Cooke, G. W. and Widdowson, F. V. 1956. The value of nitrophosphate for spring-sown cereals. *The Journal of Agricultural Science.* 47 (1), pp. 112-116.

THE VALUE OF NITROPHOSPHATE FOR SPRING-SOWN CEREALS

By G. W. COOKE and F. V. WIDDOWSON

Chemistry Department, Rothamsted Experimental Station, Harpenden, Herts

INTRODUCTION

When sulphuric acid is replaced by nitric acid in the ordinary superphosphate process, the product contains mono-calcium phosphate and calcium nitrate and is too hygroscopic for satisfactory storage and use on the farm. Most processes for treating phosphate rock with nitric acid to form nitrophosphate are modified so that calcium nitrate does not occur in the final product. Cooke (1954) has described several processes which are used commercially. In one particular process, described by d'Leny (1953), phosphate rock was treated with nitric acid, ammonia was then added and ammonium nitrate, dicalcium phosphate and calcium nitrate were formed. By adding ammonium sulphate, calcium sulphate was precipitated and the final product contained no calcium nitrate. A nitrophosphate made by a process of this nature was used in the work described here.

In 1950 a world-wide shortage of sulphur occurred and supplies of sulphuric acid for superphosphate-making were restricted. The Agricultural Research Council initiated a field investigation to test phosphate fertilizers which either needed no sulphuric acid, or which economized in acid. In half of the field experiments several kinds of nitrophosphate were compared with superphosphate plus equivalent nitrogen. The results of the work have been summarized by Cooke (1955). The test crops used were roots and grass and the experimenters were not concerned with comparisons between alternative methods of fertilizer application or with experiments on cereals.

Since most nitrophosphates contain roughly equal proportions of N and of P_2O_5 they may be suitable for supplying seedbed dressings of nitrogen and phosphorus for spring-sown cereals, provided that the water-soluble phosphorus which they contain behaves in the same way as water-soluble phosphorus in the mixtures usually used for this purpose. Crowther (1945) showed that drilling superphosphate with the seed of cereals produced higher yields than broadcasting the same quantity of superphosphate. To test the value of nitrophosphate for cereals it was therefore necessary to compare it with superphosphate plus equivalent nitrogen and also to test the fertilizers both when broadcast and when combine-drilled. Very few experiments in this country have compared water-soluble and insoluble phosphate fertilizers where the dressings have been concentrated close to the seed.

Nitrophosphates used in this work had the analyses shown in Table 1.

Table 1

		P_2O_5		N	
Year	Rothamsted no.	Total (%)	Water-soluble (%)	As NH_4 (%)	As NO_3 (%)
1952	NP 16	14·6	4·5	7·1	6·7
1953 and 1954	NP 19	14·3	4·0	8·4	6·2

Both batches of nitrophosphate contained approximately equal proportions of total N and P_2O_5. They were compared with mixtures of superphosphate and 'Nitro-Chalk' containing N and P_2O_5 in the same ratios as the nitrophosphates used. ('Nitro-Chalk' was chosen because it is the only straight nitrogen fertilizer sold in England in granular form and because it contains ammonium nitrate.)

NATURE OF THE EXPERIMENTS

The experiments were carried out in Hertfordshire from 1952 to 1954. There were three experiments in 1952, six in 1953 and four in 1954. Barley was grown in eight of the experiments and spring wheat in the other five.

Sites were chosen for the experiments by selecting soils which contained very little 'easily-soluble' phosphorus. Preliminary soil samples taken from each field proposed were examined by a rapid test for dilute acid-soluble soil phosphorus. 3 g. of soil were shaken with 7 ml. of 0·3N-HCl for 2 min. After filtering, the amount of phosphorus in the extract was determined colorimetrically (by the method of Truog & Meyer, 1929). The amounts of soluble phosphorus determined in this way in the soils used for these experiments are stated in Table 2.

The experimental treatments were: 'Nitro-Chalk' alone, 'Nitro-Chalk' plus superphosphate, nitrophosphate. In all the experiments the 'Nitro-Chalk' superphosphate mixture and the nitrophosphate were tested both when combine-drilled and when broadcast. In the 1952 experiments and in the 1953 experiment at Rothamsted dressings of 'Nitro-Chalk' alone were broadcast on duplicate plots. In all the other 1953 experiments and at all centres in 1954 comparisons were made between broadcasting and drilling 'Nitro-Chalk'.

The six experimental treatments were arranged in a randomized block. There were four blocks at each centre except Redbourn in 1952.

Table 2. *Amounts of phosphorus soluble in dilute* HCl *in the soils used in the field experiments*

Year	Centre	Soil no.	Soluble phosphorus (mg. P/100 g. soil)
1952	Leverstock Green	A 8820	0·5
	Redbourn	A 8826	0·5
	Rothamsted	—	—
1953	Aldenham	A 8943	0·2
	Eastwick	A 8925	0·4
	Leverstock Green	A 8928	0·6
	Smallford	A 8927	0·9
	Stanstead Abbots	A 8922	0·8
	Rothamsted	A 8926	1·1
1954	Aldenham	A 9125	0·5
	Eastwick	A 9113	0·7
	Leverstock Green	A 9119	0·6
	Stanstead Abbots	A 9120	0·4

Phosphate fertilizers were applied at an average rate of 0·45 cwt. total P_2O_5 per acre in each year; there were small differences in the amounts applied from centre to centre, due to variations in the delivery rate from the combine-drill. Nitrogen was applied at the same rate (roughly 0·45 cwt. N per acre) to all plots of each experiment.

METHODS OF CARRYING OUT THE EXPERIMENTS

A standard combine-drill fitted with a star-wheel fertilizer mechanism and having 12 coulters spaced 7 in. apart was used. Individual plots were normally one drill-width wide and 44 yd. long ($\frac{1}{47}$th acre). At Redbourn in 1952 the plots were two drill-widths wide; at harvest a swathe 12 ft. wide was cut through the centre of each plot with a self-propelled combine harvester. (This technique was not used in later experiments as a larger area was required for the experiment and it was less convenient to the farmer.)

The experiment was marked out and a string set along each plot boundary served as a guide for the tractor driver. The wheel of the drill ran beside the string so that the outside coulter of the drill was 3·5 in. inside the plot boundary. The right-hand coulter was blocked on each plot so that a space 14 in. wide was left between adjacent plots.

The fertilizer mechanism of the drill was set appropriately and calibrated by drilling 44 yd. along the headland of the field. The fertilizer delivered by the twelve coulters of the drill was collected in sacks and weighed. Broadcast dressings were applied by hand after drilling had been completed at the rate indicated by the calibration on each field. A basal dressing of potassium sulphate was broadcast on all plots immediately after drilling. The experimental area was harrowed after drilling was completed, afterward it received the same cultivation as the remainder of the field.

The whole plot area was harvested at every centre except Redbourn in 1952. Most of the experiments were cut by a combine-harvester; at a few centres the plots were cut by binder, the sheaves were stooked and were threshed later with a small portable threshing machine. Samples of grain were taken from each plot for moisture determinations and all yields reported here have been corrected to 15% moisture content.

RESULTS OF THE EXPERIMENTS

Results from individual experiments are given in the Appendix Table. Average yields without phosphate and average increases given by phosphate are stated for each year in Table 3. Yields of grain on plots which did not receive phosphate were much higher in 1953 and 1954 than in 1952.

Both broadcast and combine-drilled dressings of superphosphate increased yields significantly in all three of the 1952 experiments, but in 1953 and 1954 the increases were significant at only two centres in each year. Combine-drilled phosphate was superior to broadcast dressings except at Rothamsted and Aldenham in 1953, where broadcasting gave higher yields.

Broadcast nitrophosphate generally gave lower yields than broadcast superphosphate. Broadcasting nitrophosphate increased yields significantly at one centre in 1952 and at two centres in 1954. Combine-drilled dressings of nitrophosphate were superior to broadcast dressings and increased yields significantly at seven centres over the three years.

Comparisons of combine-drilling and broadcasting are also examined in Table 3. Experiments in 1953 and 1954 compared combine-drilled and broadcast dressings of 'Nitro-Chalk' in the absence of phosphate. There was no consistent advantage from drilling the dressing, but the comparisons are not entirely satisfactory since absence of phosphate often limited yields. In general, combine-drilling superphosphate was superior to broadcasting and the differences in yield were significant at three centres in 1953 and at one centre in 1954. Average gains from drilling nitrophosphate as compared with broadcasting were greater than corresponding gains from drilling superphosphate, the increases in yield being significant at one centre in 1952 and at three centres in 1953.

The yields given by superphosphate and nitrophosphate are also compared in Table 3. Superphosphate was markedly superior to nitrophosphate when the dressings were broadcast, and these differences were more marked in 1952 and 1953 than in 1954. Combine-drilled nitrophosphate gave average yields which were only a little less than those given by drilled superphosphate.

both 1953 and 1954 had unusually dry springs with cold winds and frosts at night persisting well into May. At several centres plants receiving only nitrogen and potassium showed acute symptoms of phosphorus deficiency: in the 1953 experiments at Eastwick and Stanstead Abbots root growth was very slow, many plants died and the crops became very thin.

There were marked differences between growth on plots receiving superphosphate and nitrophosphate. Where superphosphate was combine-drilled the crops developed rapidly and had dark green leaves. Plots with combine-drilled nitrophosphate were not

Table 3. *Average yields of cereals given by 'Nitro-Chalk' alone, the increases obtained from phosphate fertilizers, and the numbers of significant positive* effects*.

	1952		1953			1954		Average (all years)	
	Mean yield	No. of significant effects	Mean yield: Rothamsted	Mean yield: Other centres	No. of significant effects	Mean yield	No. of significant effects	Yield of grain	No. of significant effects
No. of experiments ...	3	—	1	5	—	4	—	13	—
	Yield of grain in cwt. per acre (15 % moisture content)								
Mean yield with 'Nitro-Chalk' alone									
Broadcast	12·9	—	29·5	20·8	—	28·6	—	22·1	—
Combine-drilled	—	—	—	21·7	—	27·5	—	—	—
Increase from superphosphate + 'Nitro-Chalk'									
Broadcast	4·3	3	3·8	2·0	2	3·2	2	3·0	7
Combine-drilled	5·4	3	2·7	4·4	2	4·9	2	4·7	7
Increase from nitrophosphate									
Broadcast	2·9	1	1·5	0·6	0	2·6	2	1·8	3
Combine-drilled	5·3	3	0·5	3·2	2	4·7	2	4·0	7
Increase from drilling over broadcasting									
For 'Nitro-Chalk'	—	—	—	0·8	0	−1·2	0	—	—
For superphosphate	1·1	0	−1·1	3·3	3	0·6	1	1·6	4
For nitrophosphate	2·4	1	−1·0	3·4	3	0·9	0	2·1	4
Superphosphate minus nitrophosphate									
Broadcast	1·4	1	2·3	1·4	1	0·5	0	1·2	2
Combine-drilled	0·1	0	2·2	1·2	1	0·2	0	0·7	1

* $P = 0{\cdot}05$ or greater.

At one centre in 1953 combine-drilled superphosphate decreased yields significantly and at the same centre drilling superphosphate was significantly inferior to broadcasting. There were no other significant negative effects.

DISCUSSION

All the experiments described here were carried out on fields recently ploughed from badly-managed old pasture. It was not possible to find fields in arable rotations within easy reach of Rothamsted where the soils were sufficiently low in dilute acid-soluble phosphorus and cereals were likely to respond to phosphate. Several experiments were on peaty soils in river valleys. On most of the soils there were marked benefits from dressings of superphosphate in the early part of the growing season. The spring of 1952 was rather dry and warm, but

so forward, although there was a visible response to the dressing. Broadcast nitrophosphate had little effect on growth and the plants had symptoms of phosphorus deficiency similar to those grown without phosphate. Later in each season phosphorus deficiency symptoms became less marked, but at some centres phosphate fertilizers continued to improve growth visually until harvest. At some of the 1953 centres, particularly Rothamsted and Aldenham, improved growth from drilled dressings of superphosphate caused the crop to lodge earlier than on plots which received no phosphate. Lower yields from drilling as compared with broadcasting phosphate at these two centres were no doubt due to this earlier lodging. At most centres the time of ripening was not affected by dressings of phosphate, but at Leverstock Green in 1954 plots without phosphate were still green when plots receiving combine-drilled superphosphate were ready to cut.

Both combine-drilled and broadcast dressings of superphosphate increased yields significantly at seven of the thirteen centres. The average increase in yield from drilled superphosphate was one-and-a-half times as great as the increase from broadcast dressings. Nitrophosphate drilled with the seed also increased yields significantly at seven centres, but broadcast dressings were less useful. The average increase in yield from drilled dressings of nitrophosphate was more than twice the increase from equivalent broadcast dressings.

The 'starter' effect of combine-drilled phosphate is very important in the early part of the growing season. Phosphate fertilizers used for cereals should contain considerable proportions of water-soluble phosphorus to stimulate growth immediately after germination. The nitrophosphates tested in these experiments contained more than one-quarter of the phosphorus in water-soluble forms, other nitrophosphates containing less water-soluble phosphorus may be less useful for cereals. The experiments show, however, that nitrophosphates of this type may be used for cereals when supplies of water-soluble phosphate are restricted, provided that they are drilled with the seed. Since nitrophosphates do not promote such rapid early growth as superphosphate they may give poorer yields in seasons when it is very important to start the crop rapidly.

SUMMARY

Thirteen experiments on spring cereals were carried out from 1952 to 1954 to compare broadcasting with combine-drilling for nitrophosphate and for mixtures of superphosphate plus equivalent nitrogen. Broadcast nitrophosphate was of little value; drilled dressings were much more effective. Superphosphate drilled with the seed produced consistently higher yields than broadcast superphosphate. Superphosphate plus equivalent nitrogen gave higher average yields than nitrophosphate both when broadcast and when drilled. When the dressings were broadcast, superphosphate was markedly superior to nitrophosphate, but when the fertilizers were drilled with the seed, average yields with superphosphate were only a little higher than with nitrophosphate.

Nitrophosphates may be substituted for mixtures containing water-soluble phosphorus for cereals providing that they are drilled with the seed. Since nitrophosphates do not make cereals grow as rapidly as does superphosphate, even when drilled with the seed, such materials may give poor crops in conditions where the plants need a rapid start. The nitrophosphate tested contained rather more than one-quarter of its phosphorus in water-soluble form; the improved early growth observed where nitrophosphate was combine-drilled may have been largely due to this fraction of the fertilizer.

This work was carried out under the auspices of the Agricultural Research Council's Conference on Fertilisers. The authors' thanks are due to the Agricultural Research Council, to H. W. Gardner of the Hertfordshire Institute of Agriculture and P. A. Naylor of the National Agricultural Advisory Service for their help in finding sites for the experiments, to R. G. Warren for the analyses of the fertilizers used, to J. H. A. Dunwoody for the statistical analyses of the results of the experiments and to other members of the Rothamsted staff for much assistance in carrying out the work.

REFERENCES

COOKE, G. W. (1954). *Proc. Fertil. Soc.* no. 27.

COOKE, G. W. (1955). *N.A.A.S. Quart. Rev.* no. 27, 95.

CROWTHER, E. M. (1945). *Agriculture, Lond.*, **52**, 170.

D'LENY, W. (1953). *Proc. Fertil. Soc.* no. 24.

TRUOG, E. & MEYER, A. H. (1929). *J. Industr. Engng Chem.* (*Anal.*), **1**, 136.

(*Received* 25 *May* 1955)

Appendix Table. *Yields without phosphate and increases from dressings of superphosphate and nitrophosphate in experiments on spring-sown cereals*

	Yield with 'Nitro-Chalk' only			Increases in yield from: Superphosphate + 'Nitro-Chalk'		Nitrophosphate		
	Broadcast	Drilled	S.E.	Broadcast	Combine-drilled	Broadcast	Combine-drilled	S.E.
	Yields of grain in cwt. per acre (15% moisture content)							
Experiments in 1952								
Leverstock Green, barley	8·0	—	0·69	7·0**	9·7**	4·1**	7·1**	1·19
Redbourn, barley	14·7	—	0·60	3·1*	3·2*	2·0	4·1**	1·05
Rothamsted, barley	16·0	—	0·71	2·7*	3·2*	2·6	4·7**	1·23
Experiments in 1953								
Aldenham, wheat	33·2	35·0	1·25	0·9	−3·6**	1·4	−1·4	1·25
Eastwick, barley	30·7	31·9	1·51	−1·5	2·7	−1·3	1·0	1·51
Leverstock Green, barley	15·3	16·2	2·00	6·4**	12·0**	2·4	12·3**	2·00
Smallford, barley	8·1	9·3	1·84	1·7	3·0	1·5	1·0	1·84
Stanstead Abbots, wheat	16·9	15·9	1·05	2·5*	8·1**	−0·9	3·3**	1·05
Rothamsted, barley	29·5	—	1·94	3·8	2·7	1·5	0·5	1·94
Experiments in 1954								
Aldenham, wheat	25·0	21·2	1·90	−0·2	4·1	−2·5	4·1	1·90
Eastwick, wheat	40·4	40·1	0·78	−0·3	−0·2	1·3	0·8	0·78
Leverstock Green, barley	20·0	20·0	1·21	9·2**	11·8**	8·7**	10·3**	1·21
Stanstead Abbots, wheat	29·1	28·6	1·01	4·0**	4·0**	3·1**	3·6**	1·01
Mean (13 experiments)†	22·1	—	—	3·0	4·7	1·8	4·0	—

† The data on which the mean increases for all years are based are not strictly comparable since the 1952 experiments and the 1953 experiment at Rothamsted did not take into account differences between drilling and broadcasting 'Nitro-Chalk'.

Significant effects marked: * for $P = 0·05$ or greater; ** for $P = 0·01$ or greater.