Dr. R. C. Sutcliffe was enthusiastic of the results obtained so far by Prof. Sheppard. The network of upper air observing stations in the British Isles is the closest in the world, and this region should be used to determine the basic facts of the structure and working of typical weather situations. Atmospheric models, so determined, may then be applied to similar phenomena in other parts of the world where upper air information is scanty or lacking. Prof. Sheppard's investigation is an example of the use to which the British Isles observations may be put, to the great benefit of meteorology generally. Dr. Sutcliffe also pointed out that the horizontal scale of these vertical currents deduced by Prof. Sheppard is implicit in the dimensions of the triangles of observations used.

In reply to questions from Mr. C. S. Durst, Prof. Sheppard said that he had found no individual cases giving ridiculous values for the vertical velocities; since the radar wind observations are averages over depths of about 3,000 ft., such small variations in the wind as Richardson[3] feared would preclude any attempt at a numerical analysis of the wind field of a weather situation are probably eliminated. The time required to analyse each wind-finding ascent for all the various levels is about half an hour, using graphical methods. This indicates the large amount of work involved in producing the basic data for his investigation.

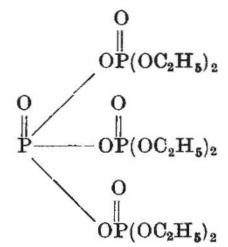
In concluding the discussion, the president, Sir Robert Watson-Watt, said that the results described showed exciting progress; as that most famous English meteorologist, Sir Napier Shaw, used to emphasize, measurements are as essential in meteorology as in every other branch of science.

[1] Bannon, J. K., *Quart. J. Roy. Met. Soc.*, **74**, 57 (1948).
[2] Graham, R. C., *Quart. J. Roy. Met. Soc.*, **73**, 407 (1947).
[3] Richardson, L. F., "Weather Prediction by Numerical Process" (Camb. Univ. Press, 1922).

INSECTICIDAL PROPERTIES OF CERTAIN ORGANO-PHOSPHORUS COMPOUNDS

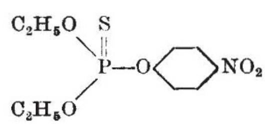
THE success of D.D.T. and benzene hexachloride insecticides has already shown the important part that synthetic chemicals can play in agriculture. Interest is therefore being shown in the organo-phosphorus group of insecticides, especially as certain of these compounds show high contact-activity and others are capable of rendering the plant systemically insecticidal. As these compounds have not yet been available in sufficient amounts for wide-scale investigations, and as little has been published on the subject, there is a considerable demand for accurate information. A meeting of the Association of Applied Biologists on November 5 sought to adjust this state of affairs by bringing together workers qualified to speak on various aspects of the subject.

Dr. H. Martin, of Long Ashton Research Station, introduced the proceedings. He referred to the classical work of Michaelis (1890–1915) on the chemistry of the organic compounds of phosphorus, and mentioned that Nylen[1] had described the tetraethyl ester of pyrophosphoric acid but had overlooked its toxicity towards insects. The discovery of, and information on, the insecticidal properties of these compounds was due almost entirely to Schrader[2]. He had shown that tetraethyl pyrophosphate is highly toxic to aphides, but had not carried forward his discovery to the manufacturing scale, as the substance rapidly lost its activity in contact with water. Instead, Schrader had investigated the reaction between phosphoryl chloride and triethyl phosphate and had obtained a product known as hexaethyl tetraphosphate (I), which he considered had the following structure:



(I)

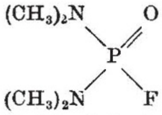
This substance was shown to be as toxic to aphides as nicotine and to have sufficient water-stability to be of practical value; consequently, its manufacture was commenced in Germany in 1944. Dr. Martin mentioned that chemical evidence had recently been produced that hexaethyl tetraphosphate is probably a mixture of alkyl polyphosphates; but investigations at Long Ashton on the toxicity of samples prepared by different processes had revealed no differences. However, it is not sufficiently stable for use with alkaline spray material such as lime sulphur or for incorporation in dusts, consequently its usefulness to agriculture is limited. Schrader found that the thiopyrophosphoric esters were more stable to hydrolysis than the pyrophosphoric esters, yet retained their pronounced insecticidal action. In 1945 a series of thiophosphoric acid derivatives was investigated, with the result that the highly potent insecticide, diethyl-*p*-nitrophenyl thiophosphate *E*.605 (II), was discovered.



(II)

E.605 was a marked improvement on hexaethyl tetraphosphate. It is more toxic to many species of aphides than nicotine, giving a complete kill at 0·005 per cent (Schrader), and is sufficiently resistant to hydrolysis to be used with lime sulphur or as a dust. It is also ovicidal, being about as toxic to *Aphis pomi* eggs as 3 : 5-dinitro-*o*-cresol. Claims had been made that *E*.605 was toxic to a wide range of insects. Schrader found that diethyl-*p*-nitrophenyl phosphate (*E*.600) was also highly insecticidal, but had not gone further with this compound on account of its toxicity to mammals.

Dr. Martin then referred to the discovery of the systemic insecticides by Schrader and Kükenthal[2]. Apparently these workers had included a soil-watering test in their routine examination for insecticidal properties, and had found that certain organic compounds could be absorbed by plants, which thereby became toxic to insects placed on them. Few of the systemic insecticides described by Schrader are available in Great Britain, but three have been examined at Long Ashton:

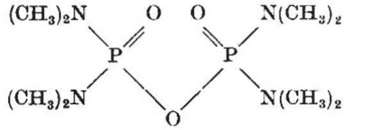


(III)

Bis-(dimethylamino)fluoro-phosphine oxide

$CH_2(OCH_2CH_2F)_2$ (IV)

Bis-(2-fluoroethoxy)methane



(V)

Pyrophosphoryl tetrakis dimethylamide

Dr. Martin considered that the systemic insecticides would prove of value in the investigation of translocation in plants, but he deprecated their practical use for insect control before it is known whether or not they are toxic to mammals or give rise to toxic products in the plant.

Dr. H. E. Coates discussed points of chemical interest concerning the phosphorus insecticides, particularly methods of synthesis and questions of chemical constitution. He said that hexaethyl tetraphosphate is a mixture of linear polyphosphoric esters, hexaethyl tetraphosphate, pentaethyl triphosphate, tetraethyl pyrophosphate and unreacted triethyl phosphate, together with a small amount of acidic by-product. The branched structure (I) suggested by Schrader is incorrect because only a small amount of *ortho*-phosphoric acid is obtained on hydrolysis, whereas the branched formula should give one molecule of *ortho*-phosphoric acid per molecule of the substance. The explanation of linear ester formation is that phosphoryl chloride and triethyl phosphate disproportionate on heating to give a mixture of diethyl chlorophosphonate and ethyl dichlorophosphonite, which then reacts with more triethyl phosphate to give the linear esters. Two methods for the preparation of tetraethyl pyrophosphate were given; the first, of academic interest only, uses silver pyrophosphate and ethyl iodide, but the second, from diethyl chlorophosphonate and triethyl phosphate, is applicable to large-scale production. *E*.605 can be prepared by allowing thiophosphonyl chloride to react with alcoholic sodium ethoxide, the resulting diethyl chlorothiophosphonate being heated with sodium *p*-nitrophenate in chlorobenzene. In the synthesis of bis-(dimethylamino)fluorophosphine oxide, it was shown to be advantageous to cause one molecule of phosphoryl chloride to react with four molecules of dimethylamine to give bis-(dimethylamino)phosphoryl chloride $[(CH_3)_2N]_2POCl$; this gave the desired end-product on reaction with sodium fluoride. Reference was made to a recent colorimetric method[3] for the estimation of *E*.605.

Mr. S. H. Bennett described preliminary experiments with systemic insecticides, referring to certain organo-phosphorus compounds, and to bis-(2-fluoroethoxy)methane, which had been investigated by Schrader, and also to sodium selenate, the systemic properties of which are more generally known. Schrader's findings had first been confirmed at Long Ashton when groundsel plants watered with a 1 per cent solution of bis-(2-fluoroethoxy)methane were shown to be highly poisonous to fully grown larvæ of the cinnabar moth (*Callimorpha jacobææ*). Similar results were obtained using tick bean plants inoculated with bean aphis (*Aphis fabæ*); infestations occurred only on untreated plants. It was found that bis-(dimethylamino)fluorophosphine oxide and bis-(2-fluoroethoxy)methane had powerful systemic properties, but pyrophosphoryl tetrakis dimethylamide was only weakly systemic. These compounds act as fumigants as well as contact poisons; but tests of the former activity failed at first because of the difficulty of separating the fumigant effect of the material in the leaf from that in the soil. This difficulty was overcome by rooting willow plants in water culture, transferring to the insecticide solution and returning to the water culture again when sufficient material had been absorbed, after which it was possible, by assuming uniform distribution of insecticide throughout the plant tissue, to calculate the amount present in a leaf. The fumigant effect was then tested by placing brassy willow beetles (*Phyllodecta vitellinæ*) on muslin with the plant material below and enclosing the whole in a glass vessel. In these circumstances it was found that the fumigant activity of the insecticide in the plant tissue was a hundred times as great as might have been expected from comparable experiments with aqueous solutions. Further experimental work is desirable to explain this effect, which may be the result of differences in the partial pressure of the fumigant in the two systems.

In further experiments, *Calandra granaria* were fed on grain from plants which had been watered with solutions of bis-(2-fluoroethoxy)methane or sodium selenate. While neither compounds caused the grain to become directly toxic to the weevil, infestation did not build up in the selenate-treated wheat, and it appeared that the reproductive powers of the insect had been affected. Referring to the phytotoxicity of these compounds, Mr. Bennett mentioned that bis-(dimethylamino)fluorophosphine oxide is the most toxic to plants growing in soil, but in water culture pyrophosphoryl tetrakis dimethylamide has caused serious plant damage.

In the general discussion that followed, Dr. J. K. Eaton referred to the ovicidal properties of *E*.605 and related compounds. He said that, of the twenty-seven substances examined at East Malling, only *E*.605 and *E*.600 (diethyl-*p*-nitrophenyl phosphate) showed appreciable toxicity to winter moth eggs (*Operophtera brumata*). The eggs of the green apple aphis (*Aphis pomi*) were more susceptible to the action of these organo-phosphorus esters, *E*.600 and di*iso*propyl-*p*-nitrophenyl phosphate giving complete kill at 0·005 per cent. The results indicated that toxicity to *Aphis pomi* eggs is associated with the incorporation into the phosphoric or thiophosphoric acid molecule of two alkyl groups and an aryl group. Toxicity is increased by the introduction of electron-attracting groups in the *para* position of the aryl substituent. Preliminary field trials for the control of certain species of aphides using *E*.605 and hexaethyl tetraphosphate had been carried out. The results showed that both give control equal to or better than nicotine at the same concentration; *E*.605 is generally the superior. No phytotoxic effects had been noted.

Mr. R. S. Pitcher said that a high kill of the raspberry cane midge (*Thomasiniana theobaldi*) had been obtained under conditions in which *E*.605 appeared to exert an ovicidal effect at a distance. Dr. Martin replied that there was little evidence that *E*.605 had systemic properties, and he considered that the action could be explained as a fumigant effect. Answering a question concerning the use of systemic insecticides marked with radiophosphorus for following the movement of these compounds in plants, Dr. B. A. Kilby said that work had just started at the University of Leeds on the synthesis of such compounds. The most convenient synthesis used phosphoryl chloride as the starting material; but radiophosphorus is most readily available as inorganic phosphate, and the conversion of this to phosphoryl chloride is not easy. The difficulty might be overcome by the discovery of a suitable exchange reaction or by a supply of radiophosphorus in a more convenient form.

Dr. R. A. E. Galley urged that the nomenclature of the organo-phosphorus compounds should be standardized and favoured the introduction of trivial names for the better known phosphorus insecticides.

J. K. EATON

[1] *Z. anorg. Chem.*, **212**, 182 (1933).
[2] *Brit. Intell. Obj. Sub-comm.*, Final Report 714 (1947).
[3] *Anal. Chem.*, **20**, 753 (1948).

'MECHANISM' OF *PHYTOPHTHORA*-RESISTANCE OF POTATOES

By K. O. MÜLLER and LOTHAR BEHR*

USING as a basis the American 'native forms' of the tuber-bearing species of Solanaceæ, German breeders during the last two decades have developed potato varieties with both leaves and tubers resistant to most of the known races of *Phytophthora infestans*. It is true that the origin and initial constitution of the material which was used for the breeding of these varieties is only imperfectly known; but we know that its refractory behaviour towards the *Phytophthora* fungus is associated with a gene *R* which is not found in any European variety of the old-fashioned type. Furthermore, according to K. O. Müller, this resistance gene has several associated alleles and is inherited independently of other economically important characters, such as yield capacity, time of maturity, and the like. Therefore it did not take very long to combine the *Phytophthora* resistance of these '*W* varieties' with the high yielding-capacity and other inherent qualities of the European cultivated potato. The first German commercial varieties resistant to *P. infestans* which appeared on the market were Erika (1941), Robusta (1941), Fruehnudel (1941), and Aquila (1942). There are at present in Germany ten new registered potato varieties, all of which possess this resistance gene.

Investigation into the mode of action of this gene, particularly as regards the tubers, led to the conclusion that the alleles present in the *W* varieties are not responsible for the resistant condition itself, but induce only a genetic predisposition of the tissues to 'acquire' a local immunity from infection when they come into contact with the hyphæ of parabiontic races of *P. infestans* (that is, those strains which kill the cells quickly, thereby arresting the further growth of the hyphæ). From the physiological point of view, whether or not a variety is resistant is not decided until the parasite has penetrated into the host tissues. Comparative investigations into the reactions of susceptible and resistant genotypes revealed that in both the host cell is destroyed after coming into contact with the protoplasm of the parasite. Judging by the morphological and physiological changes the final effect is the same—the cell collapses and loses its ability to serve the parasite as a host. But the rapidity with which this final effect is achieved differs in susceptible and resistant genotypes. While the cells of the former live relatively long —six to fourteen days at 19–21° C.—those of the latter die after one or two days, the process being too rapid for fructification of the fungus to occur; moreover, further penetration by the hyphæ is made impossible by the rapid reaction of the host tissue, which in the course of this reaction also loses its ability to serve as a host to eusymbiontic fungus strains (that is, strains which can invade the host tissue without killing it quickly). Other pathogenic micro-organisms, too, are unable to use such 'immunized' tissues as nutritive substrates. The reaction is therefore unspecific (K. O. Müller and H. Boerger).

Cytological-physiological investigations by K. O. Müller, G. Meyer and M. Klinkowski in 1938 showed that it is possible to distinguish in this 'defence-necrosis' at least five successive stages, the last two being characterized by cell collapse and by a heavy infiltration of the cell-walls and cytoplasm with phlobaphene-like compounds, which appear to arise, according to Meyer (1939), through polymerization of tannic substances. These can be demonstrated by the usual tannin reagents after infection in host cells which are still alive.

This close relation between the degree of resistance and the rapidity with which necrosis is brought about was demonstrated in extensive breeding material, consisting partly of previously unselected *F*2 families of crosses between 'resistants' and 'susceptibles'. It was also shown that the two extremes, 'highly susceptible' (the parasite penetrating uniformly through the entire tuber and fructifying luxuriantly) and 'highly resistant' (the parasite penetrating only a few cell-layers of the parenchyma of the tuber and then ceasing to grow without fructifying), are connected by at least two genotypically conditioned intermediate types. These are characterized by an intermediate reaction-rate and—in agreement with what has just been said—their tubers are penetrated to a considerable depth by the parasite (K. O. Müller).

Other investigations led to the conclusion that the 'defence necrosis' is induced by substances secreted by the parasite into the host tissue. Accordingly, the specific behaviour of the resistant genotypes would appear to depend on a specific sensitivity of the protoplasm, controlled by gene *R*, so that the highest reaction-rate would be associated with the greatest degree of resistance. Because the susceptible genotypes also react to these substances, there appears to be no fundamental, but only a graduated, difference between 'resistants' and 'susceptibles', and we conclude (paradoxical though it may appear at first) that the greater the sensitivity of the cells to the metabolic products of the parasite, the greater the resistance of the tuber. Further, the resistance gene *R* is not a factor *sui generis*; it only accelerates a reaction which the susceptible genotypes are also capable of producing. There is, however, a further conclusion. In the course of the reaction the host tissue loses the ability to serve as a nutrient substrate for the fungus. As not only *P. infestans*, but also other micro-organisms which can thrive on a wide range of organic matter (*Rhizopus nigricans*, *Aspergillus niger*, and others), are not able to exist in the necrotic, transformed tissue, the necrosis of the affected tissues must be accompanied by the formation or activation of a principle ('phytoalexin') which

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