the inoculum would become most abundant as tubers reach maturity, when they are most suceptible to infection (Allen, 1957).

The lack of macroscopic symptoms on tubers at lifting is a difficulty in the detection and control of skin-spot disease. Assessment of the attack on the root system of crops grown for seed, or improved methods of direct examination for eye infections on seed tubers, may reveal stocks likely to become severely diseased. They may then be rejected as seed, or treated chemically at lifting and stored under conditions that prevent the development of severe symptoms on the eyes and skin surface.

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EXPLANATION OF PLATES 3 AND 4

Plate 3

Fig. 1. Stem bases of Majestic, showing cortical lesions due to natural infection by *Oospora pustulans*. (*a*) Slight; (*b*) moderate; (*c*) severe.
Fig. 2. Severely infected stem base, showing cracked cortex.
Fig. 3. *O. pustulans* sporing on an infected root after incubation.
Fig. 4. *O. pustulans* sporing on infected stem base, showing branching habit.
Fig. 5. Tap-root lesions on tomato seedlings grown in soil inoculated with *O. pustulans*.

Plate 4

Fig. 1. Transverse section of uninfected part of potato stem base, showing normal cortical parenchyma.
Fig. 2. Transverse section through lesion 1 in. below on the same stem, showing septation within parenchyma cells to form cork layer below superficial infection.
Fig. 3. Cork formation in the outer layers of the phloem, where the cortex has developed a deep longitudinal crack.
Fig. 4. Transverse section of infected stem base, showing mycelium in cortical cells.

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Cereal Virus Diseases in Britain

MARION A. WATSON

Rothamsted Experimental Station, Harpenden

...R VIRUS DISEASES of cereals and grasses have been described or ...ified in Great Britain during the last four years: cereal yellow ..., European wheat striate mosaic, rye grass mosaic and barley false ... They are transmitted respectively by aphids, delphacid leaf-...ers, mites, and seed and pollen.

Cereal Yellow Dwarf Virus

...present the most important economically is cereal yellow dwarf ... This was first described by Oswald and Houston in 1953 [4]. ...ntion was drawn to it by the apparently sudden appearance in ...st barley-producing countries" of an injurious disease of barley, ...se principal symptoms were dwarfing of the plants and yellowing ...e tips of the leaves. As with many viruses of field crops the serious ...reak of disease led to the identification of the virus. Once Oswald ...isolated it, he realized that it had occurred sporadically in cereal ...s for many years, but the symptoms had not been distinguishable ...m the many other causes of yellowing in cereals.

...The first cereal virus isolated in Great Britain came from a few ...lowed plants in the headland of Long Hoos barley experiment at ...thamsted. They were selected because they seemed to resemble ...ald's description. They showed yellowing of the flag leaf and delay ...emergence of the ear within it, in contrast to conditions such as ...rogen deficiency, or root fungus diseases which usually cause yellow-... from the lower leaves upwards. However, this symptom is not ...ays diagnostic, for it may occur with other nutrient deficiencies, e.g., ...writer has seen it in potash deficient barley plots. The symptoms ...yellow dwarf are more easily diagnosed in oats, because of the bright ...or purplish discoloration, but there is still uncertainty, especially as ...us is not always transmitted in glasshouse tests from field plants ...parently showing characteristic symptoms of infection.

...E FIRST SERIOUS OUTBREAKS

...For a time, the study of yellow dwarf seemed to be a subject of purely ...demic interest, because for several years the only plants found were ...lated specimens. Then came the mild winter of 1956 followed in 1957 ...the earliest and largest spring migration of aphids ever recorded. ...mptoms appeared much more plentifully in the spring crop. With ...help of the advisory services, specimens were obtained from many ...ts of Great Britain, and a considerable number contained the virus. ...least two specimens, one from North Wales and one from Kent

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Maisack, 1955). Mann & Smithies (1955*a*) suggested that these compounds arise by spontaneous

diaminobutane and 1:5-diaminopentane as enzyme substrates the amine aldehydes postulated as possible intermediates in the reactions would be γ-aminobutyraldehyde and δ-aminovaleraldehyde.

* Part 2: Mann & Smithies (1955*b*).

yielded much more virulent virus (YDV), than that collected at Rothamsted, and it was obvious that the disease was a potential menace to any crop that became infected in a young stage of growth.

There was not long to wait, for many winter crops, particularly oats in the south of England became severely infected during the winter of 1957-58, with very serious effects on yields.

Investigation of this disease has been curiously like that of beet yellows virus, which also was first isolated from a few yellowed plants on Rothamsted farm, where it appeared to be doing little harm to the crop. Observations made in the southern and eastern counties in 1940-42 gave no indication that beet yellows would ever become sufficiently widespread to cause serious damage [11]. At this time most of the virus isolated from the field was avirulent, but virus causing more virulent symptoms was isolated and replaced the mild virus in experimental work. The potential menace to the crop was then recognized, but it was not until 1943 that a serious outbreak actually occurred in the seed-crop growing areas of Lincolnshire. In 1944 and 1945 outbreaks increased in size and severity, and from that time only the virulent necrotic types of beet yellows virus could be isolated from the field; mild types were sought, but not found. In 1950 measures were taken to break the cycle of overwintering virus and spring infection of the root crop, by controlling the spread of virus in the seed crops. After this there were several years of reduced incidence of beet yellows, and in 1957 avirulent viruses again appeared in the field. Fifty-two out of 140 specimens collected in East Anglia contained them [6]. The same sequence may be occurring with cereal yellow dwarf viruses.

EFFECTS OF YELLOW DWARF ON WHEAT, OATS AND BARLEY YIELDS

Since 1955 small-scale field experiments have been made in which plots were infested with virus-carrying *Rhopalosiphum padi* [13] under muslin cages, and the yields compared with those of untreated plots or those fed on by virus-free aphids. The results for the first three years are summarized in Table 1.

Losses were very variable and sometimes negligible. This was partly a result of using the avirulent virus (YDA), and partly because it was not possible to infect each crop at the same stage of growth in each year. The results suggested that most of the crops and varieties tested could lose up to 30 per cent of their potential yield if infected at the right time, but we were not able to distinguish the critical times. The 1958 experiment compared both YDA and the virulent virus isolate, YDV, on infected and healthy crops of wheat, oats and barley (see Fig. 1 on p. 96).

Koga II wheat and Proctor barley infected with YDV at the earliest date lost two-thirds of their potential yield; Blenda oats lost four-fifths and probably would have produced no grain at all except that a few plants escaped infection. A few plants also remained healthy for a time

Table 1

...ses of Yield caused by Avirulent Cereal Yellow Dwarf Virus (YDA) in Varieties of Wheat, Oats and Barley, tested 1955-1957.

		25-30 April *per cent*	3-4 May *per cent*	12-14 May *per cent*	
...LEY					
55	Plumage Archer	37	19	—	± 5.5
56	Maythorp	24	—	20	± 11.2
	Rika	20	—	2	
	Provost	42	—	21	
	Proctor	26	—	8	
57	Herta	0	–6	–7	± 3.9
	Proctor	16	–2	15	
...HEAT					
56	Atle	3	—	33	± 11.2
	Bersee	14	—	34	
	Koga II	20	—	20	
	Rescue	11	—	16	
57	Atle	–6	0	–5	± 4.9
	Koga II	–4	6	–9	
...TS					
56	Milford	23	—	35	± 11.2
	Onward	5	—	12	
	Blenda	32	—	33	
	Stormont Iris	–4	—	19	
57	Milford	17	17	16	± 7.1
	Blenda	37	27	22	

...the wheat and barley plots. YDA virus caused smaller losses, roughly ...mparable with those caused by YDV. There are several divergencies ...m expected trends in the data that may be of interest, but the full ...ults and statistical analysis are not yet available.

...ASSHOUSE EXPERIMENTS WITH YELLOW DWARF VIRUS

Like beet yellows virus, the yellow dwarf viruses are persistent. The ...ctors probably remain infective for at least a week or ten days after ...ingle adequate feed on infected plants. The most successful vector ...f both yellow dwarf viruses is *Rhopalosiphum padi*, which can infect ...0 per cent of the plants fed on by single individual aphids carrying ...DA, and 80 per cent if they are carrying YDV. *Sitobium fragariae*, ...*avenae* and *Metapolophium dirhodum* transmit both with varying ...egrees of success. We have no evidence that either virus is specifically ...nsmitted by different aphid species, as has been described for com...rable isolates by Toko and Bruehl [10] in America.

Sixty-two species of Gramineae belonging to 14 genera have been ...sted for susceptibility to yellow dwarf in Great Britain and America. ...n the whole there is agreement between the two estimates of host ...nge. All the cereals including maize and rice are susceptible, so are ...any species of Agrostidae, Hordeae, Phalaridae and Festucaea. The ...ly species we have found to be almost certainly immune are *Agropyron*

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Maisack, 1955). Mann & Smithies (1955*a*) sug...gested that these compounds arise by spontaneous

diaminobutane and 1:5-diaminopentane as enzyme substrates the amine aldehydes postulated as possible intermediates in the reactions would be γ-aminobutyraldehyde and δ-aminovaleraldehyde.

* Part 2: Mann & Smithies (1955*b*).

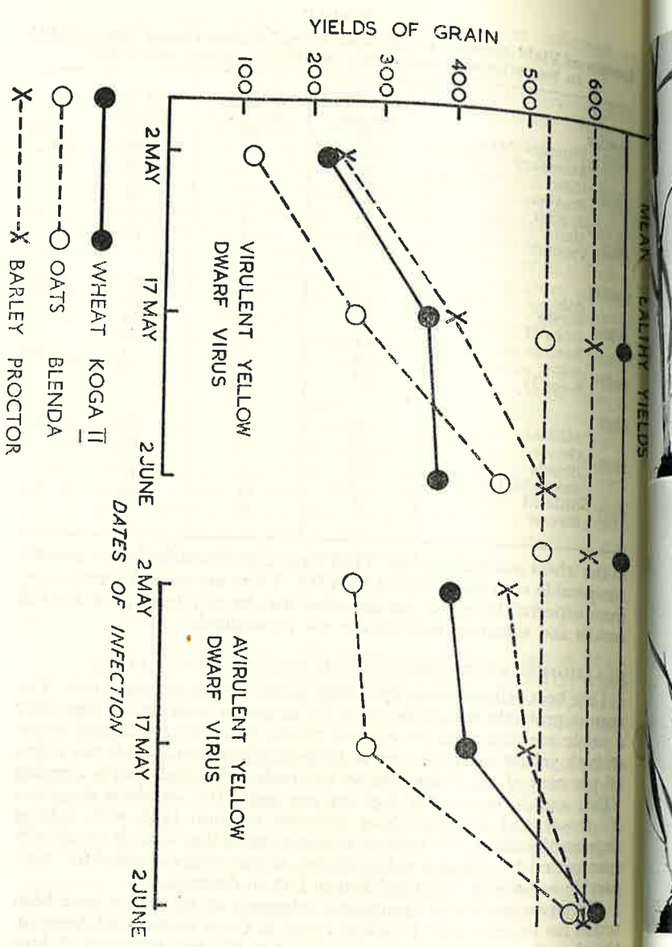
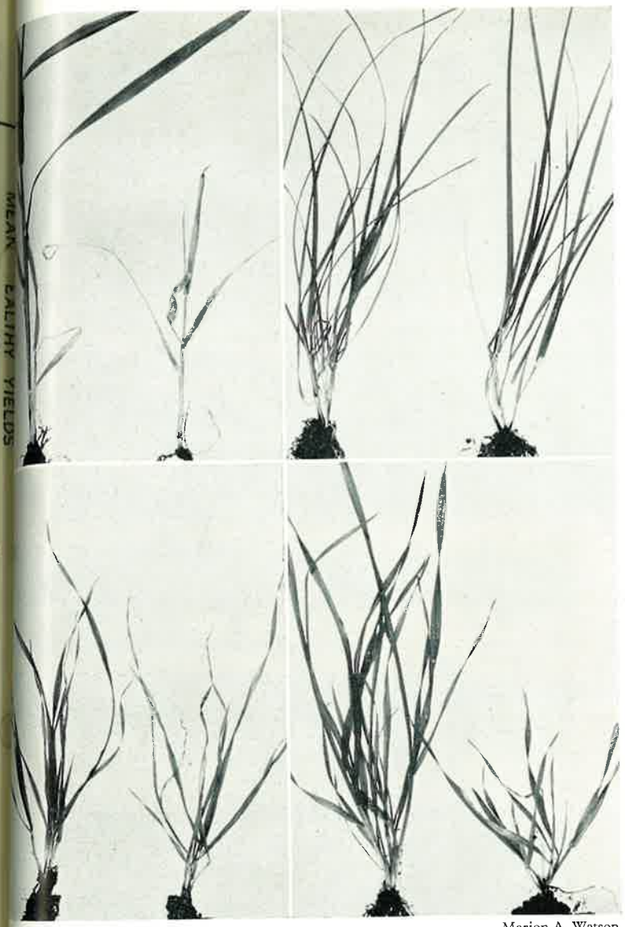


FIG. 1. Yields of wheat, oats and barley infected at different ages with avirulent and virulent strains of cereal yellow dwarf virus. Mean yields of uninfected plots are given as horizontal lines at the appropriate levels.



Marion A. Watson

PTOMS OF VIRULENT CEREAL YELLOW DWARF ON OAT, RYEGRASS AND BROMUS SPP.

ach photograph, a healthy plant is shown on the left; an infected one on the right, the latter having been experimentally infected in the glasshouse.
Top left: *Avena sativa* var. Blenda. **Top right:** *Lolium perenne* var. S.23.
Bottom left: *Bromus sterilis*. **Bottom right:** *Bromus arvensis*.

PLATE I

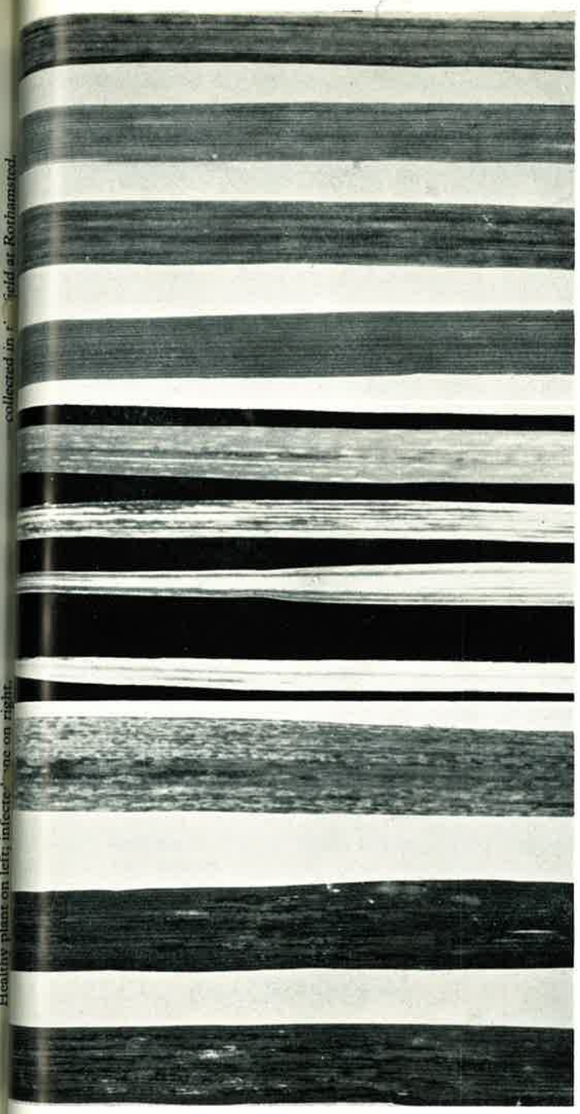
Maisack, 1955). Mann & Smithies (1955*a*) suggested that these compounds arise by spontaneous

* Part 2: Mann & Smithies (1955*b*).

diaminobutane and 1:5-diaminopentane as enzyme substrates the amine aldehydes postulated as possible intermediates in the reactions would be γ-aminobutyraldehyde and δ-aminovaleraldehyde.

RYEGRASS MOSAIC IN BLENDA OAT
Healthy plant on left; infected one on right.

STRIATE MOSAIC INFECTED WHEAT
collected in a field at Rothamsted.



Photos: Marion A. Watson

SYMPTOMS IN INDIVIDUAL LEAVES OF THE PRINCIPAL HOST PLANTS
Ryegrass mosaic in ryegrass. Wheat striate mosaic in wheat. Barley stripe mosaic in barley.

PLATE III

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* Part 2: Mann & Smithies (1955*b*).

ens (Pers)., *Arrhenatherum elatius* (L.), and *Agrostis tenuis* (Sibth.). en with YDV some of these species seem to be symptomless carriers; ers show no symptoms other than a slight reduction in size. Many dwarfed and show typical yellowing, or red discoloration of the ves. Plate I shows two species of *Bromus*, perennial ryegrass, and nda oat all infected at the same time with YDV. The infected rye-ss is slightly "poorer"; the oat and *Bromus arvensis* are dwarfed, and *sterilis* shows very marked discoloration of the leaves, which is plish red in the original.

Not many attempts have been made to recover the virus from urally infected grasses, but often their appearance in nature is kingly like that of plants infected experimentally. The red leaves of *sterilis* are so common that they seem a permanent characteristic of species, but in the glasshouse, healthy *B. sterilis* remains green and by the infected ones turn red. We do not know the extent to which d and cultivated grasses act as reservoirs for the virus or what part ey play in transferring it to the cereal crops.

ross-inoculation experiments

No anti-serum has yet been obtained for YD viruses so we could not e this method for determining their relationship with each other. owever, the symptoms of YDA and YDV are sufficiently different for ss-inoculation experiments to be carried out, and, as with the yellow- viruses of sugar beet, [12], these experiments gave evidence that the o are not strains of the same virus but different viruses with similar perties. Plants showing symptoms of YDA, when inoculated with DV, became just as dwarfed as healthy plants of the same age inocu-ed at the same time, and virus recovered from these plants produced pical YDV symptoms when re-inoculated into healthy seedlings.

Both yellow dwarf and sugar beet yellows viruses cause accumulation carbohydrate in the discoloured portions of infected leaves. Cereal ves do not usually form starch, but starch and reducing sugars are und plentifully in YD infected wheat and oats. Sometimes this sugar ncentration is strong enough to be detected by taste, and it seems ssible that some laboratory test for the presence of virus might con-ivably be based on it. This would be extremely useful, for the disease not easy to diagnose by eye observation, and even aphid transmission sts in the glasshouse are not always successful. Whether it is that her conditions simulate virus, or that there are strains that are not nsmissible by our test insects, or that plants infected for a long time the field contain little virus, it is impossible to say.

Wheat Striate Mosaic

Wheat striate mosaic is transmitted by a fulgorid leaf-hopper, *Delphacodes pellucida* (Fabricius). Like yellow dwarf it is persistent and non-sap-transmissible. The symptoms, shown in Plate III, centre, start

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Maisack, 1955). Mann & Smithies (1955*a*) sug-gested that these compounds arise by spontaneous

* Part 2: Mann & Smithies (1955*b*).

with fine discontinuous streaks along the veins of affected leaves, rather like "tacking stitches" of fine thread. These broaden and coalesce until almost the whole leaf is yellowed, and dies. If infected within the first two months of growth all the leaves become yellowed and most plants are killed by the virus [9].

The photograph in Plate II, right, is of plants taken from the Rothamsted farm on 22nd May, 1958, when about 0.02 per cent of the plants were infected. A month later scarcely any infected plants could be found. Apparently, none had become infected at any later stage than those we had already seen, and those plants had died, or become smothered by their healthy neighbours. So there appeared to be less infection than at the previous time, and no evidence of spread from plants that were then showing symptoms. This suggested that the vectors had entered the crop carrying the virus but had not bred or multiplied on the wheat plants. The instance was not an isolated one. When the virus has been found in wheat, whether early or late infected, there has been no evidence of spread from the plants first observed. The virus has infected all the varieties of wheat, oats, barley, rye and ryegrass we have tested, and could undoubtedly cause serious losses to crops if it spread rapidly in the field. In 1957, Dr. Mary Glynne brought specimens from Spain that were found to be infected with WSM virus. Patches of similar plants were common in the crops that she observed, so spread of the virus does not seem so restricted there as here. It already occurs frequently in this country, although it infects few plants in any crop, and similar diseases have been recorded from other parts of Europe and from Russia [8].

WHY DOES THE VIRUS OFTEN INFECT ONLY A FEW PLANTS?

To find out how the virus so frequently enters the wheat crops and infects a few plants without spreading within the crop, we must consider its properties, and in particular, its relations with its insect vector. Like the aphid-transmitted viruses already mentioned, WSM virus is persistent and non-sap-transmissible. It resembles other leaf-hopper transmitted viruses in undergoing a long "incubation period" within the body of the vector between the time when the virus is acquired during feeding on infected plants, and the time when the insect becomes able to transmit. This interval can vary from about 7 to 30 days, and seems to be largely independent of the length of time that the vector has fed on infected plants, although it cannot be measured at all if they feed for too long.

D. pellucida exists in a number of races that vary in their ability to acquire and transmit virus; i.e., in the proportion of individuals belonging to a particular group or race that are able to infect in comparable conditions. We have three races of *D. pellucida* which regularly transmit to 90-100 per cent, 40-50 per cent and 10-20 per cent respectively of the plants tested, and we refer to them as highly efficient, efficient and inefficient races [14]. We have no information about the proportions

hese different races that exist in field populations, but there is ect evidence that the least efficient may be in the majority.
nerican workers have long maintained that the incubation period eriod of multiplication of a virus within its insect host. There s little doubt that this is true of wheat striate mosaic in *D. pellucida*, he efficient races of hoppers transmit the virus to a high proportion eir progeny. The virus enters the eggs of infective mothers, and if nothers belong to a highly efficient vector race, the nymphs can to transmit almost as soon as they are hatched. The virus is not smitted by an infective male to the progeny of a virus-free female, s inherited through the female parent only. Vector-efficiency can, ever, be inherited through either parent. Egg transmission of the s is proportional to vector efficiency. It is common among females ighly efficient races, and a large proportion of their nymphs, up to per cent, may be infective. Egg transmission is very rare among icient races, even if the mothers are infective; indeed only one nce of egg transmission in a very inefficient race has been recorded.

ECTS OF CLIMATE

oth the multiplication of the virus in the vector and its inheritance ugh the egg are important to the dissemination and survival of the s, and therefore of great economic importance. Hoppers are on the e heat-loving insects. They flourish in warm dry climates, hence pread of curly top virus of sugar beet in California, but in England do not usually become very numerous on any particular crop pt in occasional spells of warm summer weather. It is extremely btful whether *D. pellucida* could survive even a mild winter in the stage, but it probably does in the form of eggs laid in the leaf ths of hedgerow and meadow grasses. It is doubtful whether they ld start to breed early enough in spring for wheat to become infected e end of May, if the virus had to depend on being picked up by the generation of hoppers feeding on meadow grasses. It is even unin how many of these grasses are susceptible to the virus; we are only of *Lolium* spp. However, a number of these eggs give rise to phs that are already infective, and whether or not they feed on ted grasses until they are adult, they will carry the virus with them they migrate into the wheat crop. If they multiplied on the wheat virus would spread, but it does not do so. Probably they feed in g only in sheltered places. When they move on to the young wheat e is little shelter, so they usually do not survive, although they might o in a particularly fine and warm May and June. Presumably they do ive in Spain, which is why the virus appears in large patches there only on isolated plants here.

Ryegrass Mosaic

writer is indebted to Mr. T. Mulligan for the substance of the wing notes on ryegrass mosaic which was isolated by Dr. Slykhuis

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Maisack, 1955). Mann & Smithies (1955*a*) suggested that these compounds arise by spontaneous

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* Part 2: Mann & Smithies (1955*b*).

from cultivated grasses in Hertfordshire in 1956. It was found to be sap-transmissible, but not transmissible by aphids or by leaf-hoppers. As the virus in some ways resembled wheat streak mosaic [7], a collection of mites was made, several of which were found to belong to the Eryophyid group. These successfully transmitted the virus to a small proportion of ryegrass seedlings, and eventually the vector was identified, by a process of elimination, as *Abacarus hystrix* (Keifer). This is a small elongated translucent mite, about 0.2 mm long, that lives in the grooves on the surfaces of grass leaves. Its eggs hatch into active nymphs resembling the parents. The life history probably takes about three weeks. Several species of these mites appear identical, even under the microscope, and distinctions between them depend on minuti characteristics, so it is not easy to obtain a pure culture, or to replace them if it fails.

The mites have not much mobility, and the virus is probably spread by wind dispersal of infective vectors [7], though infested leaf fragments could also be carried by machinery or grazing animals.

Some of the properties of the virus have been determined by sap inoculation. It is fairly stable at room temperature and serologically active. It has a wide host range among the Gramineae, but no dicotyledonous hosts. The host range is difficult to determine precisely, because in several genera of grasses some species are susceptible and others are not. In some species varieties respond similarly, and a species described as immune, may later be found to have susceptible varieties.

SUSCEPTIBLE PLANTS

Of the cereals, oats (Plate II, left), and rice are susceptible but not wheat, barley or maize. The virus was isolated from some naturally infected oat plants sent by Mr. E. Lester from Berkshire. They had been collected in the field because of their severe necrotic symptoms. It is common in old meadows or grass leys, particularly of Italian or perennial ryegrass (Plate III, left), which are the most favourable hosts for the virus. *Festuca pratensis*, *Cynosurus cristatus* (L.), *Poa annua* and *Dactylis glomerata* (L.) are important susceptible grasses.

Ryegrass plants inoculated as seedlings in pots in the glasshouse lost 30-40 per cent of their yield compared with healthy plants, and plants infected in the glasshouse and grown outside sometimes form rather poor tussocks, but vary in their appearance. So there is little information about possible damage that the virus might cause to hay crops or grass leys.

Probably the reason for varietal differences in response to infection is that there has already been selection for resistance, susceptible plants in breeding material having been eliminated because of their poor appearance when infected.

Barley Stripe Mosaic Virus

Barley stripe mosaic virus [3], has only once been isolated from a crop

reat Britain. This was Gloire du Velay barley grown from seed rted from France. Its presence was suspected in a variety "Olli" rted from Canada, but could not be confirmed.

e symptoms (Plate III, right), vary on different varieties of y from a mild chlorotic mottle to a severe necrotic streak that r resembles the "stripe" caused by *Helminthosporium sativum;* for reason it was at first called barley false stripe. The characteristic om in very susceptible hosts is a chlorotic streak bordered by a w region of bronze necrosis, which eventually spreads and kills the

ssanis and Slykhuis [1], from whom most of this information ained, tested twenty varieties of barley. The least tolerant were barley selections from the Plant Breeding Institute at Cambridge, 117/23/2, and H.B. 169/5/22/6. These became 100 per cent ted, with severe necrotic symptoms. The most tolerant were Rika, t Archer, Plumage Archer and Maythorp, which gave mild symp- on only about 10 per cent of the plants inoculated. Of other ies commonly grown in England, Proctor was moderately tolerant Provost moderately susceptible. Some wheat varieties and Italian ass were also found to be susceptible.

SM virus is the only one of the four cereal viruses here described has dicotyledonous hosts. Kassanis and Slykhuis found that sugar and *Chenopodium amaranthicolor* developed chlorotic lesions on lated leaves, but did not become systemically infected; summer ach (*Spinaceae oleracea*) developed systemic symptoms of a bright w mottle in the form of rings, or "oak-leaf" patterns.

e virus was found to be rather stable in extracted sap, infective dilution of around 1/2000, and serologically active. Rod-shaped cles were observed in electron micrographs, and were much more erous than the infectivity and serological dilution end points would est. BSM virus is transmitted through the seed of infected barley s, and with susceptible varieties a high proportion of the progeny nfected. It also possesses the unusual property of being transmitted gh the pollen, and virus particles have been seen in electron micro- e preparations made from pollen grains collected from infected s [2].

e virus does not seem to be a problem at present for cereal growers, it is something to be watched for, particularly in cereals grown imported seed. According to American and Canadian workers the se can cause very serious losses in barley and other cereals. It is tially dangerous in breeding stocks in this country, but plant lers are now on their guard against it, and will be taking all ble precautions.

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Plant Enzyme Reactions Leading to the Formation of Heterocyclic Compounds

3. PLANT AMINE OXIDASE AND THE FORMATION OF PYRROLIDINE AND PIPERIDINE ALKALOIDS*

BY A. J. CLARKE AND P. J. G. MANN
Biochemistry Department, Rothamsted Experimental Station, Harpenden, Herts

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The products of the oxidation of 1:4-diaminobutane and 1:5-diaminopentane, catalysed by plant amine oxidase in the presence of catalase, accumulate in the reaction mixtures as compounds of Δ^1-pyrroline and of 2:3:4:5-tetrahydropyridine respectively (Mann & Smithies, 1955*a*; Hasse & Maisack, 1955). Mann & Smithies (1955*a*) suggested that these compounds arise by spontaneous cyclization of the aldimines, which are probably the primary products of the enzyme reactions, or of the amine aldehydes formed from the aldimines by spontaneous reaction with water. Thus with 1:4-diaminobutane as substrate, the suggested reactions were those given in Scheme 1. With 1:4-diaminobutane and 1:5-diaminopentane as enzyme substrates the amine aldehydes postulated as possible intermediates in the reactions would be γ-aminobutyraldehyde and δ-aminovaleraldehyde.

* Part 2: Mann & Smithies (1955*b*).