Rothamsted Experimental Station Report for 1969 Part 2

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III. The Experiments Made from 1957 and 1962, the Soils and Histories of the Sites on Which They Were Made

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The Value of Residues from Long-period Manuring at Rothamsted and Woburn
III. The Experiments Made from 1957 to 1962, the Soils and Histories of the Sites on which they were Made

A. E. JOHNSTON and R. G. WARREN

The aim of the new experiments

The value of residues can be measured in two ways:

1. By comparing yields from soil enriched with residues with those from starved soil.
2. By comparing the responses to a series of new fertiliser dressings on plots of both starved and enriched soil.

Only the first of these ways was used to demonstrate the combined effect of the PK residues on the Exhaustion Land after basal N was given in 1941, and then only for barley (Warren, 1956). We wished to extend these results by obtaining information on:

1. Other crops.
2. The separate effects of the P and K residues.
3. The value of the residues in terms of new fertiliser dressings.

Therefore experiments were made with more than one crop grown each year, and with basal N and K where P was tested and basal N and P where K was tested. Each experiment tested a series of increasing amounts of new P and K. The valuation of residues in terms of newly applied fertiliser depends on how this fresh fertiliser is applied and on the growing conditions in the year of the experiment, so we decided: (1) to do each experiment for two years and average the results from the two seasons; (2) to apply all new fertiliser to the seedbed, except for potatoes (for details see later). This is acceptable current farming practice, though, from the results of many experiments, Cooke (1956, 1957) showed that placing fertiliser near the seed was a more efficient way of using new fertiliser, which could be particularly true on impoverished soils. In the later years, tests were made of methods of applying fertilisers.

The work was done on three sites, two at Rothamsted (a part of the Exhaustion Land experiment site in 1957–58, and on the Agdell Rotation experiment site in 1959–62), and one at Woburn (part of the Permanent Wheat and Barley Sites) in 1960–62.

History of the experimental sites

The preceding cropping and the amounts of fertiliser applied to the sites of the experiments are known. All the crops were not analysed, so the amounts of each nutrient removed, and the amounts that should have remained as a

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residue, are unknown. However, a subsequent section gives the amounts of readily soluble P and K in the soils of each plot.

The Exhaustion Land Experiment. This site, as the name implies, has been used for much work on NPK residues in soil. Its history was described by Warren & Johnston (1960). Lawes and Gilbert started the first experiment in 1852 to test effects of cultivation treatments on winter wheat; it ended in 1855. From 1856 to 1874 there was a manurial experiment with winter wheat testing 4 treatments on 4 plots: unmanured; N only (as ammonium salts); PKNaMg only (P as superphosphate, K, Na, Mg each as the sulphate); and NPKNaMg. The last wheat crop was taken in 1874, the site was fallowed in 1875, and in 1876 a manurial experiment started in which potatoes were grown each year. The plots for potatoes were superimposed on those of the wheat experiment; the PKNaMg treatments were continued, and a new treatment with FYM and a comparison of sodium nitrate and ammonium salts were introduced. Hall stopped the potato experiment in 1901. From 1902 to 1940 the site was cropped mainly with cereals, usually barley, without manures and usually without recording yields. Beginning in 1941 each cereal crop received a uniform dressing of 56 lb N/acre and from 1949 onwards yields on each plot were taken to measure the combined effects of the PK residues in the presence of new N each year for one crop, barley.

Between 1856 and 1901, annual fertiliser dressings (amounts per acre) when applied were:

N	1856–1901	86 lb N as ammonium salts or sodium nitrate
P	1856–1901	30 lb P as superphosphate, except 1897–1901 when basic slag was used
K	1856–58	120 lb K } as potassium sulphate
	1859–74	80 lb K }
	1876–1901	120 lb K }
Na	1856–58	28 lb Na } as sodium sulphate
	1859–1901	14 lb Na }
Mg	1856–1901	10 lb Mg as magnesium sulphate
FYM	1876–1901	14 tons

Table 1 shows the total P and K applied during this period, yields are discussed in Paper II.

TABLE 1

Total amounts of P and K applied on the Exhaustion Land, 1856–1901

lb element/acre

	Plot									
	1	2	3	4	5	6	7	8	9	10
P as superphosphate	0	0	210	210	0	0	1260	1260	1260	1260
P in FYM	0	210	910	910	0	0	0	0	0	0
K as potassium sulphate	0	0	0	0	0	0	4520	4520	1400	4520
K in FYM	0	800	3500	3500	0	0	0	0	0	0

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The Agdell Rotation Experiment. Warren (1958) described this experiment, started by Lawes and Gilbert in 1848, which compared two 4-course cropping systems: (1) Roots, barley, undersown with clover (replaced by spring beans when the clover failed), and winter wheat; (2) Roots, barley, fallow and winter wheat. Only one, but the same, phase of each rotation was present each year. The manurial treatments were: unmanured; P (changed to PKNaMg in 1884), and NPKNaMg (N as mixture of ammonium salts and rape cake, the rape cake also provided some P and K). The manures were applied only once every four years to the swedes or turnips. In addition to the manurial treatments tested on the two rotations, Lawes and Gilbert included a test of management when roots were grown. On half plots the roots were either all carted off or were fed on by sheep; when the weather was unsuitable for feeding, the roots and tops were sliced and spread over the land and ploughed in. This treatment, which returned the nutrients taken up by the root crop on one half of each plot, was stopped in 1900, after when all produce was removed from the whole plot. The experiment continued for 26 courses until 1951, when soil acidity on the NPK plots was harming the crops, especially the swedes, which were first ruined by clubroot on these plots but soon also on the others. The acid areas were heavily chalked in spring 1954 and given a light dressing in 1959. From 1952 to 1957 the site was uniformly cropped as follows: 1952, bare fallow; 1953 barley without N; 1954 barley with N; 1955 spring wheat with N; 1956 beans; 1957 potatoes with N. Thus the crops from 1954 to 1957 measured the combined effects of the residues of P and K. Cereal yields were small but potatoes and beans yielded well. Yields are given in Paper II (page 14).

Between 1848 and 1951 fertiliser dressings were at the following rates/acre in the year in which they were applied:

N	1848–1951	43 lb N as ammonium salts plus 100 lb total N in rape cake
P	1848–51	15 lb P as superphosphate
	1852–55	21 lb P as superphosphate
	1856–95	30 lb P as superphosphate
	1896–1903	47 lb P as basic slag
	1904–51	38 lb P as superphosphate
K	1848–51	45 lb K as pearl ash
	1852–95	120 lb K as potassium sulphate
	1896–1951	200 lb K as potassium sulphate
Na	1852–55	14 lb Na as sodium sulphate
	1856–95	28 lb Na as sodium sulphate
	1896–1951	14 lb Na as sodium sulphate
Mg	1852–95	10 lb Mg as magnesium sulphate
	1896–1951	20 lb Mg as magnesium sulphate

Table 2 shows the total P and K applied between 1848 and 1951.

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TABLE 2

Total amounts of P and K applied on Agdell Field, 1848–1951

lb element/acre

	P			K		
Plots	Super-phosphate	Rape cake	Total	Potassium sulphate	Rape cake	Total
1 and 2	890	490	1380	4160	490	4650
3 and 4	890	0	890	3280	0	3280
5 and 6	0	0	0	0	0	0

Woburn Permanent Wheat and Barley Experiments. The Classical Experiments at Woburn on the continuous growing of cereals started with sowing winter wheat in autumn 1876 and barley in spring 1877. The plots were laid out as at Rothamsted for the barley experiment on Hoosfield, strip treatments with and without PKNaMg, crossed at right angles by strips with and without N. Separate plots also tested FYM. Initially the amounts of nutrients tested each year were the same as those used on cereals at Rothamsted, 43 and 86 lb N as ammonium salts or sodium nitrate, 30 lb P as superphosphate and 80 lb K, 14 lb Na, 10 lb Mg, all three as sulphates. FYM was tested at two amounts which varied between 4 to 6 and 8 to 12 tons/acre. Plots receiving the larger amount of N were fertilised only in alternate years from 1883, to measure the effects of N residues. Major manurial changes were made for crops harvested in 1907, both amounts of N were halved, superphosphate was given at 3 cwt/acre (25 lb P), potassium at only 0·5 cwt potassium sulphate/acre (22 lb K), sodium and magnesium were omitted and the larger amount of FYM was tested on one half plot. The remaining FYM plots tested NP, NK and rape cake. At the start of the experiment the soil was slightly acid and the ammonium sulphate increased the acidity considerably, so some tests of liming were made. Because of decreasing yields and increasing weediness of the plots, the experiment was stopped in 1926 and no more FYM and P and K were applied, except as described below. From 1927 to 1940 the plots continued to grow winter wheat or spring barley, testing, in 2 cycles each of 7 years, the effect of two years fallow on the succeeding 5 unmanured cereal crops. In 1931–32 some plots on the Barley Site were manured, plots 8 and 9 received a total of 82 lb N, 50 lb P, 132 lb K; 10a received 61 lb N, 50 lb P; 11a received 61 lb N, 132 lb K. From 1941 to 1957 three amounts of N fertilisers were tested but the plots had to be fallowed in 5 of these years. Between 1955 and 1957 individual plots received various amounts of ground chalk to bring the soils on all plots to pH 6. Having brought the surface soils to somewhere near their original soil reaction, an experiment began in 1959, with winter wheat and spring barley grown side by side on every plot, to compare the yields of each crop when grown on the Wheat and the Barley Sites. The experiment continued in 1960 and in 1961 spring wheat was grown. N was given to both wheat and barley so the value of the PK residues could be measured, the yields are discussed in Paper II (page 13).

Table 3 shows the total P and K applied between 1876 and 1959 on the plots used for the microplot experiment.

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TABLE 3

Total amounts of P and K applied on the Woburn Permanent Wheat and Barley Experiments, 1876–1959

lb element/acre

	Plots				
	7	8	9	11a	11b
Wheat Site					
P as superphosphate	0	1400	1400	0	0
P in FYM	0	0	0	750	1090
K as potassium sulphate	0	2840	2840	880	0
K in FYM	0	0	0	3000	4400
Barley Site					
P as superphosphate	0	1450	1450	0	0
P in FYM	0	0	0	750	1090
K as potassium sulphate	0	2970	2970	1010	0
K in FYM	0	0	0	3000	4400

The soils

The soils at Rothamsted are mainly derived from 'Clay-with-flints', which overlies chalk at various depths, and they have been classified by the Soil Survey of England and Wales. The Exhaustion Land site on Hoosfield is on the Batcombe series (undifferentiated), on a level plateau where the 'Clay-with-flints' is thick and the soil has a flinty loam or silt loam surface. Agdell field is on the shallow or eroded phase of the Batcombe series and has a shallow flinty clay loam surface. It is one of the most difficult fields to work on Rothamsted Farm. As the other old arable fields including Hoosfield, it was given large, but unevenly distributed dressings of chalk in the early part of the last century when the practice was to dig out the underlying chalk and spread it on the arable land (Young, 1813; Russell, 1916). Part of the east side of Agdell runs into one of the resulting dell holes.

The soil in Stackyard Field at Woburn is a sandy loam of the Cottenham series developed in drift over Lower Greensand. It was slightly acid and never received the heavy dressings of chalk that were a feature of earlier treatment of Rothamsted arable fields.

H. von Liebig, the son of Baron Liebig with whom Lawes and Gilbert argued so bitterly about the source of N for plants, was the first person to analyse Rothamsted soil for P and K. He extracted P soluble in dilute nitric acid, and K soluble in dilute acetic acid, from the soil from five plots on Broadbalk, and found that, after twenty-five years, there was more soluble P and K in the manured than in the unmanured soil (von Liebig, 1872). Dyer examined the soils from the Hoosfield Continuous Barley experiment (Dyer, 1894) and those from Broadbalk (Dyer, 1901, 1902). Using 1% citric acid and constant boiling HCl, he confirmed that manured soils had more soluble P and K than the unmanured soils. Subsequently many attempts made to estimate 'available' P and K in agricultural soils used soils from the Classical Experiments for reference. Because manuring of these Rothamsted soils has continued for so long, there are large differences in soluble P and K between those with and without residues and almost any

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method of analysis will distinguish between them. The usefulness and limitations of some of the methods for P when used for Rothamsted and Woburn soils were discussed by Warren and Johnston (1965). The methods

TABLE 4

Analyses of soil from plots used for microplot experiments at Rothamsted and Woburn, 1957–62

Site and plot	Total P %	Total K %	P soluble in 0·5 *M*-$NaHCO_3$ ppm	P soluble in 0·01 *M*-$CaCl_2$ g mol/l × 10^{-6}	K soluble in 1 *N*-ammonium acetate ppm
Rothamsted					
Exhaustion Land					
1	0·044	1·31	3	0·30	83
3	0·064	1·40	15	1·24	112
5	0·046	1·39	4	0·24	76
7	0·064	1·41	12	0·66	111
9	0·065	1·37	14	0·98	83
Agdell					
1	0·074	1·21	15	0·24	160
2	0·075	1·16	12	0·17	180
3	0·071	1·15	16	0·37	184
4	0·065	1·14	8	0·25	141
5	0·054	1·04	4	0·09	104
6	0·053	1·04	4	0·11	102
Woburn					
7 Wheat Site	0·079	0·69	22	0·65	57
7 Barley Site	0·058	0·82	14	0·32	65
8 Wheat Site	0·096	0·68	56	2·34	67
8 Barley Site	0·080	0·80	37	1·51	93
9 Wheat Site	0·086	0·70	42	2·07	83
9 Barley Site	0·079	0·85	36	1·67	93
11a Wheat Site	0·070	0·73	19	0·74	77
11a Barley Site	0·068	0·81	28	0·89	102
11b Wheat Site	0·075	0·70	25	0·74	96
11b Barley Site	0·076	0·83	22	0·89	101

All total P and K analyses were done on 0–6 in. samples: readily soluble P and K analyses on the Exhaustion Land Soils were on 0–6 in. samples: for Agdell and Woburn soils the samples were 0–9 in. depth. Total P by perchloric acid digestion; total K by hydrofluoric acid digestion.

at present considered most suitable for soluble P and K were used to characterise the soils where these experiments were made, and Table 4 shows the results, together with those for total P and K for samples taken between 1950 and 1955.

The form of the experiments

Design. The design of the experiments, plot sizes and numbers had to be varied to fit the existing plot layout, allowing suitable headlands between the various crops for the necessary cultivations. This imposed considerable restrictions and all the experiments were made using microplots, which

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meant that after the initial seedbed preparation many operations, including harvesting of all crops, were done by hand. From year to year and site to site, some changes were made but all plots of each crop received basal N at optimum rate for the crop, all plots testing P received basal K, and all plots testing K received basal P. These basal dressings were at least the largest amount tested for each crop in any year. P was tested at a unit amount of 12·5 lb P/acre, i.e. P1, P2, P4 were 12·5, 25, 50 lb P/acre. K was tested at a unit amount of 14 lb K/acre, i.e. K2, K4, K8 were 28, 56, 112 lb K/acre.

The Exhaustion Land 1957–58. Plan 1 (p. 32) shows the Exhaustion Land site and the plots (1, 3, 5, 7 and 9) used for the microplot experiment. The east half of the site was divided into 12 blocks each extending across the five plots. Only alternate blocks were cropped in 1957, those that were fallowed were cropped in 1958, so there was no cumulative effect in 1958 of fertiliser applied in 1957. Each year the six cropped blocks carried one of the six crops, barley, spring wheat, potatoes, swedes, kale or sugar beet. The old plots were paired so that No. 1 (unmanured), and No. 7 (NPK), tested new K with and without K residues, and No. 5 (N), and No. 9 (P), tested new P with and without P residues. Each block contained 20 microplots (each 0·0032 acre), four per plot to test four amounts of P or K applied as new fertiliser. In 1957 each microplot was made almost square because each group of four was arranged so that two were on the north and two on the south side of each large plot. The new treatments were assigned at random. There was a constant difference in yield between pairs of plots on the north and south sides of each old plot, probably related to a soil difference. In 1958 the four microplots of each group were arranged so that each one spanned the full width of the old plot, which had the added advantage that all microplots had the same number and positions of tractor wheelings. Individual tests with each crop were not replicated in either year. Table 5 shows the basal and test fertilisers, and diagram 1 (p. 33) the arrangement of the microplots in 1957 and 1958 on the eastern 6 cropping blocks.

TABLE 5

Basal and test fertilisers, Exhaustion Land, 1957–58

lb element/acre

Crop	N basal	P test			K test		
Barley	56	12·5	25	50	14	28	56
Spring wheat	67	12·5	25	50	14	28	56
Swedes (1957)	67	12·5	25	50	14	28	56
(1958)	45						
Potatoes	112	12·5	25	50	28	56	112
Kale	201[1]	12·5	25	50	28	56	112
Sugar beet	112	12·5	25	50	28	56	112

For all crops basal P for K test was 50 lb P.
For barley, spring wheat, swedes, basal K for P test was 56 lb K.
For potatoes, kale, sugar beet, basal K for P test was 112 lb K.
N as ammonium sulphate;[1] P as powdered superphosphate; K as potassium sulphate.
[1] Applied as 67 lb N to seedbed and then 2 top dressings each of 67 lb N as 'Nitro-Chalk'.

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For all crops except potatoes, the fertilisers were broadcast by hand and harrowed in just before drilling the seed. The potato land was set up in ridges 27 in. apart and the fertilisers applied along the bottoms of the furrows and half way up the sides of the ridges, before the potatoes were hand-planted 15 in. apart and the ridges split back to cover the sets. Varieties used were: barley, Plumage Archer; spring wheat, Koga II; swedes, Wilhelmsburger; potato, Majestic; kale, Thousand Headed; sugar beet, Klein E.

Agdell 1959–62. Plan 2 (p. 34) shows the Agdell site and the division, made in 1958, of the six plots in the rotation experiment into grass and arable halves. The grass was sown in 1958, and the arable was fallowed before the microplot experiment was made during 1959–62. Because of the size of the site and to allow some replication, we decided to test only the value of the P residues for three crops on Agdell. In each year the amounts of new P were the same for all three test crops, barley, potatoes, sugar beet. Because the experiment was to be continued for several years and all crops were to be grown each year, the microplots had to be used more than once. Plan 2 also shows how each arable half plot was divided into three blocks, one for each crop, giving 18 blocks on the site. The blocks were separated by paths to prevent lateral movement of soil during ploughing and cultivating. The sequence of crops was barley, potatoes, sugar beet. In 1959, each block was divided into four sub-blocks each of three microplots, so that there were 4 replicates of each of the three treatments P0, P1, P4. Each microplot was 0·0034 acre. The response curves derived from the 1959 yields suggested that maximum yield had not been reached and 75 lb P/acre (P6) was tested in 1960. This was done by halving each microplot, that with treatment P0 in 1959 tested P0 and P1 in 1960, P1 in 1959 tested P4 and P6 (the residual effect of P1 was assumed to be very small), and P4 in 1959 tested the residues of this dressing, P4r, and the residue plus the largest amount of new P, P4r + P6. An unexpected feature of the 1960 results was how well the P4r treatment yielded. This treatment had P4 broadcast on the seedbed in spring 1959, it was ploughed-in in autumn 1959 and cropped without new P in 1960. This suggested that ploughing new fertiliser into this difficult soil could be more efficient than broadcasting it on the seedbed. We decided to test methods of incorporating new fertiliser in 1961–62, but the experiment had to be made on the blocks used in 1959–60. Those blocks on the old rotation plots 1, 3, 5 were used in 1961 and those on the old plots 2, 4, 6, were used in 1962 after being fallowed in 1961. Each block was divided lengthways and the new microplots were made this width; the length was that of the sub-block used in 1959–60, so that there were now eight microplots (each 0·0050 acre) per block each with the same amount of residues from the 1959–60 test treatments. On these eight microplots tests were made of: (a) no new P (in duplicate), (b) 37·5 and 75 lb P ploughed in, (c) 37·5 and 75 lb P to the seedbed and (d) 75 and 150 lb P half of each dressing being ploughed in and the other half broadcast on the seedbed. Diagram 2 (p. 35) shows the sequential arrangement of the microplots on one block.

The 1959–60 results showed that, on this impoverished soil, the amounts

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of the basal fertiliser dressings, which were considered optimum in general practice, may be too little because the soil is so poor and the fertiliser could not be incorporated throughout the ploughed layer. Basal K dressings were therefore increased during the course of the experiment and we tried to incorporate them thoroughly into the soil by dividing the dressings, ploughing some in, applying some over the rough ploughed land and some to the seedbed. Table 6 shows the basal and test fertilisers.

TABLE 6

Basal and test fertilisers, Agdell, 1959–62

lb element/acre

Crop		N basal	K basal	P test		
Barley	1959	56	56	12·5	50	—
	1960	67	56	12·5	50	75
	1961–62	67	84	37·5	75	150
Potatoes	1959	112	112	12·5	50	—
	1960	134	112	12·5	50	75
	1961–62	134	224	37·5	75	150
Sugar beet	1959	112	112	12·5	50	—
	1960	134	112	12·5	50	75
	1961–62	112	279	37·5	75	150

N, 1959 ammonium sulphate; 1960–62 as compound 16-0-16 (16% N 16% K_2O).
P, 1959–60 powdered superphosphate; 1961–62 granular superphosphate.
K, 1959 potassium sulphate; 1960–62 as compound 16-0-16, to seedbed, 1961–62 autumn and spring extra basal K as potassium sulphate.
Ploughed in test and basal fertilisers were applied for 1961 on 5 December 1960 and for 1962 on 12 October 1961.

In 1959 and 1960 all the fertilisers for barley and sugar beet were applied by hand and harrowed in just before drilling the seed. For potatoes the land was set up in ridges and the fertilisers applied along the bottoms of the furrows and half way up the sides of the ridges. After the potatoes were hand-planted 15 in. apart in the rows, the ridges were split back to cover the sets. In 1961 and 1962 when ploughing in P was tested and some basal K was ploughed in the fertilisers to be ploughed in were applied the previous autumn. For each crop the seedbed dressings were given in the spring as in 1959–60 except that the N and K for barley were given as a compound containing 16% N and 16% K_2O and this was broadcast from the combine seed drill as the seed was drilled (for experimental details see Widdowson *et al.* (1964)). Varieties used were barley, Proctor; potato, Majestic (chitted seed); sugar beet, Klein E.

Woburn Permanent Wheat and Barley Sites 1960–62. The microplot experiment was made on plots 7, 8, 9, 11a, 11b, on both sites. Plan 3 (p. 36) shows the positions of the plots in the field; for the microplot experiment all the plots 11a and 11b were considered as one 'plot' making seven plots in all.

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VALUE OF RESIDUES—THE 1957–62 EXPERIMENTS

The seven plots were divided into 4 blocks and cropped as follows from 1960 to 1962:

		Wheat Site			Barley Site			
	Plot	7	8	9	11	9	8	7
Block	Year							
I	1960	winter wheat without P or K						
	1961	winter wheat without P or K						
	1962	oats without P or K						
II	1960	winter wheat without P or K						
	1961	fallow			sugar beet microplots			
	1962	sugar beet microplots			fallow			
III	1960	barley microplots						
	1961	fallow			potato microplots			
	1962	potato microplots			fallow			
IV	1960	potato microplots						
	1961	fallow			barley microplots			
	1962	barley microplots			fallow			

Thus block I continued the cropping as on the remainder of the Classical Sites and blocks II, III and IV were used for the microplot experiments. Each block has 112 microplots (each 0·00257 acre except those on plot 11 which were larger), sixteen per plot, of which eight tested P and eight K, so that both P and K were tested on each old plot. In 1960 of the eight microplots in each testing unit, four received no new test fertiliser so that fresh dressings could be tested in subsequent years, two tested the smaller and two the larger amount of new P or K.

The 1960 results, together with the experience gained on Agdell, suggested the need to compare ploughed-in fertiliser with seedbed dressings, and this comparison was made in 1961–62. For the barley and potato tests, the eight microplots on each testing unit were used as follows: of the four that were unmanured in 1960, two were not given new fertiliser, the other two tested the lesser amount of P or K either ploughed in or broadcast on the seedbed. The two microplots, which tested the lesser amount of P or K in 1960, in 1961–62 tested the largest amount, either ploughed in or to the seedbed, and the two microplots with the largest amount in 1960 were unmanured in 1961–62 to test the residual effects of the dressing. For barley, potatoes and sugar beet, new P was tested at 12·5 and 50 lb P/acre (P1 and P4). New K was tested at 14 and 54 lb K/acre for barley in all three years. For potatoes the amounts were 28 and 112 lb K/acre in 1960 and these were increased to 42 and 168 lb K/acre in 1961–62. Because sugar beet in both 1961 and 1962 were grown on new ground, three amounts of new K, 84, 168 and 336 lb K/acre could be tested. Table 7 (p. 38) shows the basal and test fertilisers, and diagram 3 (p. 37) the arrangement of the microplots on one crop block on part of the Barley Site in 1960 and the subsequent use of the microplots in 1961.

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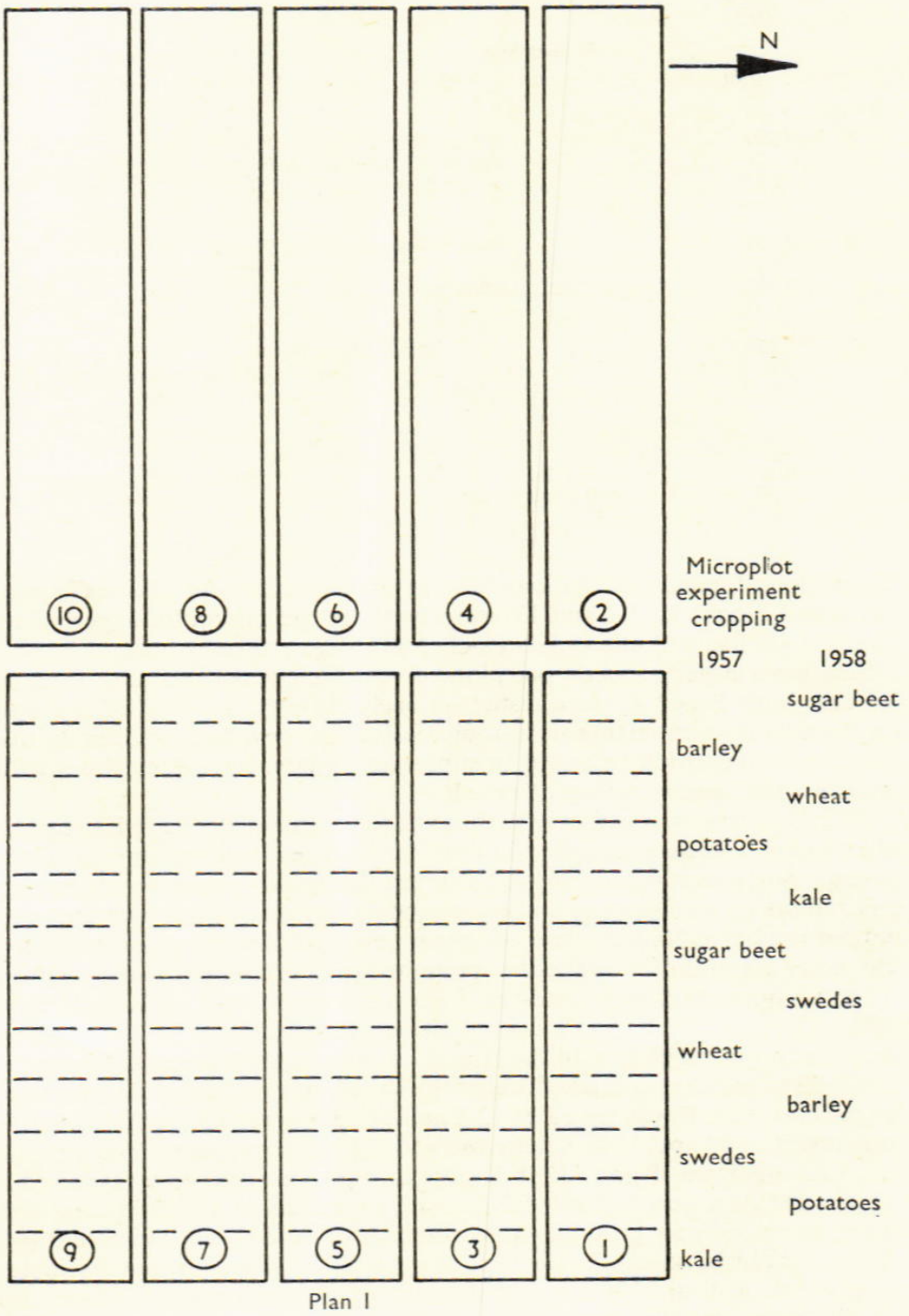

PLAN 1. The Exhaustion Land showing the twelve blocks on plots 1, 3, 5, 7 and 9 during 1957–58 and the crops grown on each block each year.

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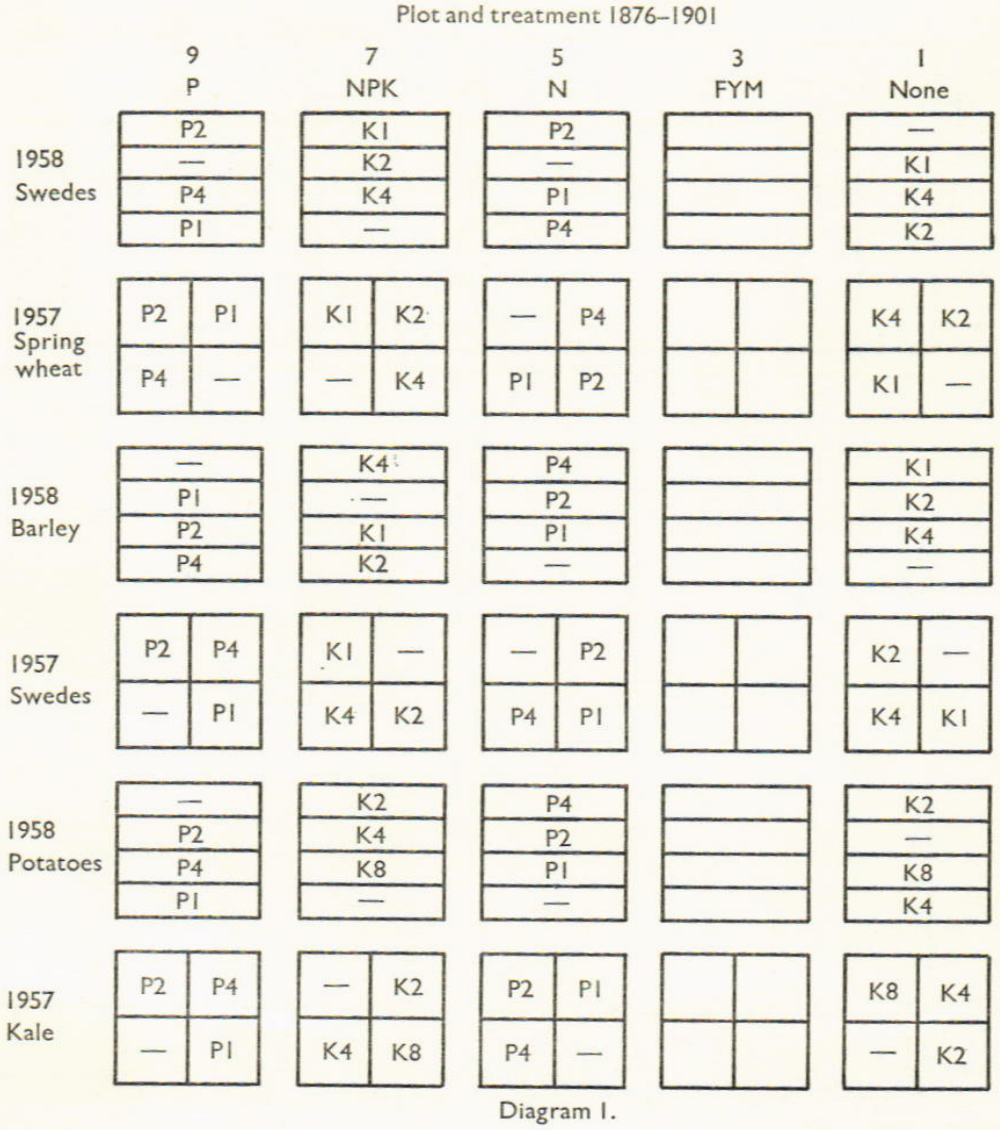

Diagram 1.

DIAGRAM 1. The Exhaustion Land, 1957–58, showing the cropping and the arrangement of the microplots and P and K treatments on six of the twelve blocks.
(P1, P2, P4: 12·5, 25, 50 lb fresh P/acre; K1, K2, K4, K8: 14, 28, 56, 112 lb fresh K/acre.)

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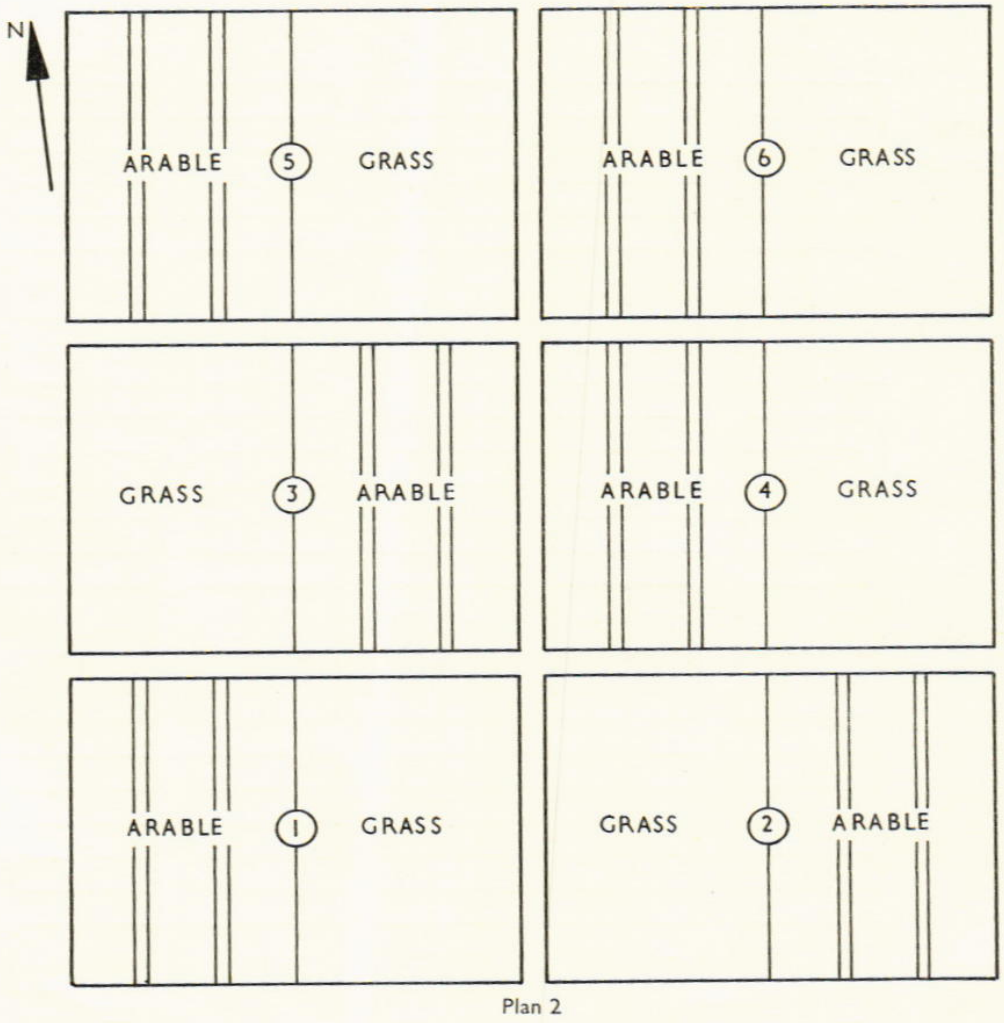

Plan 2

PLAN 2. Agdell showing the halving of the six rotation plots into grass and arable made in 1958, and the division of each arable half into three blocks for the microplot experiment from 1959 to 1962.

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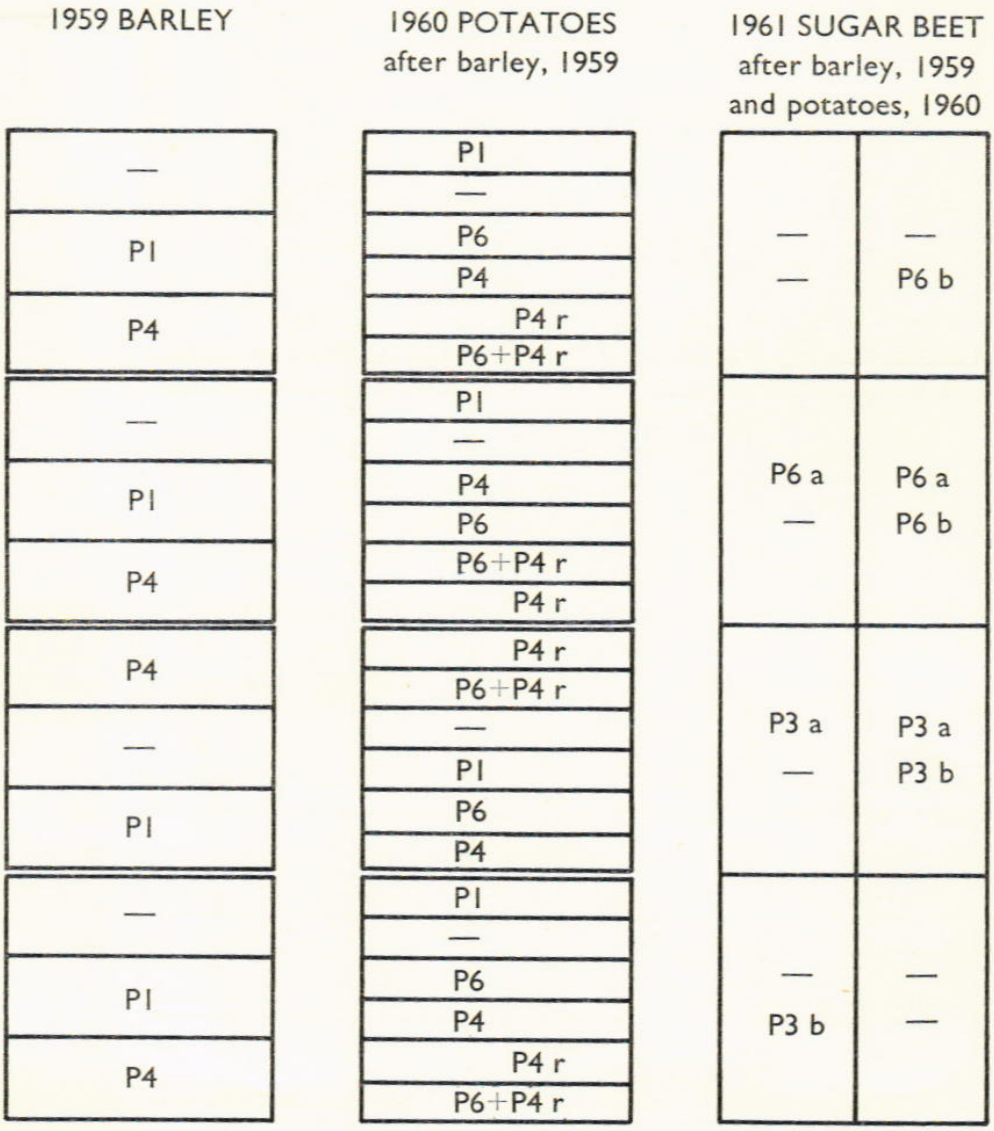

Diagram 2.

DIAGRAM 2. Agdell, 1959–61, showing the cropping and the arrangement of the P treatments on one crop strip in three successive years.
(P1, P3, P4, P6: 12·5, 37·5, 50, 75 lb fresh P/acre. 1960, P4r, residue of 50 lb P/acre applied in 1959. 1961, a, P dressing ploughed in; b, P dressing broadcast on the seedbed.)

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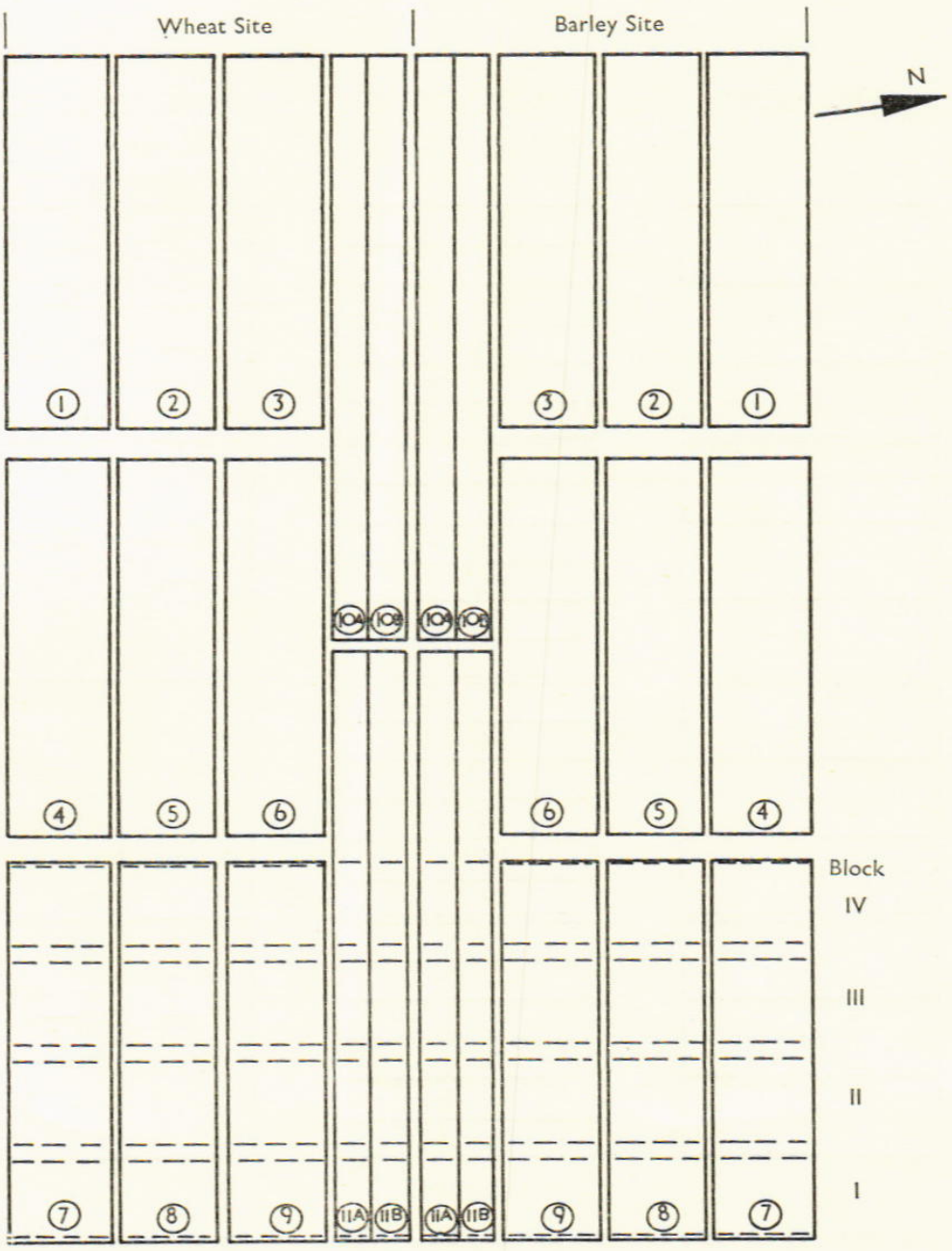

Plan 3

PLAN 3. Woburn Permanent Wheat and Barley Sites showing the four blocks on plots 7, 8, 9 and 11 during 1960–62.

DIAGRAM 3 (opposite). Woburn, 1960–61, showing the cropping, the P and K treatments and the arrangement of the microplots on each plot, on a part of one block, in two successive years.

(P1, P4: 12·5, 50 lb fresh P/acre; K1, K2, K4, K8: 14, 28, 56, 112 lb fresh K/acre; 1961, r, residue of the dressing applied in 1960; a, new dressing ploughed in; b, new dressing broadcast on the seedbed.)

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Plot and treatment 1877–1926	1960 Potatoes				1961 Barley after potatoes 1960			
7 None	—	P4	—	P1	P1 b	P4 r	—	P4 b
	P1	—	P4	—	P4 a	—	P4 r	P1 a
	—	K8	K2	—	K1 b	K8 r	K4 b	—
	K2	—	—	K8	K4 a	—	K1 a	K8 r
8 NPK	P1	—	P4	—	P4 a	P1 a	P4 r	—
	P4	—	P1	—	P4 r	—	P4 b	P1 b
	K8	—	K2	—	K8 r	—	K4 b	K1 b
	K2	—	—	K8	K4 a	—	K1 a	K8 r
9 NPK	—	K2	—	K8	K1 b	K4 b	—	K8 r
	—	K8	K2	—	—	K8 r	K4 a	K1 a
	P1	—	P4	—	P4 a	P1 a	P4 r	—
	P4	—	P1	—	P4 r	P1 b	P4 b	—
11B FYM	—	P4	P1	—	P1 b	P4 r	P4 b	—
11A NK	P1	—	—	P4	P4 a	—	P1 a	P4 r
11B FYM	—	K2	—	K8	K1 a	K4 a	—	K8 r
11A NK	K8	—	K2	—	K8 r	K1 b	K4 b	—

Diagram 3.

(see opposite page)

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TABLE 7

Basal and test fertilisers, Woburn Permanent Wheat and Barley Sites, 1960–62

lb element/acre

Crop		N basal	P test		K test		
Barley	1960–62	67	12·5	50	14	56	—
Potatoes	1960	134	12·5	50	28	112	—
	1961–62	134	12·5	50	42	168	—
Sugar beet	1961–62	112	12·5	50	84	168	336

N as 'Nitro-Chalk'.
P as granular superphosphate.
K as potassium sulphate.
Basal P for all crops for the K test was 50 lb P/acre.
Basal K for the P test varied for each crop, barley 56 lb; potatoes 112 lb in 1960; 168 lb in 1961–62; sugar beet 336 lb.
In 1960 basal P and K was applied to seedbed; in 1961–62 it was ploughed in. Ploughed in test and basal fertilisers were applied in 1961 on 24 January and in 1962 on 26 January.

In 1960 all the fertilisers were broadcast by hand on the seedbed, immediately before drilling the barley and machine planting the potatoes except that the N for the barley was broadcast from the combine drill as on Agdell. In 1961 and 1962 when ploughed in and seedbed dressings were tested all the ploughed in test fertilisers and the basal P and K were ploughed-in in January each year. The seedbed dressings and the nitrogen were applied by hand, just before drilling the barley and sugar beet and machine planting the potatoes, except that the N for the barley was applied as in 1959. Varieties: barley, 1960–61 Plumage Archer, 1962 Proctor; potato, Majestic (chitted seed); sugar beet, Klein E.

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