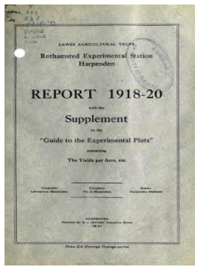
Report 1918-20 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.


REPORT 1918-20

Supplement

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Crops and Plant Growth :

Rothamsted Research

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PUBLICATIONS DURING THE YEARS 1918-20. SCIENTIFIC PAPERS.

CROPS AND PLANT GROWTH.

I. WINIFRED E. BRENCHLEY. "*Some Factors in Plant Competition.*" Annals of Applied Biology, 1920. Vol. VI. pp. 142-170.

The competition exhibited when plants of the same or different species grow in juxtaposition is complex and includes :—

1.—Competition for food from the soil. 2.—Competition for water. 3.—Competition for light. 4.—The possible harmful effect due to toxic excretions from the roots, if such occur.

The general effect of competition (including 1, 2, 3 above) has been studied in pot cultures, when a varying number of plants are grown in the same bulk of soil. The effect of competition for light was investigated by means of water cultures, in which a number of plants each equally furnished with food and water, were crowded together as closely as possible, while a similar set of plants was given sufficient space to avoid the shading of one plant by another.

With limited food supply the dominant factor in competition is the amount of food and particularly of available nitrogen. Other things being equal, the dry matter produced is determined by the nitrogen supply, irrespective of the number of plants drawing thereon.

With limited food supply the efficiency index of dry weight production decreases with the number of plants, as the working capacity of the plant is limited by the quantity of material available for building up the tissues.

(N.B.—" Efficiency Index " is the term employed by V. H. Blackman to express the rate per cent. at which the dry matter of a plant increases during growth.)

3.—The decrease in light caused by overcrowding is a most potent factor in competition, even when an abundance of food and water is presented to each individual plant. With barley the effect of light competition is to reduce the number of ears ; to cause great irregularity in the number of tillers produced ; to reduce the amount of dry matter formed ; to encourage shoot growth at the expense of root growth, thus raising the ratio of shoot to root ; to increase the variation in the efficiency indices of dry weight production of a number of crowded plants, lowering them on the average ; to decrease the power of the plants to make use of the food supplied to the roots, as evidenced by the total quantity of nitrogen taken up by similar numbers of plants when spaced out and crowded.

4.—With adequate illumination (in barley) there is a tendency towards the production of a standard type of plant in which the relation between the number of tillers and ears, dry weights, efficiency indices, and ratios of root to shoot approximates within variable degrees to a constant standard. With overcrowding, this approximation entirely disappears.

II. WINIFRED E. BRENCHLEY. "*On the Relations between Growth and the Environmental Conditions of Temperature and Bright Sunshine.*" Annals of Applied Biology, 1920. Vol. VI. pp. 211-244.

The amount of growth made by any crop in the field and the rate at which maturity is reached are influenced by many factors,

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such as temperature, rainfall, season, sunlight, soil conditions and available plant food. An attempt was made to isolate some of these factors by growing a number of series of peas in water cultures throughout a period of sixteen months, results being thus obtained for all seasons of the year. Measurements of maximum and minimum temperatures and number of hours of bright sunshine were recorded throughout, and provided a basis for statistical correlations. Parallel series were usually grown, in one of which the nutrient solutions were changed weekly so that an abundant food supply was assured, whereas in the other the solution was not renewed, and the food supply was severely restricted.

It was found that growth may be divided conveniently into two well-marked periods.

(*a*) 1st period, from the seedling stage till the time that the plant regains its initial weight after the loss by respiration, *i.e.*, the time during which a casual observer would say the plant "makes no growth."

(*b*) 2nd period, succeeding the former, during which the plant is obviously making growth, and which continues till the latter ceases and dessication sets in.

The length of the first period varies inversely with the mean maximum temperature, as the rate at which assimilation is able to make good the loss by respiration increases directly with rise of temperature, up to a certain limit.

The possible amount of growth, as measured by the dry matter produced, depends entirely upon the bright sunshine and temperature when the food supply is adequate, but when the latter is limited the total growth is much less owing to the lack of material for building up the tissues. Beyond a certain limit, however, the beneficial factors of heat and bright sunshine become harmful and result in the premature death of the plant.

During the first period the rate of growth, as shown by the efficiency index, was associated with relatively warm days and nights, bright sunshine having little significant effect; the light, however, was good throughout for the season of the year. During the second period the rate was associated strongly with sunshine and warm days, but not significantly with the night temperatures, which did not fall below 32° F.

During the greater part of the year the maximum rate of growth is reached early in life, but in winter, when temperatures are low and there is little bright sunshine, the maximum rate is not attained till much later.

Plants with a restricted food supply make less total growth than those with abundant food. The falling off in the amount of dry matter produced does not seem to be gradual but is marked by definite periods, of which the incidence varies at different seasons.

During the period of actual growth, the shoot increases in weight far more rapidly than the root. Increase in shoot growth is closely associated with rise in temperature and root growth is adversely affected by low mean maximum temperatures. Rise in maximum temperature has much less beneficial action upon the roots than upon the shoots.

In early stages of growth, the amount of nitrate absorbed by the plant is relatively large in comparison with the dry matter produced, but later on more dry matter is formed in proportion to the

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same amount of nitrate, owing to the accumulation of the products of assimilation.

III. WINIFRED E. BRENCHLEY and VIOLET G. JACKSON. "*Root Development in Barley and Wheat under different conditions of Growth.*" Annals of Botany, 1921.

Investigations have been begun on the effect of various manures as superphosphate, sulphate of potash and nitrate of soda on the root systems of barley and wheat. Most of the experiments were made in pot cultures and the roots washed out at regular intervals to obtain the various stages of development. Two forms of roots are produced:—

1.—Much branched roots, most of which proceed from the grain. These are rather thin, long, and bear very numerous fine laterals, with root hairs only near the tip.

2.—Thick unbranched roots arising from the nodes as well as the grain, white in colour, and densely clothed with root hairs throughout their length. At a later stage these roots branch and approximate more closely to the others in appearance.

With *barley*, superphosphate encourages the development of unbranched roots, sodium nitrate having no effect. When the plants are about three months old no more unbranched roots seem to be formed. The maximum root development was reached at about the time that the ears were ready to emerge from their sheaths, *i.e.*, when pollination and fertilisation of the ovule were about to take place. With superphosphate alone and with nitrate alone, however, this maximum was reached somewhat earlier, so that apparently root growth culminated with the final stage of preparation by the plant for grain formation. In other words, during the period of purely vegetative growth the plant needs large supplies of nitrogen and ash constituents to aid in building up a strong shoot in readiness for grain formation, and the root steadily increases in order to be able adequately to cope with this demand. During the reproductive phase, on the other hand, vegetative development is reduced to a minimum, and the whole of the plant's energy is diverted towards the grain. Although nitrogen and ash constituents are just as essential as before, the area of supply is increased, as migration of these substances from the straw into the grain goes on from the outset. This reduces the strain on the root, and as such a large absorbing area is no longer required it appears that the excess provision may be got rid of by a steady process of decay, as the weight of the root steadily decreases when once the maximum is reached. The ratios of root to shoot at different periods are also discussed, a great increase of the shoot/root ratio occurring where the unbranched roots cease to be formed.

With *wheat* the unbranched roots increase in numbers less rapidly than in barley, but persist as such for a longer period.

There is in wheat nothing to correspond with the sudden disappearance of white roots which occurs in barley about 11 weeks after sowing, for in wheat the decline in white roots coincides with the decrease in weight of the complete root system, whereas in barley the formation stops suddenly when the ratio between shoot and root growth begins to change.

The paper concludes with a discussion of :—

1.—The influence of environmental conditions other than manuring upon root growth.

2.—Influence of different types of manuring upon root growth.

IV. WINIFRED E. BRENCHLEY. *"The Development of the Flower and Grain of Barley."* Journal of the Institute of Brewing, 1920. Vol. XXVI. pp. 615-632.

An account is given of the development of the ear and flower of barley from the time the young ear is about ¼-inch long until the grain is fully developed. The method of flowering in barley is to a large extent characteristic of the type, as in some cases the glumes open and in others remain closed at the time of pollination. With closed-glume flowering cross-fertilisation is of course impossible, and even with open flowering it is the exception rather than the rule.

The developmental history of the grain indicates that the awns are of considerable physiological importance, and in every barley ear the largest and heaviest grains are in the middle of the ear, and the longest awns occur on these grains, indicating some correlation between weight of grain and length of awn. The awns are essentially transpiring organs. Transpiration is most active during the development of the spike and grains, rising to a maximum just about the time the grains reach the milk stage.

V. MARY D. GLYNNE, B.Sc. and VIOLET G. JACKSON, B.Sc. *"The Distribution of Dry Matter and Nitrogen in the Potato Tuber (variety, King Edward)."* Journal of Agricultural Science, 1919. Vol. IX. pp. 237-258.

King Edward Potatoes were grown in 1917 on Little Knot Wood Field, Rothamsted, lifted about the end of September, 1917, and examined in the laboratory early in 1918.

The percentage of dry matter in the potato tuber was lowest in the skin; it increased to the inner cortical layer, the zone containing the greater part of the vascular system, and decreased towards the centre of the tuber. Typical results are :—

DRY MATTER IN DIFFERENT ZONES OF THE TUBER.

	SMALL 54-84.5 gms.		MEDIUM 139.5-169.2 gms.		LARGE 184.9–259.9 gms.		AVERAGE of 18 tubers.
Zone.	% of whole.	% dry matter.	% of whole.	% dry matter.	% of whole.	% dry matter.	% dry matter.
Skin . . .	2.78	14.29	1.85	15.08	2.83	13.44	14.01
Cortical, outer	27.54	24.86	20.29	23.43	18.11	23.36	23.71
,, inner	24.68	29.25	20.11	28.72	18.92	27.57	28.30
Medullary, outer	31.32	25.76	36.43	25.49	39.95	25.05	25.28
,, inner	13.67	20.19	21.32	18.46	20.19	17.48	18.15
Cortical, outer & inner	52.22	26.93	40.40	26.08	39.03	25.52	26.00

In each zone the proportion of dry matter is higher towards the umbilical than the terminal end of the tuber.

The percentage of nitrogen in the fresh material tends to decrease from the skin to the inner cortical layer and to increase in the medullary zone. Thus it increases from zone to zone in the opposite direction to the dry matter.

Nitrogen tends to increase with dry matter from the terminal to the umbilical end. The results are :—

	Average of 3 Small Tubers. Section			
	1	2	3	4
Skin	0.40	0.42	1.13	0.42
Cortical, outer . . .	0.35	0.36	0.37	0.40
,, inner . . .	0.29	0.29	0.32	0.32
Medullary, outer . .	0.30	0.32	0.34	0.29
,, inner . .	0.33	0.36	0.39	0.40

	Average of 3 Medium Tubers. Section			
	1	2	3	4
Skin	0.26	0.40	0.45	0.45
Cortical, outer . . .	0.33	0.33	0.34	0.37
,, inner . . .	0.29	0.30	0.33	0.35
Medullary, outer . .	0.30	0.34	0.37	0.38
,, inner . .	0.34	0.32	0.30	0.36

	Average of 3 Large Tubers. Section			
	1	2	3	4
Skin	0.45	0.36	0.51	0.54
Cortical, outer . . .	0.33	0.34	0.35	0.41
,, inner . . .	0.32	0.37	0.35	0.38
Medullary, outer . .	0.30	0.35	0.44	0.40
,, inner . .	0.32	0.32	0.36	0.38

Microscopical examination shows the starch grains densest in the region of the vascular system, and decreasing towards the centre and surface of the tuber.

A high degree of correlation is found between the specific gravity and percentage of dry matter of whole tubers.

For purposes of sampling the method of taking two radially opposed sectors, or diagonally opposed eighths, was far more accurate than the coring method.

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VI. O. N. Purvis. "*The Effect of Potassium Salts on the Anatomy of Dactylis Glomerata.*" Journal of Agricultural Science, 1919. Vol. IX. pp. 338-365.

Stems of *Dactylis glomerata* were collected from grass plots which had received different manurial treatment as regards potash.

The yield of hay from these plots during the period of the investigation was in close agreement with the average, showing that the season was not abnormal.

The thickness of the wall, the diameter of the lumina and the ratio of the lumen to the wall were measured both in sclerenchyma and metaxylem elements. In the early stages the sclerenchyma walls were thinner where potash had been supplied, but this effect was lost as the season progressed.

The lumina were larger in plants which had received potash when nitrogenous fertilisers had not been added, but in the presence of ammonium salts, this effect was reversed.

In the xylem the thickness of the walls was unaltered, whether potassic fertilisers were added or not. When no nitrogenous manures were added the diameter of the lumen was decreased in the presence of potash, but when ammonium salts had been applied, the diameter was increased by the application of potassic fertilisers.

The addition of potassium salts produced an increased ratio of lumen to wall, but this effect gradually passed off. Presumably, therefore, potassic fertilisers reduced the strength of mechanical cells in the early stages of growth. This conclusion, however, would not hold if potassium salts affected the composition of the wall.

From these results it is concluded that the rigidity of plants supplied with potassium salts is not the result of anatomical strengthening, but must be attributed to other causes, such as the influence of the salts on the physiological condition of the plant, or on its chemical composition.

VII. R. A. Fisher. "*Studies in Crop Variation. An Examination of the Yields of Dressed Wheat from Broadbalk.*" Journal of Agricultural Science, 1921. Vol. XI.

A study of the variations in yield on Broadbalk where wheat has been grown continuously since 1843.

Three types of variation are found due respectively to (1) annual causes, primarily weather; (2) steady deterioration of the soil; (3) other slow changes, among which changes in weed flora are considered. The effect of weather is reserved for further consideration. The effects of soil deterioration and other slow changes are studied at length.

On the unmanured plot, the decrement in yield is of the order of 0.8%, or less than 1 bushel in 10 years. If this rate were maintained, the plot would still last out another 125 years. Where farmyard manure is applied there is practically no falling off in yield; this crop also shows the least variation due to weather. With complete artificials, however, there is a deterioration, but less with heavy than with light dressings of ammonium salts, which is not quite in accordance with the Law of Diminishing Returns. With incomplete artificials, however, the falling off is more marked, exceeding that of the unmanured crop. The figures are :—

Plot.	Manure.	Mean yield Bushels per acre.	Mean annual decrement Bushels per acre.	Mean annual decrement %
3 & 4	None . . .	12.27 ± .39	.097	.79 ± .16
2b.	Farmyard manure .	34.55 ± .74	.031	.09 ± .11
8	Complete artificials (treble ammonia)	35.69 ± .93	.092	.26 ± .14
7	Do. (double ammonia)	31.37 ± .90	.144	.46 ± .15
6	Do. (single ammonia)	27.58 ± .71	.141	.62 ± .19

INCOMPLETE ARTIFICIALS.

Plot.	Manure.	Mean yield in Bushels per acre.	Mean annual decrement. Bushels per acre.	Mean annual decrement. %
12	Sulphate of soda .	28.32 ± .98	.181	.64 ± .18
13	Sulphate of potash .	30.21 ± .91	.123	.41 ± .16
14	Sulphate of magnesia	27.76 ± .90	.231	.83 ± .17
7	All three sulphates .	31.37 ± .90	.144	.46 ± .15
11	None of the sulphates	22.05 ± .91	.219	.99 ± .21

The existence of the third type of variation precluded the possibility of obtaining true curves of exhaustion.

The paper contains a detailed analysis of the mathematical methods employed for the deduction of statistically homogenous material for the further study of meteorological effects.

RAIN.

VIII. E. J. Russell and E. H. Richards. "*The Amount and Composition of Rain falling at Rothamsted.*" (Based on analyses made by the late Norman H. J. Miller.) Journal of Agricultural Science, 1919. Vol. VIII. pp. 309-337.

The ammoniacal nitrogen in the Rothamsted rain-water amounts on an average to 0.405 parts per million, corresponding to 2.64lb. per acre per annum. The yearly fluctuations in lb. per acre follow the rainfall fairly closely. The monthly fluctuations also move in the same direction as the rain, but the general level is highest during May, June, July and August, and lowest during January, February, March and April.

The nitric nitrogen is on an average one-half the ammoniacal, *viz.*, 1.33lb. per acre per annum. The amounts fluctuated year by year and month by month in the same way as the ammoniacal nitrogen and the rainfall until 1910, since when there has been no simple relationship.

Reasons are adduced for supposing that the ammonia arises from several sources. The sea, the soil and city pollution may all contribute. Neither the sea nor city pollution seems able to account for all the phenomena: the soil is indicated as an important source by the fact that the ammonia content is high during periods of high biochemical activity in the soil, and low during periods of low biochemical activity.

The close relationship between the amounts of ammoniacal and nitric nitrogen suggests either a common origin or the production of nitric compounds from ammonia.

The average amount of chlorine is 2.43 parts per million, bringing down 16lbs. per acre per annum. The fluctuations closely follow the rainfall both month by month and year by year, but the general level is much higher during the months September to April than during the summer months. It seems probable that the chlorine comes from the sea, but some may come from fuel.

Since 1888, when the experiments began, to 1916, when they terminated, there has been a rise in the amounts of nitric nitrogen and of chlorine in the rain. In the case of chlorine a parallel series of determinations made at Cirencester over the same period shows a similar rise. There is no rise of ammonia, but on the contrary a tendency to drop: the sum of ammoniacal and nitric nitrogen shows little change over the period. This seems to suggest that a former source of ammonia is now turning out nitric acid: it is possible that modern gas burners and grates tend to the formation of nitric oxides rather than of ammonia.

Rain contains on an average 10 parts of dissolved oxygen per million, the amount being higher in winter than in summer: 66.4lbs. per acre per annum were brought down during the two years over which the determinations extended.

The marked difference in composition between summer and winter rainfall suggests that these may differ in their origin. The winter rain resembles Atlantic rain in its high chlorine and low ammonia and nitrate content: the summer rain is characterised by low chlorine but high ammonia and nitrate content, suggesting that it arises by evaporation of water from the soil and condensation at higher altitudes than in the case of winter rain.

CHANGES OCCURRING IN THE SOIL.

IX. E. J. Russell and E. H. Richards. *"The Washing Out of Nitrates by Drainage Water from Uncropped and Unmanured Land."* (Based on analyses made by the late N. H. J. Miller.) Journal of Agricultural Science, 1920. Vol. X. pp. 22-43.

An investigation of the results obtained by the drain gauges set up by Lawes and Gilbert in 1870.

At the beginning of the experiment the soil contained 0.146% of nitrogen, or about 3,500lb. per acre in the top 9 inches; it yielded up to about 40lb. of nitrogen per acre per annum to the drainage water. At the end of nearly 50 years it still contains 0.099% of nitrogen, or 2,380lb. in the top 9 inches, and it still gives up to the drainage water 21lb. of nitric nitrogen per acre per annum, enough to produce a 15 bushel crop of wheat, although neither manure nor crop residues have been added during the whole of the period. If the curve showing the rate of fall continued its present course and without further slowing down, no less than 150 years would be needed for exhaustion of the nitrogen.

So far as can be ascertained, the nitrogen lost from the soil appears wholly as nitrate in the drainage water. From the top 9 inches of the 20in. and 60in. gauges, the nitrogen lost has been respectively 1,124 and 1,172lb. per acre. The nitric nitrogen in the drainage water amounts to 1,247 and 1,200lb. per acre in the two gauges. These figures are arrived at by adding together the whole of the nitrate found and such estimated amounts as are possible for the first seven years before regular determinations were made, deducting nitrogen introduced by rain. The subsoil is left out of account, but evidence is adduced to show that it contributed little, if anything, to the nitrate in the drainage water.

There is no indication of fixation of nitrogen or loss of gaseous nitrogen. The soil is, however, now very poor in organic matter.

The amount of nitrate washed out is closely related to the rainfall and to a less extent to the sunshine of the preceding summer.

It is difficult to account for the slow rate of removal of nitrogen from the soil unless one introduces into the ordinary cycle some new element acting as a kind of immobiliser, absorbing nitrates or ammonia as they are produced and giving them up again later on. The case would be met if one supposed that some of the soil organisms, such as algæ, bacteria, fungi, etc., assimilated nitrates or ammonia and on their death were themselves decomposed, giving rise ultimately to nitrates again. On this view the nitrogen compounds of the soil would be supposed to break down with formation of ammonia and then nitrate, but only a portion, and not the whole, of this nitrate is liable to loss or assimilation by plants: the remainder would be taken up by organisms, temporarily immobilised, but re-formed on the death and dissolution of the organisms, when again part would be thrown out of the cycle and reabsorbed.

X. D. J. Matthews. "*The Determination of Ammonia in Soil.*" Journal of Agricultural Science, 1920. Vol. X. pp. 72-85.

An aeration method for determining the quantity of ammonia in the soil with more accuracy and in shorter time that hitherto, it being possible to recover 99.5% of added ammonia as against a recovery of 50-60% by the older methods. For details the paper must be consulted.*

The results of application to natural soils is to confirm the older conclusion that ammonia is present in minimal quantities only, but it now becomes possible to follow accurately the changes that occur when stubble or green manure are ploughed in, or when ammoniacal fertilisers are added to the soil.

*Or Soil Conditions and Plant Growth. 4th. ed. 1921. p. 349.

XI. G. A. Cowie. *"The Mechanism of the Decomposition of Cyanamide in the Soil."* Journal of Agricultural Science, 1920. Vol. X. pp. 163-176.

This paper is of interest as showing the occurrence in the soil of changes which apparently are not brought about by micro-organisms, but by active chemical agents not yet clearly recognised.

It is known (see p. 55) that cyanamide undergoes decomposition in the soil before it can be utilised by the crop as a fertiliser. It is now shown that the decomposition proceeds in three stages: (1) cyanamide gives rise to urea; (2) urea gives rise to ammonia; (3) the ammonia is oxidised to nitrate. The first stage, the formation of urea, seems to be brought about by a chemical agent and not by micro-organisms, but the agent has not yet been discovered. The change proceeds more rapidly in clay than in sandy soils, and it does not take place at all in pure sand, in peat, or in fen soils. There is some indication that the decomposition agent may be a zeolite or active silicate. A sample of Thanet sand taken from a boring through the London Clay near Chelmsford was found, even after ignition, to be active in decomposing cyanamide into urea. This particular sand has been shown to contain a constituent resembling a zeolite in being reactive and possessing the property of softening hard water by the substitution of sodium salts and possibly potassium for those of calcium and magnesium. In following up this clue it was found that the addition of a definite zeolite prehnite to ordinary inert sand produces a mixture capable of converting cyanamide into urea.

The decomposition of urea and the oxidation of ammonia are then brought about by micro-organisms in the usual way.

XII. V. A. Beckley. *"The Formation of Humus."* Journal of Agricultural Science, 1921. Vol. XI. pp. 69-77.

Setting out from an observation by Fenton it is shown that sugars, on treatment with acids, give rise to hydroxymethylfurfuraldehyde, which readily condenses to form a substance closely resembling humus. The author found indications of hydroxymethylfurfuraldehyde in a dunged soil and in rotting straw in which humus was being produced. He suggests, therefore, that the formation of humus in the soil proceeds in two stages:—

1.—Carbohydrates react with acids to produce hydroxymethylfurfural.

2.—Hydroxymethylfurfural condenses to form humus.

In addition, in the laboratory, there is produced some furfural and lævulinic acid.

No evidence of the formation of hydroxymethylfurfural during the decomposition of cellulose by *Spirochæta cytophaga* could be obtained.

XIII. V. A. Beckley. *"The Preparation and Fractionation of Humic Acid."* Journal of Agricultural Science, 1921. Vol. XI. pp. 66-68.

The author finds that humus may be fractionated according to the following scheme:—

Soil treated with Ammonia

Black solution Treated with Acid — Insoluble humin

Solution: Mulder's apocrenic acid — Precipitate: Humus Treated with Alcohol

Solution: Hoppe-Seyler's hymatomelanic acid — Residue: Humic acid, Treated with Pyridine

Melanin — Compounds obtained by Schreiner and Shorey — Soluble humic acid — Insoluble humic acid

The above procedure has been repeated with rotted straw and with sugar humus, and in both cases similar fractions were obtained. The residue after pyridine extraction of sugar humus was, however, only slowly soluble in ammonia, probably having been converted into humin.

SOIL ORGANISMS.

XIV. L. M. Crump. "*Numbers of Protozoa in certain Rothamsted Soils.*" Journal of Agricultural Science, 1920. Vol. X. pp. 182-198.

The method used was an improvement on that previously adopted in this laboratory, but it did not discriminate between active and encysted forms. Determinations were made at intervals of about seven days of the numbers of total protozoa and bacteria in the soil of Broadbalk Plot 2, which receives 14 tons of farmyard manure in each year, and of Harpenden Field, which is typical of poor arable land. The results are plotted on curves from a study of which the following conclusions are drawn:—

1.—Flagellates, amœbæ and thecamœbæ are usually present in these soils in the trophic condition and in comparatively large numbers, so that there is an extensive population actively in search of food.

2.—The protozoan fauna is practically confined to the top six inches of the soil.

3.—There is a definite inverse relation between the numbers of bacteria and amœbæ.

4.—The amœbæ are uninfluenced by variations in the water content and temperature of the soil and by the rainfall.

5.—The richer the soil is in organic matter the richer it is in protozoa, especially in amœbæ and thecamœbæ.

These conclusions are at variance with those arrived at by the American investigators, but it is believed that the methods employed are better than those used in America.