MEETING OF THE LONDON SECTION, HELD AT THE CHARING CROSS HOTEL, STRAND, ON MONDAY, FEBRUARY 10TH, 1930.

MR. H. W. HARMAN in the Chair.

The following paper was read and discussed :

THE NITROGEN CONTENT AND "QUALITY" OF BARLEY.

BY L. R. BISHOP, M.A., Ph.D.

THIS paper deals with studies related to my researches on the proteins of barley and malt. The present considerations are, however, of a more immediately practical nature. The intention here is to link together and extend the agricultural, biochemical, malting and brewing knowledge of nitrogen compounds and of their resultant value.

The first part of the paper gives many ways in which nitrogen plays an important rôle in determining the so-called "quality" of barley. The second part co-ordinates the available knowledge of the effects of the various agricultural factors which, during growth, determine yield and what we know of "quality."

The importance of such studies lies in the dependence of the brewing industry on the yields and "qualities" of the barleys available each season. Although the vaguely defined attribute "quality" matters in other cereal crops, particularly wheat, its monetary importance is not nearly as great as with barley, where the best samples often realize 100 per cent. more than inferior lots sold for feeding.

The word "*quality*" will have to be mentioned a number of times, but it gives only a relative idea of the value of barleys. The underlying objective of the investigations is to replace this by a *quantitative* measure of barley value. This should have many advantages both to the barley-buyer, maltster and brewer. For it is by no means certain that at present the highest valued of modern barleys are the most valuable for modern beers. The advantages of a quantitative measure would be increased in the event of a restriction of the available supplies or of the present buying power.

The keynote of my studies, as far as they have gone, has been the surprising regularity in the behaviour of the nitrogen compounds. This regularity is not only of theoretical interest, but is also the foundation of the hopes of practical applications, since the behaviour of barley in malting and brewing becomes logical and—compared with what might have been—simple.

Proteins of Barley Grain.—In the mature barley grain there is a regular relation between the amounts of nitrogen in the form of the separate proteins and the total nitrogen of the grain. This relation only holds within each variety. By regular relation it is not suggested that the different proteins exist as a constant fraction at all total nitrogen contents, but that the amount of each can be stated when the total nitrogen content is known. This was the main conclusion of my first report (this *Journ.* 1928, 101) and the conclusion has been materially strengthened by subsequent work. The regularity appears to be unaffected by conditions such as soil, season, or manuring, although these will be shown later to affect the total nitrogen content of the grain.

It may be chiefly one protein which is important in brewing or it may be more, but the value of this work lies in showing that under any of these circumstances, within each variety, the quantities of the important proteins are determined by the total nitrogen. The total nitrogen content of barley may therefore be regarded with renewed confidence, for many people were wisely sceptical of the value of the total nitrogen figure when it was considered that the quantities of the separate proteins might vary independently of one another with weather, soil and so on.

In assessing its importance it is necessary to consider all the ways in which the nitrogen content matters in malting and brewing as some of the requirements are probably mutually antagonistic. When due regard has been paid to all of these requirements it will be possible to decide which is the best barley from the nitrogen standpoint.

How Nitrogen matters.—The requirements of the maltster are straightforward. For, associated with other qualities, such as high germinative power, he prefers barley with a low nitrogen content. Such grain "modifies" more easily and has a smaller malting loss because both respiration and rootlet growth are smaller in low nitrogen content barley.

The requirements of the brewer must also be considered and they, on the other hand, are more complex. In practice the highest prices are paid for low nitrogen malts and certainly these yield the highest extracts, but there is evidence that to-day when both the nitrogen percentages and the wort gravities are much lower than in the past, the very low nitrogen content barleys may be actually of less value than some higher nitrogen barleys. Low nitrogen barleys, it is suggested, are deficient in diastase, yeast-feeding nitrogen, and those complex nitrogen compounds which give "palate fulness" to the beer. It is hoped that the Institute's Yeast and Brewing Researches will settle this question.

Meanwhile there are in preparation two papers dealing with the relation of nitrogen to the earlier stages of the malting and brewing process—on the causes of extract variation and on the nitrogenous composition of worts. A few words in explanation of these may be given here, especially as these indicate two of the ways in which nitrogen plays a part in "quality," and further how a quantitative conception may be substituted for the present qualitative one.

Prediction of Extract.—The first paper is a statistical study of the very large body of data collected by the Institute Barley Researches since 1922. It shows that, in barleys which germinate well, a measurement of the moisture content, nitrogen content and thousand corn weight, is sufficient for a reasonably accurate prediction by means of an equation or table of the extract yield of the resulting malt, if this is made under ordinary conditions. With one malting firm the standard error of the prediction will probably not be above 0.8 lb. for most barleys (of the varieties studied) which is not much greater than the analytical errors involved.

Thus one of the factors in "quality," extract, is put on a quantitative basis. So that it is possible for the barley buyer to use it in valuation, while a comparison of the observed and predicted results will give valuable indications to the maltster.

Wort Composition.—The nitrogen compounds which actually reach the wort are also important since they contribute to yeast nutrition and to the character of the beer.

A paper dealing with wort nitrogen compounds will shortly be put forward, based on results obtained by Miss E. M. Thomas and Mr. H. Lloyd Hind. In this the behaviour of the different nitrogen groupings is given in broad outline.

The total amount of "permanently soluble" nitrogen in the wort depends on two things: (1) the total nitrogen of the barley and (2) the malting conditions. Under normal malting conditions with English barleys about 35 per cent. of the total nitrogen of the barley is found as "permanently soluble" nitrogen in the wort. It ranges from 30 to 33 per cent. with under modification and 38 to 43 per cent. with over modification (modification here includes the chemical and physical changes). This percentage therefore suggests itself as a measure of modification. With increase of the total nitrogen of the barley the permanently soluble nitrogen increases proportionally (if it remains at 35 per cent.) The increase is mainly due to a proportional increase in the larger groups, peptide and undetermined nitrogen, but there may be corresponding small increases in the smaller groups amino, amide, and ammonia nitrogen.

Changing the mashing temperature causes marked changes. The ammonia, amide and amino nitrogen remain fairly constant in amount, but the peptide and with it the total permanently soluble nitrogen rise to a maximum at about 50° C. (120° F.).

This study, therefore, offers (1) a measure of the amount of chemical modification of barleys during malting, and (2) the possibility of predicting from the barley the amounts of nitrogen compounds in the wort under given malting and mashing conditions. When brewing researches have decided what proportions of the different nitrogen compounds are needed in wort the present work will be of direct practical value in guiding the choice of barleys and of malting and mashing procedure.

To summarise this section—in attempting to assess the real importance of nitrogen compounds it has been shown that the capacity of a barley to yield good results is greatly affected by the nitrogen content, and it can be stated accurately how this determines the extract of the malt. It is known, as yet only vaguely, that diastase also is affected by the nitrogen content, and there is recent evidence how the latter together with malting and mashing conditions determines the composition of worts. A knowledge of the yeast and beer requirements is lacking for a fairly complete statement of the nitrogen requirements and a *quantitative* system of assessing part of the value of barley on this basis. This makes the importance of nitrogen content unquestionable, but is not intended to suggest that everything vaguely comprised by "quality" is determined by the nitrogen content.

Effects of Agricultural Conditions.

The importance of total nitrogen content being clear the second part of this paper deals with agricultural conditions and their effects on yield and what we know of "quality." It should perhaps be pointed out here that this knowledge will be equally useful whatever is finally decided as the best nitrogen content, low, medium, or even high. From the cordial reception each year of Mr. Stewart's paper the members must be interested in this subject; and a full understanding of the effects of agricultural conditions has obvious advantages in guiding the barley buyer and stabilising prices.

Ratio of Protein to Carbohydrates.—Before going further one point should be made quite clear. The greater part of the barley grain consists of carbohydrates which have been built up from carbon dioxide and water by the activity of the plant. When the nitrogen percentage of the grain is measured this is in reality measuring the ratio of nitrogen to carbohydrate. This being so it is obvious that variations in either the nitrogen or carbohydrate amounts will cause variations in this percentage. For instance, in each of two years the barley may take up the same *weight* of nitrogen per acre, but in one year more growth and consequently more production of carbohydrate takes place, so that the nitrogen will be more "diluted" and the nitrogen *percentage* lower.

Similarly, when the farmer adds nitrogenous manures the extra nitrogen usually leads to a corresponding increase in growth and carbohydrate production. This extra carbohydrate production balances the extra nitrogen taken up and the nitrogen percentage is unaltered. When this happens the farmer gets his extra yield without depreciation of quality. There is no question of "cheating the barley valuer" as has been suggested by those who have confused the nitrogen amount with the percentage in the grain. In effect manuring has provided the plant with more nitrogen which is necessary to form its essential constituent—protoplasm. This is in turn necessary for carbohydrate production, and in some cases the increased carbohydrate production is more than proportional to the added nitrogen, so that the nitrogen percentage is actually reduced.

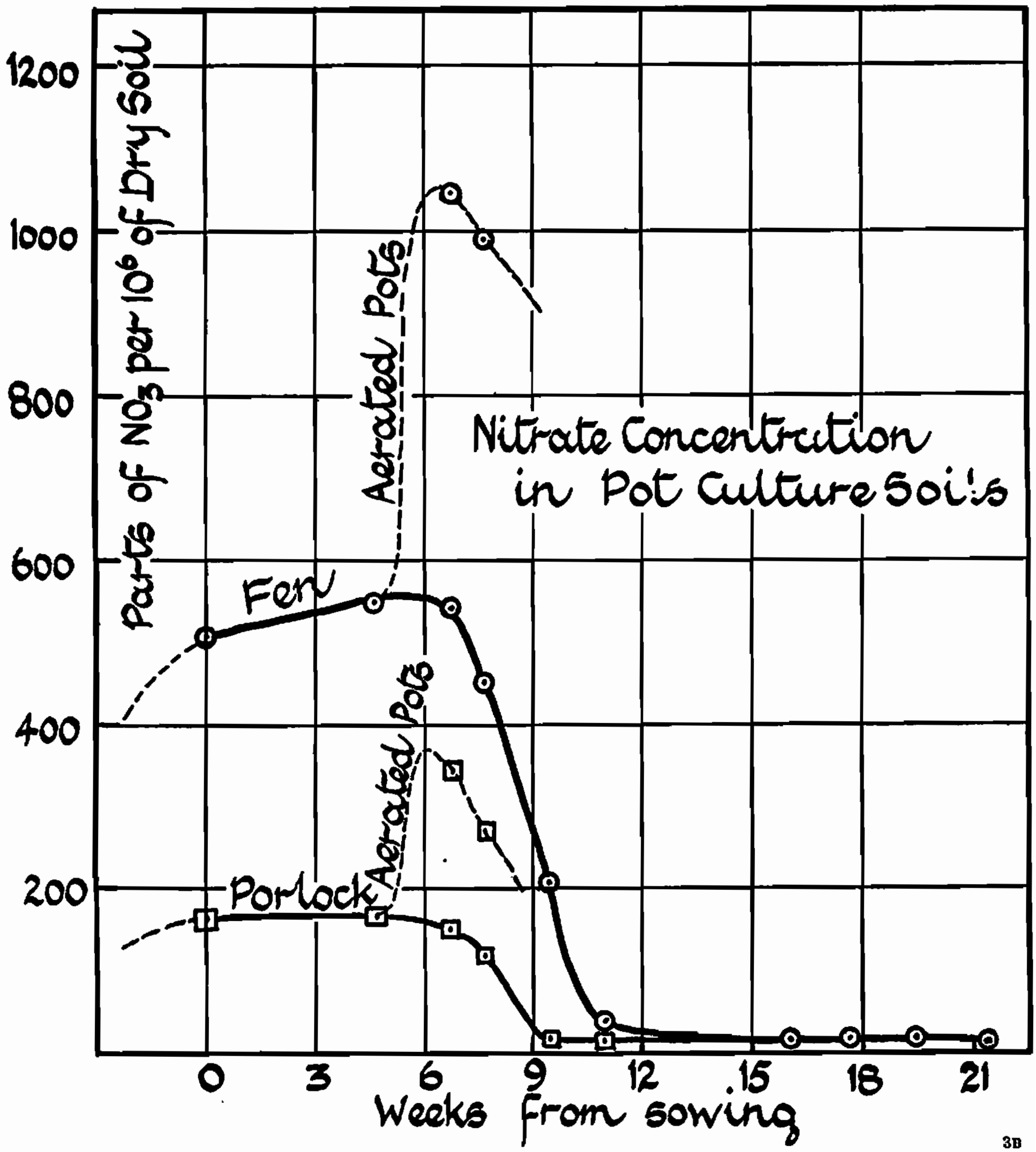
Effect of Manures.—The Institute's Barley Researches have given a clear demonstration of the fact, first pointed out by Beaven, that soil and season are the chief factors determining yield and nitrogen content. Spring dressings of artificial nitrogenous manures have given an increase of yield but, apart from this, the effect of manures is usually not striking or consistent. The two chief minerals needed by plants in English soils are phosphate and potassium; but since their widespread use as manures on farm soils in the present century enough is usually available. Further, complex chemical mechanisms in the soil tend to keep fairly constant the amount of these available to the plants. This has two results, one is that these compounds added as manures do not produce marked effects and, secondly, the amounts which the plants take up and pass to the grain are fairly constant. That is, the phosphate and potash contents of the grain tend in turn to remain fairly constant and, therefore, the "quality" of English barleys in this respect does not differ greatly. When the growth of the plant (and consequently the yield) is greater then there is a greater root growth and, approximately, proportional increase of potash and phosphate absorbed as a result of the more efficient "searching" of the soil by the greater root surface, so that the percentage remains fairly constant, but there is slightly more "dilution" from the increased yields on nitrogen manured plots. These points are exemplified by the analyses of the phosphate contents of the Institute barleys given by E. M. Crowther (p. 349).

Unlike potash and phosphate, the available nitrogen in the soil varies more with the time of the year and the type of soil. So that, among others, one of the important problems of the English farmer, as with the brewer, is a nitrogen problem. The effect of artificial nitrogenous manures varies with the time of application. Added in spring, as explained above, they increase the yield without markedly affecting the nitrogen percentage. Added late in the season they increase the nitrogen percentage without markedly affecting the yield. At this time they are absorbed by the plant, but come too late to result in growth and carbohydrate production proportional to the extra nitrogen absorbed.

Influence of the soil.—The effects of season cannot be entirely separated from the effects of the type of soil. For instance last season the clay lands produced some of the best barleys, while in most years these come from loams or medium light soils.

Both the physical and chemical properties

DIAGRAM I.

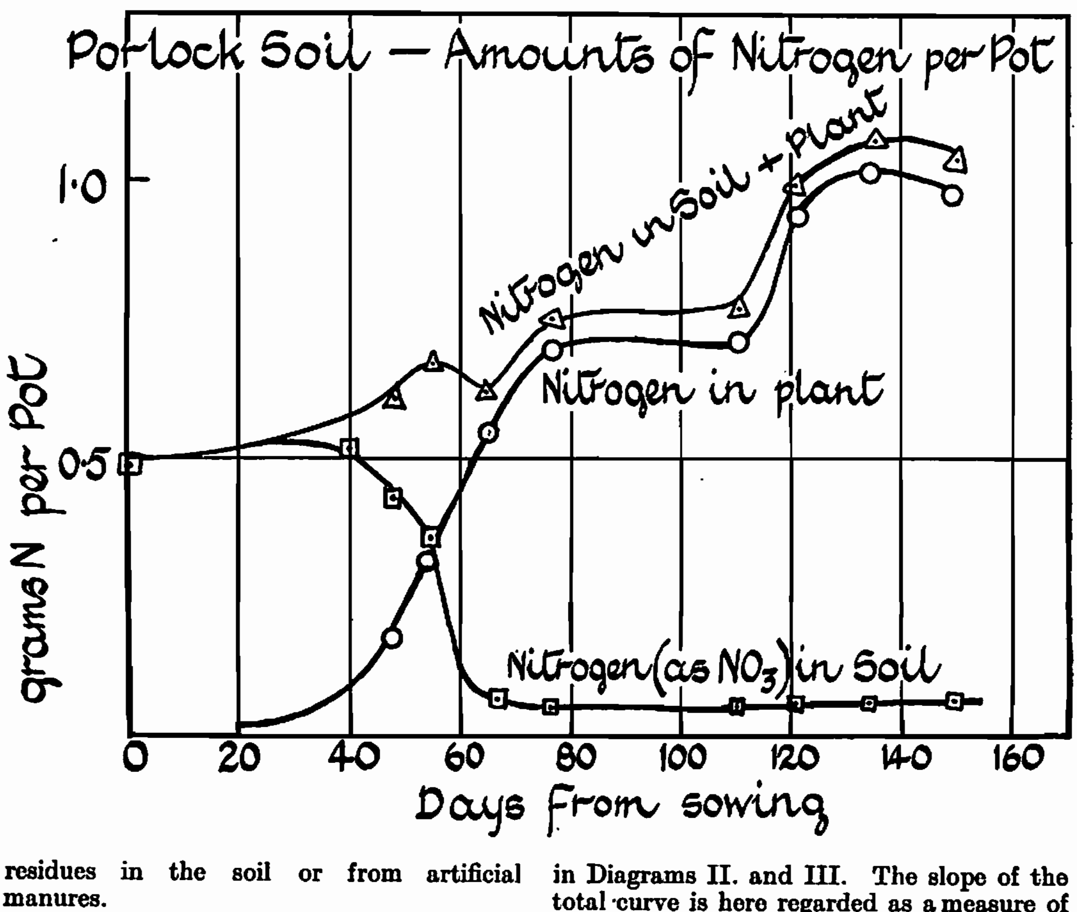


of soils affect the yield. On the chemical side the writer considers nitrogen to be the most important factor from the evidence of manuring given above. The plant roots absorb nitrogen from the soil mainly as nitrates which are produced in the soil by the action of bacteria on ammonium compounds. These ammonium compounds may come indiscriminately either from the action of other bacteria on proteins in organic residues in the soil or from artificial manures.

The nitrate amount in soil rises to a high value in spring and then falls very rapidly as absorption by the plant increases with the increasing root system. So that by 10 or 11 weeks after sowing it has reached a very low value. In fact the concentration of nitrates is afterwards about the same as in Harpenden tap water. This is illustrated from the results of a pot culture experiment where barley was grown on Fen and on Porlock soil at Rothamsted, in 1928, by A. R. Clapham and myself. (Diagram I, p. 355).

The nitrate remains at this low level because as soon as more is produced it is absorbed by the plant or by micro-organisms in the soil. It is therefore difficult to know how much nitrate is actually being produced. This difficulty was overcome by measuring the amount of nitrogen in the plant and adding it to that in the soil, as has been done in Diagrams II. and III. The slope of the total curve is here regarded as a measure of the rate of actual nitrification.

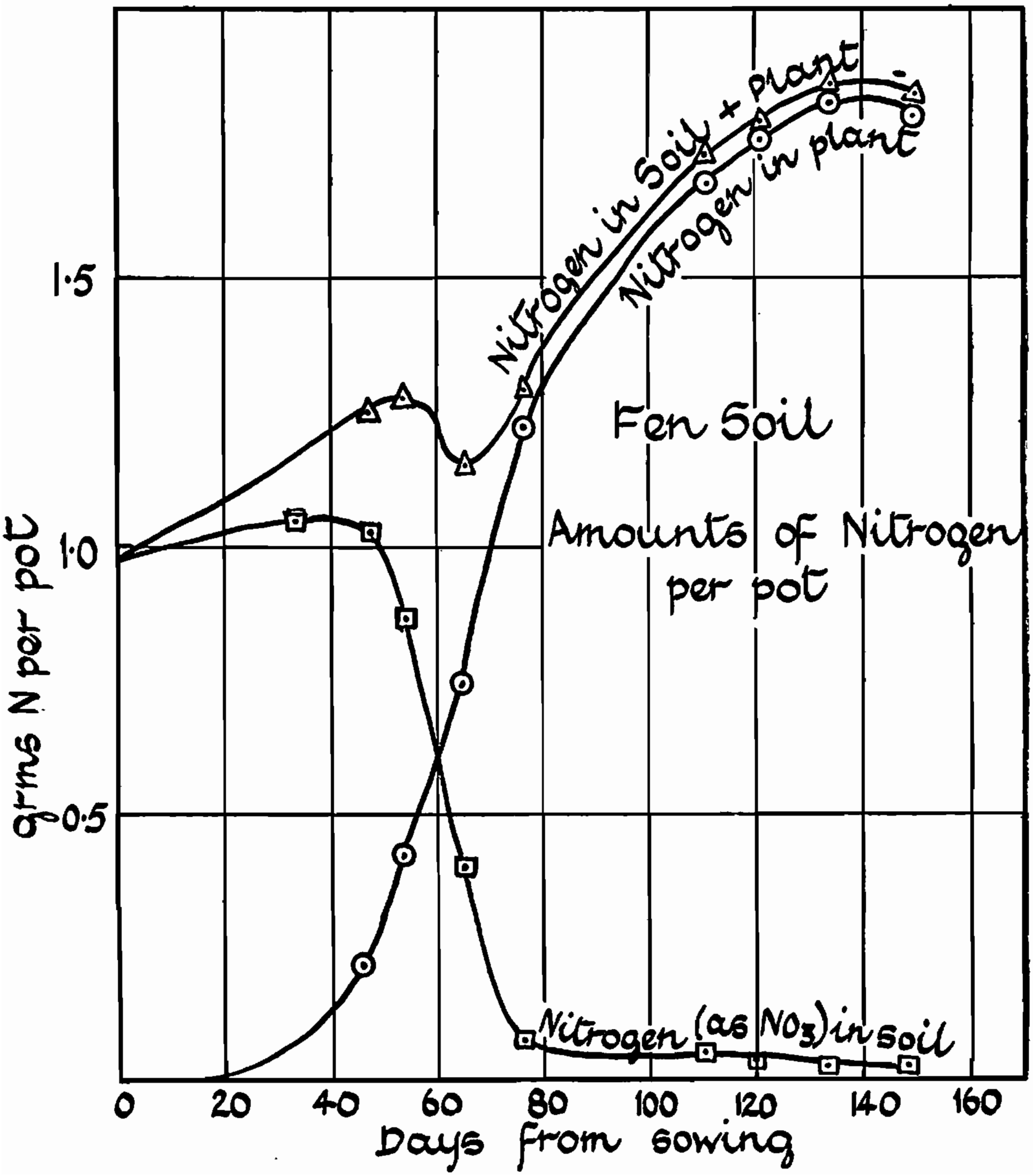
DIAGRAM II.



In organic soils or organically manured soils nitrification continues actively through the summer as a result of the different balance of bacterial activity in these soils. In other soils this nitrification late in the season is less. Plants in organic soils, therefore, get more nitrogen late in the season, and this has the same effect as a late top-dressing of artificial nitrogenous manures, and raises the nitrogen percentage without affecting the yield greatly. The late nitrification is seen in the steeper slope of the Fen (organic) soil curve (p.357) compared with the Porlock curve (p.356).

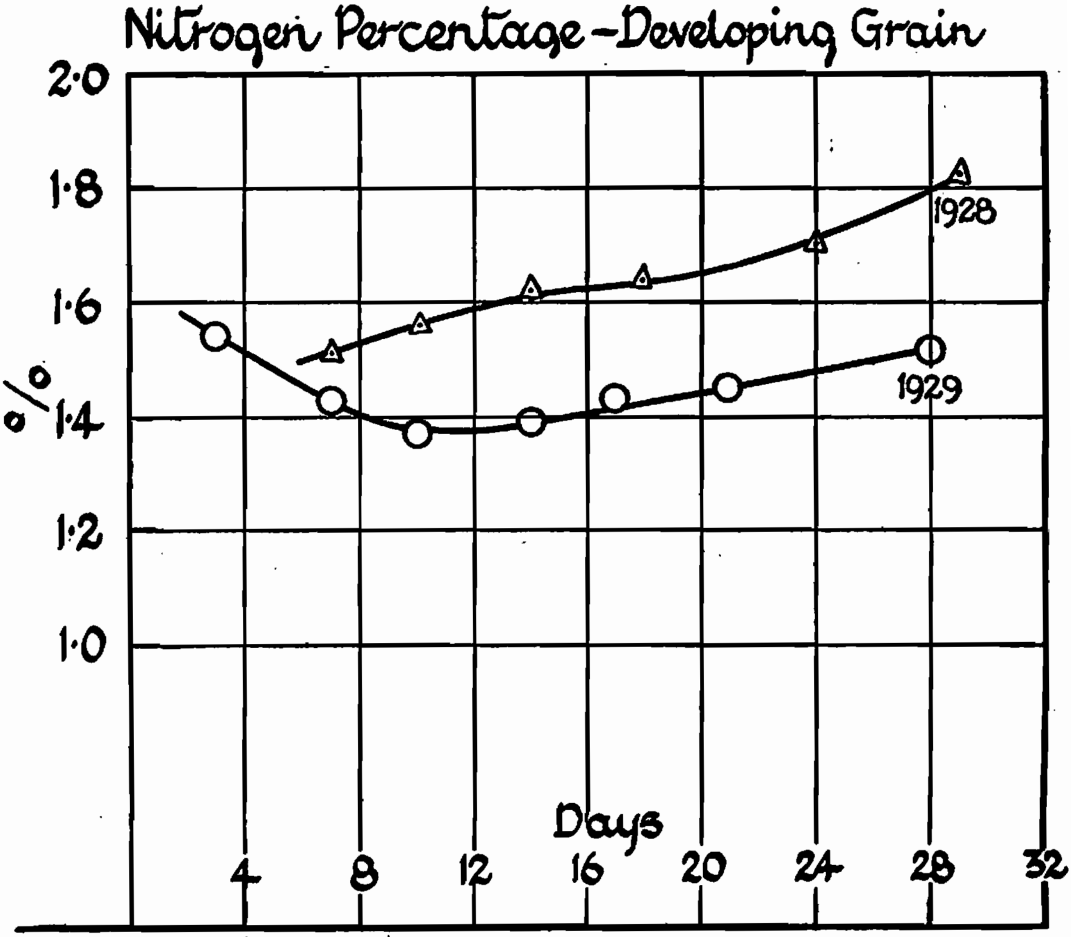
This hypothesis of early and late nitrification is put forward as explaining the main chemical differences between soils. On this basis a classification of soils into four chemical types is suggested: (1) Those giving low nitrate in spring (low yields) and little late nitrification (low nitrogen percentage). (2) Those giving low nitrate in spring and much late nitrification resulting in low yields and high nitrogen percentage. (3) Those giving high nitrate in spring and little after

Diagram III.



that resulting in a high yield of low nitrogen percentage grain (this, on present valuations, would be the ideal barley soil). (4) Those giving high nitrate in spring and high nitrate in summer (this would be the ideal wheat soil). Seasonal factors can, of course, alter these soil effects—for instance, spring nitrates may be washed out by rain or utilization may be delayed by delayed growth, so that "early" nitrate becomes in effect "late" nitrate.

DIAGRAM IV.

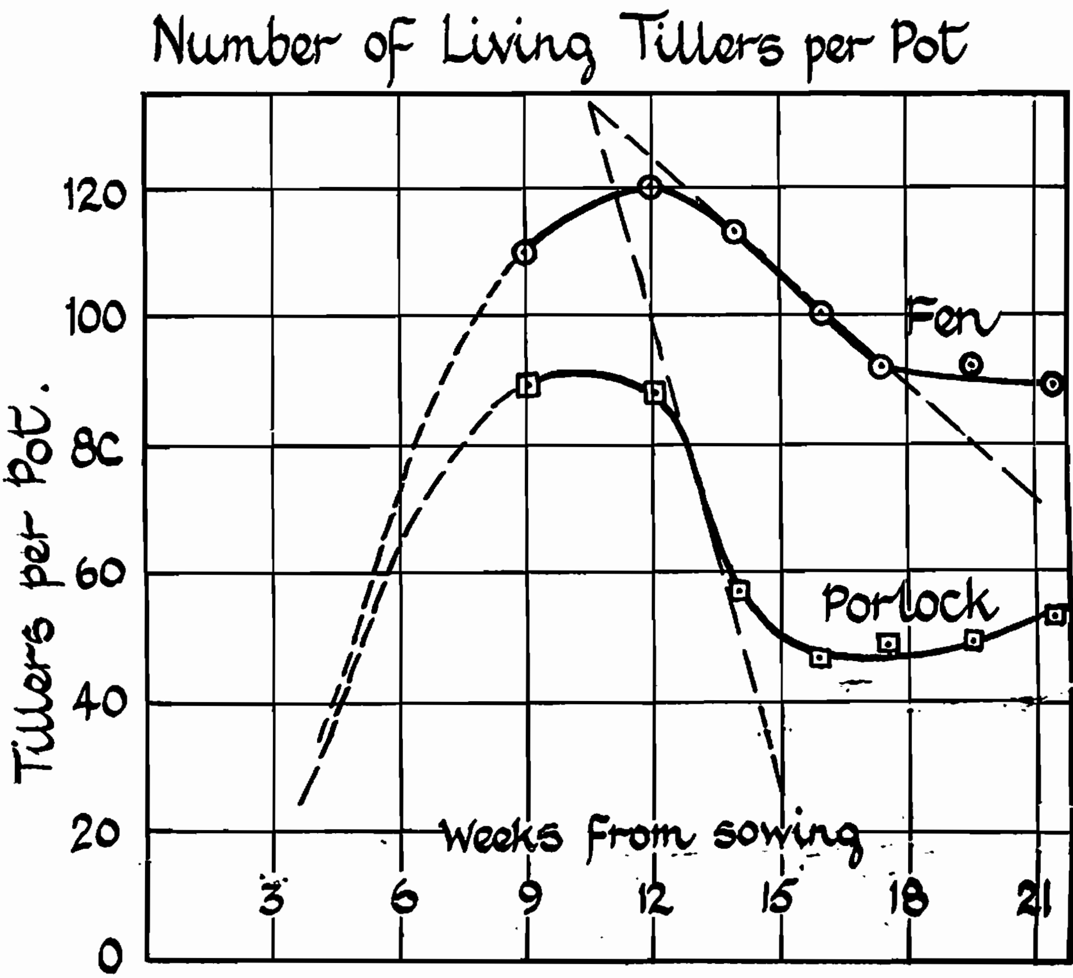


This nitrification hypothesis explains much that has been observed about barley quality. In the first place it will explain the association of high nitrogen barleys with organic soils (*e.g.*, Fen soils) or with organic manuring (*e.g.*, after farm yard manure or sheep fed off). It also explains a number of ideas in circulation which are only partly true. One is that yield and quality are incompatible. In the past the only way to increase yield was to manure with organic manures which would result in high nitrogen barley. With artificial manures this no longer holds. A striking case from the Institute results shows that high yield and high quality are not incompatible. In 1922 at Barneyhill the yield was 82·4 bushels per acre (the average English yield is 32 bushels) of good quality barley and with a nitrogen percentage of 1.44. Later in the paper conditions will be mentioned when high yield implies also high quality, *i.e.*, the converse of the old idea. Another incorrect idea is that the nitrogen enters the developing barley grain first and the carbohydrate later. This is proved to be untrue from results obtained during my studies of barley grain development in the last two seasons given in Diagram IV. (p. 358)

In these examples, the nitrogen percentage fluctuates round some value showing that nitrogen and carbohydrate are passing in approximately constant proportions, or in 1928 proportionally more nitrogen entered the grain *late* in development.

nitrogen percentage, in a number of fractionations which I have made. The association which exists between immature grain and high nitrogen content has also given rise to the idea that nitrogen manuring delays maturation. This is also often incorrect for on the Rothamsted plots those with artificial nitrogenous manures are frequently the first to ripen. I consider that this high

DIAGRAM V.



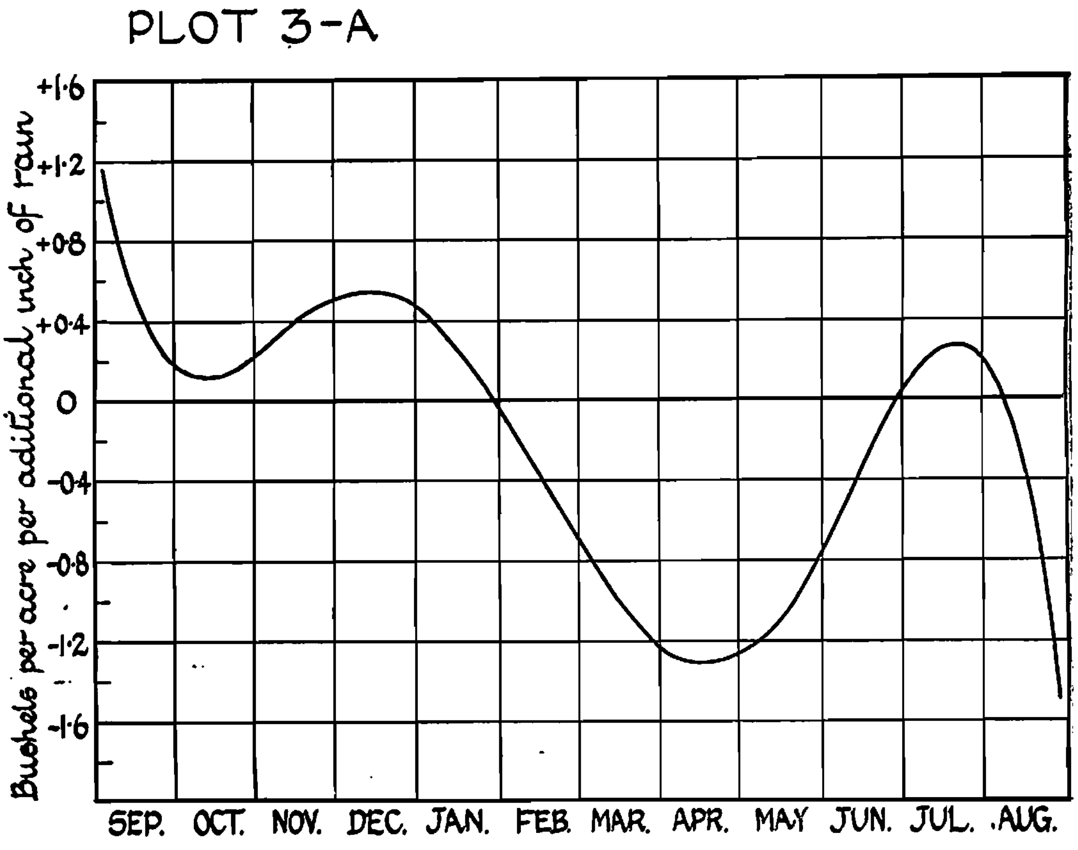
In support of the "nitrogen first" idea it is argued that high nitrogen samples are characterised by a high percentage of small immature grains. This is true, but these smaller grains do not cause the high nitrogen percentage. To do so they would need to contain about 6 per cent. of nitrogen. Actually the smaller grains have a *lower* nitrogen content and presence of immature grains are associated, because they are both effects of "late" nitrification, in organic soils. The reason for the high nitrogen content has been given above and the presence of immature grain is explained as due to the effect of the late nitrification on the survival of the tillers or shoots produced late by the barley plant. This is again illustrated from the pot culture experiment by the results given in Diagram V. (p. 359).

In this experiment the number of tillers increased in both soils until the nitrate in the soil was exhausted (10-11 weeks from sowing). After this the later formed tillers died off, but would have been saved by "late" nitrate. They got more of this in the organic Fen soil in which some of these late formed tillers survived. Consequently at harvest the Porlock grain was evenly ripened while the Fen grain contained immature corns from the young tillers which had survived, but had been formed too late to produce mature grain.

Effect of Spacing.—Beaven and others have shown that the wider the space between the rows the higher the nitrogen content of the grain. This can be explained on the same hypothesis. As the roots grow and spread they absorb the nitrate further and further from the plant. When the spacing between the rows is wide some of the nitrate is reached by the roots and absorbed late in the season thus increasing the nitrogen percentage.

Cultivation.—The ploughing and harrowing of the land by the farmer has both physical and chemical effects. The physical conditions or "tilth" of the soil is everywhere acknowledged as important for a good seed bed, but cultivation has marked effects on the nitrate content also. This is because of the effect of the aeration on the bacterial activity. This aeration effect is clearly illustrated by the dotted curves in Diagram I. (p. 355.) Here after four weeks the soil in some of the pots was taken out, thoroughly mixed and put back (without plants). The nitrate content shot up to double within a fortnight. It fell after as the nitrate absorbing bacteria also increased in number, but the effect persists and it accounts for the benefit of the

Diagram VI.



repeated cultivations during a summer fallow on the crop in the following year.

Barley roots are very sensitive to waterlogging and to the accumulation of carbon-dioxide, and these are reduced by proper cultivation.

Effects of Season.—The effects of different seasonal factors at different times of the year can only be clearly elucidated by statistical studies, and fortunately there are studies of the effect of rainfall and temperature on barley yields.

With seasonal effects an increase in yield is usually not accompanied by a proportionally greater uptake of nitrogen, so that here high yield is associated with low nitrogen percentage for which there are no direct studies.

Rainfall.—Dr. J. Wishart has analysed the effects of rainfall on the yields of the Hoos field barley plots at Rothamsted and I have his kind permission to use his unpublished results. The effect given in the curve (Diagram VI. p. 360) is that of an extra inch of rain above the average in bushels per acre on the yield of grain. Rainfall is probably the most important seasonal factor effecting yield, and the effects shown in this diagram are the chief ones determining yield.

On some of the plots the rainfall in autumn has a depressing effect, probably due to washing out of nitrates, but this is not shown on this particular plot. Winter rainfall increases the yield probably by providing stored moisture in the soil which the crop draws on in the following summer. It is interesting to note that winter rainfall may have important effects before the crop has been planted. Rainfall in spring has the most marked effect and this depresses the yield strongly, especially in March-April. This strong depressing effect is probably the result of several actions. (1) rain washes out nitrates from the soil at the time of year when they determine yield, and there is the greatest concentration free in the soil, (2) the seed germinates in a waterlogged seed-bed, to which barley is very sensitive, (3) wet conditions in spring retard sowing and so reduce the yield. Extra rain in June has no particular effect but extra rain in July increases the yield. This is probably partly because vegetative activity is prolonged but chiefly because translocation of material to the grain is prolonged. On the heavy moisture retaining clay soil of Rothamsted it is the waterlogging effect of March and April which is most important and the July drought effect less so. With the lighter soils of East Anglia the effects are similar, but earlier. This is shown by a statistical study for East Anglian Crops, by R. H. Hooker. (See *Quart. J. Roy. Met. Soc.*, 1922, p. 115). There is no beneficial effect of rain in winter and the greatest depression is from rainfall in January-February. The June rainfall is beneficial, and is probably relatively more important than is the corresponding beneficial effect of July rainfall on the mosture retaining clay soil of Rothamsted.

This dominance of the rainfall effect and its effect on different soils is well illustrated by last season's (1929) crops in the south of England (J. Stewart, this *Journ.* 1930, 105). There was a marked spring drought which, despite the fears of the practical man, was actually largely responsible for the very high yields obtained. There was some rain which alleviated the June-July drought and on the clay lands, where this does not seriously cut down translocation, the grain was well filled and of high quality. On the other hand, on the lighter Norfolk soils the yields were high, but the more pronounced effect on these soils of the summer drought reduced the yield from what it would otherwise have been by reducing translocation and resulted in less well-filled grain.

Sunlight.—The effect of sunlight on yield has not been studied for barley, but has been studied for wheat at Rothamsted. October-November sunshine has an important beneficial effect. This is probably because it enables the young plant to get well started in its growth so that it becomes far enough advanced to winter well. Light is the necessary source of energy for the formation of carbohydrates by the plant, but sunlight, except in October-November, is greatly in excess of its needs which are limited by the very small concentration of carbon dioxide in the air—the source from which the plant obtains its carbon. It is probable that with spring-sown barley sunlight has no marked effect.

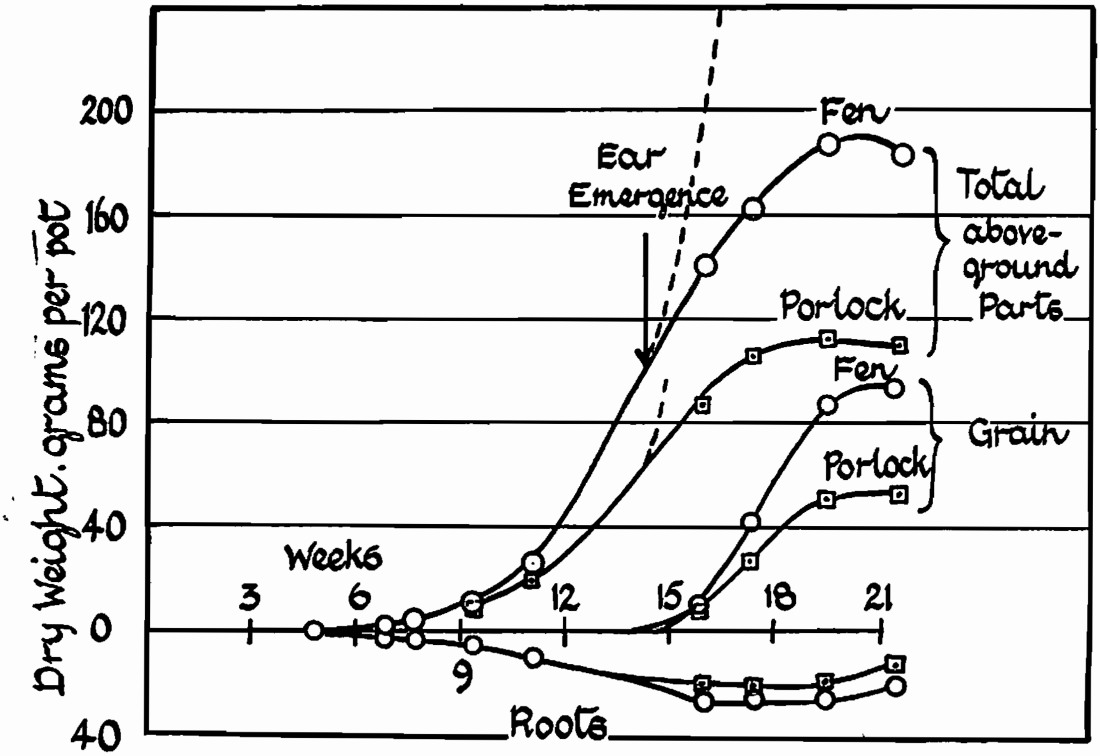
Temperature.—Hooker (*loc. cit.*) found for East Anglian barley, as for all the other crops studied, that the most striking effect is a large reduction in yield caused by the May to June temperatures. I consider the explanation of this is that high temperature at this period helps to cause the plant to change from vegetative growth to fruit formation and with cereals the period when the change sets in is one of exceedingly rapid increase in dry weight, so that delay of the change for one week would lead to a greatly increased yield. This is seen in the dry weight curves of the plants in the pot culture experiment, and it will be noted that the point of inflection of the S-shaped curve corresponds approximately to the time of ear emergence which marks the onset of the reproductive phase. The dotted curves show the increase which would take place without the intervention of the reproductive phase. (Diagram VII.)

The increasing temperature in May-June causes late sown barley to ripen almost as soon as early sown, so that the period of intense vegetative activity is cut short, and in relation to this it is found that the later the sowing the lower the yield and the higher the nitrogen content.

It is worth while noting that while the practical agriculturist would say that "the higher temperature in May and June caused the plants to "come on well" that actually this "coming on" (the shooting up of the ear-bearing stalks) is markedly reducing the yield."

Hooker's results also show that July temperature has a marked, though less important, depressing effect on yield. This is probably connected with the reduction of translocation to the grain by accelerated ripening. Thus for East Anglia the temperature through spring and summer is on the average too high for barley and the yields are lower than in Scotland where summer temperatures are lower.

DIAGRAM VII.



Effect on Variety.—This, as is well known, has regular effects on yield and nitrogen percentage; but the effect is much less than those of soil and season. The explanation appears to be that all varieties tend to take up about the same weights of nitrogen per acre on a given soil, but they differ more in the use they make of this nitrogen in producing carbohydrates and so yield. Consequently, as with climatic effects, high yields and low nitrogen percentage are closely associated since the amount of nitrogen is "diluted" more by the higher yield of, for instance, Plumage-Archer and Spratt-Archer barleys. The same thing was gradually discovered for wheat when it was found that it was almost impossible to breed for high yield and high nitrogen content at the same time.

The effect with barley is shown by calculations made from the results of the National Institute of Agricultural Botany. (Table I.)

TABLE I.

RELATION BETWEEN NITROGEN PERCENTAGE AND YIELD IN THE N.I.A.B. VARIETIES OF 1923.

Averages of Comparisons with Control.

	Control. Gartons, 1917.		Control. Archer.	
	N%	Yield.	N%	Yield.
Beaven's 1920 ...	—0·14	+19·5%	—0·10	+5·3%
59/120	+0·10	*—0·5%	—0·15	+9·2%
Webb's B. ...	—0·04	+33.7%	—0·08	+13·9%
Golden Pheasant	+0·04	—4·4%	+0·02	—18·7%

*One very exceptional result omitted.

In this table higher yields (+) are seen to be invariably accompanied by lower nitrogen percentages (—) and *vice versa.*

The varieties studied in more recent years have all given similar high yields, and this effect no longer shows.

The magnitude of varietal differences compared with those caused by different places is illustrated in Table II., and the magnitude of climatic effects is compared with varietal in Table III. The varieties showing maximum differences are chosen and these figures are given to show that the effects are clearly subordinate to those of soil and season.

TABLE II.

EFFECT OF VARIETY AND PLACE ON NITROGEN PERCENTAGE

	Cambridge.	Kirton.	Mkt. Weighton.	Norwich.
Archer	1·95	1·90	1·48	1·86
Golden Pheasant ...	1·99	1·84	1·53	1·89

TABLE III.

EFFECT OF VARIETY AND SEASON ON NITROGEN PERCENTAGE AT CAMBRIDGE.

	1925.	1926.	1927.
Plumage-Archer	1·704	1·365	1·561
Sunrise	1·669	1·322	1·620

I had also noted a point raised by Dr. E.S. Beaven in the discussion of Mr. Stewart's paper (*loc. cit.*) that is, that the varieties which ripen earlier give lower yields, and as pointed out above with the lower yields is associated a higher nitrogen percentage. The explanations is the same as that given under the temperature section above, *i.e.*, that an earlier change to the reproductive phase occurs cutting short the all important few weeks when the bulk of the assimilation is done. Standwell and Golden Pheasant are typical examples of barleys which ripen early, giving lower yields and higher nitrogen percentages.

Translocation to the Grain.—During the course of the above remarks it has been assumed that an effect on the composition of the plant implies a corresponding effect on the grain, *e.g.*, a greater formation of carbohydrates in the plant is assumed to result in a greater yield of grain, and a lower nitrogen percentage in the plant to imply a lower nitrogen percentage in the grain.

This is so, for in a normal season the grain absorbs 70-75 per cent. of the nitrogen in the above ground parts and 45-50 per cent. of the dry weight of the above ground parts. In the same way as the nitrogen, potash and phosphate absorbed by the plant depend on the amount available in the soil, so the proportions of proteins and carbohydrates in the grain depend on the proportions present in the plant, and after the very early stages the proteins and carbohydrates enter the grain together so that the percentage of nitrogen remains approximately constant. Consequently a short ripening period cuts down the amounts of both nitrogen and carbohydrate in the grain, *i.e.*, the yield is reduced, but the composition not markedly affected. For instance, in 1911, the Hoosfield grain contained only 56 per cent. of the nitrogen and 33 per cent. of the dry weight of the above ground parts. However, when the translocation to the grain is checked by drought it appears probable that the inflow of carbohydrate is checked more than that of nitrogen compounds, *i.e.*, the nitrogen percentage is somewhat raised.

Harlan has shown that during development the barley grain attains its full length in seven days after flowering, and then proceeds to fill laterally, which explains why in samples where the ripening period has been cut short, the grain has the normal length, but is not well-filled.

Summary.

This paper has been given to show the definite practical aim and coherence of purpose in the Institute Barley Researches. Together with certain other researches, the aim has already, in part, been achieved. It is to obtain an understanding of the behaviour of barley during growth, malting and brewing in order to give definite objective information and, where possible, control to the barley buyer, maltster and brewer in turn.

All three should be helped to recognise the value of different lots of barley more accurately from a knowledge of the variety, nitrogen content and thousand corn weight.

The barley buyer should be aided in estimating the yield and quality in different districts from the following agricultural considerations. He will recognise that the most important things to consider are soil and season, and that variety and artificial manuring are less important.

The most important chemical aspect of soil composition, it is suggested, is the presence or absence of organic nitrogenous matter. When this is present, owing to excess nitrification late in the season, the grain tends to be high in nitrogen content and to contain immature grain. Wide spacing of the rows produces similar effects.

The physical aspects of soil may be included with those of season. Contrary to general opinion the chief seasonal effects which determine high yield on clay soils are drought in March-April and cold weather in May-June. Rain and cool weather in July are beneficial, but to a lesser extent. With light soils the rainfall effects are somewhat earlier, the depression period is January-February, and the beneficial period June. Rain at harvest, as is well recognised, reduces yield and often quality by producing sprouted or badly germinating grain. Sunlight has probably no marked effect on yield. Seasonal conditions which give high yield tend to give low nitrogen content. Drought in June–July produces badly filled grain especially on light soils and may raise the nitrogen percentage.

Between varieties a similar though less marked difference in nitrogen percentage is produced. Varieties such as Plumage-Archer and Spratt-Archer which give high yields give also lower nitrogen percentages. Varieties such as Standwell and Golden Pheasant, which have a shorter vegetative period, give lower yields and consequently higher nitrogen percentages.

As is now generally recognised, artificial nitrogenous manures, applied in spring in moderate quantities, produce an approximately proportional increase of yield to the nitrogen absorbed, so that the nitrogen percentage is not markedly affected.

The considerations above should guide the barley buyer in the choice of markets. In fact, it is not too impossible to suggest that before long the yields and nitrogen contents on different types of soil may be calculated before harvest from the weather during the season. For the guidance of the barley buyer at the time of purchase, it is suggested that a determination of the nitrogen content should be made. This is shown here to have more value than is usually supposed.

The nitrogen content, of samples which will germinate well, together with the thousand corn weight will accurately predict the extract obtained with given malting conditions and varieties. With the same limitations the nitrogen content will predict also the amount of permanently soluble nitrogen which will be obtained in the resulting wort.

Disagreements between observed and predicted extracts and between observed and predicted amounts of permanently soluble nitrogen will indicate to the maltster departures of individual pieces from his usual conditions.

When a knowledge has been obtained of the most desirable proportions of nitrogen compounds in wort, the recent information on wort composition should be of direct practical value in guiding the choice of barleys and of malting and mashing conditions. This should lead to a *sound, quantitative* method of assessing barley value.

Rothamsted Experimental Station,
Harpenden.

Discussion.

The Chairman (Mr. W. H. Harman) said he was interested to hear the author's remarks upon the effect of artificial manure in the early stages of barley growing, and that, whilst influencing the yield of barley, it produced no effect upon the quality, and that the total final nitrogen was only reduced by this treatment in proportion to the increase in carbohydrates. There were, however, other properties of barley that were of considerable importance from the brewer's point of view, such as enzyme activity, and the amount of assimilable nitrogen, which might be affected by a particular treatment with artificial manure. He had not understood what the effect of the manure was, when used as an organic or farmyard manure, whether it would, if suitably added, give the same increased yield of barley as sulphate of ammonia, but at the same time result in a certain storage of nitrogen at the finish, as an excess of nitrogen, which might be valuable to the brewer, but which apparently did not take place when artificial manure was added in the early stages of growth. Could the author state whether the late increase in the nitrogen of the barley either from the use of organic manure, or as it was found in barleys of high nitrogen content, such as Canadian, Chilian, etc., still maintained the relative order of the proteins such as Hordein, Glutelin, etc., etc., which was found to be so consistent in the barleys of lower nitrogen percentage.

Dr. J. A. Voelcker said that Dr. Bishop and others were working on the different kinds of nitrogen that were found in barley, and, no doubt, in time they would have information concerning the relative percentages of glutelin, hordein, etc., and what such amounts meant. At present it would appear that the total nitrogen formed a good index of what might be termed "quality." It was understandable that soil, except as regards yield, did not make any great difference; season, however, must largely influence the yield and the quality, and when a heavy clay soil and a light soil were compared in such a season as the last dry one, it could be understood why the former held out better during the drought, whereas the latter might suffer. He questioned, however, whether ever in such a dry season as he had mentioned, light soils did greatly suffer. On the Woburn soils with which he had to do, and which were essentially light, the barley crop was much better than it had been for a number of years, and he could not say that they had suffered from the drought. Even among light soils there was a great difference in regard to their power of holding, and of losing, water. Some of them were subject to "burning," whilst others had singularly good drought-resisting powers; these were qualities which had to be taken into consideration.

With regard to the influence of manures, phosphates seemed to have little effect, provided the soil was fairly provided with phosphoric acid at the outset. Potash, similarly, was often unresponsive, and did not have anything like the effect of the application of nitrogen. There were, however, soils, especially those on thin chalk lands, which were distinctly responsive to the application of potash. Dr. Bishop, however, was quite right when he stated that the general influence of potash was not very marked. But the story was very different with regard to nitrogen, as this element was undoubtedly *the* factor, not merely in yield, but also in quality of the grain. Dr. Bishop had pointed out that nitrogen had very different effects according to whether it was applied early or late. From that cause alone good or bad results might follow. The common belief that the best barley was obtained by not putting on much nitrogenous manure was subject to other considerations. If the crop was a big one with good carbo-hydrate development, naturally there was a lower nitrogen percentage. If, on the other hand, it was a bad season and the crop did not mature well and the carbo-hydrates were not properly built up, the natural consequence was that the nitrogen was raised, and the more nitrogen that was put on, especially if it was added late, the higher would be the percentage of nitrogen in the grain.

He was in a position to give the meeting some late results concerning the influence of nitrogen in the manuring of barley. The results related to Woburn, where experiments similar to those at Rothamsted and elsewhere were being conducted. Last season he had a series of pot-culture experiments on barley, using nitrogen in different quantities and in the two forms of sulphate and muriate of ammonia, applied at the rate of ¼, ½, 1, 2 and 4 cwt. respectively per acre. The grain was subsequently reaped and analysed, and the following conclusions were drawn. "No manure" resulted in a nitrogen percentage in the grain of 1·47. With ¼, ½. and even up to 1 cwt. per acre of sulphate of ammonia the nitrogen percentage never exceeded 1·5. With 2 cwt. per acre the nitrogen was raised to 1·6 per cent., and with 4 cwt. to 1·7. Thus, so long as the nitrogen application was about 1 cwt. per acre, and did not exceed 2 cwt. there was little difference between the nitrogen in the manured and in the unmanured barley, and when 2 cwt. was exceeded the percentage of nitrogen at once increased.

Corresponding results were obtained when muriate of ammonia was used, the nitrogen being, however, rather lower then than with the sulphate.

MR. JULIAN L. BAKER said that it might possibly be dangerous if brewers got into their minds that high nitrogen was necessarily bad in barleys. At the present time little was known of the particular kinds of nitrogen which the yeast plant required, and until further information was available on that point the *dictum* that high nitrogen was necessarily bad could not logically be upheld. It might even be a retrograde step to breed malting barleys with a low nitrogen content, as it might lead to insufficient nutriment for the yeast. With regard to the formula which Dr. Bishop had submitted to them, he would like to ask if it was based on barley in bulk or screened barley. If on the former, it might be possible that the formula would have to be adjusted to individual maltings, depending on the percentage of screenings removed.

MR. L. C. THOMPSON, said that the data in the paper were confined to Spring sown barley. Could Dr. Bishop say anything about Winter sown barley?

MR. H. F. E. HULTON said that when the Barley Sub-Committee of the Institute's Research Scheme asked Dr. Bishop to investigate the "Nitrogen Question" he (the speaker) was in a minority in believing that the best order in which to attack the problem of "Nitrogen from Barley to Beer" was the reverse of that actually adopted and thought that it would be better to find out firstly, what types of nitrogenous compounds yeast demanded or preferred, next to find out what malts yielded them in optimum amounts or ratios in the mash tun, and finally what barleys produced such malts. Had the time so far spent in investigating the proteins of barley been thus employed he ventured to think that we should by now be in possession of much valuable information capable of more immediate application. He was the more inclined to adhere to this view since it now appeared likely that most barleys contained much the same types of nitrogenous compounds in the same proportions though in greater or less actual amounts, and although the work Dr. Bishop had so far accomplished was of the greatest value and interest and would in any case have had to be done eventually to make the story complete, he felt it was the problem of yeast nutrition that was the more urgent and the solution of which would have been of more immediate value to the brewer. The order actually being followed was of course the more logical, and he had no doubt that there was much to be said for it, and he looked forward with the greatest interest to the complete unfolding of the whole story for which all those concerned with the "Nitrogen Question" had waited so long.

MR. F. E. DAY, remarked on the important association between small grains and high nitrogen content. In the course of his work at Rothamsted he had come across several cases in which high nitrogen was associated with small grains, and at the same time with extreme irregularity in the distribution of the nitrogen in the individual grains. So much was this the case, that a small sample of barley could not be ground up for the nitrogen estimation if accurate results were to be obtained. Even samples of 20 or 30 grms. successively ground up would give different nitrogen results owing to the uneven distribution between the individual grains. He had worked out the nitrogen figures of some of Dr. Voelcker's last year's barley with which he had obtained a high yield. That barley was an exceptional case; although it had a high yield and high nitrogen it contained a great deal of immature grain. For several years, experiments had been carried out at the Norfolk Agricultural station in which ½, 1, 1½, 2 and 3 cwt. of sulphate of ammonia were put on with the grain in the Spring, and in each year the nitrogen percentage went down with increasing additions up to about 2 or 2½ cwt. per acre and the yields showed that the crop took out approximately the same proportion of the nitrogen that was put on in each case. In other words, the yield obtained with increased nitrogen slightly exceeded the proportion that it should have had to that increase of nitrogen. Proportionately more carbohydrate was formed until a certain point was reached, after which the carbohydrate did not balance the increased nitrogen and the nitrogen percentage in the grain was then increased.

Mr. J. A. Burns, said it was surprising that soil used in pot experiments retained its specific bacterial characteristics. The effect of nitrogen available after barley was well grown would suggest that if grass and clover were sown with barley, nitrifying bacteria, associated with the clover roots, would fix atmospheric nitrogen to give a continuous supply of nitrates through the summer and might thus increase the nitrogen percentage of the barley.

Mr. H. Heron said that Dr. Bishop's paper has given a reason for the low nitrogen content to the barleys harvested during the past few years. It would be remembered that 1927 was a very wet year, followed by two very dry years in 1928 and 1929, and yet, notwithstanding the entirely opposite weather conditions the barleys for each year had a low nitrogen content.

Dr. Bishop had explained that in a wet year the growth of the plant was encouraged to produce a larger number of ears, and the higher yield produced a low nitrogen content in the grain. In the two following dry years, although conditions were such that a higher nitrogen content might have been anticipated this was discounted by the higher yields which were obtained. It had been explained that these higher yields had been due to the more general use of artificial fertilisers. Now Dr. Bishop had shown that the use of artificial fertilisers gave a high yield without increasing the nitrogen in the barley, but that when organic fertilisers were used, nitrogen was supplied to the plant at a later stage of its growth, and tended to increase the nitrogen in the grain. There was no doubt that what were judged as high quality barleys were too low in nitrogen to meet present-day requirements, and he thought it was time that the methods of valuation were modified, and the farmer was taught to appreciate the fact that this kind of barley was not what the brewer desired. It seemed to him that a combination of artificial and organic fertilisers would produce a high yield, and, at the same time, would supply sufficient nitrogen to the grain to meet the brewers' requirements, and he thought that this was a line of investigation that might be considered.

Mr. H. L. Hind said he wished to emphasise the point that the Barley Research Committee had continually in view, as one of its main objects, the advantage of the British farmer. It has indeed been criticised for thinking too much of the farmer, and too little of the brewer. With this he entirely disagreed, in the belief that by helping the farmer in the cultivation and improvement of barley the brewers were helping themselves. In regard to the increase of yield already referred to, there was no doubt that the work which had been done at Rothamsted was a contributory factor. County agricultural authorities had based their instruction to farmers on the results of the manurial trials. Variety, however, constitutes another factor in the increase of yield, and farmers had largely to thank Dr. Beaven for the present state of affairs in regard to barley. Barley growers in this country would applaud the decision to offer the Horace Brown medal this year to Dr. Beaven. He had done more for agriculture and brewing in connection with the development of improved varieties of barley than anyone else.

Variety is of equal importance to the maltster as to the farmer, and purity of seed is essential to both. Anything that the National Institute of Agricultural Botany could do to increase the use of pure seed of improved varieties would benefit both farmers and brewers, and the Research Scheme was endeavouring to help the National Institute in their efforts to spread pure seed by affording technical information on the value of the varieties raised.

There was an earnest movement now to encourage trade with the Colonies and Dependencies, and as a large part of the U.K. imports of barley came from other countries, the Research Committee was assured that it would have the support of members in giving any aid in its power to Colonial authorities in their endeavours to obtain improved barleys of types similar to those imported from foreign countries. They had been for some time in correspondence with the Government of India, and, through the Department of Overseas Trade, with the authorities in Palestine. Valuable help had been given through the Valuation Committee and with the assistance of Messrs. Hugh Baird & Sons. They had already received from India samples of barley which were much superior to anything at présent on the market which had come from there. There was no reason why the varieties which had been grown in those countries from time immemorial should be the best for their soils and climates, and it was probable that the Institute would be able to help those, and other countries, in the Empire, greatly to improve their barleys. That help was not given with the anticipation that the barleys from those countries would displace British barley, but rather that they would compete with that of those foreign countries which brewers at present demanded in such large quantity.

Most brewers would think it impossible to use a home-grown barley of the six-rowed winter type, but it had been shown that excellent beer can be brewed with six-rowed Winter barley. The barley tried was again the result of Dr. Beaven's work.

Dr. L. R. Bishop, in reply, said he must, first of all, make it clear that he could not, yet, attempt to give any decision as to which was the best nitrogen content for brewing barley. As he had pointed out, low nitrogen barley had advantages in extract yield and capacity for malting; but he was in agreement with Mr. Hulton that the need still outstanding was a knowledge of the yeast and beer nitrogen requirements. With this question answered, the other researches would fit in to give a definite answer to the "nitrogen question."

From the farmer's viewpoint, the best barley of to-day was the one with a low nitrogen content, since he was paid most money for it. If, as was indicated, this was not really the best, it emphasised the need for a sound objective method of barley valuation. The farmer would then, within limits, be able to grow the barley for which he was paid the best price.

Dr. Voelcker, in mentioning the barley crop at Woburn, had given a good instance of the effect of soil, last season's weather, and manuring on the barley crop. The actual field was one with which he was acquainted, and could explain. Although as he had pointed out, the yield was very high, the evidence seems to show that, with favourable rain in summer, the yield would have been even higher. This was indicated by the small badly filled grain mentioned by Mr. Day, and also by the lack of response in yield to the higher manurings. Both nitrogen and potash separately gave increases in yield, but the two together, contrary to usual experience, gave no further increase. This suggested that on the light sandy soil of Woburn it was the water supply in the soil which was limiting the size of the crop. Mr. Day had pointed out that, despite the high yield, the nitrogen of the grain was also high. This could be attributed partly to the reduction of yield through checking of translocation by the summer drought, but chiefly to the fact that the year before that field was very heavily dressed with organic manures for the sugar beet crop. The Woburn pot experiments illustrated the relation between yield and amount of nitrogen taken up. With the smaller doses, the yield increased more than proportionally to the nitrogen taken up, and the nitrogen percentage fell. With the larger doses, the yield increase was no longer proportionally larger, but the nitrogen uptake increased, and so the nitrogen percentage rose again.

He agreed with Mr. Harman and Mr Heron that there were other things comprised in "quality" apart from nitrogen. He did, however, consider that nitrogen was the most important factor in quality. Germination was probably another important factor, and incidentally the extract equation did not hold when the germination was bad. Sunlight during ripening was mentioned by Mr. Heron as favouring quality. It might do so by leading to good germination, but this was an opinion only.

As far as he could tell neither the source from which the plant obtained its nitrogen nor the time of uptake affected the proportions of the separate proteins in the grain. So that, in answer to Mr. Harman, farmyard manure had probably no special effect on the proportions of the proteins of the grain. The curves given there carried up to a barley of 2·3 per cent. total nitrogen which, of course, no brewer would consider. As Mr. Heron pointed out farmyard manure could be used to raise the nitrogen percentage of grain, if that was found desirable, but it was as well to note that this would be accompanied by immature corns from the effects on tillering which he had described.

Mr. Baker rightly drew attention to the danger that screening might affect the extract prediction equation but as far as he (the speaker) was aware it was not a serious danger. The barley analyses were made on samples as received, but the malting (which was in bulk) was done on screened barley. The lack of effect might be explained as follows:—The smaller grain removed by screening tended to have a lower extract by reason of the smallness of the grain, but this was offset by the fact that the smaller grain had a lower nitrogen content. He could make no satisfactory answer to Mr. Thompson's query about winter sown barley as this had not been compared with spring sown on many occasions. The comparisons available suggested that winter barleys, owing to the longer vegetative period, gave higher yields and in consequence lower nitrogen percentages, subject to the proviso that the plants stood the winter well. If they did not, the reverse would be the case, as with barleys sown wide. In California where the winter was not severe, an experiment with very regular results demonstrated that the yield was greater and the nitrogen content lower the earlier the sowing.

Mr. Burns suggested that the behaviour of the Fen and Porlock soils in the experiments might not be directly comparable with those soils in the field and he (the speaker) quite agreed. The moving would cause enormous changes comparable with the effect he had shown of turning out the soil from a pot and putting it back. He had used these soils as types of general behaviour rather than exactly typical of those two in their respective homes. He knew of no experiments which would answer the question of what effect there was from undersowing with clover.

MEETING OF THE YORKSHIRE AND NORTH-EASTERN SECTION, HELD AT THE QUEEN'S HOTEL, LEEDS, ON FEBRUARY 20TH, 1930.

Major W. J. Sproulle in the chair.

The following paper was read and discussed :—

SIDELIGHTS ON COPPER AS APPLIED TO BREWING.

By D. M. Stewardson, A.M.Inst.B.E.

On account of its many and varied applications, copper is one of the most important of non-ferrous metals. It was the first metal used by man, was found native and therefore required no metallurgical knowledge to bring it to its metallic form. In the Hebrew scriptures, copper was called "*Nehoseth*," from "*Nehash*," meaning to "glisten," but derived its name from the island of Cyprus (*Κὺπρος*), where the Romans obtained their copper ores. It is interesting to note that copper has been detected in the ash of certain plants, in crabs, snails, and certain other lower animals, also in the feathers of birds, in blood, eggs, and milk, etc. In some of these cases its presence is accidental, but in a few of the lower animals it is a normal constituent. Colloidal copper is used in medicine for the treatment of cancer, tuberculosis, etc., and is also used as an antiseptic.

The bulk of copper is obtained from the United States in the region of Lake Superior, it is also mined in Chili, Belgian Congo, Japan, Canada, Mexico, Spain, Peru and Germany. Great Britain in 1926 produced about 108 tons.

Copper is distinguished from all other metals by its red colour, it is very malleable and ductile, and can be rolled into very thin sheets and drawn into very fine wire, By cold rolling or other mechanical treatment it becomes hard, but will regain its malleability and ductility on annealing, after which it is immaterial whether the metal is quenched in water or allowed to cool slowly in air. Its tenacity when cast is from eight to ten tons per sq. in., but after rolling or drawing this is increased to between 16 and 23 tons, according to the amount of mechanical treatment it has received. The sp. gr. of pure copper at 68° F., rolled, forged, or drawn and then annealed, may be taken as 8·89, but that of any ordinary commercial copper usually ranges from 8·2 to 8·6. The melting point of copper is 1,083° C., and when molten is rapidly oxidised, forming cuprous oxide (Cu_2O) which dissolves in the metal up to a limit of six per cent. The metal also dissolves hydrogen, carbon monoxide, and sulphur dioxide, which gases are given off during solidification, part, however, remains in the metal producing more or less porosity,