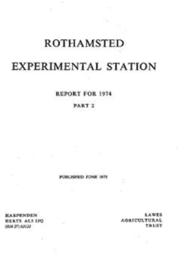
Rothamsted Experimental Station Report for 1974 Part 2


ROTHAMSTED
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The Achievements of Ten Years' Work at Saxmundham Experimental Station

G. W. Cooke

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The Achievements of Ten Years' Work at Saxmundham Experimental Station

G. W. COOKE

Two long-term experiments were laid down at Saxmundham in 1898 under the auspices of the Education Committee of the East Suffolk County Council. The first harvest was in 1899 and this year the Station celebrated its 75th anniversary with an Open Day for local farmers and advisers. Mr. A. W. Oldershaw supervised the Station from 1911 to 1947; in the latter year control passed to the newly-established National Agricultural Advisory Service (NAAS) and Mr. P. J. O. Trist became Director and was responsible for Saxmundham until the ARC took over the land in 1964 and placed the work in the charge of Rothamsted. In the whole 75 years the Station has had only three foremen; C. Cattermole for the first 40 years, H. Neal for nine years and since 1948 V. C. Woolnough. In 1974 we were pleased that Mr. Woolnough's faithful work for the Station was recognised by the award of the British Empire Medal in the Queen's Birthday Honours List.

The continuous control by (virtually) only two Directors and three foremen in 65 years meant that the experiments had been faithfully continued according to the original plans and that meticulous records of yields had been obtained. Rothamsted workers had been in contact with the Saxmundham experiments since they began and Sir John Russell was a frequent visitor. From preliminary work on the soils (Cooke, Mattingly & Williams, 1958) we realised the potential value of the long-term experiments to supplement our work on soils and crops of the Classical experiments at Rothamsted and when NAAS indicated that they might relinquish control, we suggested to ARC that continuing the work under Rothamsted auspices could be valuable.

Our immediate intentions were to modify the experiments so that we could investigate (1) the value of reserves of phosphate accumulated from 65 years of known manuring, and (2) the capacity of the soil to release potassium. After we had assumed control we saw that there were several possibilities of supplementing other Rothamsted work on cereal diseases, crop rotations and the production of herbage crops. We also found the field afforded unique opportunities for investigating the effects of bad soil structure on crop yields and of measuring the losses of nutrients in drainage water. There were originally 8 ha of land at Saxmundham but when we took charge only Harwood's field of 3 ha remained and this contained the Classical experiments that interested us. The work from 1964 was planned by a sub-committee of the Rothamsted Field Plots Committee; Dr. R. Hull of Broom's Barn gave much help in the early years when we were reorganising the Station and starting new experiments. The results obtained in the ten harvest years from 1965 to 1974 are summarised below.

Improved yields

Overall improvements in yield are shown by the following data for crops receiving the largest manuring in the last 20 years of the Classical period on Rotation I and the new manuring used on this experiment and elsewhere on the field. Much of the gain has been from the increased manuring but better cultivations and the use of new varieties have been important too.

Wheat. The best yield from fertiliser-treated plots was 2·6 t ha^{-1} in 1940–61, 4·4 t ha^{-1} with increased N fertiliser from 1966–69. Elsewhere on the field the 'Intensive Wheat'

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experiment from 1971–73 gave average best yields of about 6 t ha^{-1} of Cappelle-Desprez. In the favourable 1974 season the same variety gave 6·8 t ha^{-1}.

Barley yields in the best plots of Rotation I experiment had averaged 2·5 t ha^{-1} in 1940–61; from 1966–69 revised manuring gave 3·8 t ha^{-1}. On Rotation II experiment barley averaged 4·9 t ha^{-1} from 1970–73; in favourable years 6·3 t ha^{-1} was harvested.

Sugar beet yields from 1956–65 were 25 t ha^{-1} in Rotation I experiment, 39 t ha^{-1} with better manuring in 1966–69. On the modified Rotation II experiment yields from the most favourable treatments averaged 40 t ha^{-1} from 1969–72.

Potatoes were not grown in the Classical experiments and the soil is not suited to the crop. Nevertheless the best plots on Rotation II experiment averaged 43 t ha^{-1} from 1969–72.

Rotation I

This was a Norfolk Four-Course rotation in which roots (mangolds and sugar beet), barley, a legume (beans or peas) and wheat were grown. The main treatments (applied annually) were a factorial test of N, P and K fertilisers and one plot receiving bone meal and another 15 t ha^{-1} of farmyard manure. The small fertiliser dressings thought adequate in 1899 were still being tested in 1964; they had showed that phosphate dressings were essential for all the crops grown and that the rate of release of potassium from reserves in the soil was adequate to replace that removed by crops; potassium fertilisers only gave small increases in yields even at the end of the period. From 1965 the manuring was changed; much larger dressings of nitrogen were applied and phosphate was given to plots which had previously received none. The results of the next four years were reported by Williams and Cooke (1971). The capacity of the soil to release K appeared not to diminish in spite of the larger crops grown; on average 45 kg K ha^{-1} were removed each year. Fresh K fertiliser gave small increases in wheat and bean yields but not in barley or beet. The amounts of P and K removed by crops and the additions by fertilisers were used to construct a nutrient balance; gains and losses were linearly related to sodium-bicarbonate soluble soil P and to exchangeable K.

As we had not succeeded in depleting soil K sufficiently to measure large responses to K fertiliser by 1969 we decided to put the experiment under herbage crops. This change, made in 1970, is intended to speed work on the release of potassium, and on solubility relationships of soil phosphate, because herbage crops remove much more P and K than arable crops do. We also intend to measure the improvement in soil structure caused by growing herbage crops. At present half of each plot is under timothy-meadow fescue ley treated with N fertiliser, half is under lucerne (which receives no N). Both leys persisted well into 1974 (their fifth year) and they gave similar yields of dry herbage.

Rotation II

This second Classical experiment had tested dressings of farmyard manure and superphosphate which had left a range of phosphate residues in the soil. Our intention here was to measure the accumulations of P and to test their value in terms of fresh dressings of phosphate as we have done on Rothamsted soil. The early years were spent in augmenting reserves on some plots and in preparing for a period of testing in microplot experiments superimposed on the large plots of the old experiment. The first phase was reported by Mattingly, Johnston and Chater (1970); they discussed crop yields and fertiliser dressings in relation to soil analyses. In the second phase, completed this year,

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barley, potatoes and sugar beet have been grown. The results assessed below are valuable for guiding phosphate fertilising on Beccles series and similar soils.

Soil phosphorus. $NaHCO_3$-soluble P decreased between 1968–74 in all soils which received either no P or 62·5 kg P_2O_5 ha^{-1} every two years; larger dressings (125 and 188 kg P_2O_5 ha^{-1}) maintained, or slightly increased, the amounts of soluble P in the soils.

Crops. Potatoes and sugar beet were grown in rotation with barley: superphosphate was given to the root crops and its residues were valued by barley.

Potatoes. Mean yields averaged 43 t ha^{-1} on plots with most soluble P between 1969–72. They increased at all levels of soluble P (up to 50 mg kg^{-1} of $NaHCO_3$-soluble P); responses to fresh dressings of 125 kg P_2O_5 ha^{-1} decreased from 11·5 t ha^{-1} on the poorest soils to about 1·2 t ha^{-1} on soils enriched with superphosphate from 1965–67. It is a notable feature of this experiment that there has always been some benefit to potatoes from fresh applications of superphosphate, even on soils containing up to 50 mg kg^{-1} of $NaHCO_3$-soluble P.

Sugar beet. Yields varied greatly with season and the mean yields on plots with most soluble P averaged about 6·8 t ha^{-1} of sugar between 1969–72. Maximum yields were obtained on soils containing 25–30 mg kg^{-1} of $NaHCO_3$-soluble P and not given fresh P. Benefits from high levels of soil P were very marked in the early stages of growth, particularly in dry springs (1970 and 1974) but they rarely persisted to harvest. Fresh superphosphate supplying 125 kg P_2O_5 ha^{-1} increased yields greatly (by 1·2–3·5 t ha^{-1} of sugar) on soils from plots where $NaHCO_3$-soluble P was from 3 to 7 mg kg^{-1} but had negligible effects on P-enriched soils (30–50 mg kg^{-1} of soluble P).

Barley. The best yields of Julia barley reached 6·3 t ha^{-1} on some plots in 1972 and averaged 4·9 t ha^{-1} on plots with most soluble P between 1970 and 1973. Yields were slightly larger (by 125–200 kg ha^{-1}) on soils containing 25–50 mg kg^{-1} of $NaHCO_3$-soluble P than from those containing a little less P. Residues from 125 kg P_2O_5 ha^{-1} applied to the preceding root crop, increased yields by 0·5–2 t ha^{-1} of grain on soils low in $NaHCO_3$-soluble P (3–7 mg kg^{-1} of P) but slightly decreased yields on soils containing more soluble P. Yields following potatoes were slightly greater than after sugar beet, probably because potatoes left larger N residues in the soil.

New experiments on cereals

Wheat. In 1965 we began an experiment at Saxmundham to see if we could obtain wheat yields on the calcareous Boulder Clay (Beccles series) soil as large as the 6 t ha^{-1} or more that can be expected on Batcombe series silty clay loam (over Clay-with-flints) at Rothamsted, and whether take-all and eye-spot diseases were as damaging to wheat grown after wheat as they can be at Rothamsted. Wheat was grown continuously and in sequences following breaks of grass ley and beans. The results were reported by Slope, Etheridge and Williams (1973). Wheat yielded up to 5·5 t ha^{-1} after ley in 1967 and 5·8 t ha^{-1} after beans in 1968 but less than 4 t ha^{-1} after beans in 1969 and 1970. We could not identify the reasons for these poorer crops. Root diseases were unimportant after the break. Foliar pathogen attacks were more severe than they usually are at Rothamsted but they were as severe in 1967 and 1968 when yields were good as in the other years.

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We were forced to conclude that bad soil conditions limited yields of wheat that was free from root disease. The soil is difficult to cultivate and structure problems often occur, accentuating the effects of bad weather. Wet autumns make cultivations especially difficult, the seedbeds are cloddy, adversely affecting establishment and early growth of autumn-sown crops. Heavy rain after applying N fertiliser in spring may cause much leaching. Drought in summer can be very damaging because roots of annual crops do not penetrate deeply and the relatively small amount of available water which the soil holds (Salter & Williams, 1969) is soon exhausted.

Where wheat followed wheat, take-all was prevalent as expected and the damage done was greatest in years when yields of wheat after a break were largest. Even so wheat after wheat yielded more in 1967 and 1968 than wheat after beans in 1969 and 1970. It seemed that wheat yields at Saxmundham were more affected by weather and soil conditions than by take-all and eye-spot diseases. Nevertheless take-all can cause serious loss in wheat following wheat. The experiment showed that the take-all decline phenomenon can occur at Saxmundham as it does at Rothamsted.

In 1971 the experiment was modified to accommodate tests of seed rates, row spacings and varieties. A test of different rates of nitrogen in spring was retained but the N was applied in April instead of March. Great care was taken with all cultivations, extra P and K fertilisers were applied before sowing and a dressing of nitrogen was applied in autumn to ensure that early spring growth was not limited by N-deficiency. Wheat was grown continuously. In the first three years (1971–73) yields averaged 5·5 t ha^{-1}, the best treatment yielding over 6 t ha^{-1}. The average was a little larger than the average (4·8 t ha^{-1}) of the same variety, Cappelle-Desprez, grown on Broadbalk in the same three years. In 1974 the best yields, grown with crops sprayed with chlormequat chloride (CCC) to control lodging, were: Cappelle-Desprez 6·83 t ha^{-1} (54 cwt acre^{-1}) and Maris Huntsman 7·59 t ha^{-1} (60 cwt acre^{-1}). In other experiments on wheat we have tested extra water and extra potassium fertiliser; neither increased yields.

Barley. A series of barley experiments was begun in 1967 to compare short and tall varieties of barley treated with two rates of nitrogen, each applied either early (to the seedbed in March or April) or as a top dressing in mid-May. A soil sterilant (formalin), tested in the first two years (Widdowson & Penny, 1970), increased grain yield only by 0·2 t ha^{-1}. In the wet 1969 spring the short-strawed variety (Deba Abed) yielded consistently more with May than with seedbed nitrogen, but the tall variety (Maris Badger) did not because it lodged more. A fungicide (ethirimol) increased yields more of the mildew susceptible variety Deba Abed than of Maris Badger. Best yield was 5·1 t ha^{-1} from Deba Abed receiving 150 kg N ha^{-1} in May.

In 1970 and 1971 the brown-rust susceptible varieties Sultan (tall) and Midas (short) were grown and the yields were much smaller (only 2·5–3·3 t ha^{-1}) than in the previous three years; both varieties were attacked by brown rust which seemed to explain the poor yields.

The experiments made on barley at Saxmundham from 1967 to 1971 showed: (1) the advantage of growing a short stiff-strawed variety; (2) in wet springs nitrate was easily leached from this under-drained sandy clay soil; (3) there was little benefit from doubling the N dressing from 75–150 kg N ha^{-1}; (4) there were only small gains in yield from a soil sterilant (formalin), a systemic fungicide to control mildew (ethirimol), and a growth regulator (phenyl phosphinic acid).

From 1972–74 yields from further experiments ranged from 4·4–5·0 t ha^{-1}. The short-strawed variety (Midas) had no advantage over Julia; 100 kg N ha^{-1} was sufficient for maximum yield, 150 kg N ha^{-1} produced little more grain; nitrogen applied at sowing in March gave larger yields than May nitrogen in 1972 and 1974 (when the

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springs were dry) and a fungicide (Benodanil) tested against brown rust increased yields of Midas by 0·4–0·5 t ha^{-1}. The fungicide most increased yields of barley given ample N, especially when this was applied in May. Applying the fungicide made the nitrogen more efficient.

Soil structure

Difficulties in securing good seedbeds by cultivation, in managing the land to avoid producing clods (which do not readily weather at Saxmundham) and in avoiding surface waterlogging and runoff of heavy rain were apparent in the early years at Saxmundham. They are referred to in the earlier section on wheat experiments. The field was thoroughly examined by the Soil Survey and Hodge (1972) described the soils; most of the land is classed as Beccles series (Corbett & Tatler, 1970). This soil series occurs in scattered areas over Norfolk and Suffolk; it is typical of sandy clay soils which occur in Eastern England and is one of the kinds of soils where heavy mechanical cultivation often leads to bad soil structure and poor yields (a phenomenon discussed by the Agricultural Advisory Council, 1970).

When the problems were realised detailed work was done to try and assess them and many comparisons were made with the clay loam and silt-loam soils at Rothamsted where good and stable structure is the rule rather than the exception and where cereals have yielded consistently more than at Saxmundham.

Measurements, and experiments made to improve structure, were described by Cooke and Williams (1972). Differences in mechanical composition seemed responsible for differences between Rothamsted and Saxmundham soil; Saxmundham soil has 30–40% coarse sand and 20–30% fine sand and little silt; the easier-working Rothamsted soils have little coarse sand but 50–60% of fine sand plus silt; clay contents are similar. Soil structure at Saxmundham was greatly improved by leys, particularly with lucerne, but the effects were not long lasting. A soil conditioner (such as 'Krilium') stabilised structure but did not improve yields. It was concluded that liability to deterioration of structure was an inherent feature of Saxmundham soil and was associated with its mechanical composition. Problems of bad structure were extremely difficult to solve and were best avoided by cultivating skilfully and with appropriate implements. When the land is used for rotations of herbage crops and cereals the structure is improved by the herbage crops; cereal growing involves less risk of structural damage than growing root crops, particularly when these have to be harvested in a wet autumn.

The basic characteristics that cause 'structural' problems at Saxmundham are (1) bad drainage; (2) instability of soil crumbs when wetted—this leads to large bulk density (and smaller pore space); (3) the failure of sub-surface clods to weather so the lower parts of seedbeds are cloddy and massive structures formed by cultivations persist. Rothamsted soil does not have these characteristics; its stable units are often small aggregates (2–4 mm diameter); Saxmundham aggregates of this size are not stable, the ultimate stable units are the fine particles of the soil or the massive clods formed by cultivation.

Experiments on herbage crops

Experiments on herbage crops were made at Saxmundham by Oldershaw (1934). The work started in 1902 and much of it was involved in improving self-sown grassland by basic slag. Only small quantities of nitrogen were tested and hay yields never exceeded 4·4 t ha^{-1}. Later work tested leys including lucerne and red clover and yields averaged 6 t ha^{-1}. We made experiments from 1967–71 to test dressings of nitrogen up to 500 kg N ha^{-1} on swards of timothy and meadow fescue and also to examine the responses

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of lucerne and red clover to P and K fertilisers. The results were summarised by Williams and Cooke (1972).

Grass leys that were cut gave large yields when given much N (12·5 t ha^{-1} of dry matter was average). Recoveries of nitrogen varied greatly from 44% in the year the leys were established (1967), to 83% in 1968 and to 54% in 1969. Anhydrous ammonia injected by hand was slightly superior to single dressings of 'Nitro-chalk' in the wet 1969 spring and its efficiency was improved by treating it with a nitrification inhibitor, but best yields (15 t ha^{-1} of dry matter) were obtained when three dressings of 'Nitro-chalk' were applied.

Lucerne yielded more than red clover and persisted better. Yields of both crops were increased by P and K fertilisers. Yields of lucerne in its second and third years exceeded 13 t ha^{-1} of dry matter—practically as much as was obtained from the grass leys treated with nitrogen. The maximum N harvested in lucerne was 456 kg N ha^{-1} in 1968; over three years the total amount harvested was 981 kg N ha^{-1}.

White clover–grass leys yielded well when cut at 'grazing' stage in 1969—a wet year; they gave 8·3 t ha^{-1} of dry matter containing 250 kg N ha^{-1}; but in the following dry year yield was only one-third as much.

The amounts of P and K fertilisers needed to maintain both yields and the amounts of soluble P and K in soils were estimated for both the grass swards treated with N and the two tap-rooted legumes.

In years with adequate rain there appeared to be no problems in producing large yields of either grass or legumes at Saxmundham such as we have met with arable crops. In 1968 and 1969 the grass leys yielded more than we normally harvest in similar small-plot experiments at Rothamsted. From 1972 to 1974 each spring at Saxmundham has been dry and yields of grass leys treated with N have been smaller than at Rothamsted. However lucerne yielded at least as well there as at Rothamsted and persisted much longer (at Rothamsted third-year crops are often damaged seriously by Verticillium wilt and other diseases). The structure of the Saxmundham soil was much improved by both red clover and lucerne, but the improvement was not long-lasting. Three years of grass also improved the workability of the soil when it was ploughed.

Rotation I experiment was sown to leys in 1970 (half the area is under grass and half under lucerne); lucerne has persisted well through four harvest years and average annual yields of dry matter (t ha^{-1}) have been:

	Lucerne	Grass ley treated with N fertiliser
1971	13·0	12·1
1972	9·3	9·7
1973	8·5	8·8
1974	8·7	8·6

It is clear that herbage crops yield and persist well on the Beccles series soil at Saxmundham. Cereals can also give good yields when skilfully managed. It seems probable that suitable farming systems should involve rotations of herbage crops (with a strong preference for lucerne) followed by cereals. Herbage crops leave soil with improved structure when the land is ploughed and would maintain the best possible physical properties in this soil. Whether this improvement can improve yields of following cereals remains to be determined when leys on Rotation I experiment are ploughed. There are no serious nutritional problems at Saxmundham except the liability of nitrogen fertilisers to be inefficient when leaching is severe in wet periods. Phosphate is often needed, but satisfactory levels of soil P are easily maintained. The soil releases much potassium, but small fresh dressings of K fertiliser now increase the yields of herbage legumes, wheat and beans.

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Losses of nutrients in drainage water

Beccles series soil usually has poor permeability to water and most soils that are used for arable farming are tile-drained. The Saxmundham field had a drainage system that was installed last century and Oldershaw made observations on rate and duration of drainage flows. Extra drains were put in by NAAS in 1948; this system served only about half of the field, but it worked well. We realised that drainage water analyses might show how much nutrients were lost from the soil annually and sampling began in 1966. We have complete records of flows and analyses of the water since 1967. The results up to 1970 were reported fully by Williams (1971); Cooke and Williams (1973) have published some of the more recent data. Autumn drainage from arable land is rich in nitrate (20–50 mg $litre^{-1}$ NO_3-N); later the concentration falls to about 10 mg $litre^{-1}$. Occasionally heavy rain in April and May has caused large drain flows and this water has been rich in nitrate—some samples have contained up to 100 mg NO_3-N $litre^{-1}$. The average concentration of nitrate for the whole year is about 15 mg NO_3-N $litre^{-1}$. Total loss depends on the amount of drainage. In years when Saxmundham has its average rainfall (about 650 mm), well distributed through the year, about 20 kg ha^{-1} of NO_3-N is lost. In very wet years (such as 1968–69), the loss has been 50 kg ha^{-1} and in very dry years (for example 1972–73), very little nitrate has been lost.

A new system installed in 1972 has lines of pipes which drain separate sections of the field; the whole field is now well-drained and it has been much easier to cultivate in good time, particularly in autumn. The new system allows drainage from the grass and arable sections to be collected separately. We have found that about four times as much nitrate is lost per hectare from the arable as compared with losses from the area of herbage crops (part lucerne which receives no N fertiliser, part grass which receives about 250 kg ha^{-1} of N annually). Average compositions of drainage in the last season were about 20 mg NO_3-N $litre^{-1}$ from the arable areas and only 5 mg $litre^{-1}$ from the areas of herbage crops.

Very little phosphate is lost in drainage, the average concentration is about 0·04 mg P $litre^{-1}$ and the average annual loss is less than 0·1 kg P ha^{-1}. Losses of other nutrients are much larger. Our approximate estimates are, per hectare:

300 kg Ca, 15 kg Mg, 4 kg K, 35 kg Na, 24 kg N, 0·08 kg P, 100 kg S and 90 kg Cl.

The losses of calcium are unimportant as the soil has a large reserve of calcium carbonate. Losses of sulphur are much larger than the rain and fertilisers used supply; we now conclude that 'dry deposition' of sulphur in particulate material and absorption of SO_2 by soil and plants is the likely cause of this discrepancy. The same reason may explain the fact that rain supplies less sodium and chlorine than is removed in drainage.

Work on the Saxmundham drainage water has allowed us to quantify losses of nutrients; in particular it has drawn attention to the losses of nitrate which vary with rainfall and are large in wet years. It also shows that observations on drainage flows and analyses of the water should be useful to advisory officers.

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