POTATO VIRUS DISEASES

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THE degeneration of the potato seems to have been unknown in Europe before about 1770, but after that it rapidly assumed such proportions that by 1780 farmers in some districts had to abandon potato growing, and prizes were offered to those who could find the cause and devise a cure for this serious affliction of so important a crop. For 150 years there was continual speculation and controversy about the cause of this degeneration. Some shrewd observers drew deductions that recent work has fully confirmed, but in the absence of any direct experimental evidence the most widely held view was that potatoes degenerate because they are weakened by continual propagation by 'unnatural' asexual methods. Only within the last twenty years has it become clear that degeneration is a result of plants becoming infected with one or more viruses, which are handed on to the progeny through tubers, but rarely, if ever, through the true seeds. If one can judge from the size of the audience at a discussion on this subject, arranged jointly by the Association of Applied Biologists and the British Mycological Society*, on October 9, this advance in our knowledge has certainly not lessened interest in the problem.

Many early writers noticed that potatoes degenerated more rapidly in some districts than in others, and a few suggested that there was some correlation between degeneration and infestation with aphids. Long before virus diseases were recognized, some growers in the south and east of Great Britain regularly obtained new supplies of seed from the north and west, and in this way avoided serious losses. With the discovery that the most destructive virus diseases are transmitted by aphids, and that the weather in the north and west usually inhibits the multiplication and movement of aphids, this method of control has been increased enormously. Steps have also been taken to improve on the natural advantages of these districts. The crops are examined periodically and diseased plants removed; they are also inspected and awarded certificates of health stating that they contain less than a small percentage of infected plants. Mr. G. Samuel stated that at the present time something more than 300,000 tons of such certified seed is imported into England from Scotland and Ireland each year. Within two or three years this has become valueless for seed purposes, and he described this wastage as our most important plant pathological problem.

Some twenty viruses that affect the potato have now been described, but in Great Britain most of the losses are caused by three: leaf roll, potato Y and potato X. These differ strikingly from one another in their behaviour, and Mr. F. C. Bawden showed that conditions favouring the spread of one might not favour the spread of another. Even with viruses transmitted by aphids this is true, for the relationships between different viruses and their vectors differ. For example, aphids become infective with leaf roll only slowly; a day or so must elapse after they have fed on a diseased plant before they can infect a healthy one, but once they have become infective they go on being so for the remainder of their lives. Mrs. M. A. Watson has shown that the position with potato virus Y is very different. Aphids can transmit

this virus immediately after feeding on a diseased plant, and, oddly enough, they transmit more readily if they are first starved and then fed for only a few minutes on a diseased plant. Such aphids also remain infective for only short periods, sometimes minutes and never more than hours. These differences offer an interpretation of the fact that, with crops in which both viruses are present, one may spread considerably while the other does not. For the slow-moving, wingless aphids would seem ideally suitable for spreading leaf-roll, whereas the winged migrants are much more likely to fulfil the requirements for transmission of potato virus Y.

Scotch and Irish stocks owe their superiority to their relative freedom from these two aphid-transmitted viruses, for even the best of these stocks are often infected with virus X. In many varieties this produces a mild mottling of the leaves, insufficient to be noticed readily, especially if all the plants are uniformly affected. In spite of the slight leaf symptoms, various workers have found that such infections can reduce the yield by 20 per cent; this is small compared with the 50-90 per cent reduction found for different varieties with leaf-roll and severe mosaic, but is nevertheless considerable. There is, therefore, still room for improvement in our certified stocks. The method being tried is to test individual plants of established varieties until some are found free from this virus and then multiply these as nuclear stocks to replace those now grown. Some of the difficulties of this method were described by Dr. Kenneth M. Smith. With many of our commercial varieties it has so far proved impossible to find a single plant uninfected. But even when this first difficulty is overcome, the problem is by no means simple. We know no insect-vectors for this virus, and we are still largely ignorant of what precautions to take to keep such plants healthy. Workers in Ireland find that healthy plants can become infected if their leaves rub against infected plants, but there is some doubt if this method of spread could account for all infections. Virus X is found in crops other than potatoes, both under glass and in the field, and healthy potatoes in insect-proofed glasshouses are not always safe against it. It is obvious that the multiplication of stocks free from this virus is important; but before it can be embarked upon on a large scale further research is needed on the conditions that lead to infection.

Although Scotland and Ireland produce most of our best potato seed, they have no monopoly. On the wind-swept hills of Wales, Cumberland and Devon and Cornwall aphids are also rare, and in these districts there are now flourishing associations for the production of certified seed. The oldest of these is in North Wales, where for fifteen years Dr. T. Whitehead has maintained the same stocks in a state of vigour. Over this period he demonstrated a close correlation between aphid numbers and the health of the stocks, and only in a few exceptional years in which aphids have multiplied excessively has there been any difficulty in keeping the health of stocks up to the standards for certification. The most important aphid is *Myzus persicae*. Its normal method of overwintering is in the egg stage on peach trees; but it can also survive in the adult form under glass and, in favourable conditions, in the open on cruciferous crops, especially savoys. In North Wales, where there are few peach trees, Dr. I. Thomas considers that the degree of infestation of the potato crop is largely determined by the severity of the

* It is hoped that the proceedings will be published in full in the February number of the *Annals of Applied Biology*.

previous winter, for only when conditions favour overwintering out of doors are the numbers of aphids large. The importance of the method of overwintering is also shown by *Aphis rhamni*, which in this region is found in numbers only in the few localities where the winter host *Rhamnus catharticus* occurs.

In East Anglia conditions are very different. Mr. J. P. Doncaster finds that *A. rhamni* is the commonest aphid on potatoes, and frequently reaches an average of more than a hundred per leaf. Fortunately, this aphid does not seem to transmit leaf roll. As it moves about less readily than *Myzus persicae*, it is probably less important as a vector, but it is likely that the migratory forms play a considerable part in the transmission of potato virus Y. Overwintering on Brassicæ seems to be rare in East Anglia, but here there are sufficient peach trees and glasshouses to provide ample sources for *M. persicae* in the spring. No attempts have yet been made to control the aphids by treating their overwintering sources, for example, by wholesale winter-washing of trees and fumigation of glasshouses; but Mr. Doncaster reported that on the potato crop a complete kill was obtained by fumigation with nicotine. The effects of the treatment, however, were only temporary, and the fumigated crop rapidly became re-infested from nearby sources not treated.

After examining many potato crops in eastern England, Dr. P. H. Gregory and Mr. Doncaster could find no simple correlation between numbers of aphids and amount of spread of leaf roll and potato virus Y. It seems likely that in these districts there are almost always sufficient aphids for rapid spread and that whether this occurs or not depends on other factors, probably those influencing the movement of the insects. In many crops in 1941 there was a striking difference between the behaviour of the two aphid-transmitted viruses. Potato virus Y spread only to a small extent and only early in the season, again suggesting a correlation between the winged migrants and spread of this virus. By contrast, the number of plants infected with leaf roll virus increased steadily throughout the season, and in some stocks with large haulms, in which movement of crawling aphids from plant to plant would be facilitated, the percentage of infected plants increased more than twenty times.

The ability of one and the same potato virus to produce different symptoms in different potato varieties greatly complicates diagnosis, but can also be of value in helping to reduce losses. Paradoxically, it is the most susceptible varieties that suffer least. Some British varieties, for example, King Edward and Epicure, die quickly when infected with virus X. Infected plants leave no viable tubers to act as further sources of infection, and the stock as a whole is safeguarded by the death of the individual. Similarly, other varieties are killed by infection with viruses A, B and C. In effect, such varieties do their own roguing, and Dr. G. Cockerham showed that the health of commercial stocks of these varieties is much better than that of those which tolerate infection. This hypersensitivity is inherited, and by crossing between different varieties, the Scottish Society for Research in Plant Breeding has produced Craig's Defiance, which dies when infected with any of viruses A, B, C and X, so that stocks of this variety remain virtually free from all four. Unfortunately, no varieties are known which are hypersensitive to leaf roll and virus Y, but after testing some hundreds of different varieties Dr. Cockerham reported that he had found

some with a true resistance. As this is also inherited, it seems that the geneticist will begin to play an increasingly important part in combating potato virus diseases. However, no quick success can be expected by this method; also, viruses appear to mutate with such frequency that permanent success should not be expected either, as it is impossible to be sure for how long a new variety bred for some specific property will retain this in the field.

In an attempt to increase the health of crops from once-grown seed, the Ministry of Agriculture has since the War introduced a scheme whereby crops in England, grown from Scotch or Irish seed and planted fifty yards from other potatoes, receive a seed certificate. Mr. Samuel showed that the measure is meeting with some success, for such seed usually contains less than 10 per cent of severely affected plants and crops as well as new seed, but it does not greatly increase the useful life of the stock. One wonders whether the information we now have about potato virus diseases could not be still further applied. In normal times it may be that the import of new seed each year is the most economical control measure, but now the transport of 300,000 tons of potatoes is in itself a problem. In many parts of England it is likely that the growing of heavy crops of ware potatoes and the production of good seed are incompatible, for maximum yield is obtained only if the plants have a long growing period and this greatly increases the likelihood of infection. But crops grown especially for seed purposes could probably be kept in a good state of health for several years. These could be grown in isolation, possibly on some of the reclaimed land that cannot be expected to yield large crops, rogued, perhaps sprayed or fumigated against aphids, and the tops killed early in August, after all the tubers are formed but before virus diseases have had time to spread appreciably. The contributions at the discussion all suggested that this may be a practical control measure, but it urgently needs testing on a commercial scale.

VELOCITY OF RADIO-FREQUENCY WAVES*

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THE wireless engineer and radio physicist require to know the speed or velocity of electric waves in order, for example, to convert their measurements of frequency into the corresponding wave-lengths, while various methods of studying the propagation and direction of arrival of waves involve a knowledge of the wave velocity.

Apart from the various classical experiments on the velocity of light conducted during the latter half of the nineteenth century, the most comprehensive work on this subject was carried out by Prof. Michelson and his co-workers, and the most important part of these investigations were in progress when Michelson died in 1931. The equipment used in this work is notable by reason of the fact that the path traversed by the light waves was enclosed in a steel tube one mile long and three feet in diameter,

* Substance of the chairman's address before the Wireless Section of the Institution of Electrical Engineers, delivered on Oct. 7.