Gilbert

Results of experiments at Rothamsted on the growth of barley

RESULTS OF EXPERIMENTS AT ROTHAMSTED,

ON THE

GROWTH OF BARLEY,

FOR MORE THAN THIRTY YEARS IN SUCCESSION
ON THE SAME LAND;

BEING

A LECTURE DELIVERED JUNE 29, 1886,

AT THE

ROYAL AGRICULTURAL COLLEGE,

CIRENCESTER,

BY

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SIBTHORPIAN PROFESSOR OF RURAL ECONOMY
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CONTENTS.

	PAGE
INTRODUCTION	1
THE ROTHAMSTED FIELD EXPERIMENTS ON BARLEY	3
RESULTS WITHOUT MANURE, AND WITH FARMYARD MANURE	4
RESULTS WITHOUT MANURE, AND WITH ARTIFICIAL MANURES	7
INFLUENCE OF SEASON ON THE AMOUNTS OF PRODUCE	14
INFLUENCE OF EXHAUSTION, MANURES, AND VARIATIONS OF SEASON, ON THE COMPOSITION OF THE BARLEY CROP	17
ON WHAT DOES STRENGTH OF STRAW DEPEND?	25
OUR AREA UNDER THE CROP AND THE AMOUNT OF OUR IMPORTS	26
CONCLUSION	29

Introduction.

In my lecture last year I gave an account of the experiments at Rothamsted on the growth of wheat for more than forty years in succession on the same land, without manure, with farm-yard manure, and with a great variety of artificial manures.

Attention was directed to the fluctuations in the amounts of produce from year to year, and to the average yield per acre over the earlier, the later, and the total period of the experiments, under each of the very varying conditions as to manuring.

The results of collateral investigations were also adduced.

For example, the increased assimilation and yield of carbon per acre in the crop, for a given amount of nitrogen supplied in manure, and the connection between carbon-assimilation, nitrogen-accumulation, and chlorophyll-formation, were shown. The proportion of the nitrogen supplied in the manure, which was respectively recovered in the increase of the crop, lost by drainage, or accumulated as crop-residue in the surface soil, was pointed out. The influence of exhaustion, or of full supply of the mineral constituents, on the mineral composition of the crop was shown; the general result being that whilst the amounts taken up by the entire plant, as represented by the quantities contained in the total produce, corn and straw together, varied considerably according to the supply within the soil, the amounts accumulated in the final and definite product, the grain, were under otherwise equal conditions nearly identical.

The influence of season was illustrated by the results obtained in the best and the worst seasons of the forty years. The general accordance of the Rothamsted results with those obtained on other soils and in other localities was next pointed out, and it was shown that at Woburn, as at Rothamsted, when nitrogen was supplied as ammonium-salts, or as nitrate of soda, for wheat or barley, comparatively little of that which was not recovered in the immediate increase of crop, was recovered in the succeeding crops.

Leaving the experimental results, attention was directed to the average yield of wheat per acre in the United Kingdom over a period of 32 years. It was shown how greatly the area under the crop had diminished during that period, but that our yield per acre was greater than that of any other wheat growing country, and very much greater than that of the chief exporting countries, such as the United States, Canada, or India; and very much greater also than in most of the European countries where peasant proprietors or small holdings prevail.

The consideration of these facts naturally led to a consideration of the characteristic differences, in some important respects, of old arable soils, of pasture soils, and of prairie and other virgin soils. It was shown that a fertile soil was one which had accumulated within it, the residue of ages of previous vegetation, and that it becomes infertile as that residue is exhausted. Finally, it was concluded that it was extent of area, and cheap fertility, not good cultivation, against which the British wheat grower had to contend.

In the present lecture I propose to bring before you the results obtained at Rothamsted, on the growth of barley, not for more than forty years, but for thirty-four years in succession on the same land. The collateral investigations in connection with barley are not so numerous, or of such general interest or importance, as those to which attention was called in the case of wheat, but I shall be able to illustrate the influence of exhaustion, manures, and variations of season, on the amounts of produce, and to some extent on the composition of the crop. In conclusion, I shall adduce some statistics relating to our area under the crop, to the amount of our imports, and to the sources whence they are derived.

Barley, like wheat, is a member of the great gramineous family of plants, to which we owe so many, and such important economic products. In our own country and climate, barley comes second to wheat in importance among the cereal crops we cultivate; though, in the north, oats gain in relative consideration. The average area under *barley* in the United Kingdom is, however, only about four-fifths as great as that under wheat; and we shall see that it, like the area under wheat, has of late years diminished.

In countries with warmer and longer summers another gramineous grain crop, Indian corn, or maize, comes into prominence; and in warmer countries still grows the sugar cane. Indeed it is to this family that we owe our chief *starch-* and *sugar-* yielding crops; and it is somewhat remarkable that the plants which, at any rate in temperate climates, come next in importance as starch- and sugar- yielding crops, should belong to such widely different orders as the *Solaneæ* giving us the potato, and the *Chenopodiaceæ* giving the sugar beet, mangel wurzel, &c., whilst the organs, or parts of the plants, which yield the products are also widely different. In each case, however, it is the store of reserve material which the plant has laid up for reproduction which we turn to economic account.

But not only does the gramineous family provide us with our chief starch and sugar yielding crops, but it contributes a large proportion of the natural and cultivated herbage, upon which animals of use to man are fed over very large portions of the globe.

Although *wheat* and *barley* are thus closely allied botanically, and they have, moreover, in some respects very similar requirements as cultivated crops, yet it will be found that there are distinctions as well as similarities which it is important to recognise.

To refer to one or two points of distinction which obviously must have an influence on the results obtained in experiments on the growth of the two crops, and which must be borne in mind in their interpretation, it may be mentioned that, in our own country and climate at any rate, wheat is almost invariably sown in the autumn, whilst barley is as generally not sown until the spring.

Thus, wheat has four or five months for root-development, and for gaining possession of range of soil, before barley is sown. Under these circumstances, too, the conditions of soil most suitable to the two crops are very different. For wheat a comparatively heavy soil is adapted, and a fine tilth, encouraging superficial root-development, is not desirable. For barley, on the other hand, a comparatively light soil is more appropriate, and a fine tilth is of great importance. In other words, with the characteristic habit of growth of the plant, and the short period at its command for root-development, a very permeable surface-soil is a desideratum.

In these facts we have the indication that wheat acquires a much greater root-range, and consequently a command of the resources of a more extended range of both soil and subsoil; whilst barley must, in a greater degree, be dependent on the supplies within the surface-soil, and so be the more susceptible to the influence of the exhaustion, or the supplies, within the surface-soil.

Bearing these various points in mind, we may now turn to the results of long-continued field-experiments on the growth of barley, by different manures, and in different seasons, and to the evidence of collateral Laboratory investigations as to its composition.

The Rothamsted Field Experiments on Barley.

The Rothamsted Field Experiments on Barley were commenced in 1852, that is eight years later than those on wheat, but at the same time as that at which the arrangements of the plots in the Experimental Wheat Field devoted to chemical or artificial manures became more systematic and permanent.

The barley crop of last year, 1885, was the thirty-fourth in succession on the same land, and the thirty-fifth crop is now growing. There are nearly thirty experimental plots. Two have been unmanured from the commencement. One has received farm-yard manure every year, or rather one-half of it has, for after twenty years the plot was divided, one half being still annually manured as before, and the other half then left unmanured, to test the effects of the unexhausted residue of the twenty years' previous applications of farm-yard manure. The other plots have annually received artificial manures, for the most part the same year after year, from the commencement; but there have been a few changes, some of which will be explained as we proceed.

Results without Manure, and with Farmyard Manure.

The results to which I shall first direct your attention are those obtained *without manure*, and with *farmyard manure*. Table I. (p. 5) gives the produce of grain per acre in each year, and also the average produce over selected series of years, and over the whole period of 32 years, to 1883 inclusive.

The first column of the Table gives the produce without manure. Columns 2 and 3 give the produce by farmyard manure for the first twenty years (1852-1871) over the whole plot, and for the next twelve years (1872-1883). Column 2 gives the produce on the half of the plot on which the application was still continued, and column 3 that on the other half where the application was discontinued after the first twenty years, showing therefore the effects of the residue of the previous applications. Column 4 shows, for the last twelve years, the excess of produce on the plot where the application was continued over that where it was discontinued; and the last two columns show the increase over the unmanured produce, first by farmyard manure continuously applied, and secondly by the residue of the applications of the first twenty years.

First referring to the produce *without manure*, it is seen that in two years, the third and fourth, the yield was over thirty bushels per acre; in six years during the first thirteen, the produce was between twenty and thirty bushels, but it never afterwards reached twenty bushels, and in twenty-four out of the thirty-two years the yield was less than twenty bushels; in two of these it amounted to only ten, and in one (1879), to only $6\frac{1}{4}$ bushels.

There was thus a very great variation in the amount of produce without manure from year to year according to season. A glance at the figures, and especially at the average produce over successive series of years, as given at the foot of the Table, shows, however, that independently of these fluctuations due to season, there was a progressive decline due to exhaustion; though the last four years gave a higher average than any other four in the last sixteen years.

It may be observed that without manure there is a decline in the produce of barley grain of 31·4 per cent. over the second sixteen years compared with the first sixteen; and that this rate of decline is considerably greater than was found in the case of wheat. This result is doubtless due to the shorter period of growth, and the greater dependence on the surface soil, in the case of the barley; and hence exhaustion is the sooner manifested.

We now turn to the produce by *farmyard manure*. As without manure, there is very great fluctuation from year to year according to

TABLE I

Barley 32 *years in succession on the same land, Hoosfield, Rothamsted.*

Produce—Without Manure, and with Farm-yard Manure.

DRESSED GRAIN PER ACRE, BUSHELS.

		Farm-yard Manure			+ Unmanured	
	Un-manured every year	Every year 1852-83	20 years, 1852-71 Un-manured 1872-83	Continuous + or — Un-manured after 20 years	Manured every year	Manured 20 years, Unmanured afterwards
	Plot 1-0	Plot 7-2	Plot 7-1		Plot 7-2	Plot 7-1
1852	27¼	33			+ 5¾	
1853	25¾	36⅛			+ 10⅜	
1854	35	56⅜			+ 21⅜	
1855	31	50⅛			+ 19⅛	
1856	13⅞	32⅛			+ 18¼	
1857	26⅛	51¼			+ 25⅛	
1858	21⅛	55			+ 33⅞	
1859	13½	40			+ 26½	
1860	13¼	41⅝			+ 28⅜	
1861	16¼	54⅜			+ 38⅛	
1862	16½	49¾			+ 33¼	
1863	22⅞	59½			+ 36⅝	
1864	24	62			+ 38	
1865	18	52¾			+ 34¾	
1866	15⅞	53⅛			+ 37¼	
1867	17⅛	45⅝			+ 28½	
1868	15⅝	43⅝			+ 28	
1869	15⅛	46⅞			+ 31¾	
1870	13½	47½			+ 34	
1871	16¾	54¼			+ 37½	
1872	10¼	38⅞	38¼	+ 0⅝	+ 28⅝	+ 28
1873	14	54¼	47½	+ 6¾	+ 40¼	+ 33½
1874	17⅝	64½	46½	+ 18	+ 46⅞	+ 28⅞
1875	12½	45¼	32½	+ 12¾	+ 32¾	+ 20
1876	12¾	45	31	+ 14	+ 32¼	+ 18¼
1877	17⅛	52	36	+ 16	+ 34⅞	+ 18⅞
1878	10	46¼	21⅞	+ 24⅜	+ 36¼	+ 11⅞
1879	6¼	36⅝	16⅝	+ 20	+ 30⅜	+ 10⅜
1880	18⅞	65¼	41⅝	+ 23⅝	+ 46⅜	+ 22¾
1881	17⅞	53¾	29¾	+ 24	+ 35⅞	+ 11⅞
1882	18⅜	60¾	35	+ 25¾	+ 42⅜	+ 16⅝
1883	16¼	58½	35½	+ 23	+ 42¼	+ 19¼
AVERAGES						
4 yrs. 1852-55	29¾	43⅞			+ 14⅛	
,, 1856-59	18⅝	44⅝			+ 26	
,, 1860-63	17¼	51⅜			+ 34⅛	
,, 1864-67	18¾	53⅜			+ 34⅝	
,, 1868-71	15¼	48			+ 32¾	
,, 1872-75	13⅝	50¾	41¼	+ 9½	+ 37⅛	+ 27⅝
,, 1876-79	11½	45	26⅜	+ 18⅝	+ 33½	+ 14⅞
,, 1880-83	17⅞	59½	35½	+ 24	+ 41¾	+ 17⅝
10 yrs. 1852-61	22⅜	45			+ 22¾	
10 ,, 1862-71	17½	51½			+ 34	
20 yrs. 1852-71	19⅞	48¼			+ 28⅜	
12 ,, 1872-83	14⅜	51¾	34⅜	+ 17⅜	+ 37⅜	+ 20
32 yrs. 1852-83	17⅞	49½	43		+ 31¾	+ 25¼
Last 12 yrs. P.C. +or—first 20 yrs.	— 27·7	+ 7·3	— 28·8			

season; but instead of a gradual decline there is an obvious increase in the yield over the later years, due to the accumulation of the manure. There is, in fact, instead of a decline of 27·7 per cent., an increase of 7·3 per cent. over the last twelve years compared with the first twenty; although the second period included a number of the worst seasons of the whole series of years.

In four of the thirty-two years the farmyard manure gave more than 60 bushels of barley per acre, in thirteen years between 50 and 60 bushels, in ten between 40 and 50 bushels, in five between 30 and 40 bushels, and in no case below 30 bushels. The average yield was, over the first twenty years $48\frac{1}{4}$ bushels, over the last twelve years $51\frac{3}{4}$ bushels, and over the thirty-two years $49\frac{1}{2}$ bushels, against $17\frac{7}{8}$ bushels without manure.

So much for the produce of barley obtained by the unusual application of fourteen tons of farmyard manure per acre per annum, for thirty-two years in succession. It is estimated that the manure supplied about 200 lbs. of nitrogen per acre per annum, or over twenty years 4,000 lbs. of nitrogen. It was further estimated that at the end of twenty years, not more than fourteen or fifteen per cent. of this large amount of nitrogen had been removed in the increase of crop. There must, therefore, have been a great accumulation of nitrogen, and other constituents, within the soil; and analysis proved that this was the case. Indeed, it was calculated that, if there were no loss of nitrogen, by drainage, by evolution of free nitrogen, or otherwise, and if the accumulated residue were as available as that which had already been effective, the produce should be maintained at the level of that of the first twenty years for not far from 150 years more.

Let us see what was the result of stopping the application of manure on half the plot after the first twenty years? This is shown in the lower division of the table. The second column shows the produce of the last twelve years, where the application was continued; the third column where it was discontinued; the fourth the excess yielded by the continuous application over that by the residue from previous applications. Lastly, the fifth column shows the increase over the unmanured produce, by the continuous application, and the sixth that by the residue.

Comparing the second and third columns, it is seen that there is a general tendency to increase in yield where the application of the farmyard manure was continued, and to decrease where it was discontinued. This result is brought prominently to view in column 4, which shows that the difference between the amount of produce gradually increases until during the last four of the twelve years, the *manure-residue* plot shows an average of about twenty-four bushels per acre per annum less than where the application was continued.

The averages at the foot of the table show that over the first twenty years, with the continuous application the yield was $48\frac{1}{4}$ bushels, whilst over the succeeding twelve years, it was, where the application was continued $51\frac{3}{4}$ bushels, but where it was discontinued only $34\frac{3}{8}$ bushels; showing, therefore, an average annual deficiency under the influence of the residue only, of $17\frac{3}{8}$ bushels, or of 33·6 per cent.

Taking as the standard of comparison the unmanured produce (which, however, itself gradually declined), the last two columns show that over the three four-yearly periods of the last twelve years, the increase of produce was with the continued application $37\frac{1}{8}$, $33\frac{1}{2}$, and $41\frac{3}{4}$ bushels, but with the residue only $27\frac{5}{8}$, $14\frac{7}{8}$, and $17\frac{5}{8}$ bushels. Over the whole twelve years there was an average annual increase of $37\frac{3}{8}$ bushels with the continued application, and of only 20 bushels with the residue.

It may be observed that over the whole period of thirty-two years, the total produce (grain and straw together) was without manure less than one ton per acre per annum, whilst with the farmyard manure it was $2\frac{3}{4}$ tons, and in some years it reached from $3\frac{1}{2}$ to $3\frac{3}{4}$ tons.

To sum up in regard to the foregoing results—there was gradual exhaustion and reduction of produce without manure, and gradual accumulation and increase of produce with the annual application of farmyard manure. But when the application was stopped, although the effect of the residue from the previous applications was very marked, it somewhat rapidly diminished, notwithstanding that calculation showed an enormous accumulation of nitrogen as well as other constituents.

Indeed, determinations of nitrogen in the surface-soil, after the twenty years application of farmyard manure, showed it to be nearly twice as high as on the unmanured plot.

How then is the reduction of produce to be accounted for? The nitrogen of farmyard manure must obviously exist in very different conditions. That due to the urine of the animals will be the most rapidly available, that in the finely comminuted matter in the fæces will be much more slowly available, and that in the litter still more slowly available. Hence the small proportion that is at once effective, and the very large amount that accumulates within the soil in a very slowly available condition.

But the evidence at command leads to the conclusion that neither in the wheat field, nor in the barley field, does the accumulation within the soil account for the whole of the nitrogen supplied which is not recovered in the immediate increase of crop. Some is doubtless lost as nitrates by drainage, and some probably by evolution as free nitrogen. The fact of such losses is of considerable interest; but it is some consolation to believe that the loss will be proportionally very much less in ordinary farm practice, where the amounts of farmyard manure applied are much less, and where various crops, with different root-ranges, and different periods of accumulation, are grown.

Results without Manure, and with Artificial Manures.

We have next to consider—what is the character of the exhaustion induced by the growth of the crop without manure? and to what constituent, or constituents, of farmyard manure, its effects are mainly to be attributed? These points will be illustrated by the results given in Tables II. and III. (p.p. 8 and 9), which show the effects of various

TABLE II

Barley* 34 *years in succession on the same land, Hoosfield, Rothamsted.

Results showing the effects of exhaustion and Manures.

Dressed Grain per Acre, Bushels. Manure and produce per Acre per annum.

	SERIES 1				SERIES 2 200 lbs. Ammonium-Salts = 43 lbs. N.			
	Un-manured	Super-phosphate of Lime	Potassium Sodium, and Magnesium Sulphates	Mixed Mineral Manure (2 & 3 mixed)	Alone	And Super-phosphate of Lime	And Potassium Sodium and Magnesium Sulphates	And Mixed Mineral Manure (2 and 3 mixed)
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4
1852	27¼	28⅝	26⅛	32¾	36⅞	38⅝	36	40¾
1853	25¾	33½	27⅝	35⅝	38⅝	40⅛	36½	38¼
1854	35	40⅝	36½	42	47¾	60½	50	60⅝
1855	31	36¼	34¾	37⅛	44½	47¾	44½	48⅜
1856	13⅞	17¾	16⅝	19¾	25	29⅛	28⅜	31¾
1857	26⅛	33¼	32	39¾	38⅞	56½	42⅜	57⅜
1858	21⅛	28¾	24¼	30⅞	31½	51⅜	34¼	51½
1859	13½	19⅝	15⅞	19¾	15⅜	34½	16⅞	34⅝
1860	13¼	15¾	15¼	18¼	26⅝	43⅜	28	43½
1861	16¼	25	18⅞	29⅜	30½	55	32¾	54⅝
1862	16½	21⅞	19¾	25⅛	31⅜	48⅝	35¼	47⅝
1863	22⅞	32⅜	27⅝	33	42⅝	61⅝	48⅝	55⅜
1864	24	30¼	26⅛	33¼	38⅞	58½	43⅞	55⅝
1865	18	22½	22	24⅜	29⅞	48⅜	33¼	46½
1866	15⅞	22⅜	19⅛	24	27⅛	50½	27½	47
1867	17⅛	24⅝	17	20⅞	30⅝	44	33	43⅞
1868	15⅝	18½	14¼	17⅝	20⅜	37⅝	25	34⅝
1869	15¼	18¼	18¾	22¼	27⅞	48	34¾	49¼
1870	13½	18	16¾	18½	27¾	41½	30⅞	38
1871	16¾	23⅛	19⅝	25	36⅜	45⅛	38⅛	46½
1872	10¼	15⅜	10½	14¼	26¼	39⅜	30⅜	36⅞
1873	14	19⅞	14⅞	20⅜	32⅜	50⅞	34⅛	46⅞
1874	17⅝	21¼	17⅞	19⅛	23⅛	42⅜	30⅝	45¾
1875	12½	14⅜	14⅞	17½	27⅜	37	29¼	35⅞
1876	12⅝	16⅛	12⅝	15⅝	21	33¼	23⅜	35⅝
1877	17⅛	23⅞	20⅛	23¾	35⅛	43⅞	41½	50⅛
1878	10	12⅛	7¾	11⅜	14⅞	31⅜	20⅛	33⅝
1879	6¼	7¾	6⅛	7¼	15¾	27⅞	16⅜	27⅜
1880	18⅞	28⅝	23⅞	30⅛	33⅞	55⅝	38⅛	54⅝
1881	17⅞	19¼	17⅛	17⅞	33⅛	43⅝	37⅜	42⅝
1882	18⅜	21⅞	19	23⅝	34⅞	45¼	39¼	50⅜
1883	16¼	22⅜	18⅜	24⅛	38⅞	49⅜	43⅝	52
1884	13¾	17⅝	13⅛	14¾	26½	29	31	42¼
1885	9¼	12⅛	7⅞	12½	15⅜	29	15½	32
AVERAGES								
4 yrs. 1852-55	29¾	34¾	31¼	36⅞	42	46¾	41¾	47
„ 1856-59	18⅝	24⅞	22¼	27½	27¾	42⅞	30½	43¾
„ 1860-63	17¼	23¾	20⅜	26½	32¾	52⅛	36⅛	50¼
„ 1864-67	18¾	25	21⅛	25⅝	31⅝	50⅜	34⅜	48¼
„ 1868-71	15⅜	19½	17⅜	20⅞	28⅛	43⅛	32¼	42⅛
„ 1872-75	13⅝	17¾	14½	17⅞	27¼	42⅜	31⅛	41⅜
„ 1876-79	11½	15	11⅝	14½	21¾	34⅛	25⅜	36¾
„ 1880-83	17⅞	23	19⅝	23⅞	35¼	48½	39⅝	49⅞
8 yrs. 1852-59	24¼	29¾	26¾	32¼	34⅞	44⅞	36⅛	45⅜
„ 1860-67	18	24⅜	20¾	26	32¼	51¼	35¼	49¼
„ 1868-75	14½	18⅝	15⅞	19⅜	27¾	42¾	31⅝	41¾
„ 1876-83	14⅝	19	15⅝	19¼	28½	41¼	32½	43¼
16 yrs. 1852-67	21⅛	27⅛	23¾	29⅛	33½	48	35⅝	47⅜
„ 1868-83	14½	18¾	15¾	19¼	28⅛	42	32	42½
32 yrs. 1852-83	17⅞	23	19¾	24¼	30¾	45	33⅞	44⅞
P.C. Reduction 2nd 16 yrs.	31·4	30·9	33·7	33·9	16·0	12·5	10·2	10·3

TABLE III

Barley 34 years in succession on the same land, Hoosfield, Rothamsted.

Results showing the effects of Exhaustion and Manures.

Dressed Grain per acre, Bushels. Manures and Produce per acre per annum.

	SERIES 3 275 lbs. Nitrate Soda = 43 lbs. N (1).				SERIES 4 1000 lbs. Rape Cake = 49 lbs. N (2)			
	Alone	Super-phosphate of Lime	Potassium Sodium and Magnesium Sulphates	Mixed Mineral Manure (2 and 3 mixed)	Alone	And Super-phosphate of Lime	And Potassium Sodium and Magnesium Sulphates	Mixed Mineral Manure (2 and 3 mixed)
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4
1852	44½	43¾	41¾	45⅛	39⅛	36½	33½	38
1853	40¾	42¼	41¼	44½	39⅞	36⅛	35¼	40⅛
1854	56⅝	63¼	51½	62¾	60¾	60⅝	56½	60¼
1855	48	50⅜	47¼	49⅝	48½	53¼	48⅞	51¾
1856	36¼	31½	25⅜	37⅝	36¾	37⅛	32⅝	35⅜
1857	49¾	66½	49⅞	64⅞	64⅛	62¼	60¼	62¼
1858	39⅜	56¼	40⅝	56¼	53¾	57⅜	52	57⅛
1859	21½	35⅞	20⅜	35¾	38¾	41	34⅛	35
1860	25⅜	43¼	30¾	46¼	31¾	36¾	35¼	40¾
1861	35	55¾	36⅞	55⅞	56½	56⅞	51⅛	53⅝
1862	31½	51	36¼	48¾	41	45	36	45½
1863	49	60½	54	59½	51⅞	55	53⅛	54½
1864	41¾	56⅞	44⅝	56⅜	48⅛	51¾	49⅜	53
1865	33¾	47½	34⅛	48⅞	45	46⅛	48¾	48⅛
1866	29⅛	50⅞	29¾	50⅞	45⅞	47½	43⅞	48⅝
1867	29¾	44¼	32⅞	45	38⅝	45½	38⅞	42⅝
1868	27	44	27½	45⅜	37	35¼	35⅛	36¼
1869	32⅛	48¼	33⅞	49⅞	42½	48¼	43⅝	52⅛
1870	29¼	46¼	32⅜	44½	41¾	41¾	38½	43¾
1871	39⅛	46½	36⅛	46	44	41¾	45⅜	47½
1872	26¾	38⅝	29¾	32	30⅛	33¼	27¾	33⅛
1873	37⅛	49	33½	46¾	45⅞	48¾	44¾	46½
1874	30⅛	53¾	32	51⅜	47⅛	49⅝	45¾	49¼
1875	29¾	38¾	27¾	42⅝	38¾	42⅝	33⅜	44¼
1876	19¼	31⅝	22¾	36⅜	36⅜	34½	31	35
1877	37½	46¾	38⅛	49½	44½	42¾	43⅛	47⅛
1878	15⅞	33½	20¼	31½	27¾	32	29¼	32½
1879	13⅜	26⅜	16⅝	25½	27¼	28½	26⅝	31⅛
1880	38¼	57¼	41⅜	59⅜	50¼	55⅞	51¾	54⅞
1881	34¾	43¼	36½	47¼	41½	47⅞	40½	45
1882	34⅛	46¼	36⅛	50⅞	44¾	48¼	44¾	46⅝
1883	43⅞	53¼	44¼	54⅜	46	49	44¾	48¾
1884	34½	43¾	33½	45¼	40	43¼	38¼	40¾
1885	17½	38½	21½	31½	28⅜	34	28⅞	32⅜
AVERAGES								
4 yrs. 1852-55	47½	49⅞	45½	50½	47	46⅝	43½	47½
,, 1856-59	36¾	47½	34	48⅝	48⅜	49⅜	44¾	47½
,, 1860-63	35¼	52⅝	39½	52⅝	45¼	48⅜	43⅞	48⅝
,, 1864-67	33⅝	49⅞	35⅜	50¼	44⅜	47¾	45¼	48⅛
,, 1868-71	31⅞	46¼	32½	46½	41⅜	41¾	40⅝	44⅞
,, 1872-75	31	45	30¾	43¼	40½	43⅝	37⅞	43¼
,, 1876-79	21½	34⅝	24½	35¾	34	34½	32½	36½
,, 1808-83	37¾	50	39⅝	53	45⅝	50¼	45½	48⅞
8 yrs. 1852-59	42⅛	48¾	39¾	49⅝	47¾	48	44⅛	47½
,, 1860-67	34⅜	51¼	37⅜	51½	44⅞	48	44½	48⅜
,, 1868-75	31⅜	45⅝	31⅝	44⅞	40⅞	42⅝	39¼	44⅛
,, 1876-83	29⅝	42¼	32	44⅜	39¾	42⅜	39	42⅝
16 yrs. 1852-67	38¼	50	38⅝	50½	46¼	48	44⅜	47⅞
,, 1868-83	30½	44	31¾	44⅝	40⅜	42½	39⅛	43⅜
32 yrs. 1852-83	34⅜	47	35¼	47½	43¼	45¼	41¾	45⅝
P.C. Reduction 2nd 16 yrs.	20·3	12·0	17·8	11·6	12·7	11·5	11·8	9·4

(1) 6 yrs. 1852-7, Amm. Salts 400 lbs; 10 yrs. 58-67, 200 lbs; 1868 and since, 275 lbs. Nitrate soda.

(2) 6 yrs. 1852-71 Rape Cake 2000 lbs., and since 1000 lbs.

purely mineral manures, of purely nitrogenous manures, and of combinations of the two.

Results are given for sixteen plots, arranged in four series of four plots each, and for each plot the produce—dressed grain per acre—is given for thirty-four years in succession.

Series 1 comprises four plots, without any nitrogenous manure, namely—

Plot 1.—Without manure.
,, 2.—Superphosphate of lime alone.
,, 3.—Sulphates of potash, soda, and magnesia.
,, 4.—Superphosphate, and sulphates of potash, soda, and magnesia.

Series 2 comprises four plots, with the same four conditions as to mineral manures as Series 1, and ammonium salts supplying 43 lbs. of nitrogen per acre, per annum, in addition.

Series 3, the same four conditions as to mineral manure, with for six years 86 lbs., and for ten years 43 lbs. of nitrogen per acre per annum as ammonium salts, and for the last eighteen years 43 lbs. as nitrate of soda.

Series 4, the same four conditions as to mineral manure, with 2,000 lbs. rape cake per acre per annum, in the first six years; and 1,000 lbs. each year since.

It may be mentioned that 1,000 lbs. rape cake will, on the average, contain 48 to 50 lbs. of nitrogen, or rather more than in the amounts of ammonium-salts, or nitrate used, though probably not more is rendered available within the years of application, but there will obviously be accumulation, and some cumulative action from year to year.

Time will not allow me to call your attention in any detail to the produce of individual years, but you will observe that under all conditions of manuring, whether without nitrogenous supply as in Series 1, or with it, in the different forms and combinations, as in the other Series, there is great fluctuation from year to year, according to season. Thus, without manure the produce ranges from 35 bushels in 1854, to only $6\frac{1}{4}$ bushels in 1879; with a full mineral manure (plot 4, Series 1) from 42 bushels in 1854 to $7\frac{1}{4}$ bushels in 1879; with the full mineral manure and ammonium salts (plot 4, Series 2) = 43 lbs. nitrogen, from $60\frac{5}{8}$ bushels in 1854 to $27\frac{3}{8}$ in 1879.

As in the cases of Series 3 and 4, more nitrogen was applied during the first six years than afterwards, the comparison of the produce in individual years at the beginning and at the end of the period have not quite equal significance; but it may be observed that with the full mineral manure and ammonium salts at first, and nitrate of soda afterwards (plot 4, Series 3), the produce varied from nearly 65 bushels in 1857 to $25\frac{1}{2}$ bushels in 1879; and lastly, with the full mineral manure and rape cake it ranged from $62\frac{1}{4}$ bushels in 1857 to $31\frac{1}{8}$ bushels in 1879.

Looking to the average produce of each of the eight four-yearly periods, it is seen that, under all conditions of manuring, even in the case of the rape cake with its annual accumulation, there is a general tendency to reduction in produce from the first to, and especially in, the seventh period, 1876 to 1879; but there is as uniformly an increase over the eighth period, 1880 to 1883. There is in these facts clear evidence that the previous reduction was, independently of exhaustion in individual cases, mainly due to the seasons.

The bottom line of the Tables, which shows the percentage reduction in the amount of produce over the second 16 years compared with the first 16, enables us to discriminate in some degree between the effects of exhaustion and those of season.

It is seen that the four plots of Series 1 show a reduction over the second 16 years from about 31 to 34 per cent., or more than twice as much as in the case of either of the other Series. There is here evidence that in the case of Series 1, without nitrogenous manure, much of the reduction over the second half of the period was due to nitrogen-exhaustion.

In Series 2, with ammonium salts, there is 16 per cent. reduction on plot 1, where the ammonium salts are used alone, and only from 10 to 12 per cent. where mineral manures are used in addition.

In Series 3, with nitrate of soda, there is a reduction of 20 per cent. where the nitrate is used without mineral manure, of nearly 18 per cent. where it is used with potash, soda, and magnesia, but without phosphate (plot 3), and of only about 12 per cent. where phosphates were used in addition to the nitrate.

Lastly, in Series 4, with rape cake, which contains a considerable amount of mineral matter, there is a reduction of only 12·7 per cent. where it is used alone, of less where any mineral manure is used in addition, and of only about 9½ per cent. where a full mineral manure is also used.

As already intimated, that there should be any reduction in the yield over the second half of the period where rape cake, with its annual residue and accumulation, is used, is evidence that part of the reduction is due to an average of less favourable seasons over the later period. But that there should be the greatest reduction in Series 1, where no nitrogen is supplied, is evidence of nitrogen-exhaustion under those conditions; and that within Series 2 and 3 respectively there should be the greatest reduction, where the ammonium salts or nitrate are used without phosphates, is evidence of phosphoric-acid exhaustion in those cases.

Leaving the results relating to the produce of each individual year, or of limited series of years, as given in Tables II. and III., a general view of the effects of the sixteen different conditions as to manuring is conveniently obtained in the *Summary Table* IV. (p. 12). There is there given the average produce over the thirty-two years on each of the sixteen plots. The first column gives the results for the four plots of Series 1, without nitrogenous manure; the second column those for Series 2, with ammonium salts equal to 43 lbs. nitrogen per acre per annum; the third those for Series 3, with nitrate of soda; and the fourth those for Series 4, with rape cake. The upper division of the Table gives, for each plot, the average produce of grain per acre in bushels; the middle division, the average produce of straw in lbs.; and the lower division, the average total produce (corn and straw together) in lbs.

TABLE IV.

Barley* 32 *years in succession on the same land—Hoosfield, Rothamsted.

SUMMARY.

Showing the effects of exhaustion and manures.

	No Nitrogenous Manure	200 lbs. Am.Salts = 43 lbs. N	275 lbs. N. Soda (1) = 43 lbs. N	1000 lbs. R. Cake (2) = 49 lbs. N
DRESSED GRAIN per acre. Bushels				
Without Mineral Manure	$17\frac{7}{8}$	$30\frac{3}{4}$	$34\frac{3}{8}$	$43\frac{1}{4}$
Superphosphate	23	45	47	$45\frac{1}{4}$
Sulphates Potash, Soda, and Magnesia ...	$19\frac{3}{4}$	$33\frac{7}{8}$	$35\frac{1}{4}$	$41\frac{3}{4}$
Superphosphate and Sulphate Potash, Soda, and Magnesia	$24\frac{1}{4}$	$44\frac{7}{8}$	$47\frac{1}{2}$	$45\frac{5}{8}$
STRAW, per acre. Lbs.				
Without Mineral Manure	1128	1909	2246	2789
Superphosphate	1293	2827	3127	2953
Sulphates Potash, Soda, and Magnesia ...	1170	2151	2455	2792
Superphosphate, and Sulphates Potash, Soda, and Magnesia	1380	3019	3348	3065
TOTAL PRODUCE (GRAIN and STRAW), per acre. Lbs.				
Without Mineral Manure	2136	3649	4189	5249
Superphosphate	2584	5374	5791	5532
Sulphates Potash, Soda, and Magnesia ...	2278	4063	4490	5175
Superphosphate, and Sulphates Potash, Soda, and Magnesia	2739	5574	6042	5667

(1) Ammonium-Salts = 86 lbs Nitrogen first 6 years, = 43 lbs next 10 years; Nitrate Soda = 43 lbs Nitrogen last 16 years. (2) 2000 lbs Rape Cake first 6 yrs. 1000 lbs since.

Referring first to the results on the four plots without nitrogenous manure, as given in the first column of the Table, it is seen that plot 2, with superphosphate of lime, and plot 4, with superphosphate and salts of potash, soda and magnesia, give considerably more produce than plot 3, with the potash, soda, and magnesia, without phosphate. There is more of straw, as well as grain, and of course, therefore, of total produce, with than without the phosphate. There is, indeed, very marked effect by phosphatic manure, and very little by the alkalies.

The second column, with the same four conditions as to mineral supply, but with, in each case, 43 lbs. of nitrogen per acre per annum as ammonium salts, shows a very great increase. Even with the ammonium salts alone there is a great increase; there is somewhat more on plot 3, where the alkalies are also applied, but very much more still on plots 2 and 4, where phosphates are also used.

The third column shows that with a larger amount of nitrogen supplied in the first six years, and with nitrate of soda instead of ammonium salts in the later years, there is still greater increase; and again, the increase is by far the greater where the superphosphate is used.

The four plots of Series 4, with the rape cake, show a much greater uniformity of result with the different mineral manures. Still the two phosphate plots (2 and 4) give more produce than the two without phosphate. Referring to the produce of grain in illustration, it is seen that plots 1 and 3 without phosphate give considerably more produce than the same plots (1 and 3), in either Series 2 with the ammonium salts, or in Series 3 with the nitrate of soda. The explanation of this is that the rape cake itself contains phosphates. On plots 2 and 4, on the other hand, where phosphates are added, there is nearly as much produce in Series 2 with the ammonium salts, and more in Series 3 with the nitrate, than in Series 4 with the rape cake.

Thus, then, whilst there is evidence that the phosphate of the rape cake was effective when none was otherwise supplied, when it was so applied in addition there was more effect with the nitrate, with its more rapidly available nitrogen, than with the rape cake, with its greater actual amount of nitrogen, but in a less rapidly available condition.

Comparing the produce of plot 2 with superphosphate without potash, with that of plot 4 with superphosphate, and salts of potash, soda and magnesia in addition, it is remarkable that, both in Series 2 with the ammonium salts, and in Series 3 with nitrate of soda, there is over the whole period of thirty-two years almost identically the same amount of barley grain without as with the potash. There is, however, rather more straw and total produce with than without the potash. Thus we have, with the ammonium salts, an average of forty-five bushels without potash, and $44\frac{7}{8}$ bushels with potash; and with the nitrate of soda 47 bushels without, and $47\frac{1}{2}$ bushels with potash. Of straw, however, there is, with the ammonium salts, an average of 2,827 lbs. without, and 3,019 with the potash; and on the nitrate plots 3,127 lbs. without, and 3,348 lbs. with potash.

It will afterwards be seen that where nitrogen and phosphoric acid were liberally supplied without potash, the available potash of the soil itself became deficient; though this deficiency was to the last scarcely at all manifested in the produce of grain. It is obvious, however, that with gradual reduction in the amount of plant, the yield of grain must in time diminish.

So much for the influence on the barley crop, of different conditions of manuring, each continued for more than thirty years on the same plot, and in a field of somewhat heavy loam, with a raw clay subsoil, and chalk below, giving good natural drainage.

It is seen that nitrogenous manures alone had much more effect than mineral manures alone. It was obvious, therefore, that the exhaustion induced by the continuous growth of the crop was characteristically that of nitrogen.

Both with and without nitrogenous supply phosphates were more effective than potash salts, showing that the available store of phosphoric acid in the soil became deficient sooner than that of potash. With the shorter period of growth of barley than of wheat, and its greater proportion of surface-rooting, both nitrogenous and mineral exhaustion are sooner developed; and so far as mineral exhaustion is concerned, the available supply of phosphoric acid was sooner exhausted than was that of potash. Indeed, in ordinary agricultural practice, it is clearly established that superphosphate is more effective with the spring-sown than with the autumn-sown cereals.

Influence of Season on the Amounts of Produce.

It has been seen that there were, under all conditions of manuring, very great variations in the amount of produce from year to year according to season. The extent and character of the influence of season will be brought prominently to view by comparing the produce of the best and the worst seasons of the thirty-two, and comparing the characters of the seasons themselves.

Tables V. and VI. illustrate these points. Table V. (p. 15) gives the produce of grain, the weight per bushel of the grain, the produce of straw, and the total produce (corn and straw together), of six very different conditions as to manuring in each of the best two seasons, and in the worst season of the whole series. There is also given the deficiency of produce in the bad season, compared with that in each of the two good seasons.

For wheat, 1863 was the best season of the thirty-two—indeed of the forty—of its growth. For barley, 1863 was also a very good year for both grain and straw; but it was not so good for such a variety of manures as were 1854 and 1857, which (in the Table) are adopted as the best seasons.

For almost all conditions of manuring, 1854 was the season of the highest total produce, corn and straw together; that is it was the season of the greatest luxuriance or vegetative activity. But 1857 was, especially for the highest manuring, the one of the highest produce of grain, and of the highest quality or maturity of grain, as evidenced by the weight per bushel. Thus 1854 was the highest for luxuriance, and 1857 the highest for the maturation of the crop.

As for wheat, so for barley, 1879 was decidedly the worst season of the thirty-two.

The plots selected for illustration are those without manure, with farmyard manure, with mixed mineral manure alone, with mixed mineral manure and ammonium salts, with mixed mineral manure and nitrate of soda, and with mixed mineral manure and rape cake.

It is not necessary to detain you with any detailed consideration of the results—the figures speak for themselves. The lower division of the Table shows that under each of the six very different conditions as to manuring, 1854 yielded a much higher total produce (grain and straw together) than 1857. But the upper division shows that, notwithstanding the less amount of plant, 1857 gave in most cases nearly as much grain as 1854, and in two cases—those with the highest nitrogenous manuring—(and both years were within the first six when the larger amounts were applied), 1857 gave more grain than 1854. The weight per bushel of the grain was also higher in 1857, on all the plots where nitrogenous manures were used.

The contrast between the produce in these two very different good years, and that in the worst season 1879, is very striking, the difference amounting in several cases to as much as the average crop of the country.

TABLE V

Barley, year after year on the same land, Hoosfield, Rothamsted.

Produce of the two best seasons, 1854 and 1857; of the worst season, 1879; and average of 32 years, 1852-1883

Plots	DESCRIPTION OF MANURES; QUANTITIES PER ACRE.	Best Seasons 1854	Best Seasons 1857	Worst Season 1879	1879 + or — 1854	1879 + or — 1857	Average 32 Years
	DRESSED GRAIN per acre, BUSHELS						
1o	Unmanured	35	26⅛	6¼	—28¾	—19⅞	17¾
7-2	Farm-yard Manure	56⅜	51¼	36⅝	—19¾	— 14⅝	49½
4o	Mixed Mineral Manure, alone...	42	39¾	7¼	—34¾	—32½	24¼
4a	Mix. Min. Man. and 200 lbs Amm. Salts=48lbs N	60⅝	57⅜	27⅜	—33¼	—30	44⅞
4aa	" " " and 275 lbs Nit. Soda=43 lbs N ...	62¾	64⅞	25½	—37¼	—39⅜	47½
4c	" " " and 1000 lbs Rape Cake=49 lbs N	60¼	62¼	31⅛	—29⅛	—31⅛	45⅝
	WEIGHT PER BUSHEL OF DRESSED GRAIN. LBS						
1o	Unmanured	53·6	52·0	48·8	—4·8	—3·2	52·2
7-2	Farm-yard Manure	53·9	54·2	50·5	—3·4	—3·7	54·3
4o	Mixed Mineral Manure, alone	54·0	53·7	50·4	—3·6	—3·3	53·2
4a	Mix. Min Man. and 200 lbs Amm. Salts=43 lbs N	54·3	54·8	50·2	—4·1	—4·6	54·2
4aa	" " " and 275 lbs Nit. Soda=43 lbs N ...	52·1	53·9	49·8	—2·3	—4·1	53·8
4c	" " " and 1000 lbs Rape Cake=49 lbs N	52·8	54·1	49·6	—3·2	—4·5	53·9
	STRAW per acre, LBS						
1o	Unmanured	2442	1425	526	—1916	— 899	1128
7-2	Farm-yard Manure	4171	2649	3645	— 526	+ 996	3298
4o	Mixed mineral Manure, alone...	2595	1920	491	—2104	—1429	1380
4a	Mix. Min. Man. and 200 lbs Amm. Salts=43 lbs N	4530	3120	2333	—2197	— 787	3019
4aa	" " " and 275 lbs Nit. Soda=43 lbs N ...	5487	4057	2398	—3089	—1659	3348
4c	" " " and 1000 lbs Rape Cake=49 lbs N	4712	3705	2588	—2124	—1117	3065
	TOTAL PRODUCE (Grain and Straw) per acre, LBS						
1o	Unmanured	4405	2878	943	—3462	—1935	2136
7-2	Farm-yard Manure	7298	5564	5724	—1574	+ 160	6140
4o	Mixed Mineral Manure, alone...	4969	4111	879	—4090	—3232	2739
4a	Mix. Min. Man. and 200 lbs Amm. Salts=43 lbs N	7958	6336	3867	—4091	—2469	5574
4aa	" " " and 275 lbs Nit. Soda=43 lbs N ...	9026	7734	3819	—5207	—3915	6042
4c	" " " and 1000 lbs Rape Cake=49 lbs N	8125	7241	4246	—3879	—2995	5667

NOTE.—Plot 4aa, Ammonium-Salts=86 lbs Nitrogen first 6 years, = 43 lbs next 10 years; Nitrate Soda=43 lbs Nitrogen last 16 years. Plot 4c, 2000 lbs Rape Cake first 6 years; 1000 lbs. since.

For comparison with the produce of these selected years, the average on each of the six plots over the 32 years is given; and it will be seen how very much higher than the average is the produce in the good years, and how very much lower in the bad season.

So much for the variations in the amounts of produce in the different seasons. It will be of interest to consider, however summarily it may be practicable to do it, some of the climatic characteristics of these various seasons.

The next Table (VI.) shows, for each month of each of the three seasons, reckoning from October to September, the mean temperature, and the rainfall, above or below the average.

Table VI

Characters of the two Best Seasons, 1854 and 1857, and of the Worst Season, 1879

Temperature and Rainfall + or — Average

	Mean Temperature			Rainfall			Days of Rain, 0·01 inch, or more		
	Best two		Worst	Best two		Worst	Best two		Worst
	1854	1857	1879	1854	1857	1879	1854	1857	1879
	Deg. F	Deg. F	Deg. F	Inches	Inches	Inches	Days	Days	Days
October	+1·3	+2·1	+1·9	+1·43	—0·89	—1·14	+13	— 4	— 1
November	—0·2	—1·6	—2·6	—0·45	—1·15	+1·05	— 2	— 3	+ 2
December	—5·2	+1·0	—5·5	—1·30	—0·27	—0·94	0	+ 1	+ 4
January	+2·4	0·0	—4·7	—0·60	+0·60	+0·59	+ 3	+ 7	0
February	+0·8	+0·5	—0·5	—0·29	—1·30	+2·32	— 3	— 8	+10
March	+2·7	+0·7	+0·1	—1·28	—0·77	—1·00	— 6	— 2	+ 2
April	+2·3	—0·4	—2·9	—1·11	—0·30	+0·90	— 4	+ 7	+ 5
May	—1·6	+1·5	—4·1	+1·51	—1·67	+1·36	+ 5	— 6	+ 4
June	—2·3	+3·8	—1·3	—0·99	+0·80	+2·39	+ 1	— 2	+ 9
July	—1·3	+2·9	—3·5	—0·85	—1·50	+1·12	+ 4	— 2	+ 8
August	0·0	+4·9	—1·0	+0·21	+0·10	+2.79	+ 1	0	+ 9
September	+1·6	+3·2	—0·2	—1·42	+1·00	+0·47	— 3	+ 1	+ 2
Averages		+1·5	—2·0						
Totals				—5·14	—5·35	+9.91	+ 9	—11	+54

It is obvious that different seasons will differ almost infinitely at each succeeding period of their advance, and that, with each variation, the character of development of the plant will also vary, tending to luxuriance, or to maturation, that is, to quantity, or to quality, as the case may be. Hence, only a very detailed consideration of climatic statistics, taken together with careful periodic observations in the field, can afford a really clear perception of the connection between the ever-fluctuating characters of season, and the equally fluctuating characters of growth and produce. It is, in fact, the distribution of the various elements making up the season, their mutual adaptations, and their adaptation to the stage of growth of the plant, which, throughout, influence the tendency to produce quantity or quality. Still, it will be seen that the limited summary of the meteorological conditions of the seasons in question, which can alone be given here, is not without significance.

First then as to 1854, the season of great luxuriance and high total produce. The Table shows that there was an excess of temperature in January, February, March, and April, with a deficiency of rain from November to April inclusive; but that during May, June, and July, that is the months of active above-ground growth, there were lower than the average temperatures, with a considerable excess of rain in May, and then a deficiency—conditions obviously favouring continued vegetation and slow maturation.

In 1857, there was less excess of temperature, and less than the average amount of rain to the end of April; then from May to August inclusive there was both considerable deficiency of rain and considerable excess of temperature; that is, there were throughout the period of active above-ground growth conditions favouring seeding tendency and maturation rather than luxuriance.

Thus, then, the two good seasons were very different in their climatic characteristics, as they were in the character of their produce.

Compared with these, the very bad season of 1879 shows much lower than average temperatures throughout the winter, spring, and summer, and even somewhat in the autumn, with, at the same time, great excess of rain from January to September inclusive; and it will be seen that both the deficiency of temperature and the excess of rain were very marked from April to August inclusive, that is, during the whole period of the above-ground growth, and the ripening, if such it may be called, of the crop, for in many cases the weight per bushel was less than 50 lbs., whilst the amounts of produce were, as has been seen, very greatly below the average.

Even then this very incomplete record of the climatic characters of the three seasons is sufficient clearly to indicate the connection between such conditions, and the characteristic differences in the three crops.

Influence of Exhaustion, Manures, and variations of Season, on the Composition of the Barley Crop.

I have now considered the influence of exhaustion, manures, and variations of season, on the *amount of produce* of Barley, and I propose briefly to consider their influence on its *composition.* When discussing last year the influence of various conditions on the composition of Wheat, it was shown that although the supplies within the soil—both of nitrogen and of mineral constituents—had a very direct influence on the composition of the crop so long as it was only in the vegetative stage, yet there was nevertheless very great uniformity in the composition of the final product of the plant—the seed—provided only that it was perfectly matured. The composition of the straw, however, showed a very direct connection with the supplies by the soil. The composition of the grain, on the other hand, was materially influenced by variations of *season.* But variations of season obviously have great influence on the condition of maturation; whilst difference in maturation implies difference in organic composition—in the amount of carbohydrates (starch especially)—formed. In fact, such variations in composition imply deviations from perfect and normal maturation; and such deviations are associated not only with differences in the organic composition—the relation of the nitrogenous to the non-nitrogenous constituents—but with differences in the mineral composition also.

It follows, from what has been said, that variations in the composition of the final and very definite product—the seed, should be much more clearly traceable to variations of season than to the variations in the supplies within the soil; in other words, than to exhaustion or manures. This was found to be very strikingly so in the case of *wheat*, and we have now to consider how far it is so with its near ally—*barley*.

The results given in Table VII. forcibly illustrate the much greater influence of variations of season than of manures, on the composition of barley grain. Complete analyses of the ash of the grain (and also of the straw) grown by different manures, each in different seasons, have been made, and taking for illustration the important and characteristic consituents, potash and phosphoric acid, the Table shows for three very different manurial conditions—

1. Without manure,
2. With farmyard manure,
3. With an artificial manure supplying liberally both nitrogen and mineral constituents—

the highest, the lowest, and the mean amounts of potash and phosphoric acid, in 1000 parts of the dry substance of the grain, and of the straw, in the different seasons.

TABLE VII.

Highest, lowest, and mean amounts of potash and phosphoric acid per 1000 *dry substance.*

		Per 1000 Dry Grain					Per 1000 Dry Straw				
		Highest		Lowest		Mean	Highest		Lowest		Mean
	POTASH.										
1 O	Unmanured ...	1871	7·66	1853	6·00	6·54	1871	11·77	1856	5·25	8·55
7 2	Farm-yard Man....	1871	8·36	1856	5·89	6·81	1871	22·01	1856	6·76	13·23
4 A	Mix. Min. Man. and Amm. Salts.	1871	7·98	1852	5·62	6·61	1871	22·53	1852	5·67	14·05
	PHOSPHORIC ACID.										
1 O	Unmanured ...	1852	10·08	1854	8·85	9·27	1856	2·60	1863	1·20	1·74
7 2	Farm-yard Manure	1871	10·50	1854	9·23	9·99	1856	2·92	1863	1·48	2·19
4 A	Mix. Min. Man. and Amm. Salts....	1856	10·39	1863	8·84	9·58	1856	3·12	1863	1·06	1·94

First as to the amounts of potash in 1000 parts dry substance of grain of the differently manured plots in the different seasons. It is seen that there is much greater variation in the proportion of potash in different seasons with the same manure, than there is with different manures. Further, the seasons showing the highest amount of potash are those of much higher maturing character than those with the lowest amounts.

Next it is seen that there is still greater, indeed enormous variation, in the amount of potash in the dry substance of the straw with the same manure, in different seasons. There is also great variation according to manure; comparatively little when there was full supply, but considerable without manure, that is with exhaustion.

Turning now to the phosphoric acid in the grain: there is here again much more variation in different seasons with the same manure, than with different manures. But whilst in the case of potash there is the higher proportion in the *better* seasons, in that of phosphoric acid there are lower amounts in the dry substance in the *better* seasons. In fact high amount of potash in the ash, and in the dry substance of the grain, is as a rule associated with high maturation, that is with high proportion of starch, whilst high proportion of phosphoric acid is generally associated with low maturation and high proportion of nitrogen.

The proportion of phosphoric acid in the straw, also varies more with season than with manure, and it is the highest in the worst seasons.

The connection between maturation and composition is further illustrated in the results given in Table VIII.

TABLE VIII.

General character of the produce, mean percentage in pure ash, and parts per 1000 *dry matter, of Potash and Phosphoric Acid. Mean of* 6 *differently-manured plots in each season. Harvests in order of highest weight per bushel.*

Harvests	Weight per bushel of Grain lbs.	Per cent. Ash (pure) in dry matter	Per cent. in Ash (pure)		Per 1000 dry matter.	
			Potash	Phosphoric Acid	Potash	Phosphoric Acid
GRAIN						
1871	55·9	2·65	29·80	35·33	7·89	9·39
1863	55·3	2·55	26·59	35·80	6·78	9·15
1852	51·7	2·48	23·84	40·89	5·90	10·13
1856	47·4	2·44	24·21	41·35	5·89	10·09
STRAW						
1871	55·9	6·27	26·01	3·68	16·57	2·31
1863	55·3	5·48	24·91	2·29	13·99	1·26
1852	51·7	4·45	14·62	4·05	6·58	1·81
1856	47·4	4·49	13·51	6·42	6·10	2·89

In the Table are given the mean results for six differently manured plots, in each of four very different seasons, so far as the maturation of the grain was concerned. The different seasons are given in the order of the highest weight per bushel of the grain—high weight per bushel being upon the whole the best practical measure of high quality.

It will be seen that, as so measured, the seasons are given in the following order—1871, 1863, 1852, and 1856,—the average weight per bushel of the grain being in 1871, 55·9 lbs.; in 1863, 55·3 lbs.; in 1852, 51·7 lbs.; and in 1856 only 47·4 lbs.; or about 8 lbs. less than in the two seasons of highest weight. There is here, then, very great variation in the character of these four seasons, and in the degree of maturation of the grain accordingly.

The particulars of composition given for each of these four seasons are—the percentage of total mineral matter, or ash, in the dry matter of the grain, and of the straw; the percentage in the ash (of both grain and straw), of potash and phosphoric acid; and the amount of potash and phosphoric acid, in 1000 dry substance of both grain and straw.

No determinations of nitrogen are available, but it may be stated that the percentage of nitrogen is almost uniformly lower in the seasons of high maturation.

The Table shows that, in both grain and straw, there is a higher percentage of ash in the dry substance, the higher the quality of the grain. There are also higher percentages of potash, but lower percentages of phosphoric acid, in both the ash and the dry substance, the higher the quality of the grain.

In wheat, however, there is lower, not higher, percentage of ash in the dry substance of the grain, the higher its quality. But, in wheat, as in barley, there is higher percentage of potash, and lower percentage of phosphoric acid, in the ash, the higher the quality. On the other hand, there is not in the case of wheat, as there is in barley, a much higher percentage of potash in the dry substance, the higher the quality. This difference may be partly due to the larger proportion of starch to nitrogenous substance in the barley; but it is probably in part also due to the paleæ (or chaff) of the barley, but not of the wheat, being adherent, and retaining the surplus potash brought up for grain formation.

In both descriptions of grain there is very uniformly a lower proportion of phosphoric acid in the dry matter, the higher the quality of the grain.

In the straw, there is high percentage of ash in the dry matter, high percentage of potash, and low percentage of phosphoric acid, in the ash, and high percentage of potash, and low of phosphoric acid, in the dry matter, the higher the quality of the grain. In the straw, however, the variations show a much wider range, indicating much less definiteness, and greater irregularity in condition.

Thus, then, the higher the quality of the barley grain, that is the higher its proportion of starch, the higher is the proportion of potash, and the lower is that of phosphoric acid. It may be mentioned that with a higher proportion of potash there is generally a lower proportion of both lime and magnesia, and with a lower proportion of phosphoric acid there is a somewhat higher proportion of sulphuric acid.

Another point of interest is, although it is true the amounts are small, that there is a tendency to a higher proportion of soda in the grain ash, and in the dry matter of the grain, in the better seasons, even when there is no deficiency of potash. This, again, is probably due to the ash of the barley grain containing that of the adherent paleæ.

In relation to the composition of the straw, the most striking result is (though not shown in the Table) that there is little more than two thirds as high a percentage of silica in the ash of the produce of the better as in that of the worse seasons.

Thus far the effects of season, and coincidently with this the degree of maturity of the grain, on its composition, have chiefly been illustrated. The next results illustrate more directly the influence of *exhaustion*, or of *full supply*, of mineral, or ash constituents, on the mineral composition of the produce, both grain and straw.

The first three columns of Table IX. (p. 22), relate to the mineral composition of the produce grown for 25 years in succession, by ammonium salts and superphosphate of lime, but without supply of potash, soda, or magnesia. The last three columns show the composition of the produce by ammonium salts, and superphosphate, with potash, soda, and magnesia, in addition. There are given the results obtained by the analysis of proportionally mixed samples of the produce, of ten years 1852-61, of ten years 1862-71, and of five years 1872-76. The upper division of the Table gives for the potash, the second for the soda, the third for the phosphoric acid, and the fourth for the silica—1, the percentage in the ash (pure) of the grain and of the straw; 2, the amounts per 1000 dry matter of grain and of straw; 3, the amounts per acre per annum in lbs. in the total produce (grain and straw together), in the grain alone, and in the straw alone.

First referring to the potash, its percentege, even in the grain ash, is seen somewhat to diminish from period to period where none was supplied in manure; and in a somewhat greater degree to increase where there was an annual supply of it by manure. In the straw ash, however, whilst the percentage of potash goes down from 18·44 over the first period to only 8·70, or less than half, over the third period, where none was supplied, it increases from 27·85 per cent. over the first, to 34·43 per cent. over the third period, when it was annually supplied. Thus, the influence of exhaustion, or of full supply, has been comparatively small on the mineral composition of the grain, but very great indeed on that of the straw.

The point is further illustrated in the next results, showing the amounts of potash, per 1000 dry matter of grain, and of straw, respectively. There is again comparatively little variation in the relation of the potash to the organic matter in the case of the grain, but very great variation in the case of the straw; and when it is borne in mind, that the ash of barley grain contains that of the adherent paleæ as well as that of the grain proper, the conclusion is that the variation in the proportion of potash to the fixed organic substance of the grain itself is much less than the figures would indicate. Indeed, it is probable that the variation, such as it is, is associated with a different relative proportion of the organic compounds themselves—of the fully matured non-nitrogenous to the nitrogenous bodies. In fact, the evidence, duly considered, is not in favour of the view that there is variation in the proportion of the potash to the fixed and ripened non-nitrogenous constituents, with the formation of which it is associated.

Table IX

Experiments on Barley, Hoosfield, Rothamsted. Potash, Soda, Phosphoric acid, and Silica, per cent in Ash, per 1000 Dry subatance, and Quantities per acre

		Ammonium salts and Superphosphate			Ammonium salts superphosphate and potash, soda, and magnesia.		
		10 years 1852-1861	10 years 1862-1871	5 years 1872-1876	10 years 1852-1861	10 years 1862-1871	5 years 1872-1876
POTASH							
Per cent in Ash	of Grain	26·79	25·97	25·37	27·62	28·46	29·19
	of Straw	18·44	13·31	8·70	27·85	32·92	34·43
Per 1000 Dry Matter	of Grain	6·22	6·23	5·88	6·52	6·82	7·11
	of Straw	8·54	6·41	3·63	14·65	18·51	17·88
Per acre per annum. lbs	in Total Produce	35·60	30·88	18·16	53·74	63·73	53.05
	in Grain	13·07	14·45	11·33	13·80	15·28	13·87
	in Straw	22·53	16·43	6·83	39·94	48·45	39·18
SODA							
Per cent in Ash	of Grain	1·15	2·07	2·72	0·51	0·58	0·66
	of Straw	6·42	11·39	13·53	2·50	2·30	2·60
Per 1000 Dry Matter	of Grain	0·27	0·50	0·63	0·12	0·14	0·16
	of Straw	2·97	5·49	5·65	1·32	1·29	1·35
Per acre per annum. lbs	in Total Produce	8·40	15·21	11·85	3·84	3.69	3·27
	in Grain	0·56	1·15	1·22	0·25	0·31	0·31
	in Straw	7·84	14·06	10·63	3·59	3·38	2·96
PHOSPHORIC ACID							
Per cent in Ash	of Grain	38·55	36·36	38·20	38·53	37·31	38·61
	of Straw	3·06	2·55	3·48	2·97	2·47	3·15
Per 1000 Dry Matter	of Grain	8·95	8·72	8·85	9.10	8·95	9·39
	of Straw	1·42	1·23	1·45	1·56	1·39	1·63
Per acre per annum, lbs	in Total Produce	22·54	23·38	19·78	23·51	23·67	21·91
	in Grain	18·80	20·23	17·05	19·25	20·04	18·33
	in Straw	3·74	3·15	2·73	4·26	3·63	3·58
SILICA							
Per cent in Ash	of Grain	18·60	20·62	18·64	18·67	19·18	17·14
	of Straw	47·87	43·39	44·07	43·67	35·41	32·02
Per 1000 Dry Matter	of Grain	4·32	4·95	4·32	4·41	4·60	4·17
	of Straw	22·16	20·92	18·37	22·98	19·91	16·63
Per acre per annum, lbs	in Total Produce	67·55	65·05	42·92	71·96	62·42	44·58
	in Grain	9·07	11·47	8·32	9·33	10·30	8·14
	in Straw	58·48	53·58	34·60	62·63	52·12	36·44

The effects of exhaustion, or of full supply of constituents, is more strikingly still brought out by a study of the figures showing the amounts of potash taken up per acre by the crops without, and with, the supply of it. Thus, the average amounts of potash taken up, or rather retained, per acre per annum, in the entire crop (grain and straw together) are, over the three successive periods, without supply of it—35·60, 30·88, and 18·16 lbs.; and with full supply they are, over the same periods—53·74, 63·73, and 53·05 lbs. That is to say there is without supply little more than half as much potash annually stored up in the crop over the last five years, as over the first ten years, of the 25. On the other hand, with full supply, there is, over the second period more than, and over the third period about the same amount as, over the first period; and there is, over the first period about one-and-a-half time, over the second period twice, and over the third period nearly three times, as much as where there was no supply.

Yet, with these enormous differences in the amounts taken up and retained by the entire plant in the different cases, there is comparatively little difference in the amounts accumulated in the grain. Thus, over the first period, the amounts in the grain are—without supply 13·07 lbs., and with supply 13·80 lbs.; over the second period—without supply 14·45 lbs., and with supply 15·28 lbs.; and over the third period—without supply 11·33 lbs., and with supply 13·87 lbs.

It is thus seen that, over each period, there was rather less in the grain without than with supply, but that the deficiency was not material until the third period; that is until after 20 years without supply in the one case, and 20 years with it in the other.

In reference to these results, it has already been shown, in discussing those in Table IV. (p. 12) that over a period of 32 years, that is extending seven years later than the 25 years to which the foregoing figures relate, there was almost identically the same amount of produce of grain, without as with the supply of potash; though there was, on the other hand, rather more straw, especially in the later years, with the supply. It would appear, therefore, that the diminished amount of potash taken up by the plant was sufficient for the exigencies of grain-formation almost to the end of the period; and that at least a large proportion of the excess taken up when it was liberally supplied was surplusage so far as the requirements of the grain were concerned. Some idea of how great was this surplusage may be formed by reference to the difference in the amounts of potash eventually remaining in the straw. Thus, the average amounts of potash per acre per annum in the straw were—over the first period, without supply, 22·53 lbs., and with supply 39·94 lbs., or 17·41 lbs. more; over the second period, without supply 16·43 lbs., and with supply 48·45 lbs., or 32·02 lbs. more; and over the third period, without supply 6·83 lbs., and with supply 39·18 lbs., or 32·35 lbs. more. It is not to be supposed, however, that the whole of these plus-amounts were surplusage; for although the average yield of grain has been so well maintained, the character of the plant has obviously depreciated for a good many years, and several times in recent years even the yield of grain has been considerably deficient. Indeed, it would seem that the plant has become more sensitive to adverse conditions of soil or season.

Turning now to the soda, it is seen that whether we look at its percentage in the ash of the grain, and of the straw, its proportion in 1000 dry substance, or the amounts in the acreage crops, very much more was found in the crops grown without its supply, but where potash was deficient, than where soda was annually supplied. This is strikingly illustrated by reference to the average amounts per acre per annum in the total crops, grain and straw together. Thus, over the first period, the average amounts of soda in the total crop were, without any supply of either potash, soda, or magnesia, 8·40 lbs., and with the supply of all three, only 3·84 lbs.; over the second period, without the supply 15·21 lbs., and with the supply only 3·69 lbs.; and, lastly, over the third period, without the supply 11·85 lbs., and with the supply only 3·27 lbs.

Thus, then, not only was there much more soda taken up, or retained, by the plant where it was not supplied than where it was, but it is evident that there was the more soda taken up the less the supply of potash. The amounts of soda retained in the grain are, however, seen to be but small; there is more it is true where there was a deficiency of potash, and where more soda was taken up. But, looking to the amounts of soda per cent. in the grain ash, or per 1000 dry substance of the grain, it would seem probable that the larger amounts where there was deficiency of potash, and more total soda taken up, were probably only due to larger amounts eliminated from the grain proper, and retained in the adherent paleæ, or chaff. Whether, however, the soda has been of any avail, in the earlier, or merely vegetative stages of growth, as a carrier, or otherwise, may be a question.

Next as to the phosphoric acid, of which there was the same annual supply on both plots. It is seen that whether we take its percentage in the ash, its proportion to the dry substance, or its average quantity per acre, the amounts are, in the comparable cases, comparatively uniform; the differences not being greater than can be supposed to be connected with the differences in growth due to the differences in the supply of other constituents.

Lastly, as to the silica: the chief point of interest to remark is, that, as the figures show, its percentage in these barley grain ashes ranges from 17 to more than 20, whereas in wheat grain ash it ranges only from about 0·5 to about 1·5 per cent.; or, if we take the proportion of silica to 1000 dry substance of grain, in barley it ranges from 4 to 5 parts, and in wheat only from about 0.1 to about 0.3 parts. This difference is obviously due to the chaff being adherent in the case of barley, and not in that of wheat; and the figures afford clear illustration of the material degree in which the composition of barley grain-ash is influenced by the inclusion in it of what is, in a sense, extraneous matter. It is indeed obvious that, under such circumstances, we should expect, as we find, less definiteness in the mineral composition of the grain of barley than in that of wheat.

On what does Strength of Straw depend?

It will be appropriate to refer here to the bearing of experimental evidence on the question whether, as is frequently stated, strength of straw is dependent on a high percentage of silica. Table X. (p. 26) affords illustrations on this point. The upper division of the Table gives results relating to wheat, and the lower division corresponding results relating to barley. In the case of wheat five, and in that of barley three, very different conditions of manuring are selected for illustration; and for each condition as to manuring results obtained in bad and in good seasons, are given. The particulars indicating the character of the crops are—the percentage of grain in the total produce, and the weight per bushel of the dressed grain; and side by side with these are recorded—the percentage of ash in the dry matter of the straw, the percentage of silica in the ash, and the percentage of silica in the dry matter.

In the wheat in every case, and in the barley in every case but one, there is a higher proportion of grain in the better season; and in every case, of both wheat and barley, there is a much higher weight per bushel of grain in the better season. These conditions are, in fact, proof of the superiority of the crops in the main characters of seed-forming tendency, and ripening.

The percentage of ash in the dry matter of the straw is not a very significant character; and it is seen that in the case of the wheat it was on the average somewhat the lower, but in that of the barley uniformly the higher in the better seasons.

The percentage of silica in the straw ash is more significant, and in both the wheat and the barley it is under all the conditions of manuring much the lower in the better seasons. More significant still, is the percentage of silica in the dry matter of the straw, and it is seen that, with the wheat under each condition of manuring, and with the barley under most conditions, it is considerably lower in the better seasons. It may be observed that the exceptions in the case of the barley were where organic manure, as in rape-cake and farm-yard manure, was employed.

Direct analytical results clearly show, therefore, that the proportion of silica is, as a rule, lower, not higher, in the straw of the better grown and better ripened crops.

This result is quite inconsistent with the usually accepted view that high quality and stiffness of straw depend on a high amount of silica. Pierre and Bretschneider have, however, concluded from their experiments that this is not the case, and at Rothamsted we have long maintained a contrary view. In fact, high proportion of silica means a relatively low proportion of organic substance produced. Nor can there be any doubt that strength of straw depends on the favourable development of the woody substance; and the more this is attained the more will the accumulated silica be, so to speak, diluted—in other words, show a lower proportion to the organic substance.

TABLE X.

Per cent. Silica in the Ash, and in the dry matter, of Wheat Straw and Barley Straw grown by different manures, and in different seasons.

		Per cent. Corn in Total Produce	Weight per bushel dressed corn	Per cent. Ash in dry matter	Per cent. Silica in Ash	Per cent. Silica in dry matter
WHEAT						
Without Manure	1856	36·4	54·3	5·5	71·47	3·93
	1858	40·6	60·4	4·9	65·85	3·23
Amm. Salts alone	1856	34·8	55·5	3·9	66·23	2·58
	1858	40·3	59·6	4·0	57·47	2·30
Mixed Mineral Manure	1856	36·7	56·4	5·7	68·74	3·92
	1858	43·6	61·5	5·6	64·67	3·62
Mineral Manure and Amm. Salts	1856	33·6	58·0	4·9	64·63	3·17
	1858	38·2	62·2	5·0	55·60	2·78
Farm-yard Manure	1856	34·5	58·6	6·7	69·56	4·66
	1858	39·6	62·6	6·54	59·71	3·90
BARLEY						
Rape cake	1852	44·3	51·7	4·75	57·49	2·73
	1871	45·4	56·3	5·54	42·04	2·33
Rape cake	1856	39·1	46·1	4·63	49·39	2·29
	1863	48·4	56·3	5·17	45·62	2·36
Mineral Manure and Amm. Salts	1852	43·2	51·4	4·19	62·21	2·61
	1871	43·3	56·5	6·70	32·71	2·19
Mineral Manure and Amm. Salts	1856	40·2	46·4	5·48	57·47	3·15
	1863	47·3	56·5	6·32	35·24	2·23
Farm-yard Manure	1852	47·0	52·8	5·15	57·38	2·96
	1871	43·8	56·6	7·55	42·71	3·22
Farm-yard Manure	1856	42·8	47·1	4·92	57·85	2·85
	1863	48·3	57·2	6·21	43·08	2·68

I may mention that in my own neighbourhood, where the straw-plait industry prevails, the complaint during several recent seasons of bad harvests was that an unusually large proportion of the straw was brittle, and broke in the working; and considering the character of the seasons there can be no doubt that this was associated with low development of the woody matter, and high proportion of silica.

Our Area under the Crop, and the Amount of our Imports.

Before concluding on the subject of barley, it will be of interest to consider the extent of area devoted to the crop in the United Kingdom, the amount of our total annual imports, and from what countries our supplies are chiefly derived.

Table XI. (p. 27) shows the area under the crop in the United Kingdom, in each of the last 13 years, 1873 to 1885 inclusive. It also shows the total imports into the United Kingdom during the year succeeding each of the first 12 of the 13 harvests, reckoning from September 1 to August 31 in each case.

The figures show that since the harvest-year 1880-81, there has been a reduction of area. Further, the last column shows that since the same date there has been a considerable increase in our imports.

TABLE XI.

Area under Barley in the United Kingdom; also Imports into the United Kingdom, during each harvest year from 1873-4 *to* 1885-6.

Harvest Years	Area	Imports
	Acres	Quarters
1873-4	2,574,529	2,391,785
1874-5	2,507,130	3,667,174
1875-6	2,751,362	2,272,081
1876-7	2,762,263	3,684,725
1877-8	2,652,300	3,976,384
1878-9	2,722,879	2,798,494
1879-80	2,931,809	3,467,147
1880-1	2,695,000	2,974,892
1881-2	2,662,927	3,725,384
1882-3	2,452,077	4,398,127
1883-4	2,486,137	4,031,722
1884-5	2,346,041	4,726,903
1885-6	2,447,169	

NOTE.—The Area refers to the first of the two dates opposite to which it is placed; the Imports refer to the succeeding harvest year—September 1st to August 31st.

Now, it was in 1880 that the repeal of the malt-tax took place ; a change which it was maintained by its advocates in the agricultural interest, would greatly encourage the home growth of barley. The actual result has been, however, a diminution of our own area, and an increase in our imports. It would seem that the high duty served as a bounty on the higher qualities of our own production, and that when this was removed, the greater demand for medium qualities has given an advantage to the foreign grower.

Nor has the removal of the duty led to an extended use of malt for feeding purposes, which was one of the main objects for which the repeal was strongly advocated by farmers. At Rothamsted, much careful experiment led us long ago to the conclusion that the advocacy of repeal on these grounds was illusory, and for our pains we have been accused of not being the farmers' friends! The result has, however, fully justified the view we took on the point.

Table XII. (p. 28) shows the imports of barley from different countries over the 16 civil years to 1884 inclusive. The countries are arranged in the order of their highest average supply over those years. It will be seen that both in average, and in detail in recent years, Russia is the most important source. France and Germany show fairly equal average amounts, but Germany has sent us decidedly the most in recent years. On the other hand, it is remarkable how very large was the amount sent us by France in 1872; that is just after the war,

TABLE XII.

Imports of Barley from different Countries, into the United Kingdom, 16 *years*—1869-1884.

Years	Russia	France	Germany	Turkey	Roumania	Denmark	Sweden	United States	Egypt	Chili	Other Countries	Total	Years
	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	Quarters	
1869	277,108	431,020	406,249	424,989	79,851	295,485	53,848	228	21,575	2,285	262,417	2,255,055	1869
1870	717,997	155,203	339.248	117,102	60,148	473,539	115,972	...	7,312	...	34,342	2,020,863	1870
1871	671,656	434,715	333,655	312,030	120,987	297,473	99,839	18,517	1,864	...	108,587	2,399,323	1871
1872	491,498	1,731,259	468, 322	419,777	341,109	510,852	100,223	4,944	19,609	...	125,446	4,213,039	1872
1873	313,346	551,868	318,846	813,581	234,250	238,003	50,961	4,068	4,623	3	57,949	2,587,498	1873
1874	565,421	598,196	203,919	931,582	268,485	373,337	95,613	9,016	13.516	1,826	113,001	3,173,912	1874
1875	723,956	582,891	313 394	714,996	123,133	332,567	131,275	2,158	35,746	68,792	64,945	3,093,853	1875
1876	433,305	459,780	120,776	905,983	270,061	278,325	89,737	36,000	76,361	196	65,901	2,736,425	1876
1877	419,878	532,015	725,904	1,059,773	59,448	278,605	89,111	226,072	61,608	1,247	175,006	3,628,667	1877
1878	1,351,746	128,679	882,005	287,523	299,223	519,149	128,964	303,677	...	...	62,971	3,963,937	1878
1879	692,469	175,190	1,008,144	25,004	429,516	594,371	137,488	44,386	26,406	16,899	83,095	3,232,968	1879
1880	417,610	326,249	738,317	23,391	676,951	593,168	130,493	91,937	35,071	69,761	174,533	3,277,481	1880
1881	327,018	560,331	473,846	70,550	528,398	385,534	64,156	76,681	16,792	951	241,408	2,745,665	1881
1882	1,147,256	254,712	609,150	143,736	1,601,596	297,616	155,872	13,322	13,571	1,918	112,482	4,351,231	1882
1883	1,544,774	413,200	502,576	331,254	1,248,968	210,010	111,301	33,252	26,865	14,801	172,173	4,609,174	1883
1884	1,390,366	358,753	202,869	673,017	392,339	63,525	49,305	63,465	63,095	81,697	288,413	3,626,844	1884
Mean	717,838	480,879	477 951	453,393	420,904	358,847	100,259	57,983	26,501	16,274	133,917	3,244,746	Mean

In the above Table, the Imports are given for the Civil years, not the Harvest years.

Turkey contributes very variable quantities; as also does Roumania, which gives an average of nearly one and a half million quarters in 1882 and 1883, and little more than one-third of a million in 1884. Denmark supplies more than Sweden; but upon the whole somewhat diminishing amounts in recent years. The United States send comparatively small, and upon the whole diminishing quantities in recent years; whilst Egypt and Chili send on the average less still, but considerably increased quantities in the last year for which the records are given—1884.

Conclusion.

I have now illustrated the influence of exhaustion, of manures, and of variations of season, on the amounts of produce, and on the composition, of barley.

It has been seen that its requirements within the soil, and its susceptibility to the external influences of season, are very similar to those of its near ally, wheat; but that there are distinctions of result, dependent on differences in the habits of the plants, and in the conditions of their cultivation accordingly.

Wheat is as a rule sown in the autumn, in a heavier and closer soil, and has four or five months in which to distribute its roots and get possession of a wide range of soil and subsoil before barley is sown.

Barley is sown in a lighter surface soil, and, with its short period for root development, relies in a much greater degree on the stores within the *surface soil*. Accordingly, it is more susceptible to exhaustion of surface soil as to its nitrogenous, and especially as to its mineral supplies; and in the common practice of agriculture it is found to be more benefited by direct mineral manures, especially phosphatic manures, than is wheat when sown under equal soil conditions.

The exhaustion induced by both crops is, however, characteristically that of available nitrogen; and when, under the ordinary conditions of manuring and cropping, artificial manuring is still required, nitrogenous manures are as a rule requisite for both crops, and for the spring-sown one, barley, superphosphate also.

It has been seen, that under the influence of foreign competition (and possibly in part due to the greater attention paid to meat and milk production in later years), the area under the crop has been reduced. But there is no doubt that, in addition to the soils on which it is most appropriately grown in the ordinary course of rotation, barley may be grown, both in full quantity per acre, and of good quality, in succession to wheat, on the heavier soils, when the land is clean enough for a second corn crop.

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