JOINT MEETING OF THE MIDLAND COUNTIES SECTION AND OF THE BIRMINGHAM SECTION OF THE SOCIETY OF CHEMICAL INDUSTRY, HELD AT THE UNIVERSITY, EDMUND STREET, BIRMINGHAM, ON THURSDAY, APRIL 27TH, 1922.

Professor A. R. LING, M.Sc., F.I.C., in the Chair.

The following paper was read and discussed :—

The Barley Crop. A Study in Modern Agricultural Chemistry.

By E. J. RUSSELL, D.Sc., F.R.S.

I HAVE selected barley as my subject because of its intimate association with the vigorous School of Brewing at this University, and because we ourselves at Rothamsted are now devoting considerable attention to it. It is one of the oldest of the cereal crops, and was cultivated at least 3,500 years ago by the ancient Egyptians and the early Jews: in Exodus we read that "the wheat and the barley were smitten" during the Ten Plagues. In this country it has been grown since Neolithic times. The history of barley is a fascinating subject, but it is not one with which I can deal.

Barley is to-day probably the most widely spread of the cereal crops and grows under conditions in which wheat will not thrive. There are good Scottish agriculturists who have not seen wheat growing, but none who are unfamiliar with barley. It can be found from the Arctic Circle to the Equator. It is still much used for human food, although to an Englishman's taste it is not as palatable as wheat. In this country, therefore, it is used either for malting or for cattle food. If it can be sold to the malster it is, and farmers have tried with considerable success to satisfy the maltsters' rather ill-defined requirements. Moreover, while the cultivation of wheat in this country has shrunk considerably since the early eighties (apart from an upward flicker in war harvests of 1915, 1918, and 1919), that of barley has fallen off much less, both relatively and absolutely (fig. 1), and we are much more nearly self supporting in the case of barley than of wheat (fig. 2).

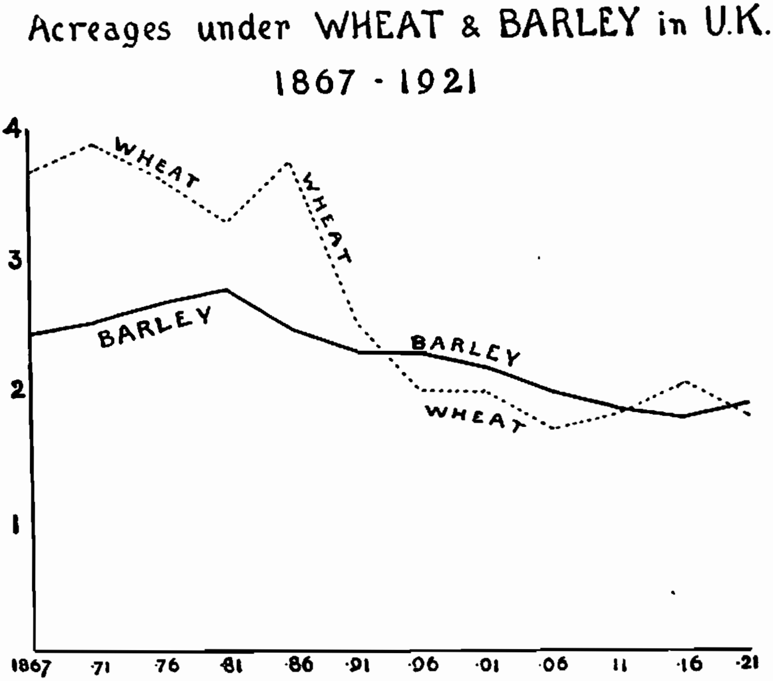

FIG. 1.

The average yields are as follows:—

Ten Years 1910—1919.

—	Bushels of grain per acre.		Weight per bushel.*		Weight of grain per acre.	
	Wheat.	Barley.	Wheat.	Barley.	Wheat.	Barley.
			lb.	lb.	lb.	lb.
England	30·7	31·2				
Wales	27·8	30·5				
Scotland	39·5	35·1				
Ireland	36·6	42·4				
Average U.K....	31·1	32·7	61·9	53·7	1,925	1,756

* The average actual weight is given here. It should be noted, however, that

The average yield shows England inferior to Scotland or Ireland, but there is a considerable difference in total acreage, England having

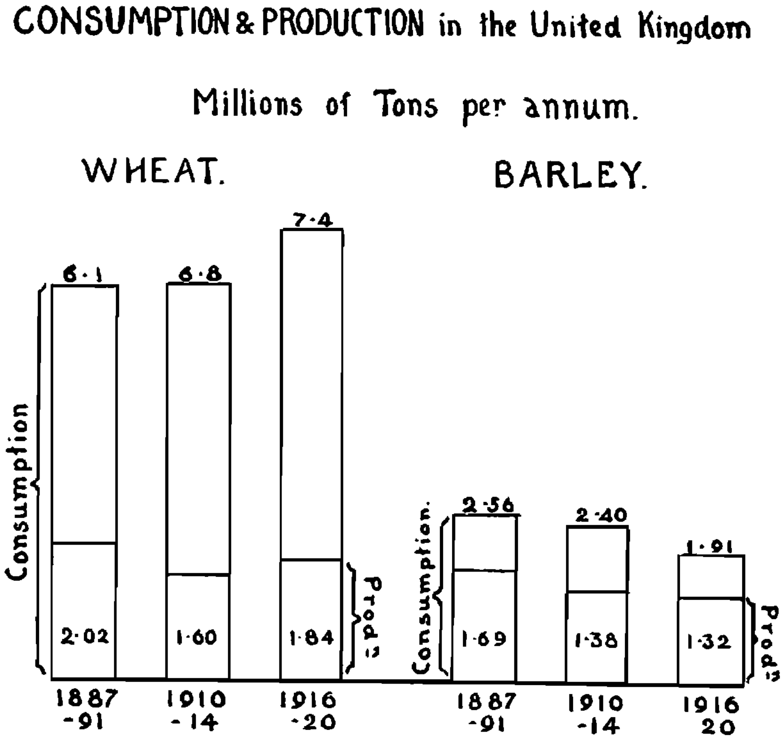

FIG. 2.

nearly 2,000,000 acres under wheat and nearly 1,500,000 acres under barley, while Scotland and Ireland have each of them only about

the word "bushel" is ambiguous, and is used in agricultural statistics in the following senses:—

—	Official statistics. A definite volume having the following average weight.	Corn Returns Act. Volume occupied by following weight.	Grain Prices Order. Volume occupied by following weight.	Frequent Practice. Volume occupied by following weight.
	lb.	lb.	lb.	lb.
Wheat ...	61·9	60	63	63
Barley ...	53·7	50	55	56
Oats	30·3	30	42	42

60,000 acres under wheat, and about 200,000 under barley. Only the most suitable soils and localities are utilised for these crops in Scotland and Ireland, while a much wider range is used in England.

Barley has certain properties in common with wheat. Both are grown for the sake of the grain, and both flourish best in relatively dry conditions. Thus the map showing the distribution of barley in England is, like that of wheat, very much like an inversion of the rainfall map. Barley is most important in Norfolk where it occupies no less than 15 per cent. of the cultivated land.* It is also very important in Suffolk, Lincolnshire, Rutland, Cambridge, and East Yorkshire, where it occupies between 9 per cent. and 14 per cent.—all counties of low average rainfall. Of the wetter counties, Cornwall, Pembroke, and Cardigan alone have more than 5 per cent., and the remaining counties have much less, of their cultivated land in barley; even in these three the barley is really a different crop from that in the east, as it is generally ground for cattle food and only occasionally sold for malting. In Ireland also the distribution of barley depends on the rainfall, and the crop is important only in the drier easterly and midland counties: Carlow, Kildare, Kilkenny, Offaly, Louth, and Wexford in Leinster: East Cork and North Tipperary in Munster; it is grown to a much smaller extent in Galway (Connaught), and Down (Ulster). Probably, however, it is presence of sun rather than absence of rain that determines the good crops.

In other characteristics it differs from wheat as a farm crop. Its general habit of growth suits it for light soils, while wheat is most suited to heavy land. Moreover, its place in the rotation differs, it being sometimes taken after wheat and sometimes after roots fed on the land.

In this country it is practically always spring sown, while wheat is autumn sown: at Rothamsted its growing period is about 150 days (from April 1st to August 20th), while that of wheat is about 290 days (from the end of October to the middle of August). Perhaps in consequence of this shorter period it yields less straw and not quite as much grain per acre as does wheat. The difference in yield of grain is less than might have been expected since barley is a very economical crop, in that it puts a larger proportion of its substance into the grain and less into the straw, than do most other cereals (fig. 3). The result is not an unmixed advantage, for the barley straw is almost worthless, while wheat straw has some value, and oat straw still more.

* *I.e.*, land in cultivation, including grass and arable.

When agricultural chemists began experimenting with barley the first problem they attacked was that of yield. The earliest important work was at Rothamsted by Lawes and Gilbert, who in 1852 laid out Hoos Field into plots and began the famous experiment which has been continued on exactly the same lines ever since. They had already had

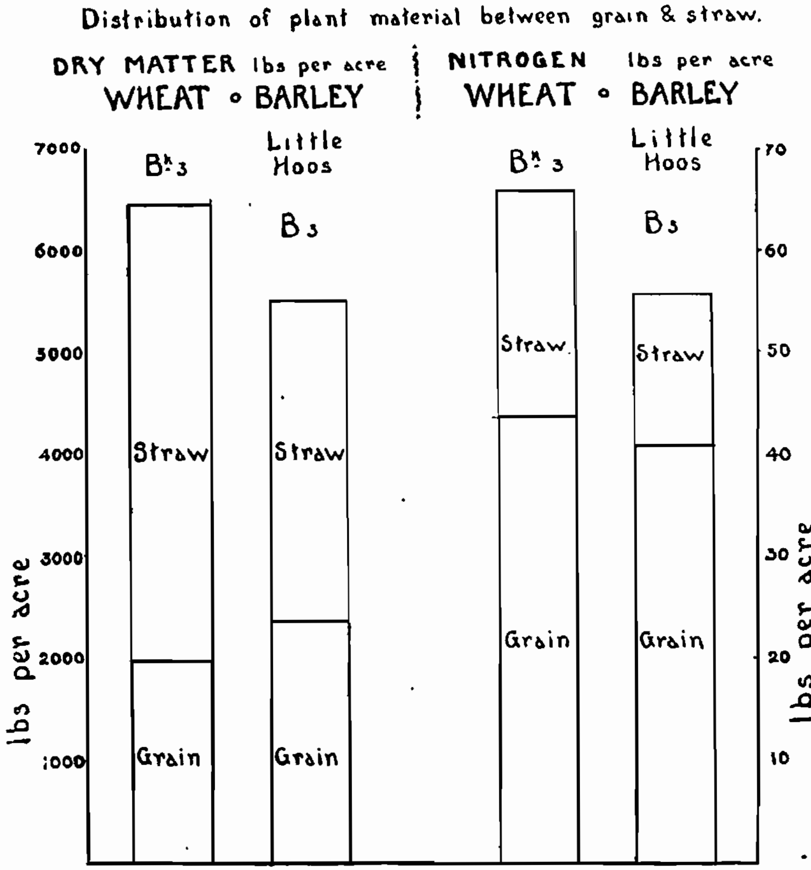

FIG. 8.

ten years' experience of field experiments, and on the more famous Broadbalk wheat field had shown that farmyard manure could be replaced as a fertiliser by compounds of the three elements—nitrogen, phosphorus, and potassium—which they had shown to be its important nutrient constituents. The result was that they were able to raise the yield of barley from under 30 bushels to more than 50 bushels per acre, simply by addition of the so-called artificial fertilisers—potassium sulphate, calcium phosphate or superphosphate, and ammonium sulphate or sodium nitrate.

Barley Experiment. Hoos Field, Rothamsted, 1*st Four Years,* 1852—55.

	Barley (bushels per acre).
No manure	29·8
Farmyard manure	44
Complete artificial fertilisers:	
Using nitrate of soda	50·5
Using sulphate of ammonia	47

This was a great achievement and it played a great part in the development of the artificial fertiliser industry, an industry which began in a barn at Rothamsted in 1843 and has since expanded to enormous dimensions.

More detailed observations revealed certain specific effects of these nutrients on the barley plant. Lawes and Gilbert soon found that the nitrogenous manures caused vigorous growth and gave a healthy green colour to the leaf; phosphates induced a greater root development and hastened ripening; and potassium salts were in some way associated with grain development. All these phenomena have become commonplaces among agricultural experts. But although the facts are well established, it must be admitted that we know very little about the physiological action that goes on. Nitrogen and phosphorus are equally necessary for the growth of the plant; both enter into the composition of the protoplasm, the nucleus, etc., yet their compounds produce strikingly different effects on the plant.

The continuation of the original experiments year after year at Rothamsted, has brought out phenomena which were not seen in the earlier years. One of the most striking is that the yields on the plots have steadily fallen. The fall is most marked on the plots receiving artificial manures only: it is much less, though quite distinct, on the plot receiving farmyard manure each year. This can be seen by plotting the yields on a curve, or better still by a distribution table, showing the number of times in each ten-year period that crops of a certain size were obtained. In the early years crops exceeding 50 bushels per acre were common, and crops below 30 bushels per acre were rare; in later years the plots receiving complete artificials have commonly given only 30—40 bushels, and have even fallen below 20 bushels. Farmyard manure has maintained productiveness much better, though even here there is a falling off. (Table I.)

TABLE I.—*Barley. Hoos Field. Complete Artificials* (4A.)
Number of Occasions when Yields were obtained.

Year.	Bushels per acre.					
	60—70.	50—60.	40—50.	30—40.	20—30.	10—20.
1852—1861.........	1	3	3	3	—	—
1862—1871.........	—	2	6	2	—	—
1872—1881.........	—	2	3	4	1	—
1882—1891.........	—	2	4	3	1	—
1892—1901.........	—	1	4	2	3	—
1902—1911.........	—	1	3	5	1	—
1912—1921.........	—	—	1	5	1	1

Barley. Hoos Field. Farmyard Manure (72).
Number of Occasions when Yields were obtained.

1852—1861.........	—	5	2	3	—	—
1862—1871.........	1	4	5	—	—	—
1872—1881.........	2	3	3	2	—	—
1882—1891.........	1	3	5	—	1	—
1892—1901.........	—	3	5	1	1	—
1902—1911.........	—	3	4	2	1	—
1912—1921.........	—	1	2	3	2	—

There is no obvious explanation of all this; the fertiliser and the soil between them contain ample quantities of all the recognised plant nutrients, and the cultivation and other operations are all as well done as ever; the seed also is quite good.

Several possibilities are being investigated. It is conceivable that the seasons have steadily deteriorated since 1871, but we have no real evidence of this. It has been supposed that plants excrete poisons, but again no evidence can be found. It is possible also that the usually accepted list of plant nutrients is incomplete, and that for complete development other elements are needed, though in small quantities only. This view finds considerable favour in France; Bertrand showed that manganese was beneficial, and Mazé has boldly added to the list of essential or favourable elements boron, fluorine, iodine, chlorine, aluminium and zinc. Dr. Brenchley, at Rothamsted, has confirmed the beneficial effect of manganese and boron in small quantities, though in both cases larger quantities do harm. The observed facts could in part be explained in this way: the falling-off in crop from artificials only could be attributed to the absence from the sulphate of potash, superphosphate, and sulphate of ammonia of the requisite small quantities of these substances, and the exhaustion of the stocks originally present in the soil; while the longer continuance of yield from farmyard manure could be attributed to the amounts held in the straw from which the manure is made.

There are, however, difficulties in this view, and there are other possibilities. Soil is known to possess fairly well marked colloidal properties, and these would be disturbed by the systematic additions of electrolytes such as the artificial fertilisers. (Again there are difficulties.) Whatever the explanation the phenomena are of great importance in agricultural science, and they are being systematically investigated at Rothamsted.

It would be a very serious thing for British agriculture if the yields of barley on ordinary farms were falling off as they are on the experimental plots of Hoos Field, and fortunately this is not happening. Indeed, the yields for the country, as a whole, are seen to be rising, for whereas in the sixties—the great years for Hoos Field—the yields of Chevalier are described by experts of the day as 36 to 40 bushels, they were just before the war put at 24 to 48 bushels. The official statistics of yields in the United Kingdom unfortunately begin only in 1887, and they include all growers and all kinds of barley, but they also show a slight rise:—

1887—1896	33·16 bushels per acre.
1897—1906	33·64 ,, ,,
1907—1916	33·67 ,, ,,

The discrepancy is more apparent than real, since the conditions on a working farm differ from those on the experimental field. Whatever the explanation, we can only say that the yield falls off when barley is grown continuously on the same land in Hoos Field and fertilised always in the same way, but it does not appear to fall off when grown in a rotation where the cultural and manurial treatment vary from year to year.

Meanwhile, however, much empirical knowledge has been gained of the manuring of barley, and when all is done that is possible on our present knowledge, the yield rises to about 50 bushels per acre in place of the average 33·6; the highest substantiated yield I have met with was 80 bushels. This highest figure, however, cannot be reproduced at will, and was obtained through a fortunate concurrence of favourable conditions, but it represents the figure at which agricultural investigators should aim, since they know it can be done.

There are two potent factors which prevent the yield of barley on the best farms from reaching its highest recorded value—season and strength of straw. Under constant manurial and other treatment, the straw is strong in some seasons and weak in others; sometimes it will stand up well, thick-set with grain, and able to carry even a large crop; sometimes, on the other hand, it is weak, and readily beaten down if the crop is heavy. Farmers, therefore, do not aim at the highest crop obtainable, but at the highest that they believe will be carried by the straw, and they allow themselves a margin of safety.

There is no problem in modern agriculture so much in need of serious study as this of the strength of straw. It is partly physiological and partly genetic; there is some empirical knowledge as to the conditions favourable to the production of strong or of weak straw, but no certain knowledge as to the cause of the variations in strength. They may be due to changes in the chemical composition of the cell walls or the fibres, to some mechanical rearrangement of the tissues, or to the degree of turgidity of the cells—in other words, the osmotic pressure of the cell sap. Apparently, the disposition to be strong can be bred into or out of barley. The stiffness of *Hordeum inerme* (practically the only stiff-strawed variety), segregates out in its offspring when it is crossed with other varieties. Stiff-strawed types therefore seem possible; but if, as is also possible, stiffness is not a simple Mendelian character, but a complex involving coarseness of grain, the grain will be offset by loss.

So far as yield is concerned, the agricultural chemist is ahead of the botanist and the agriculturist, and the rate of progress is now determined by the plant-breeder and depends on his success in producing new varieties equally suitable to the market with the present sorts, but possessing stronger straw. As soon as these new sorts are available the farmer will no longer need so large a factor of safety; he will be able to aim at higher crops, and the agricultural chemist is in a position to tell him how to obtain them.

If straw could be made of any desired strength, there would still remain several limiting factors. Lack of rainfall would certainly be one, but this in part could be overcome by devices familiar to the agriculturist. A more serious defect is temperature, with which we can deal only in a limited way by raising varieties of shorter growing period. Assuming it possible completely to overcome all terrestrial limiting factors, it is interesting to speculate as to what would happen. We should then be limited by the power of the plant to utilise the supply of sunlight. This power might be considerably increased, and finally we should be up against the amount of sunlight as the absolute final limit, which we could see no way to overcome. If plants utilised all the radiant energy received from the sun during the four growing months—April to July—we could obtain phenomenally large crops.

—	Dry matter produced (tons per acre).
Barley: grain and straw—	
Average U.K.	3
Good farmers	6
Mangold: root and leaf—	
High yields	20
Theoretically attainable if efficiency of plant as transformer of sunlight energy were 100 per cent.*	176

* Hertsprung's value is here taken: radiant energy of wave-length less than 1μ from March 22nd to September 22nd, being on an average 285,000 large calories per square metre. Taking two-thirds of this figure, since the growing period is 4 months only, the energy received per acre

$$= 2/3 \times 285{,}400/0{\cdot}00024 = 790 \times 10^6.$$

The energy in 1 ton of dry matter is $4{\cdot}5 \times 10^6$ calories, therefore the number of tons theoretically possible = $790/4{\cdot}5 = 176$. A value of 290 tons is obtained by using Abbot's estimate of solar radiation = 11,700 joules per sq. cm. per day, the total amount received in 4 months per acre = $1{,}300 \times 10^6$ large calories. The theoretically attainable crop is therefore $1{,}300/4{\cdot}5 = 290$.

I have dwelt so long on yield, partly because of its great agricultural importance, and partly because it is the factor which is more easily under control than any other. But from the maltster's point of view quality is the chief factor. Whatever may be the causes determining quality, we may be sure it is ultimately a question of chemical composition. A vast mass of data has been assembled showing the percentage of nitrogen and of ash in the grain, and their variation from season to season.

The percentage of nitrogen in the grain does not appear to be much altered by the scheme of manuring, provided the conditions are not rendered too abnormal. This is well shown in Table II, and is probably explained by the circumstance that additional nitrogen in the soil, while it passes into the plant, allows of additional carbohydrate production, unless some unfavourable circumstance prevents this, so that the percentage of nitrogen does not necessarily increase, and may even decrease. It is, however, quite easy to increase carbohydrate production without increasing the nitrogen-content of the soil, and *this is* done by adding potassic and phosphatic fertilisers. The nitrogen in the grain here shows a falling off—not, however, a large one, because these fertilisers do not as a rule increase the crop as greatly as does nitrogen.

TABLE II.—*Percentage of Nitrogen and Yield of Barley Grain. Hoos Field. Rothamsted.*

(1893 dry hot season, reduced yields; 1894 moister season, higher yields.)

—	Yield in bushels (per acre).		Weight per bushel (lb.).		Nitrogen in grain (per cent).	
	1893.	1894.	1893.	1894.	1893.	1894.
Farmyard manure.........	43·4	44·6	57·3	52·4	2·23	2·00
Complete artificials (sulphate of ammonia)	30·8	41·4	56·3	54·1	2·08	1·44
No potash	18·8	34·9	54·0	51·9	2·13	1·60
No phosphate...............	16·8	17·1	55·8	51·5	2·17	1·61
Nitrogen only	11·6	10·4	55·1	50·4	2·19	1·65
No manure.................	8·3	10·0	55·6	51·1	1·90	1·41

Other Experiments.

—	Archer.		Spratt-Archer.	
	Bushels (per acre).	Nitrogen in grain (per cent.).	Bushels (per acre).	Nitrogen in grain (per cent.).
Irish results—				
1919	49	1·33	52	1·30
1920	39	1·72	45	1·64
1921	44	1·74	46	1·70
Olympia Agric. Co.—				
1920	37	1·57	42	1·51
1921	45	1·46	46	1·40

But the percentage of nitrogen is much more altered by climatic or seasonal factors. Lack of sunshine, low temperature, and other factors unfavourable to growth all tend to high nitrogen-content of grain; whilst good growing conditions—adequate warmth and moisture up to the time of flowering, followed by drier, warmer conditions during maturation, tend to a lower nitrogen-content.

As a general rule, when the crop is above the average for the particular field, the percentage of nitrogen tends to be lower than usual, and when the crop is below the average it tends to be higher. This is illustrated in Table II, where the yields from the Hoos Field are given for 1893—a drought year of lower yields—and for 1894—a wetter, but better growing year.

The result is that the total amount of nitrogen in the crop varies less than the total amount of non-nitrogenous, or in other words, carbohydrate material. This is quite in accordance with the well known fact that plants take up their nitrogen in the early days of their life while they make their great increase in growth later on. It is, however, necessary to guard against an assumption which is often made, but we believe in error. It is often stated that during ripening plants first send to the grain their nitrogenous constituents and then carbohydrates. It is argued that a backward season, therefore, finds the nitrogen translocation more nearly completed than that of the carbohydrates and hence a larger percentage of nitrogen.

The question has been carefully studied at Rothamsted, but the evidence is all against this view. Hall and Brenchley showed that the ultimate composition of the grain varies but little from its earliest formation to complete maturation: the raw material sent into the grain seems to be of uniform composition from start to finish. It seems simplest to recognise that the nitrogen and the carbohydrate enter the plant through different doors, and that the intake of nitrogen depends on the concentration of nitrates in the soil, while that of carbohydrate is regulated by the season, but that nitrogen compounds and carbohydrates pass together into the grain, so that the constituents of the grain are largely settled by the time ripening begins.

This view affords a satisfactory explanation of many of the observed facts. In Table II omission of potash from the manure has no visible effect on ripening nor on nitrogen intake, though it distinctly depresses carbohydrate formation; in consequence, it raises the percentage of nitrogen in the grain. So in the Irish experiments the variety Spratt-Archer is rather more efficient in producing carbohydrate than is Archer (as shown by its heavier yield), and therefore, under comparable conditions, including similar nitrate concentration in the soil, it contains a lower percentage of nitrogen in the grain. And generally one may say that any factor which increases carbohydrate production in the leaf without correspondingly increasing the nitrate concentration in the soil tends to lower the percentage of nitrogen in the grain. This also explains why the effect of season is more marked than that of manuring. In a cold unfavourable season the plant is unable to make carbohydrate corresponding to the amount of nitrogen it has absorbed from the soil; the compensating action above described is therefore checked and a grain of high nitrogen-content results.

It must not be supposed, however, that the composition of the grain is uninfluenced by the weather at ripening. The raw material is built up in the grain into more complex substances, and changes continue even after the grain is threshed out and sold. These are called post-ripening changes.

Time does not allow of a full discussion of the ash constituents, but probably the same general relationships hold also. Similarly the effect of *season* is greater than that of variety, while the effect of *soil* is also great.

Unfortunately, no other constituents of the grain have been determined sufficiently frequently to allow of any discussion of their relationships to soil or climatic factors.

Finally, we turn to the much more difficult question of the factors determining the malting quality of barley. An admirable review of the very extensive literature of this subject has recently been made by H. F. E. Hulton (this Journ., 1922, 33—142). From the grower's point of view, it cannot be said that much has been added to our knowledge since the classical work of J. M. H. Munro and E. S. Beaven (*Journ. Roy. Agric. Soc.*, 1897, **58**, 65; 1900, **61**, 185) or H. T. Brown.

In general the various soil and climatic conditions affect malting quality in almost exactly the same way as they affect the nitrogen-content of the grain. Indeed, in the extensive experiments carried out by the Irish Department of Agriculture, in close connection with Guinness's Brewery, the nitrogen-content is generally used as the index of malting value.* This view is so commonly adopted that we must regard it as fitting in tolerably well with the maltster's experience. But until the relationship is proved it is not safe to assume that high nitrogen-content of the grain *causes* low malting or brewing value. It is quite possible that the relationship resembles that between nitrogen-content and yield, a low percentage being associated with favourable conditions in the second part of the plant's life, and therefore high

* See the admirable summary of the Irish Experiments in *Journ. Dept. Agric. Ireland,* 1913, No. 13.

yields; and a high one with unfavourable conditions, and therefore low yields. If we accept Munro and Beaven's description of a good malting barley—one having a large proportion of endosperm to embryo, and an endosperm amenable to modification—we seem compelled to associate these with favourable conditions during the second part of the plant's life, and this necessitates a low percentage of nitrogen. In such cases, therefore, the low percentage runs with high malting quality, but is not causally connected with it. This is shown in the Hoos Field results of Table III:—

TABLE III.—*Effect of Manures on Quality of Barley.*
Hoos Field, Rothamsted, 1889—1902.

—	Maltsters' valuation.	Bushel weight.	Weight of 100 corns.
		lb.	grms.
Farmyard manure	96·4	54·6	4·47
Complete artificials (N.P.K.)	104·3	53·8	4·21
No potassium	92·6	52·2	3·86
No phosphate	93·8	53·3	4·14
Nitrogen only (ammonium salts)	91·1	52·3	4·03
No manure	97·3	52·4	3·67

The plot receiving complete artificials, as shown in Table II, gives the highest yield and a low percentage of nitrogen, the conditions are favourable to good growth; it is seen in Table III that, in the maltster's valuation, it is the highest of the set. The unmanured also has a low nitrogen percentage; there had been only small intake of nitrogen and a correspondingly small yield of grain, yet the individual grains developed quite normally. But the plants under abnormal nutritional treatment (no potassium, no phosphate: nitrogen only), while taking in the normal amount of nitrogen, are unable to make the normal growth afterwards, hence the percentage of nitrogen remains high, and also the malting quality is low.

But we must remember that a low percentage of nitrogen in the plant is not necessarily associated *only* with favourable conditions in the second period of growth, but may also arise from a low intake of nitrogen in the earlier days of its life. This is well seen in Table IV.

In the first two plots (yielding 13·6 and 15 bushels respectively), the soil treatment is so exhausting that nitrogen intake is seriously hampered; there is, therefore, a lower percentage in the grain than in the last two plots where more nitrogen is available and therefore a much greater intake occurs. But the conditions in the latter part of the plant's life are much more favourable on these plots as shown by their higher yield, and therefore they have a higher malting value in spite of their higher nitrogen content. The differences are not great, but they are probably real.

The case shown in Table III is, however, the usual one in farm practice, but the fact that this second cause for low nitrogen percentage is unrelated to malting value probably accounts for many of the discrepancies recorded in the literature.

TABLE IV.—*Percentage of Nitrogen and Valuation. Agdell Rotation Experiments, Rothamsted. Five Seasons.*

Nitrogen in grain.	Valuation.	Treatment.	Yield (bushels per acre).
1·48	28/7	Minerals only. No nitrogen. Roots carted: Fallow.	13·6
1·56	27/10	No manure. Roots carted: Fallow	15·6
1·56	29/—	Minerals only. No nitrogen. Roots carted: Clover.	19·9
1·58	29/11	Minerals only. No nitrogen. Roots fed on land: Clover.	28·9
1·69	29/6	Complete fertiliser. Roots fed on land: Clover.	34·1

Fortunately the far-sighted action of the Institute of Brewing in setting up a Research Scheme has made it possible to begin a close investigation of the relationship between malting quality and agricultural conditions. Plots have been laid out on a number of good barley farms in good barley districts, and they are treated in accordance with the following scheme:—

Five Plots.

1. No manure.
2. Complete artificials: 1 cwt. sulphate of ammonia, 3 cwts. superphosphate, 1½ cwts. sulphate of potash, per acre.
3. Artificials without potash: 1 cwt. sulphate of ammonia, 3 cwts. superphosphate, per acre.
4. Artificials without phosphate: 1½ cwts. sulphate of potash, 1 cwt. sulphate of ammonia, per acre.
5. Artificials without nitrogen: 3 cwts. superphosphate, 1½ cwts. sulphate of potash, per acre.

Seed from the same stock (Plumage-Archer) is being used throughout.

The yields will be recorded and the resulting samples of barley will be fully examined by a competent malting chemist for the following properties:—

(*a*) Empirical valuation of barley.
(*b*) Determination of nitrogen and moisture.
(*c*) 1,000 corn weight.
(*d*) Blaber cupboard process of malting.
(*e*) Full analysis of the extract of resulting malting samples.

The results will give information of great value on the effect of fertilisers on the yield and quality of barley, and in particular we hope they will settle a vitally important agricultural problem—whether the farmer, if he manures properly, can safely aim at the highest crop that will stand up, or whether he must aim at something less, if he wishes to maintain a high quality. We can go a long way towards settling this difficult matter of manuring malting barley.

A more difficult problem on which we shall obtain information, though we may not for some time get much further, is the influence of soil and season on malting quality. It would be of great value to have more records, such as those published by Mr. James Stewart (this Journ., 1917, **23**, 169; 1921, **27**, 296; *Journ. Oper. Brewers' Guild*, 1922, **8**, 55), giving particulars of season and quality. It will be a distinct step if we can prove, what is generally accepted, that good malting quality is the same thing as favourable growth and maturation in the second part of the plant's life; if we can prove this it makes a bridge between the maltster and the plant physiologist; they will both be studying the same thing, though from different points of view and using a different language. Whether we can ever control or counteract these factors is another matter; our present purpose is to gain the information and make sure that our supposed facts really are correct.

Further, we hope to study the effect of variety on malting quality and thus to be able to advise farmers which of the different varieties now existing or to be produced in the future will prove best for them and for the maltster. There are undoubtedly great possibilities here as shown by the comparison between Archer and Spratt-Archer (p. 707). Improvements have already been effected by this means.

Finally, we hope to make an attack on that very difficult problem, the chemical characterisation of a good malting barley. For the final solution we must no doubt await advances in biochemistry. But the valuable work now being done by Professor Ling and others is gradually clearing away the difficulties, and we may yet find the end of the problem in sight.

One thing more the Research Scheme has done, and this alone would justify its existence: it has for the first time set up a co-operation which it is hoped will be permanent between the maltster, the barley grower, the expert malt and brewing chemists, and the expert in agricultural science. It includes some of the best known men in the malting and brewing industries. The amount of knowledge on the subject is very great; and if we can collate, examine, and systematise it we shall have achieved something well worth the effort.

Discussion.

At the invitation of the Chairman, the President of the Institute of Brewing (Mr. Field) opened the discussion. Mr. Field said he was pleased he had been able to induce Dr. Russell to take the Chairmanship of the Barley Committee of the Research Scheme of the Institute. With Dr. Russell's assistance in co-ordinating the work, there would now be an opportunity of bringing scientific knowledge to bear upon the farmer, and he hoped that they would no longer be liable to the accusation that the farmers did not know what the brewers wanted. He believed that, in the course of a few years, with patient study and the support of the Institute, they would be able to tell the farmers what brewers did want, and show them that what they wanted could be produced with profit to themselves.

Mr. Reid said that the lantern slides indicating the variations in rainfall suggested to him that the yield per acre was largest in those parts of England which were less favoured with a dry climate and where the rainfall was heavy. The larger yields in Scotland and in Ireland seemed to support such a view. It was significant that over a period of years the yield was definitely downwards, and he wondered whether the explanation was that there had been a deterioration in the seed. When visiting Rothamsted, it was impossible not to be impressed with the scientific and practical work which was being carried out there. With the invaluable assistance which the Barley Research Committee of the Institute of Brewing was receiving from Dr. Russell, he could assure them that, during the coming season, important results could confidently be expected.

Mr. S. K. Thorpe asked whether there were any statistics available showing the consumption of barley in this country as between brewing and feeding purposes. He thought the real basis of the market value of barley depended upon the world's demand for it for feeding purposes. Dr. Russell had called attention to the increased *yield* per acre when nitrate of soda was used as an artificial manure. Could he supply them with any information as to what was the relative value of the barley so produced, because his (the speaker's) experience was that, while the yield was increased, the barley was highly nitrogenous, and almost useless for malting purposes.

Mr. W. H. EVANS said he believed that, some years ago, a method of electrolysing seed was patented, and inquired if Dr. Russell had conducted any tests or experiments with the view of ascertaining the effect of such treatment.

Mr. COLLETT said he believed there was a process by which the seed was placed in a solution of certain salts, through which a low voltage current was passed. He had seen a wheat crop which had been so treated, and there was a distinct improvement in the crop.

Mr. RUDGARD asked how long artificial manure maintained its strength in the ground. The modern farmer was trying deep ploughing, and he would like some information as to whether that deep ploughing brought up the artificial manure in such a way as to benefit the barley crop. He was very glad to hear of the progress being made in the direction of strengthening barley straw, because weakness had been one of the biggest drawbacks to the farmer in using artificial manures for barley crops. Two-thirds of the farmers who grew barley sowed clover seed, to get a clover crop next season. If a farmer used artificial manure on that crop, he would get his young clover seeds too high in the corn, and, as a result, the clover seeds would be anything up to a foot high in the barley, and he could not avoid cutting the clover with it. If it happened to be wet, the barley had to be carried with the green clover in it. It was stacked in the rick in bad condition and the grain in the rick became heated. The barley root was a shallow one, and if much artificial manure was used on it, and there should be a quantity of rain, it would go down, and the farmer would have great difficulty in cutting the crop and getting it in. He would also get the corn discoloured.

Mr. STEWART said that barleys grown on marshy and heavy soils gave a much higher percentage of nitrogen than barley grown, for example, on the chalky soil of Norfolk. He found, this year particularly, that where there had been rain during the harvesting period the barleys were much lower in nitrogen than those which had had no rain. Scotland last year had practically the same type of weather as England until harvest, when there was rain practically every day, with a result that the nitrogen contained in Scotch barleys this year was only about 1·2 per cent.; in England the average nitrogen content would be regarded as 1·7 per cent. for the steely hard barleys, and 1·2 per cent. for the well-ripened mellow barleys.

Professor LING said that they had listened to an exceedingly interesting paper to which the members had already expressed their appreciation. He had been particularly interested in Dr. Russell's observations on the effect of the addition to the soil of small quantities of boron, manganese, etc., and it recalled to his mind Raulin's observations that in his well-known solution containing sucrose, tartaric acid, ammonium phosphate, ammonium sulphate, magnesium carbonate, iron sulphate, and potassium silicate, a minute trace of zinc salt was necessary in cultivating *Aspergillus niger.* Raulin found that this mould was poisoned by 1 part in 1,600,000 of silver nitrate, and that it could not be grown in a silver vessel.

Mr. F. R. O'SHAUGHNESSY, as Secretary of the Birmingham Section of the Society of Chemical Industry, expressed his pleasure in cooperating in the joint meeting with the Midland Counties section of the Institute of Brewing. They had had joint meetings before, he said, and the results had been equally successful and pleasurable. He had listened with the greatest interest to the lecture, and he noticed that it was only at the end that reference was made to what was probably one of the most vital factors, and that was the biochemical aspect of the matter. He inquired as to the effect on the biology of soil of the introduction of enormous numbers of bacteria of various kinds, because there was no doubt it must have an influence on the crop yield. Barley growers appeared to be impressed with the shortage of organic manures, and he called their attention to a new commercial substance which was being produced in Birmingham in considerable quantities. It was the product of a process to which they had been submitting sewage sludge, and in appearance it resembled peat. Large quantities were being sold this season because it had been found by farmers to be a source of organic material which the soil needed. That manure, in common with farmyard manure, had the advantage of being prepared by a biological process and dried in the field under normal natural conditions.

Mr. F. H. ALCOCK asked Dr. Russell whether the hardness of the straw of barleys might not be due to traces of fluoride. Those who had to analyse fertilisers knew that some samples gave off a considerable amount of fluoride and quite dulled the top of the glass vessel during the heating of them with sulphuric acid. It seemed to him that there were fertilisers and fertilisers, and that those phosphates which contained much fluoride probably differed from those which contained little. He also inquired whether in the analysis of the proteins of barley any account was taken of the effect of proteolysing enzymes upon them.

Replying to the discussion, Dr. RUSSELL said it was very difficult to say whether there had been any deterioration in the seed, though it was quite possible. He had no doubt rainfall was an important factor in determining the high yield in Scotland and Ireland, but he pointed out that in Scotland the barley grown was very localised and on magnificent soil. In the case of Ireland, too, some 160,000 acres devoted to barley was on very good soil in the Eastern and Midland Counties. If those soils were compared with, say, Suffolk soil one could understand that the soil factor was sufficiently important to have a great bearing upon variations in yield. Referring to the statistics available with respect to brewing and feeding barley, he explained that he had spent a great deal of time in trying to obtain such statistics for the purposes of the lecture. He had, however, been unsuccessful. In his own experience he did not find that nitrate of soda very much affected quality. He thought they would all recognise that appearance was not a complete basis to value barley upon, and he hoped that the outcome of the research scheme would be to arrive at a more precise basis. As to the effect of electrolysis upon grain the experiments made at Rothamsted had given negative results. In individual cases there might appear to be an increased yield, but when a number were examined they could find nothing of a definite character. He was not prepared to say that there was nothing in the idea of electrolysing of seed, but simply that its value was not yet proved, and that further evidence was necessary before an assured opinion could be expressed. Dealing with the question of deep *versus* shallow ploughing, and whether deep ploughing turned up the artificials, he said that in his opinion the improvement in crops following deep ploughing was due to the fact that the hard layer of soil formed at the level of the usual shallow ploughing depth and which prevented the barley roots going deeper was broken up with the result that the roots drew their nutriment from a greater depth. Mr. Stewart's views on the question of nitrogen were practically identical with his own. With regard to the suggestion that the falling off in yield might be due to the plants exuding something toxic themselves, he said the results of experiments had been negative. They had up to the present found no evidence of plant toxin that would explain the results. The point had been raised as to soil micro-organisms and whether their variations had been taken into account. He could not say very much on the matter, because they were not yet perfectly sure of their characterisation and could not say whether there had been any change as time went on or whether artificial fertilisers had exerted any profound effect. Material, however, was being got together. All he could say with respect to fluorine and the stiffness of straw was that traces of fluorine were, he believed, invariably found when sought for. French workers considered it to be an essential nutrient in small quantities. He emphasised the desirability of University people getting out into the field and trying to systematise and test the enormous stock of knowledge available among men whose business it was to deal with some of the realities of Nature. In going about among farmers he had been astonished at the extraordinary knowledge which they possessed of the growth of plants. They knew things about plants which no botanists or plant physiologists could explain. Men of science would do themselves a world of good if they would get into contact with practical men, because on a big scale a man could not deceive himself very long; his standards, however empirical, must correspond with something real in Nature. One of the most useful aspects of the new barley research scheme was that it had brought together for the first time in what he hoped would be permanent co-operation, men with this practical knowledge and men trained in scientific methods of enquiry.

In proposing a vote of thanks to Dr. Russell for his address, Dr. H. W. Brownsden (Chairman of the Birmingham Section of the Society of Chemical Industry) expressed the hope that on a future occasion it might be possible for the Section to reciprocate the kindness of the Midland Counties Section of the Institute of Brewing in inviting them to be present on such an interesting occasion.