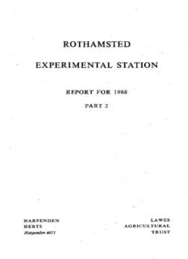
Rothamsted Experimental Station Report for 1968 - Part 2


ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1968
PART 2

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F. C. Bawden

F. C. Bawden (1969) *1. Foreword ;* Rothamsted Experimental Station Report For 1968 - Part 2, pp 7 - 11 **- DOI: https://doi.org/10.23637/ERADOC-1-2**

1. FOREWORD

F. C. BAWDEN

To say that the experiment with wheat on Broadbalk field is the most famous in the history of agricultural research is to be factual, not arrogant. The second of the systematic experiments on crop nutrition laid down by Lawes, it began in the autumn of 1843 with the same general pattern of manurial treatments as used in the first, with a root crop (turnips at first, later mangolds) started in the spring of the same year on Barnfield. The pattern was later repeated with the other kinds of crop: the main treatments were no manure; farmyard manure; nitrogen only; 'mineral manures'; 'mineral manures' plus nitrogen. The same crop was grown year after year and usually each plot was given the same manurial treatment each year. In addition to the main treatments, others tested different forms and amounts of nitrogen, different times of applying it and various combinations of inorganic materials.

There are various reasons for the experiment on Broadbalk attracting most attention. First, it was with wheat, the staff of life, and the crop with the greatest general interest. Secondly, although the simple lay-out as strip plots was not as good an experimental design as the one eventually used with roots on Barnfield, it showed the effects of nitrogen with great clarity, not only differences in colour running the length of the field, but in height, providing a vivid living histogram (illustrated by Plate 1) as seen from the top or bottom of the field. Thirdly, two features unique to Broadbalk greatly increased its value and interest: one, the installation of a drain in each plot emptying into an open ditch at the bottom of the field, allowed drainage water to be collected and analysed, so showing what nutrients were lost; the second unique feature was two plots given treatments that alternated, one getting nitrogen only in one year and 'mineral manures' only the next, and the other the reverse, which showed that 86 lb inorganic nitrogen was effective in the one year only.

The main question that interested Lawes and Gilbert in starting their experiments was the relative importance in crop nutrition of nitrogen and minerals, their word for the constituents of the ash of crops, mostly compounds containing phosphorus, potassium, sodium and magnesium (PKNaMg). In seeking to answer this question, their first concern was its practical importance to farming, but increasingly they were stimulated, or irritated, by Liebig's repeated assertions that crops could get all the nitrogen they needed from ammonia in the air, and to yield fully needed to be given only minerals. The wheat on Broadbalk soon showed the fallacy of Liebig's mineral theory, because yields were small unless nitrogen was given, and minerals produced increases only when given with nitrogen. However, Liebig remained unconvinced and his adverse criticism of the Rothamsted experiments led to increasing controversy as he minimised the importance of nitrogen while Lawes and Gilbert continued to produce more and more evidence of its paramount importance, especially for cereals. It is a tribute

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to Lawes' objectivity that, whereas his work began by showing the value of superphosphate, and he derived most of his income from its sale, he devoted so much of his effort to establishing the greater importance of nitrogen.

At the time the experiment began, almost the only manures given to crops were organic materials of which farmyard manure was by far the most common and important. Today, when the use of fertilisers is an accepted part of farming and the effects of nitrogen so well known, it is almost impossible to recapture the feelings at the time, but writings of that period leave no doubt about the excitement and wonderment that came from the demonstration that a few hundredweights of chemicals could produce wheat yields equal to those obtained with many tons of farmyard manure. Few discoveries have had greater implications for the future of mankind, but, as with so many other discoveries, its full application had to wait on education, other discoveries and on economics; this one on the discovery of how to fix atmospheric nitrogen in forms usable by crops and then for the ratio of grain prices to cost of the nitrogen to be such as to make its use profitable. Hence, despite the large increases in yield obtained with the 400–600 lb of mixed ammonium salts Lawes and Gilbert gave, (Plate 1) it was more than 100 years before such dressings became the usual practice for wheat in England.

Although the experiment soon served its first purpose by showing how wheat should be fed, this was far from being its only use, for the scope of work on it steadily increased. Also, its value was enhanced as its duration increased and the contrasting treatments were maintained. Thus, plot 8 must now have received more ammonium salts over a longer period than any other land anywhere, yet when limed it still yields at least as much as the plots given farmyard manure, unique evidence that fertility can be maintained on this type of land seemingly indefinitely by inorganic fertilisers alone.

Lawes and Gilbert early noted that yields on Broadbalk were often less than of wheat manured similarly but grown only once during a rotation of four crops. The explanation defeated them, for the existence of soil-borne pathogens that are favoured by growing only one kind of crop was then unknown. When these later came to be discovered, Broadbalk greatly helped in their study, and the occurrence there of the eyespot fungus first indicated its importance in diminishing yields and in causing wheat to lodge. However, happily the soil seems not to favour more damaging pathogens, such as the take-all fungus or cereal cyst-eelworms, and to this we may owe the continuation of the wheat experiment. Or is it, perhaps, that after all these years growing nothing but wheat, the crop and pathogens have come into a balance not too unfavourable to the crop? Attempts to answer this question by seeking an antagonist to the take-all fungus in Broadbalk soil have as yet failed, but the work substantiated the idea that take-all reaches a peak within a few years when wheat is grown consecutively and then declines in severity.

Broadbalk was weeded by hand until 1925, when a system started whereby a fifth of the field was fallowed each year to check weeds, though wild oats continue to be pulled by hand. The fallow, which acted like a dressing

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of inorganic nitrogen and for one year greatly increased the yields on the plots given little or no nitrogen, brought new interest to the experiment. The various factors responsible for the increases cannot be elucidated on Broadbalk, but the observations there have been the stimulus for much other experimentation, as they have in the study of many other problems. Nitrogen in the soil increases during the fallow, and some pathogens decrease, but disentangling nutrition from pathology is difficult because how much damage is done by some pathogens depends greatly on how well the crop is fed. Another complicating factor is that the fallow also brought into Broadbalk a damaging pest, the Wheat Bulb fly, which lays its eggs on bare ground and so is usually harmful only to the crop after fallow. Its effects also depend on the nutrition of the crop, as Broadbalk was uniquely able to show, because with the near uniform population of eggs on all plots, the damage done differs greatly on different plots and may be slight on those where the wheat grows vigorously while ruinous on those where nutrients are scarce and plants grow slowly.

Although the unmanured plot yields poorly compared with those given nitrogen, it continues to yield more than is stated to be the average for the world's wheat crops. Its source of nitrogen is still largely unsolved, but the suggestion that it is mainly from leguminous weeds receives no support from the fact that since 1955 one section has again grown wheat continuously, with herbicides used to kill weeds. Yields on plots of this section not given nitrogen have continued to be as large as previously, and on those given nitrogen slightly larger than previously.

The yields on the same plots of Broadbalk differ greatly between years and, as the same treatments are given annually, the results might seem to provide a valuable opportunity to discover the relations between weather and wheat yields. However, the variables are too many, and despite much mathematical ingenuity and many complex calculations, little has come from the attempts to elucidate the effects of weather, except that yields are usually larger in years drier than average.

The changes in 1967

From what has been said already, it is evident that the experiment on Broadbalk has often undergone changes and that all of these have added new and valuable information. However, none of these was so drastic as to introduce crops other than wheat, as was decided in 1967, and this major change provides the reason for now summarising and reviewing the work done while the whole field grew only wheat. The decision was not taken lightly. The variety of wheat had to be changed, because Squarehead's Master had become peculiar to Broadbalk and for some years we have had to grow our own seed. For the experiment to have any context in modern farming, a short-strawed variety had to be grown. With one change forced on us, the opportunity was taken to get new information relevant to modern farming, while still maintaining the desired continuity with the past. Hence, much of the field will continue to grow only wheat, but the variety will be Cappelle Desprez. Sections IA, IB, VA and VB will do so continuously unless perennial weeds necessitate a fallow, but they will never all be

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fallowed in the same year. Herbicides will be used on IA, IB and VB but not on VA, which is reserved for work on the biology of weeds. Sections II, III and IV are divided into halves, three of which will also grow only wheat, in a cycle of fallow, wheat, wheat, whereas the others will grow three crops in rotation, potatoes, spring beans (*Vicia faba*) and wheat. Obviously, this will give us information about how other crops do on land long manured very differently, but this is not the prime purpose of the change, for Broadbalk remains primarily an experiment with wheat. What it should give us is the possibility of getting better and more precise information about the various ways nutrition affects wheat yields, by helping to disentangle effects directly on the crop from those acting indirectly through soil-borne pests and diseases. Although the yields on some plots of Broadbalk were good by world standards, they were little more than half those obtained in some of our other experiments. We shall in future be able to compare yields produced by the same manuring when wheat is grown year after year, after fallow and after other crops that should act as a fallow in decreasing losses from soil-borne pathogens while avoiding the risk of severe attack by Wheat Bulb fly.

Some changes in manuring have been made. 'Nitro-Chalk', which replaces sulphate of ammonia and nitrate of soda, is applied during the spring to supply 43 (N_1), 86 (N_2), 129 (N_3) and 172 (N_4) lb N/acre. The last amount was used by Lawes but discontinued, because it caused lodging and was uneconomic. Plots with changed manuring are:

Plot No.	Till 1967	From 1968
9	N_1 P K Na Mg	N_4 P K Na Mg
14	N_2 P Mg	N_2 P K Mg
15	N_2† P K Na Mg	N_3 P K Na Mg
17	N_2	$N_2 + \frac{1}{2}$(PKNaMg)
	alternating	
18	P K Na Mg	$N_2 + \frac{1}{2}$(PKNaMg)

† Formerly all N in autumn.

Plots 2A and 2B, which get farmyard manure, have been treated as one for many years, though at the start they differed and 2A did not get farmyard manure until 1885. In the new scheme 2A gets 86 lb N/acre in addition to farmyard manure. A new plot, made next to plot 2A, gets farmyard manure + N_2PK.

The first harvest after the change was the cheerless one of 1968. Wheat yields on our other fields averaged a fifth or more less than in 1967, and the yields on the best plots on Broadbalk, about 2 tons of grain, approximated to the largest in other experiments. As usual, the smallest was from the unmanured plot; the plot given farmyard manure plus nitrogen yielded 4 cwt/acre more than the plot given only farmyard manure, which yielded the same as plot 9, which now gets most mineral nitrogen.

The new crops raised some unwanted problems, but it is already clear they add much new interest to the experiment. With the beans, the pre-emergent herbicide used over the whole area had very different effects on different plots; on the plot given farmyard manure, it only partially controlled the weeds, whereas on the unmanured plot and some others it damaged the young bean plants. With the potatoes, there was an un-

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expected proliferation of horsetail (*Equisetum arvense*) on some plots: previously present, but not one of the most troublesome weeds, it almost smothered some plots where the potatoes grew slowly because they lacked nutrients. The range of yields was proportionally greater with both the new crops than with wheat. Bean yields averaged 25 cwt/acre and ranged from 3·9 to 42·0; the largest, on plots given farmyard manure or NPKNaMg since the experiment started, exceeded those in our other experiments. In contrast to wheat, the smallest yield of beans was not on the unmanured plot, which gave more than 10 cwt/acre, but from plots given only nitrogen or nitrogen and phosphorus; also on plot 5 (PKNaMg only), where wheat yielded only 2·4 cwt/acre more than on the unmanured plot, beans yielded 3 times as much as on the unmanured plot. The yield of potatoes ranged from 2·9 to 15·7 tons/acre; the largest yields, as of beans, were from plots with farmyard manure plus nitrogen and with PKNaMg plus nitrogen and the smallest were from plots given only nitrogen or nitrogen and phosphorus.

Yields of beans and potatoes on plot 14, which was given K for the first time, considerably exceeded those on plots 10, 11 and 12, which remained without K, but were much less than on plots given K annually in the past.

I am grateful to all those who have written articles for this volume or assisted in other ways in its preparation, and I especially thank the three members of the staff who have retired, Mr. H. V. Garner, Dr. M. D. Glynne and Dr. J. Meiklejohn for so generously giving their time to record their unique knowledge of the Broadbalk experiment.

https://doi.org/10.23637/ERADOC-1-2