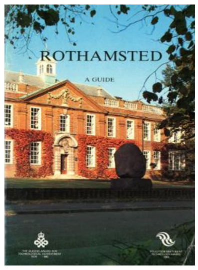
Guide to the Work of the Departments 1984



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Agronomy and Crop Physiology Division

Rothamsted Research

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AGRONOMY AND CROP PHYSIOLOGY DIVISION

The Division contains Broom's Barn Experimental Station in Suffolk, the Rothamsted Farms and Field Experiments Section and the Physiology and Environmental Physics Department. One of the objectives in setting up the Division is for a core group of crop physiologists to help to integrate the agronomic elements of the Station's work.

The Broom's Barn experimental programme, centred on sugar beet, is funded by the Ministry of Agriculture's Sugar Beet Research and Education Fund, to which growers and British Sugar plc subscribe. The Station is situated at Higham in Suffolk, 7 miles from Bury St Edmunds and Newmarket, 20 miles east of Cambridge. The Higham site provides adequately equipped laboratories, completed in 1962, and a farm of 73 ha. The research programme aims to improve yield, quality and profitability of both root and seed crops by means of laboratory, glasshouse and field experiments, and reflects the requirements of the industry, i.e. British Sugar plc, the beet farmer, the seed grower, etc. The staff cooperate closely with members of other departments at Rothamsted and other research institutes, both in the UK and on the Continent, working on related problems of sugar beet.

The Physiology and Environmental Physics Department was formed in 1983 by the amalgamation of that part of Botany which investigated plant growth and development, with the groups from the Physics Department studying plant physics and agricultural meteorology, and provides a focus for understanding the response of arable plants to the field environment. Investigations have centred on the consequences of changing the supply of water and nutrients to the plant, but a programme concerned with the dispersal of spores and spray drops in crops has also developed jointly with plant pathologists, and will in future provide the basis for wider links with those working on various aspects of crop protection. Throughout, the aim is to test ideas and combine measurements by means of simulation models.

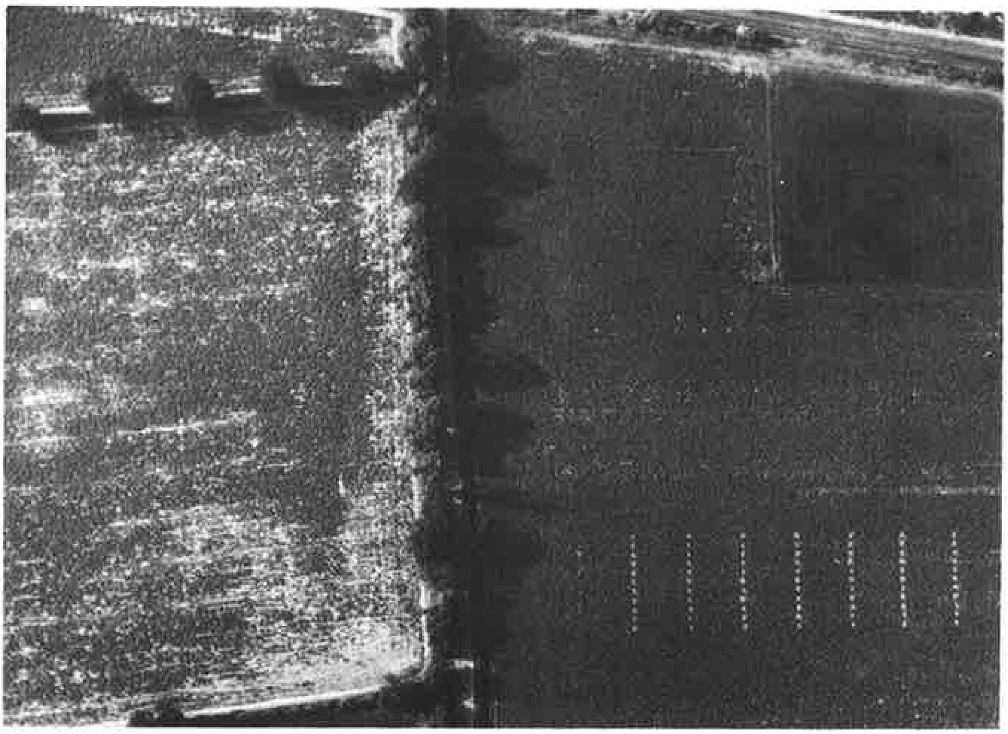
Some members of staff in the Physiology and Environmental Physics Department and the Field Experiments Section devote much of their time to the multidisciplinary experiments on sugar beet at Broom's Barn and on beans, wheat, barley, potatoes and oilseed rape at Rothamsted. Where, in these experiments, growth and development can be monitored in relation to the whole environment, they provide the opportunity for detailed study of the effects of many factors and their interactions. The objective is to measure and model in a coordinated effort by scientists from different backgrounds and disciplines, so that we are able to generalize as far as possible, despite restricted replication, over sites and seasons. It is here that the physiologists and physicists especially contribute by taking a mechanistic and quantitative approach.

BROOM'S BARN EXPERIMENTAL STATION*

The research of the Station is organized in three multidisciplinary groups which deal with major topics of concern to the sugar-beet industry.

Plant establishment

For crops drilled to a stand, we estimate that, unless establishment is at least 70%, yield is lost due to gappiness. However, in over 200 trials made by British Sugar staff between 1970 and 1977, an average of only 56% establishment was obtained; on 86% of the fields the establishment was below the target 70%. Another problem with drilling to a stand results from emergence taking place over a prolonged period, which makes it impossible to apply post-emergence herbicides at a common stage in crop development; it also contributes to variation in plant size which makes for difficulties in harvest. The aims, therefore, are to make emergence quicker and more uniform, and to increase the number and vigour of seedlings which emerge and become established.



An aerial photograph of two sugar beet fields in July. The establishment problems in the commercial crop on the left illustrate a major cause of poor yield. In the experimental field on the right, most treatments have established well. Patches of bare ground in the regular pattern in the foreground are small discard areas between trial plots.

* Those wishing to visit Broom's Barn, or who require further information, should apply to the Head of Station, Broom's Barn Experimental Station, Higham, Bury St Edmunds, Suffolk. *Phone* (0284) 810363.

Seedling pests and diseases. Soil insect and related pests that attack beet seedlings are studied with the objective of identifying the fields particularly at risk, so that soil pesticides are only used where necessary; pesticides are tested to find the most effective. Mice can drastically reduce plant stands by taking seed; recent research has identified the factors leading to damage so that a warning system can be developed allowing the mice to be controlled when necessary by poison bait. Studies are in progress on fungal seedling diseases and the most effective fungicides to control them.

Seed quality. Results of experiments at Broom's Barn, and cooperative surveys with British Sugar, indicate that to achieve, more regularly, the 70% establishment needed for maximum yield, it will be necessary to continue to improve seed quality and to avoid creating the poor seedbeds which occur on some fields. Experiments have shown that there is considerable variation in the performance of seed lots even after they have been processed to marketable quality. We are seeking explanations for this variation and investigating whether it is possible to improve on the statutory laboratory test as an indicator of performance.

Seedbed physical environment. There is accumulating evidence that sensitivity to moisture stress changes as the seed/seedling develops; thus the optimum seedbed structure is one which buffers against variation in the weather. We are therefore trying to determine this structure and suggest ways by which it might be obtained, by testing the effects of soil moisture, temperature, aggregate size and packing, on germination and emergence.

Environmental and nutritional aspects of crop growth and productivity

In the past, much of the research on the productivity of sugar beet (and most other crops) has relied heavily on measurements of final yield. This has provided very little information on the plant growth processes that limit yield. Our effort is concentrated on a limited number of experiments where detailed measurements are made on the crop and its environment; progress has been made in defining potential productivity in terms of climate and soil. From detailed measurements made during several seasons, on crops little affected by pests and diseases, close relationships have been defined between total dry matter and sugar yields, and the amount of radiation intercepted from sowing until harvest. This analysis provides the basis for investigations of the value of late nitrogen applications, transplanting, plant density and growth regulators. Measurements are being extended to include a study of root growth and distribution in relation to water uptake.

The spectral ratio meter is being tested as a method for remotely sensing the amount of radiation intercepted by either different crops or different areas within a crop in collaboration with ADAS, and the results are compared with variations in yield within and between fields.

Weed beet. In recent years sugar-beet plants which become reproductive in their first season (bolters) and produce viable seeds, have become a weed problem of arable land, particularly in the sugar-beet crop where they cannot be controlled by selective herbicides. Surveys indicate that about 27% of the English sugar-beet crop is infested. The first approach to contain the problem was to devise tests to identify seed stocks which contained the annual types that were introducing the weed. More recent work has concentrated on preventing futher multiplication of weed beet in already infested fields by preventing viable seed production. Cutting bolters and the selective application of non-selective herbicide (glyphosate) have given satisfactory results when properly used. A long-term experiment at Broom's Barn is comparing the effects of different rotations and cultivation practices on the survival of weed-beet seed.

Diseases and pests

Virus yellows and its aphid vectors. The main part of the Group's programme concentrates on the most important sugar-beet disease, virus yellows, and its aphid vectors, with the overall objective of improving forecasting and control. Using the serological testing technique ELISA, the distribution and epidemiology of the two yellowing viruses in beet, beet yellows virus (BYV) and beet mild yellowing virus (BMYV), are studied in collaboration with British Sugar's Specific Field Survey. Potential overwintering sources of aphids and viruses are assessed and the number of overwintering aphids surveyed so as to forecast the threat of damage. We have recently discovered that many oilseed rape crops, which are an overwintering host for *M. persicae*, are infected with a BMYV type virus. Studies of aphid behaviour in the root crop and the distribution of viruses in infected plants in relation to infectivity, underpin more empirical work comparing timing and methods of application of aphicides. Insecticides can be beneficial by controlling aphids, and hence virus spread, but they can also have an adverse effect by disturbing aphids, or by killing beneficial insects that control aphids. The extent of possible adverse long-term effects of γ-HCH ('Gamacol') on the incidence of aphids and yellows is being studied.

Fungal diseases. Recent work at Broom's Barn has shown the benefits of controlling powdery mildew and a substantial proportion of the sugar-beet crop is now sprayed with sulphur for this purpose. Experiments continue, to monitor the benefits obtained from controlling powdery mildew with different fungicides and with different timing of application. The potential benefits from controlling the other late season leaf diseases, ramularia leaf spot and rust, are also studied.

Nematode studies. The rotational restrictions in the sugar-beet growing contract between the processor and the grower were removed for 1983, so the need for best cyst nematode damage forecasting, and prevention strategies to allow beet to be grown more frequently, or in rotations including other hosts, became more acute. Long-term experiments are in progress on effects of different crop rotations on the build-up of nematode populations and on integrated control measures which incorporate crop rotation, nematicides and nematode-parasitic fungi. Some endoparasitic nematodes, e.g. *Pratylenchoides* spp, cause lesions on the roots of sugar-beet seedlings, and the effects of these species on sugar-beet establishment and yield, and whether invasion and/or damage are prevented by systemic pesticides is being investigated.

THE FARMS AND THE FIELD EXPERIMENTS SECTION

The start of field experiments at Rothamsted in 1843 represented the founding of the experimental station and the importance of extending laboratory findings into the field remains as great today.

Facilities for the conduct of field experiments are available to members of the scientific departments on farms at Rothmansted and Woburn. The Rothamsted estate is 325 ha of which 260 ha are farmed. Soils are mainly Clay-with-flints, cropped mainly with wheat and barley, much in rotation with potatoes, field beans, oilseed rape or oats, with some permanent grass. The Woburn farm is 76 ha, mainly a contrasted sandy loam derived from the Lower Greensand but with some heavier soil derived partly from Oxford Clay. The cropping is similar to Rothamsted but beans and oilseed rape, which are less suitable for lighter land, are replaced by additional potatoes.

The programme of field experiments is controlled by the Working Party for Field Experiments and associated sub-committees whose members include representatives from the Farms and the Field Experiments Section. Working from the committee decisions the Section produces detailed instructions for the conduct of the experiments to the Head of Farms, who is responsible for the field work of most of the experiments and the non-experimental cropping on both farms and all other matters relating to the farms. The Small-plot staff of the Field Experiments Section have responsibility, at Rothamsted only, for small-plot experiments which cannot conveniently be done by farm equipment.

The Classical experiments, started in the 19th century, total about 700 plots. They constitute only about 10% of the work of the Farms but remain of unique agricultural and historic interest; details are given in the *Guide to the Classical Field Experiments*. The modern longer-term experiments, ranging in duration from two years to more than 40, occupy just over 3000 plots and annuals a further 3500.

Both the Farms and the Field Experiments Section originate some individual field research; the Section also provides team leaders and scientific staff for the multidisciplinary field experiments on winter wheat and grain legumes.

Members of the Section provide a service to visitors by demonstrating the field experiments and by arranging suitable programmes to integrate field and laboratory interests.

PHYSIOLOGY AND ENVIRONMENTAL PHYSICS DEPARTMENT

This Department studies physical aspects of the aerial environment of crops and physiological responses of crops to their environment. Most of the research on the environment is related to the dispersal of spores and spray droplets in crops. The physiology includes the effects of temperature, radiation, water and nitrogen supply on the processes that control the expansion and functioning of leaves, and hence light interception and dry matter production, and those that control the distribution of dry matter between plant parts. Mechanisms studied range from those involved in the behaviour of crops to metabolic processes at the cellular level. Most of the work is with cereals; sugar beet is also studied in collaboration with Broom's Barn Experimental Station.

Cereal physiology

The physiological response of winter wheat to a wide range of agronomic treatments is studied in multidisciplinary field experiments in conjunction with other departments. Of particular interest are the effects of sowing date, timing and amount of nitrogen supply, growth regulators, soil type and condition, and their interactions with the weather. The proportion of the dry matter that reaches the grain is influenced greatly by the structure of the flowering parts of the crop. So plant development is studied in order to understand what controls tiller production and survival, the production of spikelets and florets, and the proportion of florets that survive to become grains. Aspects of development and crop structure are also investigated in winter barley in the field, and in wheat and barley in controlled environment experiments.

To quantify our knowledge of the physiology of leaf growth, measurements are made in the field of rates of appearance, expansion and senescence of individual leaves and of their maximum sizes. These observations are complemented by a more fundamental analysis using plants grown in nutrient solution in controlled environments. Area and weight of leaves, number and size of cells, carbohydrates and protein contents are measured.

Environmental, agronomic and ontogenetic effects on leaf function are investigated in the field, where measurements are made of photosynthesis, dark- and photorespiration, transpiration and plant water potential using specially designed equipment. More detailed research on the relations between the environment, carbon dioxide exchange and metabolic processes is done in the laboratory. Studies of the metabolic balance of drought stressed leaves show the causes of decreased carbon dioxide fixation and the accumulation of amino acids and other osmotically-active solutes in severely stressed tissues. By relating

Measurement of photosynthesis and transpiration using a leaf chamber developed in the Physiology and Environmental Physics Department. The measuring system is fully portable for use on field crops.

cellular water balance and metabolism, such research may identify control points that can be manipulated to increase drought resistance in crop plants.

Sugar beet physiology

The expansion of the leaf surface in sugar beet crops is slow during May and June, when solar irradiance is greatest, so that early growth of the crop is restricted by incomplete light interception. Later growth also varies because of differences in the decline of leaf area towards the end of the season. Causes of variation in size of leaf canopies are being sought by studying the processes involved in the initiation and expansion of individual leaves both in the field and under more experimentally controllable conditions in growth rooms. Of particular interest are the effects that conditions during initiation of leaves have on the later rates of expansion and final sizes of those leaves.

To help define ways in which the proportion of the crop's dry matter stored as sugar may be increased, the development of the storage root is studied in laboratory and field experiments. Sugar beet also accumulates compounds that impair the extraction of sugar, e.g. sodium and potassium ions and nitrogenous compounds. Their roles in the physiology of the root are being studied in order to recommend ways of manipulating the crop to improve quality.

Aerobiology and microbiology

The dispersal of plant pathogens in time and space is often the least understood process in disease epidemiology. So the physical processes which determine the dispersal of small particles within and above crops are being investigated in the field and wind tunnel in cooperation with the Plant Pathology Department. Deposition patterns of droplets and spores are measured together with detailed studies of turbulence using sonic and constant temperature anemometers. The analysis of these observations helps us to understand the dispersal of pathogens by wind (e.g. powdery mildew), by rain splash (e.g. eyespot) and to understand the behaviour of agricultural spray systems. The characteristics of turbulent air flow within and above crop canopies are also being studied to show how crop structure and atmospheric stability determine exchange processes between the atmosphere and the crop. This is important to our understanding not only of spore dispersal but also of crop gas exchange, the deposition of pollutants and many other phenomena.

Modelling

Mathematical modelling is used to integrate our understanding of various levels of the plant and crop system, and to relate theoretical studies to experimental results. In aerobiology, theoretical models are being developed to describe the interaction of weather, crop and spores on the dispersal process. Experimental results supply information necessary to run the models and are used to validate them. Modelling is also being used to investigate the importance of dispersal in the epidemiology of crop diseases. Disease development within crops is simulated using realistic descriptions of the disease cycle and the deposition process, and the results are compared with the observed development of patches of disease.

The physiological studies on cereals provide descriptions of the functioning of leaves and the responses of whole crops to the environment. These are combined into models of crop growth which may then be used to predict performance in different environments and to determine the sensitivity of growth to changes in various physiological processes. Possible uses of such models are in studying global effects of increased atmospheric carbon dioxide concentration and proposals for optimal economic strategies in agriculture. Modelling will also be used to integrate our knowledge of the influence of the major variables, temperature, water and nutrient on the physiology of leaf growth in sugar beet in order to provide a stronger diagnostic basis for analysing crop performance.

Technical equipment and routine meteorology

The Department has two field laboratories equipped for the computerized collection and processing of data from crops. One is associated with plots that can be protected from rain by an automatic movable shelter. The Department also uses growth rooms in which temperature, humidity and radiation can be varied. Commercial instruments are not available for many of the measurements we require so suitable sensors and instruments are designed, some incorporating microcomputer systems developed in the Department.

The Department is also responsible for collecting and reporting the weather records from Rothamsted and for reporting the records from Woburn. The earliest records at Rothamsted go back to 1807, before the Station was founded.

BIOMATHEMATICS DIVISION

The Division has two components, the Statistics Department and the Computing Unit.

Statistics at Rothamsted began with the appointment of R. A. (later Sir Ronald) Fisher in 1919 to study the accumulated results of the Rothamsted Classical Experiments. Fisher soon realized the need for better statistical techniques in agricultural and biological research, and the groundwork for modern statistics was done by him during the 1920s and 1930s. Under F. Yates, who retired in 1968, the size and responsibilities of the Department expanded considerably and now, besides its service for Rothamsted, it provides advice and assistance for workers at many other research stations both at home and overseas. The Department also cooperates with the Agricultural Development and Advisory Service (ADAS) in designing experiments and surveys and provides numerical analyses of the results.

It is responsible for developing statistical software, but the main responsibility for computing lies with the Computing Unit. This was formed in October 1982 in recognition that modern scientific research as undertaken at Rothamsted can derive great benefit from using computers to control experimental apparatus, to capture data both in the field and in the laboratory, and to analyse and manipulate such data. Graphical display facilities are supplied and are being increasingly used. Most scientific projects use computers at some stage and many, including plant growth modelling and statistical investigations, involve major use.

COMPUTING UNIT

Computer systems are not new to Rothamsted. The first computer, installed in 1953, was used primarily for statistical analyses. Rothamsted has steadily increased its use of computing facilities since then, and now has a DEC VAX