this reason, and also because he was more optimistic about their potential economic value than other speakers, he hoped that such experiments would be conducted on an increasing scale in the British Isles.

In a paper entitled "Radár Echoes from Precipitation", R. F. Jones (Meteorological Office) pointed out that normal radar equipments working on wavelengths of 3 or 10 cm. can, at ranges greater than ten miles, detect only that part of the cloud in which there are either raindrops, ice crystals exceeding 1.5 mm. diameter, aggregates of ice crystals or ice crystals with a wet surface. He described some results obtained with the radar equipment at East Hill (near Dunstable) which has both position-plan indicators and range-height indicators to give a three-dimensional picture of the echoes received from precipitating clouds. Different weather types are associated with markedly different radar responses, a fact which was clearly illustrated by photographs of the echoes obtained from cloud systems associated with a warm front, a cold front and an occlusion, all of which were of very different character from those obtained from shower clouds. The echoes from layer clouds are generally of limited vertical extent and contain a narrow band of great intensity (the 'bright band'), while those from cumulo-nimbus appear as narrow vertical columns attaining heights of perhaps 40,000 ft.

Mr. Jones went on to relate the appearance of the echoes, the rate of ascent of their tops and the temperatures of their summits as measured by aircraft, to the mechanisms of precipitation release. In particular, he associated the appearance of the 'bright band' in layer clouds with the melting of snowflakes, and the echoes from cumulo-nimbus (which show no 'bright band') with the existence of large water-droplets, often supercooled, which must have formed by the coalescence process. He reported on some aircraft observations which appear to support these interpretations.

In a paper read by H. P. Palmer, Dr. A. W. Brewer (Oxford) stated that in Great Britain nearly all rain originates from ice crystals, and because of this it is a reliable rule in weather forecasting that cumulus clouds will not give showers until the temperature of their summits falls below -10°C . As first suggested by Bergeron, an ice crystal will grow rapidly in a supercooled water cloud; but it is important to consider the origin of these crystals. Suitable ice-forming nuclei are found in the atmosphere; but they are comparatively rare. Their concentration has been measured by Findeisen *et al.* in Prague, and also in Oxford, by the cooling of air by expansion in Wilson cloud chambers. In the relatively polluted air of these cities the ice nuclei were present in concentrations of only about 1 per m^3 at -10°C . Dr. Brewer suggested that ice crystals must multiply during their growth by sublimation since it is not until much lower temperatures than -10°C . are reached that the ice-forming nuclei are sufficiently numerous to account for all the raindrops which are produced. He reported that ice crystals which are growing rapidly and have dendritic structures release very small splinters of ice. Thus, although only a very few ice crystals may appear originally in a supercooled cloud at -10°C ., they will grow rapidly in a form liable to fracture; several splinters may form at each fracture, and themselves act as ice nuclei. In this way, a sufficient number of ice crystals may be formed to account for the number of raindrops reaching the ground.

I. C. Browne (Cambridge) described his use of a radar set with a vertical beam and range-amplitude display to study precipitating clouds, in conjunction with observations of the mass and electrical charge of raindrops and the electric field at the ground. He has made a particular study of the variations of echo intensity with height in order to determine the mass and growth-rate of the precipitation elements. In particular, thunderstorms sometimes show a striking increase of echo intensity with decreasing height in a region beneath the freezing-level, which affords some evidence for the growth of drops by coalescence and their multiplication by a chain reaction. The observations yield a value for the updraught velocity in the chain-reaction region. In warm-front rain the echo intensity indicates that at about 1 km. above the melting-level ice crystals are growing at a rate of about $150\ \mu\text{gm./km}$. Calculation indicates that they could grow at only $50\ \mu\text{gm./km}$. by sublimation, the inference being that they were growing at about $100\ \mu\text{gm./km}$. by accretion. The observations also indicate that near the 0°C . level each snowflake, on the average, coagulates with another.

B. J. MASON

SEED PATHOLOGY*

By DR. MARY NOBLE

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Agricultural and Horticultural Aspects

EVEN the earliest agriculturists realized the general desirability of using good seed; but it is very surprising that to-day so little attention is paid to the presence of disease in what is otherwise regarded as 'good' seed. I refer in this respect to true seed in the botanical sense, the health of other planting-stock having been greatly improved recently owing to certification schemes covering potatoes, soft fruits, etc. This is probably because most seed-transmitted parasites do not have any immediate effect upon germination; they do not kill the seed outright but multiply upon the emerging seedling, which often then succumbs to the attack; or, as in the case of loose smut of barley, the parasite may pass most of its life-cycle as a symbiont. Such seed, if tested by orthodox methods, is classed as 'good seed' but is, in fact, responsible for considerable loss of crops not only in Great Britain but also the rest of the world. To take, as a case in point, an example from one of our most familiar crops—the turnip. Dry rot of turnip caused by *Phoma lingam* has been known for very many years; but although the farmer has known this disease as a rot of the root, the growers of swede and turnip seed only recognized it comparatively recently. Swede roots are replanted for seed-production in the second year, and it was found that the base of the shoot was often attacked by the disease known as 'canker'. The important point is that it was not until 1930 that this 'canker' was proved to be merely 'dry rot' in another form; and what was even more important, that the fungus also infects the seed heads, the pods and even the seed itself but without causing reduction in germination. Until this point was properly understood, turnip and swede seed samples were frequently severely infected by dry rot, because although the seed grower was

* Substance of a paper read on August 13 before Section K (Botany) of the British Association meeting at Edinburgh.

careful to select only the finest roots for propagation he very often planted them in soil which he proved to be suitable for the purpose but which had also thereby become infected with the fungus. The disease is soil-borne as well as seed-borne, so that until recently the importance of seed-borne infection was not fully realized, and even yet it is frequently overlooked that soil infection may have arisen from seed. Some years ago observations made at East Craigs showed that as little as 2 per cent infection of the seed could lead to considerable loss of crop and that this amount of infection is still quite common.

This is not surprising when the method of growing the crop is considered. The seed is sown about ten times more thickly than the resulting crop and infection is disseminated throughout the field. At the time of 'thinning', the rejected plants are not removed but left lying in close proximity to those which remain, so that the risk of infection is not reduced at thinning time but multiplied tenfold. This principle applies to very many similar seed-borne diseases. Again, if seed is sown thickly to make up for low germination the risk of infection is correspondingly increased, as in this disease the fungus does not die before the seed.

Dry rot infection can be very well controlled in the seed by treatment with hot water, and in the north of England this is done as part of the National Agricultural Advisory Service. Generally, however, swede and turnip seeds are sown without any treatment, although even dusting with a mercurial fungicide greatly reduces infection; and from this disease alone the crop loss is considerable.

Again, infection sown with the seed of one crop may remain in the soil to attack a later one. For example, another brassica crop following a swede crop which had dry rot may become in turn infected. In 1948 the ubiquitous fungal parasite *Sclerotinia sclerotiorum* was found carried as a sclerotium in turnip seed. This provided the source for soil infection capable of attacking artichoke, carrot, etc. Blind seed disease of rye-grass presents quite a different case. This disease, caused by one of the Sclerotiniaceae, was not recognized in Britain until some ten years ago, although rye-grass was for a very long time the only British cultivated grass and indeed the only one of which the seed could be purchased for sowing. The causal fungus, the fructification of which arises from the seed, is very tiny and insignificant, and it is possible that this disease was present much earlier but unrecognized; on the other hand, certain changes had occurred in the rye-grass seed-growing industry which may at least have led to its increase.

One change was the concentration of seed-growing in the areas where the best pastures were found in Britain (Kent, Ayrshire, Aberdeenshire) and, overseas, in New Zealand. This arose from the fact that farmers could not be sure of getting seed of the best pasture strains anywhere else, seed certification schemes being a very recent development. It does not follow that seed production requires the same ecological conditions as pasture development, and in this case the disease is most severe where cool moist weather conditions prevail.

Another change which was more important from the seed pathology point of view was the introduction of improved, leafy strains of rye-grass in Britain as well as in New Zealand. These strains comprised much more uniform populations than the old 'commercial' strains and came into flower much more

synchronously than the latter. Thus in adverse weather conditions the damage was greater. Again, these new improved strains have proved genetically to be more susceptible to the fungus and some at least are now being re-selected with reference to this factor. Trials are also in progress with growing the seed in suitable 'seed' areas as against the good pasture areas.

In horticulture the problem of seed health is studied even less than in agriculture. For example, all the sugar beet seed now sown in Britain is disinfected chiefly against the black leg organism (*Phoma betæ*); but very few market gardeners treat red beet seed although it is quite as common as sugar beet.

Dwarf beans, especially of the variety 'Canadian Wonder', are often infected with halo blight, a bacterial disease, and no great effort seems to be made in Britain to avoid the disease. In New South Wales, an inspection scheme ensures the health of dwarf bean seed.

Seed Pathology and Seed Testing

The practice of seed testing or seed analysis is, of course, intimately bound up with seed pathology, and in this Great Britain has from the beginning lagged behind the Continent and the United States—at least in officially implementing the recommendations of the few who pointed the way.

Thus the first official seed-testing station in the world was established in Saxony in 1869. In 1885 a writer in the *Transactions of the Highland and Agricultural Society* pleaded that Scotland might also set up such stations, especially as the Royal Agricultural Society of England had been testing seed for its members since 1871 and had in 1882 laid down standards for purity and germination. But although a departmental committee set up to examine farm seeds had recommended in 1900 the establishment of a station, nothing was done as it was officially considered that the public would not take advantage of such facilities, or perhaps the reason given by R. H. Elliot, addressing the British Association in 1904, was more accurate: "The bewildering variety of our national affairs no doubt leaves little time for the Government to notice the needs of the biggest and most important industry of the kingdom", a reproach which is fortunately not true to-day.

But seed pathology was even at this time being studied elsewhere in the world. At Iowa the work was begun by Bessey, and in 1886 a State College bulletin was issued on the results of germination tests with notes on the fungi. It is surely not without significance, considering the leading part still taken by Iowa in seed testing and seed pathology, that from the first these two studies were so closely allied in that State. Every mycologist knows the initials which represent the authorities for the fungus name *Helminthosporium sativum*, P. K. and B., but how many know that Pammel was a botanist on the staff of the Station, and that Charlotte King, at that time assistant botanist, became an official seed analyst of Iowa? Nevertheless, this fungus, so commonly seed-borne in American crops, was not named until 1910, when these authors published a bulletin on *Helminthosporium* spp. on barley, including *H. gramineum* and *sativum*, which they described as seed-borne.

For very many years the leading work in seed pathology was carried out in the United States and

in Holland, where Dr. Lucie Doyer was the pathologist at the State Seed Testing Station at Wageningen, a centre which has always been noted for generously helping and co-operating with others.

In Britain very little attention indeed was paid to seed testing in relation to pathology, and this in spite of the repeated warnings even from the time of Jethro Tull: "In some sorts of seeds the goodness cannot be known by the eye". Sir John Sinclair said in 1782: "So far as oats are concerned—the clearest and best-looking oats when sown often produce the worst crop". But at last in 1920 the first and only British Seeds Act was passed, giving the farmer much greater protection and security in purchasing seeds than ever before. But even then, only certain crops were safeguarded; the Act does not apply to all seeds. Not that this was required where honest seedsmen were concerned, and there were several excellent seed firms all over the country whose names to-day still are sufficient guarantee; but there always have been less scrupulous merchants and individuals whose activities caused severe loss to farmers and gardeners.

However, even the most skilled and honest seedsmen could not be blamed for selling seed carrying infection which no one knew how to detect. In many cases, indeed, it was not even known that the seed was infected at all, as has been shown in the case of dry rot of swedes. Surveys of the various seed crops would have given valuable information; but plant pathological survey work of this nature in Britain was greatly restricted because of lack of staff and facilities.

But pioneer survey work was done by Dillon, Weston and Brett on cereal seed in England, by Hickman on pea seed, when he found twenty-six out of twenty-nine English-grown samples to be infected with pod spot; the Ministry of Agriculture's Plant Pathology Laboratory continues to examine seed for export, and in Northern Ireland Prof. A. E. Muskett and his collaborators are doing valuable work. In Scotland the work begun by Mrs. Alcock, who published in 1931 an annotated list of seed-borne diseases, has been to some extent continued.

In Canada, however, such a survey began in 1937, where, to quote Craigie: "Seed-borne diseases exact a heavy annual toll from every important farm crop in this country".

As already noted, the United States and Holland were among the first countries seriously to study the problem.

The development of techniques by which these diseases could be detected is in itself a fascinating study which can only now be briefly outlined.

There are two main lines of approach: (1) to reveal the total number of seeds in any given sample which are harbouring an organism—fungal, bacterial, animal or virus, saprophytic or parasitic; (2) to assess the likelihood of specific infection giving rise to disease in the crop.

The first approach is appropriate when surveying and also when examining seed for export, and the second when examining seed for such purposes as the operation of inspection schemes where specific diseases require to be detected. With any one sample of seed the result obtained is greatly affected by the method used. In a recent paper from Canada, Wallen and Skolko state: "Standardization of seed testing methods in respect to germination and purity has been attained through the Association of Official Seed Analysts of North America and, at the inter-

national level, through the International Seed Testing Association. Much less agreement exists in the matter of testing seed for the presence of pathogenic organisms. The reason for this lack of uniformity in methods of disease diagnosis may be attributed primarily to the development by individual laboratories of seed testing methods especially suitable to their own requirements, facilities and personnel. Standardization has undoubtedly also been hampered by the fact that comparatively little is known of the seed-borne phases of many of these organisms, the failure to develop satisfactory methods of detection for seed-borne pathogens, and the emphasis on the empirical application of seed treating procedures for their control, with the consequent neglect of fundamental information as to how the seed treatment is operative. As a consequence of the differences in seed testing methods, misunderstandings are inevitable and proper interpretation of reports is not possible."

In this paper the authors were dealing with the 'Ulster', 'Ottawa' and 'New Zealand' methods—variations in the agar plate method of testing flax seed. The seed to be examined is, in the Ulster method, plated directly on to malt agar without prior surface disinfection or washing; slow-growing fungi are soon overgrown if the seed is heavily contaminated. In the Canadian method a disinfectant is used, and this makes the separation of the fungal flora easier. But in both methods the seed germinates, and in so doing may lift the infected cotyledons or even the testa above the surface of the agar. In the New Zealand method this difficulty is overcome by using deep agar and submerging the seeds, which are first washed in running water. More recently, Hagborg and Warren in Winnipeg have very ingeniously used 2,4-D to inhibit germination of the seed, simply adding the 2,4-D to the agar. Wallen and Skolko draw this very reasonable conclusion from their study: it is not the purpose of this paper to suggest which of the three methods should be adopted in seed-testing procedure but rather to indicate the necessity of defining the method on which a given report is based.

It might be further mentioned that even the disinfectant used for surface sterilizing can alter results. Thus in examining wheat seed for *Septoria nodorum* by plating, I found that 'Chlorox', a chlorine type of dairy disinfectant, was less drastic in killing fungi than methylated spirit, but controlled bacterial contaminants more efficiently. This type of disinfectant has also the added advantage that the seed need not be washed again before plating—a process in which certain fungi (for example, those with pycnidiospores?) may be spread from an infected to a healthy seed. These methods, however, do not differentiate between saprophytes and parasites. It is often easier to grow the seed in such conditions as are known to induce the parasitic fungi to attack the developing seedling, identification then depending on the symptoms produced. Thus in Sweden *Fusarium* infection in rye is determined by sowing seed under ground brickstone, which induces characteristic twisting of the shoots. A variation of this method using sterilized sand has proved successful at East Craigs for testing oats for *Helminthosporium* as well as *Fusarium* spp. Some samples with 'official' germination capacity of around 95 per cent were found by this method to be perhaps 20–30 per cent infected, so that their value to the grower was reduced accordingly. In the case of oats infected with these

diseases, the official figure is generally too favourable; but in others the reverse is true. *Ascochyta imperfecta*, the cause of black stem disease, is very common in trefoil samples and spreads very rapidly from seed to seed under the conditions of the official test in incubators, so that infection appears much higher than if the seed is sown in soil. This fungus illustrates another point: that certain seed-borne diseases are already well known to skilled analysts because of their effect on the appearance of the seed: trefoil seed severely infected by *Ascochyta imperfecta* is dark brown in colour and rather flat, while more superficial infection appears as thin black lines, which are, in fact, thick-walled hyphae, visible on the seed to the naked eye. The analysts at East Craigs recognized these marks as indications of poor quality seed before we proved them to be specific fungal infection. There is no doubt that similar investigational and survey work on seed crops as well as seed after harvesting would yield most interesting results. There is now a very large industry in crop protectants, including seed disinfectants, but more attention should be paid to the production of healthy, vigorous seed. In this respect chemistry has outrun biology.

International Aspects of the Problem

These problems are not confined to Britain, for this country is involved in the international trade in seeds. In 1950 Britain imported seeds to the value of £4½ million and her exports were more than £2½ million. It may, of course, be argued that so far as seed-borne disease is concerned we must already have spread them around and received every possible foreign trouble and that it is now too late to shut the stable door. There are, however, still some diseases which might be imported here; bacterial blight of peas is one, and as it is most severe where frost pockets are found we might expect it to do great harm in Scotland to our expanding industry of growing peas for canning. Then a recent attempt to grow soya beans in Scotland was unsuccessful owing, at least in part, to seed-borne bacterial blight. Our seed came from Sweden, where the disease was unknown until a few years ago, when it was imported with seed of new American varieties.

To endorse this aspect of the problem, I should like to quote again from a paper read at the British Association at Cambridge in 1904. The speaker was R. H. Elliott, of Clifton Park, Kelso, to whom Stapledon has referred as the father of grassland husbandry. In his paper he appealed for seed testing to be begun officially in Great Britain. He died in 1914, the year that the Department of Agriculture for Scotland began the first advisory, as against statutory, seed testing. But he also asked that our farmers should be protected against the introduction of diseased seed from abroad. Now, almost fifty years after, it seems that there is hope that this also will be done.

Last year the Government issued the report of the committee set up to investigate the qualitative control of seeds. As a member of this committee recently said: "In the early stages of the development of seed testing practice, the emphasis appears to have been upon providing a ready means of assessing seed values, largely for the purpose of facilitating trade in seeds, without particular thought as to the value of the data to the grower".

The committee in its report has fully met this point and has further recommended, so far as health is concerned: (1) there should be an early extension

of health surveys of home-grown and imported seeds; (2) there should be further research into methods of detecting seed-borne organisms, and to find suitable technique whereby seed samples can be examined speedily and accurately for the presence of diseases or pests; (3) seed-testing practice should be extended to cover health; (4) seed certification schemes should include inspection for disease.

Further, there should be close collaboration between the seed-testing stations and the plant pathology services and continued close liaison with the International Seed Testing Association.

The International Seed Testing Association, which had its first post-war meeting in Washington in 1950, has a Pathology Committee which will undoubtedly welcome this approach. Then in spring 1951 Great Britain signed the convention of the European Plant Protection Organization, under which we now commit ourselves to survey our crops for the presence of certain pests and diseases with the view of ensuring, in collaboration with the other subscribing countries, that these are not further spread abroad. One of the means of dissemination to which attention will be paid will undoubtedly be the seed.

In conclusion, therefore, the outlook for the further study of seed pathology in Great Britain and abroad is distinctly promising.

MINERALS AND MAGMAS: STUDIES AT HIGH TEMPERATURES AND PRESSURES*

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A CARDINAL aim of the petrologist must be to explain the natural history of the rocks of the earth's crust in physico-chemical terms. To that end investigation of equilibria in dry silicate melts has been pursued for many years, with fruitful results, notably in the Geophysical Laboratory, Washington. Although studies on hydrous silicate systems were commenced there as long ago as 1914, their range has been limited until comparatively recently.

Water is an important component of magmas and of many minerals, and its presence in magmas is significant in several respects. The viscosity of the fluid is diminished and crystallization temperatures are lowered. Hydrous minerals such as amphibole or mica may be precipitated, though it does not necessarily follow that they will. At a late stage in the cooling a fluid rich in water may remain, capable of profoundly modifying either the early crystallized material or neighbouring rocks, or of transporting substances, such as sulphides, to a locality where lower temperature brings about their precipitation. When magmas reach the open air, the water they contain is largely fugitive, but when they cool at depth the water may be retained, at least for a time, because of the load of superincumbent rocks.

The part played by water in the metamorphic rocks is less well understood. Here the mineralogy and texture now displayed is due to recrystallization, which took place in the solid. Complex conditions attend such change and it is certain that water in

* Substance of a paper read on August 14 before Section C (Geology) of the British Association meeting at Edinburgh.