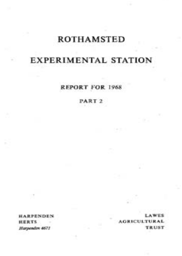
Rothamsted Experimental Station Report for 1968 - Part 2


ROTHAMSTED

EXPERIMENTAL STATION

REPORT FOR 1968

PART 2

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Investigations into the Effects of Weather on Yields

F. Yates

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between plot 6 (43 lb N) and plot 5 (no N), but this change may be attributed to the change in the method of applying ammonium sulphate (see Table 3·6).

TABLE 3·19

Broadbalk wheat: yields in the first, second, third and fourth years after bare fallow

Mean of six cycles, 1935–64, total grain and total straw (cwt/acre)

		Grain				Straw			
Years after fallow		1	2	3	4	1	2	3	4
Plot No.	Treatment								
2A	FYM[1]	25·8	21·5	20·0	17·9	52·0	40·3	38·2	36·6
2B	FYM	26·4	23·3	21·2	20·0	53·2	44·5	41·8	41·2
3	none	16·3	9·8	9·5	9·5	25·7	14·4	14·0	14·2
5	P K Na Mg	18·7	10·8	10·2	11·4	32·2	18·2	17·8	19·5
6	N_1 P K Na Mg	21·6	14·7	13·0	14·2	39·4	25·3	23·6	25·7
7	N_2 P K Na Mg	23·4	19·8	17·7	18·0	45·7	37·0	33·1	34·1
8	N_3 P K Na Mg	24·5	22·7	20·5	20·6	48·9	46·5	43·4	42·9
9	N_1*P K Na Mg	21·4	16·6	14·9	15·3	39·5	29·0	26·3	27·4
10	N_2	16·7	18·8	15·5	15·3	28·7	29·2	24·7	24·2
11	N_2 P	17·1	17·9	14·7	14·8	30·1	29·2	25·0	24·8
12	N_2 P Na	18·7	19·0	16·6	16·9	34·7	31·8	27·5	28·0
13	N_2 P K	23·2	18·3	16·4	17·0	44·3	34·6	30·6	31·8
14	N_2 P Mg	20·0	18·9	16·7	16·6	36·3	32·2	27·8	28·0
15	N_2†P K Na Mg	23·0	16·4	15·4	15·9	41·8	29·1	27·1	29·3
16	N_2*P K Na Mg	24·3	21·7	20·2	20·2	47·8	39·8	37·4	36·8
17/18	N_2	22·8	18·1	17·9	18·8	40·9	31·2	31·5	31·9
17/18	P K Na Mg	17·8	9·4	7·9	8·0	31·7	16·0	13·7	13·9
19	R	21·9	17·0	14·9	15·8	38·7	28·9	25·4	26·4
	Mean	21·3	17·5	15·7	15·9	39·5	31·0	28·3	28·7

[1] Since 1885.

N Nitrogen as ammonium salts.
N* Nitrogen as sodium nitrate.
N† All nitrogen as ammonium sulphate in autumn.

Investigations into the Effects of Weather on Yields

By F. Yates

The records of Broadbalk field, and of the other classical fields at Rothamsted, seem at first sight to be ideal for the study of the effects of meteorological factors on the yield of crops grown under uniform conditions, and of variations of these effects with contrasting fertiliser treatments.

Fisher turned his attention to this problem early in his career at Rothamsted, when he made an extensive investigation of the effects of rainfall (1924). It is, of course, to be expected that rain falling at different times of the year may well have very different effects on the yield. The arbitrary division of the rainfall record into periods, each of which is used as an independent variate in a multiple regression on yield is a crude method of allowing for this, but is open to the objection that the effect of rain falling on say 31 March, can only be trivially different from that falling on 1 April. To overcome this defect, Fisher fitted a smooth

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curve (actually a fifth degree polynomial) to the six-day rainfall totals for each year. The rainfall in each year and its distribution over the year was therefore summarised by the values of the six coefficients of these polynomials. He then calculated the multiple regressions of the yield on these coefficients, after eliminating slow trends over the years, also by fitted polynomials.

The results of such an analysis can be expressed in graphical form, giving the effect on the yield of an additional inch of rain falling at any time of the year. Graphs of the results for the more important plots are exhibited in Fisher's paper. These differ greatly in form and fall into three groups:

(*a*) Plots without nitrogen.
(*b*) Plots receiving nitrogen.
(*c*) The farmyard manure plot.

Those in group (*a*) show a depression in yield of about 0·2 cwt/acre per additional inch of rain, with little variation according to time of year. Those in group (*b*) show a large depression with additional rain in mid winter (0·5–0·8 cwt/acre), a minimum around April, and a further peak depression with rain in July (0·4–0·9 cwt/acre). The farmyard manure plot has a peak depression of 0·6 cwt/acre in mid winter and a minimum of 0·1 cwt/acre in May increasing to 0·7 cwt/acre in August.

Fisher was confident that the observed effects and the differences between the different groups were real, and explained them mainly in terms of leaching of nitrogen from the soil. When, however, the investigation, which in the days before electronic computers required an immense amount of numerical calculation, was repeated by other workers on the records from the other classical experiments at Rothamsted, in particular Hoosfield Barley, and the similar classical experiments on wheat and barley at Woburn, there was no consistency in the curves obtained from the different fields. It was remarkable, however, that the curves for Hoosfield and Woburn, though not individually showing much evidence of statistical significance, grouped themselves according to the amount of nitrogenous manuring, as had the Broadbalk curves, which were very definitely significant.

The reasons for these discrepancies were examined by Cochran (1935). He concluded that the observed grouping by nitrogenous manuring in large part reflected other sources of variation, which were correlated with nitrogenous manuring but were random with respect to the linear rainfall effects covered by the Fisherian procedure. Some of these, of course, may have been meteorological, but of a more complex type than those covered by linear effects.

Other investigations using the Broadbalk records were made by Tippett (1925) and Buck (1961). Tippett investigated the effect of sunshine on yields from the farmyard manure plot, working on the residuals after eliminating rainfall effects obtained by Fisher. He found that sunshine had 'a large positive effect in autumn and winter' which he thought might be caused by associated changes in soil temperature that affected root development. The effect is not very large, a maximum of 0·2 cwt/acre per ten additional hours of sunshine during early November.

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Buck used an electronic computer and was consequently able to study various factors much more thoroughly than earlier workers could. In particular he investigated temperature, taking into account also rainfall, and found that neither by itself, nor in conjunction with rainfall, did it produce any appreciable effect. His analysis also brought out very clearly that the highly significant effects of rainfall observed by Fisher were almost wholly attributable to variation in the total rainfall in the crop-year; the distribution of this total over the season had little apparent effect. This supports Cochran's conclusion.

Buck also repeated Tippett's analysis to assess the significance of Tippett's results, which Tippett had not tested. He found that taking into account total sunshine over the year decreased the variance by 10% after allowing for rainfall, and that allowing also for the distribution over the year decreased it by a further 7%. These decreases, though not fully significant, are suggestive of a real effect.

Buck also used the Broadbalk records to investigate whether Penman's estimated actual transpiration rate would relate better to the yields than did the Fisherian rainfall coefficients. With water non-limiting, Penman (1956) showed that the growth of grass (over a period of about four years) was closely proportional to the total energy supply at the ground surface. Because this energy is used mainly in providing latent heat for transpiration, the growth would be expected to be proportional to the potential transpiration E_T, which is the transpiration taking place when the crop has an adequate supply of water. Penman found that this expectation was fulfilled by grass and Thornthwaite (1953) found it true for the development of peas.

Under usual meteorological conditions, the crop does not always have an adequate supply of water. If this state continues then a moisture deficit may be set up in the leaves, the stomata may close and the rate of photosynthesis slows (Kramer, 1949). In this situation actual transpiration E_A is less than potential transpiration E_T.

Penman (1949, 1963) gave a method for estimating E_T from the weather records in any particular year. E_A can then be derived from E_T, using the rainfall records and assumed values of the 'root constant' for the crop over the season. Buck obtained values of E_T and E_A for the years 1939–58, but found no correlation between the Broadbalk yields and either E_T or E_A. However, with sugar beet, using yields for the whole of England and Wales, and for the Bury and Spalding factory areas separately, he found that except for the Bury area, E_A was more effective than rainfall in predicting yield. He also obtained similar results with potatoes, using yields from two areas in England and Wales.

The results that have emerged from this immense amount of arithmetic on the Broadbalk yields are therefore somewhat meagre. All that can be said with confidence is that they are larger in dry years than in wet ones, that variations in sunshine have little effect, and variations in temperature none. Buck probably had greater success with sugar beet and potatoes not only because they may be more sensitive to changes in meteorological conditions, in particular moisture deficit and radiation during the growing season, but also because he incorporated estimates of the incidence of the

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two principal diseases, virus yellows and blight, and used average yields over a whole district. One motive for the meteorological investigations on Broadbalk, was the belief that, because the field was growing wheat year after year under conditions that were kept as uniform as possible, much of the variation in yield must depend on relatively simple meteorological differences. The secondary effects, e.g. cultivation under difficult conditions, or disease dependent on many factors other than the weather of the current crop year, almost certainly account for much of the variation, and some of this at least will be averaged out when yields over a whole district are taken.

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