COMPARISONS BETWEEN PLACING AND BROADCASTING OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZERS FOR POTATOES, PEAS, BEANS, KALE AND MAIZE

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(With Plate 3)

Experimental work showed that considerable improvements in fertilizer efficiency could be obtained for some row crops and for potatoes by adopting suitable placement techniques (Cooke & Widdowson 1953; Cooke, Jackson & Widdowson, 1954). In these earlier experiments comparisons between placing and broadcasting were made using granulated PK or NPK compound fertilizers. Therefore it was not possible to determine which of the individual plant nutrients was improved in efficiency through being placed to the side of the seed. For cereals Crowther (1945) showed that higher yields could be obtained by combine-drilling rather than by broadcasting dressings of superphosphate, but little information is available on the benefits of placing nitrogen and potassium. It appeared unlikely, however, that the gains from placement obtained in earlier work on row crops were due entirely to improvements in efficiency of phosphate in the compound fertilizers tested since most of the soils used contained satisfactory supplies of 'available' phosphorus and responses to phosphate fertilizers were therefore unlikely. In the work described here experiments were carried out on potatoes to measure the possible gains from placing nitrogen and potassium fertilizers. In addition, comparisons between placing and broadcasting of nitrogen, phosphorus and potassium fertilizers were made on green peas, broad beans, kale and maize.

NATURE OF THE EXPERIMENTS

Experiments on potatoes

Seven experiments were laid down in 1953 and one in 1954 to compare the yields given by placed and broadcast dressings of nitrogen and potassium. Ammonium sulphate at two levels (0·5 and 1·0 cwt. N/acre) was compared either broadcast over the seedbed before planting or placed in a single band 3 in. to the side of the seed. Both methods of application were tested in the presence of a placed basal dressing of 1·5 cwt. K_2O/acre (as potassium sulphate) and 1·00 cwt. P_2O_5/acre (as superphosphate). (In addition, comparisons were made between single seedbed dressings of nitrogen and dressings applied partly at planting and partly as a mid-season top-dressing. The results of this part of the experimental work have been published previously by Cooke, Widdowson & Wilcox (1957).) Comparisons between placed and broadcast dressings of potassium sulphate at one level (1·5 cwt. K_2O/acre) were made in the presence of placed basal dressings of ammonium sulphate (1·00 cwt. N/acre) and superphosphate (1·00 cwt. P_2O_5/acre). In addition, two plots receiving no nitrogen and one plot receiving no potassium were included; the ten experimental treatments were arranged in a randomized block. There were four blocks at each centre except Thrales End and Hillesden where there were only three. Each plot was 22 yards long and contained 4 rows spaced 28 in. apart ($\frac{1}{71}$ acre).

In 1954 and 1955 factorial experiments were layed down at Rothamsted to compare all combinations of ammonium sulphate (supplying 0·0, 0·5 and 1·0 cwt. N/acre) and potassium sulphate (supplying 0·0, 0·75 and 1·5 cwt. K_2O/acre) either broadcast before planting or placed to the side of the seed. Superphosphate was placed beside the seed on all plots at 1·05 cwt. P_2O_5/acre. The treatments were arranged in six blocks, each of twelve plots, by partially confounding the interaction of rates of nitrogen by rates of potassium. In 1956 modifications were made to the experimental design. The comparisons between drilling and broadcasting nitrogen or potassium in the absence of each other were discontinued. All combinations of ammonium sulphate (supplying 0·5 and 1·0 cwt. N/acre) and potassium sulphate (supplying 0·75 and 1·50 cwt. K_2O/acre) were compared either broadcast or placed. In addition, two plots receiving no nitrogen or potassium were included. The eighteen treatments were arranged in a randomized block and there were four blocks in each of the experiments which were laid down at Hatfield and Rothamsted.

Experiments on peas, beans, kale and maize

Experiments on green peas and broad beans carried out in 1955 and 1956 tested the same fertilizer treatments. Superphosphate (P) (at 0·0 and

0·36 cwt. P_2O_5/acre) and potassium sulphate (K) (at 0·0 and 0·72 cwt. K_2O/acre) were each tested both broadcast over the seedbed and placed 2 in. to the side of the seed and 3 in. below the soil surface. In addition, ammonium sulphate (N) (at 0·42 cwt. N/acre) was compared both broadcast and placed in the presence of phosphorus and potassium. The ten treatments were arranged in a randomized block; there were four blocks in each experiment. Individual plots contained three rows spaced 24 in. apart and were 11 yards long ($\frac{1}{220}$ acre).

The kale experiments carried out in 1955 and 1956 were of the same design, but rates of dressing were increased to 0·54 cwt. P_2O_5 and 1·00 cwt. K_2O/acre. In addition to the seedbed dressings of nitrogen given to two treatments the whole experiment was top-dressed with ammonium sulphate in late June at rates adjusted so that each plot received a total dressing of 1·2 cwt. N/acre. It was therefore possible to compare the yields given by divided dressings of nitrogen (part at planting and part in mid-season) with those given by dressings applied wholly in mid-season. Each plot contained three rows of kale spaced 24 in. apart and was 22 yards long ($\frac{1}{110}$ acre).

One experiment on maize (variety C.I.V. 2) was laid down at Rothamsted in 1956 to compare placed and broadcast dressings of nitrogen and potassium. All combinations of ammonium sulphate (N_1) (at 0 and 0·5 cwt. N/acre) with potassium sulphate (K) (at 0 and 1·0 cwt. K_2O/acre) were tested. In addition, the plots receiving both nitrogen and potassium were repeated with a higher level of nitrogen (N_2) (1·0 cwt. N/acre). The five fertilizer treatments were compared either broadcast or placed 2 in. to the side of the seed and 3 in. deep. There were four randomized blocks each of 10 plots. A basal dressing of 3 cwt./acre of superphosphate was placed beside the seed on each plot. Individual plots contained three rows of maize spaced 24 in. apart and were 11 yards long ($\frac{1}{220}$ acre).

METHODS OF LAYING DOWN THE EXPERIMENTS

Experiments on potatoes

A preliminary visit was made to each centre in early spring to select a suitable site. The seedbed was prepared by the farmer, and on a second visit the experiment was marked out and fertilizer was broadcast over appropriate plots. For planting a string set 14 in. to the right-hand side of the centre line of the experiment served as a guide to the tractor driver. An experimental potato planter fitted with an end-delivery fertilizer mechanism which was built by the National Institute for Agricultural Engineering (described by Cooke *et al.* 1954) was used to plant seed and place fertilizer as required. After the first two rows had been planted the furrows served as a guide. The tractor was driven round the experimental area, completed work always being on the driver's right, until the correct number of rows had been planted exactly within the prescribed limit. Potatoes were planted continuously from headland to headland, the fertilizer being applied to each plot by the attachment on the planter. The dressings of fertilizer required for each treatment were made up from appropriate amounts of ammonium sulphate, powdered superphosphate and potassium sulphate. The quantities were weighed out in bulk and were thoroughly mixed in a small concrete-mixer. Dressings of the mixtures for each row were weighed out separately. After planting the experiments were cultivated, sprayed and treated in the same way as the rest of the field. At harvest the two centre rows were dug by hand, discarding a short length at each end of each row. The tubers were picked, cleaned and weighed.

Experiments on other crops

After cultivating to prepare a seedbed broadcast fertilizer was applied by hand to appropriate plots. Drilled fertilizer was then placed 3 in. below the soil surface and 2 in. to the side of the seed coulter on appropriate plots with a self-propelled seed and fertilizer drill described below. Peas and kale were sown with a single-row hand-drill following the line left by the seed coulter of the placement drill. Broad bean and maize seed was dibbled in by hand on the same line.

After sowing the crops received normal cultivations. Green peas and broad beans were picked when ready for market and the quantity of saleable produce was recorded. The maize failed to ripen properly due to unfavourable weather in 1956 and the cobs were harvested in November. The kale was harvested with a motor scythe after cutting and discarding paths along block boundaries. All three rows of each crop were harvested.

The self-propelled seed and fertilizer drill used was built by the National Institute for Agricultural Engineering so that comparisons between placing and broadcasting individual plant nutrients could be made. This machine, which is illustrated in Pl. 1 (A), is a development of the single-row drill used for earlier work on horticultural crops (Cooke *et al.* 1956). The drill is mounted on a self-propelled tool-frame and is fitted with an end-delivery fertilizer mechanism. It can be used for row-crops or cereals. With cereals the individual rows were spaced 6 in. apart and seed and fertilizer are sown in contact. Row widths of 12, 18 and 24 in. may also be selected. At these spacings the coulters can be set in pairs so that fertilizer can be placed 2 in. to the side of the seed. In these experiments only fertilizer was sown with the drill, the seed being sown sepa-

rately to save weighing the appropriate quantity for each row. The drill is very versatile and as it is self-cleaning, experiments with Latin Square or randomized block lay-outs having no paths or headlands between rows of plots, can be drilled successfully. (With ordinary placement drills it is often necessary to have the plots in a long narrow strip side by side, which may result in higher experimental errors.) The trays which contain the seed and fertilizer are illustrated in Pl. 1 (B), they are adjustable so that wide variations in dressings can be accommodated. When using more than one fertilizer the contents of three trays are delivered into a funnel and then pass down a tube to the coulter. It is not necessary to mix various proportions of fertilizers beforehand as individual fertilizers can be spread in separate trays for each row.

Placed and broadcast dressings of potassium sulphate were compared in the presence of drilled nitrogen and phosphorus (Table 1). There were non-significant gains from placement at five centres, two of these positive effects being greater than the standard error; on average there was no difference between the yields given by the two methods of application.

It appeared possible that the tendency to lower yields from placing as compared with broadcasting 1·00 cwt. N/acre was due to placing the heavy dressings of both nitrogen and potassium together. The second series of experiments was therefore laid down in 1954–6 to see whether the comparisons of broadcasting and placing nitrogen were influenced by whether potassium was placed or broadcast and vice versa. In 1954 and 1955 drilled and broadcast

Table 1. *Increases in yields of potatoes from drilling over broadcasting for nitrogen with drilled potassium and for potassium with drilled nitrogen in experiments in* 1953–4

(Significant effects are marked ** for $P > 0{\cdot}01$.)

	Gain from drilling over broadcasting for			
	Nitrogen at			Standard error of difference
	Low rate	High rate	Potassium	
	Yields of total tubers (tons/acre)			
Experiments in 1953				
Barton Hill	0·50	−0·79	0·45	0·946
Great Munden	−0·74	0·21	−0·39	0·503
Hambleton	−0·06	−0·08	0·84	0·665
Hillesden	0·63	−0·31	0·56	1·513
Little Dalby	0·75	−0·66	−2·13	1·161
North Luffenham	0·73	−0·24	0·53	0·741
Thrales End	2·37**	−0·29	0·76	0·631
Experiment in 1954				
Great Munden	1·08	−0·42	−0·24	0·566
Mean (8 centres)	0·66	−0·32	0·05	—

RESULTS OF THE EXPERIMENTS

Potatoes

The detailed results from the first series of eight experiments designed to compare drilled and broadcast dressings of nitrogen and potassium are given in Appendix Table 1, and they are summarized in Table 1. There were gains from drilling the lower level of nitrogen at six of the eight centres, only one of the differences in favour of placement was significant, and only one of the other positive effects was greater than the appropriate standard error. On average, yields were increased by just over half a ton per acre by placing rather than by broadcasting this level of nitrogen. When the heavy dressing was applied (1·0 cwt. N/acre) higher yields were given by broadcasting at seven of the eight centres, but none of the differences were greater than the appropriate standard error. All these comparisons were made in the presence of placed phosphorus and potassium.

dressings of ammonium sulphate were compared in the absence of potassium and in the presence of drilled and broadcast dressings of potassium sulplate. Similar comparisons were made between drilled and broadcast dressings of potassium in the presence and absence of nitrogen. The results of the 1954–6 experiments are given fully in Appendix Table 2 and are summarized in Tables 2 and 3. In 1954 the only significant benefit from placing nitrogen was obtained in the presence of drilled potassium. In 1955, on the other hand, placing nitrogen at the high rate reduced yields in the presence of placed potassium, this was the only significant difference between broadcasting and placement. In 1956, comparisons between drilling and broadcasting nitrogen in the absence of potassium were not made. All placed dressings of nitrogen were superior to broadcasting at Hatfield (three significant effects out of four comparisons), but at Rothamsted broadcasting nitrogen produced higher yields in three out of four comparisons (one significant effect).

The results of these four experiments do not provide any clear evidence on the benefits from placing as compared with broadcasting nitrogen; in particular the gains from placement did not depend in any consistent way on whether small or large potassium dressings were used or whether they were placed or broadcast.

Comparisons of placing and broadcasting potassium in the 1954–6 experiments are made in Table 3. There were significant gains from placed dressings of potassium in each of the three experiments at Rothamsted. Sixteen of the twenty comparisons made in Table 3 are in favour of placement (six significant effects). There was only one instance where broadcasting gave significantly higher yields than placing potassium (at Hatfield in 1956) and no obvious reason for this effect can be given.

Table 2. *Increases from drilling as compared with broadcasting nitrogen fertilizers for potatoes in experiments in* 1954–6

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

	Extra yields (in tons/acre) from placing nitrogen				
	At low rate	At high rate	At low rate	At high rate	Mean of both rates in two experiments
	Rothamsted 1954		Rothamsted 1955		
Without potassium	0·47	0·24	0·26	0·06	0·26
Broadcast potassium	0·93	0·34	−0·67	0·58	0·30
Drilled potassium	−0·16	2·28**	0·61	−1·10*	0·41
Standard error	±0·771		±0·455		—
	Hatfield 1956		Rothamsted 1956		
Broadcast potassium	2·02**	2·04**	−0·29	−1·62**	0·54
Drilled potassium	0·57	1·97**	0·63	−0·36	0·70
Standard error	±0·395		±0·375		—

Table 3. *Increase from drilling as compared with broadcasting potassium fertilizers for potatoes in experiments in* 1954–6

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

	Extra yields (in tons/acre) from placing potassium				
	At low rate	At high rate	At low rate	At high rate	Mean of both rates in two experiments
	Rothamsted 1954		Rothamsted 1955		
Without nitrogen	0·10	0·54	0·30	−0·87	0·02
With broadcast nitrogen	−0·46	1·00	1·90**	0·14	0·64
With drilled nitrogen	1·78*	−0·40	0·70	0·95*	0·76
Standard error	±0·771		±0·455		—
	Hatfield 1956		Rothamsted 1956		
With broadcast nitrogen	0·78	0·22	0·92*	0·42	0·58
With drilled nitrogen	−0·82*	0·29	1·96**	1·56**	0·75
Standard error	±0·395		±0·375		—

Peas and beans

Experiments on green peas (variety Onward) and broad beans (variety Aquadulce) were carried out at Rothamsted in 1955 and 1956. The detailed results from each experiment are given in Table 4. Broad beans were the more responsive crop and gave consistently higher yields from placing (seven out of eight increases were significant) than from broadcasting (none of the effects were significant). Placing gave higher yields of beans than broadcasting for all the fertilizer combinations tested, the gains from placement were significant with potassium in 1956 and with the NPK fertilizer mixture in both years. Placing gave consistently higher yields than broadcasting in the 1955 pea experiment and placement was significantly superior when phosphorus and potassium were tested alone and when the NPK mixture was used. In 1956 none of the fertilizer treatments gave a significant increase in yield, but placing PK fertilizer gave significantly more peas than broadcasting.

Kale

Experiments on kale were carried out at Rothamsted in 1955 and 1956 (Table 4). The experiment in 1955 was very inaccurate, probably due to a combi-

nation of drought and an acid subsoil. None of the increases in yield from fertilizer dressings were significant. In 1956 the crop was satisfactory, P, PK and NPK fertilizers gave significant increases in yield, both when placed and when broadcast, placing the same fertilizers gave higher yields, and the effect was significant when the NPK fertilizer

Maize

The results of one experiment laid down at Rothamsted in 1956 to compare placed and broadcast dressings of nitrogen and potassium on maize are given in Table 4. Early growth was improved by placed dressings of potassium and by the lower level of placed nitrogen in the presence of

Table 4. *Unmanured yields and the increases from broadcast and placed dressings of fertilizer on beans, peas, kale and maize at Rothamsted in* 1955 *and* 1956

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

Yields without fertilizer (cwt./acre)		Increases in yields (cwt./acre) from P	K	PK	NPK	Standard error of difference
	1955 experiment on broad beans (yields of beans + pods)					
	Broadcasting	4·2	3·8	9·2	4·0	5·05
	Placing	14·3**	9·5	17·2**	19·5**	
80·6 (± 2·92)	Placing minus broadcasting	10·1	5·7	8·0	15·5*	5·83
	1956 experiment on broad beans (yields of beans + pods)					
	Broadcasting	3·4	−5·5	6·0	−2·9	4·89
	Placing	13·9**	10·8*	17·5**	20·7**	
71·4 (± 2·82)	Placing minus broadcasting	10·5	16·3**	11·5	23·6**	5·64
	1955 experiment on green peas (yields of peas + pods)					
	Broadcasting	1·3	−3·8	4·0	2·5	2·57
	Placing	7·6**	3·7	9·7**	10·6**	
88·7 (± 1·48)	Placing minus broadcasting	6·3*	7·5*	5·7	8·1*	2·97
	1956 experiment on green peas (yields of peas + pods)					
	Broadcasting	−4·6	2·7	−8·4	−7·3	4·78
	Placing	−0·8	−2·4	4·9	−4·6	
80·2 (± 2·76)	Placing minus broadcasting	3·8	−5·1	13·3*	2·7	5·52
	1955 experiment on kale (yields of total crop)					
	Broadcasting	20·4	20·2	−4·0	4·6	18·95
	Placing	19·6	7·2	32·8	13·8	
222·6 (± 10·94)	Placing minus broadcasting	−0·8	−13·0	36·8	9·2	21·88
	1956 experiment on kale (yields of total crop)					
	Broadcasting	75·8**	48·2	151·0**	151·0**	24·48
	Placing	123·6**	−13·0	201·2**	210·8**	
409·8 (± 14·14)	Placing minus broadcasting	47·8	−61·2*	50·2	59·8*	28·26
		Increases in yield (cwt./acre) from N_1	K	N_1K	N_2K	
	1956 experiment on maize (yields of corn + cobs)					
	Broadcasting	3·9	6·2	15·0**	−2·2	4·79
	Placing	−15·0**	10·6*	2·5	−12·0*	
103·5 (± 2·77)	Placing minus broadcasting	−18·9**	4·4	−12·5*	−9·8	5·53

treatment was used. Placing potassium alone gave significantly less kale than broadcasting. The highest yield was obtained by placing a 'starter dose' of nitrogen in conjunction with phosphorus and potassium (i.e. the 'NPK' treatment). There was no advantage from broadcasting this 'starter dose' of nitrogen, however, and dressings of nitrogen applied wholly as a late-June top-dressing (i.e. together with broadcast PK fertilizer) gave identical yields.

placed potassium. The weather was cold and wet and the crop did not ripen, all nitrogen dressings delayed maturity and significantly lower yields were obtained from placed than from broadcast dressings of the single dose of nitrogen both alone and together with potassium. Dressings of potassium increased yields slightly in the absence of nitrogen and the increase in yield given by placing the potassium was significant.

DISCUSSION

The experiments on potatoes were undertaken to compare placing and broadcasting of nitrogen and potassium and tests on superphosphate were not made. Nitrogen and potassium components in compound fertilizers are largely responsible for fertilizer 'scorch' and the purpose of side-band placement is to obtain the advantages of localized dressings without damaging plant establishment. There would be little justification for special side-band placement attachments if broadcast and placed dressings of nitrogen and potassium were of similar value, since superphosphate could be applied in contact with the seed (which is safe) and the other two nutrients broadcast before planting. This method would have many practical and mechanical advantages and would simplify the construction of potato planters.

The 1953 potato experiments were carried out on commercial farms on a variety of soils in the eastern and midland counties. All experiments were planted under good conditions in March and early April, afterwards the season was generally favourable. Placing nitrogen tended to be superior to broadcasting at the lower level of manuring but gave lower yields than broadcasting when the heavier dressing was applied. There was little extra increase in yield on average from placing the heavy dressing as compared with the light dressing.

The 1954 potato experiment at Rothamsted was planted under good conditions, but the summer was cold and wet and yields were not high. The 1955 experiment was planted under reasonable conditions but heavy rain in May and early June was followed by hot dry weather which lasted into the autumn. Unmanured yields were low and there was little response to the dressings of nitrogen, dressings of potassium were of more value and gave consistent differences in favour of placement. The experiments in 1956 were planted under good conditions, although that at Rothamsted was badly infested with twitch. The experiment at Hatfield was on a free-working silty loam; at this centre, where the dressing of nitrogen appeared to be below optimum, placing gave consistently higher yields than broadcasting. At Rothamsted, on the other hand, placing the heavier dressing of nitrogen produced lower yields than broadcasting. There were consistent gains from drilling potassium at Rothamsted.

Although the two series of experiments on potatoes do not provide any clear and consistent evidence on the value of placing nitrogen, there was an over-all advantage from placement and the gains tended to be greater when the lighter dressings were used. In the 1954–6 experiments the benefits from placed dressings of potassium were more regular and higher yields of potatoes were generally given by placement. There was, however, no consistent relationship between the gains from placing one nutrient and the way in which the other nutrient was applied.

The experiments on peas and beans at Rothamsted in 1955 and 1956 were sown on ordinary arable soils which were low in 'available' phosphorus and potassium. The growth of both crops was improved by dressings of fertilizer, placing gave much more vigorous crops and the effects were particularly marked in the pea experiments. Unfortunately, the maturity of both pea crops coincided with unfavourable weather. In 1955, drought and hot weather prevented many of the pods on the better plots (with placed fertilizer) from filling properly and these pods were not included in the yields of saleable produce. As a result, the gains from placement were much smaller than expected. In 1956 the visual benefits from placement were even more marked and the haulm became very long in the cold wet weather. Many of the plants on the best plots rotted and mildew was widespread. Yields were seriously affected and several fertilizer treatments produced lower yields than the unmanured plots. The broad bean experiments were not so affected by these extremes of weather and consistent effects were obtained in each year. Much higher yields of beans were obtained by placing than by broadcasting nitrogen, phosphorus and potassium; there was little benefit from broadcast dressings on either crop. The work suggests that benefits from placing a PK fertilizer beside the seed, demonstrated in earlier experiments on peas and beans, were due to both the phosphorus and potassium components of the mixture. These experiments also emphasize that testing broadcast fertilizers for peas and beans may give misleading impressions since much larger yield increases can be obtained by placing the fertilizers beside the seed.

The 1955 kale experiment was unsatisfactory as a result of summer drought and acid subsoil conditions. The 1956 experiment produced large and consistent increases in yield in a wet season and there were marked gains in yield from placing phosphorus and potassium together, and from the complete NPK mixture. Placed dressings of potassium (in the absence of phosphorus) depressed yields throughout the growing season.

The weather in 1956 was unsuitable for the ripening of maize, nitrogen increased vegetative growth and delayed maturity and yields of corn plus cobs were reduced. In the earlier part of the season the experiment did show that maize benefited from placing potassium fertilizer on this potassium-deficient soil.

SUMMARY

1. In eight experiments on main-crop potatoes in 1953–4 placing 0·5 cwt. N/acre in a band beside the seed tended to give higher yields than broadcasting the dressing; when 1·0 cwt. N/acre was applied,

Fig. 1A

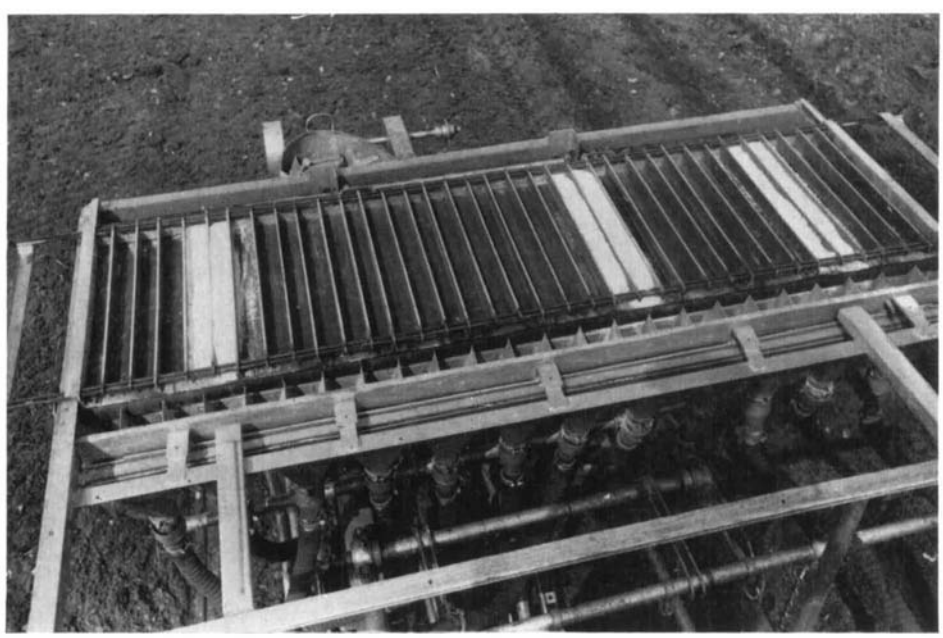

Fig. 1B

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(*Facing p.* 59)

broadcasting tended to be superior to placement. There were no consistent gains from placing 1·5 cwt. K_2O/acre.

2. Four other potato experiments in 1954–6 tested all combinations of placing and broadcasting two levels of nitrogen and potassium. There was no clear relationship between the effects of broadcasting or placing one nutrient and the way in which the other nutrient was applied. When 0·5 cwt. N was applied, placing gave higher yields in seven out of ten possible comparisons (one effect was significant). With 1·0 cwt. N/acre there were also seven of ten comparisons in favour of placement (three significant effects), but in two other comparisons broadcasting gave significantly higher yields. Placing potassium gave higher yields than broadcasting in sixteen out of twenty comparisons (six significant effects), in one of the remaining comparisons broadcasting potassium was significantly superior. Placing of the potassium and, to a lesser extent, the nitrogen components of a complete potato fertilizer is likely to be beneficial.

3. In two experiments each on green peas and broad beans placing of phosphorus and potassium separately and together gave consistently higher yields than broadcasting these nutrients. When nitrogen was used in addition to phosphorus and potassium there were small gains in yield of broad beans provided the mixture was placed. There were no gains in yields of green peas from nitrogen however the mixture was applied.

4. In one kale experiment in 1955 there were no significant effects on yield. In a 1956 experiment placing P, PK and NPK fertilizers beside the seed gave higher yields of kale than broadcasting these fertilizers.

5. In one maize experiment in 1956 the crop did not ripen properly. All nitrogen dressings delayed maturity and where nitrogen was placed (with or without potassium) it gave significantly less crop than broadcasting.

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EXPLANATION OF PLATE

Fig. 1A. Multi-row fertilizer placement drill fitted with end-delivery fertilizer mechanism and mounted on a self-propelled tool-frame.

Fig. 1B. Trays of the end-delivery fertilizer mechanism showing compartments loaded with fertilizer and (beneath) fertilizer delivery tubes.

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Appendix Table 1. *Unmanured yields of potatoes (in tons/acre of total tubers) and the increases given by broadcast and placed dressings of nitrogen and potassium*

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

	Without nitrogen		Increases in yield from nitrogen				
			At low rate		At high rate		Standard error of increase
	Yield	Standard error	Broadcast	Placed	Broadcast	Placed	
Experiments in 1953							
Barton Hill, Beds	10·42	±0·473	0·55	1·05	1·84*	1·05	±0·819
Great Munden, Herts	6·75	±0·252	3·38**	2·64**	3·96**	4·17**	±0·436
Hambleton, Rutland	11·93	±0·332	0·86	0·80	1·01	0·93	±0·575
Hillesden, Bucks	8·56	±0·760	0·86	1·49	3·67*	3·36*	±1·309
Little Dalby, Leics	9·99	±0·581	2·97**	3·72**	3·55**	2·89**	±1·006
North Luffenham, Rutland	6·37	±0·371	0·48	1·21	1·11	0·87	±0·642
Thrales End, Beds	9·10	±0·315	2·42**	4·79**	4·42**	4·13**	±0·546
Experiment in 1954							
Great Munden, Herts	5·94	±0·462	0·14	1·22	2·27**	1·85**	±0·653
Mean of 8 centres	8·63	—	1·46	2·12	2·73	2·41	—

	Without potassium		Increases in yield from potassium		
	Yield	Standard error	Broadcast	Placed	Standard error of increase
Experiments in 1953					
Barton Hill	10·97	±0·669	0·05	0·50	±0·946
Great Munden	10·23	±0·356	1·08*	0·69	±0·503
Hambleton	13·52	±0·470	−1·50*	−0·66	±0·665
Hillesden	7·21	±1·070	4·15*	4·71**	±1·513
Little Dalby	13·59	±0·821	1·42	−0·71	±1·161
North Luffenham	5·09	±0·524	1·62*	2·15**	±0·741
Thrales End	10·21	±0·446	2·26**	3·02**	±0·631
Experiment in 1954					
Great Munden	6·79	±0·462	1·24	1·00	±0·653
Mean of 8 centres	9·70	—	1·29	1·34	—

Appendix Table 2. *Unmanured yields of potatoes (in tons/acre of total tubers) and the increases given by combinations of broadcast and placed dressings of nitrogen and potassium in 1954–6 experiments*

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

	Yield without nitrogen	Standard error	Increases from nitrogen: At low rate, Broadcast	At low rate, Placed	At high rate, Broadcast	At high rate, Placed	Standard error of increase
Rothamsted 1954							
No potassium	8·06	±0·385	1·16	1·63*	3·21**	3·45**	±0·667
Increases from potassium at low rate							
Broadcast	−0·22	±0·667	2·49**	2·76**	3·67**	3·82**	±0·862
Placed	−0·12	±0·667	2·24*	3·52**	2·99**	6·63**	
Increases from potassium at high rate							
Broadcast	0·07	±0·667	1·47	3·06**	3·48**	4·02**	
Placed	0·61	±0·667	3·14**	1·54	3·82**	4·74**	
Rothamsted 1955							
No potassium	4·85	±0·227	−0·32	−0·06	−0·44	−0·38	±0·393
Increases from potassium at low rate							
Broadcast	−0·48	±0·393	0·07	−0·90	−0·26	1·52**	±0·508
Placed	−0·18	±0·393	0·88	1·22*	2·74**	0·80	
Increases from potassium at high rate							
Broadcast	0·10	±0·393	0·79	0·42	1·85**	1·23*	
Placed	−0·77	±0·393	0·82	1·70**	2·10**	1·85**	
Rothamsted 1956							
No potassium	6·72	±0·265	—	—	—	—	—
Increases from potassium at low rate							
Broadcast	—	—	3·56**	3·22**	5·83**	4·09**	±0·459
Placed	—	—	4·96**	5·51**	6·26**	5·71**	
Increases from potassium at high rate							
Broadcast	—	—	5·34**	5·10**	7·62**	6·14**	
Placed	—	—	6·05**	6·76**	7·76**	7·60**	
Hatfield 1956							
No potassium	7·35	±0·279	—	—	—	—	—
Increases from potassium at low rate							
Broadcast	—	—	1·37**	3·66**	2·77**	5·28**	±0·484
Placed	—	—	2·40**	2·59**	3·30**	4·71**	
Increases from potassium at high rate							
Broadcast	—	—	2·38**	4·13**	3·52**	5·10**	
Placed	—	—	2·85**	3·80**	3·48**	6·01**	