ROTHAMSTED RESEARCH

Malting Barley

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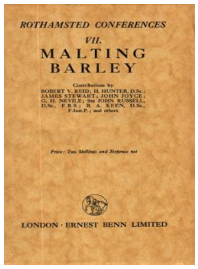

Five Years' Experiments on the Growth of Barley for Malting

Sir J. Rusell

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FIVE YEARS' EXPERIMENTS ON THE GROWTH OF BARLEY FOR MALTING

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These experiments were made as part of an extensive investigation into malting barley fostered by the Institute of Brewing. From the outset the agricultural side of the investigation has been conducted from Rothamsted, and the purpose of this has been to ascertain the influence of soil, season and manuring on the yield and quality of the grain. The method of the experiment consisted in growing a particular strain of barley on a number of farms recognized as good barley-growing farms, using the same scheme of manuring at each, but leaving the farmer free to cultivate in whatever way might be the best. The variety chosen was Plumage Archer, selected because it is probably more commonly used at the present time for malting than any other variety, and further, because it has the advantages that its heads stand up and its straw is stiff and strong. Seed from the same threshing was used at all the centres so that the results might be strictly comparable. The experiment was continued for four years without change at any centre ; it is still continuing at a selected few.

Effect of Soil, Season and Manuring on Yield

Effect of Soil.—The effect of soil is very marked, both on yield and on quality. Probably the chief factor determining yield is the ease of drying out ; they are lowest on the light sandy soils in dry districts ; they are higher, and indeed may be very high, on sandy soils in moister conditions, or where evaporation is low ; they are intermediate on the heavy loams. On the very light dry soil at Martlesham, Suffolk, the yield has varied from $7\frac{1}{2}$ to 16 bushels per acre, while on the moist sand of Dunbar it rose to 65 to 78 bushels. On the light loam overlying chalk or limestone the yields have been about 40 to 50 bushels, on the heavier loams they were less.

Effect of Season.—Barley being very sensitive to the soil tilth, it is much affected by the weather before the time of sowing. If the seed-bed is good the best seasons are those having ample rain in April, May and June, with dry sunny July and August. Up to the end of June the amount of sunshine seems to make little difference to the yield : England is apparently always sunny enough during spring and early summer for the not very exacting barley crop. Sunshine in July and

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August seems, however, to be more important. Spring drought, which is not uncommon in the Eastern Counties, where most of the barley of the country is grown, is unfavourable to yield on all soils, and may be very harmful on light sands ; on the loams, however, the crop may still recover if sufficient rain comes in time in June.

The years 1922, 1924 and 1926 were all good yielding years ; in all these the spring months were wet : 1923 and 1925 had dry springs, in both years some of the centres suffered.

Effect of Fertilizers.—1 cwt. sulphate of ammonia per acre increases the yield of barley almost every year, and at almost every centre, by about 3 cwt. (6 bushels) per acre, even when the crop followed roots fed to sheep or mangolds or sugar-beets receiving farmyard manure. The exceptions have been on the fen soils, the good Shropshire soils and, in 1922 only, the light Woburn soil, where the barley had been grown after a crop receiving farmyard manure.

Even better increases are obtained by muriate of ammonia in quantity supplying the same amount of nitrogen : some of the results are :

EFFECT OF MURIATE OF AMMONIA ON BARLEY : BUSHELS[1] PER ACRE

	Woburn 1926	*Rothamsted* 1926	*Longniddry* 1927
No Nitrogen	32·2	47·9	...
Muriate of Ammonia . .	47·1	47·7	63·6
Sulphate of Ammonia[2] . .	39·3	44·4	58·8
Advantage of Muriate over Sulphate	7·8	3·3	4·8

These increases given by ammonium salts are the most consistent of all the results.

The increased yield is due to an increase in the number of heads bearing grain, not in the number of grains per head.

Effect of Potassic and Phosphatic Fertilizers

When all the results are brought together, and averaged out, it does not appear that either superphosphate or sulphate of potash has had much effect on the yields. The figures are :

[1] Throughout this paper 1 bushel = 56 lb.
[2] 1 cwt. sulphate of ammonia = 90 lb. muriate of ammonia per acre.

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PERIOD 1922-1925

Decrease in Bushels per Acre due to Omission of	*After a Straw Crop*	*After Roots fed off*	*After Potatoes or Beets (well manured)*	*Mean of all Experiments*
1 cwt. Sulphate of Ammonia .	6·20	4·6	6·6	5·8
3 cwt. Superphosphate .	1·70	(1·1)	3·0	1·2
1½ cwt. Sulphate of Potash .	0·25	(0·1)	1·9	0·7

When, however, the figures are studied more closely, it is seen that both phosphate and potassic fertilizers have beneficial results in some seasons and on some soils, but both are very dependent on weather conditions. In each year superphosphate has increased yields at about half the centres, except in 1924, when it was less effective. At the Norfolk centres—all light loams—it has always acted beneficially, and this result is important, because Norfolk is the chief of the barley-growing counties of Great Britain. On the heavy soil of Rothamsted it acted in 1926, and still more in 1925, when a warm moist sunny May was followed by a June drought, but it was ineffective in 1922 and 1923, years of dry May and June, and also in 1924, when May was very wet: taking all the results into account, no single relation between weather and phosphate efficiency can be seen, nor is there any obvious connexion with soil type. The reason for the increased yield is an increase in the amount of tillering—an effect well seen on the Hoos field at Rothamsted. Another effect, clearly shown there, was not observed with any certainty. With the possible exceptions mentioned later, at none of the centres, not even those where the phosphate increased the yield, was there any sign of the marked hastening of ripening that is so striking a feature at Rothamsted.

The broad result is that only at the Norfolk centres would dressings of superphosphate have paid; elsewhere a profitable increase is obtained only in certain seasons. This does not mean that barley can do without phosphate; indeed the Rothamsted experiments show clearly that any attempt at phosphate starvation brings down the yield badly; this is shown by the following data, given in bushels per acre:

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Year	*Superphosphate given at time of Seeding*	*No Phosphate given since* 1904
1909 . .	40·60	36·60
1914 . .	37·32	23·27
1922 . .	37·80	20·25

There had been no superphosphate given for five years before the first barley crop was taken, and yet the yield suffered but little —only 4 bushels per acre. But the withholding of superphosphate for a second period of five years caused the serious drop of 14 bushels per acre, while further starvation brought the yield still lower.

In ordinary practice the most economical way of supplying the necessary phosphate to the barley is to give sufficient to the root crop, and, if necessary, to the seeds. Depressions in yield are recorded on the plots receiving superphosphate at Orwell in 1922 and 1924, Woburn in 1924, and Chiselborough in 1925 ; these are all light soils. The only explanation that can at present be offered is that the phosphate hastened ripening too much, and it was already rapid enough on these soils.

Potassic Fertilizer.—The effectiveness of sulphate of potash is almost entirely determined by weather conditions, there being no centre where it consistently increased the yield.[1] It was most effective in 1922, when a wet April was followed by a dry May and June, and a sunless July and August ; it then acted well at about half the centres, being as effective as nitrogen at Rothamsted, Cawkwell, Woburn and Dunbar. At Rothamsted the plants without the potash suffered during the spring drought, and by the end of June were beginning to look yellow. This beneficial effect of sulphate of potash during drought, but still more its great advantage in the sunless July and August, accord with what is known of the effect of potash on the plant. Potash increases the efficiency of the leaf as an assimilator of carbon dioxide : it thus helps to overcome the bad effect of lack of sunshine.

Another way of stating the same result is that sulphate of potash is most helpful in years when ripening is most delayed, while phosphate seemed more useful when it was less delayed. Setting out the crops in the order of their dates of cutting, which indicate approximately the order of ripening, the results are :

[1] There was no centre on the thin chalk soil, where potassic fertilizers generally act well.

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Year	Date of		Interval Days	Increased Yield given by	
	Sowing	Cutting		Sulphate of Potash	Super-phosphate
1922	Mar. 30	Sept. 12	167	+5·6	*nil*
1926	Mar. 16	Aug. 23	160	+1·7	+2·7
1925	Mar. 19	Aug. 18	152	*nil*	+4
1923	Apr. 18	Aug. 16	120	*nil*	*nil*
1924	Mar. 18	Aug. 15	150	−4·6	*nil*

If at the time of sowing the barley we could predict the date of cutting it would be possible to decide whether to give phosphates or potash in addition to the sulphate of ammonia. Neither the time of sowing, nor the number of days in the ground, shows so close a connexion with effectiveness of manure as does the time of ripening.

The sulphate of potash had no effect at most of the centres in 1923 and 1925, when April and May were dry and July was sunny. In 1924, however, a remarkable result was obtained, it *lowered* the yield. A wet May and June had succeeded a wet April, and July was very sunny. The effectiveness of the fertilizer is apparently independent of the hours of sunshine during April, May and June, but, as 1922 shows, it does depend on hours of sunshine during July and August. The results at Rothamsted are :

POTASSIC FERTILIZERS ON BARLEY AT ROTHAMSTED

Year	Effect on Yield. Bushels per Acre	Rainfall, Inches		Sunshine, Hours		July	August	Temperature, Mean		
		April	May and June	April	May and June			April	May	June
1923	*nil*	1·5	2·3	115	282	224	257	45·1	49·3	53·7
1925	*nil*	1·7	2·6	140	464	184	133	44·6	52·8	59·1
1922	+ 5·6	3·5	2·6	150	509	149	127	41·7	55·2	57·0
1926	+ 1·7	3·0	4·9	108	335	151	195	48·0	50·1	55·6
1924	− 4·6	3·2	6·6	157	391	236	169	44·8	53·1	57·7

The remarkable depression obtaining in 1924 was not confined to Rothamsted, it was seen at most centres.

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Influence of Soil, Season and Manuring on the Quality of Barley Grain

Of the various indications of quality, percentage of nitrogen in the grain is one of the best: as a general rule, grain with low nitrogen-content is of higher quality than grain with high nitrogen-content.

Effect of Conditions on the Nitrogen-Content of the Grain

The general average per cent. of nitrogen in the dry grain is 1·5, but the values range from 1·13 to 2·44.

The two most important factors determining nitrogen-content are:

(1) Place, which includes soil and the prevailing climate.

(2) Season, which expresses the weather variations between one year and another.

PERCENTAGE OF NITROGEN OF GRAIN FROM EACH CENTRE. AVERAGE OF ALL PLOTS, 1922-1926

	1922	1923	1924	1925	1926
Black Soils—					
Eye	2·13	...	...	...	...
Walcott	1·80	1·80	1·58	...	...
Light Sands (Dry conditions)—					
Orwell	1·51	1·93	1·52	2·28	...
Woburn	1·95	1·71	1·23	2·01	1·57
Light Loams (Dry conditions)—					
Wellingore (Lincoln Hth.)	1·79	1·44	1·42	1·52	1·38
Norfolk Centres	1·65 (D)	2·01 (D)	1·32 (N)	1·65 (S)	1·54 (F)
Wye	...	...	...	...	1·48
Sand and Loam (Moist conditions)—					
Chiselborough	...	1·50	1·46	1·55	1·49
Dunbar	1·44	1·71	...	...	1·53
Porlock	1·44	1·71	...	...	1·53
Medium to Heavy Loams (Moist conditions)—					
Cawkwell	1·52	1·49	1·22	...	1·69
Beverley	...	1·34	...	1·55	1·53
Rothamsted (Heavy)	1·62	1·61	1·56	1·62	1·62

D = Dereham. F = Fakenham. N = Newton St Faiths. S = Sprouston.

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The Place Factor.—High percentages of nitrogen are obtained in the black soils of Eye and of Walcott ; low percentages on the moist, stony soil of Porlock ; medium percentages on the medium and heavy loams ; and variable percentages, sometimes high and sometimes low, on the sands. Typical results are given in the Table on page 39.

The most important results are those for the light soils ; these fall into three groups :

(1) Light sandy, very dry district, therefore tending to dry out : the lightest, Orwell ; less light, Woburn. Here the percentages vary much ; at Orwell they were 1·5 in 1922 and 1924, but 1·9 and 2·3 in 1923 and 1925 respectively. At Woburn they were 1·23 in 1924 ; 1·6 in 1926 ; but 1·7, 1·9 and 2 in 1923, 1922 and 1925 respectively.

(2) Light loams in dry districts. The percentages vary less from year to year, but they still show some range : at Wellingore, on the Lincoln Heath, they were 1·79 in 1922 ; 1·52 in 1925 ; but round about 1·42 in 1923, 1924 and 1926 ; at the Norfolk centres (unfortunately it was not possible to retain one centre throughout all the period) they were 2·01 in 1923 ; 1·65 in 1922 and 1925 ; 1·5 in 1926 ; but 1·3 in 1924. At Wye, Kent, 1·7 in 1924 ; 1·6 in 1926 ; and 1·4 in 1925. At the Shropshire centres : 1·9 in 1922 ; about 1·55 in 1924 and 1925 ; but 1·36 at Eyton in 1924.

(3) Sandy or stony soils or loams in moist districts or districts of low evaporation. The percentages vary still less from year to year and the value is below the average for the above : Chiselborough (loam), between 1·46 and 1·55 in the four years 1923-1926. Dunbar (sand), 1·7 in 1923, but 1·44 and 1·53 in 1922 and 1926 respectively. Porlock (stony soil), 1·2 and 1·3 in 1925 and 1924 respectively.

On the medium and heavier loams the nitrogen-content is less variable than on the light loams. On the medium loams of the Lincolnshire and Yorkshire wolds the percentage of nitrogen shows some fluctuation. At Cawkwell (Lincs) it varies from 1·2 to 1·5 ; at Beverley (Yorks), from 1·3 to 1·5 ; on the heavier loam of Rothamsted the variation is smaller : in the five years it has varied only from 1·53 to 1·62.

The *high* nitrogen percentage is associated with dry conditions in May and June, while the *low* nitrogen percentage is associated with wet May. This rule is found to hold at all centres : it is seen most clearly at Orwell and Woburn, where the percentage of nitrogen is most variable, but it also holds where the variations in nitrogen percentage are quite small, as at Chiselborough. At Orwell, 1925 and 1923 are years of high nitrogen percentage, with dry May and June, while 1922 and 1924 are years of low nitrogen percentage and wet May and June. At Wellingore the year 1922 stands out sharply from the rest with a severe May and June drought and a high nitrogen percentage. In the other years the nitrogen varies but little from the 1924 figure ; in each of these the May rainfall is of the same order.

Time of Sowing.—There is, however, another factor that affects the

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nitrogen-content on light soils, but not so much on heavy ones—the time at which the barley is sown ; the *high* nitrogen-content being associated with the *late* sowing and the *low* nitrogen-content with *early* sowing.

The dates of sowing on the light soils of the preceding Tables are :

Year	*Nitrogen per cent.*	*Walcott*	*Wellingore*	*Dates of Sowing*		
				Cawkwell	*Woburn*	*Orwell*
1922	High	Apr. 3	Mar. 22	Apr. 24	Apr. 19	Apr. 29[1]
1924	Low	Mar. 10	Mar. 13	Mar. 25	Mar. 11	Apr. 7

From the foregoing it appears that the percentage of nitrogen in the grain is, in the main, determined by June, and it should not be impossible to devise means whereby an estimate could be made then of its probable amount.

The effect of fertilizers on nitrogen-content is less than that of either soil or season. The effect of nitrogen fertilizers is, perhaps, the most important : it varies with the size of the dressing. In small quantities sulphate of ammonia lowers the nitrogen-content of the grain. There is a certain size of dressing that has little or no effect on nitrogen-content ; larger dressings increase it. This safe or harmless dressing of sulphate of ammonia is larger when superphosphate and potassic sulphate are given than when the sulphate of ammonia is given alone, and even when these fertilizers do not increase the yield they may ensure against a fall in quality. Of the two, potassic fertilizers seem to have the most potent effect in lowering the nitrogen percentage.

Valuation of Barley

The valuation put on the barley by the buyer seems to depend more on the soil and the climate than on anything the farmer can do. Although most soils can produce good sound barleys in certain seasons, only the light loams produce high-priced barleys every year, and even on these the barley of any particular farm may have low value because of damage at or after harvest. Barleys grown on light sands may be valued higher or lower than those grown on loams. There is a wide variation from season to season—in some years they are valued higher than the valuation of the malt appears to justify. Barleys grown on chalk loam may be valued below what their malting history justifies. On the average the barley buyer comes out right, but the chalk farmer may lose.

[1] 1925.

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The justification for paying so much attention to the nitrogen-content of the grain is that it is closely related to valuation. The higher the nitrogen-content of the grain the less the buyer will pay for it, and a comparison of the analytical figures with the valuation shows that the buyer may deduct as much as 2s. 9d. per quarter for an additional 0·1 per cent.—one-tenth of 1 per cent. The high nitrogen barley has the disadvantage of giving a low extract in the malt, and also of leading to certain fermentation troubles ; hence the brewer prefers a grain with lower nitrogen-content.

THE DISCUSSION

Lieut.-Col. Sir Archibald Weigall, Chairman of the Conference, in opening the proceedings, stated that the barley crop, if successful, was one of the most profitable crops for an arable farmer. It was most essential that growers and buyers should come to a thorough understanding with one another, and this especially applied to districts, since the requirements of buyers in one district differed from those of another. Any information therefore which could be given, both with regard to the cultivation and manuring of the crop, would prove of the utmost value. In referring to land under cultivation for barley, Sir Archibald remarked that it was a significant fact that the average return of sugar-beet was increasing each year.

Dr E. S. Beaven (Warminster), in referring to phosphatic and potassic fertilizers, said that it was not the usual practice of growers to apply these to their barley, for the reason that they had in all probability given the root crop a good dressing of both. What they more often did apply was either sulphate of ammonia or nitrate of soda. The results of the manurial experiments described by Sir J. Russell had been generally confirmatory of the conclusions drawn by Munro and himself thirty years ago, which were based on examination of Rothamsted samples grown in Agdell field. The permanent plots on Hoos Field at Rothamsted were primarily a demonstration of the effects on the crop of phosphatic starvation, and showed clearly that such starvation was inimical to malting quality. With reference to the experiments on the use of ammonium chloride, he wondered whether there would be any deleterious effect after a certain time. The general effect of acid-soil conditions on barley was such that he felt more attention should be given to the study of the effects of lime and chalk. Locality and climate were probably the two most important factors in the growing of barley. There was no such thing as a best barley, but some varieties responded better on some soils.

Mr F. Rayns (Norfolk Agricultural Station) stated that on his farm, and also on many farms in Norfolk, the application of phosphatic

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