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THE VALUE OF MID-SEASON TOP-DRESSINGS OF NITROGEN FERTILIZER FOR MAIN-CROP POTATOES

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Experienced growers have stated that potatoes mature and die down earlier than was general some years ago. There are many possible explanations for this early maturity, considerable areas of arable land are now cropped continuously without organic manures and soil structure deteriorates so that physical conditions are unsuitable for crop growth. Heavy dressings of compound fertilizers rich in phosphorus have been applied over a long period in many areas of intensive arable cropping. Very large reserves of phosphate remaining in the soil from these dressings can also result in early maturity of crops. It is also possible that dressings of soluble nitrogen fertilizers applied before planting may be leached out of the root zone by heavy rains during the growing season. To counteract such losses some growers reserve part of the normal dressing of nitrogen and apply it as a top-dressing just before the final inter-row cultivations are carried out; others apply top-dressings of nitrogen in addition to normal seedbed dressings. The purpose of these experiments was to determine whether mid-season top-dressings of nitrogen prolonged the growing season and increased yields of potatoes, or whether equivalent amounts applied wholly at planting gave higher yields than split applications.

NATURE OF THE EXPERIMENTS

In 1953 the experiments compared dressings of ammonium sulphate applied wholly at planting with equivalent dressings of nitrogen applied partly at planting (as ammonium sulphate) and partly as mid-season top-dressings (of 'Nitro-Chalk'). The treatments were:

No nitrogen.
0·5 cwt. N/acre at planting.
0·5 cwt. N/acre at planting plus 0·5 cwt. N applied as a top-dressing.
1·0 cwt. N/acre at planting.

In 1954 and 1955 the comparisons were extended by adding two further treatments:

1·0 cwt. N/acre at planting plus 0·5 cwt. N/acre as a top-dressing.
1·5 cwt. N/acre at planting.

In 1953 the first four treatments listed above were included with others, comparing placed and broadcast dressings of nitrogen and potassium. There were four randomized blocks each of ten plots at every centre. In 1954 the six treatments were arranged in Latin squares or in randomized blocks, there were six blocks at each centre. In 1955 the experiments included, in addition to the six treatments listed above, comparisons of calcium nitrate and ammonium sulphate; the twelve treatments were arranged in randomized blocks, three blocks were laid down at each centre. The results of the comparisons of broadcasting and placing, made in 1953, and of the two forms of nitrogen, made in 1955, will be given in later papers.

In addition to this main series of experiments six subsidiary experiments were laid down in 1953 to measure the effects of mid-season dressings of 'Nitro-Chalk' applied in addition to the farmer's normal manuring. The experiments were of a very simple pattern: they tested 1·5 and 3·0 cwt./acre of 'Nitro-Chalk' applied as a mid-season top-dressing. The two plots, together with a plot without nitrogen, were arranged in a randomized block; there were six blocks at each centre.

Uniform dressings of P and K fertilizers were given to all plots testing nitrogen fertilizers. In 1953 superphosphate (at 1·0 cwt. P_2O_5/acre) and sulphate of potash (at 1·5 cwt. K_2O/acre) were applied. In 1954 and 1955 a granular compound fertilizer containing 10% P_2O_5 and 20% K_2O was used to supply 0·75 cwt. P_2O_5 and 1·5 cwt. K_2O/acre. The basal PK fertilizers were broadcast over the seedbed before planting by machine; in experiments where potatoes were planted by hand these dressings were broadcast over the ridges immediately before planting. Seedbed dressings of ammonium sulphate were applied to appropriate plots at the same time as the basal dressings.

Methods of laying down the experiments. A visit was made to each centre in early spring and a site was selected for the experiment parallel to the planting line to be used by the farmer. A second visit was made to the field just before the potatoes were planted and the fertilizer dressings were applied by hand to each plot. After the fertilizer had been applied the potatoes were planted by hand or by machine. Normal cultivations were carried out afterwards. Top-dressings of 'Nitro-Chalk' were applied to appropriate plots just before the potatoes were ridged-up for the last time in both the main

series of experiments and also in the subsidiary experiments carried out in 1953. Individual plots normally contained eight rows of potatoes each 11 yards long, at harvest the centre four rows were dug by hand and the total produce was picked, cleaned and weighed.

RESULTS OF THE EXPERIMENTS

Yields without nitrogen fertilizer and the increases given by each rate of nitrogen at each centre in the main series of experiments are set out in the Appendix. Mean yields for each treatment tested in each year are stated in Table 1. In each year the highest average yield of potatoes was obtained by applying all the nitrogen before planting.

The risk of loss of early dressings of nitrogen by leaching from the root zone is likely to be greater on light than on heavy soils. The twenty-one experiments have therefore been divided into two groups in the Appendix, the first group contains experiments on open-textured light soils. The second group contains experiments carried out on medium and heavy soils, it includes several free-working medium loams derived from lime-stone. For the two lower levels of manuring, which were tested in all three years, averages of nine 'light-land' and twelve 'heavy-land' centres are presented.

There was no difference between the average response to nitrogen on the two groups of soils at the medium rate of dressing, but the low rate (0·5 cwt. N/acre) gave a larger average increase in yield on the light soils. In general a dressing of 1·0 cwt. N/acre was almost adequate for maximum yields. The heavy dressings of nitrogen (1·5 cwt. N/acre) gave higher yields than the medium dressing at five of the eight centres on light land and at only one of the six heavy land centres.

Data in the Appendix show that 0·5 cwt. N/acre (as ammonium sulphate) increased yields at nineteen centres (there were eight significant increases). The second increment of ammonium sulphate applied at planting was less effective and gave further increases in yield in sixteen experiments (there were five significant differences). The heavy dressing (1·5 cwt. N/acre) of ammonium sulphate was tested in fourteen experiments; at eight centres it gave lower yields than the medium dressing (there were no significant differences).

The value of mid-season top-dressings of 'Nitro-Chalk' is examined in Table 2. Top-dressings applied to plots which had received the light dressing of ammonium sulphate increased yields at fourteen out of twenty-one centres (no significant effects). Top-dressings tested in the presence of the medium seedbed dressing decreased yields at nine out of fourteen centres; two of these effects were significant.

On average the highest yields were obtained when all the nitrogen was applied at planting (Table 1); effects at individual centres are examined in Table 2. When the medium rate (1·0 cwt. N/acre) was used, split applications produced slightly higher yields than dressings given wholly to the seedbed at five out of nine centres on light soils and was triflingly superior at one of the twelve heavy land centres. The heavy dressing was tested only in the two later years, split applications were slightly superior to full seedbed dressings at four out of eight light land centres and in one of six heavy land experiments. None of the differences in yield between split dressings and whole applications to the seedbed was significant. Taking the two rates of dressing together, of eleven gains in yield from splitting the dressing only one exceeded the magnitude of the standard error for the comparison. Of twenty-three decreases in yield given by splitting the dressing thirteen were larger than the appropriate standard error.

Even on light soils and in wet years there was no evidence in these experiments that growth could be prolonged to any worth while extent, and extra yields obtained, by holding back part of the normal spring-time dressing of nitrogen until mid-season.

Table 1. *Yields of potatoes given by different rates of nitrogen fertilizers applied to the seedbed and as mid-season top-dressings*

(Average of 7 experiments in each year.)

Nitrogen fertilizer applied* (cwt. N/acre)		Yields of potatoes (tons/acre)				
					Mean	
To seedbed	As top-dressing	1953	1954	1955	3 years	1954, 1955
None	None	9·0	8·8	7·2	8·3	8·0
0·5	—	10·7	9·8	8·4	9·6	9·1
1·0	—	11·8	10·1	9·3	10·4	9·7
0·5	0·5	11·3	9·9	8·9	10·0	9·4
1·5	—	—	9·9	9·7	—	9·8
1·0	0·5	—	9·5	9·4	—	9·4

* Seedbed dressings were in the form of ammonium sulphate, 'Nitro-Chalk' was used for top-dressings.

At almost every centre on heavy land lower yields were obtained by splitting the dressing. It appears that the ill-effects of late top-dressings of nitrogen for potatoes are less marked on light than on heavy soils.

In the subsidiary series of experiments carried out in 1953 top-dressings of 'Nitro-Chalk' were applied in addition to the farmer's normal manuring given at planting. There were no significant increases in yield from top-dressing at any centre. On the average of all six experiments there were very small responses to both levels of manuring. Mean increases from top-dressing (averaging the two rates of 'Nitro-Chalk') are set out in Table 3, together with the dressings of nitrogen which the farmers stated were applied at planting.

There was no clear correlation between the amounts of nitrogen applied at planting and the response to the top-dressings. Visual observations on the crops showed that top-dressings prolonged growth only at Tilbrook where the crop received the smallest dressing of nitrogen at planting.

Table 2. *Gains in yields of potatoes (tons/acre) from mid-season top-dressings of 'Nitro-Chalk' and comparisons of split applications with dressings applied wholly at planting*

	Gain from top-dressing in presence of seedbed dressing applied at		Gain from splitting the dressing		Standard error of difference
	Low rate	Medium rate	Medium rate	High rate	
	Experiments on light land				
1953					
Hambleton	0·45	—	0·30	—	0·665
1954					
Eversholt	−0·52	−0·10	−0·14	−0·39	0·600
Milton	0·18	−0·46	0·55	0·29	0·443
Cottesmore	0·53	−0·73	−1·16	−1·28	0·652
1955					
Eversholt	−0·06	0·50	0·39	−0·58	0·775
Landbeach	−0·76	0·37	−1·21	0·40	0·662
Rearsby	0·16	0·05	−1·26	0·26	0·889
Spalding	1·84	1·05	0·68	0·16	1·137
Hambleton	0·58	−0·34	0·40	−0·60	0·561
Mean yields					
All years	0·27	—	−0·16	—	—
1954 and 1955	0·24	0·04	−0·22	−0·22	—
	Experiments on medium and heavy land				
1953					
Barton Hill	0·63	—	−0·66	—	0·946
Thrales End	1·08	—	−0·92	—	0·631
Hillesden	1·73	—	−1·08	—	1·513
Great Munden	0·26	—	−0·32	—	0·503
Little Dalby	0·59	—	0·01	—	1·161
North Luffenham	−0·40	—	−1·03	—	0·741
1954					
Navestock	0·54	−1·46*	−0·69	−1·21	0·590
Offord D'Arcy	−0·51	−0·17	−0·11	0·13	0·331
Little Dalby	−0·34	−1·07*	−0·08	−0·15	0·452
Great Casterton	0·40	−0·44	0·00	−0·11	0·307
1955					
Takely	1·35	−1·10	−1·14	−0·90	0·745
Great Stukely	−0·16	0·29	−0·64	−0·68	0·543
Mean yields					
All years	0·43	—	−0·56	—	—
1954 and 1955	0·21	−0·66	−0·44	−0·49	—

Significant effects * marked for $P < 0.05$.

DISCUSSION

If the leaching of inorganic nitrogen by rainfall is of economic importance, losses should be most severe on light soils in wet seasons. The experiments described in this paper were carried out from 1953 to 1955 on a wide range of soils and in contrasted growing seasons. As the experiments were carried out in different regions long-term monthly averages of rainfall, and the departures from average in each month, are given for Rothamsted and Oakham (Rutland) in

Table 4. There were three experiments quite near to Oakham in each year and four in the Eastern Counties.

The spring of 1953 was very dry in both areas. Ample rain fell during the summer and provided excellent conditions for washing top-dressings of 'Nitro-Chalk' into the root zone of the potatoes. In several of the experiments the tops died in August; this early maturity occurred on plots top-dressed with 'Nitro-Chalk' and could not have been due to a shortage of nitrogen. In 1954 April was very dry, but rainfall was well above average in both areas from May to the end of August, and the season was marked by excessive rain, low temperatures and a deficit of sunshine. Once again there was ample opportunity for seedbed-dressings to be leached away and for top-dressings to become available to the crops by being washed into the soil. The weather in 1955 was in marked contrast to that of the two previous years. A cold dry spring was followed by heavy rainfall in late May and early June. After this wet spell, late June, July and August were dry and hot in both areas; under these conditions top-dressings would be expected to be at a disadvantage.

Top-dressings of 'Nitro-Chalk' were applied in late June, a few days afterwards the potatoes were ridged up for the last time and the fertilizer was incorporated in the final ridges. Table 5 showed that these dressings were applied rather less than half-way through the period from planting to harvesting. From the beginning of April to the end of June there were at least six inches of rain in this period in both areas in each year. Rainfall following top-dressing was much more variable, being very heavy in 1954 and very light in 1955. There was no obvious correlation between rainfall following top-dressing and increases in yield from 'Nitro-Chalk' seedbed dressings were superior to top-dressings in all three seasons.

The results of these experiments suggest that early maturity observed by many growers in the main potato-growing areas is not due to leaching of

Table 3. *Yields of potatoes obtained without top-dressing and the mean increases from mid-season dressings of 'Nitro-Chalk'*

	Dressing given at planting (cwt. N/acre)	Yield without top-dressing (tons/acre)	Mean increase from top-dressing	
			Tons/acre	S.E.
Stapleford, Cambs	1·12	11·86	0·58	0·28
Matching Green, Essex	0·82	12·94	0·12	0·39
Chatteris, Isle of Ely	0·94	11·05	0·24	0·50
Sawtry, Hunts	1·20	12·30	−0·15	0·24
Tilbrook, Hunts	0·70	11·11	0·68	0·60
Spalding, Lincs	0·94	12·31	−0·66	0·66
Mean (6 centres)	0·95	11·93	0·14	—

Table 4. *Average monthly rainfall (in inches) at Rothamsted and Oakham, the departures from average and the number of rainy days*

	Average rainfall (1880–1939)	Departure from average rainfall			Number of rainy days		
		1953	1954	1955	1953	1954	1955
		Rothamsted					
January	2·42	−1·21	−1·21	+0·33	14	15	19
February	2·00	+0·47	+0·33	+0·31	11	17	19
March	2·00	−1·45	+0·59	−0·55	8	17	10
April	2·00	+0·63	−1·70	−1·51	13	6	9
May	2·02	−0·29	+0·45	+2·60	11	14	16
June	2·13	+0·17	+1·54	−0·02	14	15	9
July	2·60	+1·36	+1·03	−2·35	19	18	4
August	2·51	−0·85	+1·12	−1·70	8	18	8
September	2·34	−0·22	−0·38	−0·46	14	19	14
		Oakham					
	(1942–1955)						
January	2·17	+1·32	−0·52	+0·21	14	17	18
February	1·93	−0·02	+0·35	+0·78	16	24	18
March	1·82	+0·35	+0·44	+0·62	7	16	12
April	1·63	−0·11	−1·37	−0·63	16	7	11
May	2·23	−0·39	+1·13	+1·02	12	17	22
June	2·06	+0·36	+0·86	+0·88	18	14	12
July	1·68	−0·02	+0·41	−1·04	17	21	4
August	2·35	+0·11	+0·51	−1·69	12	22	8
September	1·96	−0·98	+0·41	+0·62	12	23	10

nitrogen fertilizers given at planting time. A longer growing season and improved yields cannot be obtained either by reserving part of the spring dressing of nitrogen for later application, or by applying a top-dressing of nitrogen where the level of manuring at planting is adequate. These results agree with the work of Brasher (1941), who found that full amounts of complete fertilizer applied at planting gave the highest yields; the longer the fertilizer application was delayed after planting, the lower the yields. Other American workers have shown that under some circumstances split applications of fertilizers may be superior to dressings applied wholly at planting. Hawkins (1946) found that potatoes grown in Maine absorbed only 11 % of the total nitrogen present in the crop at harvest during the first 50 days after planting; two-thirds of the total quantity absorbed was taken up during the period 51–81 days after planting. The crop continued to take up nitrogen, but at a decreasing rate, until harvested 110 days after planting. Hawkins concluded that nitrogen applied at planting should be resistant to leaching, particularly during the first few weeks, but that it should be highly available during the month after the plants were about 6–8 in. high. In investigations in Kentucky Emmert (1949) obtained considerably better yields by splitting the nitrogen dressings (half was applied at planting and half was given along the rows at flowering stage) than by giving the whole dressing at planting. He stressed the need for high concentrations of nitrogen in the later stages of growth.

On the other hand, the results of field experiments carried out by Uhlen in Norway (summarized by Emilsson, 1955) agree with the findings of the work described here. Nitrogen and potassium fertilizers applied during the growing season were of little use and gave lower yields than corresponding amounts of fertilizers applied before planting. Late dressings given at the time of ridging up were more effective than dressings applied when the crops were in flower, but applying fertilizer to the seedbed was markedly superior to either method of top-dressing.

The reasons for differences in the results of field experiments on the value of mid-season top-dressings in U.S.A. and in Europe are not clear. They are probably concerned with the frequency and intensity of rainfall and with the textures of the soils used for the experiments. No information is available on either of these factors.

SUMMARY

Twenty-one field experiments were carried out from 1953 to 1955 on main-crop potatoes to compare dressings of nitrogen applied wholly to the seedbed (as ammonium sulphate), with equivalent dressings applied partly to the seedbed (as ammonium sulphate) and partly as a top-dressing (of 'Nitro-Chalk') just before the final ridges were set up.

There were consistent increases in yield from seedbed dressings of 0·5 and 1·0 cwt. N/acre. Seedbed dressings of 1·5 cwt. N/acre increased yields further in some experiments on light soils but depressed yields at most heavy-land centres. In general a dressing at 1·0 cwt. N/acre given to the seedbed was nearly sufficient for maximum yields.

The second increment of 0·5 cwt. N/acre increased yields at four-fifths of the centres when applied to the seedbed, but gave increases at only two-thirds of the centres when applied as a top-dressing. When the seedbed dressing was 1·0 cwt. N/acre a further seedbed dressing of 0·5 cwt. N gave increases in half of the experiments, but the same amount given as a top-dressing increased yields at only one-third of the centres. Splitting the dressing was inferior to applying it all to the seedbed in practically all experiments on medium and heavy soils. There was a slight advantage from splitting the dressing in about half of the experiments on light soils, but most of these gains were very small. On average, dressings of nitrogen applied wholly to the seedbed produced higher yields than equivalent amounts applied partly to the seedbed and partly as top-dressing.

In a subsidiary series of experiments top-dressings of 'Nitro-Chalk' were applied to commercial crops

Table 5. *The average number of days and average rainfall from planting to top-dressing and from top-dressing to harvesting in* 1953, 1954 *and* 1955

	Days from planting to top-dressing	Rainfall, April to June	Days from top-dressing to harvesting	Rainfall, July to September
	Eastern Province (4 centres in each year)			
1953	96	6·66	94	7·74
1954	69	6·44	107	9·22
1955	71	7·22	93	2·94
	East-Midlands Province (3 centres in each year)			
1953	81	6·00	95	5·10
1954	78	6·54	98	7·32
1955	68	7·19	104	3·88

which had been given normal manuring by the farmers at planting. On average of six experiments top-dressings gave only small increases in yield, none of the effects at individual centres was significant.

In both series of experiments top-dressings failed to prolong growth at centres where the crops were considered to have died prematurely. There is no justification for applying top-dressings of nitrogen fertilizer to potatoes which have received adequate amounts at planting. On the kinds of soil used for these experiments any loss of nitrogen (applied to the seedbed as ammonium sulphate) by leaching does not appear to be sufficient to reduce yields substantially.

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APPENDIX

Yields of potatoes grown without nitrogen fertilizer and the increases from different amounts of ammonium sulphate applied to the seedbeds and 'Nitro-Chalk' applied as a mid-season top-dressing, in tons of potatoes per acre

(Significant effects marked ** for $P < 0{\cdot}01$, * for $P = 0{\cdot}05$ to $0{\cdot}01$.)

	Without nitrogen	Increase from ammonium sulphate applied to seedbed			Increase from ammonium sulphate on seedbed plus top-dressing of 'Nitro-Chalk'		Standard error of increase
		Low rate	Medium rate	High rate	Medium rate	High rate	
Experiments on light land							
1953							
Hambleton, Rutland	11·93	0·86	1·01	—	1·31*	—	0·575
1954							
Eversholt, Beds	8·29	2·86**	2·48**	2·77**	2·34**	2·38**	0·600
Milton, Cambs	12·63	0·00	−0·37	−1·12*	0·18	−0·83	0·433
Cottesmore, Rutland	7·18	2·76**	4·45**	5·00**	3·29**	3·72**	0·652
1955							
Eversholt, Beds	7·18	0·90	0·45	1·53*	0·84	0·95	0·671
Landbeach, Cambs	7·14	1·41*	1·86**	1·83**	0·65	2·23**	0·573
Rearsby, Leics.	4·93	3·25**	4·67**	4·46**	3·41**	4·72**	0·770
Spalding, Lincs	9·38	2·01	3·17**	4·06**	3·85**	4·22**	0·984
Hambleton, Rutland	10·50	0·71	0·89	1·15*	1·29*	0·55	0·485
Mean yields							
All years	8·80	1·64	2·07	—	1·91	—	—
1954 and 1955 only	8·40	1·74	2·20	2·46	1·98	2·24	—
Experiments on medium and heavy land							
1953							
Barton Hill, Beds	10·42	0·55	1·84*	—	1·18	—	0·819
Thrales End, Beds	9·10	2·42**	4·42**	—	3·50**	—	0·546
Hillesden, Bucks	8·56	0·86	3·67*	—	2·59	—	1·309
Great Munden, Herts	6·75	3·38**	3·96**	—	3·64**	—	0·436
Little Dalby, Leics	9·99	2·97**	3·55**	—	3·56**	—	1·006
North Luffenham, Rutland	6·37	0·48	1·11	—	0·08	—	0·642
1954							
Navestock, Essex	9·88	1·17	2·40**	2·15**	1·71**	0·94	0·590
Offord D'Arcy, Hunts	9·56	0·45	0·05	−0·25	−0·06	−0·12	0·331
Little Dalby, Leics	7·18	−0·29	−0·55	−1·47**	−0·63	−1·62**	0·452
Great Casterton, Rutland	6·50	0·81*	1·21**	0·88**	1·21**	0·77*	0·307
1955							
Takely, Essex	4·85	0·71	3·20**	3·00**	2·06**	2·10**	0·646
Great Stukely, Hunts	6·20	−0·02	0·46	1·43**	−0·18	0·75	0·470
Mean yields							
All years	7·95	1·12	2·11	—	1·56	—	—
1954 and 1955 only	7·36	0·47	1·13	0·96	0·68	0·47	—