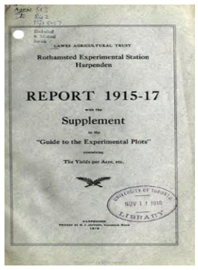
ROTHAMSTED RESEARCH

Report 1915-17 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.



Papers Published

Rothamsted Research

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PAPERS PUBLISHED.

SOIL PROBLEMS.

I. "*The Atmosphere of the Soil: its Composition and the Causes of Variation.*" E. J. Russell and A. Appleyard. Journal of Agricultural Science, 1915. 7, 1-48.

The free air in the pores of the soil to a depth of six inches is very similar in composition to the atmospheric air, but it differs in two respects:

(*a*) It contains more carbon dioxide and correspondingly less oxygen, the average in 100 volumes being 0.25 volumes of carbon dioxide and 20.6 of oxygen against 0.03 volumes of carbon dioxide and 20.96 of oxygen in atmospheric air.

(*b*) It shows greater fluctuation in composition.

Usually the sum of the carbon dioxide and oxygen is only slightly less than in atmospheric air, but at periods when nitrates rapidly increase there is a perceptible falling off of oxygen, and a still greater one in waterlogged soils.

Besides this free air there is another atmosphere dissolved in the water and colloids of the soil. This consists mainly of carbon dioxide and nitrogen and contains practically no oxygen.

The fluctuations in composition of the free soil air are mainly due to fluctuations in the rate of biochemical change in the soil, the curves being similar to those showing the amount of nitrate and the bacterial counts as far as they were taken. The rate of biochemical activity attains a maximum value in late spring and again in autumn, and minimum values in summer and winter. In autumn the bacteria increase first, then the carbon dioxide rises, and finally the nitrate increases.

From November to May the curves closely follow those for the soil temperature which thus appears to be the dominating factor; from May to November they follow the rainfall and to a less extent the soil moisture curves. The difference between rainfall and soil moisture indicates that rainfall does something more than add water to the soil. It is shown that the dissolved oxygen brought in is probably a factor of considerable importance in renewing the dissolved soil atmosphere and facilitating biochemical change.

Grass land usually contains more carbon dioxide and less oxygen than arable land, but we cannot attribute the difference wholly to the crop owing to the large differences in soil composition and conditions. It is difficult to ascertain the precise effect of a crop, but as the soil differences are eliminated so the differences in composition of the soil air becomes less and less. No evidence could be obtained that the growing crop markedly increases the amount of carbon dioxide in the soil air; if it gives rise to any great evolution of carbon dioxide in the soil it apparently exercises a correspondingly depressing effect on the activities of soil bacteria. This result agrees with one obtained earlier in reference to the nitrates in the soil.

Such weather conditions as barometric pressure, wind-velocity, variations in temperature from the mean, small rainfall, etc., seem to have but little effect on the soil atmosphere.

II. "*The Influence of Soil Conditions on the Decomposition of Organic Matter in the Soil.*" E. J. RUSSELL and A. APPLEYARD. Journal of Agricultural Science, 1917. **8**, 385-417.

The changes in bacterial numbers and in nitrate content of the soil and in carbon dioxide content of the soil air were determined at frequent and regular intervals during several seasons on five different plots of land, and the results are set out on curves.

There is sufficient resemblance between the curves for bacterial numbers, carbon dioxide (except for a period on cropped land), and nitrate content to justify the conclusion that they are all related.

The curve for nitrates, however, is always behind that for bacterial numbers, the lag amounting to two or three weeks. Assuming that the curves are connected, this would indicate two stages in nitrate production: one related to the bacterial numbers, the other not. Evidence is brought against the view that the stages are simply ammonia production and then nitrate production; the division has apparently to be carried further back and ammonia production to be divided into two stages.

The biochemical decompositions in the soil are determined in the first instance by the temperature and do not proceed to any notable extent below 5° C.

As soon as the temperature rises in spring, action takes place rapidly. But it soon slows down and other factors begin to operate.

Moisture is one of them. Action came to a minimum in June, when the moisture fell to 10 per cent. by weight of the unmanured soil and 15 per cent. by weight of the dunged soil, or 16 and 22 parts respectively by volume, assuming there was no contraction.

Rainfall is an even more important factor, a shower of rain having a notable effect in starting the decompositions. It seems probable that the dissolved oxygen plays an important part here.

The growing crop exerts a depressing effect, though whether by taking up the dissolved oxygen, giving out carbon dioxide, or some other action is not clear.

The fluctuations in bacterial numbers are not wholly explicable as functions of the temperature and moisture content. Some of the rises and falls are of the kind obtained during the investigations on partial sterilisation; further work on this problem is in hand in our laboratories.

III. "*Dissolved Oxygen in Rain Water.* ERIC HANNAFORD RICHARDS. Journal of Agricultural Science, 1917. **8**, 331-337.

Rain water was collected in a special form of apparatus, and the amount of dissolved oxygen was determined by Winkler's method on each occasion when 0.3 inches or more fell—this being the lowest rainfall that gave sufficient liquid for the analysis. During autumn, winter and spring, when the temperature was below 15° C., the rain was practically saturated with oxygen, the quantities found being on an average 93 per cent. of Dittmar's complete saturation values for distilled water. Rain collected in summer, however, was less saturated, the amount of oxygen being 85 per cent. of the full saturation value. The difference was carefully examined and found to be real; it is not an accident of the method of collection. It is difficult to understand why the summer rain should contain less oxygen than rain falling in the rest of the year, especially in view of the circumstance that the relative temperatures of the rain clouds and of the air at ground level ought to cause super-saturation in summer and not under-saturation.

The significance of the dissolved oxygen in the soil is discussed.

IV. "*Methods for the Examination of Soil Protozoa.* CHARLES HENRY MARTIN and KENNETH R. LEWIN. Journal of Agricultural Science, 1915. **7**, 106-119.

Descriptions are given of some of the organisms isolated in the trophic state by the two methods already described (Annual Report for 1914, page 19). Amœbæ and thecamœbæ were most frequently met with; ciliates and flagellates* were relatively rare.

The organisms described are *Euglypha* and *Chlamydophrys* among the thecamœbæ; *Chilodon*, a ciliate; *Vahlkampfia soli*, a limax amœba, *Amœba gobaniensis* and *Amœba cucumis*, lamellipodian amœbæ, and *Boda caudatus*, a flagellate; all these had been found in the trophic state in the soils examined.

V. "*Soil Protozoa and Soil Bacteria.*" E. J. RUSSELL. Proceedings of the Royal Society, 1915. **89**, 76-82.

The experimental evidence of the existence in soil of a living protozoan fauna in the trophic, as distinct from the encysted, state is collected. The fauna is shown mainly to consist of flagellates, amœbæ and thecamœbæ; ciliates only being present in smaller numbers, and probably for the most part in the encysted form. This conclusion is in harmony with Goodey's work, and with all the facts at present ascertained.

VI. "*The Utilisation of Organic Residues for Nitrogen Fixation and the Losses of Nitrogen from the Soil.*" HENRY BROUGHAM HUTCHINSON. Journal of Agricultural Science, 1918. **9**, 92-111.

It has long been known that appreciable quantities of gaseous nitrogen may be assimilated from the atmosphere when a soil or a culture of a soil organism (*Azotobacter chroococcum*), is supplied with soluble carbohydrates under laboratory conditions. The present paper shows that this action also occurs under natural conditions, and that plant residues can be utilised for nitrogen fixation in the laboratory and in pot experiments. Crop increases may also be obtained when field soils are treated with an easily oxidisible carbohydrate such as sugar, and these may be attributed to the assimilation of atmospheric nitrogen.

The effect of carbohydrates and of plant residues on the soil is shown to be complex, and under certain conditions—when the soil temperature is low, or when the applications are made too near to the time of sowing—marked depression of the crop may occur. This effect appears to be largely due to destructive processes, which result in a withdrawal of available nitrogen compounds or a loss of free nitrogen from the soil.

*Subsequent work has shown that amœbæ and thecamœbæ are much more numerous than ciliates, though, as a matter of fact, the flagellates are often more numerous still—not less so as these earlier observations suggested.

VII. "*The Non-Persistence of Bacterio-Toxins in the soil.*" HENRY BROUGHAM HUTCHINSON and AAGE CHRISTIAN THAYSEN. Journal Agricultural Science, 1918, **9**, 43-62.

It has been claimed by other workers that the phenomena of partial sterilisation of soil are due, in part, to the destruction of bacteric-toxins when a soil is subjected to heat. The experiments on which this conclusion is based were, therefore, repeated and extended; in particular, a comparison was made of the growth of a test organism—*B. prodigiosus*—when inoculated into an extract of untreated soil and into a similar portion of extract which has been heated with the object of destroying any toxins present. The results obtained with six normal English soils show that the initial depression occurring when a culture is carried into an extract of untreated soil is not due to the action of toxic substances in the extract, as has been assumed by other experimenters, but is more probably a starvation effect. When these extracts were subjected to heat, their suitability for growth was still further reduced, but the addition of minute quantities of peptone was sufficient to convert them into media suitable for active growth.

The only extract which showed improvement on boiling was that of a very acid soil, but in this case the observed toxicity appears to be connected with the presence of acid iron and aluminium compounds, which are liberated by the action of neutral salt solutions, but thrown out of action when the extracts are heated.

VIII. "*The Reaction between Dilute Acids and the Phosphorus Compounds of the Soil.*" E. J. RUSSELL and JAMES ARTHUR PRESCOTT. Journal of Agricultural Science, 1916. **8**, 65-110.

This reaction is of great importance in soil analysis, as it forms the basis of the methods for determining the amount of phosphate "available" in the soil for the plant. In studying this reaction in the laboratory it was found to throw important light on the constitution of the soil.

When soil is shaken with a dilute acid a certain amount of phosphoric oxide (P_2O_5) is dissolved, the quantity depending on the particular acid and the conditions of the reaction. Under similar conditions the amount varies widely with different acids, being greatest with citric and oxalic acids, which are usually regarded as weak acids, and least with hydrochloric and nitric acids, the strong acids. The investigation cleared up this anomaly.

It was shown that the action is really complex; two changes are proceeding simultaneously, a direct and a reverse action, and the observed result is the difference between the two.

When soil is shaken with a dilute acid some of the phosphorus compounds go into solution, and the amount dissolved by different acids at equivalent concentrations is much the same; nitric, hydrochloric and citric acids give the same results; sulphuric acid gives a somewhat higher result.

A reverse reaction at once sets in, however. Some of the phosphoric oxide is withdrawn from the solution in spite of the presence of excess of acid. The process is an ordinary adsorption and obeys the usual law expressed by the equation $y=Kc^{\frac{1}{p}}$. Its extent varies with the different acids; it is much more marked in the presence of nitric than of citric acid.

The amount of phosphoric oxide actually determined by the analyst is, therefore, not the true amount dissolved, but the difference between these two wholly different actions.

It is now obvious why the amount of "available Phosphoric Oxide" determined by extraction with dilute acids shows such great variations in different methods of analysis and so little correlation with the actual quantities obtainable by the crop. In no case do they stand for any single quantity, but only for a difference between a direct action and an adsorption which varies with the nature of the acid and the conditions of the experiment.

So long as they are confined to the same type of soil, however, any of the acids investigated would have given useful results, but difficulties would arise directly an attempt was made to compare dissimilar soils. The proper way to use a soil analysis is in conjunction with a soil survey.

A diffusion method is described in which the reverse reaction is eliminated and which therefore gives a true measure of the direct action. But until we have had more experience with it we are not prepared to say what value it has for soil analysis.

IX. "*The Phenomenon of Adsorption in its Relation to Soils.*" James Arthur Prescott. Journal of Agricultural Science, 1916. **8**, 111-130.

A résumé of the subject in which the voluminous literature is critically examined and summarised. Several directions are indicated in which more investigations are needed.

X. "*Note on the loss of Phosphoric Acid during Fusion with Ammonium Fluoride.* W. A. Davis and J. A. Prescott. Journal of Agricultural Science, 1916. **8**, 136-138.

Considerable loss of phosphoric acid may occur when salts or minerals containing this substance are ignited with ammonium fluoride in the ordinary process of analysis of silicates. It seems possible that the phosphorus is volatilised as a fluoride. The loss is least in the case of salts containing an alkali metal, but is greater for phosphates of the alkali earth metals, such as apatite and other calcium phosphates.

XI. *The Recovery of Ammonium Molybdate used in phosphate Estimations.* J. A. Prescott. The Analyst, 1915. **40**, 390-391.

The mixed residues are acidified if excess of acid is not already present and evaporated to small bulk. The yellow precipitate of molybdic acid which separates is filtered off, washed with cold water, dissolved in ammonia and freed from phosphoric acid by means of magnesia mixture. The filtered solution is concentrated, keeping ammonia present in excess, and allowed to crystallise.

If the solution is blue owing to the presence of lower oxides of molybdenum it is treated with hydrogen peroxide.

XII. "*Studies of the Lime Requirements of Certain Soils.* Henry Brougham Hutchinson and Kenneth MacLennan. Journal of Agricultural Science, 1915. **7**, 75-105.

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Two different effects of lime are studied, its sterilising action and its power of neutralising acidity. Sterilisation is effected when so much lime has been added that an aqueous extract of the soil is alkaline to phenolphthalein; chemical, bacteriological and physiological tests all closely agree. This can be effected by lime only; the carbonate is of no use for the purpose.

Neutralisation, however, requires much less lime, and can equally be brought about by the carbonate. The amount necessary is indicated by the adsorptive capacity of the soil for calcium bicarbonate.

A definite connection was traced between soil reaction and natural flora on soils of the same type and similarly situated; for example, in making a close survey of Harpenden Common the following plants were dominant in patches of differing lime requirements, clover appearing only where the need for lime was small, Yorkshire fog and finally sorrel where the need was great :—

LIME REQUIREMENTS AS RELATED TO VEGETATION.

Average Lime requirement of Soil.	Dominant Flora.
Approx. 0.22% $CaCO_3$	*Trifolium repens* (wild white clover)
,, 0.26% ,,	*Festuca ovina and rubra*
,, 0.31% ,,	Mixed. *Achillea Millefolium*, *Luzula* and moss.
,, 0.39% ,,	*Ulex europæus* (gorse)
,, 0.43% ,,	*Holcus lanatus* (Yorkshire fog)
,, 0.53% ,,	*Rumex Acetosa* (sorrel)

XIII. "*The Effect of Removing the Soluble Humus from a Soil on its Productiveness.*" William Weir. Journal of Agricultural Science, 1915. 7, 246-253.

A large quantity of soil was divided into two portions; one was treated with dilute hydrochloric acid and repeatedly extracted with dilute caustic soda solution so as to remove soluble humus; the other was left untouched. Chalk was added to the treated soil to make the carbonate content equal to that of the untreated soil; the soils were then put into pots and sown with four crops in succession: wheat, mustard, rye, and finally mustard again. In each case the yields, both of dry matter and of nitrogen, were approximately the same for the untreated and the treated soils, in spite of the circumstance that the extraction had removed 40 per cent. of the nitrogen from the soil.

Laboratory experiments were also made to ascertain the effect of the extraction on the production of ammonia and nitrates in the soil. It was found that the extraction increased the bacterial numbers and ammonia accumulation, but diminished nitrate production, though the sum of ammoniacal and nitric nitrogen is usually less in the extracted than in the untreated soil. These results agree with those obtained by W. Buddin, when soils were treated with non-volatile antiseptics (Report for 1914, p. 12), and they suggest that one result of the extraction process is partially to sterilise the soil.

INVESTIGATIONS ON FARMYARD MANURE.

XIV. *"The Changes taking place during the Storage of Farmyard Manure."* E. J. Russell and E. H. Richards. Journal of Agricultural Science, 1917. **8**, 495-563.

The changes in a manure heap are at a minimum under anaerobic conditions, and they are as follows :—

In the laboratory experiments as much as 17 per cent. of the dry matter may be converted into gas, in the heap the proportion is less.

The non-nitrogenous constituents are particularly affected, one quarter of the pentosans may disappear during the process and other constituents break down in like proportion. The gas evolved contains carbon dioxide, marsh gas and hydrogen.

The nitrogenous compounds also break down, part of the complex compounds giving rise to ammonia. In the laboratory experiments more ammonia is found at 26° C. than at 15° C ; in the only heap where we were satisfied that the conditions were anaerobic there was no accumulation of ammonia.

No nitrates are formed.

There is no loss of nitrogen during the process ; the whole of the initial nitrogen being recovered within the error of the experiment.

The aerobic changes are as follows :—

The loss of dry matter is greater and the temperature rises higher than under anaerobic conditions. The gases evolved contain no hydrogen or marsh gas. The loss of dry matter shows some relationship to the aggregate rise of temperature.

There is almost always a larger decomposition of complex nitrogen compounds than under anærobic conditions. Usually no ammonia accumulates in the laboratory experiments, and in the heap there is invariably a loss. Nitrate is found in the dry outer portion of the heap, but not in the moister interior, nor was it found in the laboratory experiments where the manure remained moist ; the necessary conditions appear to be dryness and sufficient air.

Under conditions of perfect aeration no loss of nitrogen occurs. Under ordinary conditions of incomplete aeration, however, there is an evolution of gaseous nitrogen.

The loss of ammonia shows some relationship to the maximum temperature attained.

Exposed heaps lose more dry matter than sheltered heaps and also more ammonia, if any appreciable quantity is present ; but the loss of total nitrogen is not always greater. Field experiments show that the loss of crop producing power caused by exposure is greater than the analytical figures indicate.

The loss of nitrogen is not a necessary accompaniment of the loss of dry matter, since, as already stated, it does not occur under purely aerobic or purely anaerobic conditions, although other constituents are lost. But the loss of nitrogen that takes place in the mixed aerobic and anaerobic conditions occurring in practice varies under comparable conditions with the loss of dry matter, all constituents of the heap apparently breaking down simultaneously. An exception occurs when the temperature has risen high, *e.g.*, to 70° C., after which decomposition of dry matter and loss of nitrogen proceed more slowly than loss of dry matter, so that there is an actual concentration of nitrogen in the heap.

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Similarly also in exposed heaps the loss of dry matter is usually proportionally greater than that of nitrogen.

The loss of nitrogen might occur by
(*a*) washing away of soluble nitrogen compounds,
(*b*) volatilisation of ammonia,
(*c*) evolution of nitrogen,
(*d*) other ways.

From the sheltered heap (*a*) is excluded.

It is further shown that (*b*) can hardly account for the observed losses in the heap, and certainly not for those in the laboratory experiments, where the extent of volatilisation was measured and found to be only small. An evolution of nitrogen has been demonstrated in the laboratory experiment and presumably a similar change goes on in the heap.

In the laboratory experiments decomposition never proceeded very far, the maximum losses being 17 per cent. of dry matter, 30 per cent. of complex nitrogen compounds, and 33 per cent. of total nitrogen.

In our heap experiments we find this last fraction of complex nitrogen compounds, representing 50 to 60 per cent. of the original total nitrogen, only decomposes very slowly indeed.

XV. "*On Making and Storing Farmyard Manure.* E. J. Russell and E. H. Richards. Journal of the Royal Agricultural Society, 1917. 77, 1-35.

In this paper the above results are applied to the practical problem of storing farmyard manure.

The objects to aim at in a manure heap are to secure
(*a*) as much dry matter,
(*b*) as much ammonia, and
(*c*) as little loss of nitrogen as possible.

The laboratory experiments show that these objects can all be attained by storing the manure heaps under anaerobic conditions (*i.e.*, with complete exclusion of air) at about 26° C. Under these circumstances there is a formation of ammonia and no loss of nitrogen, although some loss of dry matter occurs.

The farm experiments, on the other hand, show that these desirable results are not attained in manure heaps, no matter how well put up. However compact the heap some nitrogen is always lost and there is never an accumulation, but commonly a loss of ammonia.

Apparently the requisite conditions can only be attained in a water-tight pit or tank that could be closed so as to keep out oxygen and keep in the carbon dioxide produced by fermentation. This would be the ideal method for storing farmyard manure. But as this ideal method presents practical difficulties, we must see how nearly the best methods of practice approximate to it, and whether any further improvements can be suggested.

Two cases arise :

1.—Manure left undisturbed under the beasts, *e.g.*, manure made in covered yards or stalls by fatting beasts.

2.—Manure thrown out daily, *e.g.*, manure made from dairy stock or from the horse stables.

1.—All experiments show that the manure left under the beasts suffers a loss of about 15 per cent. of its nitrogen ; there is no accumulation of ammonia, but, on the contrary, less ammonia than corresponds with the digestible nitrogen in the food. This method is far from being perfect ; but in comparative experiments it has always come out better than any heap, and if the buildings are good and the manure is well made there is probably little scope for improvement.

Further losses set in as soon as the beasts are removed or the manure is hauled out into a clamp ; in particular, there is always a loss of nitrogen.

The losses become more serious if the heap is not properly compacted or if it is left exposed to the weather. Compacting only delays, and does not prevent loss, especially in the heaps stored over summer. Shelter from rain proved distinctly effective in conserving the crop-producing power of the manure.

2.—Manure thrown out daily. From the outset the conditions are aerobic, involving marked losses of dry matter, of ammonia, and to a less extent of total nitrogen, and the losses are aggravated when the heaps are thrown out into the open and exposed to the washing of the rain and the drying of the sun. Improvement can be effected by carrying the manure into a sheltered place, such as the Cheshire dungstead or the Oxford manure house, but even the best dungstead still retains some of the imperfections of the clamp.

We think the best prospect of dealing with manure from dairy cows is to aim straight away at storage in a pit or tank, and experiments to this end are being carried out on the farm of the Hon. Rupert Guinness at Hoebridge, Woking.

The practical conclusions are :—

(*a*) The method of leaving manure under the beasts in boxes or covered yards until it is wanted remains the best that we can suggest where it is practicable.

(*b*) If the manure has to be stored it should be under anærobic conditions (*i.e.*, complete absence of air), and if possible at a temperature of about 26° C.

(*c*) No heap, however well compacted or sheltered, fully satisfies these requirements. Probably the making of the heap has been developed to as perfect a pitch as possible, and we have no further improvements to suggest.

(*d*) The best hope for improvement lies in storing the manure in watertight tanks or pits, so made that air can be completely excluded and the proper temperature maintained.

We are hoping the experience gained in the new Woking experiments will indicate a method whereby this end can be achieved in practice.

XVI. "*The Fixation of Nitrogen in Fæces.*" ERIC HANNAFORD RICHARDS. Journal of Agricultural Science, 1917. 8, 299-311.

During the course of the preceding investigations gains of nitrogen were occasionally recorded instead of losses, and on examination it was found that horse fæces contain material which can be utilised by the free-living nitrogen-fixing organism *Azotobacter* in presence of sufficient moisture and calcium carbonate. The amount of nitrogen that can be fixed depends on the diet, and is much reduced when the horses are fed on grass alone, instead of corn and hay.

Under the most favourable conditions, four mgms. of nitrogen is fixed per gram of dry matter present in the fæces.

Nitrogen fixation also takes place in bullock fæces, but to a smaller extent than in horse fæces. Here also it depends on the diet, as it occurs only when animals are fed with cake, and not when they receive grass alone.

Evidence is adduced to show that fixation is brought about by a mixed culture of *Azotobacter* and *B. lactis aerogenes*. Of these the latter is normally present in fæces; *Azotobacter* is not, but readily comes in by infection. Both organisms are present in the soil.

XVII. "*Some Experiments on the House Fly in relation to the Farm Manure Heap.*" H. ELTRINGHAM. Journal of Agricultural Science, 1916. 7, 443-457.

The possibilities of the manure heap as a breeding ground for flies were investigated. Heaps were made up and left for a certain period to allow of infection; they were then covered over completely with gauze frames fitted with fly traps, and the flies as they emerged were collected, identified, and counted.

Manure heaps near to dwelling houses form a prolific breeding ground for the ordinary house fly; heaps remote from the house, however, are but little frequented, and then only later in the season when the flies have become numerous and widely dispersed. It is shown that the flies do not live in the heap, but only use it as a convenient breeding place; they travel backwards and forwards to the house for their food. Care should be taken, therefore, to place the manure heap so far from the kitchen that it is no longer possible for them to continue feeding in the kitchen and breeding in the manure heap.

Even when this is done, the heap may still remain a prolific source of the biting fly, *Stromoxys calcitrans*, a blood sucking insect, harmful to man and beast, and of *Musca autumnalis*, which closely resembles the house fly, but swarms in the open and only enter houses in autumn. Where these are sufficiently numerous they are harmful, and the heap should be treated with an insecticide.

PLANT NUTRITION PROBLEMS.

XVIII. "*Studies of the Formation and Translocation of Carbohydrates in Plants. I.—" The Carbohydrates of the Mangold Leaf.*" WILLIAM ALFRED DAVIS, ARTHUR JOHN DAISH and GEORGE CONWORTH SAWYER. Journal of Agricultural Science, 1916. 7, 255-326.

Starch is entirely absent from the leaf after the very earliest stages of growth and disappears entirely as soon as the root begins to develop and receive the sugars formed in the leaf. Maltose is entirely absent from the leaf, mid-ribs and stalks at all stages of growth and at all times of night and day.

During the early stages of growth of the mangold, when leaf formation is the principal function, saccharose is present in the leaf tissues in excess of the hexoses. The reverse holds good later in the season, when sugar is being stored in the root; hexoses then largely predominate in the leaf.

In the mid-ribs and stalks the hexoses always predominate and they vary widely in amount during day and night and throughout the season, whilst the saccharose remains practically constant. In passing from leaves to mid-ribs, from mid-ribs to the tops of the stalks, and from the tops of the stalks to the bottoms, the ratio of hexoses to saccharoses steadily increases. As the season advances the predominance of the hexoses in leaf, mid-ribs and stalks becomes more and more marked.

The proportion of hexoses to saccharose in the leaf tissue follows the temperature curve closely during the day time.

The facts brought forward can apparently be best explained by Brown and Morris' view that saccharose is the primary sugar formed in the mesophyll of the leaf under the influence of the chlorophyll ; it is transformed into hexoses for the purpose of translocation. This transformation occurs in the veins, mid-ribs and stalks, the proportion of hexoses increasing more and more as the root is approached. The sugar enters the root as hexose and is therein reconverted into saccharose ; once in this form the saccharose is not able to leave the root until it is put under contribution for the second season's growth.

These views are in accord with de Vries' micro-chemical observations as to the nature of the sugars in the different tissues, but entirely in contradiction to those of Strakosch, which are considered to rest on no secure foundation.

They also agree with Parkin's results with the snowdrop, with Pellet's analyses of the sugar cane, with Collins' results with the sugar beet, and the authors' observations on other plants, such as the vine (*Vitis vinifera*), potato, dahlia, etc., which store carbohydrates in other forms (dextrose, starch, and inulin).

As regards the mechanism by which saccharose is synthesised from the hexoses, it is improbable that this change is effected by invertase by a process of reversible zymo-hydrolysis. The entire absence of invertase from the root is against this view.

XIX. "*Studies of the Formation and Translocation of Carbohydrates in Plants.*" II.—"*The Dextrose-lævulose Ratio in the Mangold.*" WILLIAM A. DAVIS. Journal of Agricultural Science, 1916. 7, 327-351.

Previous observers have always found more lævulose than dextrose in the leaves of plants and, as they have assumed that the two sugars are formed in equal proportions from the inversion of cane sugar, it seemed to follow that dextrose was more readily put under contribution for the respiratory processes of the cell than is lævulose. The value of the analytical results, however, depends entirely on the readings of the rotatory power, and any small error is considerably magnified in the final calculation.

The author shows that the readings are completely falsified by the presence of optically active substances other than sugars, which are not entirely removed by the preliminary purifying processes.

At present it is not possible to determine with accuracy the proportions of dextrose and lævulose in different plant tissues, nor is it possible to draw any conclusions as to their functions in the plant. Some tentative determinations have been made which, while not entirely correct, probably show the type of variation which the sugars undergo. The results agree with the assumption that dextrose and lævulose occur in equal proportions in the leaves, stalks and roots, being formed by inversion of the saccharose in the leaf ; they then

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travel in equal proportions to the root, where they are reformed into saccharose. Where the rotatory power seems to suggest a difference in amount of the two sugars, it is shown that other optically active substances are present which might account for the results obtained.

XX. "*Studies of the Formation and Translocation of Carbohydrates in Plants.*" III.—"*The Carbohydrates of the Leaf and Leaf-stalks of the potato. The Mechanism of the Degradation of Starch in the Leaf.*" W. A. DAVIS and G. C. SAWYER. Journal of Agricultural Science, 1916. 7, 352-384.

The potato leaf differs from the mangold leaf in that it contains considerable quantities of starch. Previous investigators had found maltose also, but the authors could not. They attributed the discrepancy to the circumstance that in other investigations the leaves had been dried prior to analysis, and during this process the enzyme diastase had continued to form maltose, but the enzyme maltase, which in the living leaf breaks down the maltose, had been destroyed, thus causing an accumulation of maltose in the tissues. Instead of drying the leaf they dropped it into boiling alcohol containing a little ammonia, thereby destroying all enzymes and putting an end to further action ; in these circumstances analysis gives a faithful representation of the substance in the living leaf.

The general results clearly resemble those obtained with the mangold leaf. Saccharose is greatly in excess of the hexoses in the leaf, but not in the stalks. All the evidence indicates that saccharose is the sugar first formed in the mesophyll tissue ; it is then broken down in the veins, midribs, and stalks, and reaches the tubers in the form of hexoses ; there it is built up into starch. In the leaf any excess of sugar is converted temporarily into starch, and reconverted into sugar when necessary.

As in the case of the mangold accurate values could not be obtained for dextrose and lævulose individually, owing to the presence of optically active impurities which are not removed by lead acetate ; the sum of these two sugars was readily determined.

XXI. "*The Estimation of Carbohydrates.*" IV.—"*The Supposed Precipitation of Reducing Sugars by Basic Lead Acetate.*" W. A. DAVIS. Journal of Agricultural Science, 1916. 8, 7-15.

Previous workers have found that loss of lævulose occurs when basic lead acetate is added to a solution containing a mixture of sugars, and have generally supposed that precipitation occurred. The author finds that the decomposition of lævulose undoubtedly occurs when the lead acetate acts fcr a long time, but not otherwise. There is no precipitation, but the lævulose is transformed into another sugar, apparently Lobry de Bruyn's glutose, which is optically nearly inactive and has only half the reducing power of dextrose.

XXII. "*The Distribution of Maltase in plants.*" I.—"*The Functions of Maltase in Starch Degradation and its Influence on the Amyloclastic Activity of the Plant Materials.*" W. A. DAVIS. Biochemical Journal, 1916. 10, 31-48.

Some 500 analyses of the sugars of leaves have been made in the laboratory, but in no case could maltose be detected. Many different plants were examined, some of which, such as potatoes, turnips, *Tropæolum*, and sunflowers, elaborate large quantities of starch in the leaf during the daytime to be used as a reserve during the night; while others, such as mangolds, dahlias, and the grape vine, store reserve carbohydrates other than starch (saccharose, inulin, and glucose).

Unless we decline to accept the view that the starch breaks down in the usual way to maltose we must suppose that the enzyme maltase is present, which decomposes the maltose as quickly as it is produced. Evidence is adduced in favour of this supposition, and the view is put forward that the transformation of the starch proceeds on the following lines :

Starch—soluble starch and dextrines (by Liquefying enzymes.)
Dextrines—maltose (by Dextrinase).
Maltose—glucose (by Maltase).

The failure of other workers to find maltase is attributed to its instability, it being readily decomposed by alcohol or chloroform, and to the circumstance that it is endo-cellular and therefore not easily extracted by water. Beyerinck's results indicate that the maltase s mainly localised in the aleurone layer of the endosperm.

XXIII. "*The Distribution of Maltase in Plants.*" II.—"*The Presence of Maltase in Foliage Leaves.*" ARTHUR JOHN DAISH. Biochemical Journal, 1916. **10**, 49-55.

The crushed pulp of all the leaves examined (*Tropæolum*, potato, dahlia, turnip, sunflower, and mangold) acts upon soluble starch or gelatinised starch and forms reducing sugars; of these the greater part consists of glucose and the rest is maltose. It seems clear that the pulp contains the enzyme maltase which acts on maltose, converting it into glucose. By reason of the instability of maltase it is necessary to avoid the use of heat or chloroform in preparing the pulp.

XXIV. "*The Distribution of Maltase in Plants.*" III.—"*The Presence of Maltase in Germinated Barley.*" ARTHUR JOHN DAISH. Biochemical Journal, 1916. **10**, 56-76.

Previous observers have shown that the action of malt extract on starch gave rise to maltose, but not to glucose. It has, therefore, been supposed that maltase is absent from barley. The author finds, however, that the extract had usually either been treated with chloroform, or heated to 50-60°, by either of which treatments the maltase is destroyed. By allowing the finely powdered germinated barley grain to act on starch or maltose at 38° a large amount of glucose is formed, and, as the proportion of glucose increases, that of maltose falls. It seems evident that maltase is present and is acting on the maltose.

XXV. "*The Use of Enzymes and Special Yeasts in Carbohydrate Analysis.*" W. A. DAVIS. Journal of the Society of Chemical Industry, 1916. 35.

The analytical methods elaborated by the author at Rothamsted for the estimation of saccharose, raffinose, maltose, starch, and the mixture of dextrose and lævulose are summarised. The necessary working details are given.

XXVI. *"Organic Plant Poisons."* I.—*"Hydrocyanic Acid."* Winifred E. Brenchley. Annals of Botany, 1917. **31**, 447-456.

Experiments have been carried out to test the action of hydrocyanic acid on plants when applied to the roots in water culture, and comparisons were made of the effects of formic acid and sodium cyanide. The results showed that prussic acid is very toxic to peas and barley. All strengths up to and including 1/100,000 kill peas outright, either immediately or after a short interval of poor growth. All strong concentrations kill barley, but with 1/100,000 a period elapses during which no growth occurs, after which a little progress is made, though the plants never attain any size.

The peas killed by prussic acid shrivel from the cotyledons upwards and the roots contract so intensely that they are often completely withdrawn from the nutrient solution. Barley roots decline to enter strong solutions at all, but often put out laterals, which stop short at the surface of the solution and develop the bunchy habit characteristic of growth in the presence of poison.

Formic acid is comparatively harmless to barley, except in very strong concentrations, whereas sodium cyanide is quite as toxic as prussic acid.

No trace of stimulation in peas or barley has been obtained with any of the compounds tested.

XXVII. *"Organic Plant Poisons."* II.—*"Phenols."* Winifred E. Brenchley. Annals of Botany, 1918. **32**, 259-278.

Experiments on similar lines were carried out with various phenols, phenol itself, the three cresols, resorcinol, pyrocatechol, pyrogallol, phloroglucin, and orcinol.

The general action of these various phenols upon barley and pea plants grown in water cultures is very similar, though the individual substances exercise specific actions at somewhat varying concentrations. In every case a solution containing one per cent. of the molecular weight in grams per litre (M/100) of the phenol proves to be fatal, death usually occurring within a very short time after the plant comes in contact with the solutions. Occasionally, as with resorcinol and orcinol on peas, the shoots continue to make a certain amount of growth for a few days, even though the roots are killed. Apparently the toxin in these cases is not conveyed to the leaves at once, so that they are able to grow for a time at the expense of the food stored up in the seeds. More usually, however, the growth of the shoots is checked simultaneously with that of the roots, though the leaves retain their green colour for a long time before they wilt.

The difference in the relative toxicity of the phenols is well shown by the action of solutions one-fifth as strong as the above (M/100 x 1/5). Marked toxic action is evident at first in every case, and the roots are often killed and discoloured. *o*-cresol, pyrocatechol and pyrogallol kill peas outright at this strength, but with the other substances the roots make an attempt to right themselves after some time has elapsed. New laterals are pushed out, which frequently refuse to enter the solutions, so that the recovery is only partial. Peas make only very slight recovery from the effects of *m*-cresol, rather more from those of *p*-cresol, phenol and phloroglucin ; while in presence of resorcinol and orcinol good root development is ultimately able to take place, and there is a corresponding improvement in the shoot growth. Barley is more sensitive than peas, as recovery seldom takes place, and even with resorcinol and orcinol the roots make very little improvement.

The lower strength M/100 × $\frac{1}{5}$ 2 also shows clearly the difference in the action of the phenols, the range of variation being considerable. In nearly every case an initial check is produced, but the degree of injury varies very much. Resorcinol at this strength has very little effect on peas as growth is fairly good from the beginning, and with orcinol also strong growth is made. Phenols cause the roots to become bunchy through the development of short laterals, but recovery from the toxic effects is so complete that the plants make nearly as much dry weight as the controls. Recovery from the effects of most of the other substances is variable in amount, but pyrocatechol is so poisonous that very little growth is made up to the end. Barley behaves in much the same way as peas, though owing to its sensitiveness the recovery is not always so complete as in the case of peas.

Lower concentrations of all the poisons seem to exercise no injurious action on growth.

The root recovery observed in strong solutions suggests that in these cases the poison acts largely by suspending the activities of the plant, paralysing it without killing it outright. Consequently, when the paralysing effect wears off or the concentration of the solution is somewhat reduced by oxidation the plant reasserts its vitality, struggles to put out lateral roots, and frequently succeeds so well that fairly good growth is eventually made.

No signs of stimulation have been observed in the case of any of the phenols tested, except that barley plants in the dilute solutions of orcinol looked better than the controls before they were cut. This appearance was not corroborated by the dry weights.

When the plants were killed or badly injured by high concentrations of the phenols, moulds appeared very rapidly on the dead roots and in the solutions, except only in the strongest solutions of phenol and the three cresols. With the latter no mould formation set in during the whole course of the experiment, but with phenol the antiseptic action ceased after some time and moulds eventually appeared. Where no root injury was caused no moulds grew in any case.

XXVIII. "*Effect of the Concentration of the Nutrient Solution on the growth of Barley and Wheat in Water Cultures.*" WINIFRED E. BRENCHLEY. Annals of Botany, 1916. 30, 77-90.

For some years past much discussion has taken place as to whether the concentration of the nutrient solution has any appreciable effect upon plant growth, and at the present time the controversy is far from settled.

A number of water culture experiments have been made to see if further information could be obtained on the effect of varying concentrations of nutrient solutions upon growth, barley being used as the test plant in three series of experiments, and wheat being grown in a fourth.

Four strengths of solution were used ; N, ordinary strength (called N.) containing 3 grms. of nutrient salts dissolved in one litre of water), N/5, N/10, N/20. In each experiment with barley 120 plants were grown in units of ten :—

1.—All concentrations (N, N/5, N/10, N/20), the solutions being changed regularly every four days.

2.—All concentrations, the solutions being changed once, half way through the experiment.

3.—All concentrations, the solutions never being changed.

An examination of the figures and curves of dry weight shows that in all cases there is a steady decrease in the dry weights of the plants as the strength of the nutrient solution becomes less. This decrease in weight is very considerable and always outside the limits of experimental error. The results run in the same direction in all the experiments, the differences being accentuated in the sets grown later in the year, when growth is more rapid. The falling off in dry weight, as the concentration of the solution falls from N to N/5, is far less when the solutions are changed frequently, and in some cases there is very little difference in the two cases. This suggests that the N/5 solution might be as favourable to growth as the N solution if it were sufficiently frequently renewed. There are, however, indications that toxic effects would set in under these circumstances in the N solution, as some of the constituents might be present in so great a quantity as actually to check plant growth. In the N/5 solution, on the other hand, this action is less likely, and the plants could continue to make full use of the food salts, thus approximating in growth to those in the N solution. If this supposition be correct, it is not true to say that the plant is indifferent to the variation in the strength of these two solutions, but that up to a certain limit it responds to increased strength by increased growth.

With the highest concentration, however, another factor, toxic action, comes into play, counterbalancing the increased growth and reducing it to the level attained with the lower concentration.

XXIX. "*Recolonisation of Cultivated Land allowed to revert to Natural Conditions.*" Winifred E. Brenchley and Helen Adam. Journal of Ecology, 1915. **3**, 193-210.

Broadbalk and Geescroft Wildernesses were originally under arable cultivation, but they have been left untouched for many years and allowed to recolonise themselves. Careful observations of the herbage have been made from time to time, and for at least twelve months in 1914-1915 the changes in each flora were noted every month. Broadbalk wilderness is in a relatively dry situation and the soil contains calcium carbonate ; Geescroft is wetter and there is practically no calcium carbonate present.

Broadbalk wilderness consists of two distinct parts :—

1. an area which has been left untouched and has developed into an oak-hazel wood ;
2. an area from which the trees and shrubs have been grubbed out at regular intervals and is now colonised by a great variety of herbs,* notably *Arrhenatherum avenaceum* with a good deal of *Centaurea nigra, Poa trivialis, Agrostis sp., Heracleum spondylium* and many others.

* Using the word in its strict botanical sense, to comprise all plants except shrubs and trees.

During the season, 1913-1914, 79 species of plants (herbs, shrubs and trees) came under notice, of which 40 per cent. are included in the three orders, Graminaceæ, Leguminosæ and Compositæ, and a further 20 per cent. are in the Umbelliferæ and Rosaceæ. The herbage is fairly well mixed, as several of the species are plentifully represented, but the dominant species during the early summer months is *Arrhenatherum avenaceum*, whereas later on in the summer *Centaurea nigra* is the most conspicuous and dominant plant.

Geescroft wilderness is densely covered with tufts of the very coarse grass, *Aira cæspitosa*, studded with a few small trees and shrubs of various kinds. At one end the *Aira* dominates the situation almost to the exclusion of other plants, whereas at the other end many species have a firm footing in spite of the domination of this grass.

Altogether at the present time 88 species (herbs, shrubs, and trees) are to be recognised, of which nearly half are included in three orders (Graminaceæ, Compositæ, Leguminosæ), and a further 10 per cent. are in Rosaceæ and Umbelliferæ.

At the present time the great majority of species are common to both wildernesses, but certain species are peculiar to each. One noticeable point is the abundance of *Anthoxanthum odoratum* and *Holcus lanatus* in Geescroft, and their scarcity on Broadbalk. The plants peculiar to Geescroft are characteristic of damp land. Some of them, *e.g.*, *Phalaris* and *Aira*, are characteristic of marsh or fen associations ; while those peculiar to Broadbalk are characteristic of dry meadows. *Hedera Helix* has probably spread from the thicket. *Brachypodium sylvaticum*, which is fairly abundant in the meadow, is also a woodland grass. The most abundant grasses, *Arrhenatherum* and *Dactylis*, are recorded as abundant in the undergrowth of the " damp oak wood " types, as are many of the other plants in the meadow portion, *e.g.*, *Veronica Chamædrys*, *Nepeta hederacea*, *Stachys Betonica*.

XXX. "*The Effect of Weeds upon Cereal Crops.*" WINIFRED E. BRENCHLEY. New Phytologist, XVI, 1917. 53-76.

Wheat and barley were grown in pot cultures and water cultures in conjunction with certain common weeds, including poppy, charlock (or white mustard), spurry and black bent. Various combinations of the test plants were made over a period of four years.

When poppy, black bent and spurry were grown with wheat they developed less than when grown alone, showing that they had suffered from the competition of the wheat. The wheat, on the other hand, made more growth per individual plant than when the weeds were replaced by an equal number of wheat plants, indicating that the competition of the wheat with itself when thickly sown is more severe than that of weeds with thinly sown wheat plants. On the other hand, when equal numbers of wheat plants were grown, both with and without weeds, the weedless wheat made much better growth. In these experiments spurry proved more harmful than the others, smothering the young wheat by its straggling growth; giving the plant a bad check from which it never properly recovered. The effect of charlock was rather different from that of the other weeds, possibly on account of its habit. The competition between charlock and wheat seems to be nearly equal, and the two plants settled down to some sort of equilibrium, neither gaining the mastery over the other. Barley, on the other hand, suffered more severely from the presence of poppy, spurry or charlock than it did from the same number of barley plants, whereas black bent was not nearly as powerful a competitor.

So far as could be seen, however, the effect was solely one of competition for food, and it made no difference to the individual wheat plant whether its competitor was another wheat plant or a plant of some wholly different order. The phenomena could all be explained by supposing that the number of plants the soil could carry depended on the amount of food present in the soil and the amount of space available for growth ; if the food and space are to be shared by many plants each individual will get a smaller share and therefore make less growth than if there are fewer plants to participate.

XXXI. "*Buried Weed Seeds.*" WINIFRED E. BRENCHLEY. Journal of Agricultural Science, 1918. 9, 1-31.

A number of samples were taken from different grass fields by means of a sampling iron, 6 inches by 6 inches by 9 inches. This was driven into the ground, and the soil was carefully removed inch by inch, each inch being placed in new paper bags and carefully labelled to indicate the depth from which it was taken. The iron was driven far enough in to permit of sampling to a depth of 12 inches, and special precautions were taken that no crumbs of soil from the surrounding areas fell inside the sampling iron. The samples were then placed in clean sterilised pans or boxes in a glasshouse, kept watered, and left undisturbed for a time. Seeds soon began to germinate, and as soon as the young plants were large enough to be recognised they were noted and removed from the soil. A striking difference exists between the buried seed flora of permanent grassland and of land that has at one time been under the plough, even though nearly 60 years have elapsed since grassing down. The buried seeds of permanent grassland include species of grasses and miscellaneous plants which are definitely associated with pasture and never with arable land. Land that was originally arable, however, contains a large number of buried seeds, such as *Centaurea nigra, Cerastium vulgatum, Stellaria media, Plantago lanceolata* etc., which are common to both arable and grassland. This may indicate that these species are really arable weeds, but being able to accommodate themselves to grassland conditions they can persist when once they are established on an area, whether the cultivation be arable or pasture.

A fair number of true arable weeds appeared from soil that has been grassed over for 58 years (Laboratory House Meadow), many of which may certainly be regarded as survivors of seeds left in the soil when it was under arable cultivation. The proportion of grassland plants, however, is large compared to that of the arable weeds. Geescroft has been under grass for a shorter period of time, and the number of arable seeds is greater, while the proportion of grassland seeds has decreased. This tendency becomes more marked as the period in grass becomes less, and on New Zealand field, only ten years under grass, the arable weeds bear a heavy proportion to the grassland plants, particularly if the clovers (which might have been derived from buried seeds of a sown crop), are left out of consideration.

The changes in the proportion of the arable and grassland plants derived from buried seeds are so consistent and so regularly associated with the history of the land that one is irresistibly forced to the conclusion that, when arable land is grassed over a certain number of seeds are able to retain their vitality for many years. Many of the seeds die comparatively soon after burial, and as time goes on the number of living seeds gradually becomes less, though the evidence shows that some seeds will survive burial for at least 58 years. Usually most of the older arable seeds survive in the lower depths of the soil where the conditions are less variable, whereas the shorter the time that land has been under grass the greater the proportion of arable seeds found near the surface. While the stock of arable seeds is diminishing with the lapse of time, the supply of grassland seeds is being augmented by fresh seeds ripened by the surface vegetation and gradually carried down into the soil. Naturally the greater proportion of these seeds are found in the upper inches of soil, comparatively few penetrating below the eighth inch.

TECHNICAL PAPERS.

XXXII. "*West Country Grasslands.*" WINIFRED E. BRENCHLEY. Journal of Bath and West and Southern Counties Society, 1917. 11, 85-112.

During the summer of 1916 a survey was made of some of the grassland in Gloucester and Somerset with special reference to the weed flora. In this paper an account is given of the association of some of the chief grassland weeds with alluvium, clay soils, peat, calcareous and non-calcareous sandy soil, and also of the effect of herbage on stock in some special cases.

Some weeds were found to be specially obnoxious because they tainted the milk or had bad effects upon the animals themselves. Garlick, ramsons, hemlock, moon-daisy and woodwax were all accused of tainting the milk. Horsetail has a bad reputation for causing scour, and huffcap is disliked by animals and is regarded as being very detrimental to them.

Besides these directly harmful weeds a number of plants require special attention; these include nettles, creeping thistle, black-bull thistle, yellow rattle, bindweed, hardhead, and others.

Some parts of the fields were characterised by a special flora. Round the gates and along paths where the soil becomes much trodden, greater plantain, silverweed and rough meadow grass were common. The site of an old manure heap was marked by arable weeds derived from seeds carried in the manure, as knotgrass, groundsel, fat hen and shepherd's purse; and on the site of old ricks strong growths of broad dock, dandelion and nettle were often seen.

Under the shadow of trees the herbage takes on a distinctive character, particular species growing in definite association. Cocksfoot, foxtail and rough meadow grass are the three most marked species in these situations, but a few others are found occasionally, as buttercups, dock, sorrel and pignut.

Bindweed = *Convolvulus arvensis.*
Black Bull Thistle = *Cirsium lanceolatum.*
Broad Dock = *Rumex obtusifolium.*
Buttercup = *Ranunculus sp.*
Cocksfoot = *Dactylis glomerata.*
Dandelion = *Taraxacum vulgare.*
Dock = *Rumex crispus.*
Fat Hen = *Chenopodium album.*
Foxtail = *Alopecurus pratensis.*
Garlic = *Allium vineale.*
Greater Plantain = *Plantago major*
Groundsel = *Senecio vulgaris.*
Hard-head = *Centaurea nigra.*
Hemlock = *Conium maculatum*
Horsetail = *Equisetum arvense.*
Huffcap = *Aira caespitosa.*
Knotgrass = *Polygonum aviculare.*
Moon-daisy = *Chrysanthemum leucanthemum.*
Nettle = *Urtica dioica.*
Pignut = *Conopodium denudatum.*
Ramsons = *Allium ursinum.*
Rough Meadowgrass = *Poa trivialis.*
Shepherd's Purse = *Capsella bursa-pastoris.*
Silverweed = *Potentilla anserina.*
Sorrel = *Rumex Acetosa.*
Thistle = *Cirsium arvense.*
Woodwax = *Genista tinctoria.*
Yellow Rattle = *Rhinanthus crista-galli*

XXXIII. *"Weeds on Arable Land and their Suppression."* WINIFRED E. BRENCHLEY. Journal of the Royal Agricultural Society of England, 1915. 76, 14-37.

During the summer of 1914 a careful survey was made of the weeds of arable land in parts of Nottinghamshire and Derbyshire, and in the present paper the results are correlated with those obtained in other parts of the country.

Although many weeds are of general occurrence, some are more definitely associated with particular types of soil, and a partial classification may be made as follows :—

1.—Weeds that are indifferent to the soil type. These include some of the most common and troublesome weeds, as knotgrass, shepherd's purse, chickweed, groundsel, curled dock, creeping thistle, mayweed, horsetail, ivy-leaved speedwell and couch grass. Willow-weed and hempnettle are found on all soils except chalk.

2.—Weeds that are more general on medium or heavy land, as orache, charlock, coltsfoot, creeping buttercup, sowthistle, bindweed, corn buttercup.

3.—Weeds that are common on heavy loam and clay, as greater plantain, goosegrass.

4.—Weeds characteristic of very light sandy land, as poppy on calcareous soil, and corn marigold, spurry, sheep's sorrel and annual knawel on non-calcareous land.

5.—Weeds associated with chalk, as white mustard, toad-flax, wild mignonette.

Local peculiarities occur, however, so that a plant that is usually of wide distribution may be confined to or absent from a particular soil in a district, or may be so abundant as to be characteristic of some particular type of soil. The shepherd's needle will apparently grow on any soil, but it is characteristic of chalk in Wiltshire, absent from chalk in Norfolk, absent from sand in Bedfordshire, absent from peat in Nottinghamshire. Again, the field forget-me-not is never seen on sand in Notts (being chiefly found on heavy soils), whereas in Norfolk it is usually found on sand, and in Wiltshire it is confined to chalk. Although chickweed, horsetail and shepherd's purse are really universal in distribution, yet in Nottinghamshire the two former are more common on the heavier soils, while the latter is more frequent on light soils, such as sand and gravel. Many other instances could be cited, but with due reservation on account of these local differences the commoner arable weeds can be classified according to the soils they frequent.

Annual Knawel = *Scleranthus annuus.*
Charlock = *Brassica sinapis.*
Chickweed = *Stellaria media*
Coltsfoot = *Tussilago farfara.*
Corn Buttercup = *Ranunculus arvensis.*
Corn Marigold = *Chrysanthemum segetum.*
Couch Grass = *Triticum repens.*
Creeping Buttercup = *Ranunculus repens.*
Field Forget-me-not = *Myosotis arvensis.*
Goosegrass = *Galium aparine.*
Hemp Nettle = *Galeopsis Tetrahit.*
Ivy-leaved Speedwell = *Veronica hederæfolia.*
Mayweed = *Matricaria inodora.*
Orache = *Atriplex patula.*
Poppy = *Papaver rhœas.*
Sheep's sorrel = *Rumex Acetosella.*
Shepherd's Needle = *Scandix pectens*
Spurry = *Spergula arvensis.*
Sowthistle = *Sonchus arvensis.*
Toad-flax = *Linaria vulgaris.*
White Mustard = *Brassica alba.*
Wild Mignonette = *Reseda lutea.*
Willow-weed = *Polygonum persecaria.*

XXXIV. *"The Comparative Yield of Second Rate Arable and Pasture-land."* E. J. RUSSELL. Journal of the Farmers' Club. November, 1917.

The subject is discussed from the standpoint of food production and of the profit of the individual farmer. It is shown that arable land produces considerably more food than grassland ; one acre of arable land yields on an average more than half a ton of flour and over five tons of potatoes, but it commonly gives less than one hundredweight of beef, and sometimes considerably less. Translated into food units, one acre of arable land furnishes sufficient calories to keep a man going for 500 to 1,500 days, according as cereals or potatoes are grown ; while an acre of grass will only furnish sufficient calories to keep him going for 6 to 200 days, according as it is used for rough grazing or as good pasture for dairy stock.

On the other hand the cost of working the arable land is considerably higher. Numerous estimates are available of the cost of growing wheat. These show that prior to the War it was about £6 to £8 per acre ; during the War it has risen to £10 to £12 per acre. Less information is available as to the cost of growing other crops, but at Rothamsted barley and oats cost sometimes more and sometimes less. but on an average almost as much as wheat ; mangolds cost £14 per acre before the War, but £18 now ; while potatoes cost £20 before the War and £24 now. Moreover, the farmer has to stand out of his money for many months. Grassland, on the other hand, costs much less per acre, and the money is turned over more quickly. Less capital is therefore required for grass than for arable land.

But if the cost of working arable land is greater than that for grassland the returns are also higher. Recent instances are quoted in which grassland that only yielded 10 to 15 cwts. of hay per acre, or kept only one sheep or less per acre, gave, when ploughed up, from 40 to 70 bushels of oats, and similarly good yields of other crops. Further, arable farming presents far greater possibilities of improvement than grass farming. Ordinary grassland can rarely be made to yield more than 40 cwts. of hay or 2 cwts. of beef per acre, but the possibilities of arable land are considerably greater, and the gross returns may be pushed up very considerably. There is, of course, a corresponding increase in risk, but this can be diminished by the adoption of co-operative methods and by the technical improvements that one hopes will be forthcoming.

XXXV. " *How can Crops be Grown without Potash Manures next Year?* " E. J. Russell. Journal of the Board of Agriculture, 1915. **22**, 393-406.

Two methods can be adopted (1) other sources of potash can be used instead of the usual Stassfurt salts, (2) the reserves of potash in the soil can be made available. It is shown that various plant ashes, bonfire ashes, etc., contain about 10 per cent. of potash (K_2O), not much less than is present in kainit. Sheltering the manure heap was found to reduce loss of potash considerably, an exposed heap losing 30 per cent. of its total potash, while a corresponding sheltered heap lost 12 per cent. only. The ploughing up of grassland and clover leys also sets free potash stored up in the root residues. The utilisation of potash stored in the soil is made possible by liming the land or applying dressings of sodium salts, such as agricultural salt or sulphate of soda. Salt has long been known to benefit mangolds, and on light land it has good effects on most other crops. Sodium salts have the further advantage of economising the supplies of potassium salts. The application of these various methods to different crops is discussed.

XXXVI. "*On Growing Two White Straw Crops in Succession.*" E. J. RUSSELL. Journal of the Board of Agriculture. 1915. **22**, 533-542.

It has long been a tradition of good farming that two white straw crops should not be grown in succession, and this still survives in spite of many instances to the contrary, including the classical case of Broadbalk Field, where wheat crops have been grown every year since 1843. Two conditions are necessary: the land must be reasonably clean, and the crop must be supplied with satisfactory spring dressings. The most suitable fertilisers are nitrate of soda or sulphate of ammonia and superphosphate; these must go on early in the year, it is not safe to wait until the crop shows signs of starvation. Suitable dressings are suggested.

XXXVII. "*The Washing out of Nitrates from Arable Soils during the Past Winter.*" E. J. RUSSELL and A. APPLEYARD. Journal of the Board of Agriculture, 1916. **23**, 22-27.

The rainfall during the winter months of 1915-16 had been exceptionally heavy, and the amount of percolation through the soil was correspondingly above the average. There had been an unusual loss of nitrates from the soil, varying in the different cases examined, from 5 to 125 lbs. per acre (reckoned as nitrogen); in the case of a field worked as part of the ordinary farm the loss was 30 lbs. of nitrogen per acre, equivalent to 190 lbs. per acre of nitrate of soda, this being as much as is contained in eighteen bushels of wheat and the corresponding quantity of straw. A piece of fallow land lost very heavily. The actual figures were:—

	Nitrogen as nitrate: lb. per acre, top 18 ins.		
	Autumn. 1915	Feb. 1916	Loss.
Broadbalk, dunged, fallow	175	50	125
,, ,, cropped (wheat)	90	47	43
Great Harpenden Field, cropped (wheat)	70	40	30
Broadbalk, unmanured, fallow	68	40	28
,, ,, cropped (wheat)	51	46	5
Hoos, unmanured, fallow	34	9	25
,, ,, cropped (wheat)	32	12	20

In addition to the losses of nitrate the soil also suffers through defloculation of the clay. Thus, at the time of writing the land was depleted of its nitrates, and the clay had passed into a sticky unworkable state. Much of the damage could have been avoided had a catch crop or a green crop to be ploughed in for manure been grown in the previous autumn. The best remedies now available are soot, sulphate of ammonia and lime; methods of using these are indicated.

XXXVIII. "*Soil Analysis.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1915. **22**, 116-119.

The value of soil analysis to the farmer is discussed. It mainly serves to effect comparisons and may be of help in at least three cases:—

1.—When the farmer wishes to know whether he has a reasonable chance of obtaining results with particular fertilisers, similar to those demonstrated by field experiments on another farm in the locality.

2.—When he decides to adopt some system of cropping or soil treatment known to give good results elsewhere, but before embarking on it wishes to ascertain how closely his soil conditions resemble those where the method is known to answer.

3.—When he is entering on a new farm and wishes to obtain as complete information as possible about the soil. This is the most difficult case of all, and much time is saved by going over the land with an expert and discussing with him on the spot the various points on which information is desired. If no satisfactory field experiments have been made on similar soils and no soil survey has been carried out, the problem becomes more difficult, and the analyst cannot be expected to do more than give a general opinion or submit schemes for consideration and trial.

XXXIX. "*On Taking Samples of Soil for Soil Surveys.*" E. J. Russell. Journal of the Board of Agriculture. 1916. **23**, 342-349.

The investigator should go over the district with the map and divide it up into areas within which similar agricultural and vegetation characteristics prevail. In moderately level regions these areas agree tolerably well with those differentiated on the geological map so long as the nature of the soil is fairly uniform throughout. Where the formation consists of alternations of sands and clays of no great thickness the soil belts are neither wide nor very definite ; in this case the soils should be graded between two limits, the lighter and the heavier types being described in some detail, and the various intervening grades dealt with in a more general way.

In hill districts it is necessary to distinguish between high land and low land.

The selection of spots for the final sampling presents some difficulty, but the variations reported by the farmers often cause less trouble than might be expected and arise from small differences in the amount of calcium carbonate or organic matter, or in the water supply or management. It is immaterial for the purposes of the survey whether the samples are taken from pasture land or arable land, but it is well to have samples from both.

Very full information should be collected as to the agricultural value of the land, the crops and manures most suitable, the behaviour of the soil during drought and wet weather, and any special points to be observed during cultivation. Note should also be taken of the position of the soil in regard to water supply, the relation of the strata to the permanent water table, etc.

XL. "*The Possibilities of Increased Crop Production.*" E. J. Russell. Presidential Address to the Agricultural Section of the British Association, 1916. Transactions of the British Association.

The three great lines of agricultural development in the United Kingdom in the past have been (*a*) the introduction, usually from

Flanders, of crops that had not previously been grown on British farms, (*b*) the removal of obstacles which prevented crops from making as full growth as they might, (*c*) the introduction of new methods for increasing the growth of the plant.

On *light* soil the two great obstacles to be overcome are the lack of water and the poverty in plant nutrients. The problem can be dealt with by increasing the depth of soil through which the roots can range, or by adding the necessary colloidal substances—clay, marl, or organic matter. As regards depth of soil, where a thin layer of rock separates the top soil of sand from a great depth of sand below, improvement can be effected by removing the rock—a cheap method being possibly the use of the high explosives available at the end of the war; to prevent reforming of the rock occasional deep ploughing must be carried out. The process of adding marl to sand has disappeared in England on account of transit difficulties; the usual methods are to add organic matter, either by dressings of farmyard manure, by feeding crops to sheep on the land, or by ploughing crops and crop residues straight into the soil; the addition of organic matter must generally be accompanied by the addition of lime or limestone (otherwise the soil may become sour), and all the plant nutrients, nitrogen, potash, and phosphates, as well as by constant cultivation to keep down weeds and retain soil moisture. When all this is done, light soils become very productive; they will grow almost any crops, and they can be cultivated easily and almost (but not quite) at any time. On account of the cost of the above processes crops must be grown which bring in a high money return, potatoes, greens, peas, sugar-beet, or two crops in a season, although the money-finding crop need not be taken very often. The best hope for improvement of light soils lies in increasing the number of money-finding crops, improving the methods of growing them and their relation to the other crops or the livestock, so that farmers will feel justified in spending the rather considerable sums of money without which these light soils cannot be successfully managed.

Heavy land can be improved by liming or chalking, followed by drainage. Mole drainage promises to be an efficient and much cheaper substitute for the old system of tile drainage, but co-ordination and a certain amount of control over the whole drainage area is needed, it being undesirable that a great fundamental improvement should be at the mercy of individuals. The cultivation of clay lands is always risky, however, as it is suited only to a limited number of crops, and is difficult to cultivate, and hence most men lay down this land to permanent grass. The risk can be reduced:

(*a*) By quicker ploughing in autumn, so as to bring the work well forward; this seems only possible by the use of the motor plough.

(*b*) By keeping up the supplies of organic matter in the soil; the simplest plan seems to be the adoption of the North Country system, in which the land is alternately in grass and in tillage.

There will always be some grass on the clays and this must be improved, in most cases by basic slag, with possibly further treatment of the improved herbage.

Loams present no special difficulties. The crop may be hampered by lack of root room, in which case periodical deep ploughing or sub-soiling may bring about a substantial improvement; sub-soiling at Rothamsted was followed by an increased yield per acre of 10 cwt. of potatoes.

All the above soils can be still further improved by proper treatment with fertilisers. There comes a point, however, where further increases in fertiliser dressings cease to be effective, because the plant cannot grow any bigger, or it cannot stand up any longer, or its resistance to disease is weakened; here, therefore, new varieties must be found that can grow bigger or stand up better or are more resistant to disease. Considerable improvements may be anticipated from a closer co-ordination of crop variety and soil and climatic conditions.

It is also necessary to reduce the cost per acre and to increase the certainty of production. One of the most hopeful ways of attacking this problem is to increase the efficiency of the manurial treatment; the whole of the fertilising constituents applied to the soil are never recovered in the crops, but by arranging a proper rotation and properly balanced manurial dressings the loss can be reduced.

Economy is also possible in the management of farmyard manure, and of the soil; where there is no crop there is loss of valuable nitrates during the winter, the heaviest loss occurring on the best manured land.

Again, it is necessary to keep close accounts so as to replace unprofitable crops by profitable ones. Steps must be also taken to raise by educational methods the ordinary farmers to the level of the good ones.

There is, however, a factor which operates against increased crop production, which we can never hope to see entirely destroyed. The farmer has to get his pleasure as well as his work out of the countryside, so that trees, hedges, and copses are left, pheasants are bred, foxes and hares preserved, and rabbits spared. It would be wholly unreasonable to expect the farmer to lead a life of blameless crop-production unrelieved by any pleasure. The amenities and pleasures of the countryside will probably always be kept up, and we must maintain the best equilibrium possible between them and the crops.

XLI. "*Chalking, a useful Improvement for Clays overlying the Chalk.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1916. **23**, 625-632.

This paper contains a description of the method of applying chalk to the land as adopted in Hertfordshire and neighbouring districts, where a layer of heavy soil overlies the chalk. The method has the advantage that it requires very little materials, no horses and only a minimum of skilled labour. A well is sunk to the chalk and excavation is continued until a bell-shaped chamber is formed; the chalk is hauled to the surface, carried in wheel-barrows to the proper position in the field, and then spread. One well furnishes sufficient material for three or four acres. The cost of sinking the well is usually 6d. per foot depth, and it is commonly necessary to go down about 20-25 ft. Hauling, barrowing, and spreading cost 7d. per load of 20 buckets, each bucket holding approximately a bushel. The total cost is about £2 to £3 for a dressing of 50 to 60 loads per acre.

XLII. "*The Composition of Army Stable Manure.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1917. **23**, 1053-1065.

Samples of army stable manure collected during the summer of 1916 were found to have the following composition :—

	ARMY STABLE MANURE				FARMYARD MANURE, ROTHAMSTED		
	A From Dumps 8 months old (Sling)	B Old Dump (Cross Belt)	C New Manure (Bustard)	D New Manure (Colchester)	Farm Stable Manure (Rothamsted)	Cake Fed	No Cake Fed
Organic matter	20.7	28.3	22.2	19.6	20.5	—	—
Mineral matter	13.1	24.1	30.8	41.3	4.6	—	—
Moisture .	66.2	47.6	47.0	39.1	74.9	72.6	72.8
Total dry matter	33.8	52.4	53.0	60.9	25.1	27.4	27.2
Total nitrogen	0.524	0.563	0.470	0.475	0.442	0.77	0.54
Nitrogen as ammonia	0.105	0.140	0.106	0.126	0.10	0.18	0.04
Potash (K_2O)	0.82	0.94	0.87	0.53	0.73	0.60	0.67
Phosphoric acid (P_2O_5)	0.20	0.33	0.40	0.31	0.24	0.39	0.23

Unfortunately from the farmers' point of view much of the urine is lost so that the manure is not as rich as it might be. Another characteristic is that Army manure contains only little litter; it consists mainly of solid excreta.

XLIII. "*Report on Humogen.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1917. **24**, 11-20.

Field and pot experiments were made both at Rothamsted and at the Harper Adams Agricultural College, with samples of humogen especially supplied by the makers, but no positive results could be obtained. It was, however, subsequently claimed by the makers that the material had not been properly prepared.

XLIV. "*Comparative Field Trials with Dried and Degreased Sewage Sludges at Rothamsted.*" E. J. RUSSELL and E. H. RICHARDS. 9th Report of the Sewage Commissioners, 1915. **2**, 158-160 (Cd. 7820).

Experiments were made on permanent grass laid up for hay and on oats. The dried sludge contained 1.76 per cent. of nitrogen, and the degreased sludge 1.55 per cent.; they were applied at a rate sufficient to give 20 lbs. of nitrogen per acre, and nitrate of soda and nitrolim were given at the same rate to the other plots.

The nitrate of soda proved the most effective on hay, raising the yield from 15.6 to 26 cwts. per acre. Nitrolim was less effective, producing 21.6 cwts. per acre ; the sludges, on the other hand, had no appreciable effect. The experiments with oats had a similar result ; the control plot gave 41.3 bushels of grain and 4,040 lbs. of total produce ; nitrate of soda and nitrolim gave respectively 44.1 and 46.0 bushels of grain, and 4,700 and 4,900 lbs. of total produce, while the sludges gave only 36 and 37.4 bushels of grain and 3,600 and 3,800 lbs. of total produce, thus showing no increase, but an apparent decrease as compared with the control plots.

XLV. "*The Use of Charcoal as a Medium for Plant Growth.*" A. Appleyard. Journal of the Royal Horticultural Society, 1915. **40**, 473-5.

A considerable number of experiments are on record in Horticultural Journals, which seem to show that charcoal has considerable value in increasing soil fertility. A summary of the evidence is given with a view to further work on the subject.

PAPERS SUMMARISING RECENT PROGRESS IN AGRICULTURAL INVESTIGATIONS.

I. "*The Principles of Crop Production.*" E. J. Russell. Transactions of the Chemical Society, 1915. **107**, 1838-1858.

II. "*Artificial Fertilisers, their Present use and Future Prospects.*" E. J. Russell. Journal of the Society of Chemical Industry. 1917. **36**, 250-261.

III. "*The Masters' Lectures: Recent Investigations on the Production of Plant Food in the Soil.*" E. J. Russell. Journal of the Royal Horticultural Society, 1916. **41**, 173-199.

IV. "*The Recent Work at Rothamsted on the Partial Sterilisation of Soil.*" E. J. Russell. Bulletin of the International Institute of Agriculture, Rome. 1917. **8**, 1-11.

V. "*The Making of Soil.*" E. J. Russell. Transactions of the Highland and Agricultural Society of Scotland, 1916. **28**, 1-32

A description of the processes involved in the making of the soil as they are at present understood. So far as the mineral particles are concerned, the processes are largely beyond control, but the organic constituents can be altered more readily, especially by green manuring and clover and grass leys of varying duration. The micro-organic population which brings about the necessary changes in the organic matter is hardly yet under control, though a beginning has been made; attempts are also in progress to deal with the various insects, etc., which play an important part in agriculture.

BOOKS PUBLISHED.

The following books and new editions have been published during the past two years:—

I. "*Manuring for Higher Crop Production.*" E. J. Russell. Cambridge University Press.
1st edition, 1916. 2nd edition, revised and enlarged, 1917.

II. "*Soil Conditions and Plant Growth.*" E. J. Russell. Longman, Green & Co.
3rd edition, revised and enlarged, 1917.

III. "*Soils and Manures.*" E. J. Russell. Cambridge University Press.
2nd edition (in the press).

IV. "*The Book of the Rothamsted Experiments.*" A. D. Hall. 2nd edition, revised by E. J. Russell, 1917. John Murray.