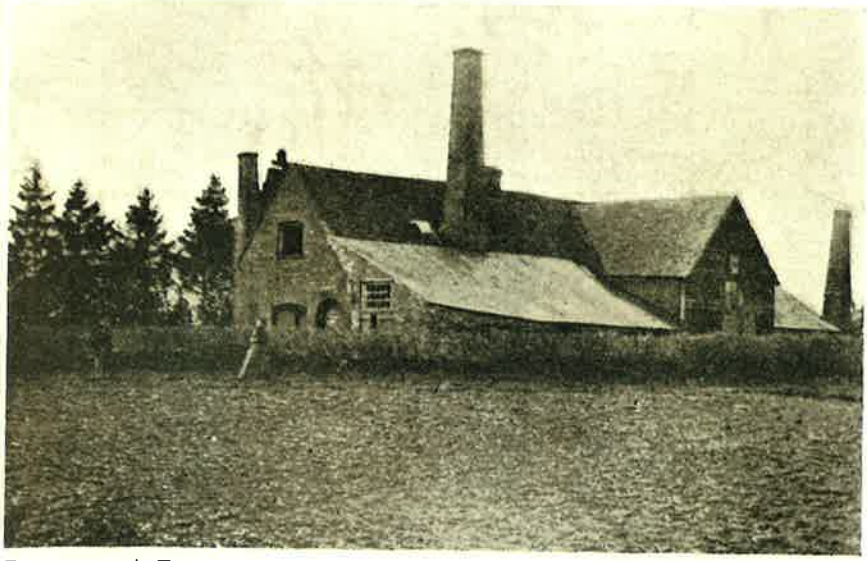

ROTHAMSTED'S FIRST LABORATORY

Photograph : ROTHAMSTED EXPERIMENTAL STATION

The lady in the crinoline is believed to be Mrs. (afterwards Lady) Gilbert

APPLICATIONS OF PHOTOGRAPHY TO AGRICULTURAL RESEARCH

By Hugh Nicol, Ph.D., M.Sc., A.I.C., and F. M. L. Sheffield, M.Sc., Ph.D., F.L.S.

AT the Meeting of The Royal Photographic Society held on Tuesday, January 17th, 1933, with the President, Mr. Olaf Bloch, in the chair, two short lectures were delivered on the application of photography to agricultural research. The evening was to have been occupied by Mr. D. Ward Cutler, of the Rothamsted Experimental Station, but he was unable to come owing to illness, and in his absence Dr. Nicol and Dr. Sheffield, both from Rothamsted, undertook to bring forward the subject.

Dr. NICOL began by apologizing for Mr. Ward Cutler's absence; he was suffering from severe laryngitis. To go into all the applications of photography to agriculture would open up a vast subject, far too long for one evening. Even X-ray photography had been used for investigating the structure of wool and the anatomy of insects. The microscopist had been largely employed on soil research. But with such highly complicated and specialised kinds of photography he did not intend to deal, but rather with the more ordinary kind, which took the form mostly of record work. Colour photography, so far, had found little application in this field. Stereoscopic photography was a subject in which he was personally rather interested, but he thought it was unsuitable for the study of living material, though excellent for machinery and the like. When a stereoscopic photograph was taken of an animal or group of plants one felt that it looked as if the subject was in some lunar atmosphere and awaiting some inspiriting breath which never came.

He had to thank the Society for identifying Rothamsted so conspicuously with the history of research. The station was founded in 1843 by private enterprise. A good deal of what would now pass for commonplace in regard to the nutrition of plants and animals was really due to the early work carried out there. He showed a very early photograph, dated about 1860, of the laboratory in which was laid the beginning of the industry of superphosphate manufacture. It is on record that even towards the 'eighties, or a little later, when a photograph of the laboratory was required, so long

ROTHAMSTED LABORATORY IN 1890,
SHOWING BOYS WORKING AT GRASS SEPARATION

ROTHAMSTED EXPERIMENTAL STATION PHOTOGRAPH

was the exposure that selections were played on a concertina to occupy the attention of the persons posing and to while away the time.

He proceeded to show some examples of how photography had been applied to the study of crop fertility. The first of these showed the effect of lime on grass land and various manurial experiments in the field. The difference in the resulting crops, not always so marked to the casual glance, was very clearly recorded in the photograph. The same was true of the sporadic appearance of weeds or a difference in vegetation of any kind. Formerly, to get an "all-over" view of a field laid out in different experimental plots it was necessary to place a chair on a farm cart, and on that insecure foundation to erect the camera. Nowadays photographs were taken from aeroplanes, and Rothamsted was the first place where aeroplane photographs were applied to this purpose of agricultural recording. These photographs, shown in the United States, inspired the Americans with the idea, with the result that numerous aerial photographs of experimental fields in America had now been made. The photographs showed fairly well the difference in the yields under different manurial treatments. Differences in vegetation showed up recognisably. Modern experiments were arranged on small plots and many of them. He showed a

PHOTOMICROGRAPH TAKEN WITH DARK-GROUND ILLUMINATION BY DR. R. H. STOUGHTON.
Circa ×1500

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"WINDOWS" IN CELL WALL OF LUCERNE PLANT ROOTLET, STAINED. The first photograph of these delicate structures ever taken. Their length varies between 2 and 8 thousandths of a millimetre
Photograph by HUGH NICOL
Reproduced by courtesy of The Royal Society

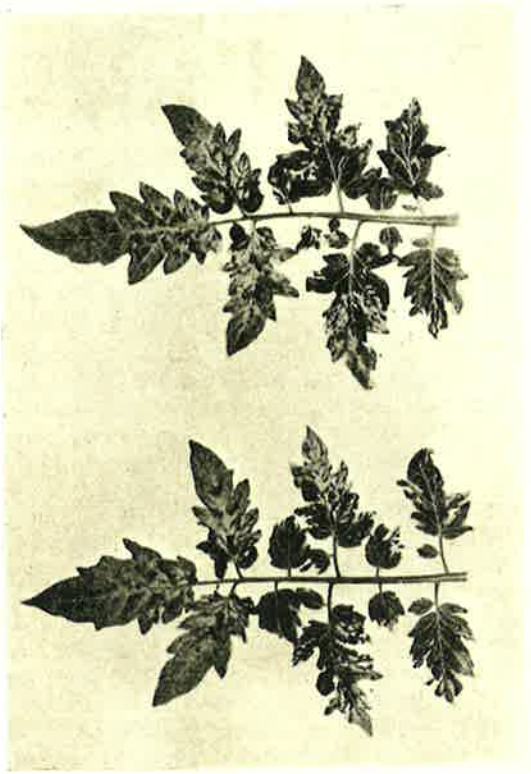
photograph in which there were 25 squares, representing five different treatments, each repeated five times.

At Rothamsted many other kinds of work were done in addition to investigating the fertility and productiveness of the soil. It was necessary to investigate plant diseases and insect blight on growing crops. Some of this was greenhouse work, and some had to be done in the laboratory. The immunity of certain plants to insects was also tested. In the laboratory there was frequent microscopic examination to be done. The lecturer showed one or two examples of photomicrography, the subjects including the developing egg of an osier midge. The life history of these pests had to be investigated.

An important line of research concerned a bacterial disease of a cotton plant. The research was undertaken with the idea of investigating the disease as it appeared in the Sudan, and an elaborate set of chambers had been devised where the conditions were rigorously controlled. The causal bacteria were brought into relation with the plant so as to induce the plant to take the disease, and he showed a transverse section of one of the leaves which had become infected. The records of the bacteria were shown, some of them by means of dark-ground illumination.

There was an important class of bacteria known as the leguminous bacteria which were distinctly beneficial. These helpful bacteria were peculiar to the natural order of plants known as *Leguminosæ*. The bacteria produced little warty masses, known as nodules, on the roots. Nodules were small factories fixing, that is, capturing, the nitrogen of the air ; they enabled the farmer to a great extent to be independent of bought nitrogen and to economise on his farmyard manure. The beneficial effect of these bacteria had been known empirically since the time of the Romans, but nodules were first figured by Malpighi. He showed a number of records bearing on this branch of work. Leguminous plants included peas, beans, and clovers. An experiment with the legume lucerne was mentioned, and he showed what it meant in farming practice. These and many other

CHARLOCK GROWING AMONGST BROAD BEANS
A STUDY IN WEED INFESTATION
VICTOR STANSFIELD, F.R.P.S.



LEAVES OF TOMATO PLANT WITH *Aucuba mosaic*. ×½
Photograph by VICTOR STANSFIELD, F.R.P.S.

pieces of work were carried out by the most rigorous laboratory investigation, and, in conclusion, he exhibited a set of slides tracing by photomicrography the whole process of infection from the bacterium up to the nodule upon the plant.

The Kinematograph in the Study of Plant Diseases

Dr. F. M. L. SHEFFIELD added some remarks on another part of the work at Rothamsted. She devoted herself particularly to the possibilities of the use of kinematography in the study of the living organism. A plant, she said, was built up of myriads of minute cells. Although they were so very minute each of them had within itself a definite and somewhat complicated structure, and the whole interior was in a constant state of turmoil. The study of the cell was a comparatively new science, and had developed largely during the present century. As it necessitated very high magnifications, its development had depended greatly on that of the microscope. Most of the early work was done on fixed and stained material (by fixing she meant the killing of the tissues by chemicals, an endeavour being made to preserve the structure as nearly as possible as in life). But when practicable, the processes are now studied in the living plant. As an example, she took one of the so-called virus diseases. Various diseases, such as smallpox, common colds and influenza in man, and foot and mouth disease in animals, were said to be due to viruses. Actually, there was no idea as to the real cause of these diseases, but by common consent the causative agent was called a virus, and similar diseases were equally prevalent among plants. An instance was the tomato plant infected with yellow mosaic disease.

Dr. Sheffield proceeded to give a description of the cell structure of plants and to contrast the diseased cell with the healthy. An infected cell contains a large protein body which was presumed to be the organism producing the disease. She said that by the study of the living cell and the use of the kinematograph camera it had been possible to prove that this body was not an organism at all. She showed, first of all,

LEAF OF *Solanum nodiflorum* WITH YELLOW MOSAIC DISEASE. ×½
Photograph by VICTOR STANSFIELD, F.R.P.S.

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CELL FROM HAIR OF NORMAL *Solanum nodiflorum*
×400
Photograph by F. M. L. SHEFFIELD

a number of "stills" from a kinematograph film, each of them revealing part only of a cell. She indicated that minute particles of protein appeared in the protoplasm of an infected cell, and how, by means of successive fusions, large aggregations of these were built up to form the protein body. Later, this body crystallised out and then the crystals dissolved. The process of infection in the plant thus took place before one's eyes, or at least was represented on the kinematograph film on the screen where the cell was magnified some fifteen thousand times.

She then proceeded to show the film, in the preparation of which she had been assisted by Mr. F. Percy Smith.

Dr. Sheffield said that the kinematograph has been applied to the study of the cell structure of plants, and in particular to the study of the virus diseases by which plants were affected. Before showing a film she acknowledged her indebtedness to Mr. F. Percy Smith, whose aid in its preparation, she said, had been absolutely invaluable. The action of the film, which showed the continuous movement in the cell structure, has been speeded up by about 18 times, and in one section 150 times. One saw in the film the appearance of minute particles in the streaming cytoplasm, their fusion into large plastic aggregations and then to a spherical body which presently crystallised out. The whole was evidence that the body which occurs in the cells of diseased plants is not an organism and the causal agent must be sought elsewhere.

Dr. Sheffield said that the kinematograph had not yet been used to any large extent in agricultural research, but the film shown was one of several initial experiments which had been made, and it suggested great possibilities for the future. The ordinary photographic plate might be regarded as a document on which to record the results of a piece of research, but the kine film in itself became an instrument for furthering research. For instance, through the speeding up or slowing down of movement, it could often reveal events which would never be obvious to the unaided eye. When she began to make the film which had just been shown she wanted a

HARVEST ON BROADBALK FIELD, 1925

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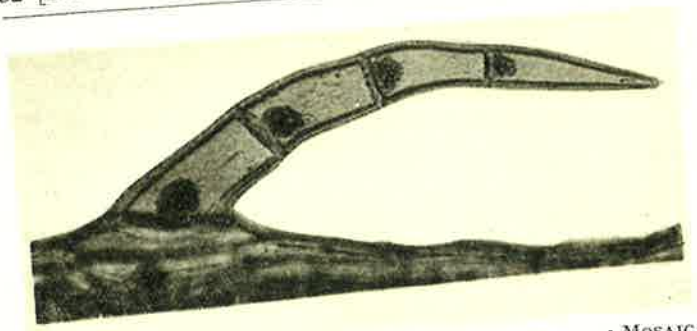
One of the earliest photographs taken from the air, of an agricultural experiment



HAIR FROM *Solanum nodiflorum* INFECTED WITH YELLOW MOSAIC DISEASE. ×150
Photograph by R. H. STOUGHTON

record by which she could demonstrate to others the results she had obtained by visual observation, but when the film was projected she was astonished at the amount of fine detailed movement brought to her notice, and which she had not seen during all the months she had studied the object itself. The kinematograph was an excellent method of study; its scope and possibilities had scarcely begun to be explored. She hoped the near future would see the use of the kine camera extended in the microscopic and other fields of agricultural research.

The PRESIDENT said that two very interesting addresses had been delivered, and in the second one the audience had been brought once more inside Nature's laboratory. It showed how much agricultural research was indebted to institutions like Rothamsted.

Mr. A. C. BANFIELD asked what was the total time period represented from beginning to end by the film which was shown, from the first appearance of the protein bodies to their dissolution in the form of crystals.

Dr. SHEFFIELD replied that the bodies were completely formed about a week after infection, and they crystallised after about a month—not less than a month. By about six months they would possibly all be dissolved. Such time periods assumed good growing conditions. Under bad conditions the whole process was very much slowed down.

The PRESIDENT expressed to Dr. Sheffield

"Stills" from the Kinematograph Film

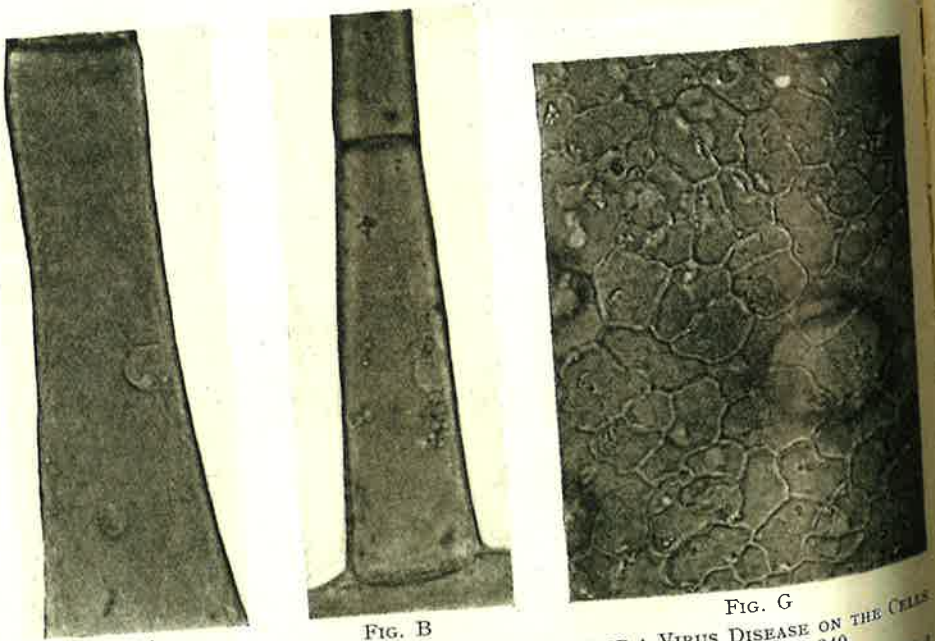


FIG. A FIG. B FIG. G

FIGS. A-G ARE PHOTOMICROGRAPHS SHOWING THE EFFECT OF A VIRUS DISEASE ON THE CELLS OF THE TOBACCO PLANT. (*Nicotiana tabacum*). Magnification ×340.

FIG. A. A cell from a healthy plant. The cell has a thin wall. The nucleus is suspended towards the right-hand side of the cavity by several strands of cytoplasm which radiate from it.

FIG B. As a result of infection small groups of protein particles move about the cell.

FIG. G. Virus bodies formed in the epidermal cells behave exactly as those in the hairs. Here they are shown crystallising out.

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and Dr. Nicol the hearty thanks of those present for the clear and interesting manner in which they had presented this subject. The virus certainly presented many problems to the bacteriologist as well as to other people. He did not know whether viruses had always existed in past history, or whether, with the introduction of in-breeding and other things, viruses, like other evils, made their first appearance. He hoped that a flood of light would be thrown by the methods suggested upon virus diseases generally, and that it would be possible to cope successfully with them. He referred, in conclusion, to the extraordinarily valuable work which was continually proceeding in these research centres, and which so increased man's power over Nature that it promised some day to be illimitable.

The vote of thanks was accorded by acclamation.

of the Study of Plant Diseases

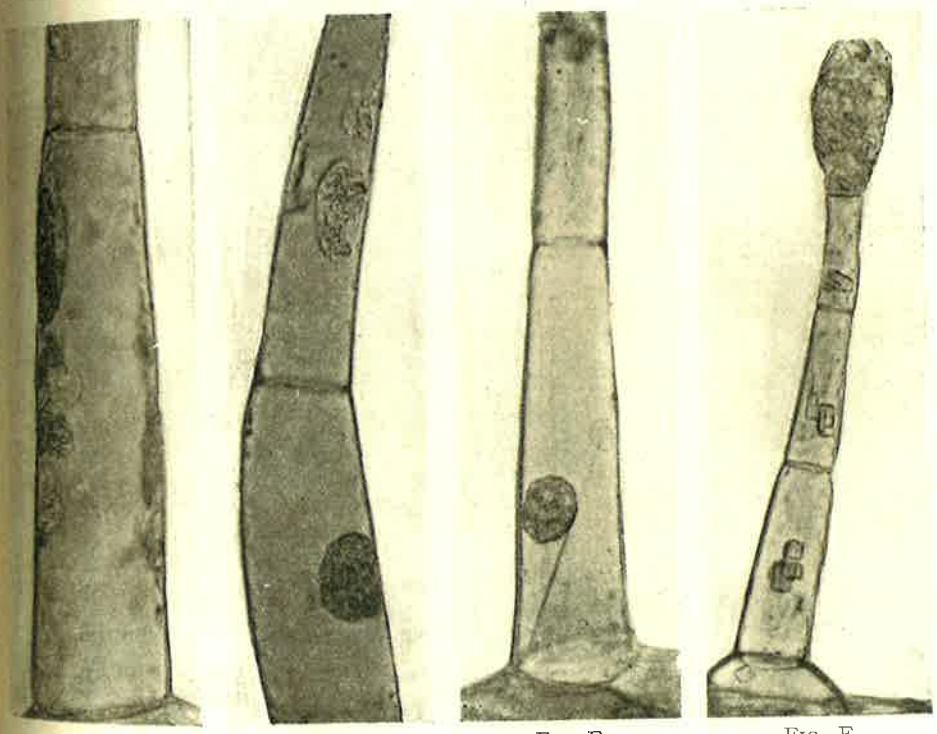


FIG. C FIG. D FIG. E FIG. F

FIG. C. The particles agglomerate.

FIGS. D and E. All the protein material becomes fused into a single large mass which becomes rounded.

FIG. F. After some weeks the bodies break down into crystals, which are seen in each of the three stalk cells of this glandular hair.

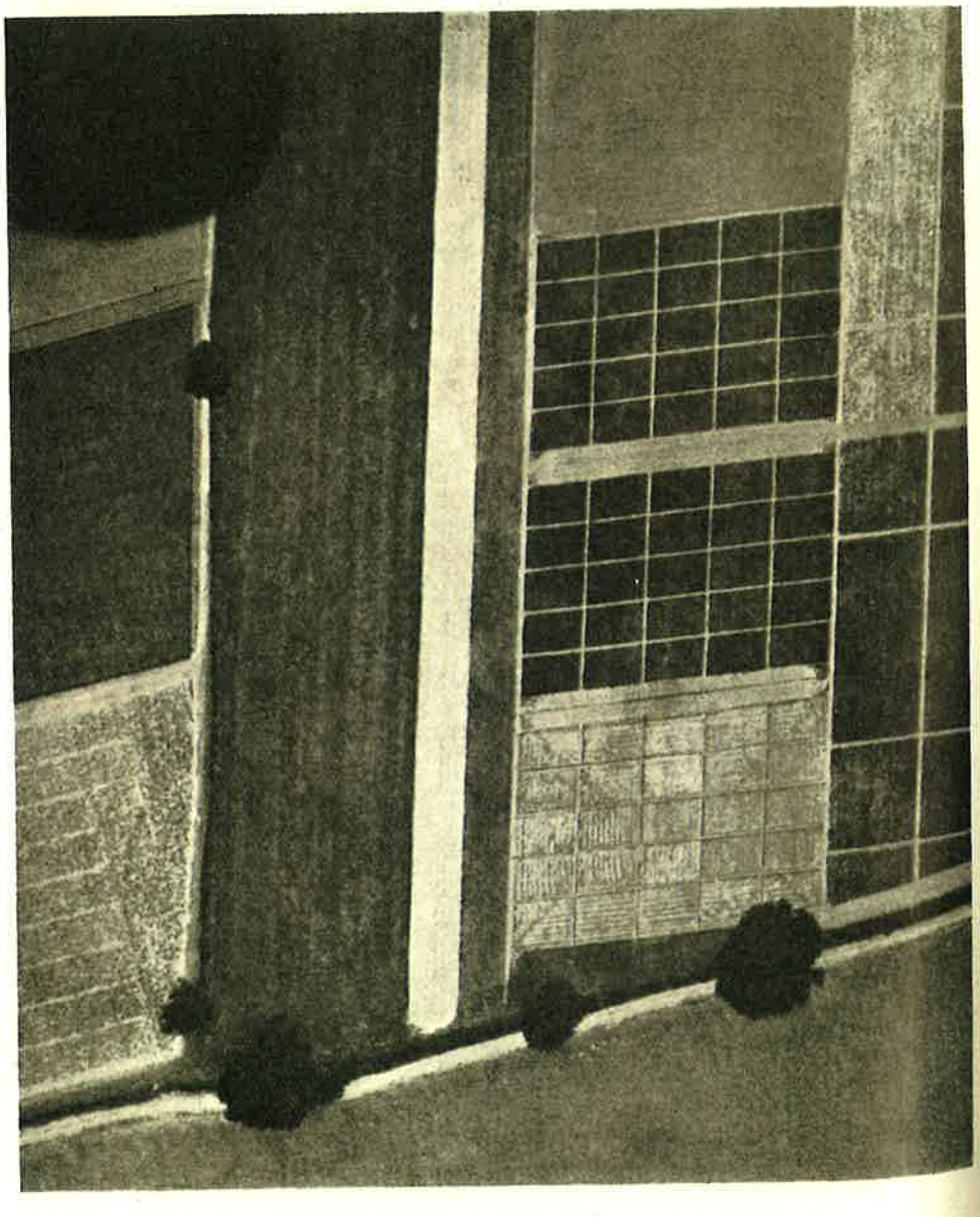
F

NOTE ON DOMENICO CIRILLO

By HUGH NICOL, Ph.D., M.Sc., A.I.C.

IT is interesting to note that some of the earliest recorded experiments on the alteration of silver salts on exposure to light were made with a botanical bearing. Domenico Cirillo, the Neapolitan Linnaeus, examined some water from Olmitello, Ischia, which had been reported to contain potassium ferrocyanide because it turned blue upon addition of silver nitrate. Working independently of Scheele, Cirillo found that "a white substance was instantly produced, but after a short time it changed to a very beautiful and dark azure colour. This experiment having been repeated by me towards evening, I observed that the mixture remained white during the whole night, becoming azure after the rising of the sun. The intensity of the colour in the sediment increased with the growing intensity of sunlight." (This and the following quotations are abridged from the article by Italo Giglioli, in *Nature*, vol. 30 (1900), pp. 15-18.) The phenomenon was found to be general. "As soon as the white precipitate was formed, I shut the glass in a place impenetrable to light. For many days the precipitate remained white; but on exposure to light it became cerulean in a few minutes." In Cirillo's mind these phenomena had a connection with the action of sunlight upon plants, a subject upon which he

was then working. According to Giglioli, the above-mentioned experiments were made between 1783 and 1789. Cirillo was unjustly hanged in 1799, and according to a diarist was mourned by all Naples.



MODERN FIELD EXPERIMENTS AT ROTHAMSTED, FROM THE AIR, 1930

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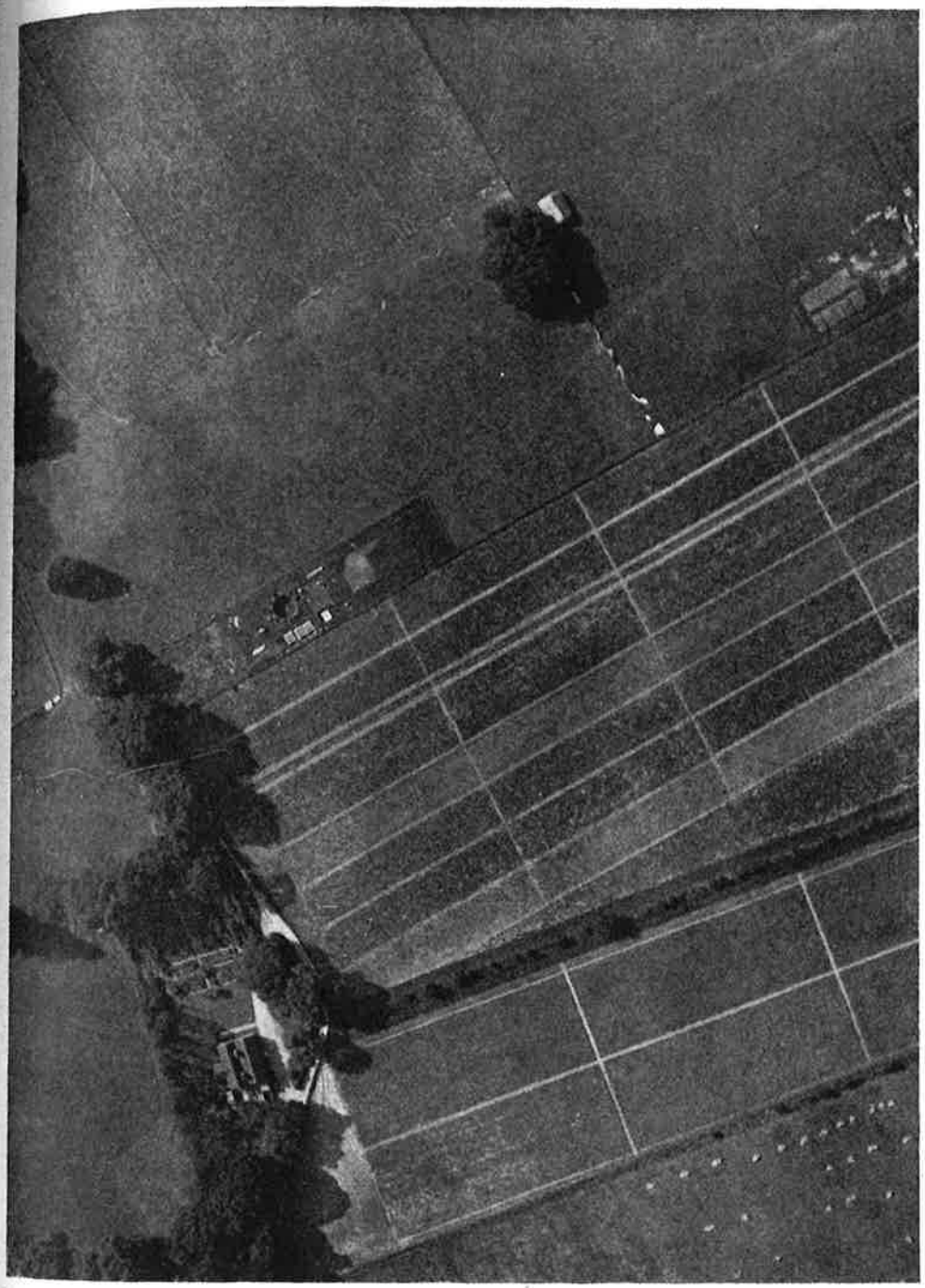

TWO OF THE CLASSICAL EXPERIMENTAL FIELDS AT ROTHAMSTED, PHOTOGRAPHED FROM THE AIR

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