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Disease Testing at NIAB, Britain's Unique Agricultural Institute

The National Institute of Agricultural Botany (NIAB) was founded in 1919 to make good the practical deficiencies in seeds and varieties revealed by the critical need to increase food production during World War I. Farmers and seedsmen had drawn attention to the need for accurate information on the weed content and germination of seeds available, and the application of Mendel's work to practical plant breeding had shown that it was possible to improve the varieties of wheat, potatoes, and other crops then in cultivation—crops which in general suffered from low yields, liability to diseases, weakness of stem, or some other defect (6).

A trust deed was signed in 1919 setting up the NIAB at Cambridge, England. An important feature in the establishment of the new institute was the warm support it received from the agricultural industry for crop improvement under its motto "Better Seeds:Better Crops." Generous financial support was received from the seed trade, millers, agricultural merchants, and farmers to supplement contributions from the Ministry of Agriculture, Fisheries and Food (MAFF). The Official Seed Testing Station (OSTS) for England and Wales was transferred from London to the NIAB at Cambridge.

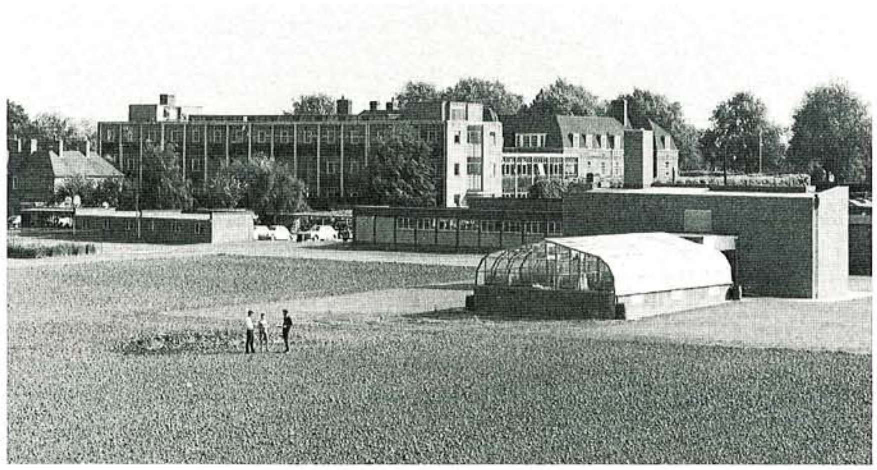
The terms of reference were widely drawn and included "promoting the improvement of existing varieties of seed, plants and crops in the United Kingdom and aiding the introduction or distribution of new varieties" (6). The members of the governing body, the council, are nominated by all the main interests of the agricultural industry. This active, widespread support and participation is still regarded as a major contributing factor in the success of the work of the NIAB.

Because the trust objective of the NIAB did not include plant breeding activities, the institute can act as a truly impartial authority in evaluating varieties, testing seed, and independently supervising the multiplication of seed by inspecting the crops and certifying the produce. Thus, the NIAB holds a unique position in being an independent body responsible for evaluating and comparing all aspects of seeds and varieties of agricultural and vegetable crops.

There is an active fellowship scheme through which 6,000 subscribing members, ie, farmers, seed merchants, breeders, chemical companies, universities, etc., receive trial results and publications as soon as these are available. Members also are invited to demonstrations, conferences, and courses to discuss results and to receive general help and advice from staff.

The value of close international cooperation has always been recognized since the NIAB took the lead in establishing the International Seed Testing Association (ISTA) in 1924. Cooperation has been expanded to cover many aspects of crop improvement, eg, with the Union for the Protection of Plant Varieties (UPOV), the European Brewery Convention (EBC), the Organization for Economic Cooperation and Development (OECD), the Food and Agriculture Organization (FAO), the European Economic Community (EEC), the European Yellow Rust Trials Project, and the International Institute for Sugar Beet Research (IIRB).

The institute is mainly financed by the MAFF with direct payments for the statutory tests and trials to produce results for the National Lists of varieties or with grants-in-aid for the tests, trials, and investigations required for independent NIAB Recommended Lists that provide advice for farmers. The services provided by OSTS and the seed certification authorities are self-supporting.



Headquarters of the National Institute of Agricultural Botany in Cambridge, England.

The Situation in 1982

The OSTS now consists of three sections, one primarily concerned with providing seed testing and an analyst training service, another with the technical control of licensed commercial testing stations and with research and development, and the third with seed pathology. Thus, the OSTS carries out statutory tests on seed samples required for certification, tests samples of farmers' own seed, and reports on germination, purity, and presence of disease.

The seed production branch, acting on behalf of the MAFF, supervises the technical operations required for the statutory Seed Certification Scheme in England and Wales and trains inspectors from commercial firms to inspect and report

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Table 1. Major diseases used in NIAB disease resistance testing

Cereals

Wheat: Mildew (*Erysiphe graminis*), yellow rust (*Puccinia striiformis*), brown rust (*Puccinia recondita*), glume blotch (*Septoria nodorum*), eyespot (*Pseudocercosporella herpotrichoides*), loose smut (*Ustilago nuda*)

Barley: Mildew (*Erysiphe graminis*), yellow rust (*Puccinia striiformis*), brown rust (*Puccinia hordei*), leaf blotch (*Rhynchosporium secalis*), loose smut (*Ustilago nuda*)

Oats: Mildew (*Erysiphe graminis*), brown rust (*Puccinia coronata*)

Occasional tests: Barley yellow dwarf virus, oat mosaic virus, net blotch (*Pyrenophora teres*)

Vegetables

Lettuce: Downy mildew (*Bremia lactucae*)

Peas: Pea wilt (*Fusarium oxysporum*), downy mildew (*Peronospora viciae*)

Tomato: Wilt (*Fusarium oxysporum* f. *lycopersici*, *Verticillium albo-atrum*), tobacco mosaic virus

Dwarf French beans: Gray mold (*Botrytis cinerea*), anthracnose (*Colletotrichum lindemuthianum*)

Leeks: Rust (*Puccinia allii*)

Brussels sprouts: Powdery mildew (*Erysiphe cruciferarum*)

Occasional tests: White blister (*Albugo candida*), ring spot (*Mycosphaerella brassicicola*), downy mildew (*Peronospora parasitica*), club root (*Plasmodiophora brassicae*)

Root and fodder crops, oilseed rape

Swede (rutabaga): Powdery mildew (*Erysiphe cruciferarum*), club root (*Plasmodiophora brassicae*)

Turnip: Club root (*Plasmodiophora brassicae*)

Forage rape: Powdery mildew (*Erysiphe cruciferarum*)

Sugar beet: Downy mildew (*Peronospora farinosa*), powdery mildew (*Erysiphe betae*)

Maize: Stalk rot (*Fusarium culmorum*)

Oilseed rape: Stem canker (*Phoma lingam*), light leaf spot (*Pyrenopeziza brassicae*), downy mildew (*Peronospora parasitica*)

Occasional tests: Beet rust (*Uromyces betae*)

Grasses

Italian and perennial ryegrass: Powdery mildew (*Erysiphe graminis*), crown rust (*Puccinia coronata*), leaf spot (*Drechslera* sp.), leaf scald (*Rhynchosporium* sp.), ryegrass mosaic virus

Occasional tests: Barley yellow dwarf virus, bacterial wilt of ryegrass (*Xanthomonas graminis*)

Herbage legumes

Red and white clover: Clover rot (*Sclerotinia trifoliorum*), powdery mildew (*Erysiphe trifolii*)

Lucerne (alfalfa): Wilt (*Verticillium albo-atrum*), bacterial wilt (*Corynebacterium insidiosum*)

Table 2. Disease resistance tests for barley and oats (National List for 2 years, Recommended List for 3 years)

	Artificial infection			Natural infection	
		Adult plant			
Pathogen	Seedling	Field	Polyethylene tunnel	Yield trials	Observation tussocks
Winter barley					
Erysiphe graminis	+			+	
Puccinia hordei	+	+	+	+	
Puccinia striiformis	+	+	+[a]	+	
Rhynchosporium secalis		+		+	+
Ustilago nuda		+[a]		+[a]	
Spring barley					
Erysiphe graminis	+			+	+
Puccinia hordei	+	+	+	+	+
Puccinia striiformis	+	+	+[a]	+	+
Rhynchosporium secalis		+		+	+
Ustilago nuda		+[a]		+[a]	
Winter and spring oats					
Erysiphe graminis	+			+	
Puccinia coronata	+[a]	+[a]		+[a]	

[a] Recommended List tests only.

on seed crops. The crop and service branches together are responsible for the technical aspects of variety evaluation. This is now a major part of the institute's work with both statutory and advisory sectors. In 1974 the introduction of uniform standards throughout the EEC required member states to produce national lists of varieties that may be marketed. To qualify for inclusion on these lists, varieties must be shown, in trials, to be distinct, uniform, and stable (DUS) and to possess a satisfactory value for cultivation and use (VCU) (8). The NIAB is responsible to the MAFF for the trials in England and Wales that provide results for the U.K. National Lists.

Trial Procedures

After a set period (usually 2 years) of trials and tests for compliance with the National List regulations, a variety found to be satisfactory is normally added to the list. The relatively few most promising varieties from these trials are then grown for a further period (usually 1 year) of much more intensive advisory trials to test their suitability for inclusion in the NIAB Recommended Lists, the lists that recommend only the best varieties to farmers.

There are 14 Regional Trial Centres, manned by NIAB staff and situated in the main crop-producing areas of England and Wales, at which yields are determined in field trials and other economic characters are recorded. The main crops tested include wheat, barley, oats, ryegrass, clover, lucerne (alfalfa), potatoes, sugar beet, oilseeds, fodder crops, and vegetables. In addition to the records for field characters and yield, disease resistance and quality are assessed in appropriate tests and in controlled conditions by specialists at headquarters in Cambridge.

Disease Resistance Testing

Resistance to disease is a major factor taken into consideration in deciding whether a variety complies with the National List requirements. The aim of the disease tests is to avoid inclusion on the list of varieties that are unduly susceptible to a disease of national economic importance and might adversely affect the health of any persons, animals, or plants (5). Higher disease standards are required for the varieties on the Recommended Lists, where the aims are to positively recommend to farmers varieties with a high, durable genetic resistance and to give farmers a choice of varieties with a wide range of different resistance factors as an insurance against a "breakdown" of the variety to disease. The frequency and intensity of epidemics that may cause considerable annual yield losses should be reduced with this policy.

The most important diseases used in tests are selected according to advice and information from the Agricultural

Development and Advisory Service (ADAS), NIAB trials, and national disease surveys (Table 1). Diseases are always assessed using diagrammatic or descriptive keys to ensure standard records are obtained from a large number of recorders. Assessment keys are available for cereal diseases (5) and for diseases of vegetable, fodder, and herbage crops (2).

Records are made at specific plant growth stages of infection levels occurring naturally on all varieties in replicated, randomized yield trials at the regional centers. Records are also made on small disease observation plots of each variety that are situated in areas with a history of prevalence of specific diseases. Because natural infections of one or more diseases may not occur during the years when a variety is in trials, additional tests in which varieties are uniformly inoculated are essential to obtain sufficient information for a resistance rating. These tests are performed at Cambridge, where varieties are inoculated in tests in controlled-environment rooms, glasshouses, and polyethylene tunnels and where epidemics of diseases are induced in small fields. Table 2 shows the disease resistance tests for barley and oats.

Virulent isolates of each pathogen are used separately on each variety to identify resistance factors (seedling and adult plant tests) and to obtain a resistance rating in the presence of pathogen strains capable of overcoming such factors (adult plant tests). The cereal pathogen isolates used are selected after consideration of the annual reports of the U.K. Cereal Pathogen Virulence Survey (UKCPVS), which was set up in 1966 and is responsible for monitoring the presence of known virulences and also for detecting new virulences in pathogen populations (1). The cooperating organizations of the UKCPVS also provide samples of isolates to breeders and the NIAB for their tests. Virulent isolates of other crop pathogens are collected, stored, and used as they become available. Virulences with high frequency as well as the most important new infrequent virulences are used in tests (Table 3).

Disease Resistance Ratings

Data from all trials and tests over the 2-or 3-year period are summarized to produce for each variety and each disease a rating on a 0–9 scale (9 = very good resistance) (3). The results are then considered by the appropriate committee for each crop for entry on the National List or the Recommended List. The basic aim is to encourage use of varieties with reasonable levels of resistance and discourage use of very susceptible varieties.

To ensure that varieties being considered for the Recommended List have an adequate level of disease resistance,

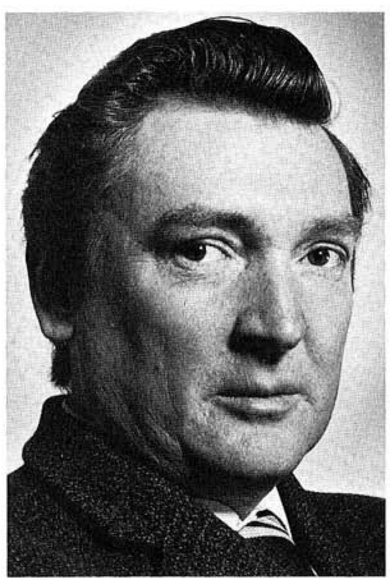
Table 3. Virulence factor frequency (%) for yellow rust of wheat

Virulence factor	Common name	1976	1977	1978	1979
V1	Chinese 166 virulence	92	73	73	83
V2	Heine VII virulence	100	100	97	100
V3	Vilmorin 23 virulence	100	100	100	100
V4	Hybrid 46 virulence	12	24	27	17
V5	*Triticum spelta album* virulence	0	0	0	0
V6	Heine Kolben virulence	4	16	26	17
V7	Lee virulence	0	8	0	0
V8	Compair virulence	2	4	0	0
V9	Riebesel 47/51 virulence	6	0	0	0
V10	Moro virulence	0	0	0	0
	Number of isolates tested	52	26	66	30

Table 4. Standards of disease resistance for wheat, barley, and oats[a]

Pathogen	Desirable standard	Minimum standard
Wheat		
Erysiphe graminis	5	3
Pseudocercosporella herpotrichoides		
Winter	7	3
Spring	None	None
Puccinia recondita	4	None
Puccinia striiformis	4	3
Septoria nodorum	5	3
Ustilago nuda	None	None
Barley		
Erysiphe graminis	6	3
Puccinia hordei	None	3
Puccinia striiformis		
Winter	5	4
Spring	4	3
Rhynchosporium secalis	None	2
Ustilago nuda	None	None
Oats		
Erysiphe graminis	5	3
Puccinia coronata	None	None

[a] Rated on a 0–9 scale (9 = best).



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Testing at the National Institute of Agricultural Botany

Resistant bean variety (right) can be distinguished from susceptible variety (left) only by resistance to a specific race of *Colletotrichum lindemuthianum* and thus can be accepted as a distinct variety.

Detached leaf technique is used to identify virulence factors of brown rust of barley.

Aphids infected with barley yellow dwarf virus are caged on individual seedlings to identify varieties with tolerance.

Lettuce varieties are tested with *Bremia lactucae* in polyethylene tunnels that ensure suitable conditions for infection.

Small plots of wheat and barley varieties are subjected to intense inoculum pressure from susceptible "spreader" varieties severely infected with *Puccinia striiformis* (yellow rows).

Infected pieces of straw are placed in rows of test varieties to spread infection of *Pseudocercosporella herpotrichoides*; control plots are to the left of the polyethylene guard.

Table 5. Varietal diversification to reduce spread of yellow rust and mildew in winter wheat, 1981[a]

Diversification group[b]	Winter wheat variety
1B	Avalon
	Bounty
	Mardler
1E	Aquila
	Flanders
1F	Prince
	Rapier
2A	Copain
2B	Hustler
	Maris Huntsman
	Virtue
3A	Norman
4C	Armada
6B	Brigand
6F	Hobbit
	Kador

[a] Adjacent fields are sown with varieties from different diversification groups to reduce spread of disease from one to the other. Varieties grown in the same field in successive years or in a seed mixture are chosen from different diversification groups.

[b] 1–6 = yellow rust groups; A–F = mildew groups.

the NIAB has introduced disease standards for cereal diseases after discussion and agreement with the breeders (Table 4). The *desirable* standard is the level at which the amount of inoculum in each crop would be unlikely, under normal conditions, to result in regional or national epidemics causing yield losses. A variety with a *minimum* standard can be accepted only if it has other compensating characters (eg, grain quality). Any variety with a disease resistance rating lower than the minimum is not recommended, whatever its merit in other characters (4). With this policy, the general level of resistance of varieties grown in England and Wales is gradually and continually being improved.

Although such formal standards are not implemented for diseases of other crops, susceptible varieties are considered very critically before being recommended. It is therefore unlikely that red clover varieties very susceptible to clover rot or oilseed rape varieties very susceptible to canker or light leaf spot would be recommended.

Diversification

In the past, pathogens with virulence toward widely grown varieties spread rapidly, causing epidemics and leading to the rapid decline in the acreage of many outstanding varieties. If varieties do not possess the long-lasting, nonspecific durable type of resistance, then it is essential to ensure that specific resistances bred into varieties are used as efficiently as possible. A practical way to protect these specific resistance factors, which the grower can understand and implement, is to diversify by growing two or three varieties on the farm that differ in their resistances to the important diseases. The UKCPVS produces this information every year for mildew and yellow rust of wheat and barley, and the NIAB summarizes the information for farmers (Table 5).

A survey of farmers indicated that over 50% of growers are using the diversification schemes as an insurance to reduce disease spread (7); a further 20% are making a good selection by chance. It is thus a deliberate policy to ensure that a range of varieties with different resistance factors is available to growers whenever possible.

Instead of diversifying by growing varieties with different types of resistance in adjacent fields, varieties could be grown as adjacent plants in a single field, ie, a mixture of two or three varieties. Trials have shown that disease levels can be reduced by such a technique; yields are usually either improved or similar to the mean of the component varieties. Component varieties can be selected by a grower from different diversification groups, taking account of other varietal characters, such as height, date of maturity, etc. Investigations are in progress at the NIAB to ensure that it is valid to use all these data for the formulation of a variety mixture in a single crop.

The acreage of mixtures grown in the United Kingdom is low but may increase in the future because of rising fungicide costs.

Fungicides to Supplement Genetic Resistance

It is unlikely that many commercially acceptable varieties will possess high resistance to all the more important pathogens, and thus fungicides are required to maximize yields. The NIAB presents yield data from additional national trials that incorporate a fungicide treatment to reduce all diseases below an economic level, so progressive farmers can compare yields of varieties in the presence and absence of disease to help in their management decisions.

Varieties differ in the size of their yield increases when all diseases are controlled so that some varieties perform relatively better when treated with a fungicide. The more resistant varieties tend to be largely free from disease when untreated, so there is only a small yield increase when disease is controlled. Thus, yield returns are not economical from fungicide-treated resistant varieties in low disease risk areas and are rarely economical in high disease risk areas.

The use of varieties with high resistance levels, the application of disease standards, the efficient use of resistance genes, and the planned use of effective fungicides should decrease the frequency and intensity of disease epidemics leading to higher, more consistent yield returns.

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