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NITROGEN FERTILIZERS FOR SPRING BARLEY AND WHEAT

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(With Plate 11)

Stiff-strawed varieties of winter wheat have been generally grown for some years, they give large and consistent increases in yield from generous nitrogen manuring. Previously the risk of lodging made it undesirable to apply heavy dressings of nitrogen but, with the newer varieties, this restriction does not apply on most soils, and it is possible for farmers to apply nitrogen freely up to the economic limit of the response. More recently stiff-strawed varieties of spring wheat and barley have been introduced, and heavier dressings of nitrogen may now be given to these crops. The purpose of the experiments described here was to measure the responses by modern varieties of spring wheat and barley to increasing dressings of nitrogen, and also to compare the yields given by alternative methods of application.

Most farmers apply a compound fertilizer containing nitrogen, phosphorus and potassium for spring cereals, this may either be broadcast over the seedbed or combine-drilled with the seed. Most current compound fertilizers supply insufficient nitrogen to give a full crop on the poorer soils, unless excessive quantities of phosphorus and potassium are applied at the same time. In practice, rates of dressing are also limited by the output of the combine-drill and by the capacity of the fertilizer hopper. To overcome these practical limitations seedbed dressings have often to be supplemented with top-dressings of nitrogen after the crop has become established, this allows actual dressings to be adjusted to the fertility of individual fields and to the appearance and growth of the crop. Previous experimental work (Crowther, 1945) showed that combine-drilled dressings of phosphorus and potassium produced higher yields of cereals than equivalent broadcast dressings, but there is little experimental evidence on the relative values of drilling and broadcasting for nitrogen. These experiments compared ammonium sulphate combine-drilled with dressings broadcast over the seedbed immediately after sowing. In addition, comparisons were made between dressings of ammonium sulphate given at sowing and equivalent top-dressings of nitrogen as 'Nitro-Chalk' applied in mid-May.

NATURE OF THE EXPERIMENTS

Sites for the fourteen experiments carried out over three seasons (1954–6) were selected on different kinds of soil in Bedfordshire and Hertfordshire. Spring wheat was grown on most of the heavy soils, but on the lighter land the experiments were on barley.

In the 1954 experiments comparisons were made between equivalent combine-drilled and broadcast seedbed dressings of ammonium sulphate; in addition the response to combine-drilled superphosphate was measured at each centre by including a plot without N or P. The effect of a top-dressing of 4 cwt./acre of 'Nitro-Chalk' (0·6 cwt. N/acre) applied in mid-May was also examined. The main plot comparisons and the dressings/acre in the 1954 experiments were:

(1) No nitrogen or phosphorus.
(2) Superphosphate only.
(3) Superphosphate + 0·25 cwt. N, as ammonium sulphate broadcast on seedbed.
(4) Superphosphate + 0·50 cwt. N, as ammonium sulphate broadcast on seedbed.
(5) Superphosphate + 0·25 cwt. N, as ammonium sulphate combine-drilled.
(6) Superphosphate + 0·50 cwt. N, as ammonium sulphate combine-drilled.

All dressings of superphosphate supplied 0·5 cwt. P_2O_5/acre and were combine-drilled; every plot received a basal dressing of 2 cwt./acre of potassium sulphate broadcast after drilling. Individual plots contained eleven rows spaced 7 in. apart and were 88 yards long. In mid-May one-half of each main plot (selected at random) was top-dressed with 4 cwt./acre of 'Nitro-Chalk'. The six main treatments were arranged in a randomized block and there were three blocks at each centre.

The experiments were continued in 1955 in modified form. Top-dressings of 'Nitro-Chalk' were included in the main-plot comparisons and were applied at the same rates as the drilled and broadcast seedbed dressings. The experimental treatments and the dressings/acre were:

(1) No nitrogen or phosphorus.

(2) Superphosphate only.

(3) Superphosphate + 0·25 cwt. N, as ammonium sulphate broadcast on seedbed.

(4) Superphosphate + 0·50 cwt. N, as ammonium sulphate broadcast on seedbed.

(5) Superphosphate + 0·25 cwt. N, as ammonium sulphate combine-drilled.

(6) Superphosphate + 0·50 cwt. N, as ammonium sulphate combine-drilled.

(7) Superphosphate + 0·25 cwt. N, as 'Nitro-Chalk' applied as top-dressing in May.

(8) Superphosphate + 0·50 cwt. N, as 'Nitro-Chalk' applied as top-dressing in May.

All superphosphate dressings supplied 0·5 cwt. P_2O_5 and were combine-drilled. In addition treatments 3, 4, 5 and 6 were repeated with the addition of 0·50 cwt. N/acre applied as a top-dressing of 'Nitro-Chalk' in mid-May. The twelve experimental treatments were arranged in a randomized block and there were three blocks at each centre. Individual plots were 44 yards long and 7 ft. wide (1/47th acre).

In 1956 the experimental design was again modified, all plots received a broadcast basal dressing of superphosphate and muriate of potash, treatment 1 (no N or P) was replaced by a test of 1·00 cwt. N/acre applied as a single top-dressing of 'Nitro-Chalk' in mid-May. The twelve experimental treatments were arranged in a randomized block and again there were three blocks at each centre.

Methods of laying down the experiments

In 1954 and 1955 granular NP compound fertilizers were used to supply the nitrogen in the combine-drilled dressings. Granular superphosphate was drilled with the seed on each of the remaining plots, except where neither nitrogen nor phosphorus was given; the two compound fertilizers used contained 9 % N, 9 % P_2O_5 and 9 % N, 18 % P_2O_5, respectively. By adjusting the gears of the drill uniform dressings of phosphate were applied together with two levels of combine-drilled nitrogen. Ammonium sulphate was broadcast on appropriate plots immediately after drilling. In 1956 coarsely crystalline ammonium sulphate was used for both combine-drilled and broadcast seedbed dressings, and 4 cwt./acre of a granulated PK compound fertilizer containing 10 % P_2O_5 and 20 % K_2O was broadcast by hand uniformly over each experiment. In each year 'Nitro-Chalk' was broadcast by hand on appropriate plots in mid-May.

A standard combine-drill having twelve coulters spaced 7 in. apart was used in the experiments. It had a star-wheel fertilizer mechanism. Each experiment was marked out and a string set along a plot boundary served as a guide for the tractor driver. The wheel of the drill was run outside this string so that the outer seed coulter ran 3·5 in. inside the plot boundary. The outside right-hand coulter on each plot was not used (the seed being diverted into a box fastened to the foot-board of the drill) to give a space 14 in. wide between adjacent plots. The fertilizer mechanism of the drill was set in the appropriate gear (determined by previous field calibrations). Measurements of the actual amounts of fertilizer delivered by the drill were made at each centre over a distance of 44 yards by diverting the fertilizer into bags attached to the drill, normally two calibrations were made for each setting of the gears at each centre, and their mean value was used to determine the rates of broadcast dressings which were applied after drilling had been completed.

Modern stiff-strawed varieties were grown at all centres except at Wheathampstead in 1954, where Plumage Archer was used. The other barley varieties are listed below. Proctor was grown at Hertingfordbury in 1954 and 1956, at Essendon in 1955 and at Wheathampstead in 1955 and 1956, at Hitchin in 1956 and at Ridgmont in 1956. Herta was grown at Kensworth and Marston Valley in 1956. Svenno spring wheat was grown at Northaw in 1956 but all other crops were Atle.

After the crop was well established a path 14 in. wide was cut across each end of each experiment with a small rotary hoe to facilitate harvesting. Normally the whole plot area was cut by combine-harvester. At some centres the plots were cut by binder, stooked and threshed with a small portable threshing machine. Samples of grain were taken from each plot for dry-matter and nitrogen determinations and all yields have been corrected to 15 % moisture content. At some centres in 1955 and 1956 yields of straw were also recorded, a small hay sweep attached to a self-propelled motor scythe being used to collect the straw. To secure satisfactory yields of straw the cutter-bar of the combine must be maintained at constant height. At some centres samples of straw from bulked treatments were taken for dry-matter and nitrogen determinations.

The gains from applying superphosphate alone were measured in 1954 and 1955, the effects were small and as none were significant they are not discussed here.

RESULTS OF THE EXPERIMENTS

Effects on yields of grain

Detailed results for grain yields and percentages of nitrogen in the grain at each centre are set out in the Appendix Tables. Mean yields without nitrogen and the average increases from seedbed dressings of ammonium sulphate and top-dressings of 'Nitro-Chalk' in each year are given in Table 1 for barley and wheat separately. The results are also summarized in Table 2 for each of the 3 years after averaging experiments on barley and wheat.

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Significant increases in yield from broadcasting or combine-drilling 0·25 or 0·50 cwt. N/acre were obtained at all centres where barley was grown except Hertingfordbury in 1954 (where the low rate broadcast gave a non-significant increase) and at Marston Valley in 1956 (where none of the increases were significant) (Appendix Table 1). Direct comparisons between seedbed applications and top-dressings at the same rate of dressing were not possible in 1954, and estimates of the yields given by top-dressings

Table 1. *Yields without nitrogen and mean increases in yield from seedbed dressings of ammonium sulphate and top-dressings of 'Nitro-Chalk' in spring-sown cereal experiments*

Crop	Barley	Wheat
No. of experiments	10	4
	Yields of grain (cwt./acre)	
Without nitrogen	20·2	21·0
	Increases in yield (cwt./acre)	
Low rate (0·25 cwt. N/acre)		
Broadcast on seedbed	6·5	1·7
Drilled on seedbed	7·7	1·7
Top-dressed in May	(6·2)*	(1·4)*
High rate (0·50 cwt. N/acre)		
Broadcast on seedbed	9·7	2·7
Drilled on seedbed	12·1	3·1
Top-dressed in May	(9·2)*	(1·9)*
Low rate on seedbed + high rate as top-dressing		
Broadcast on seedbed	12·8	2·7
Drilled on seedbed	13·2	3·2
High rate on seedbed + high rate as top-dressing		
Broadcast on seedbed	13·3	3·1
Drilled on seedbed	12·8	3·5

* Takes into account estimated values for the 1954 experiments.

equivalent to the seedbed dressings used have been obtained by graphical interpolation; no tests of significance can be applied to these data. On average of ten barley experiments combine-drilled dressings produced higher yields of grain at both levels of manuring than either seedbed applications or top-dressings (Table 1).

Responses to nitrogen dressings were much smaller in the spring wheat experiments, which were all situated on heavy clay–loam soils. Broadcasting or drilling ammonium sulphate on the seedbed had only small effects in 1954 or 1955, but at Northaw in 1956 there were significant increases in yield from these dressings. May top-dressings were markedly superior to seedbed applications for wheat at Northaw in 1955, when the experiment was sown late on a badly prepared seedbed (Appendix Table 1). The average responses to nitrogen given by spring wheat were only about one-quarter as big as those obtained from equivalent dressings of nitrogen on spring barley (Table 1).

The increases in yield from drilling as compared with broadcasting or top-dressing nitrogen at the two rates of manuring are examined for both crops in Table 2. There were consistent gains from drilling as compared with broadcasting on the seedbed in 1954 and 1956, but in 1955 the results were more conflicting as drilling was only superior to broadcasting when the heavier dressing was applied. On the average of all the experiments, however, there were extra gains in yield from combine-drilling at ten centres when the lower dressing was applied and at eleven centres when the heavier dressing was tested; one of the differences was significant in each case. There were also consistent gains from drilling as compared with top-dressing in 1954 and 1956 (Table 2), but in 1955 top-dressing produced higher increases in yield than combine-drilled dressings at Wheathampstead (barley) and at Northaw (wheat), (these effects were significant at Northaw). Higher yields were obtained from combine-drilling than from top-dressing at ten centres when the lower dressing was applied and at twelve centres when the heavier dressing was being tested. Three of these gains in favour of drilling were significant (out of ten comparisons where tests of significance may be applied).

The increases in yield from combinations of seedbed dressings and top-dressings supplying either 0·75 or 1·0 cwt. N/acre are examined in Table 2. In general, there were worthwhile increases in yield from these heavier dressings (over those given by 0·5 cwt. N/acre combine-drilled) in the 1954 and 1955 experiments although the increases were accompanied at many centres by considerable lodging. In 1956, however, additional top-dressings were of little extra value, and drilling the heavier rate of seedbed dressing was almost sufficient for maximum yields. At some centres in each year yields at the heaviest level of manuring were reduced as the result of lodging, and at most centres there was a marked deterioration in the quality of the grain.

Effects on quality of barley

The extent of lodging in the barley experiments varied from season to season, but in each year top-dressings delayed maturity and increased the risk of laid crops. In 1956 lodging was widespread and the design of the experiments enabled direct comparisons to be made between broadcasting, drilling and top-dressing at rates equivalent to 0·25, 0·50 and 1·00 cwt. N/acre. Visual estimates of the degree of lodging immediately before combine-harvesting were made at Kensworth on the variety Herta and at Hertingfordbury and Ridgmont where Proctor was grown; the results are given in Table 3. A 3 cwt./acre top-dressing of 'Nitro-Chalk' (in the absence of any seedbed dressing) was sufficient to cause lodging at Hertingfordbury and Kensworth. Drilling or broadcasting an equivalent quantity of nitrogen did not affect the standing capacity of the crop at Hertingfordbury, although there was some lodging with these seedbed dressings at Kensworth. Plots receiving the full nitrogen dressing in May (1·00 cwt. N/acre as 'Nitro-Chalk') could be picked out easily at each centre. With this level of top-dressing the crop was quite flat and secondary each group is given in Table 4 and the effects are illustrated in Pl. 11. The method of application had a marked effect on the proportion of first-quality grain and was in fact more important than the actual level of manuring. Top-dressings produced a consistently higher proportion of third-quality grain than either drilled or broadcast seedbed dressings, the difference in quality was measurable even when top-dressing was restricted to 0·25 cwt. N/acre. The importance of these effects is illustrated

Table 2. *Average yields of cereals without nitrogen, the increases given by seedbed dressings of ammonium sulphate and top-dressings of 'Nitro-Chalk', and the numbers of positive, and significant positive effects* (*P* = 0·05 or greater)

	Mean yields (cwt./acre)			All years		
	1954	1955	1956	Yield (cwt./acre)	No. of positive effects	No. of significant positive effects
No. of experiments...	4	3	7	14	—	—
Mean yield without nitrogen	24·8	25·5	15·8	20·4	—	—
Increase in yield from low rate of nitrogen						
Broadcast on seedbed	2·6	5·7	6·4	5·2	13	9
Drilled on seedbed	3·8	4·6	7·9	6·0	12	10
Top-dressed in May*	(2·0)†	4·7	6·5	(4·8)†	13	8*
Increase in yield from high rate of nitrogen						
Broadcast on seedbed	5·0	7·3	9·4	7·7	13	10
Drilled on seedbed	6·8	9·6	11·0	9·5	14	10
Top-dressed in May*	(4·1)†	9·8	7·8	(7·2)†	13	9*
Increase from low rate drilled						
Over broadcasting	1·2	−1·1	1·5	0·8	10	1
Over top-dressing*	(1·8)†	−0·1	1·4	(1·2)†	10	1*
Increase from high rate drilled						
Over broadcasting	1·8	2·2	1·7	1·8	11	1
Over top-dressing*	(2·7)†	−0·3	3·3	(2·4)†	12	2*
Increase from light seedbed dressing + heavy top-dressing						
Broadcast + top-dressing	7·1	11·9	10·6	9·9	13	11
Drilled + top-dressing	8·0	11·1	11·4	10·3	14	11
Increase from heavy seedbed dressing + heavy top-dressing						
Broadcast + top-dressing	7·8	12·7	10·8	10·4	12	12
Drilled + top-dressing	7·4	10·7	11·6	10·2	13	11

* Tests of significance could only be applied in 1955 and 1956 for the marked comparisons (i.e. a total of ten experiments), for all other comparisons tests were made in all fourteen experiments.

† Estimated values for the 1954 experiments are included in data in parentheses, no tests of significance can be applied to these data.

growth in the form of green heads and tillers occurred. Plots receiving the same total quantity of nitrogen, half of which was applied to the seedbed and the remainder as a top-dressing, were also lodged, but not to the same extent.

The samples of wheat and barley from plots receiving the higher levels of manuring were much inferior to those obtained from plots receiving the two lower rates of dressing. The most marked effect was on the colour of the sample, but there was also an increase in the proportion of small grains. It was possible to make quantitative estimates of grain quality at one centre only. Barley samples from Kensworth were divided into first, second, and third quality grain by shaking 100 g. for 1 min. over a set of hand sieves. The proportion of barley falling into in the final column of Table 4 which gives the yield of first quality grain. The highest yield of both ungraded and first quality grain was obtained by combine-drilling 0·5 cwt. N/acre. All of the heavy dressings (1·00 cwt. N/acre) produced lower yields of first quality grain than unmanured plots.

Effects on the amounts of nitrogen in grain

The effects of nitrogen dressings on the percentages of nitrogen in grain are set out for each centre in Appendix Table 2, and a summary is given in Table 5. Applying 0·25 cwt. N to the seedbed had negligible effects on the percentage of nitrogen in the grain, drilled dressings reduced nitrogen percentage in seven of the ten experiments, but top-dressings consistently increased the nitrogen content of the grain even at this low level of manuring. When the dressing was increased to 0·5 cwt. N/acre there were small increases in the nitrogen content of the grain where broadcast or drilled seedbed dressings were given and marked increases from equivalent top-dressings. Wheat and barley behaved similarly. There were further increases in the nitrogen content of the grain when seedbed dressings were supplemented with top-dressings so that a total of 0·75 or 1·00 cwt. N/acre was supplied. These increases in nitrogen content were accompanied by a deterioration in the quality of barley grain and a higher proportion of small unfilled kernels. The 1956 experiments included a test of 1·0 cwt. N/acre applied as a single mid-May top-dressing. The nitrogen content of grain following this treatment was much higher than that given by the same total quantity of fertilizer divided equally between the seedbed and top-dressing.

The recovery of the fertilizer nitrogen varied widely from centre to centre. Yields of straw were only obtained at a few centres and were rather inaccurate owing to inevitable variations in the height of the cutter-bar on the combine-harvester, recoveries of nitrogen in the grain plus straw are therefore not presented. Recoveries of nitrogen in the grain are summarized in Table 6. At the more responsive barley centres 40–50 % of the lower nitrogen dressings were recovered in the grain. The maximum recovery was measured at Ridgmont in 1956, where 78 % of a dressing of 0·25 cwt./acre of nitrogen was contained in the grain. On average for barley combine-drilled dressings of nitrogen appeared to be slightly more efficient than broadcast seedbed dressings. The percentage uptake fell off considerably when the heavier dressings (0·75 and 1·00 cwt. N/acre) were applied. Recoveries of

Table 3. *Effects of different rates and methods of applying nitrogen on the standing capacity of barley in* 1956

	Degree of lodging		
Dressing/acre	Horting-fordbury	Kens-worth	Ridgmont
No nitrogen	0	0	0
0·25 cwt. N broadcast	0	0	0
0·25 cwt. N drilled	0	0	0
0·25 cwt. N top-dressing	0	0	0
0·50 cwt. N broadcast	0	1	0
0·50 cwt. N drilled	0	2	0
0·50 cwt. N top-dressing	2	4	0
Heavy nitrogen dressings			
0·25 cwt. N broadcast + 0·50 cwt. N top-dressing	3	6	1
0·25 cwt. N drilled + 0·50 cwt. N top-dressing	4	6	2
0·50 cwt. N broad-cast + 0·50 cwt. N top-dressing	5	6	2
0·50 cwt. N drilled + 0·50 cwt. N top-dressing	6	6	3
1·00 cwt. N top-dressing	9	9	6

(Marks for individual treatments indicate: 0, no lodging; 3, partly lodged; 6, badly lodged; 9, quite flat.)

Table 4. *The effect of alternative methods of application and increasing rates of nitrogen on the quality of barley at Kensworth in* 1956

		Percentage of sample			
Dressing/acre	Yield as combined (cwt./acre)	Larger than 2·42 mm. (grade 1)	2·42 mm.–2·20 mm. (grade 2)	Passing 2·20 mm. (grade 3)	Yield of first grade grain (cwt./acre)
No nitrogen	22·0	81	10	9	17·9
0·25 cwt. N/acre					
Broadcast on seedbed	30·2	82	9	9	24·9
Drilled on seedbed	30·8	86	7	7	26·4
Top-dressed in May	31·4	69	14	17	21·7
0·50 cwt. N/acre					
Broadcast on seedbed	33·8	80	10	10	27·1
Drilled on seedbed	37·6	79	9	13	29·4
Top-dressed in May	32·9	55	20	25	18·0
0·75 cwt. N/acre					
0·25 cwt. broadcast + 0·50 cwt. top-dressing	36·0	55	18	27	19·9
0·25 cwt. drilled + 0·50 cwt. top-dressing	37·2	65	16	19	24·1
1·00 cwt. N/acre					
0·50 cwt. broadcast + 0·50 cwt. top-dressing	31·2	56	19	25	17·3
0·50 cwt. drilled + 0·50 cwt. top-dressing	32·7	52	19	29	16·9
1·00 cwt. top-dressing	30·5	47	18	35	14·4

applied nitrogen by spring wheat were much lower and in some cases were slightly negative; average effects were considerably influenced by the results at Northaw in 1955, where the experiment was sown late under bad conditions and seedbed dressings were of little value.

Table 5. *The mean percentages of nitrogen in the grain of spring barley and wheat grown without nitrogen fertilizer and the effects of seedbed dressings of ammonium sulphate and top-dressings of 'Nitro-Chalk'*

Crop ...	Barley	Wheat	Both crops
No. of experiments ...	10	4	14
Dressing/acre	Percentage of nitrogen in grain		
No nitrogen	1·50	2·14	1·68
	Increase due to nitrogen fertilizer		
Low rate (0·25 cwt. N/acre)			
Broadcast on seedbed	0·01	0·00	0·01
Drilled on seedbed	−0·03	0·00	−0·02
Top-dressed in May	0·06	0·06	0·06
High rate (0·50 cwt. N/acre)			
Broadcast on seedbed	0·09	0·04	0·08
Drilled on seedbed	0·08	0·08	0·08
Top-dressed in May	0·20	0·15	0·19
Low rate on seedbed + high rate top-dressing			
Broadcast on seedbed	0·28	0·26	0·27
Drilled on seedbed	0·23	0·27	0·24
High rate on seedbed + high rate top-dressing			
Broadcast on seedbed	0·32	0·32	0·32
Drilled on seedbed	0·38	0·32	0·36

Table 6. *The amounts of nitrogen in the grain of unfertilized barley and wheat and the average percentages of applied fertilizer nitrogen which were recovered*

Crop ...	Barley	Wheat	Both crops
No. of experiments ...	10	4	14
Dressings/acre	Nitrogen in unfertilized grain (lb./acre)		
No nitrogen	28·4	42·8	32·5
	Percentage uptake of fertilizer nitrogen		
Low rate (0·25 cwt. N/acre)			
Broadcast on seedbed	34·6	14·1	28·7
Drilled on seedbed	36·8	12·0	29·7
Top-dressed in May	36·6	13·6	30·0
High rate (0·50 cwt. N/acre)			
Broadcast on seedbed	29·6	11·6	24·4
Drilled on seedbed	35·8	15·2	29·9
Top-dressed in May	34·6	11·7	28·0
Low rate on seedbed + high rate top-dressing			
Broadcast on seedbed	31·6	12·1	26·0
Drilled on seedbed	30·3	12·8	25·3
High rate on seedbed + high rate top-dressing			
Broadcast on seedbed	25·8	11·6	21·7
Drilled on seedbed	27·4	12·4	23·1

DISCUSSION

The experiments were carried out on a wide range of soils on commercial farms in Hertfordshire and South Bedfordshire. Most of the barley experiments were situated on medium-textured free-draining soils, but Marston Valley (1956) was on heavy clay soil and Ridgmont (1956) was on light sand. All the spring wheat experiments were on heavy clay-loams. These heavy-land centres were less responsive to the dressings of nitrogen than the lighter centres.

In 1954 the experiments were sown in good conditions in March and April; June, July and August were unusually wet, however, and the summer was marked by a deficit of sunshine and by low temperatures. There were good responses to the dressings of nitrogen by barley grown on the two medium-textured soils and drilled dressings produced consistently higher yields than broadcasting. No direct comparisons were possible in 1954 between top-dressings and seedbed dressings, as top-dressings at a uniform rate were applied to one-half of each main plot, graphical interpolation indicated that equivalent rates of top-dressings were of less value than seedbed dressings. For wheat grown at the two centres on heavy land there was little benefit from the dressings of nitrogen, yields were reduced by the heavier levels of manuring although there was little lodging at either centre.

In 1955 two barley experiments were sown under good conditions, but the spring-wheat experiment was sown late on a bad seedbed following spring ploughing of a heavy clay-loam. Adequate rainfall in May was followed by a long dry spell which lasted until autumn. The yields given by the three methods of application were rather variable. For barley at Essendon drilling was superior to both broadcasting and top-dressing, the experiment following the pattern of the previous year's work. At Wheathampstead drilling was superior to broadcasting for barley when the heavier dressing was applied, but top-dressings were generally of more value. On spring wheat at Northaw seedbed dressings were of little value whereas top-dressings produced significant increases in yield.

All the 1956 experiments were sown under good conditions in March and early April. A long dry spell continued into early June, and crops on many of the experiments suffered from drought, top-dressings given in May were of no value until washed in by rain in June. Thereafter, the growing season was unusually wet with above average rainfall in each month. Under these conditions top-dressings promoted vigorous late growth and much new leaf was formed, the plants changed their habit of growth and many new tillers and ears were thrown up. By harvest top-dressings had produced much lodging and delayed ripening considerably. At some centres practically all the top-dressed plots became lodged, while plots receiving seedbed dressings remained standing. At harvest, combine-drilled dressings produced consistently higher yields than broadcasting. Top-dressings produced lower yields than seedbed dressings at all centres and the effect on the samples of grain was most marked.

This series of experiments indicates that improvements in yield can be obtained by combine-drilling the whole of the nitrogen for spring cereals rather than by broadcasting it on the seedbed. No reductions in yield as a result of fertilizer 'scorch' occurred, although 2·5 cwt./acre of ammonium sulphate was applied in contact with the seed in all experiments. In other experiments still in progress, heavier rates of dressings have been applied by combine-drill safely, even though there was some initial check to growth. It is commonly thought that late top-dressings are less likely to promote lodging than equivalent seedbed dressings, and that they will encourage the production of grain rather than of straw. This has not been the experience in this series of experiments, in fact late dressings have encouraged growth of straw without any commensurate increase in grain yields. Where the late leafy growth resulting from top-dressings coincides with heavy rains in July and August the crop is subject to unnecessary risks from lodging.

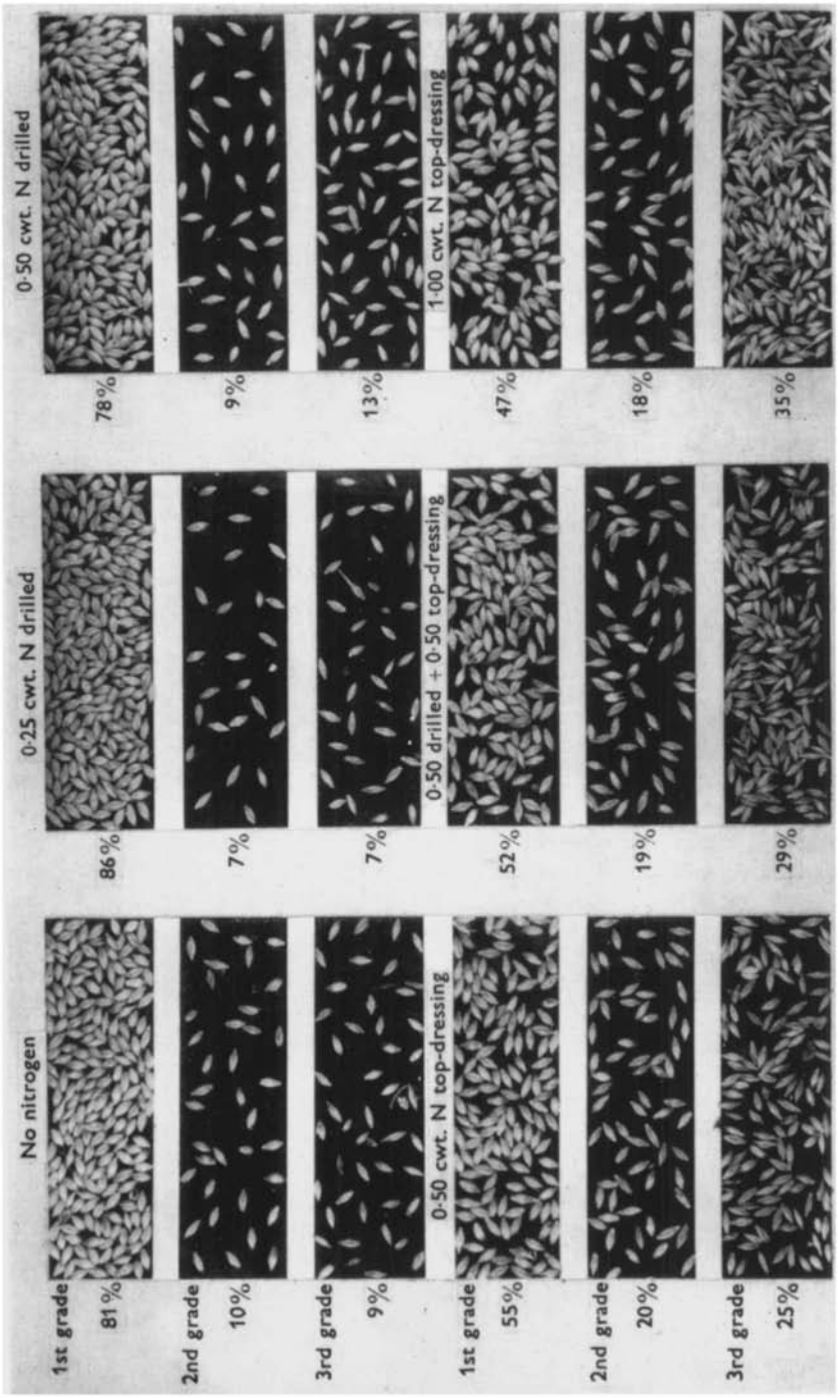
The results of these experiments are in agreement with recent work on main-crop potatoes (Cooke, Widdowson & Wilcox, 1957). In both sets of experiments it was important to supply adequate nitrogen in the early stages of growth. Later dressings of nitrogen promoted vegetative growth which was not reflected in higher yields of grain or tubers. Farmers may be advised to apply the whole of their nitrogen for spring-sown cereals at planting as later dressings have been less efficient, caused more lodging, and produced a poorer sample of grain. May top-dressings generally increase the percentage of nitrogen in the grain, and may be of some value where barley is grown for feeding, but it is difficult to say whether this increase in protein is justified on economic grounds, since if lodging occurs, the cost of harvesting may be increased.

The experiments indicate that about 0·6 cwt. N/acre may be sufficient for maximum yields of barley. It was not possible to explore potential yields at higher levels of manuring, since severe lodging was caused by top-dressings applied after moderate seedbed dressings at many centres. It is possible that heavier dressings applied by combine-drill would produce still higher yields, and that the risk of lodging would be reduced by applying the whole of the nitrogen in this way. New compound fertilizers containing percentages of N about twice as great as the percentages of P_2O_5 and K_2O will be required if advantage is to be taken of this experimental work. It is wasteful to apply excessive quantities of phosphorus and potassium in order that sufficient nitrogen may be applied to the crop. In addition, mechanical limitations and hopper capacity frequently set a limit to the output of combine-drills, and restrict the quantity of nitrogen which may be applied with current compound fertilizers.

This work has been carried out in a restricted area of the Eastern Counties, it needs to be extended to other areas so that more general recommendations on manuring spring cereals may be made.

SUMMARY

1. Ten experiments on spring barley (mainly Proctor) and four on spring wheat (mainly Atle) in 1954–6 compared 0·25 and 0·5 cwt. N/acre (as ammonium sulphate) when drilled with the seed, with dressings broadcast before sowing. Tests were also made of 'Nitro-Chalk' dressings given in mid-



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May. In heavier split applications seedbed dressings were supplemented by top-dressings of 0·5 cwt. N/acre.

2. Barley gave much larger average responses than wheat. For barley combine-drilling 0·25 or 0·5 cwt. N/acre gave consistently larger yields than broadcasting the same nitrogen dressing on the seedbed; for wheat combine-drilling gave slightly higher yields at the high rate of dressing only.

3. For both crops 0·5 cwt./acre of N drilled with the seed was almost sufficient for maximum yields, but where only 0·25 cwt. N was applied at sowing a mid-May top-dressing of 0·5 cwt. N/acre gave higher yields.

4. At most centres May top-dressings of 'Nitro-Chalk' gave lower yields than equivalent ammonium sulphate drilled with the seed. Yields were often reduced by lodging on plots which received seedbed dressings plus top-dressing or the heavier rates of top-dressing alone; these treatments also reduced the quality of the grain. Combine-drilled or broadcast seedbed dressings did not cause serious lodging or reduce grain quality.

5. 0·25 or 0·5 cwt. N/acre broadcast on the seedbed or combine-drilled had little effect on the percentage of nitrogen in the grain; equivalent top-dressings in mid-May consistently increased nitrogen content. Seedbed dressings plus top-dressings supplying heavier total quantities of nitrogen continued to increase nitrogen percentage in grain without giving any increase in yield.

6. On average about one-third of dressings supplying 0·5 cwt. N/acre was recovered in barley grain, wheat grain recovered only about one-eighth of the nitrogen applied. Percentage recoveries of nitrogen from heavy dressings applied partly on the seedbed and partly as top-dressings were rather smaller.

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REFERENCES

COOKE, G. W., WIDDOWSON, F. V. & WILCOX, J. C. (1957). *J. Agric. Sci.* **49**, 81.
CROWTHER, E. M. (1945). *Agriculture, Lond.*, **52**, 170.

EXPLANATION OF PLATE

Changes in the saleable proportions of barley from combine drilling or top-dressing with nitrogen (Kensworth, 1956).

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APPENDIX

Table 1. *Unmanured yields of grain and the increases in yield from seedbed dressings of ammonium sulphate and top-dressings of 'Nitro-Chalk' in experiments on spring-sown cereals*

(Significant effects are marked * for $P=0·05–0·01$; ** for $P>0·01$)

Centre	Unmanured yields	Increase from low rate of nitrogen			Increase from high rate of nitrogen			Increase from heavy top-dressing with low rate of ammonium sulphate		Increase from heavy top-dressing with high rate of ammonium sulphate		Increase from 1·0 cwt. N/acre all as top-dressing	S.E. of increases
		Broad-cast	Drilled	Top-dressed	Broad-cast	Drilled	Top-dressed	Broad-cast	Drilled	Broad-cast	Drilled		
	Yields (in cwt./acre) of grain containing 15 % moisture												
Experiments on barley													
1954													
Hertingfordbury‡	25·1	6·1	7·5*	(5·8)†	10·2**	13·7**	(12·0)†	15·6**	17·6**	21·2**	16·0**	—	2·90
Wheathampstead‡	20·9	4·5*	6·1*	(3·2)†	8·1**	9·2**	(6·2)†	12·8**	13·5**	12·2**	13·0**	—	1·96
1955													
Essendon‡	32·0	9·9**	9·2**	4·9	13·0**	17·9**	13·9**	16·9**	15·8**	16·3**	13·4**	—	2·59
Wheathampstead‡	26·1	5·0**	4·7**	6·3**	7·0**	8·8**	9·5**	12·1**	11·0**	11·9**	11·5**	—	1·02
1956													
Hertingfordbury‡	13·7	6·0**	7·9**	7·0**	10·7**	13·7**	9·4**	14·3**	14·6**	14·9**	16·2**	9·6**	1·02
Hitchin‡	20·2	6·8**	8·3**	4·0**	8·8**	8·2**	6·7**	6·3**	7·8**	5·7**	7·3**	3·8**	1·32
Kensworth§	22·0	8·2**	8·8**	9·4**	11·8**	15·6**	10·9**	14·0**	15·2**	9·2**	10·7**	8·5**	2·49
Marston Valley§	15·1	1·1	3·2	3·1	2·3	4·0	0·5	3·8	2·9	6·8**	4·5	1·9	2·32
Ridgmont§	12·2	10·8**	13·5**	12·0**	16·0**	18·6**	15·0**	18·2**	19·4**	18·8**	19·4**	18·0**	1·26
Wheathampstead‡	14·9	7·0**	8·1**	6·3*	9·1**	11·0**	8·4**	13·7**	14·0**	15·6**	16·3**	12·9**	2·38
Mean of ten experiments	20·2	6·5	7·7	(6·2)†	9·7	12·1	(9·2)†	12·8	13·2	13·3	12·8	—	—
Experiments on wheat													
1954													
Northaw‡	29·0	0·1	−0·1	(0·1)†	2·2	2·4	(0·3)†	−0·8	0·7	−0·5	1·0	—	1·82
Tilsworth§	24·4	−0·4	1·6	(−1·2)†	−0·3	1·9	(−2·2)†	0·9	0·2	−1·7	−0·6	—	1·19
1955													
Northaw‡	18·5	2·1	−0·1	2·8*	2·0	2·0	6·1**	6·8**	6·4**	9·8**	7·2**	—	1·28
1956													
Northaw‡	12·2	4·9**	5·3**	3·8*	6·9**	6·2**	3·5*	3·8*	5·7**	4·9**	6·5**	2·6	1·38
Mean of four experiments	21·0	1·7	1·7	(1·4)†	2·7	3·1	(1·9)†	2·7	3·2	3·1	3·5	—	—
Mean of fourteen experiments on wheat and barley	20·4	5·2	6·0	(4·8)†	7·7	9·5	(7·2)†	9·9	10·3	10·4	10·2	—	—

† Estimated values are included in averages given in parentheses. ‡ Hertfordshire. § Bedfordshire.

Table 2. *Percentages of nitrogen in the grain of barley and wheat grown without nitrogen dressings and the increases in percentage of nitrogen given by seedbed dressings of ammonium sulphate and top-dressings of 'Nitro-Chalk'*

Centre	Without nitrogen	Increase from low rate of nitrogen			Increase from high rate of nitrogen			Increase from heavy top-dressing with low rate of ammonium sulphate		Increase from heavy top-dressing with high rate of ammonium sulphate		Increase from 1·0 cwt. N/acre all as top-dressing
		Broadcast	Drilled	Top-dressed	Broadcast	Drilled	Top-dressed	Broadcast	Drilled	Broadcast	Drilled	
Experiments on barley												
1954												
Hertingfordbury‡	1·42	−0·01	−0·06	(0·06)†	0·04	−0·02	(0·11)†	0·31	0·28	0·13	0·50	—
Wheathampstead‡	1·31	−0·11	−0·10	(0·06)†	−0·01	−0·07	(0·11)†	0·16	0·13	0·24	0·24	—
1955												
Essendon‡	1·39	0·08	−0·02	−0·04	0·06	0·10	0·14	0·28	0·23	0·33	0·47	—
Wheathampstead‡	1·41	0·09	0·04	0·12	0·09	0·19	0·30	0·36	0·43	0·44	0·64	—
1956												
Hertingfordbury‡	1·39	−0·10	−0·03	0·19	−0·07	0·07	0·24	0·13	0·09	0·09	0·23	0·55
Hitchin‡	1·56	0·08	0·06	0·07	0·18	0·18	0·40	0·42	0·36	0·49	0·41	0·57
Kensworth§	1·60	−0·09	−0·04	0·03	0·04	−0·02	0·19	0·23	0·05	0·26	0·26	0·34
Marston Valley§	1·68	0·00	−0·13	0·01	0·13	0·05	0·22	0·14	0·22	0·32	0·29	0·41
Ridgmont§	1·71	0·04	0·03	0·07	0·19	0·06	0·18	0·49	0·26	0·55	0·47	0·63
Wheathampstead‡	1·51	0·14	−0·01	0·05	0·21	0·23	0·14	0·28	0·24	0·35	0·34	0·40
Mean of ten experiments	1·50	0·01	−0·03	0·06	0·09	0·08	0·20	0·28	0·23	0·32	0·38	—
Experiments on wheat												
1954												
Northaw‡	2·16	−0·04	−0·06	−(0·02)†	0·00	0·08	−(0·04)†	0·22	0·24	0·30	0·26	—
Tilsworth§	2·08	0·01	0·04	(0·06)†	0·07	0·10	(0·11)†	0·20	0·24	0·19	0·20	—
1955												
Northaw‡	2·13	0·00	0·00	−0·02	−0·09	−0·04	0·05	−0·02	0·03	0·06	0·05	—
1956												
Northaw‡	2·21	0·03	0·04	0·24	0·17	0·20	0·47	0·64	0·58	0·74	0·75	0·87
Mean of four experiments	2·14	0·00	0·01	0·06	0·04	0·08	0·15	0·26	0·27	0·32	0·32	—
Mean of fourteen experiments on wheat and barley	1·68	0·01	−0·02	0·06	0·08	0·08	0·19	0·27	0·24	0·32	0·36	—

† Estimated values are included in averages given in parentheses. ‡ Hertfordshire. § Bedfordshire.