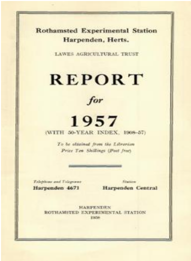
ROTHAMSTED RESEARCH

Report for 1957

Full Table of Content


Rothamsted Experimental Station
Harpenden, Herts.
REPORT
for
1957

Field Experiments Section : Summary of the Deep Cultivation Experiment, 1944-1956

H. D. Patterson

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FIELD EXPERIMENTS SECTION

The field experiments at Rothamsted and Woburn are controlled by the Plot Committee consisting of the following members of the staff: F. Yates (Chairman), H. V. Garner (Secretary), F. C. Bawden, G. W. Cooke, J. R. Moffatt, C. A. Thorold, R. G. Warren and D. J. Watson. Most of the long-term experiments were planned and designed by the Plot Committee, but proposals for short-term experiments are received from workers in the scientific departments and, after examination by the appropriate Working Party, are passed on to the Committee for approval.

In addition to these full-scale experiments a number of problems are studied on microplots laid down in various enclosures on both farms. In most cases the work on these small plots is carried out by the scientific departments.

The number of full-scale plots carried out by the experimental staff on the two farms in 1957 and some totals for the last 10 years are given in Table 1.

TABLE 1

	Grain	Roots	Hay	Grazing	Total
Classical experiments:					
Rothamsted	303	177	47	—	527
Woburn	—	—	—	—	—
Long-period experiments:					
Rothamsted	343	342	187	96	968
Woburn	173	250	55	12	490
Annual experiments:					
Rothamsted	676	270	112	—	1,058
Woburn	192	164	—	—	356
Total	1,687	1,203	401	108	3,399
1948	817	558	103	3	1,481
1951	888	1,011	438	108	2,445
1954	1,104	1,027	470	108	2,709
1957	1,687	1,203	401	108	3,399

The number of plots has more than doubled since 1948, and in the last two seasons has stood at about 3,400. Until 1952 cereals, roots and hay plots all increased in step, but with the introduction of the combine-harvester in 1952 on an experimental scale, and its almost general adoption in 1954, the number of cereal plots continued to rise while the others were stabilized at about the 1952 level. At present cereal plots account for half the total.

Although the Rothamsted land in all is 603 acres, it is by no means entirely occupied by experimental plots, nor is the whole of the area suitable for this purpose. The present partition of the acreage is estimated as closely as possible in Table 2.

The non-agricultural area, amounting to one-fifth of the whole, includes roads, woods, allotments, buildings and the Manor grounds.

Farmland unsuited to experiments takes in the headlands of fields, land shaded by trees, dell holes and steep slopes; it amounts to over a quarter of the estate. Thus about half the area is classed as potential experimental sites. One-fifth of this is permanently occupied by classical and long-period experiments, and even when these are discontinued the sites are not likely to come into use again for many years. There remain 249 acres of land to accommodate the annual experiments and any new long-term ones. Of this only 85

TABLE 2

Utilization of the land in the Rothamsted Estate 1957

	Acres	%
Total area ...	603	100
Non-agricultural area ...	126	21
Farm-land unsuitable for experiments ...	163	27
Land available for experiments ...	314	52
Experimental land ...	314	100
Classical experiments ...	38	12
Long-term rotation experiments ...	27	9
Land suitable for tests of potash and phosphate ...	85	27
Suitable for nitrogen and pathology experiments ...	164	52

acres are sufficiently poor in phosphorus and potassium to accommodate critical experiments on these nutrients. The remaining 164 acres can be used either for experiments involving nitrogen, crop varieties or field experiments on plant diseases.

The weather for 1957 is described in the report on the Farms; the following is a summary of its main features. The autumn of 1956 was unusually dry till well into December; consequently the arrears of cultivations that had built up during the long slow harvest were gradually overcome; but it was late in November before all the winter wheat was sown. The most remarkable feature was the mild winter: the period December to February inclusive was very warm, rather wet and singularly free from frost. On the heavy land this gave the worst spring seedbeds for many years. The drought which set in in March did not improve matters, for the land baked very hard so that potatoes went in rough and roots had to wait some weeks for softening showers. April and May continued very dry and, although bad for spring corn, were excellent for hoeing. June and July had normal rainfall, but it was well into summer before the effects of the drought began to wear off. When harvesting started in earnest in mid-August it continued practically without a check, though most of the grain needed drying. Ploughing made good progress in September and the first fortnight of October gave ideal weather for potato lifting. The weather then became showery though still warm, and the land was very sticky when mangolds and sugar beet were lifted. Harvesting of these crops was completed by the middle of November.

THE CLASSICAL FIELDS

Broadbalk

The field was drilled on 12 November in a seedbed that was rather wet, but just dry enough to cover the seed. Germination

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was rapid, and the plant was very forward and green all through the winter. In early spring there was the usual attack of wheat-bulb fly (*Leptohylemyia coarctata*), particularly on Section Ib after fallow, the infestation ranging from 15 to 65 per cent. Nevertheless, this section yielded considerably more than any other. The crop was too well established to be affected by the spring and early summer drought. On 16 May the continuous wheat area in Section I, now carrying its sixth crop, was sprayed with MCPA, this being the first occasion that a weedkiller had been used on Broadbalk. This operation was very effective, and in addition to reducing the broad-leaved weeds, the spray checked the growth of common vetch (*Vicia sativa*), which in recent years has been so prevalent on Plots 2, 5 and 6, where the nitrogen level is low. On the parts of these plots where fallowing is practised the vetch was so prevalent that it competed seriously with the crop, especially on Sections III and IV.

Take-all (*Ophiobolus graminis*) was prevalent on some of the plots this year, particularly on Plot 8, Section Vb, which had received 5 tons of chalk/acre in the autumn of 1956 and its annual dressing of complete fertilizer including 6 cwt. of sulphate of ammonia. This treatment usually gives one of the highest yields on Broadbalk, but this year the limed section only yielded 7·1 cwt. of grain, as compared with 19·0 cwt. on the neighbouring section with the same fertilizer but without the 1954 lime dressing. The effect corresponded closely with the plot boundaries and is being more closely studied in pot culture to discover the factor responsible for the heavy incidence of take-all.

The crop stood well until the end of July, but from then onwards it began to look increasingly untidy, partly due to straggling caused by eyespot (*Cercosporella herpotrichoides*), which always occurs, and partly due to the damage to the ears by small birds. Before harvest lodging was severe on the section after fallow, on the dunged plot and on Plot 8 with heavy nitrogen; elsewhere it was more distributed, Plot 16 being one of the worst.

The harvest of 1957 was a notable one on Broadbalk, for the combine-harvester was used for the first time. For a parallel innovation one has to go back to 1901, when the binder took over from the traditional band of reapers. The plot yields in 1957 were measured by a single cut with a 10-foot Massey Harris self-propelled machine taking about half the manured area. The outside rows, which are usually more or less abnormal, were excluded. The combine handled lodged plots well and cut a stubble of about the usual height, but some discontinuity in straw yields was inevitable because the chaff and small cavings, formerly measured from the threshing-machine, could not be collected and weighed. The effect of combine-harvesting on weed infestation will be kept under observation.

Wild oats on Broadbalk have shown a steady decrease in the past 6 years as a result of systematic hand-pulling. In 1957, however, there was a noticeable increase. This situation is being closely watched.

Broadbalk Wilderness

The North half of the Wilderness, which has been kept clear of bushes since 1882 but otherwise left entirely undisturbed, was divided into two sections in the spring of 1957. One part has continued under the usual system to show the unchecked growth of grasses and weeds; the remainder has been mown repeatedly throughout the season without removing the cut material. The changes in the balance of species under the different systems of management are being studied by the Botany Department.

Hoosfield

The permanent barley plots were drilled on 6 April; this rather late sowing caught the full effect of the drought. As always happens on the classical experiments in a dry spring, the dunged plots showed much better early growth than the others, and this year the fertilizers never caught up. The dunged plot was obviously the best, and was the only one which lodged before harvest. On the whole yields were poor; the best of the plots without organic manure were rather thin and short. Once more the whole field was pulled for wild oats and the full area of every plot was harvested. In order to reduce coltsfoot, thistles and other perennials that were beginning to become conspicuous, it was decided to spray with MCPA in 1957 instead of DNOC, which had been used since 1944.

Barnfield

The permanent mangold field was too dry to drill till 17 May. The plant came well, and singling started on 9 July, with the dunged plots well in advance of the rest. Owing to shortage of staff, it was possible to single only four rows of mangolds and four rows of sugar beet per plot; the remainder of the crop was discarded. The plots carried a fairly good plant after singling, and in the cool moist weather that followed growth was rapid. There was no real check for the rest of the season, and yields were above average. Lifting began towards the end of October, and the reduced acreage was completed within a fortnight under rather wet conditions.

Park Grass

After a very mild winter the Park Grass plots started the season with an unusually heavy growth of grass. On 18 June this gave a first cut well above the average; the crop was baled and weighed in very favourable weather only 4 days after cutting. The bare patches, caused by the frost and spring drought of 1956, on the very acid plots were almost completely recolonized during the growing season of 1957. Once more white clover was more than usually conspicuous in the plots without added nitrogen. A rather heavy second cut was taken and weighed green on 26 September.

Agdell

The crop of winter beans grown without manure in 1956 showed such large effects due to the residues of phosphate and potash applied to the old rotation that it was decided to look once more for residuals. This year the crop was potatoes, and a heavy dressing of 5 cwt. of sulphate of ammonia was given to every plot. Ulster Supreme potatoes were planted rather late, 27 April, since it was very difficult to obtain a satisfactory tilth. After a late start the crop on the plots that had formerly received fertilizer grew well, but on the former unmanured plots the growth was very poor indeed, each plant producing one fair-sized tuber but no chats, with a total yield of about 3 tons/acre. Elsewhere the yield was very good and consisted of a small number of large tubers on each plant. The best plots gave 15 tons/acre.

Exhaustion Land

From 1949 to 1956 the plots of the Exhaustion Land had carried eight crops of continuous barley with a basal dressing of 0·5 cwt. N. The yields showed marked residuals from phosphate, potash and dung applied to the old potato experiment which formerly occupied these plots and ended in 1901. Much work on the soils and crops has been carried out in the Chemistry Department. In 1957 for the first time the cropping on the original strips has been widened to include sugar beet, potatoes, kale, swedes, spring wheat and barley. Additions of phosphorus and potassium have been given to all crops on a microplot scale so that the residual effects can be evaluated in terms of direct additions.

The behaviour of the various crops under phosphate deficiency was very striking. All harvesting and sampling of this experiment has been undertaken by the Chemistry Department.

Long-period Experiments

Deep-cultivation rotation

The last two crops in this experiment were harvested this year; they were 1-year seeds hay and wheat. The experiment has now ended, and the whole site has been sown uniformly with wheat to provide material for foot-rot observations following several different crop sequences. A summary of the results from two complete rotations of this experiment are given on pp. 193–199 below.

Ley–arable rotations

The season was rather unfavourable for the establishment of young grasses. The 1-year hay on Highfield was killed under a lodged nurse crop of barley and had to be resown in spring 1957; it gave only about half the yield of the corresponding undersown crop on Fosters. The sowings of leys, cut grass and lucerne made in the open ground in spring 1957 had a very poor start in the drought, and in spite of the rain that came in mid-summer they never reached the normal level of yield. The first year of the 3-year grazing lay in Fosters was particularly poor. Seeds in their second year were much nearer average, but the third-year grazing leys on both fields were abnormally poor, for they produced only 21 cwt. of dry matter for the whole grazing season, which is half the mean yield of the last 7 years. Grazing began early this year on account of the very mild winter. The sheep were on the plots by mid-April, but after one or two rounds they had to be taken off because of the dry weather. The grazing season extended into October, when grass was again very plentiful. The yields of the herbage crops in cwt./acre are given in Table 3.

The yield of third-year lucerne in Highfield was abnormally low. The two plots in question had been noticeably affected with lucerne wilt (*Verticillium*) in their second year, 1956, and had been sprayed with TCA (sodium trichloroacetate) in winter 1956–57. Some *Sclerotinia* was also found. The amount of *Verticillium* found in 1957 was probably insufficient to account for the whole damage, but plants weakened by *Verticillium* may have been further repressed by the spraying. Nitrogen responses were high on Highfield cut grass, the double dressing of 2 cwt. "Nitro-Chalk" per cut giving about 17 cwt. dry matter/acre more than the single dressing. Slightly lower but still satisfactory returns were obtained from Fosters. The grazing grass, which received much lighter dressings of "Nitro-Chalk", gave a slight gain of 5 cwt. dry matter on Highfield as measured by pasture cuts, but much less on Fosters.

TABLE 3

Rothamsted ley–arable experiment: Highfield and Fosters
Yield of herbage crops

(Dry matter, cwt./acre)

	Old grass		Reseeded grass		3-year ley	Cut	Cut	1-year
	Hay	Grazing	Hay	Grazing	grazing	grass	lucerne	hay
				Highfield (formerly old grass)				
First-year blocks...	72·2	20·5 *	40·4	19·7 *	30·2	46·5	32·6	24·7
Second-year blocks	—	27·7	—	30·5	38·7	74·4	92·6	—
Third-year blocks	—	29·5	—	30·8	21·3	54·8	63·0	—
				Fosters (formerly old arable)				
First-year blocks...	—	—	19·3	21·7 *	18·2	34·0	24·7	44·3
Second-year blocks	—	—	—	21·2	38·2	56·4	92·6	—
Third-year blocks	—	—	—	26·8	21·1	46·1	98·4	—

* Aftermath grazing.

The test crops, whose yields are used to evaluate the effect of the various leys on soil fertility, were all satisfactory in 1957. Yields were surprisingly similar on both fields, Highfield now 9 years out of grass and Fosters with a long arable history. Proctor barley yielded over 2 tons of grain, Yeoman wheat gave 35 cwt. and Majestic potatoes about 12 tons/acre. The effect of the leys on the three test crops are given in Table 4.

The most remarkable figure in the table of wheat yields for Highfield is the yield after cut grass, which this year was practically as good as any other treatment. In former years cut grass has been noticeably poorer than the rest as a preparation for wheat. In 1956, for example, wheat after cut grass yielded 19 cwt./acre less than wheat after arable crops only. This bad effect of cut grass has never been observed on Fosters. Once more on Highfield the purely arable sequence has given the highest yield; on Fosters, however, the lucerne continues to be the best preparation for wheat. Highfield showed small but definite improvement due to doubling the rate of "Nitro-Chalk" top-dressing; in previous years the extra nitrogen had caused a depression. Fosters, as always, gave a good response to extra top-dressing.

The second-year test-crop potatoes on Highfield showed the usual superiority of the 3-year grazed ley, with the arable rotation 2 tons behind. On Fosters, however, the potatoes after arable cultivation were the best, and on the average of the last 6 years they have been as good as any. The differences in behaviour of the two fields is probably in part due to the supply of readily available potash. In Highfield it is low, as is shown by the big response to dung and to extra muriate of potash on all treatments except the ley. In Fosters it is high; only after lucerne is there evidence

TABLE 4

Rothamsted ley–arable experiment: Highfield and Fosters
Yield of test crops, 1957

	S.E.	After 3 years' cropping with: Lucerne	Grazed ley	Cut grass	Arable crops	Mean	S.E.
First test crop:							
Wheat, grain, cwt./acre—							
Highfield		35·3	30·9	35·9	38·2	35·1	
Effect of 0·3 cwt. N ...	±1·91	+4·8	+1·0	+2·1	+0·8	+2·1	±0·96
Fosters		40·6	33·4	33·2	35·4	35·6	
Effect of 0·3 cwt. N ...	±1·12	+2·6	+3·0	+4·0	+5·0	+3·7	±0·56
Second test crop:							
Potatoes, tons/acre—							
Highfield		13·18	14·24	12·25	11·98	12·91	
Effect of 12 tons dung...	±0·682	+1·47	+0·14	+1·54	+1·69	+1·21	±0·341
Effect of 0·5 cwt. N ...	±0·682	−0·08	+0·08	+0·69	+0·98	+0·42	±0·341
Effect of 0·9 cwt. P_2O_5...	±0·355	0·00	+0·04	+0·06	−0·40	−0·08	±0·178
Effect of 0·9 cwt. K_2O...	±0·355	+1·84	+0·60	+1·78	+1·24	+1·37	±0·178
Fosters		12·39	11·66	11·15	12·67	11·97	
Effect of 12 tons dung...	±0·503	+1·34	+0·62	+0·57	+0·87	+0·85	±0·252
Effect of 0·5 cwt. N ...	±0·503	−0·92	−1·24	−0·27	+0·57	−0·46	±0·252
Effect of 0·9 cwt. P_2O_5...	±0·459	+0·96	+0·10	+0·04	−0·47	+0·16	±0·229
Effect of 0·9 cwt. K_2O...	±0·459	+1·26	+0·48	+0·29	+0·11	+0·54	±0·229
Third test crop:							
Barley, grain, cwt./acre—							
Highfield		45·3	44·4	46·3	45·4	45·3	
Effect of 0·2 cwt. N * ...	±2·18	−0·7	−3·8	−0·3	+0·3	−1·1	±1·09
Fosters		43·7	42·4	42·8	41·2	42·5	
Effect of 0·2 cwt. N ...	±1·05	−0·9	+0·7	−0·1	+2·1	+0·5	±0·52

Note: The fertilizer effects are the increases of the double dose of nutrients above the single dose; i.e., the effect of 0·5 cwt. N to potatoes is 1·0 cwt. N–0·5 cwt. N.

* No single dose of nitrogen in this case.

of a response to extra potash. The economy of potash due to 3 years grazing is of little advantage to potatoes on this field. Doubling the phosphate has been ineffective on both fields.

The third test crop, barley, was so heavy that none of the pre-treatments showed any marked effect.

ANNUAL AND SHORT-PERIOD EXPERIMENTS

These experiments continue for several seasons but occupy a new site each year. For fertilizer tests sites must be chosen that are not too rich in the nutrients in question, and this usually involves some restriction in the manuring of potential sites in the years when they are not under experiment. For the field study of pathology problems it is usually sufficient to provide the experimenters with well-grown crops; consequently part of the farm in high fertility is reserved for this work. A brief note on the type of problems studied in 1957 is given below.

Fertilizer experiments

(1) Winter wheat, Great Knott I. A comparison of eight varieties at 2 and 4 cwt. of sulphate of ammonia/acre.

(2) Spring wheat, Little Hoos. "Nitro-Chalk" at three rates, 2, 4 and 6 cwt./acre, in seedbed, as early top-dressing and as late top-dressing. Both single and divided dressings were tested. Variety: Koga II.

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(3) Spring wheat, Great Knott III. A comparison of seven varieties at 2 or 4 cwt. of sulphate of ammonia/acre.

(4) Spring wheat, Little Hoos. A test of sulphate of ammonia at several rates, combine-drilled or broadcast. All plots had phosphate and potash combine-drilled; some had in addition 0·22, 0·54, 0·68 cwt. N as sulphate of ammonia combine-drilled (as appropriate granular compounds); the controls had the same amount of nitrogen broadcast on the seedbed before drilling.

(5) Barley, Great Field II. Farmyard manure and all combinations of N, P and K were applied to potatoes in 1956. The residues of N and P were evaluated in barley in terms of direct applications of sulphate of ammonia and superphosphate. Variety: Proctor.

(6) Barley, Great Field II. Farmyard manure and all combinations of N, P, K and salt were applied to sugar beet in 1956. The residues of N were evaluated in barley in terms of a direct application of sulphate of ammonia. Variety: Proctor.

(7) Barley, Great Field II. A comparison of five varieties at 0 and $1\frac{1}{2}$ cwt. of sulphate of ammonia/acre.

(8) Barley, Little Hoos. Levels of nitrogen and time of application as in spring wheat (2). Variety: Herta.

(9) Barley, Little Hoos. Combine-drilling of sulphate of ammonia as in spring wheat (4). Variety: Herta.

(10) Oats, Fosters. A comparison of eight varieties at 0·36 and 0·72 cwt. N.

(11) Beans, Great Harpenden II. A comparison of autumn-sown and spring-sown beans, including a test of three levels of phosphate and three levels of potash in all combinations. Spraying against aphids was also tested. Varieties: S.Q. Giant and Spring Tick.

(12) Potatoes, West Barnfield II. Farmyard manure at 0, 5, 10 and 20 tons/acre in all combinations with 0·9 cwt. N as sulphate of ammonia, 0·75 cwt. P_2O_5 as superphosphate and 1·5 cwt. K_2O as muriate of potash. Variety: Majestic.

(13) Sugar beet, West Barnfield II. As potatoes experiment (12), including a test of 5 cwt. agricultural salt/acre. Variety: Kleinwanzleben E.

(14) Lucerne, Great Harpenden II, third year. Three levels of muriate of potash, 1, 2, 3 cwt. K_2O/acre, either in a single dressing in 1955 or in three equal annual dressings in 1955–57. Variety: Du Puits.

(15) Ryegrass, Long Hoos I, second year. Formalized casein, casein, urea, calcium nitrate and ammonium sulphate at 0·75 and 1·5 cwt. N/acre.

Pathology experiments

(16) Winter wheat, Pennells Piece (R. Bardner, Insecticides Department). Test of various insecticides broadcast or combine-drilled against wheat-bulb fly (*Leptohylemyia coarctata* Fall.) on wheat after bare fallow.

(17) Various cereals, Hoosfield, old four-course land (M. D. Glynne, Plant Pathology Department). Effect of various crop sequences on the incidence of foot rots on barley, oats and three varieties of winter wheat.

(18) Cereal–bean rotations, Great Field I, first year (M. D. Glynne, Plant Pathology Department). The first year of a number of different rotations involving cereals and beans in preparation for a test crop of wheat in 1960. Detailed observations on foot-rot diseases are being made.

(19) Spring wheat, Highfield I, second year (G. A. Salt, Plant Pathology Department). Effect of take-all (*Ophiobolus graminis*) and of weeds on yield. The weeds were controlled on certain plots by herbicides or by hand hoeing. The cropping in 1956 was designed to set up differences in the incidence of take-all.

(20) Spring beans, Long Hoos V (M. J. Way, Insecticides Department). Field studies on bean aphis (*Aphis fabae*). Spraying early and late on crops sown at four dates in spring.

(21) Spring beans, Deacons (M. J. Way, Insecticides Department). Field studies on bean aphis. Several insecticides tested at high and low volume.

(22) Potatoes, Highfield IV (J. M. Hirst, Plant Pathology Department). Test of copper fungicide against late blight (*Phytophthora infestans*).

(23) Potatoes, Long Hoos VII and III (D. H. Lapwood, Plant Pathology Department). Field studies of resistance to late blight in four varieties. On Long Hoos III the plots were isolated from each other by kale.

(24) Potatoes, Highfield V (L. Broadbent, Plant Pathology Department). Effect of spraying against aphids with DDT on the spread of virus in the crop. Infector plants carrying leaf roll and virus Y were planted in each plot. Spraying was carried out on one, two, three or four occasions.

(25) Potatoes, Highfield IV (G. A. Salt, Plant Pathology Department). Test of dung and of two fungicides applied by two methods against skin-spot (*Oospora pustulans*).

Experiments on soil structure (J. Currie, Physics Department)

(26) Ploughed-up leys, Fosters Field, ninth year. Effects of various grass species on soil structure measured by carrots and red beet as second test crops; and by barley as third test crop. One block has been returned to perennial ryegrass, lucerne and bare fallow to start a fresh cycle.

(27) Long Hoos I, second year. Plots in preparatory period under perennial ryegrass, cocksfoot and bare fallow.

Experiment on wild oats (J. M. Thurston, Botany Department)

(28) Survival of wild oats under leys, Great Knott I, third year. Arable land infested with *Avena fatua* was put down to long ley in spring 1955. Plots have been ploughed up each year and counts of wild oat plants made.

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Fertilizer experiments at Woburn

(29) Barley, Butt Close. Residues of dung and fertilizers applied to potatoes, as number (5).
(30) Barley, Butt Close. Residues of dung and fertilizers applied to sugar beet, as number (6).
(31) Barley, Lansome Field. Combine drilling nitrogenous fertilizer at various rates, as number (4).
(32) Beans, autumn and spring, Warren Field N. Test of PK and spraying, as number (11).
(33) Potatoes, Road Piece. Effect of dung, N, P, K, as number (12).
(34) Sugar beet, Road Piece. Effect of dung, N, P, K and salt, as number (13).

Pathology experiment at Woburn (G. A. Salt, Plant Pathology Department)

(35) Potatoes, Great Hill. Experiment on skin-spot with fungicides, as number (25).

Deep Cultivation Experiment, 1944–56

The results of experiments testing deep cultivation have already been summarized and discussed by E. W. Russell: namely a rotation experiment carried out at Rothamsted during the years 1934–39 * and later an extensive series of experiments on commercial farms in 1945–51.†

A long-period rotation experiment testing deep and shallow ploughing has now been concluded at Rothamsted after two complete rotations; the present note summarizes some of the main agricultural results. A more detailed examination of the yield data and chemical results will be made later.

The object of the experiment was to test whether ploughing to a much greater depth than usual led to increased yields. It was carried out on the crops of a six-course rotation: sugar beet (Kleinwanzleben), barley (Plumage Archer), 1-year hay, wheat (Yeoman), potatoes (Majestic), oats (Star), each crop being grown in turn on six blocks of land so that yields were obtained from every crop each year. The deep ploughing was repeated on the same plots each time the appropriate crops came round. Other manurial and cultivation factors, also cumulative, were included in the experiment to give the following factorial arrangement:

On main plots

Ploughed 6 inches deep *v.* ploughed 12 inches deep (for sugar beet, potatoes and wheat).

No dung *v.* dung (20 tons/acre for potatoes, 10 tons/acre for sugar beet).

No phosphate *v.* superphosphate (0·8 cwt. P_2O_5 for potatoes, 0·6 cwt. P_2O_5 for sugar beet).

* Russell, E. W. & Keen, B. A. (1941). Studies in soil cultivation. *J. agric. Sci.* **31**, 326–347.

† Russell, E. W. (1956). The effects of very deep ploughing and of subsoiling on crop yields. *J. agric. Sci.* **48**, 129–144.

N

No potash *v.* muriate of potash (1·0 cwt. K_2O for potatoes, 0·6 cwt. K_2O for sugar beet).

On sub-plots

Phosphate and potash, separately or together, ploughed in or in the surface soil.

For potatoes the phosphate and potash were ploughed in either 6 or 12 inches, or spread down the ridges before planting; for sugar beet the manures were ploughed in, either deep or shallow, or harrowed into the seedbed before drilling. This placement effect was measured only in the root crops.

Basal dressings of sulphate of ammonia were given to the crops as follows: sugar beet 0·8 cwt. N, potatoes 0·6 cwt. N, wheat 0·5 cwt. N, barley 0·3 cwt. N, oats 0·2 cwt. N. In addition the barley received 0·6 cwt. P_2O_5 as basic slag.

The top soil was heavy loam with flints resting on a reddish yellow clay subsoil at a depth of 12–18 inches. In places still heavier subsoil came to within 12 inches of the surface. Drainage and root penetration were good.

The deep cultivation was carried out by a single-furrow digger plough with tracklaying tractor. The previous depth of ploughing had been about 7 inches for many years; hence the deep ploughing brought up 5 or 6 inches of raw subsoil. The deep-ploughed plots were consequently much lighter in colour than the others, and sometimes needed extra surface cultivations to make a satisfactory seedbed. Although some plots were ploughed to full depth on six occasions during the course of the experiment, their characteristic appearance persisted till the end.

In spite of the unpromising appearance of the seedbeds, yields did not suffer on the plots newly ploughed to 12 inches deep, even in the first year. Thus two sugar-beet crops on fresh subsoil yielded 47·2 cwt. sugar and gave an extra 2·3 cwt. sugar for the deep ploughing. Over the whole 12-year period ploughing to ordinary depth gave 43·8 cwt. sugar, which was improved by 2·9 cwt. by deep tillage. Three potato crops grown after the first deep ploughing gave results much above the average. Wheat gave a comparison in one season only, but the yield on the new 12-inch ploughing was over 30 cwt., and the increase for deep ploughing was above average.

The yields over the 12-year period were satisfactory. Sugar beet averaged 45 cwt. sugar/acre; potatoes, though they gave light crops in two very dry summers, averaged 8·9 tons; the seeds hay at 60 cwt./acre in a single cut was very productive, while the cereals, all lying between 32 and 34 cwt./acre, could be regarded as satisfactory, since the modern higher-yielding sorts were not available when the experiment started.

The main effects of deep ploughing, dung, superphosphate and muriate of potash, and their interactions in pairs, are given for sugar beet and potatoes in Table 5; all treatments had been tested on each block on two occasions.

The main effects, which for any one factor are averaged over all combinations of the remaining three, show that deep ploughing improved the yield of sugar beet by 2·9 cwt. of sugar/acre (about

0·9 tons of washed roots). The actual value of the increase varied widely from year to year, the extremes being +12 cwt. in 1947 and −4 cwt. in 1948; in 9 years out of 12 the effect of deep ploughing was beneficial. Seedbeds tended to be much cleaner after the deep than after the shallow ploughing, and some of the benefit from deep ploughing may be attributed to this cause. This was particularly noticeable in 1947, when the beet on a clean seedbed after deep ploughing enjoyed a considerable advantage in seedling growth and

TABLE 5

Direct effects and interactions, 1944–55

Response to	Mean	Ploughing Shallow	Ploughing Deep	Dung Absent	Dung Present	Phosphate Absent	Phosphate Present	Potash Absent	Potash Present
		Sugar beet, total sugar cwt./acre: mean yield 45·2							
Ploughing, deep–shallow ...	2·9	—	—	3·7	2·1	2·5	3·3	3·3	2·5
Dung	6·8	7·6	6·0	—	—	7·8	5·8	8·3	5·3
Phosphate ...	1·1	0·7	1·5	2·1	0·1	—	—	1·2	1·1
Potash	2·2	2·6	1·8	3·7	0·7	2·2	2·1	—	—
		Potatoes, ware tubers tons/acre: mean yield 8·88							
Ploughing, deep–shallow ...	0·00	—	—	0·14	−0·13	0·23	−0·22	−0·11	0·12
Dung	2·66	2·80	2·52	—	—	2·55	2·76	3·60	1·72
Phosphate ...	0·62	0·85	0·40	0·52	0·73	—	—	0·46	0·79
Potash	1·53	1·41	1·64	2·47	0·59	1·37	1·69	—	—

duration of singling. The difference in weediness persisted right to the end of the inter-row cultivations. At lifting time the roots on the deeply ploughed plots were found to have very long tap roots that penetrated more deeply than the others. Dung at 10 tons/acre gave the very considerable increase of 6·8 cwt. sugar/acre or about 2 tons of roots. The results for phosphate and potash are the means of the two methods of application, and under the conditions of this experiment potash was more needed than phosphate. The mean increase of 2·2 cwt. of sugar for 1 cwt. of muriate of potash is quite considerable, and there was only one very small negative in the 12-year period. Superphosphate gave about half the effect of potash and had two small negatives. For sugar beet there are also yields for tops and plant number. Deep ploughing increased the yield of tops by 1·0 tons, dung by 1·8 tons on the average. Superphosphate had no effect, but potash increased the tops by 0·5 tons/acre. The effect of deep ploughing on plant number was to increase the population by 730 plants/acre—this in spite of the fact that in the early years at any rate the seed was sown in practically pure subsoil. Thus in the years 1944 and 1945 the land for sugar beet was ploughed deep for the first time, yet the increase in plants at harvest was 700/acre. Dung had practically no effect on the number of plants at lifting time, while the effect of fertilizers was also negligible.

Potatoes responded quite differently to deep ploughing. On the average of the twelve seasons the effect was zero; positive and negative responses, which were never more than 1½ tons, cancelled each other out. Dung at 20 tons/acre gave a large average increase of 2·66 tons/acre. In no season was the increase less than 1 ton, in 2 years it was almost 5 tons. The effect of potash was, as usual, shown strongly in potatoes, the average increase being 1·53 tons/acre. As with sugar beet, the overall effect of phosphate was rather small, but for potatoes it was always positive, amounting in three seasons to as much as 1·5 tons/acre.

Of the two factor interactions given in Table 5, the largest are those showing the effect of dung on the responses of sugar beet to phosphate and potash; each gave good increases in sugar per acre on the plots without dung, but when 10 tons of dung was given the responses to phosphate and potash were negligible. The only other interaction of any magnitude concerned dung and ploughing depth: dung gave 1·6 cwt. of sugar/acre less if it was ploughed in deep than if it was ploughed in shallow; this effect was also shown on potatoes, but in a much smaller degree. So far as the actual effect of dung is concerned, there was no advantage to be gained from ploughing it in deeply for either crop.

On potatoes there was the usual strong negative interaction of dung and potash, for 20 tons of dung supplied almost the whole of the potash requirement of the potato crop. There was also some indication that the action of phosphate on the potato crop was greater at the 6-inch ploughing depth than at the 12-inch depth.

In Table 6 the residual effect of the treatments applied to sugar beet and potatoes are given for the three cereals and the hay crop. In the case of wheat only the deep ploughing is tested as a direct treatment.

TABLE 6

Residual effects

Mean yields, cwt./acre, and increases for deep ploughing, dung, P and K

Barley and oats, 1945–56, *hay* 1946–57

	Barley	Oats	Hay	Wheat
Mean yield	32·1	32·2	59·8	33·4
Residuals	1st year	1st year	2nd year	3rd year
Deep ploughing...	+0·2	−1·2	−0·2	+0·5 *
Dung	+1·8	+1·2	+4·0	+1·4 †
Phosphate	+0·6	+0·9	+0·9	+0·2 †
Potash	+0·6	+0·1	+1·9	+0·5 †

* Direct effect of deep ploughing 1946 and 1948–57.
† 1947–57.

On those plots that were deep ploughed for sugar beet the gain in the following barley crop and subsequently in the hay was negligible. If anything, the effect of deep ploughing for potatoes was slightly to depress the following oat crop.

Wheat measured the direct effect of deep ploughing, which was never large. The gains and losses almost cancelled out over the 11-year period. The biggest gain was +3·6 cwt. of grain/acre in 1956, while in 1948 and 1957, when the plant was clearly thinner on the deep-ploughed plots, there were losses of about the same size.

Farmyard manure gave appreciable residual effects in all crops, including wheat, which was the fourth crop after the dung had been given. The hay yields were considerably improved by dung applied to sugar beet 2 years before. The potash given to sugar beet had a smaller, but nevertheless appreciable, effect on the ley. The two factor interactions in the residual years were on the average quite small, the only consistent effect being the negative interaction be-

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tween dung and muriate of potash measured in the hay crop, for the residual effect of dung was 1·9 cwt. of hay less when residual potash was also present.

The effect of ploughing in the phosphate and potash, instead of broadcasting on the surface for sugar beet or down the ridges for potatoes, was tested on half plots in conjunction with all the main plot treatments.

Table 7 summarizes the results averaging the two depths of ploughing. The table separates the effects of phosphate and potash in the presence and absence of dung.

TABLE 7

Effect of location of phosphate and/or potash, 1944–55
Ploughed in v. *in seedbed* (*beet*) *or in ridges* (*potatoes*)

(Mean of 6- and 12-inch ploughing depths)

	Sugar, cwt./acre		Potatoes, tons/acre	
	No dung	Dung	No dung	Dung
No phosphate, no potash... ...	39·2	47·9	6·21	9·61
Increase for:				
Phosphate and potash ploughed in	+6·3	+1·8	+2·23	+0·85
Phosphate and potash in seed-bed or ridges	+5·4	−0·3	+3·70	+1·73
No potash—				
Phosphate ploughed in ...	+2·4	+1·5	+0·12	+0·72
Phosphate in seedbed or ridges	+0·7	0·0	+0·36	+0·54
No phosphate—				
Potash ploughed in	+3·6	+1·4	+1·91	+0·26
Potash in seedbed or ridges...	+2·5	+1·3	+2·45	+0·74

Phosphate and potash applied together for sugar beet gave a substantial response in sugar per acre in the absence of dung, and the result was better by 0·9 cwt. sugar if the fertilizers were ploughed in. This was also true when these fertilizers were used separately; phosphate in particular was ineffective when broadcast on the seed-bed, but gave a good return when ploughed in.

Dung greatly reduced the phosphate and potash responses, but there was still an advantage in ploughing these fertilizers in. Indeed, on dunged land phosphate alone gave no result when applied in the seedbed.

The results with potatoes were quite different; in the absence of dung there was a big response to potash, either alone or with phosphate, and this response was much bigger when the fertilizer was in the ridges. Phosphate used in the absence of potash was practically ineffective, but even here the advantage lay with ridge application. Dung reduced the potash response, but the ridge application was still superior. In contrast to this, dung increased the phosphate effect, possibly because the experiment showed that potatoes responded better to phosphate when potash was also supplied.

The experiment gives some information on the effect of the depth of ploughing on the two methods of incorporating the fertilizer. In this case the results in Table 8 are obtained as an average of the dunged and undunged plots.

When phosphate was ploughed in for the sugar-beet crop either alone or, as would almost always happen in practice, with potash also the advantage of ploughing in over broadcasting, previously shown in Table 7, was somewhat increased if the ploughing was done deeply. This effect was not found when potash was used alone.

Potatoes again behaved differently; when potash was used alone or in conjunction with phosphate the advantage of ridge application

TABLE 8

Placement effects in relation to depth of ploughing

(Mean of dung and no-dung)

Depth of ploughing	Sugar, cwt./acre 6 inches	Sugar, cwt./acre 12 inches	Potatoes, tons/acre 6 inches	Potatoes, tons/acre 12 inches
No phosphate, no potash... ...	42·1	45·0	7·73	8·08
Increase for:				
Phosphate and potash ploughed in	+3·7	+4·4	+1·82	+1·27
Phosphate and potash in seed-bed or ridges	+2·8	+2·2	+2·67	+2·78
No potash—				
Phosphate ploughed in ...	+1·2	+2·6	+0·84	+0·01
Phosphate in seedbed or ridges	+0·2	+0·5	+0·96	−0·05
No phosphate—				
Potash ploughed in	+3·5	+1·5	+1·27	+0·91
Potash in seedbed or ridges...	+1·8	+2·1	+1·66	+1·54

over ploughing-in the fertilizer, shown in Table 7, was greater when the ploughing was deep than when it was shallow. Phosphate used without potash gave no increase at all when the ploughing was deep.

The following are some of the main conclusions on the average effects of 12-inch ploughing in this experiment:

1. Deep ploughing increased the yield of sugar beet by about 6 per cent, but not of potatoes or wheat.
2. The effect of deep ploughing was very variable from season to season, large increases and equally large depressions being occasionally recorded. The cause of these variations has not yet been found.
3. The residual effect of deep ploughing measured in cereals and hay after one, two or three seasons was negligible.
4. Raw subsoil could generally be reduced to a seedbed for sugar beet, and no loss of plant number or yield occurred. These seedbeds were often cleaner than those on shallow ploughed land.
5. Dung ploughed in deep for sugar beet had slightly less effect than if ploughed in shallow.
6. When PK was used for sugar beet it was more useful when ploughed in than in the seedbed. Deep ploughing was slightly more effective than shallow in this respect.

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7. When PK was given to potatoes it was more efficient placed in the ridges than ploughed in. Deep ploughing slightly increased the relative advantage of ridge application.

Staff

G. V. Dyke was seconded for a year to Hunting Technical Services Ltd. for field experimental work in Iraq in connection with an irrigation scheme. G. F. Jarvis transferred from the Farm to the Field Experiments Section.