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## PLACEMENT OF FERTILIZERS FOR POTATOES PLANTED BY MACHINES

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(With Plate 20 and Three Text-figures)

### INTRODUCTION

Earlier experiments (Cooke, 1949) compared different methods of applying fertilizers for potatoes planted by hand in the furrows of ridged land. There was no advantage from special placement methods. Broadcasting over the ridges immediately before planting, the method then commonly used by farmers, gave similar yields to placing the dressing in bands beside the seed. Fertilizer broadcast on flat land before ridging was mixed with all the soil in the final ridges, and was consistently inferior to dressings broadcast after ridging but before planting, which were concentrated over and around the seed. The general conclusion was that 7 cwt. of complete potato fertilizer broadcast after ridging produced the same average yield as 10 cwt./acre broadcast before ridging.

Since 1947, when these experiments were concluded, the proportion of the potato acreage planted by machines has increased rapidly. The Ministry of Agriculture (1950) records that the number of mechanical planters used in England and Wales rose from approximately 7000 in 1948 to 11,000 in 1950. Boyd & Dyke (1950), from a survey of main-crop potatoes, showed that in 1948 one-third of the sampled acreage was planted by machines. In 1950, when 40% of the sampled acreage was planted mechanically, 80% of the machines used worked on flat land, planting the seed and covering it with a ridge of soil in one operation (Boyd & Dyke, 1952). When potatoes are planted in this way broadcast fertilizers are distributed throughout the ridges and may not be used as efficiently as when they are concentrated near the seed (Cooke, 1950).

Boyd & Dyke (1952) found that one-quarter of the mechanical potato planters encountered in their 1950 survey were fitted with a fertilizer attachment, generally placing fertilizer in a planting-shoe. Heavy dressings used in this way in dry years may check growth and reduce yields. United States experiments (Cumings & Houghland, 1939) showed that fertilizer placed too close to the seed delayed emergence and reduced yields; bands placed beside and a little below the seed were safe and gave consistently higher yields than broadcast fertilizer.

### *Types of potato planters and methods of planting*

Although fully-automatic machines supervised by one person are available, most British potato planters are semi-automatic and need one operator for each row to fill the cups of the planting mechanism. A proportion of these machines have fertilizer attachments. Automatic and semi-automatic planters are expensive and are used mainly by farmers growing an appreciable acreage of potatoes. During the last few years much cheaper machines have been introduced and have become very popular. They consist of seed hoppers, planting-shoes fed by tubes and seats for the operators who drop seed directly down the tubes leading to the planting-shoes. No fertilizer hoppers are fitted. These attachments fit on to tractor tool-bars fitted with three ridging-plough bodies.

Mechanical planters are used in three ways. The field may be ridged separately, the machine being used to plant seed in the furrows and split the ridges in one operation. Fertilizer broadcast over the ridges immediately before planting is concentrated near to the seed when the ridges are split and there is no need for special placement equipment. Other farmers use their machines to plant in the ridges of ridged land, generally to ensure deep planting and accurate spacing between rows when light equipment is used on heavy soils or on sloping fields. Broadcast fertilizer must be applied on the flat before the ridges are made. The most common method is to plant from flat land, planting and ridging being combined. It is very difficult to compare different planting methods, as well as different methods of applying fertilizers in experiments on ordinary commercial farms. The work reported here was restricted to planting from flat land which is likely to remain the most important method of using all types of planting machines.

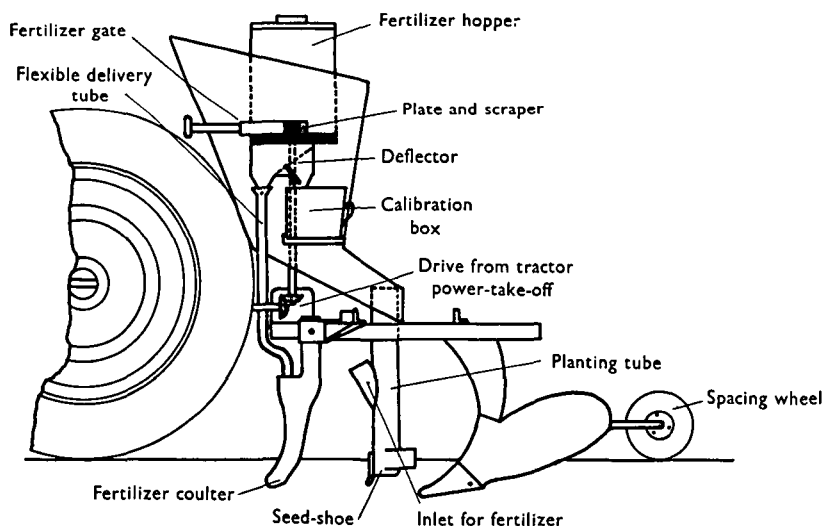
### *Description of the experimental planter*

No potato planters sold in England are suitable for experimental work on fertilizer placement without some modification, and it was decided to adapt a hand-dropping planting attachment. The National Institute of Agricultural Engineering (1950) has

described tests of the 'Scarcliffe' Two-Row Potato Planter which was modified for these experiments. It is an attachment for a rear-mounted tractor toolbar fitted with ridging bodies and consists of a sheet-steel hopper, two steel delivery tubes to each of which are attached foot-rests and seats, and a spacing wheel. The base of the hopper slopes to the rear where potatoes roll into a shallow trough. Two operators pick the potatoes from the trough and drop them down the delivery tubes to the timing of a clicker on the spacing wheel.

The complete planter fitted on the tractor toolbar by the National Institute of Agricultural Engineering for the 1951 experiments is shown in Pl. 1a. It was fairly satisfactory, but planting depths

of each can carried fertilizer through adjustable gate openings; scrapers on the plates diverted the flow to delivery tubes. Three settings of the gates were intended to deliver 3.75, 7.5 and 15 cwt./acre. For field calibrations fertilizer was diverted to collecting boxes, but normally it was led through flexible rubber hoses into an adjustable coulter, into the seed-shoe, or was allowed to fall on the ground ahead of the seed-shoe. The two operators made these adjustments by moving the ends of the delivery tubes. The tractor driver varied the gate openings from the driving seat. A fourth person supervised the general operation of the planter, recorded the calibrations and applied broadcast fertilizer.



Text-fig. 1. Potato planter fitted with fertilizer attachment used in 1951 experiments.

varied on different seed-beds. On dry and compacted or heavy and moist seed-beds potatoes could not be planted deeply, the seed-shoes had little adjustment and would not penetrate hard soils. The National Institute of Agricultural Engineering modified the planter for the 1952 experiments. The ends of the seed tubes were replaced by sturdy adjustable seed-shoes having sharp leading-edges and a shape which tended to keep them in work as the planter was drawn forward. These seed-shoes penetrated well and potatoes were planted at the correct depth on most soils.

#### *Fertilizer delivery mechanism used in 1951*

Text-fig. 1 illustrates the mechanism, which was driven from the 'Power-Take-Off' of the tractor. Two fertilizer hoppers were fitted into the seed hopper of the machine. Each consisted of a semi-cylindrical can, the outer face being the wall of the seed hopper. Circular plates rotating in the bottom

The amount of fertilizer delivered by one revolution of the plate was the volume of an annular ring having a cross-section equal to the area of the gate opening. The plate was covered with fertilizer from the bulk in the hopper above by gravity; positive delivery depended on the absence of 'slip' between the fertilizer and the plate surface within the hopper. Delivery rates were theoretically proportional to plate speed, but condition of the fertilizer affected its bulk density and dry material passed more easily than wet through the gate opening. Satisfactory conditions for using this mechanism in experiments have been described previously (Cooke, 1951).

Field variations in delivery rates were due to several causes. In stationary calibrations the fertilizer delivered by each revolution of the plates was collected and weighed separately. Two-thirds of the fertilizer in the full hoppers was delivered at constant rate, and the last third at decreasing

rates. In all field work the hoppers were therefore refilled when two-thirds of the fertilizer had been used.

Further tests on the stationary planter showed that to obtain uniform delivery the plates should be horizontal. The toolbar was set so that one delivery plate was tilted upwards and the other downwards. The delivery was low from the plate which was tilted upwards and correspondingly high from the other plate tilted downwards. It was difficult to keep the toolbar level in the field, and variable delivery rates were recorded in a few of the experiments which were on sloping land. The average rate of dressing for a whole plot was not affected by tilting of the planter but adjacent rows did not receive identical quantities of fertilizer.

Fertilizers in poor 'condition' have absorbed water and do not flow easily; they are delivered irregularly by most mechanisms which do not depend on positive displacement. Damp material (containing 12% of moisture) was delivered at low and irregular rates, delivery ceased when one-fifth of the fertilizer still remained in the hopper. One uniform batch of fertilizer stored in sealed paper bags was used in the field experiments. Fertilizer in damaged bags was not used in the machine.

The planter was calibrated twelve times at each experiment. One calibration was made before planting the experiment and the remaining eleven were made on plots having broadcast fertilizer. The output from the machine was broadcast on appropriate plots, work being arranged so that fertilizer collected on one plot was spread on the next plot requiring a broadcast dressing. Broadcast fertilizer was therefore applied at the same rates as placed fertilizer and chance variations in delivery rates affected all treatments equally. The average delivery rates for experiments at fourteen centres and the standard deviations for the variations between centres were:

	Cwt. of fertilizer per acre		
	High rate	Medium rate	Low rate
Mean	14.1	5.8	3.3
S.D.	± 0.37	± 0.17	± 0.16

There were day-to-day variations in delivery caused by changes in atmospheric humidity and differences in the sizes of granules in individual bags of fertilizer, but variations from centre to centre caused by differences in the seed-beds were much greater. The fertilizer mechanism was driven from the Power-Take-Off of the tractor and tractor wheel-slip was therefore reflected in increased fertilizer delivery rates. No quantitative records of wheel-slip were obtained but excessive amounts were noted at Bolnhurst, Little Dalby and Waresley, where average

delivery was high. At any one centre the amount of wheel-slip varied in different parts of the field and delivery rates varied accordingly.

The average delivery rates were not in the intended ratio of 4:2:1. With such mechanisms alterations in rates should be made by changing the speed of the plates and not by varying the gate openings. An independent drive should also be provided which is not affected by tractor wheel-slip.

#### *End-delivery fertilizer mechanism used in 1952*

The 1952 work was planned to compare fertilizer dressings broadcast early and worked deeply into the soil with late dressings applied on the seed-bed immediately before planting. A predetermined quantity of fertilizer had to be applied perhaps 2 or 3 weeks before planting and before any field calibrations had been carried out. The National Institute of Agricultural Engineering therefore fitted a mechanism to deliver an exact amount of fertilizer under any conditions.

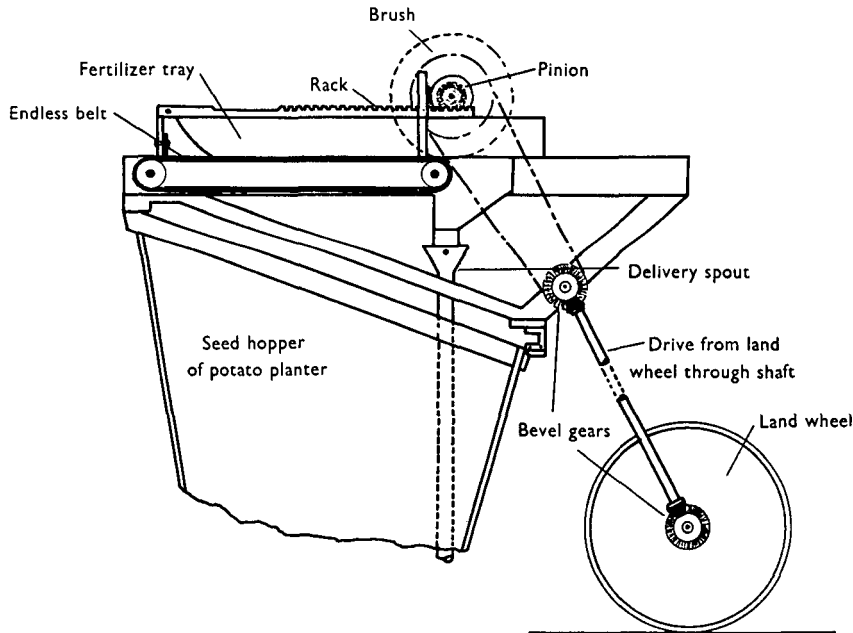
An end-delivery fertilizer mechanism described by Fairbank & Minges (1942) has been used largely in recent American fertilizer placement work and in experiments using radioactive fertilizers. A weighed (or measured) quantity of fertilizer was spread evenly along the upper surface of a belt stretched over two rollers. A tray resting on the belt prevented loss of fertilizer at the sides and edges, and a rack fitted to the tray engaged with a pinion driven by a land wheel. Both tray and belt moved horizontally as the pinion was rotated to move the rack forward. As the belt moved forward over the roller, fertilizer was discharged from the open end and delivered through tubes to the fertilizer coulters. A rotating brush with long stiff bristles (fitted on the pinion shaft) filled the open end of the tray. The brush prevented excessive delivery due to fertilizer flowing freely over the end of the belt when the machine was jolted and, by wiping fertilizer from the end of the belt as it moved forward, gave an even rate of flow. (It is not essential to fit a brush at the end of the tray unless heavy dressings are applied, and there is risk of unrestricted gravity flow from the open end of the belt when the machine is used on sloping ground.) The drive was arranged so that the load of fertilizer was discharged exactly within the length of row used in one plot.

A two-cell tray and belt of this pattern was fitted over the seed-hopper of the potato planter, the mechanism being driven by a trailing land wheel. Fertilizer falling from the end of the belt was collected by a funnel and passed through rubber hoses either to adjustable coulters or into the seed-shoes. In the experiments the only alterations necessary at plot boundaries were variations in the positions of the outlets from the funnel to provide

for either sideband placement or placement in contact with the seed. A team of four, including the tractor driver, was needed. Two operators on the planter 'dropped' seed, and at plot boundaries refilled the fertilizer trays and adjusted the mechanism. A fourth person measured out fertilizer dressings for each row and supervised the general working of the machine. The planter used in the 1952 experiments is illustrated in Pl. 1b and the mechanism is shown diagrammatically in Text-fig. 2.

was placed in contact with the seed. Dressings were placed in a band 3 in. to the side of the seed and a little below its level by a coulter mounted on the toolbar and running ahead of the seed-shoe. Only one band was placed beside the seed since two coulters needed to place fertilizer on both sides would have restricted soil flow and caused blockages under the planter.

Granular National Compound Fertilizer No. 1 (7% N, 7% P<sub>2</sub>O<sub>5</sub>, 10.5% K<sub>2</sub>O) was used in all the



Text-fig. 2. End-delivery fertilizer mechanism fitted to potato planter for 1952 experiments.

#### *Scope of the experiments*

The methods of fertilizer application tested in 1951 were:

- L Broadcast on the seed-bed by hand immediately before planting.
- S Placed on the soil surface immediately in front of the planting-shoe.
- C Placed in contact with the seed.
- D Placed in one band to the side and a little below the seed.
- LC Half broadcast on the surface before planting and half placed in contact with the seed.

Broadcast fertilizer was mixed with the soil by the seed-shoes and ridging bodies. Fertilizer was placed on the soil surface by clipping the delivery tubes in front of the seed-shoes. It was hoped that this method would give the advantages of placement without being dangerous or needing special coulters. By leading the delivery tubes into the seed tubes through holes cut a little above the shoes, fertilizer

1951 experiments. The first four methods of application listed were tested at 5.8 and 14.1 cwt./acre (averaging all centres) and may be compared directly. Dressings were applied half in contact and half broadcast at 6.5 and 11.6 cwt./acre.

The methods of application tested in the 1952 experiments were:

- E Broadcast before cultivating to prepare the seed-bed.
- L Broadcast on the seed-bed immediately before planting.
- C Placed in contact with the seed.
- D Placed in one band to the side and a little below the seed.

Broadcast fertilizer was applied at early and late stages in the preparation of the seed-bed. Early dressings were generally applied to the winter-ploughed land 2 or 3 weeks before planting; at Bugbrooke and Wing the dressings were ploughed-in during April. Subsequent cultivations mixed

fertilizer and soil intimately. Late dressings were broadcast immediately before planting and fertilizer was mixed with the soil by the seed-shoes and ridging bodies. Fertilizer was placed in contact with the seed and in a band beside the seed as in the 1951 experiments. Each method of application was tested at exactly 7.5 and 15.0 cwt./acre of granular National Compound Fertilizer No. 1A (8% N, 6% P<sub>2</sub>O<sub>5</sub>, 10.5% K<sub>2</sub>O).

#### *Methods of laying down the experiments*

In both years each plot was 22 yards long and contained four rows spaced 28 in. apart. In 1951 five methods of application were each tested at two rates, and the ten fertilized plots, together with two plots without fertilizer, were arranged in a randomized block. There were three blocks in each experiment. A preliminary visit was made to each field and the most suitable area was chosen. The seed-bed was prepared by the farmer and a second visit was made to plant the experiment. The experimental planter, mounted on its own tractor, was taken from centre to centre on a four-wheeled trailer drawn by a lorry. A string beside the plots guided the tractor driver while two rows of potatoes were planted beside the experimental area to adjust the machine and to obtain the first set of calibration data. Work then began on the experiment; potatoes were planted continuously from headland to headland, placed fertilizer being applied to appropriate plots. The planter was stopped on plot boundaries while adjustments were made to the fertilizer delivery mechanism. Calibrations were carried out on plots having broadcast fertilizer by diverting the flow into collecting boxes over a 22-yard run. After weighing, the fertilizer was spread by hand on the next plot requiring a broadcast dressing.

In 1952 each of the four methods of application was tested at 7.5 and 15 cwt. of fertilizer per acre. The eight fertilized plots, together with two plots without fertilizer, were laid down in a randomized block. There were four blocks at most centres, occasionally there was insufficient land and only three blocks were laid down. A preliminary visit was made to each field before cultivating in spring, to mark out the site and apply early dressings of broadcast fertilizer. The seed-bed was prepared by the farmer, and a second visit was made to plant the experiment. The site was marked out again and fertilizer was broadcast over the seed-bed on appropriate plots. A string set to the right-hand side of the centre line of the experiment guided the tractor driver. After the first two rows had been planted, the furrows were used as guides. The planter was driven round the experimental area, completed work always being on the tractor driver's right, until the correct number of rows had been planted exactly within the prescribed width of the

experiment. Potatoes were planted continuously from headland to headland, the attachment being used to place fertilizer on appropriate plots. Dressings of fertilizer required for each row were measured in the field using a calibrated metal can. The planter was stopped on plot boundaries, the fertilizer dressing was placed in the tray and spread evenly over the exposed surface of the belt. When the belt was completely discharged at the end of the row it was reset ready for the next plot.

After planting, each experiment was cultivated, sprayed and treated in the same way as the rest of the field. At harvest the centre two rows were dug by hand, discarding a short length at the end of each row. The tubers were picked, cleaned and weighed. In each year the number of plants in the area harvested was recorded at all centres except one.

## RESULTS OF THE EXPERIMENTS

### *Positions of fertilizer dressings within the ridges*

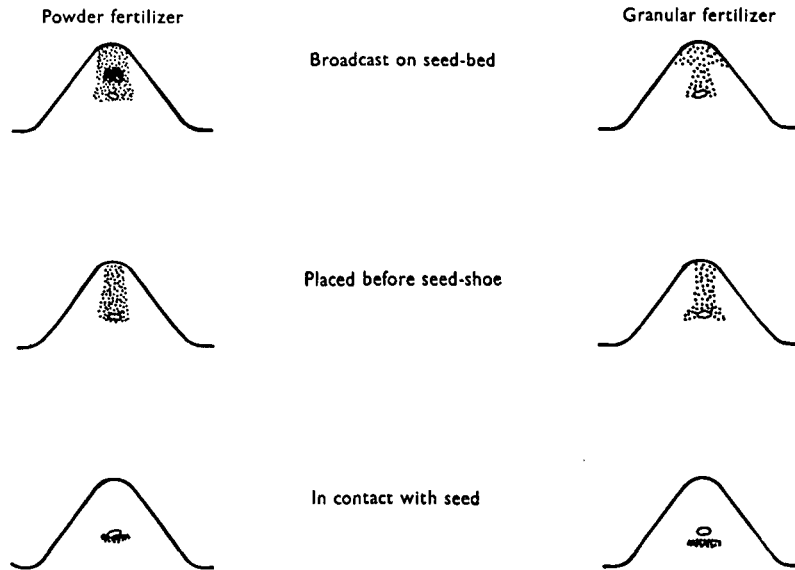
In 1951 gross structure and moisture determined how the soil flowed over the mould boards and influenced the position of broadcast fertilizer within the final ridges. With soil in 'average' condition fertilizer applied broadcast or placed in front of the seed-shoes was thrown to the middle of the ridges and concentrated above the seed. When the soil was very wet much of the fertilizer remained on the surfaces of the ridges; under very dry conditions it formed broad bands below the seed. There was little opportunity while the experiments were being planted for systematic examination of the positions assumed by broadcast fertilizer. The information gathered was supplemented by further tests at Rothamsted where granulated and powdered fertilizers were broadcast, placed in front of the seed-shoe and placed in contact with the seed. The ridges were opened immediately and the positions of the fertilizer dressings were measured. The measurements are illustrated in Text-fig. 3.

When granulated fertilizer was broadcast on the seed-bed, most was thrown to the centre of the ridge but some was visible on the outer surface. Powdered fertilizer behaved more regularly, being thrown to the centre of the ridge and concentrated immediately above the seed. Granulated fertilizer placed in front of the seed-shoe was found in the middle of the ridge extending from below the seed to the soil surface. Powdered fertilizer occupied a rather narrower zone extending from the seed to the top of the ridge. Granulated fertilizer placed in the seed-shoe lay below the seed in a broad band 4 in. wide and separated from the seed by 1 in. of fertilizer-free soil. Powdered fertilizer formed a band 3 in. wide and 1 in. thick, the seed touching the top of the band. Planting conditions were good and soil structure and moisture were roughly

averages of the conditions met at various centres in 1951.

In 1952 the early dressings of broadcast fertilizer were not visible after the seed-beds had been prepared; presumably they were distributed throughout the soil.

Fertilizer placed in contact with the seed gave slightly higher mean yields than fertilizer drilled in bands beside the seed, both methods gave much higher yields than broadcasting fertilizer or placing it before the seed-shoe. Placing half the fertilizer in contact with the seed and broadcasting the remain-



Text-fig. 3. Distribution of fertilizer within potato ridges at Rothamsted.

At each centre in 1952 the ridges were opened on plots having placed fertilizer. The distances of fertilizer from the seed were measured. Similar measurements of fertilizer placed in sidebands were made in 1951. The positions of the bands (averaging all experiments in each year) were:

	Distance of sideband		Band in contact	
	To side of seed (in.)	Below seed centres (in.)	Width of band (in.)	Distance below seed-base (in.)
1951	3.4	0.9	—	—
1952	2.4	1.1	1.5	0.5

#### Yields of potatoes

There were fourteen experiments in 1951 and nineteen experiments in 1952. Yields of total tubers were determined at all centres and the numbers of plants harvested were recorded at all centres, except one, in each year. Mean yields and plant numbers are set out in Table 1 averaging all experiments in each year.

On the average of all the experiments in 1951 broadcast fertilizer and fertilizer placed before the seed-shoe gave similar yields at both rates of applica-

tion. Fertilizer placed in contact with the seed gave slightly higher mean yields than fertilizer drilled in bands beside the seed, both methods gave much higher yields than broadcasting fertilizer or placing it before the seed-shoe. Placing half the fertilizer in contact with the seed and broadcasting the remain-

der gave yields between those given by broadcasting the whole dressing and by placing it in contact. In 1952 early and late broadcasting gave similar average yields at both rates of application. Fertilizer placed in contact with the seed gave slightly higher mean yields than fertilizer drilled in a band beside the seed at the low rate; at the high rate of dressing contact placement was slightly inferior to sideband application. Both methods of placing fertilizer gave much higher yields than broadcasting.

#### Relative efficiencies of methods of applying fertilizer

Relative efficiencies of different methods of application were obtained by drawing a smooth curve for the yields given in each year by sideband placement which was taken as the standard. The amounts of fertilizer applied in a sideband required to give yields equal to those given by the other treatments were read off from the curves. These 'equivalent dressings' are expressed in Table 2 as percentages of the amounts of fertilizer actually applied.

In both years broadcasting on the seed-bed was about half as efficient as sideband placement at the low rate and two-thirds as efficient at the high rate of application. Fertilizer broadcast before cultivating was a little less efficient than seed-bed dressings in the 1952 experiments. Contact placement

Table 1. *Variations in yields and numbers of potatoes with different rates and methods of applying fertilizer*

1951 experiments						
Rate of fertilizer* (cwt./acre)	No fertilizer	Broadcast on seed-bed L	Placed			Half broadcast* half in contact LC
			Before seed-shoe S	In sideband D	In contact C	
Yields of tubers in tons per acre (14 experiments)						
5.8	—	9.15	9.22	10.30	10.39	9.97
14.1	—	10.98	11.07	11.60	11.75	11.14
Mean rate	7.37	10.06	10.15	10.95	11.07	10.55
Number of plants in thousands per acre (13 experiments)						
5.8	—	11.2	11.2	11.1	11.2	11.2
14.1	—	11.0	11.1	11.3	11.2	11.3
Mean rate	11.2	11.1	11.2	11.2	11.2	11.2
1952 experiments						
Rate of fertilizer (cwt./acre)	No fertilizer	Fertilizer broadcast		Fertilizer placed		
		Early E	Late L	In contact C	In sideband D	
Yields of tubers in tons per acre (19 experiments)						
7.5	—	7.94	8.06	9.34	9.05	
15.0	—	9.58	9.70	10.29	10.58	
Mean rate	5.74	8.76	8.88	9.81	9.82	
Number of plants in thousands per acre (18 experiments)						
7.5	—	11.2	11.2	11.4	11.3	
15.0	—	11.2	11.3	11.2	11.4	
Mean rate	11.0	11.2	11.2	11.3	11.4	

\* The stated rates do not apply to dressings which were half broadcast and half placed in contact; 6.5 and 11.6 cwt./acre were applied by that method.

was more efficient than sideband placement at the low rate in both years; for the high rate of dressing it was more efficient than sideband placement in 1951 and less efficient in 1952. In 1951 some plots had half the fertilizer applied in contact with the seed and the remainder broadcast; heavy dressings used in this way were more efficient than light ones.

Table 2. *Relative efficiencies of methods of applying fertilizer taking sideband placement as the standard (equal to 100)*

	Low rate	High rate
1951 experiments		
Broadcast on seed-bed	50	68
Placed before seed-shoe	51	72
Placed in contact	> 100	> 100
Half broadcast, half in contact	75	89
1952 experiments		
Broadcast early (before cultivating)	57	63
Broadcast late (on seed-bed)	61	67
Placed in contact	> 100	87

#### *Yields at individual centres*

There were good responses to fertilizer in practically all the experiments. Unmanured yields and increases from fertilizer applied in different ways are presented for each centre in the Appendix, after

averaging rates of dressing. Early crops harvested in July were grown at Potter Street in both years and at Bolnhurst in 1952. The results of these experiments were similar to those where main crops were grown and they have not been treated separately. Gains from placing fertilizer in each of the experiments on early potatoes were rather larger than the average gains for all experiments in each year. In 1951 yields were satisfactory at all centres except two (Elstow and Meldreth) where early growth was very slow due to late planting in rough and dry seed-beds followed by summer drought. All methods of applying fertilizer increased yields significantly at eleven of the fourteen centres.

In 1952 yields were satisfactory at all centres except Little Dalby where the crop was heavily infected with virus diseases. The increases in yield from each method of applying fertilizer were significant at every centre except Melbourne, where contact placement gave a small, non-significant, increase in yield.

#### *Comparisons of different methods of applying fertilizer*

In 1951 the split dressing (half in contact, half broadcast) was applied at different rates from those used for other methods of application; it was not



possible to compare this method rigidly with other methods simply by averaging rates of application. As the split application behaved as was expected, yields being intermediate between those given by broadcasting and by contact placement, detailed comparisons of this method with others have not been made at individual centres. The differences between yields given by the remaining four methods of applying fertilizer were calculated after averaging rates of application. Similar comparisons were made

in 1952 contact placement, although superior at the low rate, gave lower yields than sideband placement at the high rate (Table 1). Since damage must be most marked when heavy dressings are used, comparisons were made for each centre between yields given by the heavy dressing placed in contact and in a sideband. The differences between yields given by the heavy and light dressings placed in contact with the seed were also calculated. These comparisons are summarized in Table 4.

Table 3. Nature of the differences between yields given by different methods of applying fertilizer and the numbers of significant positive effects at individual centres

	Broadcast		Placed		
	Early	Late	In contact	In sideband	Before seed-shoe
Fourteen experiments in 1951					
Number of centres where greater yields were given by:					
Broadcast (late)	>	—	3	2	7
Placed					
In contact	>	11	—	7	10
In sideband	>	12	7	—	11
Before seed-shoe	>	7	4	3	—
Number of significant positive effects:					
Broadcast (late)	>	—	1	0	1
Placed					
In contact	>	7	—	1	5
In sideband	>	5	1	—	4
Before seed-shoe	>	0	0	0	—
Nineteen experiments in 1952					
Number of centres where greater yields were given by:					
Broadcast					
Early	>	8	3	1	—
Late	>	11	2	4	—
Placed					
In contact	>	16	—	11	—
In sideband	>	18	8	—	—
Number of significant positive effects:					
Broadcast					
Early	>	1	1	0	—
Late	>	1	1	1	—
Placed					
In contact	>	11	—	1	—
In sideband	>	9	1	—	—

between yields given by the four methods tested in 1952. The natures of the differences at individual centres between methods of applying fertilizer are summarized in Table 3. These data demonstrate the consistent superiority of fertilizer placed either in contact with the seed, or in sidebands, over broadcast fertilizer. In 1951 fertilizer placed in front of the seed-shoe behaved in much the same way as dressings broadcast on the seed-bed and was consistently inferior to other placement methods. In 1952 the two methods of broadcasting behaved similarly.

#### Comparisons of contact and sideband placement

On the average of all centres in 1951 the heavy dressing placed in contact gave the highest yields;

Two of the 1951 experiments were on light soils (Great Gransden and Gayton) and gave similar results to the other experiments on heavier land. In 1952 six experiments (Tingrith, Denham, Great Gransden, Bugbrooke, Easton and Wing) were on light soils, and comparisons are made separately in Table 4. Fertilizer placed in contact in 1951 did not reduce average yields. When the heavy dressing was applied contact placement was significantly inferior to sideband placement at Barton and Meldreth; at Albury placing fertilizer in contact gave a significantly higher yield than placing in sidebands.

On six light soils in 1952 contact placement was consistently superior to sideband placement at the low rate; at the high rate contact was consistently

inferior to sideband placement, but the difference was significant only at Easton. On the average of thirteen heavier soils contact placement was somewhat superior at the low rate but the two methods gave similar yields at the high rate. At Melbourn the heavy dressing placed in contact gave significantly lower yields than the same dressing placed in a sideband and the light dressing placed in contact. There were no other instances of significant reductions in yield from fertilizer placed in contact with the seed.

check in 1952 occurred on light soil at Tingrith. On 31 May unmanured plots and plots receiving broadcast fertilizer carried a full crop and the plants were about 6 in. high; on plots having fertilizer in contact with the seed only about 20% of the plants had emerged and they were very small. Roots growing into bands of fertilizer directly below the seeds were killed and in the early stages such plants relied on roots developed at the side and above the seed. After a few weeks soluble salts had diffused away from the band and the soil immediately below the

Table 4. Comparisons of contact and sideband placement and of the high and low dressings placed in contact

	Sideband minus contact placement		Contact placement, high rate minus low rate
	At low rate	At high rate	
Fourteen experiments in 1951			
Mean yield (tons/acre)	-0.08	-0.16	1.36
Number of effects			
Positive	6	7	12
Negative	8	7	2
Number of significant effects			
Positive	0	2	4
Negative	0	1	0
Six experiments on light soils in 1952			
Mean yield (tons/acre)	-0.39	0.88	1.03
Number of effects			
Positive	1	5	5
Negative	5	1	1
Number of significant effects			
Positive	0	1	2
Negative	0	0	0
Thirteen experiments on heavier soils in 1952			
Mean yield (tons/acre)	-0.24	0.02	0.92
Number of effects			
Positive	4	7	10
Negative	9	6	3
Number of significant effects			
Positive	0	1	5
Negative	1	1	1

*Effect of fertilizer placed in contact with the seed on early growth and plant establishment*

Observations were made on the growing crops in each year. In 1951 the high rate of fertilizer placed in contact caused a marked check to early growth at nine centres. On such plots emergence was delayed and early growth was stunted so that plots having 14 cwt. of fertilizer per acre placed with the seed were 10-14 days behind plots having the same quantity of fertilizer applied in other ways. Within a month or 6 weeks the check to growth had disappeared at all centres except Elstow and Meldreth.

In 1952 the heavy dressing placed in contact checked early growth in five of the six experiments on light soils. A similar check was observed in five of the experiments on heavier soils. The most severe

seed was filled with active fine roots. Later in the season in each year crops having fertilizer in contact with the seed grew away and gave very vigorous dark green tops at most centres.

The numbers of plants harvested are stated in Table 1, averaging all experiments in each year. In both years the average plant population was slightly reduced by the high rate of fertilizer placed in contact with the seed as compared with the same dressing placed in a sideband. Plant numbers at individual centres were examined. In 1951 the low rate placed in contact gave more plants than the high rate at five of the thirteen centres where the plants were counted and the effects were significant at Meldreth and Redbourn. Meldreth was the only centre where contact placement consistently damaged the plant, all methods of application gave

significantly more plants than contact placement (averaging the rates of application). In 1952 the low rate of fertilizer placed in contact gave more plants than the high rate at twelve of the eighteen centres where the plants were counted. The differences were large at Bolnhurst and Tingrith. (In 1952 the numbers of plants harvested were not analysed statistically and levels of significance cannot be stated.)

*Weather in 1951 and 1952*

For the first 5 months of 1951 rainfall at Rothamsted was much above average (Table 5). June and July were both dry months but August and September were very wet. Planting began in the third

In both years at Rothamsted there was dry weather in June and July followed by excessive rain in August and September. In 1951 summer drought was preceded by five wet months, but in 1952 3 of the first 5 months had lower rainfall than usual. The first half of 1951 was colder than average while the spring and early summer of 1952 were warmer than usual. Since there was less subsoil moisture in spring 1952, and the summer was hot and dry, many of the potato crops made the bulk of their growth after rain in August and September. Neither year can be regarded as normal, but the results from different methods of applying fertilizer were remarkably consistent in the two seasons.

Table 5. *Weather at Rothamsted in 1951 and 1952*

	Rain (in.)			Air temperature (° F.)				
	Average 1880-1939	Departure from average		Rainy days		Average 1878-1939	Departure from average	
		1951	1952	1951	1952		1951	1952
January	2.42	+1.07	-0.50	21	18	37.6	+0.5	-1.1
February	2.00	+2.74	-1.30	23	12	38.5	-0.8	-1.8
March	2.00	+1.61	+0.84	22	21	41.2	-2.1	+1.9
April	2.00	+0.85	+0.01	18	15	45.4	-1.7	+4.1
May	2.02	+0.60	-0.30	17	12	51.8	-2.1	+3.9
June	2.13	-0.98	-1.32	9	12	57.2	-0.7	+1.0
July	2.60	-1.29	-2.05	9	5	60.7	+0.9	+1.7
August	2.51	+1.41	+2.62	18	16	60.0	-1.3	+1.5
September	2.34	+1.13	+1.34	13	21	55.8	+1.3	-4.0
October	3.11	-1.80	-0.17	14	16	48.6	-0.1	-1.1

week in April and was completed on 29 May. Wet seed-beds and low temperatures with higher rainfall than normal during May undoubtedly minimized damage from fertilizer placed in contact with the seed. Generally crops grew well during early summer but were checked by dry warm weather in July; they recovered after heavy rain at the beginning of August.

In 1952 January and February were dry months. Early dressings of broadcast fertilizers were applied at some centres in the first days of March, and the first experiments were planted in the middle of March. Heavy rain in the last week of March brought the total for the month above average. Wet weather continued until mid-April and planting was not completed until 13 May. May rainfall was below average. June and July were very dry months and the long dry spell lasted until early August. By the end of July most of the crops were suffering from drought and at some centres potatoes on plots without fertilizer and with low rates of broadcast fertilizer began to die off and did not recover. After heavy rain in August and September most of the crops grew well and where heavy dressings of placed fertilizer had been used flowering was maintained well into August. At many centres potatoes having placed fertilizer continued to grow after those having broadcast fertilizer had died.

## DISCUSSION

Early dressings of broadcast fertilizer worked deeply into the soil and late dressings applied on the seed-bed gave similar results. Farmers using machine planters without a placement attachment may broadcast fertilizer at any convenient stage while cultivating before planting. The value of broadcast fertilizer for potatoes is determined by its position in the final ridges. In these experiments surface soil was pushed aside by the planting-shoes and then gathered by the mouldboards to form the ridges. In moist soils having fair proportions of fine material and small clods, much broadcast fertilizer was thrown into the centre of the ridge extending from the seed to the apex. Wetter soils, containing more fine material, moved in a very confused manner, broadcast fertilizer was mixed with most of the soil in the ridges and part was visible on the surface.

The planter used had fairly long mouldboards. Disks or narrower and shorter mouldboards move the soil in different ways. Some types of potato planters may place a higher proportion of broadcast fertilizer close to the seed, but farmers should choose equipment to suit their soil conditions and to cover the potatoes properly. Potato ridges are generally harrowed down soon after planting and fertilizer mixed with soil above the seed is pushed aside;

later cultivations mix it further with the soil between the rows of potatoes. The last operation of earthing-up replaces fertilizer-rich soil on the sides and top of the ridges. When the ridges are moist throughout, fertilizer in any part may be useful, but in dry weather the upper parts dry out and fertilizer near the apex or close to the sides is useless.

Most British potato planters with fertilizer attachments place dressings in the seed-shoes. Placing fertilizer and seed together is a simple method, and manufacturers have tended to adopt it rather than to fit extra coulters to place fertilizer beside the seed. Contact placement gave a well-marked check to early growth at most centres in both years, but generally the crops recovered and yields at harvest were satisfactory. On most soils the disadvantage of an early check by contact placement is far outweighed by the advantage of this method over broadcasting. Gains from sideband over contact placement were greater on light than on heavy soils. Dressings up to 12 cwt./acre of ordinary strength compound fertilizer can be placed in contact with the seed safely, even on light soils. On most heavy soils full dressings placed in contact are likely to give satisfactory yields. Good yields were obtained from the heavy dressing of fertilizer when half was broadcast and half placed in contact with the seed. This method caused little check to growth and can be recommended to farmers who wish to apply heavy dressings for potatoes grown on light soils.

Damage from contact placement may depend on whether powdered or granular fertilizers are used. (The present trend is for most compound potato fertilizers to be sold in granular form.) Broadcast powdered fertilizer adhered to the soil on which it fell and moved with the soil during cultivation. In contrast, granular fertilizer only adhered to wet and sticky soils and in drier conditions rolled between the clods and sometimes penetrated several inches below the soil surface. Granular fertilizer placed in the seed-shoes moved through the clods and crumbs on which the seed rested and formed bands below the seed with fertilizer-free soil intervening (Text-fig. 3). Powder fertilizer, lacking momentum, did not move far between the soil particles and lay immediately below the seed. When granular fertilizers are placed in seed-shoes separation of seed and fertilizer which occurs during planting may be responsible for good yields obtained both on commercial crops and in these experiments.

Some commercial potato planters with fertilizer attachments are fitted to place fertilizer before the seed-shoes. This method gave yields similar to those given by broadcasting and cannot be recommended.

The planter used in these experiments had separate fertilizer coulters running ahead of the seed-shoes. An alternative is to build seed-shoes having double walls on either side to serve as fertilizer coulters.

There are several advantages of this arrangement; it should be cheaper to manufacture double-walled shoes than separate seed-shoes and fertilizer coulters. Separate fertilizer coulters are liable to be bent or broken by striking obstacles; in contrast, seed-shoes and seed-tubes are usually very sturdy. In American experiments (Cummings & Houghland, 1939) higher yields were obtained from a given quantity of fertilizer when the dressing was split and placed in bands on either side of the seed than when a single band was placed on one side. It is easy to place bands on either side when fertilizer and seed coulters are combined. Seed-shoes are usually about 6 in. wide and seed remaining in the centre of the shoe is about 3 in. from each fertilizer band. If the seed falls to either side it can only come in contact with one band, equivalent to half the dressing and there will be little risk of a check to growth. A combined seed and fertilizer shoe will be designed and tested in later work.

#### SUMMARY

A two-row hand-dropping potato planter was modified by adding fertilizer equipment. The machine was used in thirty-three experiments in 1951 and 1952 to plant potatoes from flat land and compare broadcast dressings of granulated compound fertilizer with dressings placed near to the seed.

Fertilizer placed either in one band at the side and below the level of the seed, or in contact with the seed, gave consistently higher yields than broadcast dressings. Broadcast fertilizer gave yields similar to those given by only one-half to two-thirds as much placed fertilizer. On the average of all the experiments, placing fertilizer gave about 1 ton/acre more potatoes than broadcasting. The advantages of placement were greatest when low rates of dressing were used.

Broadcast fertilizer was cultivated deeply into the seed-beds in nineteen experiments in 1952 and gave slightly lower average yields than late dressings broadcast on the seed-beds.

Fertilizer placed in bands on the soil surface immediately in front of the seed-shoes gave yields similar to those given by dressings broadcast over the seed-beds in fourteen experiments in 1951. In average planting conditions fertilizer broadcast on the seed-beds or placed in front of the seed-shoes was thrown to the middle of the ridges and concentrated above the seed.

Fertilizer placed in contact with the seed gave higher average yields than dressings in a sideband at both rates of manuring in the 1951 experiments. In 1952 contact placement was slightly superior to sideband placement at low rates of fertilizer and slightly inferior at high rates. In most experiments in each year emergence was delayed by 10–14 days

when the heavy dressing was placed in contact with the seed. Early growth was poor but at most centres the crops recovered later in the season and gave good yields. There is most risk of damage from contact placement on light soils, on badly prepared seed-beds and in dry years. Dressings of 10 to 12 cwt./acre of ordinary-strength compound fertilizers are likely to be quite safe when applied in contact with the seed. If heavier dressings are to be used, part should be applied in contact with the seed and part broadcast, such split applications were satisfactory in experiments in 1951.

Farmers planting even moderate acreages of potatoes by machines will benefit by using a suitable

fertilizer attachment. Equipment is needed to place fertilizer at the side of the seed so that heavy dressings can be used to secure maximum yields without risk.

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#### DESCRIPTION OF PLATE 20

- (a) Toolbar-mounted potato planter fitted with fertilizer attachment used in the 1951 experiments.
- (b) Potato planter fitted with end-delivery fertilizer mechanism used in the 1952 experiments.

(Received 16 June 1953)



(a)



(b)

AGRICULTURE—COOKE, JACKSON & WIDDOWSON

## APPENDIX

*Unmanured yields of potatoes and increases from different methods of applying fertilizer averaging rates of application, in tons of potatoes per acre*

(Significant effects marked \*\* for  $P < 0.01$ , \* for  $P = 0.05$  to  $0.01$ )

## 1951 Experiments

Centre	Without fertilizer		Increase in yield from fertilizer					S.E.
	Yield	S.E.	Broadcast on seed-bed	Placed before seed-shoe	Placed in sideband	Placed in contact	Half broadcast, half in contact	
Barton, Beds	8.89	0.626	2.21*	2.76**	4.16**	3.30**	3.50**	0.885
Bolnhurst, Beds	12.64	0.783	2.28	1.64	2.57*	3.50**	1.58	1.107
Elstow, Beds	4.34	0.399	1.70**	2.66**	1.55*	2.16**	2.39**	0.565
Thrales End, Beds	4.38	0.327	4.89**	5.64**	6.60**	5.96**	5.39**	0.463
Burwell, Cambs	8.56	0.534	0.46	0.79	0.54	0.33	0.54	0.755
Meldreth, Cambs	2.03	0.246	0.97*	0.48	0.63	-0.19	0.48	0.347
Potter Street, Essex	5.24	0.218	1.72**	1.55**	3.03**	2.68**	2.55**	0.308
Albury, Herts	6.25	0.339	3.22**	2.76**	3.50**	4.55**	4.18**	0.480
Redbourn, Herts	5.92	0.435	2.97**	3.76**	3.27**	4.50**	3.31**	0.615
Rothamsted, Herts	7.04	0.593	4.16**	4.15**	4.51**	3.79**	4.40**	0.838
Great Gransden, Hunts	7.01	0.430	2.29**	2.92**	5.18**	5.18**	3.74**	0.608
Waresley, Hunts	8.62	0.435	3.39**	1.93**	4.64**	4.80**	3.59**	0.616
Little Dalby, Leics	8.64	0.616	3.25**	4.72**	5.53**	5.80**	4.42**	0.871
Gayton, Northants	13.57	0.527	4.24**	3.12**	4.45**	5.52**	4.54**	0.745
Mean (14 experiments)	7.37	—	2.70	2.78	3.58	3.70	3.19	—

## 1952 Experiments

Centre	Without fertilizer		Increase in yield from fertilizer				S.E.
	Yield	S.E.	Broadcast early	Broadcast late	Placed in contact	Placed in sideband	
Barton, Beds	6.13	0.257	1.09**	1.31**	1.05**	1.35**	0.363
Bolnhurst, Beds	4.31	0.250	1.49**	0.99**	2.72**	3.00**	0.353
Keysoe, Beds	7.17	0.381	2.84**	3.84**	4.45**	2.43**	0.539
Thrales End, Beds	3.83	0.254	3.12**	3.18**	5.66**	5.36**	0.359
Tingrith, Beds	10.89	0.297	2.36**	1.77**	2.75**	3.48**	0.421
Denham, Bucks	6.97	0.349	3.65**	4.55**	5.00**	4.49**	0.494
Hillesden, Bucks	5.24	0.765	5.35**	6.14**	6.16**	5.43**	1.082
Burwell, Cambs	5.78	0.302	1.51**	1.03*	2.15**	2.09**	0.428
Melbourn, Cambs	9.44	0.435	2.21**	2.00**	0.21	2.35**	0.616
Potter Street, Essex	4.01	0.173	1.32**	1.11**	3.00**	2.78**	0.244
Datchworth, Herts	2.53	0.209	2.46**	3.29**	5.89**	5.91**	0.295
Great Munden, Herts	4.57	0.238	3.06**	2.78**	3.76**	3.55**	0.337
Great Gransden, Hunts	7.59	0.480	3.14**	3.53**	4.72**	5.41**	0.679
Waresley, Hunts	3.90	0.335	2.37**	2.59**	3.05**	2.42**	0.474
Little Dalby, Leics	1.79	0.216	1.94**	2.30**	2.81**	2.73**	0.305
Bugbrooke, Northants	3.30	0.366	6.69**	7.14**	8.25**	8.22**	0.518
Easton, Northants	6.33	0.599	6.85**	6.55**	6.84**	7.63**	0.848
North Luffenham, Rutland	5.72	0.278	2.65**	1.65**	3.07**	3.22**	0.394
Wing, Rutland	9.48	0.505	3.39**	3.97**	5.91**	5.71**	0.714
Mean (19 experiments)	5.74	—	3.02	3.14	4.07	4.08	—