Erioschia brassicae) damage by killing its egg predators (Wright, Hughes & Worrell, 1960). Conventional soil insecticides may also cause notable changes in the general soil fauna (Satchell, 1955; Bollen, Morrison & Crowell, 1954; Sheals, 1956; Sanger, 1960), though there is little evidence that the induced changes in populations of Collembola, mites, earthworms and micro-organisms are harmful. On the contrary, they sometimes appear to stimulate growth (Zaki & Reynolds, 1961) I have noticed this with combine drilled treatments of dieldrin on wheat and of phorate and thiodemeton on field beans. There is also recent evidence that aldrin in pot experiments can affect the incidence of the soil borne disease of wheat Ophiobolus graminis. These subtle effects of seed dressings and soil insecticides have not been studied adequately nor has sufficient attention been paid to Ripper's (1956, 1957) important conclusions that both seed and soil applications of some systemic insecticides may do insignificant harm to natural enemies of insects attacking the aerial parts of plants in contrast to their effects as foliar sprays and I wish to exphasise the potential value of this type of selective action which for rational pest control is in general more realistic than the development of chemicals which are intrinsically highly selective.

Returning to seed dressings, the minute doses do not leave harmful residues or cause off-flavours in contrast to conventional soil applications of some insecticides which may persist too long and accumulate in the soil and in plants (Reynolds, 1958; McPhee, Chisholm & MacEachern, 1960; Lichtenstein, 1959a, 1959b; Lichtenstein & Polivka, 1959). For example, in Britain dieldrin at recommended rates for carrot fly (Psila rosae) control can accumulate in soil to levels which cause off-flavours, though Wheatley, Wright & Hardman (1960) have shown that this can be avoided by relating the amount of re-treatment to existing residues to maintain a level of about $1\frac{1}{2}$ lbs/acre which is adequate for carrot fly control. However, the insecticide pressure from soil residues which have been shown to remain toxic for many years to insects such as the carrot fly, flea beetles (Morrison & Crowell, 1959) and ants (Durr, Joubert & Walters, 1955) also favours the development of strains resistant to certain insecticides as has already happened with carrot fly and onion fly in parts of North America (Howitt & Cole, 1959; Finlayson, Crowell, Howitt, Scott & Wade, 1959). Insecticidal seed dressings would not favour the development of resistance in this way.

Unfortunately the valuable properties of seed dressings - ease of application, economy of use, lack of harm to beneficial organisms and no residue problems are offset by disadvantages. First, many are liable to be phytotoxic at much lower rates than would be harmful if applied as conventional soil insecticides. Phytotoxicity is enhanced by factors such as high storage temperature, moisture content and poor quality of seed which can however be alleviated. It also depends on the plant species; brassicae, for example, are relatively unaffected perhaps because the insecticides do not penetrate directly into the seed as shown by Bardner (priv. comm.) with phorate seed dressings on mustard seed. In contrast phorate readily penetrates seeds of wheat, which is much more susceptible. The nature of the seed dressing also affects phytotoxicity (May & Needham, 1957) and there is promising evidence that seed dressing carriers such as activated charcoal and stickers such as polyvinyl acetate can release the insecticide relatively slowly thereby lessening phytotoxicity and enhancing persistant action especially of systemic insecticides (Bardner, 1960).

Furthermore, some insecticides are comparatively non-phytotoxic - dieldrin for example - and although the doses of phosphorus insecticides that can be used have hitherto been limited by their phytotoxicity, it is a good omen that at any rate one new systemic - menazon - developed for aphid control appears virtually harmless to many plants. For example - seed dressings of active ingredient amounting to over 20% of the weight of the seed were harmless to field beans compared with some other systemic phosphorus insecticides which affected plant growth at under 0.1% of seed weight (Way, unpub.).

Another disadvantage of some chlorinated hydrocarbon insecticides is their harm to birds feeding on dressed cereal seed after drilling. Unfortunately this has been enhanced by widespread routine application regardless of pest incidence. In 1958, for example, about three-quarters of the 2 million acres in Great Britain were sown with insecticide dressed seed. This problem should be solved not by restrictive legislation but rather by more accurate means of predicting damage so that insecticides are used only when necessary, and perhaps by the search for suitable bird repellents incorporated in the seed dressing.

I am not suggesting that seed dressings are always likely to be more effective for controlling insects than other methods of soil application. Seed dressings and soil insecticides may be best when used together as Dunn, (1960) has shown with endrin for lettuce root aphid, Pemphigus bursarius, control; also, although seed dressings will be increasingly used to give prolonged protection - for example, field beans can be protected from aphids throughout the season by a menazon seed dressing (Way, unpub.) - they may not always be placed in the best position for prolonged systemic action. Thus Burt, Broadbent & Heathcote (1960) showed that phorate combine drilled with the fertiliser, protected potatoes from aphids better and for longer than the same amount placed under the "seed" tuber. This is perhaps because lasting protection depends on continued uptake by roots, the absorbing region of which may sometimes grow beyond the area of the treated seed (Way & Needham, 1957) and also becomes concentrated where the fertiliser is placed (Cooke, 1954).

This kind of evidence emphasises our lack of the information on modes of action of seed dressings and soil insecticides which is needed if they are to be used to the best advantage. We do not know why, for instance, the highly toxic phosphorus insecticides such as phorate and thiodemeton have, with few exceptions (Jepson & Mathias, 1960) proved ineffective against soil insects; also little is known about how seed dressings affect wireworms despite over twelve years of use. Wireworms attacking the ungerminated or newly germinated seed may be killed by the insecticide on the seed (Lange, Carlson & Leech, 1949; Kulash & Monroe, 1954; Starks & Lilly, 1955; Long & Lilly, 1958) but in the older plant wireworms attack the shoot, not the seed and although not always killed by a seed dressing they may be deterred presumably by the insecticide acting systematically in the shoot. This is suggested by the results of experiments by Potter, Healy & Raw (1956). 1.2 oz of $\gamma$ BHC per acre applied as a seed dressing was compared with soil treatments when the insecticide was combine drilled with the seed at 6 oz $\gamma$ BHC and broadcast at 1 lb $\gamma$ BHC per acre on plots of wheat drilled in November. Next year the plots were redrilled without further treatment. Results in table 1 show that although in the first year the seed dressing gave a good response in yield it did not kill the wireworms which severely damaged the subsequent untreated crop.

Wireworms, which occur in overlapping generations and may each spend five years in the soil feeding on many different plant species before pupating, contrast with soil inhabiting larval Anthomyidae and Chloropidae (Diptera) which are mostly specific in their choice of host plants, usually appear only after the host is planted and develop from egg to pupa in 2 - 8 weeks. Unlike wireworms they would soon die of starvation if deterred by an insecticidal seed dressing, so that kill by "contact-action" could be either direct or indirect through starvation.

Table 1. Comparison of Different Soil Applications of γ BHC for Wireworm Control. (Potter, Healy & Raw, 1956)

| | | 1st year | 2nd year | |
|---|---|---|---|---|
| Method of application | Dose per acre | Crop yield/ cwt per acre | Crop yield/ cwt per acre | Log. no. of wireworms per plot |
| Seed dressing | 1.2 oz | 24.0 | 24.2 | 3.73 |
| Combine drilled | 6 oz | 24.8 | 37.3 | 2.2 |
| Broadcast | 1 lb | 30.6 | 39.6 | 1.33 |
| Untreated | - | 8.9 | 28.4 | 3.3 |

Three species of Diptera, the onion fly, *Delia antiqua*, the wheat bulb fly, *Leptohylemyia coarctata* and the frit fly, *Oscinella frit* have larvae which mainly feed inside the underground parts of the shoot of seedling ionions, wheat and oats respectively. They damage or destroy the growing point and kill or stunt the plants and provide an interesting series illustrating the ways in which seed dressings act (or fail to act) against soil insects.

I have already mentioned that the newly hatched onion fly larvae burrows down through the soil to the underside of the onion shoot where it almost invariably enters close to the position of the treated seed. This happens even if the seed is deeply sown and thus, regardless of sowing depth, a suitable seed dressing will give virtually complete kill by contact action before the larva reaches the plant. For example, Table 2 shows that 0.04 mg dieldrin per seed gave almost complete protection to onions from treated seed sown at both $\frac{1}{4}$ and 1 in.

Table 2. The Effect of Sowing Depth on the Action of Insecticidal Seed Dressings Against Three Species of Dipterous Larvae

| Insect species | Insecticide and dose per seed (mg) | Depth of sowing (in.) | *Damaged plants | *Living larvae |
|---|---|---|---|---|
| Onion Fly | Dieldrin (0.04) | $\frac{1}{4}$ | 2 | 0 |
| | | 1 | 6 | 2 |
| Wheat Bulb Fly | Dieldrin (0.086) | $\frac{1}{2}$ | 49 | 0 |
| | | 3 | 76 | 22 |
| | γ BHC (0.086) | $\frac{1}{2}$ | 3 | 0 |
| | | 3 | 66 | 78 |
| Frit Fly | Dieldrin (2.0) | $\frac{1}{4}$ | 36 | 30 |
| | | 1 | 105 | 107 |

* Given as percentages of the numbers in untreated "controls"

Wheat bulb fly larvae, however, enter the shoot about $\frac{1}{2}$ - 1 in. below the soil surface regardless of the sowing depth of the seed. This suggests that kill by contact is likely to be best if the seed is sown shallowly and the figures for damaged shoots (Table 2) confirm this for both dieldrin and γ BHC. However, of the larvae that entered and damaged the shoots of dieldrin treatments comparatively few or none survived. For example, with seed sown at $\frac{1}{2}$ in. the number of damaged shoots was 49% of those in the "controls" but no larvae survived and many were found dead in the damaged shoots. Experiments in which parts of plants from dieldrin dressed seed killed larvae in circumstances which excluded kill by contact showed that dieldrin in lethal quantities was acting systemically after uptake from the seed (Way, 1959a). This was confirmed using labelled dieldrin. It is well known that γ BHC is taken up systemically from seed dressings and from the soil (Bradbury & Whitaker, 1956; Jameson, 1958) and it now seems that the limited systemic action of several chlorinated hydrocarbon insecticides can be a very important factor in their control of soil insects (e.g. Gough & Woods, 1954; Walker, 1960). This makes it even more surprising that true systemic phosphorus insecticides are generally ineffective and it can only be assumed that the latter are translocated so quickly to the leaves that they fail to reach lethal concentrations in the stem or underground parts of the shoot.

It is interesting that 0.04 mg dieldrin per onion seed gave much better control of onion fly than 0.086 mg dieldrin per seed against wheat bulb fly, although, as mentioned earlier, the recommended field rates are similar. This is because in practice against wheat bulb fly, dieldrin kills mainly by systemic action and since this can only happen after the insect has fed, it cannot prevent damage like a treatment which kills by contact action outside the plant. However, it is fortunate that this initial damage can often be tolerated because the wheat plant, unlike the onion, can compensate by extra tillering so that yields may be unaffected despite apparently serious damage.

The third example (table 2), that of seed dressings against the frit fly, (Way, 1959b) shows that a very high dose of 2.0 mg of dieldrin per seed killed some larvae by contact with treated seed down at $\frac{1}{4}$ in. depth but those larvae which entered the shoots were unharmed by systemic action. Consequently at 1 in. sowing depth, dieldrin was ineffective both systemically and by contact since apparently all larvae entered the shoot well above the position of the treated seed. The failure of dieldrin seed dressings to act systemically against frit fly larvae is inexplicable especially as they are highly susceptible to dieldrin sprays and behave like wheat bulb fly larvae after entering the shoot; also this effect is not specific to oats since dieldrin dressings on wheat also failed against frit fly.

Despite these anomalies we can conclude that seed dressings may kill insects by contact action if they pass close to the treated seed and that this action might be direct, or indirect through starvation after the insect is repelled. The limited systemic action of chlorinated hydrocarbons may also be very important in the control of some soil insects and is usually the sole factor in the action of soil applied systemic phosphorus insecticides though mechanical transport may sometimes be important. For example, Jameson (1958) has shown that the colyledons may collect particles of insecticide from the surface of the seed and carry them above the soil surface as the plumule elongates.

You will appreciate that the work on mode of action which I have mentioned is incomplete and some of the evidence needs confirmation. But, at least it typifies the inadequacy of present knowledge of the many biological physical and chemical factors that must be better understood if we are to use seed dressings and soil insecticides to the best advantage.

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# RESULTS OF EXPERIMENTS WITH SYSTEMIC INSECTICIDAL SEED DRESSINGS

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There is much current interest in controlling insects attacking the foliage of plants by the use of systemic insecticides applied to seed or to the soil. These methods are particularly suitable to control sucking insects like aphids, but may also be useful against chewing insects like flea beetles and cut worms. The idea is not new, but only recently have suitable insecticides been available in Britain. As yet, no materials have received official approval for use in this way.

The conventional methods of spraying or dusting the foliage of young seedlings have several disadvantages that might be overcome by the use of seed or soil treatments. Irregular germination may mean that more than one dusting or spraying is needed to cover all the plants at an early stage of growth. The area of the foliage of young plants is only a small fraction of the ground area, so that most of the insecticide falls on the soil may be wasted. Rapid growth can soon dilute and render ineffective the insecticide which does reach the plant. With systemic insecticides applied to seed or soil the plant is usually toxic to insects from germination onwards. The reservoir of insecticide below ground can keep the plant toxic for a long period, 3 - 8 weeks being the usual range for seed dressings.

Soil applications are usually more persistent and less phytotoxic than seed dressings, but needing 5 - 10 times as much insecticide, and it is less certain that the plant will be toxic on germination, the plant often taking a few days to attain its maximum toxicity.

Systemic insecticides applied to seed and soil have been used extensively in North America to prevent mechanical damage by insects to plants such as cotton and alfalfa (See reviews by Lange (1959) and Reynolds (1958)). It is likely, however, that one of their principal uses in the U.K. will be to prevent early infections with insect-transmitted viruses in such crops as sugar-beet and potatoes. (Burt, Broadbent & Heathcote 1960). Aphids are the principal vectors of these viruses and nearly all systemic insecticides are effective against aphids. Most systemic insecticides belong to the organophosphorus group.

To use these materials to their best advantage it is necessary to know how they are absorbed by the plant and what factors are likely to affect the length of time for which the plant remains toxic to insects. For seed dressings knowledge of this kind is particularly important. As the dose is small and concentrated near the plant they tend to be more phytotoxic and less persistent than insecticide applied to soil. This paper describes the results of simple experiments on plants grown in the glasshouse in which seeds of wheat or white mustard were treated with phorate and the toxic effects measured by caging insects on the plants grown from these seeds. The extent to which the results obtained are generally applicable is considered after describing the experimental results.

## Materials and Methods

Phorate, diethyl S-(ethylthiomethyl) phosphorothiolothionate, is an oily liquid of low water solubility (50 parts per million) and with a vapour pressure similar to that of parathion to which its mammalian toxicity is also comparable. It decomposes in the plant and the soil fairly rapidly, but the primary decomposition produces are themselves insecticidal, so that the systemic effect lasts a long time.

Wheat and mustard seeds were used for the experiments because of their contrasting structure and germination. Wheat seed is hypogeal and monocotyledonous, with a large endosperm. The seed remains buried in the soil and attached to the plant, which absorbs from it for some time after germination. Mustard seed is a dicotyledonous epigeal seed with no endosperm. The cotyledons contain the food reserve but emerge through the soil to form the smooth leaves, leaving the empty seed coat behind.

Wheat seeds were treated with a slurry composed of 0.4 g technical phorate, 4 g silicious earth filler and 6 ml 3% methyl cellulose in water per 100 g of seed. Mustard seed was treated with a slurry containing 4 g technical phorate 12 g siliceous earth and 12 ml 3% methyl cellulose solution per 100 g seed. Wheat seeds weighed 53 mg and mustard seeds 7.5 mg. The dose of insecticide in milligrams per seed was very similar, 0.21 for wheat and 0.30 for mustard, but in terms of milligram per milligram of seed the dose was 10 times as great on mustard as on wheat.

Seeds were usually planted in 5" plastic pots or standard seed boxes filled with John Innes No. 1 compost and kept in a heated glasshouse. Insecticidal effect was tested by caging adult or late instar aphids on the plants, the bird cherry aphid *Rhopalosiphum padi* being used on wheat and the mealy cabbage aphid *Brevicoryne brassicae* on mustard (for fuller details see Bardner 1960).

## Results

The experiments and their results will be described in chronological sequence of the stages from the time the seed is treated with insecticide until it reaches the foliage on which the insects are feeding.

When a slurry consisting of the insecticide, filler, sticker and water is applied to the seed and allowed to dry it seems probable that some of the insecticide, being an oily liquid of high vapour pressure, would pass through the seed coat into the seed. As described below, this probably happens with wheat seed, but not to any significant extent with mustard.

Mustard seed was treated with a phorate slurry. After this had dried the seed was stored for three days. Seeds were then put on damp filter-paper for three hours. The seeds absorbed water, the seed coat becoming soft. The seeds were washed briefly in water and the seed coat was dissected off, the embryo being planted in the soil. Plants treated in this way were not toxic to aphids, although plants grown from seeds that were washed but had the seed coat left intact were toxic. Thus the seed coat prevents any significant amount of phorate from reaching the embryo of mustard seed before germination.

It is difficult to devise an equally conclusive experiment with wheat, and the evidence for penetration into the seed is less direct. Untreated seeds of wheat were planted in sand. When the coleoptile of the seedling was $1\frac{1}{2}$-2" long the seedlings were removed and washed thoroughly in running water, leaving the seed attached to the plant. The plant and the seed was blotted dry and a dose of phorate slurry at the normal rate applied with a micro-syringe to the exterior of the seed, care being taken to see that the roots and coleoptile were not contaminated. The plants were then suspended over culture solution into which the roots but not the seeds dipped. Even when care was taken to exclude the possibility of fumigant action plants with treated seeds killed aphids. This experiment shows that phorate from a slurry applied to wheat seed can penetrate into the seed and be directly translocated to the foliage.

When the seed is planted it absorbs water and swells in the process of germination. The sticker in the coating of insecticide slurry is water-soluble so that, shortly after planting, the slurry particles are only loosely attached to the seed and can pass into the soil. This process is assisted by the germination of the seed. Insecticidal activity can be detected in the soil at a greater distance from live treated seed than from heat-killed treated seed.

Several lines of evidence confirm this:- The anti-cholinesterase activity in soil caused by the spread of insecticides from the seed can be detected by placing a gelatine-coated glass plate in contact with a vertical soil profile. The gelatine will absorb insecticide, and when the plate is removed and pressed against a filter paper soaked in an aqueous suspension of insect esterases the inhibitory action of the insecticide can be detected by a colorimetric method (Bardner et al., unpub.). The method is sensitive to roughly 1 part in 10,000 of phorate. So far, only wheat seeds have been tested, but the area of inhibition round the seed is greater with seeds treated alive than dead. Similarly if wheat or mustard seeds are treated with a slurry containing a water insoluble fluorescent dye (Fire Orange) instead of insecticide, a vertical soil profile will show that the dye is spread over a wider area with live than with dead seeds. Particles of fluorescent dye are not carried by the roots, and tests in which roots from plants grown from treated seeds dip into water containing young mosquito larvae show that the roots do not excrete insecticide.

When untreated wheat or mustard seeds are grown $\frac{3}{4}$"-$1\frac{1}{2}$" away from treated seeds, plants from untreated seeds pick up enough insecticide to become toxic to aphids, and this effect is more pronounced near live treated seeds than near dead treated seeds.

Mustard seedlings, unlike wheat, can acquire insecticide by surface contamination of the cotyledons as they emerge through soil containing insecticide derived from a seed dressing. Mustard seeds were treated with a slurry containing Fire Orange and planted in soil. Examination of the young seedlings under ultra-violet light showed that the cotyledons and the upper part of the hypocotyl were covered with particles of dye. Coleoptiles of wheat grown from seed treated in a similar manner occasionally have a few particles near the base of the coleoptile, but this is insignificant compared to the amount on mustard seedlings.

The reservoir of insecticide present in the soil but derived from the seed dressing is very important for the continued toxicity of the plants.

Treated wheat and mustard seeds were grown in soil and transplanted at various intervals after sowing, the roots being thoroughly washed before replanting. Transplanted plants lost their toxicity much sooner than undisturbed plants. For example, mustard plants transplanted 11 days after sowing, when the 2nd pair of rough leaves were just appearing, were tested 22 - 26 days after sowing. Both the cotyledons and the first pair of rough leaves were still killing all aphids, but the "killing index" =

$$\left( 1 = \frac{\text{mean square root of aphids on treated}}{\text{mean square root of aphids on untreated}} \right) \times 100$$

was 81 for the cotyledons of the transplanted plants and 41 for the rough leaves (complete control = 100). With both wheat and mustard, new leaves produced after transplanting were not toxic. Leaves and cotyledons formed before transplanting lost their toxicity quicker than those of undisturbed plants. Removing the wheat grain before transplanting sometimes accelerated this loss, but cutting the union between the seed and the coleoptile in otherwise undisturbed plants did not affect it.

These experiments show that to become and remain toxic all the leaves depend to some extent on continued uptake of insecticide from the soil and that insecticide is not translocated in toxic amounts from old to young leaves.

The distribution and availability of the insecticide to the soil will be affected by soil conditions. Soil insecticides and seed dressings are less effective in soils containing much organic matter. Leaching can also have a big effect on the time for which the plants remain toxic and these two factors interact with one another.

Treated wheat seeds were grown in pots containing a fen peat soil and sand mixed in various proportions by volume:- 100% peat, 50% peat, 10% peat and 100% sand. Half the pots received a standard culture solution watered on to the soil daily ("leaching"), and half were stood in dishes containing culture solution ("no leaching").

Under no-leaching conditions the amount of insecticide available to the plant and hence the time for which it remains toxic was least with 100% peat and most with 100% sand, but under leaching conditions the intermediate mixtures of peat and sand gave the longest toxicity. Similar results were obtained with mixtures of sedgemoor peat and sand. When mixtures of clay and sand were tried, the clay was found to have no effect under non-leaching conditions, and only a slight effect under leaching conditions.

These experiments show that soils containing much organic matter absorb insecticides and either release it slowly or retard the process of leaching. Prevention of leaching by interference with free drainage seems to be the only effect of a high clay content.

## Discussion

The experiments on seed dressings described here were limited to one insecticide (phorate) in one particular type of formulation applied to seeds of two plant species only. Nevertheless, they showed the way in which the insecticide reached the plant could differ greatly. These differences seem especially important in the very early stages of the seedlings growth, older seedlings being dependent on the continued uptake of phorate from the reservoir in the soil. Phorate in the aqueous slurries used in the experiments can penetrate the seed coat of wheat, but although it is absorbed to a certain extent by the seed coat of mustard it cannot pass into the embryo in insecticidal quantities until after germination. Perhaps this explains why brassica seedlings tolerate large insecticidal seed dressings. The experiments revealed that the cotyledons of mustard can pick up particles of seed-dressing on their way through the soil, a deduction used by Jameson (1958) to explain how relatively poor systemics like lindane were so effective on kale seed against flea beetles.

What the mechanisms of uptake are when dicotyledonous hypogeal seeds such as field beans are treated with systemic insecticide slurries is at present unknown, nor is it known whether young wheat and mustard seedlings can immediately absorb the insecticide present in the soil or whether this has to wait upon the development of an absorptive root system.

There is evidence that the mode of action of other formulations and methods of application may differ. Bardner (1960) has shown that with insecticidal slurries fillers can be used which adsorb insecticide and release it slowly over a long period, so that under suitable conditions phytotoxicity can be reduced and insecticidal persistence lengthened. Preliminary work in which phorate in the usual slurry formulation applied to wheat was compared with a liquid formulation of phorate in cyclohexanone and an aqueous emulsion of a liquid formulation of phorate indicated that the slurry formulation was more easily leached away but under non-leaching conditions was much more persistent. Differences in persistence and resistance to leaching probably reflect differences in penetration into the seed.

As much of the insecticide from slurry seed dressings passes into the soil, persistence is greatly affected by soil factors such as structure, amount of organic matter and water movements, and also by the water solubility of the insecticide and its decomposition products. If high seeding rates are used, so that the seeds are only $\frac{3}{4}$" or so apart, some reinforcement of insecticidal and phytotoxic effects must be expected and this will be most noticeable in sandy soils containing little organic matter. Persistence of insecticidal effect will probably be brief with seedlings grown in sandy soils and irrigated to excess.

Because oldest leaves retain their toxicity longest, the persistence of insecticidal effect may depend on the behaviour of insects attacking the plant.

Aphids normally colonize the youngest foliage of seedlings. They may be able to survive and reproduce where more mobile and less discriminate feeders such as flea beetles would be killed by insecticide still present in the older leaves.

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# STUDIES OF EFFECT ON GERMINATION OF CERTAIN SOLVENTS USED IN EXPERIMENTAL LIQUID INSECTICIDAL SEED DRESSINGS APPLIED TO CEREALS WHICH HAVE RECEIVED A STANDARD APPLICATION OF A LIQUID ORGANO-MERCURIAL COMPOUND

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## Introduction

During the war and for a number of years afterwards, the crop losses due to wireworm (Agriotes spp.) were considerable. It had been found by Jameson, Thomas and Woodward (Ann. appl. Biol. 1947, 34, 346.) that BHC when applied to cereal seed prevented damage by this pest and in 1948 a powder dressing based on this insecticide and containing an organo-mercurial fungicide was introduced to the market. Seed dressings of this nature have been generally termed 'Dual Purpose' because control of certain soil borne and seed borne diseases is also achieved. Subsequently, dual purpose powder seed dressings containing aldrin, dieldrin and heptachlor were placed on the market and widely used.

When liquid organo-mercurial seed dressings were first introduced into the U. K. it was appreciated that there would be a demand for seed to be treated not only with the fungicide but also with an insecticide to give the necessary measure of control of wireworm. Whilst the simplest method of dealing with this problem is to formulate a dual purpose liquid, such a product has the disadvantage that the ratio of the insecticide to the organo-mercurial compound is fixed. However, if two separate liquid formulations are employed and applied separately to the seed, then the ratio of the organo-mercurial compound to insecticide can be varied by mechanical means. This variation in ratio is of importance if the same liquid insecticide is to be employed for the prevention of damage by wireworm as well as damage by Wheat Bulb fly. Trials previously carried out in East Anglia and East Midlands by the N. A. A. S. have clearly shown that a higher concentration of insecticide is required for the protection of the seed against attack by Wheat Bulb fly than by wireworm.

Because the insecticides normally employed for treating seed against these pests are chlorinated hydrocarbons, a solvent with a high solvent power for this type of chemical has to be employed. The solvent in a liquid insecticidal formulation should have the following characteristics:- (1) virtually no phytotoxicity to the seed; (2) compatibility with the solvent used for the organo-mercurial compound; (3) good solvent power for the chosen insecticide at low temperatures; (4) good stability in the formulation.

Other important characteristics of the solvent are:- (a) absence of high inflammability; (b) safety in handling in confined spaces; (c) a sufficient volatility to prevent the seed remaining coated with the liquid for a prolonged period; (d) absence of adverse effects on germination if the seed is stored for a lengthy period

## Method

All the tests referred to in this report were carried out either by the National Institute of Agricultural Botany at Cambridge or by the Department of Agriculture for Scotland Seed Testing Station at East Craigs. In nearly all cases the figures were those from the normal routine soil tests carried out by the station concerned. Untreated control samples were sometimes also treated with the dye alone and sometimes all the samples were treated with colourless solutions only. The reason for doing this was to prevent the possibility of slight, but nevertheless normal, symptoms being classified as abnormal in the germination tests. Reports were received where 'abnormals' appeared in the untreated control samples.

An indication of the effect of a liquid insecticidal seed dressing is given by the percentage of 'abnormals' appearing in a sample. However, many abnormal seedlings may grow to a normal healthy plant because any abnormality in the developing seedling, whether slight or gross, is reported under this single heading.

As large a number of cereal varieties as possible have been used in the tests. Only when normal farmers quality seed of the variety to be tested was not obtainable, was high quality or once grown seed used. It was appreciated that the use of such seed might result in greater loss in germination and increase the percentage of abnormals but it had the advantage of showing what results might be expected under typical conditions.

In practically every case the seed was treated in a liquid seed treating machine in order that the results might be as nearly comparable as possible with those that would occur in seed dressing establishments.

Samples were either taken at random from the flow of grain as it left the seed treater or by drawing off samples from the centre of the sack. The samples were sent to the seed testing station under code. Treated seed retained for storage trials was packed in multi-wall paper sacks, the opening being folded over and tightly tied to prevent any loss of solvent.

## Trials Results

As it was planned that the liquid insecticide should be applied to the seed at the rate of 1 fl. oz per bushel, solubility of the insecticide in the solvent was the first consideration in the selection of potential materials. The solvents concerned in this report are shown in Table 1 with some of their more important characteristics:

Table 1

| | HCS* | Carbon tetra-chloride CT | Dimethyl formamide DMF | Cyclo-hexanone CX |
|---|---|---|---|---|
| Specific Gravity | 0.877 at 15/15°C | 1.59 at 20/4°C | .953 at 15/15°C | .948 at 20/4°C |
| Aromatic Content | 98% | - | - | - |
| Flash Point | 117°F | Non. inflam. | 153°F | 147°F |
| Distillation Range | 162° - 180° | - | - | - |
| Boiling Point | - | 77oC | 153°C | 156°C |
| Vapour Pressure | above 10 mm Hg at 20°C | 91 mm Hg at 20°C | 3.7 mm Hg at 20°C | 10 mm Hg at 38°C |
| Solubilities in g/100 ml of solution at 25°C | | | | |
| DIELDRIN | 32g | 38g | 46g | 49g |
| ALDRIN | 73g | 105g | 55g | 69g |
| LINDANE | 23g | 7g (20°C) | 40g | 49g |

*HCS = Fully refined petroleum-derived Hydrocarbon solvent.

Another and almost equally important consideration was the low temperature storage stability of the solutions since treatment of cereal seed is carried out during the winter months. In periods of prolonged frosts the temperature in some seed dressing establishments can fall below 0°C. Table 2 shows the results obtained when certain formulations containing 30% dieldrin were subject to cold storage stability tests; the formulation passed the test if no dieldrin was deposited from solution when stored 48 hours at -5°C.

Table 2

| H. C. Solvent % vol/vol | Chemical Solvent % vol/vol | TEST RESULTS 48 hours at -5°C |
|---|---|---|
| 0 | 100% cyclohexanone | Passed |
| 30% | 70% " | " |
| 80% | 20% " | Failed |
| 100% | 0% " | " |
| 0 | 100% carbon tetrachloride | " |
| 30% | 70% " " | " |
| 60% | 40% " " | " |
| 80% | 20% " " | " |
| 0 | 100% dimethyl formamide | " |
| 30% | 70% " " | Passed |
| 60% | 40% " " | " |
| 80% | 20% " " | " |

Those formulations that passed the cold storage test, together with some of those that failed, were applied to three varieties of cereals to assess the effect on germination and degree of phytotoxicity. The results of these tests are shown in Table 3:

Table 3

Rate of application - 1 fl.oz per bushel

| | Wheat "Eclipse" | | | | Barley Pioneer | | | | Oats S147 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Ph | Ab | D | N | Ph | Ab | D | N | Ph | Ab | D |
| Untreated | 97 | - | 2 | 1 | 94 | - | 3 | 3 | 96 | - | 2 | 2 |
| 30% dieldrin in 100% CT | 97 | - | 2 | 1 | 97 | - | 2 | 1 | 92 | 8 | 8 | - |
| 70% " + 30% HCS | 95 | T | 3 | 2 | 92 | - | 4 | 4 | 94 | - | 4 | 2 |
| 100% CX | 96 | - | 2 | 2 | 93 | - | 4 | 3 | 94 | - | 3 | 3 |
| 70% " + 30% " | 93 | - | 5 | 2 | 91 | - | 4 | 5 | 90 | - | 6 | 4 |
| 40% " + 60% " | 96 | - | 4 | - | 91 | T | 5 | 4 | 92 | - | 3 | 5 |
| 100% DMF | 98 | - | 1 | 1 | 91 | 3? | 5 | 4 | 99 | - | 1 | - |
| 70% " + 30% " | 97 | - | 3 | - | 93 | - | 3 | 4 | 93 | 5 | 7 | - |
| 40% " + 60% " | 96 | - | 4 | - | 91 | T | 5 | 4 | 92 | - | 3 | 5 |
| 20% " + 80% " | 95 | - | 4 | 1 | 89 | 3 | 7 | 4 | 88 | 10 | 10 | 2 |
| 100% HCS | 94 | 4 | 4 | 2 | 89 | 4 | 4 | 7 | 87 | 5 | 7 | 6 |

Abbreviations used in the Tables: N = Normal germination; Ph = Phytotoxicity; Ab = Abnormal germination; D = Dead seeds; T = Trace less than 1%.

Straight varietal testing at normal rates of application is of greatest value but it may not show up the adverse effects that could arise if accidental overdosing should occur under practical donditions. Table 4 shows the effects of normal application and overdosing on a number of oat varieties with 30% dieldrin solutions; together with the effects of this overdosing during storage.

Table 4

| | Rate | After one months storage | | | After four months storage | | |
|---|---|---|---|---|---|---|---|
| | fl. oz/ bushel | N | Ph | Ab | N | Ph | Ab |
| Untreated | | 97.0 | - | 1.3 | 97.7 | - | 1.0 |
| Organo-mercury only | | 98.3 | - | 1.0 | 96.6 | T | 1.6 |
| + 60/40 HCS/CX | 1. | 96.7 | - | 2.5 | 96.6 | T | 1.7 |
| " " | 2. | 95.0 | - | 3.3 | 97.0 | T | 1.3 |
| " " | 3. | 95.0 | - | 3.2 | 96.0 | 1.3 | 1.0 |
| + 100% CX | 1. | 97.0 | - | 2.0 | 96.7 | Nil | 1.6 |
| " | 2. | 96.3 | - | 2.7 | 97.3 | 1.0 | 1.3 |
| " | 3. | 95.0 | - | 3.0 | 97.2 | 1.0 | 1.0 |
| + 80/20 HCS/DMF | 1. | 97.7 | - | 1.6 | 96.7 | Nil | 1.0 |
| " " | 2. | 96.0 | - | 3.2 | 97.3 | T | 1.0 |
| " " | 3. | 96.3 | - | 3.0 | 97.4 | T | 1.3 |

Subsequent parallel trials using aldrin as the insecticide gave results not materially different from those obtained with dieldrin. The result confirmed that the solvent or solvent mixture is likely to have some effect and to emphasise this, a still higher dosage rate was employed. Table 5 shows the averaged effect on a number of oat varieties of a 30% aldrin solution in a mixture of 60% HCS and 40% CX, immediately after application and during storage.

Table 5

| | Immediate | | After one months storage | | After two months storage | |
|---|---|---|---|---|---|---|
| | N | Ab | N | Ab | N | Ab |
| Untreated | 90.5 | 3.8 | 90.3 | 3.2 | 92.8 | 2.0 |
| Organo-mercurial only | 91.5 | 3.8 | 92.0 | 2.2 | 90.8 | 6.3 |
| 30% aldrin in 60/40 HCS/CX | | | | | | |
| at 1 oz/bushel | 92.8 | 2.0 | 91.2 | 4.0 | 91.3 | 3.0 |
| at 2 oz/bushel | 90.5 | 5.0 | 87.7 | 4.7 | 93.8 | 2.3 |
| at 4 oz/bushel | 83.3 | 10.5 | 84.2 | 9.0 | 87.5 | 6.8 |

## Lindane

Many tests were carried out to check the reported phytotoxicity of lindane seed formulations. Table 6 shows the results obtained in a trial using lindane and lindane/aldrin mixture in various solvents and mixtures of solvents. 30% lindane solutions were employed in this series of trials in order that some comparisons could be made with the known effect of 30% aldrin and dieldrin solutions although it was known that such a solution would not be suitable from a low temperature stability point of view. Rates of $\frac{3}{4}$ and $1\frac{1}{2}$ fl. oz per bushel were employed in order to be able to **obtain bracket assessment** of the effects of a 1 fl. oz per bushel rate.

Table 6

| | fl. oz per bushel | Wheat. av: 5 varieties | | | | Barley 3 varieties | | | | Oats 3 varieties | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | no storage | | 1 month storage | | no storage | | 1 month storage | | no storage | | 1 month storage | |
| | | N | A | N | A | N | A | N | A | N | A | N | A |
| Untreated | - | 95 | 0 | 96 | 0 | 96 | 0 | 95 | 0 | 95 | 0 | 95 | 0 |
| Organo-mercury only | $\frac{3}{4}$ | 93 | 2 | 95 | 1 | 95 | 0 | 97 | 0 | 96 | 0 | 93 | 0 |
| + 30% lindane in CX | $\frac{3}{4}$ | 95 | 3 | 91 | 5 | 95 | 0 | 93 | 1 | 94 | 3 | 95 | 2 |
| " " " " | $1\frac{1}{2}$ | 87 | 9 | 96 | 9 | 95 | 0 | 89 | 5 | 93 | 3 | 95 | 3 |
| 20% " 10% aldrin in CX | $\frac{3}{4}$ | 94 | 3 | 90 | 4 | 97 | 0 | 96 | 0 | 92 | 1 | 93 | 2 |
| " " " " " | $1\frac{1}{2}$ | 91 | 5 | 93 | 4 | 95 | 1 | 92 | 3 | 93 | 3 | 91 | 4 |
| 30% " in 60/40 HCS/CX | $\frac{3}{4}$ | 95 | 2 | 96 | 3 | 98 | 0 | 95 | 0 | 95 | 0 | 95 | 3 |
| " " " " " | $1\frac{1}{2}$ | 93 | 5 | 90 | 5 | 94 | 2 | 92 | 2 | 94 | 4 | 93 | 3 |
| 20% "/10% ald in 60/40 HCS/CX | $\frac{3}{4}$ | 93 | 2 | 92 | 4 | 95 | 1 | 95 | 1 | 95 | 0 | 94 | 2 |
| " " " " " | $1\frac{1}{2}$ | 94 | 2 | 91 | 3 | 95 | 0 | 94 | 1 | 91 | 5 | 92 | 5 |
| 30% " in DMF | $\frac{3}{4}$ | 95 | 3 | 90 | 7 | 96 | 0 | 93 | 2 | 97 | 0 | 93 | 2 |
| " " " | $1\frac{1}{2}$ | 95 | 3 | 89 | 5 | 94 | 0 | 94 | 0 | 94 | 3 | 94 | 2 |
| 20% " 10% ald in DMF | $\frac{3}{4}$ | 96 | 2 | 94 | 2 | 97 | 0 | 95 | 0 | 95 | 0 | 96 | 1 |
| " " " " | $1\frac{1}{2}$ | 94 | 1 | 92 | 3 | 94 | 0 | 93 | 2 | 95 | 1 | 94 | 2 |

A further trial employing higher rates of application confirmed that 30% lindane in CX and CX + HCS were liable to be phytotoxic at rates of application over 1 fl. oz per bushel.

The indications from this and other trials showed that lindane formulated with DMF is less liable to produce abnormalities in the developing seedling. There were also indications that the addition of aldrin to lindane might reduce the phytotoxicity of the latter material.

Table 7

Mean of 3 varieties

| | Rate fl. oz per bushel | no storage | | one months storage | |
|---|---|---|---|---|---|
| Untreated | - | 93 | 0 | 95 | 0 |
| Organo-mercurial only | normal | 95 | 0 | 93 | 0 |
| + 30% lindane in CX | 1 | 90 | 6 | 80 | 12 |
| " " " " " | 2 | 84 | 12 | 70 | 22 |
| " " " " " | 4 | 50 | 48 | 46 | 42 |
| " 20% " 10% Ald in CX | 1 | 94 | 2 | 91 | 2 |
| " " " " " " | 2 | 84 | 8 | 84 | 9 |
| " " " " " " | 4 | 70 | 27 | 68 | 22 |
| " 30% " in 60/40 HCS/CX | 1 | 93 | 1 | 88 | 5 |
| " 20% " 10% Ald in 60/40 HCS/CX | 1 | 93 | 2 | 89 | 6 |
| " " " " " " " | 2 | 95 | 3 | 85 | 10 |
| " " " " " " " | 4 | 61 | 35 | 72 | 15 |
| " 30% " in DMF | 1 | 90 | 2 | 87 | 4 |
| " 20% " 10% ald in DMF | 1 | 95 | 3 | 90 | 6 |

Trials using 25% lindane in DMF at 1, 2, and 3 fl. oz per bushel on cereal varieties liable to damage by lindane indicated that this solvent is less likely to produce phytotoxic symptoms if overdosing occurs and Table 8 shows that DMF applied alone does not produce any significant number of abnormalities in the germinating seedlings or reduce the germination capacity.

Table 8 also shows that a 25% lindane in DMF solution at 1 and 2 fl. oz per bushel does not produce any significant reduction in germination nor materially increase the very small percentage of 'abnormals'.

Table 8

Average of 6 varieties

| | Rate in fl. oz/bu | no storage | | one months storage | |
|---|---|---|---|---|---|
| | | N | Ab | N | Ab |
| Untreated | | 94.5 | 0 | 95.0 | 0 |
| 25% lindane in DMF | | 91.2 | 1.1 | 94.6 | 1.6 |
| " " " | | 92.6 | 2.4 | 93.3 | 2.1 |
| " " " | | 87.3 | 5.7 | 87.5 | 7.7 |
| DMF alone | | 93.8 | 0.1 | 94.0 | 0.3 |

## Discussion of Results

The application of a 30% aldrin or 30% dieldrin liquid insecticidal seed dressing based on certain solvents had no significant harmful effect if applied to barley and oat seed at up to 2 fl. oz per bushel. It therefore appears that these two insecticides, in liquid formulations, are virtually non-phytotoxic to seed of good germination capacity provided the solvent employed is also non-phytotoxic.

Cereal seed treated with liquid seed dressing containing 30% aldrin or 30% dieldrin can be stored safely for at least two months without materially affecting the germination capacity.

A 30% lindane in cyclohexanone liquid seed dressing formulation can cause abnormalities in germinating seedlings at all tested rates of application. This phytotoxicity appears to be reduced when aldrin replaces part of the lindane in the formulation. Furthermore, the replacement of part of the cyclohexanone by a suitable hydrocarbon solvent also appears to reduce the phytotoxicity of the former solvent to some extent.

When dimethyl formamide is wholly or partly employed as the solvent in a lindane liquid seed dressing then the phytotoxicity associated with this insecticide is reduced to almost insignificant proportions provided the rate of application is not appreciably greater than 1 fl. oz per bushel.

Unlike aldrin and dieldrin liquid seed dressings, those based on lindane tend to reduce, during prolonged storage, the germination capacity of cereal seed, particularly some varieties of wheat. Field trials (not reported here) comparing seed treated with a solution of lindane in dimethyl formamide with seed dressed with commercially available products, have confirmed the safety of such a formulation.

## Summary

Cereal seeds were treated with solutions of aldrin, dieldrin or lindane in various solvents and mixtures of solvents. Germination tests were carried out on the treated seed to assess the degree of phytotoxicity that might arise under practical conditions.

Solutions of aldrin or dieldrin in cyclohexanone or in a mixture of this solvent and a hydrocarbon solvent produces no significant adverse effects at normal or up to three times normal rates of application. When solutions of lindane in cyclohexanone or in mixtures of cyclohexanone and a hydrocarbon solvent were applied to cereal seed, damage occurred, which was not the case when solutions of lindane in dimethyl formamide were applied at 1 fl. oz per bushel.

In storage trials, seed treated with solutions of aldrin or dieldrin in dimethyl formamide or cyclohexanone did not show any significant adverse effects. Lindane in dimethyl formamide tends to produce adverse effects if the treated seed is stored for prolonged periods.

## Discussion

Q. Mr. D. Rudd Jones

As I understand it, there are certain internal fungal diseases of seed which are not controlled because the fungicidal seed dressings are not normally systemic and I am wondering in view of the increasing popularity of liquid dressings whether this might be taken a stage further and attempts made to control internal fungal parasites by fumigation. Is Dr. Noble aware of any use of fumigation to control seed borne diseases and can she tell me what fumigants might be fungitoxic and non-phytotoxic in the treatment of seed?

A. Dr. M. Noble

I am afraid I have very little first-hand information about this but methyl bromide has been tried, particularly in connection with nematode treatment of Medicago, and some of my colleagues tried to see whether the fungus Aschochyta imperfecta was killed, but unfortunately the seed died before the fungus. It is a line which should be followed up and might give better results.

Q. Dr. A. G. Fisken

In official Seed Testing Station reports on germination capacity of cereal seeds a figure is given for abnormality. Would it be possible for these Stations to predict, at the time of reporting, the likely effect on ultimate yield of the varying types of abnormality?

A. Dr. M. Noble

The question of abnormality, I think, is judged in cereals by whether the seedling is likely or not to give a good plant, a normal plant, in favourable soil conditions, i.e. for untreated seed. It is asking a tremendous lot to predict at the time of reporting the effect of abnormality on ultimate yield. One even may not know whether the seed has been treated. This may be possible in the future because of the increasing practice of labelling treated seed. This is the kind of information which I feel is going to come from the Seed Pathology Sections of the Seed Testing Stations. The straight germination figure must still be the maximum figure but must be supplemented by a statement, e.g. "This treatment may lead to abnormality in certain soils." I think information will come forward from seed pathology people and from advisory people who can give a tremendous amount of help.

Comment from Mr. H. C. Mellor on Dr. Noble's reference to the term "dressing":

We have had a most interesting session of papers this morning on seed dressings and I should particularly like to make mention of Dr. Noble's reference to the term "dressing" because I remember in the 1930's a series of advertisements relating to seed treatment which read "it pays to be properly dressed". We take Dr. Noble's point.

Q. Mr. H. C. Mellor

I should like to ask Mr. Way if I misheard his reference to the use of 3 oz per bushel of chlorinated hydrocarbons - was this in terms of active agent or of product?

A. Mr M. J. Way

The reference was to active ingredient per acre. Against onion fly, 3 oz on 6 lb of seed per acre, and against wheat bulb fly my rough estimate was 3 oz active ingredient on 150 lb of seed per acre. With seed dressings it would seem to be more useful to define dosage as amount per seed rather than amount per acre or per unit weight of seed.

Q. Mr. H. C. Mellor

In referring to the apparent unnecessary use of dual purpose seed dressings, one must take into account the not inconsiderable insurance value of the treatments. Also seed merchants who carry out most of the treatment must treat well in advance of the season to meet the demand. Could Mr. Way define the infestation level above which the treatment is necessary and if so who is to advise the farmer?

A. Mr. M. J. Way

My reason for referring to "unnecessary" use of seed dressings was because most of the insecticidal seed dressings are used on cereals against wireworms which nowadays are generally scarce in arable land and relatively uncommon even in grassland. Therefore, where the insecticidal component of seed dressings is aimed entirely at wireworms I would suggest that its use in most instances is unnecessary. It is difficult to say when treatment is necessary without a previous assessment of wireworms. I appreciate the argument that, without such assessment, seed dressing of cereals as an insurance against wireworms may still be felt to be justified even though a very small proportion of crops would benefit.

Comment from Dr. G. H. L. Dicker on Mr. Way's contribution:

The use of systemics, applied either to the soil or to the trunks of fruit trees has received study, but the practical application of this method is limited by the present need for foliar applications of fungicides. A plea was made for the Agricultural Chemical Industry to find suitable systemic fungicides for use on fruit.

Observation to Dr. M. Noble from Dr. W. Ripper

With reference to the suggestion that fungicide application to the seeds for the protection against soil borne diseases other than on the seed were desirable, the American practice of applying fungicides such as captan simultaneously with sowing either through seed box or special applicators is worth noting.

Q. Dr. L. Broadbent

Is phytotoxicity assessed by germinating treated seeds in Petri dishes?

Recent tests showed that tomato seeds often failed to germinate after soaking in a solution of tri-sodium orthophosphate to inhibit tomato mosaic virus, whereas germination was not affected in soil.

A. Dr. M. Noble

This is a point which has been very carefully investigated by Seed Testing Stations. It is legitimate to do a germination test in a "blotter" which could be flat with a cover or on a rolled paper towel. I think I am right in saying that especially when BHC was introduced first, seeds treated with this chemical had to be specially tested in soil to avoid undue abnormality. Tests are conducted taking these points into account.

Q. Dr. F. Raw

Mr. Mellor has questioned Mr. Way's use of the word "unnecessary" (NOTE: The printed version of Mr. Way's paper "unwarranted" is used but "unnecessary" was used in the spoken version) when speaking of the widespread practice of making routine applications of insecticidal seed dressings regardless of pest incidence and I wish to ask Mr. Mellor a related question. Passing reference has been made to the high proportion of potato fields treated with aldrinised fertiliser although the proportion of such fields which have a significant pest population is very low (about 5%). Does Mr. Mellor consider such widespread routine use of aldrinised fertiliser "necessary" or "justifiable" and, if not, what should be done about it?

A. Mr. H. C. Mellor

I'm sorry I have no personal experience with aldrinised fertilisers as my Company does not sell them. I think the problem must be looked at from the point of view of the farmer who must judge by the experience on his farm in preceding years. If he has had severe trouble in previous seasons, he can perhaps be forgiven for using such products as an insurance factor.

Observation from Mr. Way

What is unfortunate is that the extensive use of certain insecticidal seed dressings on cereals has been largely responsible for problems of bird poisoning. Otherwise seed dressings would have been an ideal method of insurance.

Observation from Mr. Womack

Mr. Way says that most dual purpose seed dressings are used for control of wireworm. My experience is that there is sometimes an increase in yields even where the wireworm population is low. There are other pests in the soil which are controlled to a certain extent and this factor must be taken into account.

Q. Mr. J. S. W. Simonds

You suggested that the insecticide portion of the seed dressing is probably unnecessary to the now apparent low level of wireworm population. Can we balance the potential and presumably low damage to cereals from a low level of attack with the infinitesimal cost of the insecticidal portion of the seed dressing to the farmer. Surely this is an excellent form of insurance inasmuch as one willingly pays fire insurance premiums on one's own property?

A. Mr. M. J. Way

Fire insurance does not have undesirable side-effects whereas with insecticidal seed dressing on cereals you have got to consider the benefits of a cheap insecticidal insurance policy in relation to the harm that some of the insecticides may cause to birds. I appreciate Mr. Womack's point about additional beneficial effects of seed dressings. These may be important and a great deal more research needs to be done on them.

Comments by D. W. Wright

At the N. V. R. S., we have been working for a number of years on the use and behaviour of insecticides in soils. This has shown that some of the chlorinated hydrocarbon insecticides are extremely persistent there. With regard to the unnecessary use of insecticides it would seem that aldrin mixed with fertiliser is now very extensively used in soil, in most cases as an insurance against wireworm damage. On many fields its use in this way appears to have been quite unnecessary, since the pest was either absent or present in numbers too low to cause crop damage. Repeated use of insecticides in this way is liable to lead to a build-up of residues in the soil and these may be harmful. They can be taken up into crop plants and when present at fairly high levels may adversely affect crop flavour. In addition, high residue levels of certain insecticides in the soil have been shown to increase the damage caused by the cabbage root fly through, we believe the killing of predatory insects.

Q. Mr. T. E. T. Trought

Does Dr. Noble consider that work on the effect and methods of seed treatment of grass mixtures is justified?

A. Dr. M. Noble

Yes, certainly in the case of ryegrass. There are fungi on ryegrass especially pedigree strains which might be controlled with mercurials. Timothy Grass will certainly repay treatment but more work is necessary to find out what are the common seed-borne diseases and their reactions. More and more seeds will, I believe, prove to be benefitted by such treatment.

Q. Mr. L. E. W. Stone

There appears to be a schism between the findings of N. V. R. S. on the one hand and the firm's findings on the other concerning the production of taint (off flavour) by aldrin to potatoes.

A. Mr. D. W. Wright

There would seem to be some misunderstanding here, for we have never found aldrin to cause taint in potatoes. With carrots, however, both aldrin and dieldrin can cause change in flavour. At low dosage rates in the soil, little or no effect has been recorded but at higher rates both insecticides may cause the carrots to take on a distinct chemical flavour.

The effect of lindane on crop flavour is much greater, and when grown in soils treated at $\frac{3}{4}$ lb per acre both carrots and potatoes showed a musty off-flavour ('tainting') in the years immediately following treatment and loss of crop flavour where the insecticide had been in the soil for several years.

Comment from Mr. Billitt to Mr. D. W. Wright, Chairman of Session.

You did make reference, Mr. Chairman, to the uptake by the plant of some of the chlorinated hydrocarbons. We do know that certain chlorinated hydrocarbons are very toxic to birds. There is need for more work particularly on residues on cereals and other crops that are fed to poultry in particular. Avian toxicity particularly low in proportion to mammalian toxicity and it would be advisable for all concerned to look very carefully at the residues in feeding stuffs and then we shall be making real progress.