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Rothamsted Report for 1967

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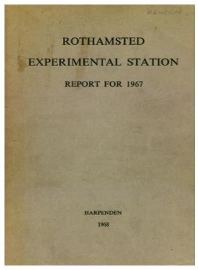

The Saxmundham Experiments

G. W. Cooke

G. W. Cooke (1968) *The Saxmundham Experiments ;* Rothamsted Report For 1967, pp 235 - 248 - **DOI: https://doi.org/10.23637/ERADOC-1-120**

The Saxmundham Experiments

By G. W. Cooke

The two long-term Rotation Experiments and the Intensive Wheat Experiment continued, leaving only about an acre for new experiments, which were therefore all in microplots. The new ones, which will last two or more years, are mostly concerned with manuring of barley, red clover, lucerne and a newly sown grass sward, but effects of soil compaction and partial soil sterilisation were also tested.

Further work on the physical properties of Saxmundham soil and the composition of rain and drainage water stressed the importance (and difficulty) of manuring correctly with nitrogen, as leaching caused large losses during spring. When we started work at Saxmundham we regarded it as a "phosphate site", but using nitrogen correctly seems the major nutritional problem once the soil phosphate deficiency has been corrected.

Weather. The weather records are primarily intended to help in interpreting the experiments at Saxmundham and to compare with weather at Rothamsted and Woburn, but they should have further uses, as no other station makes such detailed observations in this part of East Anglia. For much of our work, better estimates of evaporation are needed than the published calculations for the area. We obtain two estimates, one from radiation measured by a solarimeter (installed by G. Szeicz, Physics Department) and the other from a pair of evaporimeters measuring loss from an open-water surface. Table 1 summarises some of the measurements (long-term rainfall averages were given in last year's Report (p. 248)).

Rainfall was 1¼ in. less than average in January to March, 1·7 in. more in April and May, 2·2 in. less in June and July and 1·4 in. more in August to October. All crops were sown during a dry spell in March. Land that had been fallowed, or had carried potatoes or cereals in 1966, was ploughed early and gave good seed-beds. Sugar beet had not been removed from Rotation I Experiment before the weather deteriorated in October 1966, and ploughing was delayed; there was little frost to improve the bad structure of the soil on this area, and a good seed-bed could not be prepared for the barley sown at the end of March 1967. The other crops on the Rotation experiments were sown in satisfactory seed-beds.

April was both wet and cold (colder than March). Wet but warmer weather in May started crops well, although the rain in these two months leached much of the nitrogen fertiliser applied earlier. Dry weather in June and July helped work with roots; the slightly wetter than average late summer and early autumn did not prevent timely harvesting of corn and root crops, or ploughing and sowing of winter wheat.

Temperatures at Rothamsted, Woburn and Saxmundham were compared by calculating accumulated temperatures above and below 42° F from the daily maxima and minima recorded. (Accumulated degree-days above a base (such as 42° F used here) are often called "heat units" and are used for monitoring the development of crops (such as peas) intended for processing when fresh, and for forecasting harvesting dates.) Accumulated

https://doi.org/10.23637/ERADOC-1-120

TABLE 1

Weather observations and evaporation at Saxmundham in 1967

	Mean temperature (° F)	Temperature (° F) in soil		Relative humidity (%)	Rainfall		Energy Cals.cm^{-2}	Evaporation from open water (in.)	Accumulated† day degrees		Wind (mph)
		4 in.	12 in.		Inches	Rainy days			A	B	
January	38·4	37·2	37·5	87	1·62	15	2184	—	36	141	6·5
February	41·4	39·1	39·8	78	1·54	11	2989	—	94	213	8·9
March	45·4	41·9	42·8	76	0·83	8	6021	—	227	244	9·8
April	44·6	44·0	45·1	77	2·26	15	7505	(1·66)*	347	288	7·8
May	51·1	50·8	52·1	78	2·76	22	10303	3·29	640	299	7·6
June	56·1	60·0	61·6	80	0·75	6	—	4·80	1066	300	5·2
July	63·1	65·7	67·4	80	1·08	11	—	6·10	1720	300	5·0
August	61·2	61·6	64·5	83	2·83	11	8980	4·06	2317	300	4·7
September	57·4	56·4	58·4	90	2·83	22	5780	3·22	2780	300	6·0
October	52·9	50·8	52·4	89	2·85	19	3860	1·52	3121	303	8·1
November	42·5	41·3	42·8	85	2·85	14	1320	—	3191	364	5·4
December	37·8	37·0	38·7	84	1·64	13	1720	—	3228	530	7·3
Year Total	—	—	—	—	23·84	167	—	—	—	—	—
Year Mean	49·3	48·8	50·2	82	—	—	—	—	—	—	6·8

* Evaporimeters were installed on 18 April, data for the month are from 18 to 30 April

† A Accumulated temperature above 42° F } Calculated from daily maxima and minima
B Accumulated temperature below 42° F }

https://doi.org/10.23637/ERADOC-1-120

degree-days at the three places were generally similar, but were most at Woburn and least at Saxmundham in spring and most at Saxmundham by August.

Accumulated day degrees above 42° F

	Saxmundham	Rothamsted	Woburn
April	347	364	383
August	2317	2291	2304

Moisture deficits were calculated from two evaporimeters (each 22 in. diameter and 12 in. deep) which were half embedded in soil and first filled on 18 April. Evaporation from the open water surface was converted to evaporation from a crop by multiplying by 0·75 (H. L. Penman, *J. Soil Sci.* (1949), **1**, 74–89):

	Rain (in.)	Accumulated moisture deficit (in.)	
		From evaporimeters	From solarimeter
18–30 April	0·53	0·71	0·59
May	2·76	0·42	0·45
June	0·75	3·27	2·97
July	1·08	6·76	—
August	2·83	6·97	—
September	2·83	6·55	—
October	2·85	4·84	—

Moisture deficits calculated from solarimeter readings until the end of June, when the instrument stopped recording, agreed reasonably with those from the evaporimeters.

The large moisture deficit that had developed at Saxmundham by the end of July caused crops to ripen earlier than at Rothamsted. (Rothamsted had twice as much rain as Saxmundham in May, June and July.) Dry weather affects crops more at Saxmundham than at the other two Stations because its soil holds less available water. The following are typical measurements made by Dr. G. Salter, of the National Vegetable Research Station, on plots of long-term experiments:

	Inches of available water/ft of soil	
	With FYM	With NPK fertiliser
Rothamsted (Clay loam)	2·10	1·82
Woburn (Sandy loam)	1·95	1·59
Saxmundham (Sandy clay)	1·38	1·35

The sandy clay at Saxmundham holds only two-thirds as much water as Rothamsted clay-loam; surprisingly the light Woburn soil holds more water than Saxmundham soil. (R. J. B. Williams)

Drainage. Two outfalls of an old drainage system, for which there are no plans, still run on Harwood's Field. In 1948 drains were put in to serve the northern and eastern parts of the field, but the main areas of Rotation I and Rotation II Experiments were avoided. Two of the three outfalls run regularly in winter. Flow from the drains is observed each day; drainage-

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water samples have been taken for analysis once each 2 or 3 weeks since October 1966. The drains started to run in October 1966, and ran regularly until March 1967. Intermittent flows in April, and again in May, followed more than 1 in. of rain falling in the few days before the observations; this flow was much faster than any observed during winter, and caused a large loss of nitrate. Drainage stopped in mid-May, and there was no large or regular flow until mid-October (1967). Since then there has been continuous drainage, but flow rates have varied greatly. Large flows occur when more than 1 in. of rain falls in the 2 weeks before; small rainfall (0·3 in./2 weeks) has little effect on the usual slow drainage.

The moisture deficits calculated from the evaporimeters assume that the soil is completely covered with a growing crop. Harwood's Field always has much bare land on headlands and roadways; cereals were harvested in mid-August, thereafter only about a sixth of the land carried crops, and the sugar beet was lifted early in October. The calculated deficit at the end of July was 6·8 in., 7·2 in. of rain had fallen by 17 October, when a permanent flow from the drains began. (R. J. B. Williams and G. W. Cooke)

Long-term experiments

Rotation I Experiment. The new manuring, described in *Rothamsted Report* for 1965 (pp. 236–237), continued. Only sugar beet yielded well (Table 2).

The maximum yield of Cappelle wheat, sown after a poor crop of beans in 1966, with fertilisers (including 1·0 cwt N/acre) was only 39 cwt/acre; with FYM and a top-dressing of 0·5 cwt N/acre, yield was 45 cwt/acre.

Barley was much poorer, yielding 25 cwt/acre with the most fertilisers and 24 cwt with FYM plus 0·5 cwt fertiliser N/acre. After measuring large losses of nitrate in drainage water in early May extra 0·25 and 0·5 cwt N/acre top-dressings were applied to "discard" areas of the plots. There was an immediate response, and the main parts of the barley plots on Rotation I Experiment were top-dressed with 0·25 and 0·5 cwt N/acre (to N1 and N2 plots respectively) on 15 June. Although the barley improved quickly, it had been too checked by shortage of N, by a bad seed-bed and by serious mildew to yield well. Even larger top-dressings should have been applied earlier after the rain in May. No doubt the wheat would also have yielded more with extra top-dressing. (Tests were also made on small discard areas of the wheat; the crop responded visibly and yield increased.)

Beans established well, were successfully protected from weeds (simazine) and from aphis ("Metasystox"), but they yielded badly. (Perhaps because their roots were damaged by a pest or disease.) Largest yields (on both fertiliser-treated and FYM plots) were 23 cwt grain/acre.

Sugar beet was much better than in 1966. As with the wheat and barley, it suffered from shortage of nitrogen caused by leaching of the N applied in March and April. By early July the crop had stopped growing and was turning yellow. Extra dressings of 0·25 and 0·5 cwt N/acre given to N1 and N2 plots on 18 July restored colour and growth. Best yields were satisfactory (60 cwt/acre of sugar with NPK fertilisers, 67 cwt with FYM plus extra nitrogen); the beet could probably have yielded still more, as the

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TABLE 2

Yields per acre of cereals, beans and sugar beet in Rotation I Experiment at Saxmundham in 1967

Plot	Annual Treatment* to 1965	Annual Treatment* to 1966	Barley grain Treatments Old	Barley grain Treatments New	Wheat grain Treatments Old	Wheat grain Treatments New	Beans Treatments Old	Beans Treatments New	Sugar beet Old Treatments Roots (tons)	Sugar beet New Treatments Roots (tons)	Sugar beet New Treatments Tops (tons)	Sugar beet New Treatments Sugar (cwt)
6	None	1N, 2P	6·3	15·0	9·1	21·0	8·0	18·8	4·68	10·74	3·86	37·1
3	n	2N, 2P	12·7	25·0	19·5	34·3	11·5	18·8	9·12	15·78	6·12	53·0
4	p	1N, 1P	11·7	16·5	15·8	27·7	16·4	18·6	5·76	10·80	4·03	36·8
5	k	1N, 2P, K	7·7	16·2	12·9	25·9	8·2	17·0	4·20	11·95	3·73	43·9
9	np	2N, 1P	15·8	24·8	29·1	36·8	19·2	16·3	9·36	17·74	7·60	59·3
8	nk	2N, 2P, K	12·6	26·4	22·2	38·8	12·0	22·9	9·60	17·29	6·22	59·9
7	pk	1N, 1P, K	8·1	20·8	15·3	29·2	15·6	22·8	6·96	11·75	3·93	41·2
10	npk	2N, 1P, K	17·5	24·9	32·4	35·3	19·3	21·7	8·52	16·27	6·51	57·2
2	Bone meal	Bone meal	14·2	11·8	15·9	14·0	21·0	17·5	5·76	5·24	2·13	17·7
1	FYM	FYM+1N	16·6	24·0	35·1	45·3	17·2	23·2	12·36	19·18	5·96	66·6

* 1N *and* 2N were 0·5 and 1·0 cwt N/acre respectively for cereals and sugar beet, 0 and 0·5 cwt for beans, all applied in April.
In addition, top dressings were applied to barley in June and sugar beet in July, these supplied 0·25 cwt N to 1N plots and 0·5 cwt N to 2N plots.
All other manuring rates are as stated on p. 249 of the *Rothamsted Report* for 1966.

TABLE 3

Yields per acre of turnips and sugar beet in Rotation II Experiment

Plot No.	Treatment per acre: 1899–1964 per 4 years	cwt P_2O_5 since 1965	tons FYM since 1965	Yields of turnips (tons): Fresh roots	Dry matter Roots	Dry matter Tops	Yields of sugar beet: Roots fresh (tons)	Sugar %	Sugar (cwt)	Dry matter Roots (tons)	Dry matter Tops (tons)
1	None	0	0	2·22	0·29	1·16	8·30	15·7	26·2	1·91	1·15
2	10 tons FYM	0	0	5·00	0·68	1·30	13·50	17·6	47·5	3·22	1·00
3	10 tons FYM + 5 cwt super (7½ cwt since 1920)	0	0	6·84	0·91	1·51	16·88	17·6	59·4	3·96	1·04
4	10 tons FYM + 5 cwt super (7½ cwt since 1920)	0	40	7·71	0·94	1·73	19·55	17·2	67·2	4·44	1·30
5	10 tons FYM + 5 cwt super (7½ cwt since 1920)	4·5	40	8·13	1·00	1·89	19·51	17·3	67·3	4·40	1·24
6	10 tons FYM + 5 cwt super (7½ cwt since 1920)	4·5	0	7·92	0·97	1·51	18·35	17·3	63·4	4·12	1·28
7	10 tons FYM + 5 cwt super (7½ cwt since 1920)	9·0	0	7·88	1·02	1·64	18·61	17·3	64·4	4·24	1·17
8	10 tons FYM + 10 cwt super to 1952	0	0	7·25	0·91	1·35	17·44	17·3	60·1	4·03	1·19

https://doi.org/10.23637/ERADOC-1-120

extra top-dressing of nitrogen should have been larger and given earlier. (R. J. B. Williams and G. W. Cooke)

The beet crop was more vigorous and more regular than in 1966. Virus yellows became prevalent late in the season. Beans were healthy above ground, but in July and August tap-roots were killed and the plants died early. Proctor barley was severely attacked by mildew. Cappelle wheat had much yellow rust; more surprising was a severe attack of take-all, although the wheat followed a crop of beans that contained few grass weeds. Excavations elsewhere on the field showed that stubbles from 1966 cereal crops had not decayed completely a year later; perhaps fungi causing root diseases survive longer at Saxmundham than in better-aerated soils where organic materials decay quicker. (G. D. Heathcote, Broom's Barn, and D. B. Slope, Plant Pathology Department)

The old (1899–1965) manurial treatments, maintained on small areas at an end of each block of plots, gave yields shown in Table 2. Wheat yielded considerably more than the long-term (1900–61) average, barley slightly less. Beans gave less than the average of crops in 1920–39, sugar beet less than the average of yields in 1956–65. The mild wet weather late in 1966 damaged soil structure, and the rain in April and May of 1967 leached much nitrate, probably causing the small yields of three of the 1967 crops. The effects of the old fertiliser treatments resembled those of earlier years.

Average yields per acre from the new treatments were:

		(N_0)	1N	2N
Wheat, cwt		(14·0)*	26·0	36·3
Barley, cwt		(11·8)*	17·1	25·3
Beans, cwt		(19·3)	19·9	—
Sugar beet	Roots, tons	(5·2)*	11·3	16·8
	Tops, tons	(2·1)*	3·9	6·6
	Sugar, cwt	(17·7)	39·7	57·4

		(P_0)†	1P	2P
Wheat, cwt		(22·2)	32·2	30·0
Barley, cwt		(12·6)	21·8	20·6
Beans, cwt		(12·0)	19·8	19·4
Sugar beet	Roots, tons	(9·6)	14·1	13·9
	Sugar, cwt	(35·4)	48·6	48·5

		K_0	1K
Wheat, cwt		30·0	32·3
Barley, cwt		20·3	22·1
Beans, cwt		18·1	21·1
Sugar beet	Roots, tons	13·8	14·3
	Sugar, cwt	46·6	50·6

* Yields "without nitrogen" marked * are from the continued bonemeal treatment.
† Yields without phosphate are from the "nk" treatment on the small areas still receiving the old treatment.

Beans gave a small response to 0·5 cwt N/acre. All other crops responded well to N; the response curve was almost linear up to the largest amount given, suggesting that the crops would have benefited from more N than the most given (1·5 cwt N/acre for barley and beet, 1·0 cwt N for wheat).

The test of phosphate is now 0·4 cwt P_2O_5 (1P) on plots where P has been

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applied each year since 1899, against 0·8 cwt P_2O_5/acre (2P) applied for each of the last 2 years to plots not previously given phosphate. All crops yielded slightly more on plots given the smaller dressings of phosphate for nearly 70 years, as in 1966. The only surprising feature is that land given no phosphate for 70 years, and then only two modest amounts, yielded nearly as well as where phosphate has been given every year.

All crops yielded a little more where potash was given, contrary to what happened in 1966, but in agreement with results obtained from 1956 to 1965 by P. J. O. Trist and D. A. Boyd (*J. agric. Sci., Camb.* (1966), **66,** 327) when the small responses to potash tended to increase. (G. W. Cooke and R. J. B. Williams)

Rotation II Experiment. The modifications made to measure the value of the residues from phosphate fertilisers in this experiment were described in the *Rothamsted Report* for 1965 (p. 237). The last of the dressings to accumulate large fresh residues were given in 1966/7. FYM applied to Plots 4 and 5 in autumn 1966 supplied 318 lb N, 96 lb P and 170 lb K/acre. One-half of the phosphate dressings in treatments 5, 6 and 7 was applied in autumn before ploughing, the remainder in March 1967 along with basal dressings supplying 1·2 cwt N and K_2O/acre. The plots were split; white turnips and sugar beet, each sown on half plots, grew well and looked healthy. Fresh farmyard manure on Plots 4 and 5 probably provided N for both crops, and their tops were greener throughout the season than with inorganic N only. Table 3 gives yields of turnips harvested on 11 July and sugar beet harvested on 5 October.

Turnips were large and coarse, about a fifth having flowered after drought in June. Residues of FYM (Plot 2) or FYM and superphosphate (Plot 3) more than doubled turnip yields. Fresh FYM or superphosphate applied between 1965 and 1967 gave an extra ton of roots/acre. Most of this increase seems to be from recently added phosphate, because plots with superphosphate alone (Nos. 6 and 7) yielded as well as Plot 5 with superphosphate plus fresh FYM.

Yield of sugar increased from 26 cwt/acre on Plot 1 (without phosphate) to about 60 cwt/acre on Plots 3 and 8, where FYM and superphosphate had been applied between 1899 and 1964. Fresh superphosphate, supplying 4·5 and 9·0 cwt P_2O_5/acre since 1965, gave 4–5 cwt more sugar/acre on Plots 6 and 7. 40 ton/acre of FYM between 1965 and 1966 further increased yields by 3 cwt sugar/acre, probably because nitrogen was released from the manure. (G. E. G. Mattingly and A. E. Johnston)

Intensive Wheat Experiment. This experiment, begun in 1965 (*Rothamsted Report* for 1966 (pp. 251–252)), measures the prevalence of soil-borne diseases and the effect of one- and two-year breaks on yields of winter wheat. The Cappelle wheat established slowly on a rough seed-bed. It grew satisfactorily in spring, but its yield was limited by yellow rust. The alternative crops in the rotation, Italian ryegrass and beans, grew satisfactorily. Grass weeds were not abundant in the wheat, but there were patches of *Poa trivialis* (rough-stalked meadow grass) and *Poa annua* (annual meadow grass), and a little *Alopecurus myosuroides* (blackgrass) was present. Table 4 gives mean yields and the proportions of plants with take-all.

TABLE 4

The mean yields and incidence of take-all in Cappelle winter wheat at Saxmundham in 1967

	cwt N/acre applied		
	0·6	1·2	1·8
Grain, cwt/acre (at 85% dry matter)			
Wheat after wheat	27·6	35·6	37·6
Wheat after 1-year ley	36·2	43·7	39·4
% plants with take-all (in June)			
Wheat after wheat	68	76	58
Wheat after 1-year ley	11	13	12
Grain, cwt/acre			
Section A Beans in 1964	22·1	33·6	35·7
Section B Wheat in 1964	33·2	37·6	39·5
% plants with take-all (in June)			
Section A Beans in 1964	82	83	79
Section B Wheat in 1964	54	68	38

Before 1965 the two halves of the experimental site had been cropped differently:

A 1963 wheat, 1964 beans
B 1963 barley, 1964 wheat

Spring barley in 1965 and winter wheat in 1966 had less take-all and yielded more on A than on B (i.e. the 1964 bean "break" crop was beneficial in both years), but in 1967 wheat after wheat had more take-all and yielded less on A than on B. The yield of wheat after ley on the two halves differed only with the smallest dressing of nitrogen, 34·0 cwt grain/acre on A and 38·4 cwt/acre on B.

Farmers growing mostly wheat and barley may be surprised that a break crop can have harmful effects 3 years after it is grown, but these results resemble some obtained at Rothamsted (*Rothamsted Report* for 1966, p. 123). When wheat is grown continuously take-all usually begins to decline in the 4th and 5th consecutive crop. The effect is usually small, but can be important in determining the value of break crops where take-all is the most important factor limiting yield of wheat. (D. B. Slope and Judith Etheridge)

Soil structure and compaction

Soil Conditioner Experiment. This experiment began in 1966, and described in last year's Report (pp. 38–39), "Krilium" was again unique in preserving through the season the surface tilth established in spring, and in preventing slaking. (R. J. B. Williams)

Soil Compaction Experiment. The poor growth and yield of sugar beet on Rotation I in 1966 was thought to be caused by seed-bed preparation compacting the soil, leading to water-logging, inadequate aeration and plants with a small, diseased root system. The effect of soil compaction was

https://doi.org/10.23637/ERADOC-1-120

tested by three treatments: (1) soil worked by rotary cultivation during the winter and allowed to settle; (2) soil compressed by rolling in the spring; (3) soil as open as possible. Each of these treatments was combined with fertiliser tests (0·6, 1·2 or 1·8 cwt/acre of N, or 1·2 cwt/acre of N plus an extra 0·8 cwt/acre P_2O_5).

The compacted seed-bed gave the smallest yield (49·5 cwt/acre of sugar on average) and the open seed-bed the largest (55·8 cwt/acre). Nitrogen gave a large response, and the largest dressing gave the largest yield. The extra phosphate gave a consistent but not significant response. There was no interaction between the seed-bed treatments and the fertiliser dressings. Sugar yield increased linearly with the number of roots harvested, suggesting that the treatments might have influenced sugar yield through their effect on plant population, but this needs further testing. (R. Hull and A. P. Draycott)

Soil sterilisation. Observations on sugar beet made in 1966, and the small yields of cereals, suggested that soil-borne pests and diseases may be damaging after a 1-year break in Rotation I Experiment. The effect of partial sterilisation of soil by formalin for barley, and by methyl bromide for sugar beet, potatoes and barley was therefore tested. Results are described earlier in this Report (p. 57–58). Sterilants increased yields of all crops slightly, but the gains were partly (and may have been entirely) from the extra nitrogen released from soil by sterilising. None of the tests (all made on crops grown on land fallowed in 1966) suggested that soil-borne pests and diseases persist for long at Saxmundham, or that there is any serious but unidentified pest or disease that lessens yields. Small yields of roots and cereals are more likely to be because of bad soil structure, lack of nitrogen or both. (R. J. B. Williams and G. W. Cooke)

Experiments on herbage crops

Experiments on grassland began on the adjoining Fiske's Field at Saxmundham in 1902, and A. W. Oldershaw (*J. R. agric. Soc.* (1934), **95**, 18–33) described 30 years' work. Starting with "semi-derelict" grassland yielding only 10 cwt/acre of dry matter, sowing more productive grasses and legumes and giving phosphate to encourage the legumes, more than doubled the yield. Giving a little nitrogen each year (15 lb/acre) increased yield to the most achieved in these experiments—30 cwt/acre of dry matter. Later, when lucerne, red clover and wild white clover were sown, annual yields averaged from 2 to 2½ ton/acre. Oldershaw suggested that good yields from tap-rooted legumes could not be maintained for long.

New experiments were started to measure responses of red clover and lucerne to P and K and the amount of nitrogen these crops fix, and to test the efficiency with which perennial grasses use nitrogen fertiliser.

Identical experiments with Dorset Marl red clover and Europe lucerne tested 0·5 against 2·0 cwt P_2O_5/acre and 2·0 cwt K_2O/acre against none. Table 5 shows yields from two cuts. The two crops yielded similarly; both gave significantly more with the larger than with the smaller amount of phosphate and responded significantly to potash.

https://doi.org/10.23637/ERADOC-1-120

A mixture of meadow fescue (S215) and timothy (S352) was sown in March. The nitrogen tested was from none to 4 cwt N/acre. On some plots these amounts were divided into two, and half applied before each of two cuts. On other plots a quarter of the total dressing was intended to be applied for each of four cuts, but the grass grew slowly at first, and only

TABLE 5

Yields of red clover and lucerne at Saxmundham in 1967

P_2O_5 applied (cwt/acre)	Cwt/acre of dry matter (totals of 2 cuts) Without K	With 2·0 cwt K_2O	Standard error
	Lucerne		
0·5	47	51	±1·26
2·0	50	55	
	Red clover		
0·5	46	51	±1·36
2·0	51	57	

three cuts were taken, so only three of the four nitrogen dressings were applied. On two other plots nitrogen was applied only for the first two cuts, and later cuts taken to see how much nitrogen is recovered from the soil; these plots also were only cut three times in 1967. Table 6 shows that giving 112 lb N/acre doubled the yield, but responses to increasing amounts diminished quickly. With 3 cwt N/acre, yields were the same

TABLE 6

Yields per acre of grass and the nitrogen it contained at Saxmundham in 1967

	Total amount of N used in year (lb/acre)	Times per year fertilised	cut	Total of all cuts yield (cwt)	nitrogen content (lb)
1	0	0	2	24·1	42
2	112	2	2	49·2	86
3	224	2	2	57·2	113
4	336	2	2	61·9	145
5	448	2	2	67·6	176
6	168	3	3	48·6	116
7	336	3	3	61·7	176
8	224	2	3	51·4	128
9	448	2	3	64·7	212
		Standard error		±1·90	±8·0

whether plots were cut two or three times; 112 lb of N with two cuts produced the same yield as 168 lb of N on plots cut three times.

Grass given 2cwt N/acre yielded almost the same as red clover and lucerne given potash and phosphate. The grass and the clover contained the same N (about 210 lb/acre), the lucerne less (165 lb/acre). (R. J. B. Williams and G. W. Cooke)

The compositions of rain and drainage water

Table 7 shows that sodium was the dominant cation in rainwater; there were two peaks, in April and late October, when the concentrations were

https://doi.org/10.23637/ERADOC-1-120

TABLE 7

Analyses of rainwater and amounts of nutrients provided per acre; from December 1966 to November 1967

	Range (ppm.)	Total amounts (lb/acre)	
Na	1–8	17·8	in 11 months
K	0·2 –1·8	1·6	
Ca	0·2 –5·0	4·4	
Mg	0·2 –1·5	2·4	
P	0·01–0·11	(0·2)	
NH_4–N	0·1 –4·0	2·1	in 3 months
NO_3–N	Trace–1·2	1·0	
Conductivity (μ mho/cm $\times$ 10^2)	0·3 –1·65	—	

more than five times as much as in June. Although there was no close relationship with direction of wind, larger concentrations of sodium were usually associated with winds from north-west, east and south-east. Potassium, calcium and magnesium were much less than sodium, and phosphorus was negligible. Nitrogen was measured only between August and November 1967, when the rain supplied 3 lb/acre (most was ammonium). The amounts of nutrients supplied by 1 in. of rain in 1966 and 1967 were:

	Na	K	Ca lb/acre	Mg	Total N
March–October 1966	0·47	0·55	0·30	0·11	—
December 1966–November 1967	0·85	0·08	0·21	0·11	0·33

In 1967 rain provided more sodium, much less potassium and about the same amounts of calcium and magnesium as in 1966. The rain was collected 6 ft above the ground. Contamination (thought to be soil dust) was detected during only one sampling period, and analyses for the sample are excluded from those given here.

Observations on drainage from Harwood's Field are discussed earlier (p. 237); 14 samples of drainage water taken were analysed. Measurements in Table 8 for the arable land of Harwood's Field are averages of several drains; separate results are given for water collected from an adjacent field under grass until ploughed in September 1967.

TABLE 8

Ranges of concentrations of elements in Saxmundham drainage water, December 1966 to January 1968

	Arable land	Grass field
	parts per million	
Sodium	12·5–19·5	13·0–20·7
Potassium	0·4–3·4	1·0–4·6
Calcium	150–240	121–296
Magnesium	5·0–17·1	7·7–16·4
Total N	6·9–47·4	0·0–48·6
Phosphorus	0·01–0·08	0·02–0·20
Sulphur	40–90	12–90
Chlorine	32–57	16–76
	(μ mho/cm. $\times$ 10^2)	
Specific conductivity	8·2–12·9	6·7–14·2

https://doi.org/10.23637/ERADOC-1-120

Concentrations of sodium, calcium and magnesium varied much less than nitrogen and potassium. Mg and Na increased slightly during late May and November. Concentrations of K and total N were relatively small from December 1966 to March 1967, but became large in April and May. In early autumn drainage from the field previously grassland had more K and N than drainage from arable land; presumably both were released as grass roots and stubble decayed. By mid-November drainage from the two fields had similar compositions. The most striking changes during the year were the very large (and closely related) increases in nitrogen and potassium concentrations when much spring rain leached the recently fertilised soil. In the same period both sodium and magnesium concentrations diminished, presumably because the usual amounts in the soil solutions were diluted by the large amount of drainage.

All nutrient cations were much more concentrated in drainage water than in rain. Sodium is probably concentrated in the soil during dry periods, and leached out later by large rainfall. Soluble constituents dissolve quickly in rain that falls on the soil, even when it does not immediately percolate deeper. Compositions of rainwater collected in November and of the drainage it caused are given below, together with a range of concentrations of elements in surface water standing on the land in November and January. Surface and drainage water contained similar amounts of most

	Rainwater	Drainage (ppm)	Surface water (range)
Na	2·0	16·5	11–16
K	0·20	1·1	1·5–4
Ca	0·50	224	102–176
Mg	0·27	17·6	3–7
Total N	0·10	14·8	8–22

of these elements, whereas rainwater had a very different composition. Evidently surface water flowing over the field can remove as much nutrients as leaching, and this explains their movement by downwash across the plots. (R. J. B. Williams)

Efficiency of nitrogen fertilisers

Unexpectedly large concentrations of nitrogen in drainage water during spring showed how easily nitrate is lost from Saxmundham soil. Two large flows, sampled in April and May, contained, respectively, 32 and 47 ppm of N, presumably from the nitrogen fertiliser applied in March. In 24 hours during early May the total flow from all the drains together removed 30 lb of N. The corresponding loss of nitrate-N between mid-October 1966 (when a regular flow began) to mid-March (when flow ceased) through the drains was 33 lb—little more than was lost in a day after much rain in May.

These figures cannot be used to assess losses per acre in a short period because we do not know what fraction of the water percolating through the soil is removed by the drains and how much passes into deeper strata.

When the drains run continuously in winter, presumably soil and subsoil are at field capacity and all rain drains through the soil (except for the small amount evaporated—usually estimated to be 3 in. from October to March).

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Drainage-water compositions may therefore be used to estimate losses by leaching in winter; from 1 November 1967 to 2 January 1968 4·3 in. of rain fell and our analyses suggest this removed 15 lb N/acre. (R. J. B. Williams and G. W. Cooke)

Fertiliser-N recovered by crops. We commented in last year's Report (p. 252) on the small proportion of the fertiliser nitrogen that is recovered by crops at Saxmundham. Most of the 1967 crops were analysed to estimate the amount recovered.

In Rotation I all plots now get some nitrogen, but the bone meal supplied only a few lb/acre, and this plot is used as the "control" in the table below:

	Fertiliser-N applied (lb/acre)	Amounts of N in crops receiving Bone meal	NPK fertiliser	FYM + N fertiliser	Fertiliser-N recovered (%)
Wheat (grain + straw)	112	24	61	82	33
Barley (grain + straw)	168	20	54	49	20
Sugar beet (tops + roots)	168	28	94	106	39

The Intensive Wheat Experiment had both wheat after ley and wheat after wheat (where the crop had much take-all). The amounts of nitrogen in grain and straw together were:

Crop sequence		Amount of fertiliser N applied (lb/acre) 67	134	201
1	Wheat after wheat	45	62	71
2	Wheat after ley	53	73	83

The wheat with root disease (sequence 1) yielded less and recovered less of the fertiliser-N than the wheat on sequence 2, but even this recovered only 30% of the second increment of N, and 15% of the third increment.

The amounts of N in the crops grown with various amounts of fertiliser in the experiments testing methyl bromide as a soil disinfectant were:

	Amount of fertiliser N applied (lb/acre) 0	56	112	168	84*	Standard error
Barley	33	55	68	78	74	±5·4
Potatoes	36	47	48	55	60	±7·6
Sugar beet	67	73	89	105	80	±9·0

* with methyl bromide

All the crops responded well to fertiliser-N up to the most tested, but barley recovered only 27% of the dressing, sugar beet 23% and potatoes 11%. Barley and potatoes from plots treated with methyl bromide contained more N than from untreated plots with equivalent fertiliser-N, but all the experiments were too inaccurate for this difference to be significant.

At Rothamsted grass usually recovers considerably more of a fertiliser dressing than arable crops do. Table 6 shows that at Saxmundham grass recovered between 30 and 44% of the N. More was recovered from the

https://doi.org/10.23637/ERADOC-1-120

smallest dressings and by the more frequent cutting (39% of 112 lb/acre applied to a crop cut twice was recovered and 44% of 168 lb/acre given to grass cut three times). At Rothamsted grass rarely recovers less than half of the N applied, and commonly recovers two-thirds to three-quarters.

The small efficiency of N fertiliser at Saxmundham is serious because it increases the costs of growing either arable crops or grass. Unless later work with grass can show how to use N more efficiently, legumes may prove to be more profitable herbage crops. In 1967 red clover produced about the same weight of dry matter containing as much N as grass manured with 224 lb N/acre. Both crops had about the same amounts of P and K, but the grass needed nitrogen fertiliser that cost at least £10/acre to buy and apply. (R. J. B. Williams and G. W. Cooke)

https://doi.org/10.23637/ERADOC-1-120