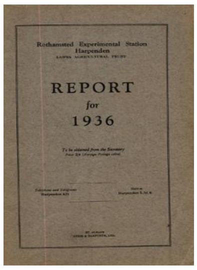
ROTHAMSTED RESEARCH

Rothamsted Report for 1936

Full Table of Content



Relation of Cultivation to Crop Yields

Rothamsted Research

Rothamsted Research (1937) *Relation of Cultivation to Crop Yields ;* Rothamsted Report For 1936, pp 37 - 48 **- DOI: https://doi.org/10.23637/ERADOC-1-68**

THE RELATION OF CULTIVATION TO CROP YIELDS

The study of methods of soil cultivation began at Rothamsted in 1926. The early results were rather unexpected, so increasing attention was given to the subject in succeeding years, and it now forms an important part of our field experiments programme. The work will, of course, be continued for some time to come, but it has reached a stage where an interim statement of our conclusions is both possible and, for the following reasons, desirable.

The changed economic conditions have forced farmers to reduce production costs wherever possible. Although there may be but little direct saving of money by reducing the number of cultivations with horse-drawn implements (for horses must be fed, whether working or idle) there may be an important saving of time and of useless labour. But, with mechanised cultivation methods, a direct saving in fuel and depreciation costs is made by avoiding unnecessary operations. British farmers have been reluctant to abandon their tradition that thorough cultivations are essential for high crop yields, and the majority firmly believes that yields suffer by just the extent that the tilth falls short of perfection. This belief is based to a great extent on the simple theory of soil water movement, so long current in text-books of agriculture, which asserts that a delicate control of soil moisture content can be secured by appropriate cultivation. The work in the Soil Physics Department has disproved this theory (*see* Report 1934, pp. 35-48) and therefore the practical problem reverts to its original form : the degree of dependence of crop yield on specific cultivation operations.

There is a considerable body of evidence from other countries that yields are not increased either by extra or by deeper cultivations above a certain minimum number, which minimum is well below what the British farmer would accept.(1) Further, the bearing of the results on British practice has been legitimately criticised by reference to the different climatic and soil conditions of this country. The criticism merits careful attention : evidently, results for a single year, soil (or crop) will not necessarily have general application. Nevertheless, if the traditional belief in the virtues of cultivation is well founded, the great majority of these experiments ought to show its truth, even if only by a reduction in yield when certain cultivations are withheld. Our eleven years' experiments on heavy soil at Rothamsted and on light land at Woburn give little support to the idea that yields are greatly dependent on cultivation ; on the contrary our results are in general accord with those obtained in other countries. At a conservative estimate, they justify further critical examination of the traditional beliefs regarding cultivation, and afford good grounds for the hope that appreciable reductions in production costs and in labour are still possible.

The full details and plot yields of the experiments discussed below will be found in the earlier Rothamsted Reports, to which reference is given. The experiments fall into two main groups : (*a*) examination of the effects of standard operations, varying from subsoiling to rolling, (*b*) comparison of standard methods with rotary cultivation.

(1) For details see B. A. Keen, "The Physical Properties of the Soil" (Longmans).

Every experiment was designed in accordance with modern statistical principles, so that the degree of significance of differences in yield can be assessed.

(*a*) EFFECTS OF STANDARD OPERATIONS

Fourteen separate experiments were made during the years 1930-1934 : 12 at Rothamsted, and one each at Woburn and Angus. The crops included sugar beet (9 experiments), potatoes (2), wheat (2), and kale (1). In the discussion below the experiments are grouped according to the cultivation operation under test.

1. *Subsoiling*. Early observation on the effect of subsoiling for potatoes at Rothamsted suggested that an increased yield of about 10 cwt. might be expected which, at the prices then ruling, was about sufficient to pay for the extra cost of the operation ; no measurable benefit was seen in the succeeding crops. In 1928 a subsoiler working to a depth of 14 inches was used for sugar beet (Report 1927-1928, p. 147) with the following results :—

Sugar beet	Increase due to subsoiling Mean	Standard Error	Mean yield
Roots, tons per acre	0.03	0.14	9.15
Tops, tons per acre	0.40	0.30	11.43
Root numbers, thousands per acre	0.61	0.13	17.71

Although the number of roots per acre was significantly increased by subsoiling, this was not reflected in any increase of yield. In 1931 and 1933 two further experiments were done at Rothamsted also on sugar beet. Micro-plots were used and the subsoil was hand-dug with forks, thus simulating a very thorough subsoiling. In the first experiment (Report 1931, p. 117) the results were :

Sugar beet	Increase due to subsoiling Mean	Standard Erorr	Mean yield
Roots, tons per acre	—0.23	0.148	12.66
Tops, tons per acre	—0.09	0.295	15.95
Sugar, cwt. per acre	—0.4	0.568	48.6

In the second experiment (Report 1933, p. 135) hand-digging of the surface and subsoil was combined with a comparison of applying minerals and dung in the subsoil as against incorporation in the top spit. The results were :

Sugar beet	Increase due to "deep" manure Mean	Standard Error	Mean yield
Roots, tons per acre	0.56	0.462	6.73
Tops, tons per acre	−0.39	0.546	7.84
Sugar, cwt. per acre	2.0	1.46	21.3

(This experiment gave low yields and high standard errors.)

2. *Extra Ploughing*. Two experiments were made at Rothamsted in 1934, one on potatoes and one on sugar beet. In the potato experiment ploughing in autumn and again in spring was compared with only spring ploughing ; and in the sugar beet experiment autumn and spring ploughing were compared with autumn ploughing only.

The experiments bear directly on practice, for in a bad season the land may have to lie unploughed until the spring ; and it is generally held that ploughing in autumn and again in spring is desirable in preparing for root crops. The results of the two experiments were as follows :

Potatoes (Report 1934, p. 182)	Increase of twice ploughed over once ploughed Mean	Standard Error	Mean yield
Tons per acre	0.26	0.194	11.43
Sugar beet (Report 1934, p. 184)			
Roots, tons per acre	0.36	0.268	15.36
Tops, tons per acre	0.38	0.310	14.36
Sugar, cwt. per acre	1.1	0.95	54.5

In each experiment there was an increased yield from the double ploughing which was a little greater than the standard error. Although the results are not significant, the possibility of a slightly beneficial effect is suggested, but the increase would not pay for the extra time and labour involved.

3. *Heavy rolling of seed bed.* At Rothamsted we have occasionally observed that consolidation has had a marked influence on plant growth. The effect is usually seen in cereal crops grown on tractor-worked land ; the portion compressed by the tractor wheels shows up strikingly as strips of taller growth running across the field. The effect is not uncommon elsewhere, and receives occasional notice in the grricultural press. In root crops no such striking visual differences would be expected, but if consolidation improved germination and early growth, there should be fewer accidental gaps in the rows at singling time, and hence, after singling, a higher number of plants per acre with, other things being equal, a corresponding increase in total yield. A field observation that improved germination of sugar beet occurred on a small area that had become heavily consolidated, led to two sugar beet experiments at Rothamsted on the effect of consolidating the seed bed with a heavy roll. In addition to yield of tops, roots and sugar, measurements of plant number were made. The results follow :

Sugar Beet (Report 1934, p. 188)	Increase of heavily rolled seed bed over ordinary roll Mean	Standard Error	Mean yield
Roots, tons per acre	—0.45	0.318	14.03
Tops, ,, ,, ,, ...	—0.53	0.355	11.62
Sugar, cwt. ,, ,, ...	—1.2	1.08	47.8
Plant number, thousands per acre	3.0	0.85	47.9
Sugar Beet (Report 1935, p. 186)			
Roots, tons per acre	—0.22	0.199	11.57
Tops ,, ,, ,, ...	—0.64	0.270	9.58
Sugar, cwt. ,, ,, ...	—0.4	0.68	39.5
Plant number, thousands per acre	—0.5	0.51	29.4

https://doi.org/10.23637/ERADOC-1-68

Whatever may have been the effect of the heavy rolling on germination and growth, it led to no improvement in yield. In fact, each experiment showed depressions in yields of roots, tops and total sugar as a result of heavy rolling, but with the exception of the tops in the 1935 experiment none of the decreases reached the level of significance. In the 1935 experiment heavy rolling did not affect the plant numbers. In the 1934 experiment the increase in plant numbers was significant. Hence, in the conditions of that experiment heavy rolling did encourage better germination, but the only effect was to produce a larger number of smaller sized roots whose total yield was below the average for the experiment. When examined in conjunction with the manurial treatments, rolling produced some significant effects in the 1934 experiment. Thus, the increased yield of roots due to sulphate of ammonia was 2.26 tons per acre with heavy rolling, and 0.96 tons per acre with ordinary rolling ; the corresponding figures for the total sugar were 6.8 and 1.9 cwt. per acre respectively. On the other hand, the 1935 experiment, in which agricultural salt was used, showed no such effects.

4. *Rolling and Harrowing.* Two experiments were made on wheat at Rothamsted, arranged to test the effect on yield of rolling and harrowing, separately and in combination. The following table shows the increase (or decrease) of yield for harrowing (H), rolling (R), rolling and harrowing (HR) over the control plots (O), that were neither rolled nor harrowed.

	Increased yield in cwt. per acre				
Wheat (Report 1931, p. 148)	H-O	R-O	HR-O	Standard error	Mean yield
Grain	1.8	0.8	2.1	0.57	15.8
Straw	—0.2	3.0	—0.7	1.32	39.1
Wheat (Report 1933, p.128)					
Grain	0.3	0.3	1.4	1.1	23.3
Straw	—0.7	1.8	—0.6	2.1	34.0

Comparison of the two sections of this table shows that, although the 1931 results reached a higher level of significance, the same results were obtained in each experiment, although they were done in different years and in different fields. When both harrowing and rolling are done, there is an increased yield of grain but a slight decrease in the weight of straw ; a result in the same direction is obtained from harrowing alone. When the plots are only rolled, there is a slight increase in the grain, but an appreciable increase in the weight of straw, which can probably be attributed to the effect of this operation on tillering.

These two experiments also included manurial and other cultivation treatments. A detailed study of the data from the 1933 experiment disclosed some interactions between treatments in which there were large differences of yield. Thus, the grain yield on the shallow ploughed and unharrowed plots was increased by 4.5 cwt. per acre, or 20 per cent. by rolling ; the grain yield on the deep ploughed plots receiving sulphate of ammonia was increased by 3.7 cwt. per acre, or 15 per cent. by harrowing; and the straw yield on the ploughed and unharrowed plots receiving sulphate of ammonia was increased by 7.8 cwt. per acre. or 23 per cent. by rolling.

5. *Inter-row cultivations.* In the root-break of a rotation, inter-row cultivation serves to give the land a periodical cleaning. It is commonly claimed that in addition to the mechanical effect of uprooting and killing weeds, the cultivations directly improve the soil by breaking up crusts on land liable to "capping," by creating a mulch for conserving soil moisture, and by increasing the fertility of the soil. For these reasons there is a general belief that the more the land can be cultivated during the growth of a root crop the better will be the results both on the root crop itself and succeeding ones. The necessity of weed eradication, and of the prevention of capping are self-evident, but the value of frequent mulching is open to question, while the alleged increased fertility effect can be directly tested by comparing the effect on yields of ordinary and intensive inter-row cultivations. The last of these points has been examined in six experiments since 1932: three experiments on sugar beet, and one on kale at Rothamsted; one on sugar beet at Woburn; and one on potatoes at Kingennie, Angus.

In the Rothamsted and Woburn experiments on sugar beet, ordinary inter-row cultivation consisted of sufficient hand or light horse-hoeing and motor-hoeing to keep down weeds. Intensive cultivations were additional to these and, subject to weather conditions, were given at approximate ten-day intervals after singling. The results follow below:

Sugar Beet

	Increase of intensive over ordinary cultivation: Mean	Standard Error	Mean yield
Rothamsted (Report 1932, p. 157)			
Roots, tons per acre	—1.03	0.138	13.47
Tops, ,, ,, ,, ...	—2.56	0.346	14.58
Sugar, cwt. ,, ,, ...	—4.0	0.51	50.1
(Cultivations: ordinary, 3; extra for intensive, 5)			
Rothamsted (Report, 1934, p.186)			
Roots, tons per acre	—1.79	0.268	15.36
Tops, ,, ,, ,, ...	—0.53	0.310	14.36
Sugar, cwt. ,, ,, ...	—7.2	0.95	54.5
(Cultivations: ordinary, 2; extra for intensive, 6)			
Rothamsted (Report 1935, p.186)			
Roots, tons per acre	0.25	0.199	11.57
Tops, ,, ,, ,, ...	0.26	0.270	9.58
Sugar, cwt. ,, ,, ...	1.0	0.68	39.5
(Cultivations: ordinary, 3; extra for intensive, 5)			
Woburn (Report 1932, p.163)			
Roots, tons per acre	—0.23	0.207	11.88
Tops, ,, ,, ,, ...	0.52	0.260	15.80
Sugar, cwt. ,, ,, ...	—1.3	0.75	43:0
(Cultivations: ordinary, 5; extra, for intensive, 3)			

https://doi.org/10.23637/ERADOC-1-68

The above table lends no support to the idea that yields are increased by extra inter-row cultivations. On the contrary it shows that the sole reward for the extra cost of the intensive cultivations is either no significant increase of yield, or else an actual depression. Thus in 1932 and 1934 intensive cultivation significantly depressed the yield of roots at Rothamsted, while in 1935 at Rothamsted and 1932 at Woburn it effected a slight increase and a slight depression respectively which did not approach significance. For tops, intensive cultivation significantly depressed the yield at Rothamsted in 1932 but had no nett effect in the other three experiments.

The possibility cannot be entirely dismissed that the extra cultivations caused some damage to the leaves and superficial feeding roots, which more than offset any beneficial effect of the cultivations themselves on the soil fertility. Although the cultivations were done by skilled labourers some slight damage was probably inevitable, but it was not enough to affect plant numbers, which showed, in the two experiments where counts were made, no significant difference between ordinary and intensive cultivation.

Kale (*Rothamsted*) (Report 1932, p.162)	Increase of intensive over ordinary cultivation		Mean yield
	Mean	Standard Error	
Green weight, tons per acre . .	—1.84	0.323	25.50

(Cultivations : ordinary 2, extra for intensive 5)

This table shows that a significant depression in the yield of kale occurred on the intensively cultivated plots.

Potatoes (*Angus*) (Report 1932, p. 215)	Increase of intensive over ordinary cultivation						Mean yield
	Sulphate of ammonia				Mean	Standard Error	
	none	1 cwt.	2 cwt.	3 cwt.			
Tons per acre . .	—0.69	—0.38	0.44	0.09	—0.14	0.180	14.13

In this experiment the ordinary cultivations were : two harrowings, two grubbings, one hoeing, and earthing up ; the extra cultivations on the intensive plots were : one harrowing and earthing up, one grubbing and subsoiling.

There was no gain from the extra cultivations, taking the experiment as a whole, but there is a suggestion that with none, or small dressings of sulphate of ammonia, extra cultivations depress the yield, while with heavier dressings of the fertiliser, the extra cultivations are associated with an increased yield, which is however just short of significance.

The nett conclusion from all the inter-row cultivation experiments is that stirring the land beyond the minimum required to keep down weeds and to prevent capping on soils prone to this behaviour, is useless labour at the best, and may even reduce the crop yield.

https://doi.org/10.23637/ERADOC-1-68

(*b*) COMPARISON OF STANDARD OPERATIONS AND ROTARY CULTIVATIONS

Experiments on the methods of preparing a seed bed from a stubble have been in progress since 1926. The results have been given in detail in the following Rothamsted Reports :

Year	Crop	Field	Report
1926	Swedes	Sawyers	1925-26 p. 153
1928	Swedes	Great Harpenden	1927-28 p. 152
1929	Barley	Great Harpenden	1929 p. 98
1930	Mangolds	The Broad Baulk*	1930 p. 149
1931	Wheat	Little Hoos	1931 p. 148
1933	Wheat	Pastures	1933 p. 128
1934	Wheat	Pastures	
1934	Long Hoos Rotation Experiment		1934 p. 175
1935	,, ,,	,, ,,	1935 p. 170
1936	,, ,,	,, ,,	This Report p. 198

* Now called Pennels Piece.

Until 1932 the main comparison was between rotary cultivation(1) and the standard method of ploughing and harrowing. The results of five experiments, three on root crops and two on cereals, were :

	Decrease due to Rototiller as compared with plough and harrow: Mean	Standard Error	Mean yield
1926 Swedes, roots, tons per acre ..	1.65	0.57	10.2
1928 Swedes, ,, ,, ,, ,, ..	2.55	0.71	21.4
1930 Mangolds ,, ,, ,, ,, ..	3.78	2.94	29.0
1929 Barley, grain, cwt. per acre ..	0.6	0.81	30.2
straw, ,, ,, ,, ..	1.2	1.68	44.3
1931 Wheat, grain ,, ,, ,, ..	1.5	0.73	15.1
straw, ,, ,, ,, ..	1.9	2.68	38.6

There is thus a small decrease of yield in using rotary cultivation instead of ploughing and harrowing.

In 1933 a new experiment with winter wheat was made in which two depths of working of the plough and the Rototiller were used. The " deep " cultivations were carried to a depth of about 7-8 ins., and the " shallow " to between 3-4 ins. This experiment was continued in 1934 when half the plots ploughed in 1933 were now rotary-cultivated and half the plots rotary-cultivated were ploughed. In addition, a much more extensive field programme was begun in 1934. A section of Long Hoos was divided into three main sections, each section growing wheat, mangolds and barley in a three-course rotation and each section carrying a different crop. Each section is divided into four blocks. Two blocks have plots which are always cultivated in the same way year after year and are called the continuous series and two blocks are cultivated according to a cycle lasting six years and are called the rotating series. The three methods of preparing the seed bed are using the plough and harrows,

(1) A Rototiller, supplied by Messrs. Geo. Monro, Ltd., of Waltham Cross was used in these experiments.

https://doi.org/10.23637/ERADOC-1-68

using the cultivator and harrows, and using a Rototiller. Two depths of working are used ; deep, which is between 7-8 ins., and shallow, which is between 3-4 ins. On the rotating plots, each plot that is worked deep one year is worked shallow the next, and half the plots ploughed one year are, in the next year, worked with the cultivator and the other half worked with the Rototiller ; and similarly for the cultivated and rotary-cultivated plots.

In the discussion the results will be grouped according to the crop grown.

(1) *Autumn-sown wheat*

The experiments have been divided for examination into three groups. In the first group are experiments in the first year after commercial cultivation ; they are, one in 1933 on Pastures field and one in 1934 on Long Hoos. The second group consists of plots where the land was under a cultivation experiment in the previous year and where the same cultivation treatment was not used in the year under discussion ; they are the rotating plots in Long Hoos in 1935 and in 1936 and half the plots on Pastures field in 1934. The third group consists of plots where the land was under cultivation experiments in the previous year and where the same cultivations have been continued ; they are the continuous plots on Long Hoos in 1935 and 1936, and half the plots on Pastures in 1934.

The results are presented in two sections, namely a comparison of deep and shallow tillage and a comparison of the three methods of tillage.

The effect of the depth of tillage is shown in the following table :

Beneficial Effect of Deep Tillage compared with Shallow (in cwt. per acre)

	GRAIN					STRAW				
	Mean yield	Plough	Roto-tiller	Culti-vator	Standard Error	Mean yield	Plough	Roto-tiller	Culti-vator	Standard Error
Group 1. (After Commercial)										
Pastures 1933	23.3	0.8	1.6	—	1.1	34.0	2.1	0.1	—	2.1
Long Hoos 1934	23.4	0.2	2.7	2.1	1.0	28.0	0.9	2.6	2.6	1.1
Mean of Group 1		0.5	2.2	2.1			1.5	1.3	2.6	
Group 2. (Rotating)										
Pastures 1934	10.9	1.4	4.1	—	1·7	13.6	1.2	4.8	—	—
Long Hoos Rotating 1935 ..	20.6	1.1	2.2	2.7	—	33.4	−0.4	4.0	3.9	—
Long Hoos Rotating 1936 * ..	20.4	0.0	0.0	0.3	—	41.0	−2.7	−1.9	−4.0	—
Mean of Group 2		0.8	2.1	1.5			−0.6	2.3	0.0	
Group 3. (Continuous)										
Pastures 1934	10.8	1.6	3.1	—	1·7	13.3	2.6	3.6	—	—
Long Hoos Continuous 1935 ..	21.3	−2.0	−2.1	1.0	1.7	34.6	−4.8	−1.8	1.7	3.8
Long Hoos Continuous 1936 * ..	21.6	−0.4	0.0	0.6	1.0	43.9	2.8	1.2	3.5	2.8
Mean of Group 3		−0.3	0.3	0.8			0.2	1.0	2.6	
Mean of all groups ..		0.3	1.5	1.4			0.5	1.6	1.7	

* Autumn-sown crop failed. Field spring-tine harrowed and re-sown in March.

There is perhaps a slight advantage in using the Rototiller or the cultivator deep instead of shallow, but the advantage is only about 1½ cwt. per acre in the grain and the straw. There is no advantage in deep ploughing.

A comparison between the effect of the different tillage implements on the yield is given in the following table.

Beneficial Effect of Ploughing (P) compared with the Rototiller (R) and the Cultivator (C) (in cwt. per acre)

	GRAIN					STRAW				
	Deep		Shallow		Standard Error	Deep		Shallow		Standard Error
	P-R	P-C	P-R	P-C		P-R	P-C	P-R	P-C	
Group 1. (After Commercial)										
Pastures 1933	0.5	—	1.2	—	1.1	2.7	—	0.6	—	2.1
Long Hoos 1934	2.6	0.0	5.1	1.9	1.0	3.2	0.6	4.8	2.3	1.1
Mean of Group 1	1.6	0.0	3.2	1.9		2.9	0.6	2.7	2.3	
Group 2. (Rotating)										
Pastures 1934	−0.6	—	2.1	—	1.7	0.0	—	3.6	—	—
Long Hoos 1935	0.8	3.5	1.9	5.1	—	−1.4	1.4	3.0	5.7	—
Long Hoos 1936 * ..	0.3	0.8	0.3	1.1	—	0.3	4.8	1.2	3.5	—
Mean of Group 2	0.2	2.1	1.4	3.1		−0.4	3.1	2.6	4.6	
Group 3. (Continuous)										
Pastures 1934	0.5	—	2.0	—	1.7	2.1	—	3.1	—	—
Long Hoos 1935	2.6	1.5	2.5	4.5	1.7	1.4	0.6	4.4	7.1	3.8
Long Hoos 1936 * ..	1.1	1.1	1.5	2.2	1.0	5.6	7.1	4.0	7.8	2.8
Mean of Group 3 ..	1.4	1.3	2.0	3.4		3.1	3.8	3.9	7.4	
Mean of all Groups ..	1.1	1.1	2.2	2.8		1.9	2.5	3.1	4.8	

* Autumn-sown crop failed. Field spring-tine harrowed and resown in March.

The plough gives consistently better yields than the Rototiller or the cultivator, while the cultivator tends to give the lowest yield, particularly if used shallow. There is as yet no sign of deterioration in the plots continuously tilled with the Rototiller or the cultivator, for the depression of yield following their use for three years in succession (Long Hoos 1936) is not consistently greater than after two years' use (Long Hoos 1935).

2. *Spring-sown barley*

These experiments have all been made in the Long Hoos experiment, and have been divided into two groups. The first group consists of the yields in the first year after commercial farming, and the second and third year of the rotating series. The second group consists of the results for 1935 and 1936 on the continuous plots.

The effect of the depth of tillage is shown in the following table :

Beneficial Effect of Deep Tillage compared with Shallow (in cwt. per acre)

	GRAIN					STRAW				
	Mean yield	Plough	Rototiller	Cultivator	Standard Error	Mean yield	Plough	Rototiller	Cultivator	Standard Error
Group 1. (First year and Rotating)										
1934	26.4	−0.5	3.2	0.7	0.8	25.6	−0.5	3.0	0.2	0.7
1935	34.1	1.0	1.5	1.4	—	38.4	1.4	1.4	2.1	—
1936	28.0	0.7	2.4	1.4	—	40.0	1.7	1.4	−0.8	—
Mean of Group 1		0.4	2.4	1.2			0.9	1.9	0.5	
Group 2. (Continuous)										
1935	35.6	−1.6	0.1	1.6	2.4	39.9	0.7	−0.2	1.3	3.1
1936	25.0	2.9	1.7	3.8	1.4	38.0	3.3	1.6	3.3	1.7
Mean of Group 2		0.6	0.9	2.7			2.0	0.7	2.3	
Mean of the Groups ..		0.5	1.7	1.9			1.4	1.3	1.4	

The experiments show that it is advantageous to use the Rototiller and the cultivator to the full 8-inch working depth rather than to 4 inches, but for the plough the advantage of the deeper working is only manifest in the straw yield.

https://doi.org/10.23637/ERADOC-1-68

The comparison between the different tillage implements on the yield is given in the following table :

Beneficial Effect of Ploughing (P) compared with the Rototiller (R) and the Cultivator (C) (in cwt. per acre)

	GRAIN					STRAW				
	Deep P-R	Deep P-C	Shallow P-R	Shallow P-C	Standard Error	Deep P-R	Deep P-C	Shallow P-R	Shallow P-C	Standard Error
Group 1. (First year and Rotating)										
1934	−1.6	−0.6	2.1	0.6	0.8	−0.5	0.1	3.0	0.7	0.7
1935	−0.3	−0.5	0.2	−0.1	—	1.8	0.1	1.8	0.8	—
1936	−0.1	1.9	1.7	2.7	—	1.0	0.7	0.7	−1.9	—
Mean of Group 1 ..	−0.7	0.3	1.3	1.1		0.8	0.3	1.8	−0.1	
Group 2. (Continuous)										
1935	−0.4	0.2	1.3	3.4	2.4	2.0	3.3	1.1	3.9	3.1
1936	2.7	5.9	1.4	6.8	1.4	2.1	6.5	0.3	6.5	1.7
Mean of Group 2	1.1	3.0	1.3	5.1		2.0	4.9	0.7	5.2	
Mean of the Groups ..	0.2	1.6	1.4	3.1		1.4	2.6	1.2	2.6	

On the plots that do not have the same cultivation year after year (group 1), deep tillage with either of the two cultivators gives about the same yield as the plough, though when used shallow both cultivators give about 1 cwt. per acre less grain, and the Rototiller gives about 2 cwt. per acre less straw.

The tilth produced by the cultivator if used for two or three years in succession becomes progressively less suited to barley. Comparing the yields on the cultivator shallow with the plough shallow plots there is a decrease of 1.1, 3.4 and 6.8 cwt. of grain, and 0.1, 3.9 and 6.5 cwt. of straw per acre for the first, second and third year of continuous cultivator treatment. The effect is as noticeable for the straw on the deep tilled plots, but for the grain is about 0, 0 and 6 cwt. There is no strong evidence that deterioration has yet begun in the continuously rototilled plots, for the means of group 1 are not appreciably less than those of group 2.

3. *Spring-sown mangolds*

These experiments have been made in the Long Hoos cultivation experiment and fall into the same two groups as barley.

The effect of the depth of tillage is shown in the following table:

Beneficial Effect of Deep Tillage compared with Shallow (in tons per acre)

	ROOTS					TOPS				
	Mean yield	Plough	Rototiller	Cultivator	Standard Error	Mean yield	Plough	Rototiller	Cutivator	Standard Error
Group 1.										
1934	35.9	1.0	−0.3	1.0	1.57	7.30	−0.04	−0.87	−0.56	0.38
1935	20.2	−0.8	1.7	0.1	—	4.96	−0.27	−0.13	0.17	—
1936	21.3	0.9	2.4	0.7	—	3.42	0.26	0.27	−0.03	—
Mean of Group 1		0.4	1.3	0.6			−0.02	−0.24	−0.14	
Group 2.										
1935	20.6	1.7	5.1	8.7	2.12	4.85	−0.36	0.38	0.54	0.37
1936	20.0	1.6	2.9	−0.7	1.33	3.42	0.19	0.36	−0.10	—
Mean of Group 2		1.7	4.0	4.0			−0.08	0.37	0.22	
Mean of the Groups ..		1.0	2.6	2.3			−0.04	0.06	0.04	

https://doi.org/10.23637/ERADOC-1-68

The results suggest that continued shallow ploughing is not ideal for mangolds but that the mangold seed bed should be deep ploughed every second year. If the plots have been ploughed deep every alternate year the depression due to shallow ploughing in one year is only 0.4 tons per acre, whereas if the plots have been shallow ploughed for two or more years in succession the depression in yield as compared with continuous deep ploughing is 1.7 tons per acre. Deep tillage with the cultivators is never harmful, and may be very beneficial. In 1935, for example, the yield of mangold roots on the plots that had two years' shallow cultivation with the Rototiller and the cultivator were 5.1 and 8.7 tons per acre less than on the plots that had two years' deep cultivation. But this effect is not always found, for in the next year (1936) the advantage of deep tillage was much less apparent.

The comparison of the different tillage implements on the yield is given in the following table :

Beneficial Effect of Ploughing (P) compared with the Rototiller (R) and the Cultivator (C) (in tons per acre)

	ROOTS					TOPS				
	Deep		Shallow		Standard Error	Deep		Shallow		Standard Error
	P-R	P-C	P-R	P-C		P-R	P-C	P-R	P-C	
Group 1.										
1934	3.6	0.2	2.3	0.3	1.57	0.30	0.07	−0.53	−0.45	0.38
1935	−0.4	1.1	2.1	2.0	—	−0.10	−0.02	0.04	0.42	—
1936	1.4	2.0	2.8	1.7	—	0.39	0.55	0.41	0.26	—
Mean of Group 1	1.5	1.1	2.4	1.3		0.20	0.20	−0.03	0.08	
Group 2.										
1935	2.2	3.2	5.6	10.2	2.12	0.37	0.49	1.11	1.39	0.37
1936	2.1	5.6	3.3	3.3	1.32	0.13	0.75	0.30	0.46	—
Mean of Group 2	2.1	4.4	4.5	6.8		0.25	0.62	0.71	0.92	
Mean of the Groups ..	1.8	2.7	3.5	4.0		0.22	0.41	0.34	0.50	

The plough definitely gives the highest mangold yields. In group 1, i.e. on the rotating series, the cultivator-tilled plots probably yield rather better than the rototilled plots, particularly in the shallow tilled plots. In group 2, i.e. on the plots always worked with the same tillage implement, the rototilled plots usually yield better than the cultivator-tilled, and in one case the shallow-tilled plots in 1935 yielded 4.6 tons per acre more. There is not yet any clear evidence of deterioration of yield on the plots that have not been ploughed, but there is an indication of it on the deep cultivator-tilled plots, for the depression in yield below the ploughed plots is 1.1, 3.2 and 5.6 tons per acre after one, two and three years' continuous tillage with the cultivator. On the shallow-tilled plots in 1935 two years' ploughing was much better than two years' tillage with either the Rototiller or the cultivator, the depression due to these implements being 5.6 and 10.2 tons per acre, but after three years' continuous tillage the depression was only 3·3 tons per acre in each case. The explanation of the striking result in 1935 is not clear, for if it were due to the unsuitable condition of the ground one would have expected the " rotating " plots to have shown up the weakness of the cultivators. There are two sets of rotating plots

https://doi.org/10.23637/ERADOC-1-68

relevant to the discussion: a comparison of Cultivator 1934 Plough 1935 with Rototiller 1934 Cultivator 1935, and a comparison of Rototiller 1934 Plough 1935 with Cultivator 1934 Rototiller 1935. On the shallow-tilled plots the advantage of plough over two years without plough is 2.3* tons per acre over the cultivator and 3.3* tons per acre over the Rototiller plots, which are far below the 10.2 and 5.6 tons per acre on the " Continuous " plots.

4. *Conclusions*

The first obvious result that emerges is that there is no apparent advantage in ploughing to a depth greater than 4 inches for cereals, but for mangolds it is worth while ploughing to 8 inches every second year.

The second result is that the plough and harrow as a method of preparing the seed bed is never worse than the cultivators and is often better. But the point of the experiment was not to demonstrate this, but to find out how much worse were the other methods for they may be far quicker or cheaper than ploughing. The results indicate that if time is important it is possible to dispense with ploughing for one year and to substitute quicker methods with very little, if any, detriment to the yield, particularly if the cultivators are worked deeper than 4 inches. The reduction of yield will only rarely be more than 1 cwt. per acre of either wheat or barley, or more than 2½ tons per acre of mangolds or swedes.

The third result is that so far no harmful effects of using the Rototiller instead of the plough year after year have yet come to light with the proviso that it should be worked to about 8 inches for mangolds. But the cultivator is not a suitable implement to replace the plough for several years running, though if used deep it can probably be used two years consecutively for barley and longer for wheat.

Applicability of the Results

The fact that the numerous experiments discussed above show that yields are not greatly dependent on cultivation methods is of considerable importance in practice. The results must, naturally, be interpreted with discretion. But, although they have mainly been carried out at Rothamsted, one might expect the results to hold wherever the soil and the climate are similar to that obtaining here. The main features of the climate and the soil are probably widespread over many parts of England, though in the absence of good soil surveys for the country it is not possible to say exactly how widespread are the main soil features. It is probable that unless there is some striking reason to the contrary, these results will be typical of the medium to heavy lands of the drier parts of this country.

*These figures cannot be derived from the condensed table given above: they must be picked out from the individual plot yields printed in the 1935 Report.