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THE INSTITUTE FOR PHYTOPATHOLOGICAL RESEARCH (I.P.O.) WAGENINGEN, THE NETHERLANDS

by

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IN 1895 Ritzema Bos became director of the Phytopathological Institute "Willie Commelin Scholten" in Amsterdam (later to be transferred to Baarn). Some years later (1899) the Netherlands Phytopathological Service was founded, mainly as a result of his activities. In 1906 he established the Institute of Phytopathology (not to be confused with the Institute for Phytopathological Research) at Wageningen; he became its first director. This institute still exists as an organizational part of the State Agricultural University. It is composed of the laboratories of Entomology, Phytopathology, Virology and Bulb Research, the last one at Lisse. From the beginning important work has been carried out at these laboratories, expecially in the field of nematology (Ritzema Bos) and virology (Quanjer). As for virology it may be mentioned that it was Adolf Mayer who in 1886, while working at the Agricultural High School of Wageningen, proved the infectiousness of a tobacco disease which he named mosaic. Work with tobacco mosaic (TMV) brought Beyerinck to his famous postulate of the "contagium vivum fluidum" after he had shown that no fungus or bacteria was the cause of this infectious disease. Ever since, TMV has been the subject of numerous virological and biochemical investigations.

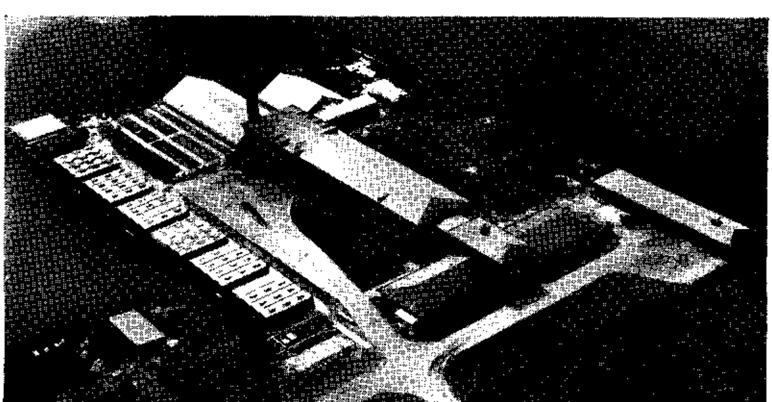
Phytopathological Research

In the beginning of this century the Netherlands Plant Protection Service started but its duties are so manifold that little time remains for extensive research on special diseases or pests or on more general phytopathological problems. It is for this reason that the Institute for Phytopathological Research (Dutch abbreviation I.P.O.), a Government-sponsored research institute with no educational duties, was established in 1949.

More Research Necessary

After the discovery of DDT and parathion as insecticides and of dithiocarbamates as fungicides, it was optimistically believed that it would be possible to control all pests and diseases merely by a simple chemical treatment. But this did not come true. More research on the biology, epidemiology and spread of the noxious organisms appeared to be necessary.

During the war years some plant pathologists and entomologists were already studying pests



The I.P.O. complex three years ago. Two large greenhouses have been added since this photograph was taken

and diseases of special importance in the Netherlands. Most of these scientists were paid by private funds; some worked in University Laboratories, others in primitive field laboratories or even in an abandoned poultry house!

Practical Research

The first task of the newly established Institute for Phytopathological Research was to co-ordinate this research and to provide laboratory space, greenhouses and equipment. It was deemed unwise to concentrate all research workers in the Wageningen laboratory; for the study of pests and diseases of some crops it seemed more advantageous to allow the specialist to work in the main growing centre of such crops where he could follow the development of the crop plant and the pest or disease step by step under practical field conditions. At the present time one plant pathologist and two entomologists are attached to the Experimental Station for fruit growing at Goes, one plant pathologist and one nematologist at the Experimental Station for vegetables at Alkmaar; two plant pathologists (a mycologist and a virologist) at the Experimental Station for flowers under glass at Aalsmeer, one plant pathologist is studying diseases of tomato and endive at the Experimental Station for fruit and vegetables under glass at Naaldwijk; and one plant pathologist is working on diseases of gherkins and tomatoes at the Experimental Garden at Venlo.

The total staff of the I.P.O. numbers 117. About half of the 38 scientists hold the M.Sc. or Ph.D. of the Wageningen University in agriculture or horticulture; the others are biologists graduated at the Universities of Amsterdam, Utrecht, Leiden and Groningen.

Most have specialized in plant pathology (including virology), entomology or nematology. The others graduated in plant physiology or biochemistry.

Facilities Available

Modern laboratory equipment such as ultracentrifuges, spectrophotometers, equipment for electrophoresis, chromatography and for work with radioactive isotopes are available. Other facilities include a low temperature room, refrigerated store rooms for mycological cultures and media, transfer rooms, light chambers, temperature and humidity controlled chambers, Wisconsin tanks, battery thermostats and a modern potato storehouse with six chambers. Conditioned greenhouses have been built or are under construction for virus and mycological work. In total, 2500 m^2 of greenhouse space will soon be available. Several hectares of experimental fields, partly on heavy clay, partly on sandy soil are in use for field trials.

A special team takes care of other field trials which are carried out in co-operation with the Agricultural and Horticultural Extension Services throughout the country. The research workers also have at their disposal the services of a statistician and of a meteorological assistant. The I.P.O., with the adjacent Laboratories for Entomology, Phytopathology and Virology of the University, situated at the Binnenhaven forms the centre for Phytopathological and Entomological Research.

Subjects Under Study

The subjects studied at the I.P.O. are divided among the following departments and sections: 1. mycology and bacteriology; 2. virology; 3. entomology; 4. nematology; 5. plant disease resistance; 6. biochemistry and the use of radioactive isotopes; 7. agricultural aviation; 9. influence of air pollution on plant growth. Several research workers are participating in working parties on special subjects (e.g. potato root eelworm, harmonious control of insect pests, soil borne virus diseases).

After this general introduction a survey of the present research projects will be given. Some of the most important results already obtained in the past will be mentioned too. The results of the work have been published in more detail in various journals. Reprints and sometimes also original articles are collected in a numbered series of contributions of the Institute called: "Mededelingen van het Instituut voor Plantenziektenkundig Onderzoek (I.P.O.)". Articles are written in Dutch or English; they always contain a summary in English. A full list of the contributions of the I.P.O. is available on request.

Mycological-Bacteriological Department

A variety of subjects has been studied or is still under investigation in this department due to the large number of fungus and bacterial diseases which threaten our crops. The plant pathologist of I.P.O. attached to an Experimental Station elsewhere therefore will in the main pay attention to diseases of economic importance occurring in the special crops for which the station is responsible.

Financial support has been or is being given to the Institute at Wageningen by various grower organisations. It therefore seems convenient to classify these investigations according to crop.

Eradicant Action

A working group on apple scab (*Venturia inaequalis*) investigated the circumstances under which infection occurs in order to develop a rational spraying scheme.

Special attention was paid to the curative (eradicant) action of fungicides. Although organo-mercury compounds are good eradicants their high toxicity to human beings limits their application and they are used only in early spring and as a correction of the normal spraying programme in which protectant fungicides are used. Some of the newer organic fungicides also have an eradicant action, but the time between infection and the latest moment possible for their successful application is usually too brief to make them attractive to the fruit grower. In general the Mills correlation between weather conditions and scab development was found to be valid for the Netherlands. This subject was studied by Roosje[75] at the Fruit Tree Experiment Station at Zeeland. A warning system based on these investigations is now used by the Netherlands Plant Protection Service. It enables the grower to decide whether corrective spraying is necessary; a good nontoxic eradicant fungicide would make it possible to reduce the number of spray applications considerably.

Apple mildew (*Podosphaera leucotricha*) is another important disease of many apple varieties. The much grown Jonathan is especially susceptible. Roosje is studying this disease and he also pays attention to *Gloeosporium*, responsible for storage rots of Golden Delicious. *Phytophthora cactorum*, first found by ten Houten[45] as the cause of collar rot of the apple variety Cox's Orange Pippin in the Netherlands is now controlled either by the application of copper fungicides to the stem or, in the case of young trees, by grafting Cox's on an intermediate stem of a resistant variety.

Effect of Changing Physiology

Silver leaf disease, especially of plum-trees, has been studied by Grosjean who found that the disease did not spread in the trees at low temperature nor during periods of active assimilation. The main development of the causal fungus *Stereum purpureum* takes place if temperature is high enough and if the physiological condition of the tree permits. This led Grosjean[36] to the idea that control might be possible by changing the physiology of the tree. For example, a combination of ferrous sulphate and salicylic acid, applied to the soil four times a year often gives a marked improvement of diseased plum trees. Breeding of new resistant plum varieties has been carried on since 1943[35]. Some interesting selections were obtained, but they cannot compete with the well-known plum varieties already on the market. The same worker saw some improvement of cherry trees affected by bacterial canker (*Pseudomonas mors prunorum*) after spraying with oxyquinoline sulphate 4 times between the beginning of August and leaf fall.

Blight on Raspberries

Cane blight of raspberries appears to be due to various fungi; some may affect the cane directly, others only after the feeding of the larvae of the gallmidge *Thomasiniana theobaldii*. On sandy soils removal of the first spring shoots (May shoots) was successful because the first generation of the gallmidge is deprived of egg-laying sites[57]. Moreover, this procedure prevents too dense growth of the canes and thus guarantees sufficient ventilation and a lower humidity. But sometimes fungicidal sprays may still be necessary.

Black root rot of strawberries, which is of particular importance in some sandy areas in

Trapping spores of *Gloeosporium* from a 6 months-old canker on apple twig

the western part of the country, has long been a problem; many weak pathogens were isolated, none of which reproduced the disease. Finally it became clear to Miss Klinkenberg and Seinhorst that the primary cause of the disease was an attack by the nematode *Pratylenchus penetrans* followed by a secondary invasion of various weak parasitic fungi[53].

A leaf disease of leek was found by van Hoof[44] to be caused by *Phytophthora porri*, a fungus not previously known to occur in our country. Corky root of tomato, long considered to be a virus disease, was shown to be caused by a fungus, belonging to the *Mycelia sterilia*[66]. Termohlen intends to publish a paper on this disease and its control. Blight of endive is caused by the fungus *Marssonina panattoniana*[41]. Spraying with maneb gave good results.

Bacterial diseases of carnations have been studied both by Scholten at Aalsmeer and by Miss Bakker (now Mrs. Post) at Wageningen. One disease is caused by *Pseudomonas caryophylli*, the common cause of bacterial rot in the U.S.A. This disease is not dangerous under greenhouse conditions in the Netherlands contrary to a second bacterial disease caused by *Pectobacterium parthenii* var. *dianthicola* (= *Erwinia* sp.). By soil sterilization and a careful selection of healthy clones for propagation it was possible almost to get rid of the latter disease[3]. Scholten proved that a root rot of Cyclamen which had hitherto been described as caused by *Thielaviopsis* was in fact mainly due to *Cylindrocarpon radicicola*. This disease can be controlled by steam sterlization of the greenhouse soil or by mixing the soil with zineb[80].

Storage of Potatoes

Much work has been done by Mooi[64] on storage diseases of potatoes. Dry rot, caused by *Fusarium caeruleum*, depends on the physiological condition of the tubers during storage. When sprouting takes place the tubers become more susceptible. Therefore storage at low temperature has proved the best method of control. *Colletotrichum atramentarium* causes a serious storage disease in one of the less important varieties[65]. Early disinfection of seed potatoes with organic mercury compounds gives good results, but can only be used on seed potatoes. Other storage diseases such as silver scurf can be reduced considerably by drying the tubers as soon as possible after harvesting followed by storage in special potato storehouses at low temperature (+3-5°C).

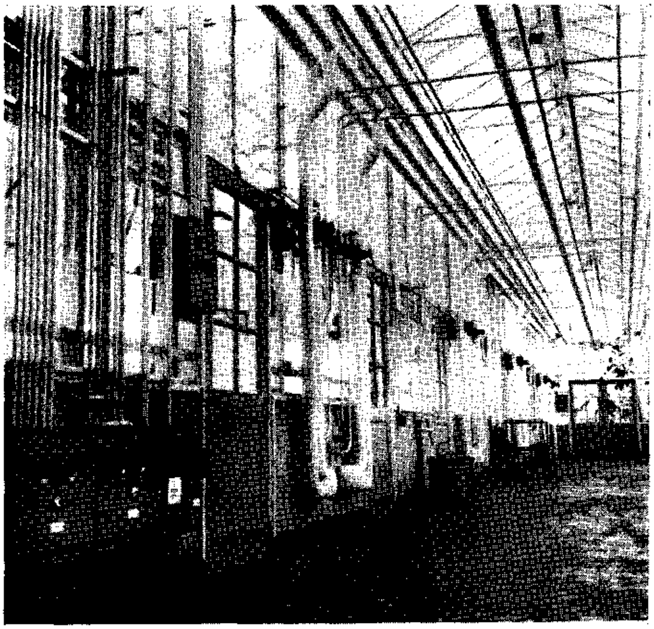
Other important potato diseases under investigation are: late blight (*Phytophthora infestans*) where special attention is being paid to field-resistance and tuber resistance; Rhizoctonia disease, being studied by van Emden, Labruyere and Miss de Boer. They have proved that in the majority of Dutch agricultural fields no soil infection takes place but that sclerotia on the seed tuber were the main source of infection. The best possible control, therefore, can be obtained if healthy clean tubers are used or if the seed tubers are disinfected thoroughly before planting. Furthermore all factors favouring quick initial growth limited damage[13]. In some cases the use of pentachloronitrobenzene as a soil disinfectant appeared beneficial for seed tuber production. It sometimes causes an off-flavour, which makes this treatment less attractive for ware potatoes. This is the more regrettable as such a soil treatment also controls potato scab[14].

Downy Mildew

Good results have been obtained with zineb for the control of downy mildew (*Peronospora destructor*) in onions. The application of zineb should be stopped several weeks before harvest time because otherwise vegetative growth will continue with the result that neck rot (*Botrytis allii*) may become very severe[11]. Control of neck rot is difficult, but by harvesting the onions at the right moment, drying them for a certain period on the field and afterwards drying them indoors with much air at a rather low temperature the losses are reduced considerably, as van Doorn[12] in his trials demonstrated.

Both in the case of peas and poppies, infection with downy mildew takes place by means of oospores of the fungus present in the soil. With the peas good results have been obtained by fertilizing the soil with calcium cyanamide previous to sowing. Poppies are too sensitive to this treatment[60]. Van der Spek[87] showed that infection of flax with *Botrytis cinerea* takes place mainly via the seeds. If only a light contamination is present on the seed, treatment with thiram or quinones is sufficient. In case of heavy contamination it is necessary to use a volatile organic mercury compound three to four weeks before sowing. The disease spreads from seedling to seedling with mycelium growing on or just below the surface of the soil. Aerial infection by spores has only been found if the flax plants were also infested by other fungi, e.g. *Pythium megalacanthum*.

As soil treatments with fungicides are not always attractive, much attention is being paid by van Emden, Labruyère, van der Spek and



Left: General view of the virus greenhouse
Below: Inoculating test plants for identifying potato diseases

Tichelaar to the possibilities of a biological control of parasitic soil fungi. Maas Geesteranus is now concentrating his attention mainly on all types of bacterial plant diseases. One of his aims is to use bacteriophages as a means of identification for bacterial plant diseases. He also cultivates bacteria harmful to noxious insects.

Virological Department

As virus diseases have been an important subject of study at Wageningen ever since Adolf Mayer found tobacco mosaic, this department of the institute is well equipped with personal and working facilities.

Unknown Virus Diseases

One of the first diseases van Hoof[40] studied was black speck in cabbage which develops mainly during storage. This disease had caused severe losses in our main cabbage growing area in North-Holland. At the time the pathogen was unknown. Van Hoof soon proved cauliflower mosaic virus to be the cause. Seed cabbage was the major source of infection. By treating all seed cabbages with systemic insecticides against *Brevicoryne brassicae*, an aphid transmitting this virus, it was possible to get rid of the disease. Since 1951 spraying is carried out under the direct supervision of the main cabbage auction in this area. No damage has been found since the spraying programme started whereas in 1949, the disease caused a loss of over one million guilders.

Another virus disease of cruciferous crops which caused heavy damage in fodder turnips in 1949 was studied by Beemster[5]. He proved that the seriousness of this disease was due to the abnormally high temperatures during September, which averaged 20°C over several weeks. At 15°C almost no symptoms were visible. Since the Royal Netherlands Meteorological Institute in the last 200 years has recorded such abnormal temperatures in September only once, it was decided to abandon further research on this disease.

Leguminous Crops

Virus diseases of leguminous crops have been studied since the foundation of the I.P.O. in 1949. Van der Want[98] concentrated on such diseases of bean. He found that beside Phaseolus virus 1, which is the most common bean virus in the Netherlands, Phaseolus virus 2 appeared quite frequently. This virus is also present in Gladiolus, an ornamental which is often grown in the neighbourhood of bean crops thus forming a dangerous source of infection, especially in years with many aphids, which act as vectors. From van der Want's work it became evident that many viruses of leguminous plants are in various hosts. Therefore virus diseases of all leguminous crops are at present being studied simultaneously by Bos. In peas he found two important virus diseases, top yellows and early browning which were previously unknown in our country. Breeders are now able to select their breeding material for resistance to these viruses. A careful description of the symptoms and uniform methods of identification are of the utmost importance for a good diagnosis. Together with Hagedorn (U.S.A.) and Quantz Germany), Bos wrote an article[9] on this subject which is considered to be of great value for all workers in this field. He also initiated an international working group on viruses of legumes.

Fruit Viruses

Work of fruit tree viruses was started by Mulder. It is continued by Miss Pfaeltzer. A virus disease of cherries appeared to be caused by a complex of viruses of which one is definitely soil borne and probably transmitted by nematodes[18]. Miss Pfaeltzer is also working on virus diseases of apple and pear, this year with Dr. Nyland from California.

De Fluiter studied strawberry viruses and their transmission by the strawberry aphid, *Pentatrichopus fragaefolii*. He proved that the spread of most viruses could be strongly limited by killing the vectors with systemic insecticides in field plots before and after harvest[20]. De Fluiter and van der Meer also investigated virus diseases of raspberries, especially Rubus stunt, a severe disease of cultivated raspberries in some areas. They proved that this disease is transmitted by the leafhopper *Macropsis fuscula*[23]. Fifteen other leafhoppers investigated could not transmit the virus. This was the first case of a leafhopper-transmitted virus in Western Europe. The disease can be controlled by killing the vector (see also under Entomological Department). Other virus diseases of raspberry are transmitted by aphids. Van der Meer succeeded in curing some of these virus diseases by heat treatment of the canes[62]. He is also studying the virus diseases of black and red currants, spoon leaf disease of red currant being his major interest. This appears to be a soil-borne virus that remains in the soil for years. Work on possible transmission by nematodes is in progress. Various weeds may function as host plants. The research on potato viruses and carnation—see chrysanthemum viruses—will be treated below in relation to some special methods either of identification or of control.

Virus Transmitted by Aphids

It is well known that aphids act as vectors of many viruses, but how this transmission takes place is not always clear. In the case of the non-persistent viruses (viruses which can only be transmitted during a short time after the aphid has been feeding on a diseased plant), van der Want thought that such viruses were absorbed to the outer surface of the stylets (mouth parts of the aphid) to be liberated only by elution with saliva. The differences in effectiveness of virus transmission, existing between various aphid species, may then be due to differences in the outer structure of the stylets. Van Hoof proved this hypothesis to be correct. By means of the electron microscope he could see chitinous ridges on the outside of the mandibular stylets. It seems highly probably that the virus is transported mechanically in the furrows behind these ridges, for when van Hoof clogged these furrows with paraffin wax, almost no transmission took place. Van Hoof[42, 43] found that aphids which had been sucking only intercellularly in the epidermis of a diseased plant were able to infect a healthy plant. This lead him to the important conclusion that virus can be taken from the cell wall and that it also can be transmitted to a cell wall.

Transmission of Soil-borne Viruses

Since the foundation of the I.P.O. soil-borne viruses have been studied by van der Want, especially rattle virus of tobacco and stipple streak of beans. Such diseases are almost certainly restricted to light soils. It was not clear how such viruses remained in the soil after harvesting and how they were transmitted. Many years ago the author[97] suggested that nematodes possibly were the vectors and he persuaded the virus workers to investigate this possibility in close co-operation with the nematological department. Unfortunately a soil-borne disease of tomato was chosen, that afterwards was shown to be caused by a sterile mycelium. Later Sol[86] found that rattle virus of tobacco was transmitted by *Trichodorus pachydermus*, a nematode living in the soil in rather small numbers. Other nematodes present in large numbers were not vectors. It seems that the virus builds up in the body of *Trichodorus* for it appears to be persistent and even one individual nematode can transmit the virus to a healthy plant. Theoretically this opens new possibilities for controlling virus diseases, although the fact that one individual eelworm can be a vector will make it problematic whether the use of nematicides will be successful in controlling such diseases.

Translocation of Potato Plant Viruses

In seed potato production in the Netherlands early harvesting is one of the conditions for obtaining virus-free tubers. Harvesting too early, however, means a loss of weight. It therefore was important to know how much time elapses between infection of the leaves and infection of the tubers. Beemster[6] carried out a great number of very careful investigations with leaf roll, X, Y and the tobacco veinal necrosis strains of Y-virus. He found that in the case of leaf roll and virus X the period between leaf and tuber infection is longer the older the plant.

This phenomenon which he calls mature plant resistance may be of importance for the grower of seed potatoes. He should endeavour to get his plants as early as possible in this stage. This might be done for instance by early planting and pre-sprouting of the tubers. External factors such as fertilizing seem to be of importance also. Large field and laboratory trials on this subject are being carried out. The earlier work[4] resulted also in the discovery of partial infection of the tubers. Peculiarly enough the tobacco veinal necrosis strain of Y shows no mature plant resistance[7], which may well be one of the reasons why this new strain has spread so rapidly in the last few years.

Diagnosis of Virus Diseases

In studying virus diseases the diagnosis of the virus is of utmost importance. There are various possibilities in this respect, several of which were applied or were developed in the I.P.O. laboratory. Maat is trying to prepare for a wide range of viruses, especially those of leguminous and fruit crops. Rabbits are used for this purpose. It is essential to start with a pure virus if possible. Therefore several methods of virus purification are being used and new ones are being developed in conjunction with the biochemical section.

The General Netherlands Inspection Service for seeds of field crops and for seed potatoes (N.A.K.) uses several methods of diagnosis on a practical scale such as the serological test for the viruses X, S, M and Y in sprouts and leaves. De Bokx[8] in close co-operation with N.A.K. is trying to improve existing methods and to find new ones especially for testing the tubers for the presence of virus.

Control of Virus Diseases

In the foregoing, indirect control of virus diseases by controlling the insect vector has been mentioned several times. But not all viruses are insect transmitted; moreover, this method is of little use for the non-persistent viruses. Another possibility is the propagation of varieties resistant to the virus. This was successfully done by Tjallingii[91], who produced a new gherkin variety tolerant to cucumber mosaic, a disease causing serious losses in the southern part of the country. In the first year of the large scale introduction of this new variety, Guntruud, the auction at Venlo estimated the extra yield at two million Kg, representing a monetary value of one million guilders.

In other cases a vegetatively-propagated variety of a crop (potato, carnation, chrysanthemum, strawberry, raspberry) may be fully infected with virus. Curing of even one individual plant may then open possibilities for building up healthy stock. Such curing can in some cases be done by heat treatment (Thung: raspberry; de Fluiter: strawberry; van der Meer: red currants); in others this is impossible. Meristem cultures have been used alone (Hakkaart and Miss Quak: chrysanthemums), in combination with heat treatment (Miss Quak: carnations) or with a chemical treatment (Miss Quak: potato, especially the early potato variety Eersteling which always is infected with both X and S-virus). Only the minute apical meristem in such plants, measuring $\pm 100\mu$ appears to be free of the virus[72]. Miss Quak is now studying the fundamental background of

Fluorine damage to gladiolus (See page 41)

this phenomenon—a fascinating scientific problem, but also of major practical importance as it may lead to a more successful use of this method which under the present circumstances still fails frequently.

Entomological Department

Netherlands' agriculture and horticulture are not only aiming at the production of high yields but products of high quality are also required, to compete with other countries on foreign markets. Regulation of populations of noxious insects therefore must take place while the pests are still at a low level. Experience of many centuries has taught man that natural enemies alone are not capable of taking care of this. That is one of the main reasons why chemical control methods have been introduced with overwhelming success. However, in the long run chemical control methods appear not to be ideal.

Harmonious Control of Pests

The high general toxicity of many insecticides and their lack of selectivity endanger the natural balance. Moreoever, strains of the pests have become resistant to insecticides and acaricides and the development of new pests as a result of the elimination of important predators and parasites also are clear indications of the dangers involved in the exclusive use of such chemicals. Therefore, in the Netherlands during the last few years, more and more attention is being paid to the possibilities of a harmonious control; this control is based on a combination of biological, chemical and physical methods and the use of cultural measures. This work is co-ordinated in a working group of the harmonious control of insect pests, in which several entomologists of I.P.O. participate. Prof. de Wilde is chairman and Dr. de Fluiter (I.P.O.) acts as its secretary.

Integration of biological control (by saving and/or stimulating the natural enemies and diseases of the pest) and chemical control places the use of specific and therefore selective pesticides in the foreground. In this method agents with a wide range of activity and a long residual action will be applicable only in very special cases.

Harmonious control aims at the prevention of a pest by:—

(*a*) modifying the environment of the noxious organism to increase the effect of its natural enemies.

(*b*) integrating ecological, chemical and physical control.

(*c*) protection of the host plant by increasing its physiological or/and morphological resistance.

At I.P.O. investigations in the field have been started in apple orchards as populations of the fruit tree red spider mite (*Metatetranychus ulmi*), resistant either to organophosphorus compounds, to ovolarvicides or to both, are becoming more and more common. Spraying with nonselective pesticides often seriously interferes with the action of the natural enemies of fruit tree pests. In several orchards the effect of modified spraying schemes with selective chemical compounds on the populations of noxious and beneficial organisms is being studied by de Jong (Tortricidae), Evenhuis (aphids) and van de Vrie (mites). The effect of pesticides on useful organisms is being tested in laboratory experiments. Much attention is also paid to investigations on the uses of pathogens such as bacteria and viruses, especially in the control of Tortricidae.

Van de Vrie investigated the predatory mites present in Dutch orchards. De Jong in his studies on the integrated control of Tortricidae used Trichogramma species as egg-parasites. In Evenhuis' doctoral thesis[15] the interrelations between the woolly apple aphid, *Eriosoma lanigerum* and its parasite *Aphelinus mali* were described. At the moment he is studying the interrelations between the noxious aphids in orchards and their natural enemies, viz. predators and parasites under influence of normal and modified spraying programmes.

Research on Noxious Insects and Mites

Until rather recently most of the time of the entomologists of I.P.O. was concerned with these subjects as there were many problems of economic importance in this field which asked for quick solution. In several cases this solution has been found and is now being used by farmers or growers.

Since the I.P.O. started in 1949 work has been done on the control of insects and mites in orchards. Shortly after the war Kuenen and van de Vrie studied the biology and control of the apple-sawfly (*Hoplocampa testudina*) which at that time was a serious pest. Their method of control[56] solved this problem. Against *Metatetranychus ulmi*, van de Vrie[95] developed a successful control scheme with acaricides and/or ovolarvicides.

Since 1957 he has studied the possibility of control of these populations of this mite which have become resistant to some ovolarvicides or organophosphorus compounds. This research is going more and more in the direction of harmonious and intergrated control which has already been described briefly.

Studies on Leafrollers

De Jong investigated the biology and control of noxious leafrollers in Dutch orchards. The most important species are: the codling moth (*Enarmonia pomonella*), and the leafrollers *Adoxophyes reticulana* and *Cacoecia rosana*. His research[52] revealed the relation between temperature at dusk and flight intensity viz: egg-laying for the first two species. This enabled the establishment of an efficient warning system for the chemical control of these pests. Recently integrated control has been his main interest. Beside leafrollers he has studied the biology and control of the drab moths (*Orthosia spp.*), the apple fruit miner (*Argyresthia conjugella*), the pear leaf blister moth (*Leucoptera scitella*) and the aphid *Dysaphis devecta*. The, biology and control of the pear Buprestid. *Agrilus sinuatus*, has been studied by Leefmans[59]. Control has been based on the phenology of the beetles and on the fact that there is a rather long pre-oviposition period during which the beetles feed on the pear leaves and can be controlled by spraying the leaves with lead arsenate.

Evanhuis made thorough investigations of the transmission of a virus disease of sweet cherries. It was expected that he would find a leafhopper to be the vector. But virus transmission by these insects never succeeded[18]. It appeared to be a soil-borne virus. Also small fruits like strawberries, red and black currants and raspberries may suffer from insect pests either directly or by their transmission of virus diseases. The control of the strawberry aphid, *Pentatrichopus fragaefolii*, the vector of several virus diseases of strawberry has been investigated by de Fluiter as mentioned already under the Virological Department. The strawberry mite *Tarsonomus fragariae*, was found not to be identical with the cyclamen mite *T. pallidus* by Mrs. Haanebrink-Groenewold. Van de Vrie[94] studied the control of the former, and as a result "Kelthane," endrin and thiodan are now successfully used against this mite by growers. Phenology, spread and control of the black currant gall mite (*Eriophyes ribis*) was investigated by van de Vrie[96]. Good control has been obtained by applying thiodan or endrin in spring during the migration period of the mites. The relation between the occurrence of the gall mite and the spread of reversion (a virus disease), which has been suggested by English workers, is now being studied by van der Meer and van de Vrie in field experiments. Thiodan and endrin also gave good control of the black currant midge (*Dasyneura tetensi*) as shown by Nijveldt[68] who studied the biology and phenology of this insect.

Leafhoppers

Aphids and the leafhopper *Macropsis fuscula* have already been mentioned as vectors of raspberry virus diseases. De Fluiter and van der Meer[24] investigated the biology of the leafhopper in its relation to the spread of Rubus stunt. The insect could be controlled by a tar-oil winterwash of the canes, killing the eggs which are deposited just below the surface of the bark. Large scale control of the vector resulted in a reduction of the disease to a very low level.

Mites and Flies

The biology of the raspberry mite (*Eriophyes gracilis*) and the symptoms caused by this mite have been studied by van Dinther[10A].

Spider mites are important pests of many glasshouse crops. Van Marle studied their control on roses and carnations. As early as 1950[61] he discovered on roses in a glasshouse a population resistant to parathion. In recent times spider mite populations highly resistant to all organophosphorus compounds have developed on carnation.

In 1856 Nijveldt published his studies[67] on the biology and control of the asparagus fly (*Platyparea poeciloptera*) in the Netherlands. His investigations confirmed that the cultural methods, dictated by law at that time, were the most efficient control measures.

In brussels sprouts, cabbage aphid (*Brevicoryne brassicae*) is a serious pest. De Fluiter[21] studied its biology and control and Hafez[39], an Egyptian guest worker, made thorough investigations on the seasonal fluctuations of the population density of this aphid in the Netherlands and on the significance of its parasite *Aphidius* (*Diaeretiella*) *rapae* as a regulating factor. *B. brassicae* also is an important vector of cauliflower mosaic in cabbage (see page 30).

The cabbage root fly (*Chortophila brassicae*) not only attacks the root system but also causes much damage to the sprouts of brussels sprouts. Field experiments by van 't Sant[76] showed that, with parathion or diazinon, cabbage aphid and root fly can be controlled simultaneously. Very good control of the maggots of this fly in the sprouts has also been obtained with heptachlor. The attack of the roots of cabbage plants by the cabbage root fly can be successfully controlled by the applications of various insecticides at the base of the plant or by dipping the root system in insecticidal solutions or suspensions at the time of planting.

Van 't Sant[77] also studied the biology, phenology and control of the carrot fly (*Psila rosae*) in the Netherlands. This resulted in a recommendation to carrot growers on the control of the carrot fly by soil and seed treatment.

Damage by Weevils

Since 1957 the attack of witloof chicory by the leaf miner *Napomyza lateralis* increased to such an extent that much damage was done both to the roots in the field and to the crops in the clamps. Van 't Sant[79] is studying the biology, phenology and control of this insect. In the case of the onion weevil (*Ceuthorrhynchus suturalis*) good control was obtained by Franssen by spraying the very young onion plants with "Gusathion" as soon as damage becomes visible. In the field a related weevil (*Ceutorrhynchus pleurostingma*) causing galls on swedes was successfully controlled by van 't Sant *et al*[78]. by soil application of 3 g. of chlordane or aldrin per plant. This also controls the cabbage root fly (*Chortophila brassicae*).

Much work has been done by Franssen on the biology and control of insects of peas and beans. On peas he studied the pea weevil (*Sitonia lineatus*), the pea midge (*Contarinia pisi*), the pea moth (*Enarmonia nigricana*) and the pea thrips (*Kakothrips robustus*). Thorough investigations were also made of *Bruchus rufimanus*, a weevil which is noxious to Vicia beans in the Netherlands and on the biology and control of the common bean weevil (*Acanthoscelides obtectus*) which in our country is mainly a pest of stored Phaseolus beans. All these investigations led to a successful control of the insects mentioned[27–33].

Franssen and his assistant Mantel now concentrate on thrips species, the damage they do, their biology and phenology and the best methods of control. They started on thrips in peas and flax[34]. Thrips in cereals is their next item.

Colza seed pod weevil (*Ceuthorrhynchus assimilis*) and the brassica pod midge *Dasyneura brassicae*) were the insects studied by Ankersmit[1]. The midge only can oviposit in pods which are damaged, e.g. by the weevils and their larvae.

Treatments of the crop with dieldrin or a mixture of dieldrin and BHC carried out at the right time gave excellent control of the weevils and decreased the midge infestation considerably

In recent years a new pest, the wheat stem gall midge (*Haplodiplosis equestris*) developed locally into a serious pest of wheat and barley. Nijveldt is in charge of the investigations on its biology. He proved[68] that a good crop rotation reduces the infestation considerably. A direct control of the midge is possible by spraying insecticides. Another gall midge having Nijveldt's special attention is *Rhabdophaga heterobia*, a species which causes great damage to willows especially *Salix amygdalina*.

Vectors of virus diseases

Several examples of insects as virus vectors have been given already, e.g. on raspberry, strawberry and potatoes. The transmission of top yellows, a virus disease of peas, has been studied in the Netherlands by de Fluiter and Hubbeling. The virus appeared to over-winter in lucerne. In spring and early summer it is transmitted again from lucerne fields to pea fields by the pea aphid (*Acyrthosiphon pisum*). This insect also plays an important role in the spread of this virus to other leguminous crops such as broad beans and clover. It is not the only vector, however, for the aphid *Macrosiphum euphorbiae* can also transmit top yellows virus. The best control measure against this disease appeared to be the use of resistant pea varieties[22].

The transmission of a virus causing phyllody of clover was studied by Evenhuis[16, 17] who found that various leafhopper species are able to transmit this virus. In all these cases not only the biology of the vector is being studied, but also the relations which exist between the vector and the virus in connection with the infection feeding period, the transmission feeding period, the latent period of the virus in the vector, egg transmission of the virus, etc.

Fundamental Physiological Investigations

In 1962 entomological and biochemical research will be started on the influence of the physiological condition of various stages in the growth of potato plants on the development and population dynamics of the green peach aphid (*Myzus persicae*). Laboratory experiments on the effect of the physiological condition of other food plants on the development of other aphids (e.g. the black bean aphid, *Aphis fabae*), are also on the programme.

Taxonomic Research on Noxious Insects

For studies on the biology and control of insect pests the Institute considered it was important to become better acquainted with the Thysanoptera (thrips species) and Cecydomyidae (gall midges) in the Netherlands. Therefore

Franssen and Mantel made an extensive collection of the first group and studied the identification of these insects thoroughly. Nijveldt is doing the same for gall midges. The results of these studies are not only of importance to the Netherlands but research workers from all over the world send specimens to these specialists for identification.

Nematological Department

Stem Eelworms

One of the main research subjects of this department was originally the search for resistance against stem eelworm (*Ditylenchus dipsaci*) in rye and clover and the influence of various factors on the activity of stem eelworms in the soil. For the investigations with rye, Seinhorst developed a special method for propagating the eelworm. He also devised a laboratory inoculation technique for this purpose. With the latter it was possible to inject the stem eelworms directly by means of a syringe into the young rye seedlings to be tested[81]. Resistant rye seedlings showed little or no symptoms, where as resistant red clover seedlings often reacted with necrosis. If too many eelworms were used per plant, the resistant clover plants especially were severely damaged by necrosis. Several biological races of the stem eelworm exist in the Netherlands, but as a rule they are not very host-specific. By a hot water treatment it was possible to kill stem eelworms in shallots[10]. This method is now in common use with the growers.

Pratylenchus penetrans was found by Miss Klinkenberg to be the primary cause of black root rot of strawberries on sandy soil in the western part of the Netherlands[53]. Several weak parasitic fungi enter through the lesions made by this nematode, thus causing the final decay of the root system. "DD" and "Vapam" could be used successfully against this disease[55].

The main topics of research in this department are at present: population studies on the stem eelworm (*Ditylenchus dipsaci*); the potato root eelworm (*Heterodera rostochiensis*) and some migratory root eelworms; behaviour of root eelworms when attacking plant roots and the reactions of the latter. Most of these investigations required the improvement of existing research methods or the development of new ones.

Measuring Nematode Population Densities

A method for the measurement of population densities of migratory nematodes in soil was developed by Seinhorst[83]. This method is widely used now by nematologists in other countries. It enables the separation of ± 95% of the eelworms up to a length of 6-8 mm. from soil. A technique which made observation of growing roots possible in the presence of eelworms or other micro-organisms was developed by den Ouden[69]. In this method the plants are grown on thin layers of nutrient agar, thoroughly mixed with air bubbles of 0.5 to 2 mm. diameter, which are enclosed in polythene bags in order to keep them sterile and to prevent evaporation of water. Only the (aseptic) roots are inside the bag. Stem and leaves develop freely in the air. Plants can be kept growing in this way for several weeks. Aseptic nematodes or other organisms can easily be inserted in the bags. These organisms and the roots can be observed under the microscope even with oil immersion objectives. The method proved very useful in investigations[58] on the cause of early yellowing of peas. This disease appeared to be caused by a fungus *Fusarium oxysporum* forma *pisi*, race 3. However, this fungus could only do severe damage to pea roots when they were attacked by the nematode *Rotylenchus uniformis*. This nematode alone did not damage pea roots apart from causing some harmless cracks in the root cortex. This method was also very useful in demonstrating that males are indispensible in the multiplication of *Heterodera rostochiensis*[70].

Observations by Seinhorst on nematode populations in many fields revealed that all soils contain several widely spread species of plant parasitic nematodes. Population densities of these species are generally low and they are not considered to be very important to agriculture. Dangerous species like *Heterodera rostochiensis*, *Pratylenchus penetrans* and *Ditylenchus dipsaci* only occur in a limited area. The distribution of these species, except *Heterodera*, appeared to be more dependent on soil type than on the crops grown[84]. Thus stem eelworms are largely restricted to silty soils and loam soils. On certain soils in the south western part of the country, this nematode maintains a minimum population density at which considerable damage in onions can be expected irrespective of the previous crops grown[82]; on other soils such population densities only occur when onions and peas are grown at short intervals. Farmers, who want to grow onions on such soils are therefore advised not to use peas in their rotation.

Stability of Populations

A striking phenomenon observed during

seven years of population measurements on several fields, was the high degree of stability of populations of certain indigenous, polyphagous root-infesting nematodes[85]. Generally fluctuations in population densities appeared to be reduced by density dependency of population increase. As a result numbers of nematodes fluctuated at a level, which apparently depended on soil type or other site characteristics. Even continuous cropping with host plants would not raise population levels very considerably, whereas on the other hand growing poor hosts would result in very moderate decreases of nematode numbers. This reduces the economic importance of most of these nematodes very considerably if they do any damage at all. Only by studying each species separately and carefully, will it be possible to get reliable information in this respect. Such research revealed for instance that it may be very difficult to keep the level of infestations with *P. penetrans* low enough not to be harmful to certain crops once a field is infested with this nematode.

Laboratory and greenhouse observations by Miss Klinkenberg[54] have demonstrated that *P. penetrans* is much more harmful to a number of plants than *P. crenatus* (which is a more widely-spread species than *P. penetrans*). The former often causes severe necrosis in roots of hosts and even of some non-hosts, whereas attacks by the latter have very little effect on roots.

Plant Disease Resistance Department

This department was established in 1951 at the request of some breeding institutes, which needed more information on reliable methods for testing disease resistance. The workers of this department have given countless recommendations on this subject not only to breeding institutes but to a large number of private plant breeders. In order to be able to give a good advice, existing methods of inoculation had to be evaluated and frequently they had to be changed or improved.

Inoculum Availability

The breeders may order inoculum. This consists of various fungi, viruses, aphids (infected for instance with strains of beet yellow virus) and eelworms. It will be clear that much research was and still is necessary in order to find the best media for growth of the pathogens and to identify the possible physiological races or strains of parasitic fungi and viruses. The department is not testing plant material for the breeders. They have either to do this themselves, or, if the methods are too complicated or too dangerous with respect to the spread of the disease, their material can be sent to the Plant Protection Service. This is done for instance with potato-root eelworm and wart disease of potato caused by *Synchytrium endobioticum*. Once the breeders have developed new promising varieties they send these to the Institute for Research on Varieties of Field Crops (I.V.R.O.) if agricultural crops are involved. and to the Institute of Horticultural Plant Breeding (I.V.T.) if horticultural crops are involved.

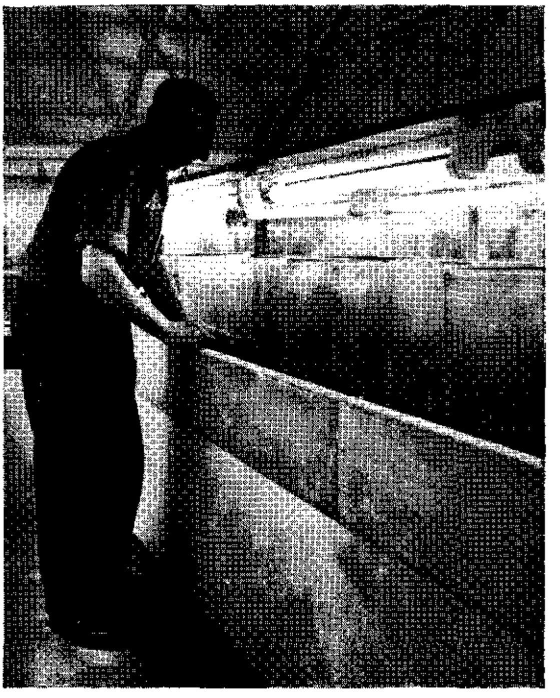
New varieties of cereals, flax, peas, beans, cucumber and spinach are tested by the Department for Disease Resistance of the I.P.O. against the major diseases as far as reliable testing methods and infection material are available. Most tests are carried out on the experimental fields or greenhouses of the I.P.O. For this reason and for the investigation of the influence of climatical conditions on the infection techniques as well as for maintaining various virus strains and obligate parasitic fungi, such as rusts on cereals, the department has a modern greenhouse at its disposal. In the compartments of this greenhouse temperature and humidity can be regulated independently, and once these are established, they can be kept constant between reasonable limits. Shortage of light can be almost eliminated by using artificial light to a maximum of 500 watt/m^2. Artificial light also enables the research workers to use various day lengths. In two compartments soil temperature can be regulated independently of the air temperature. Automatic changes from day to night temperature will be established in the near future. Some examples of physiological specialization of fungi which are now being studied and some of the infection methods which have been developed are worth mentioning.

Physiological specialization of parasites

The study of this phenomenon is of the utmost importance in order to protect the plant breeders against erroneous and too optimistic interpretations of their results. Hubbeling[48,49] has studied the physiological strains of *Colletotrichum lindemuthianum*, the cause of bean anthracnose, those of spinach downy mildew (*Peronosporaspinaciae*) and those of pod spot of Ascochyta blight of pea (*Ascochyta pisi*). He also investigated the strains of Phaseolus viruses 1 and 2. For agricultural crops 'sJacob[50] and his assistants studied the physiological specialization of loose smut (*Ustilago tritici*) and yellow rust (*Puccinia striiformis*=*P. glumarum*) of wheat, and flax rust (*Melamsora lini*).

As breeding resistance against yellow rust is still based on adult plant resistance, determination cf physiological races of this rust on seedlings alone appears to be of less value because of the large differences in susceptibility between young and adult plants. However, as Zadoks has reported, physiological specialization in the field takes place also. Therefore 's Jacob is testing the new wheat varieties not only with a mixture of all physiological races which are known to exist in the Netherlands, but he also uses some isolated "physio-fields" on which the most important and newly found physiological races are being tested separately.

Tjallingii is investigating the physiological specialization of club root (*Plasmodiophora brassicae*) on cabbage and turnips. He[92] has found a sharp difference between physiological races of cabbage and turnip, and within the latter he can distinguish at least two different physiological races.



Inoculating wheat plants with yellow rust

Methods of Infecting

After Hubbeling[47] had developed several simple testing methods for the breeders of horticultural crops, interest in breeding disease resistance became well established. This may be seen from the large amounts of infection material now supplied by the I.P.O. For Colletotrichum the annual average is 3,000 cultures ranged over four physio-groups. Last year, in close co-operation with a private breeder, the original method of infection and selection was radically changed and simplified; the same method is now used for testing peas on their resistance to wilt (*Fusarium oxysporum* f. *pisi* race 1). Breeders of cucumbers are interested in resistance to blotch disease or leaf spot (*Corynespora melonis*) and scab (*Cladosporium cucumarinum*) and want to combine testing against these fungi in one test. Hubbeling[49] succeeded in doing so by using a day temperature cf 28°C and a night temperature of 22°C for the infection with the first fungus on the cotyledons, followed by inocculation with the second fungus immediately afterwards on the first leaves at a temperature of 18°C.

's Jacob[51] recently altered his method of field testing cereals against yellow rust, enabling him to determine which of the physiological races used as inoculum, took part in the infection of new wheat varieties. As the growth of the different rust races is influenced differentially by the climatical conditions, not all of the races of a mixture develop with equal vigour. Each year the dominant race may differ. When using only one susceptible variety it is impossible to establish at the end of the season which races have failed to develop. By using various more specialized "infection varieties" this difficulty can be overcome.

In investigating resistance against loose smut of wheat the partial vacuum method described by Oort is used by which means the absolute physiological resistance may be determined. Since 1945 eight physiological races of the smut fungus have been found, two of which are of importance for the new wheat varieties.

Different Method for Barley

With barley an entirely different method is used for evaluating loose smut resistance because physiological resistance does not exist in western European barleys. It would take a very long time to start a breeding programme using wild resistant material in this case. Fortunately with barley a useful form of field resistance is known, based on the characteristic of the non-opening of the flowers thus preventing the entrance of loose smut spores. Moreover, a special advantage of this field resistance is its independence of physiological specialization of the pathogen.

The artificial inoculation method Tjallingii is using with the club-root organism for testing cabbage and turnips does not give any difficulties if he uses Wisconsin tanks or benches with soil heating in the greenhouse. Neither tanks nor benches are large enough for the purpose of commercial breeders. Therefore they asked for artificial infestation of non-infested fields. Peculiarly enough in many cases ploughing under of large quantities of diseased plant material does not give a high enough infestation of the field. Introduction of small amounts of infested soil in the sowing drill gives much better results[92]. Such an infestation may last for a shorter or longer period, depending on the type of soil.

Biochemical Section

In this section which was established in 1959, research activities are mainly concentrated on biochemical methods for diagnosing plant viruses. Many plants are propagated vegetatively. If such plants become infected with a virus which does not show symptoms growers may be spreading infected plants. Therefore the aim is to recognise the infected plants even though they show no symptoms. It is clear that it depends to a large extent on the sensitiveness of the method used whether the virus can be detected directly or indirectly. Of course there must be an absolute minimum of virus present for this detection but where this minimum lies is still inknown.

Metabolic Changes

After the second world war our knowledge of the metabolism of healthy and diseased plants was extended rapidly by new techniques. Many chain processes were found of which the physiological importance became more and more clear. For the purpose of virus diagnosis, metabolic changes due to the presence of virus need to be recognised. Respiration increases and the content of polyphenols becomes higher in a virus diseased plant than in a normal plant and this was Venekamp's starting point. The content of various compounds in healthy and diseased plants was measured in tomato plants, tobacco or *Physalis floridana* with TMV, potato with leaf roll, X. or Y. In all cases concentrations of citric acid, malic acid and oxalic acid were higher in diseased than in healthy plants[93]. The same was true for the content of amino acids. Venekamp simultaneously measured the concentration of various pigments in the leaves. In tobacco chlorophyll content decreased whereas carotenes and xanthophyls increased as a result of TMV infection. However, no specific material was found by Venekamp or others as a result of such an infection, although some research workers have been trying to establish the presence of viruses on the basis of an increase in the concentration of reducable sugars and especially chlorogenic acid. But metabolic processes may also reflect changes in the environment (temperature, light, day-length, etc.), and the increases in the amount of certain compounds found as a result of virus infection may well be nullified by the environment.

The only really specific material on which one can count is the virus itself or the corresponding X-protein. Therefore Venekamp is now concentrating on the recognition of the smallest possible amount of virus by means of biochemical techniques, especially chromatography and electrophoresis. Nucleoproteins are very sensitive to environment influences such as high temperature and pH. In the isolation of nucleoproteins from plant material proteolytic enzymes and ribonuclease are also liberated, enzymes which destroy the virus. Therefore all manipulations are being carried out at 0°C to reduce enzyme activities. The absorption-chromatography technique as described by Tiselius in 1954 was used but recent research is concentrated on the partition of various plant viruses in high polymer two-phase systems, using the method of Albertsson at Uppsala.

Influence of Virus Production

In connection with general virus research the influence of virus production on phosphate uptake of tobacco plants was investigated. If such plants has been inoculated with TMV three weeks before the application of P^{32} they showed 20% less uptake than healthy plants. Plants incolulated with TMV seven hours before the application of P^{32} however had 27% higher uptake of P^{32} than healthy plants.

Inoculation with radioactive TMV showed that immediately after rubbing the leaves with this virus, 70-80% could no longer be washed off with water.

P^{32} was also successfully used in work in co-operation with the mycological department. Tichelaar[90] had found that gladiolus roots checked the formation of sclerotia of *Sclerotium cepivorum*, the cause of white root rot in onions. By producing radioactive sclerotia on an agar medium containing P^{32}, Tichelaar and Noordink could easily follow the production of new sclerotia in pots with gladioli by means of a G.M. counter. After a few days onion plants were thoroughly infected with the mycelium of this fungus, marked with P^{32}.

Agricultural Aviation Section

This section has concentrated on the possibilities of using fixed wing aircraft and helicopters for the control of diseases and pests of agricultural crops in the Netherlands. In close co-operation with private firms and organisations, many field trials have been carried out on the usefulness of special spraying equipment which was built by others.

Aerial Spraying

In such a windy country as the Netherlands spraying is more feasible than dusting. In spite of many difficulties in the early period, two small private agricultural aviation companies were founded in 1952. This meant that the use of government aircraft for agricultural research was no longer necessary.

Attention was paid initially to the possibilities of controlling insect pests and weeds by means of aerial spraying. Some years later the control of late blight of potatoes (*Phytophthora infestans*) became one of the main problems. Prevention of wheel damage and the ability to spray when the fields were still too wet for ground machines made aerial application of fungicides attractive. The first trials of aerial spraying of copper fungicides were carried out in 1951 with promising results[19]. Soon farmers in some area adopted aerial spraying against late blight and this is one of the most important tasks of aerial spraying companies, forming 40-50% of their total activities.

Distribution of Spray

Much work has been done by Franssen, Miss Kerssen and their assistants on the distribution of the spray over the crop. This is of particular importance as the maximum amount which is still economic for the aircraft to apply is only 45 l/ha.

An even distribution of the spray liquid over the crop therefore is essential. The best distance of the nozzles in the spray boom and the best distribution of the biocides in the field in relation to weather conditions during the flight is frequently evaluated. For this purpose droplet size and distribution in the swath are measured either on glassplates or on special cardboard[25]. Sometimes leaves of the sprayed crops are also collected for laboratory investigation of residue distribution. This is measured either chemically (fungicides) or biologically (insecticides)[26].

Normally the formulations used in aircraft spraying are those used for application with ground machines, where they are used in higher volumes per hectare. As the same total amount of toxic chemical considered necessary for ground application is also used for aircraft spraying, the concentration of the formulation used is much higher, leading to difficulties such as clogging of the nozzles, e.g., the copper fungicides or it may result in phytotoxicity. Every chemical company formulates its own products taking into account the concentration of the toxic chemical, but they also may add compounds to improve rain-resistance and wetting-agents to give a better coverage of the leaves. If the product is then applied at higher concentrations there may be adverse effects. Miss Kerssen found for instance that a copper oxychloride with high sticking properties gave less protection against tuber infection of potatoes by Phytophthora than the same fungicide formulated with less sticker when applied from the air[46].

All new pesticides which may be used in low volume aircraft spraying are first investigated both in the laboratory and in the field, in close co-operation with the Netherlands Plant Protection Service.

At present six companies operate with aircraft in the Netherlands for pest control purposes; some go to North Africa in the winter.

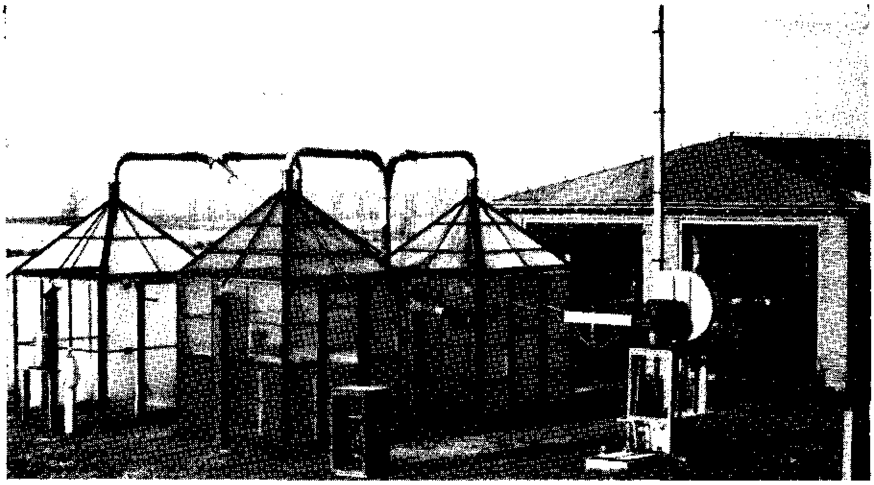
The major crops sprayed are potato, pea, flax, sugar beet, colza, poppies and caraway. Hormone herbicides, previously avoided for reasons of drift hazard, find widespread use on the larger acreage of the new polders.

Air Pollution Research Section

Since the war, industry in several regions of the Netherlands has expanded rapidly. As a result crops in the neighbourhood have suffered damage by industrial air pollution. Research of the possible causes of such damage became necessary in order to locate the responsible industries.

Research in fumigation chambers

The main poisonous gases are sulphur dioxide (SO_2) and hydrofluoric acid (HF) and the first aim was to investigate symptoms caused by these pollutants and to determine the susceptibility of varieties and species of crop plants to these gases. This research is done in fumigation chambers, built with glass (for SO_2) or with plastic (for HF). Temperature, humidity and the amount of air circulation can be controlled to a satisfactory degree. The chambers stand in the open and normal daylight is used. In the first experiments with which Spierings[88] was concerned, tulips and gladioli



Fumigation chambers for air-pollution studies

were placed in an atmosphere containing various concentrations of HF or SO_2. The plants appeared to be extraordinary sensitive to HF, gladioli showing damage at as low a concentration as 20 parts HF per milliard parts of air, Later the sensitivity of a large number of varieties of tuplis, gladioli and fresias were investigated, Peculiarly enough there appeared to be a great difference in susceptibility to HF between the varieties of these species, as was also observed with apple and pear varieties in orchards.

Leaf Damage

At present investigations are being carried out in order to find whether there exists a correlation between the seriousness of visible damage and the amount of HF found in the leaves. During the experiment an air sample is taken from the fumigation chamber for measuring the concentration of the poisonous gas. With HF an evaluation of leaf damage is easier than with SO_2. HF damage is localized in the leaf tips if monocotyledons like gladioli are used, whereas with dicotyledons the necrosis is concentrated along the leaf margin. The higher the concentration of HF the larger the damaged area of the leaf tip or the leaf margin. The damaged surface can easily be measured. If SO_2 is the cause of damage, however, the necrotic spots are scattered over the leaf with sharp limits against the healthy green leaf section. In this case a colorimetric method is used for quantitative evaluation.

Investigations on Air Pollution

As soon as damage to crop plants and ornamentals is reported the area is visited. If air pollution is suspected, leaf samples for chemical analysis are collected. If necessary small experimental squares are planted with a gladiolus variety (HF susceptible) and with lucerne (SO_2 susceptible) at various distances and wind directions from the suspected factory. Regularly the tests plant are checked on leaf damage. Leaf samples are collected and analysed in the laboratory at Wageningen for fluorine and sulphur. An air sampling apparatus is placed near the test plots. This apparatus accumulates either HF or SO_2 for a period of 2-4 weeks. This period actually is too long to locate each days' peak-values for HF or SO_2 but the equipment is simple and cheap and gives a rough idea of what happened.

One of the first cases Spierings investigated was damage to gladioli and tulips in the neighbourhood of large steel works. Damage appeared to be due to HF. It was possible to stop damage in the following years by changing the flux in the smelting process during the growing season. In some cases poisoning of crops was not caused by HF or SO_2 but by zinc or organic fumes. With the latter severe damage was found on ornamentals in a greenhouse. The adjacent chemical industry was not convinced that the losses were due to fumes from their factory. Therefore van Raay established two small glasshouses in the area, one with and one without an air filter. Van Raay[73] showed clearly that only plants growing in the house without a filter were damaged. The toxic agent which caused the damage is still unknown.

Extensive research is also being carried out in the surroundings of a cement factory to determine the possible reduction in quality and storability of vegetables and fruit by cement dust.

The large industrial area west of Rotterdam is still expanding rapidly. North of it is situated the concentrated glasshouse district of the Province of South-Holland. It is feared that this expansion may lead to increasing damage of glasshouse crops. Together with public health institutes, The Royal Meteorological Institute and industrial laboratories, investigations are being carried out in order to get acquainted with air pollution in this area at present and in the future. As far as the influence on crop plants is concerned the I.P.O. is responsible for these investigations. It is hoped to locate the sources of contamination not only by means of a large number of small experimental plots with susceptible plants, but also by direct measurements of the toxic contaminants in that area. If this succeeds, it is hoped to reduce the dangers in close co-operation with industry.

Finally, the influence of dust, smoke and fog on light intensity in this horticultural district situated so close to industry is measured with special light meters.

International Contacts

For research workers it is essential to know the latest developments in their special fields of activity. Therefore visits to foreign research institutes and participation in international conferences are stimulated. Several staff members belong to international working parties or committees. Sometimes scientists of I.P.O. are invited by F.A.O. or other organizations to work for a longer period in a foreign country. At the moment one of our virologists is on a one year mission to Chile, another is working on virus diseases of tropical crops in Suriname. Frequently it has been possible for the staff members to go to the U.S.A. or Canada for periods varying from several months to a year. On the other hand some 60 research workers from 30 countries have worked in the I.P.O. since its establishment in 1949.

At the moment there are two American guest workers in the virological department, an Egyptian worker in the mycological department, and an Italian in the nematological department.

Acknowledgement

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