PLACEMENT OF FERTILIZERS FOR ROW CROPS

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

Chemistry Department, Rothamsted Experimental Station, Harpenden, Herts

INTRODUCTION

Experiments in 1947 and 1948 (Cooke, 1949) showed that germination of sugar beet, mangolds, peas and swedes was damaged when normal dressings of complete fertilizer were drilled in contact with, below, or 1 in. to the side of the seed. Bands placed 3 in. to the side of the seed were safe. For sugar beet and mangolds similar yields were given by broadcast fertilizer and by fertilizer placed in safe positions at the side of the seed. Placed and broadcast fertilizer gave similar yields of sugar beet in further experiments carried out in 1949 (Cooke, 1951). All methods of placing fertilizer gave higher yields of swedes and peas than broadcasting.

The experiments described here were designed to continue and extend comparisons between placed and broadcast fertilizer, and to determine whether there was any advantage from broadcasting half the dressing and placing half beside the seed. Experiments on peas were continued and the work was extended to winter and spring beans grown for animal feeding. At the same time, simple exploratory experiments were laid down on beetroot, kale, carrots and spinach. Most experiments were carried out in the eastern counties of England to avoid long journeys with the special equipment used. The scope and results of the experiments on legumes and on the other crops used are described separately.

EXPERIMENTS ON PEAS AND BEANS

Scope of the experiments

Experiments on threshed peas were continued in 1949 and 1950. The work was extended in 1949 to peas picked green for market which were also grown in 1950 and 1951. Spring-sown beans were used in 1949, 1950 and 1951, and autumn-sown beans in 1950 and 1951.

The experiments in all years were of uniform pattern, the methods of fertilizer application tested being:

(1) Broadcast early and worked deeply into the seed-bed.

(2) Broadcast on the seed-bed and harrowed in shallowly.

(3) Placed in one band 3 in. below the soil surface and 2 in. to the side of the seed (duplicate plots).

(4) Half broadcast early and half placed beside the seed.

(5) Half broadcast on the seed-bed and half placed beside the seed.

Each method of application was tested at two rates of phosphate-potash fertilizer. The twelve treatment combinations, together with four 'no fertilizer' plots, were arranged in two randomized blocks of eight plots, a high-order interaction being confounded.

The fertilizers used were granular mixtures of superphosphate and muriate of potash; the composition and amounts used for various crops in each year are given in Table 1. Broadcast fertilizer was applied both at early and late stages in the preparation of the seed-bed to compare the effect of deep and shallow incorporation with the soil. For spring-sown crops early dressings were broadcast on the winter-ploughed land and were worked into the soil by the normal cultivations given to prepare the seed-bed. These cultivations varied with the nature of the soil and the weather, but at most centres fertilizer was worked in approximately 4 in. deep. Early dressings for spring-sown crops were broadcast and ploughed-in for threshed peas at Silsoe in 1949, for green peas at Elstow and Potter Street in 1951, and for spring beans at Rothamsted in 1951. For winter beans early dressings were broadcast on stubble or fallow and were ploughed-in at all centres, except for the 1950 experiment at Rothamsted. Late broadcast dressings were applied on the seed-bed before drilling and were worked into the soil to a depth of 1–2 in. by harrowing, either before or after sowing. Peas were normally sown about 2 in. and beans about 3 in. below the soil surface. Placed fertilizer was applied in a band about 1 in. wide; the centre of the band was 2 in. to the side of the seed. Earlier work (Cooke, 1949) had shown that this distance between seed and

Table 1. *Composition and amounts of fertilizers used in experiments on peas and beans*

	1947–8	1949	1950*	1951
Composition				
P_2O_5 %	10	16	14	14
K_2O %	20	13	14	14
Amounts (cwt./acre)	3·0	3·5	2·3	2·6
	6·0	7·0	4·6	5·3

* The winter beans experiments in 1949–50 were made with 3·2 and 6·4 cwt./acre of the mixture used for the 1949 experiments.

fertilizer is necessary to avoid damage to germination. Combinations of both placed and broadcast fertilizer were tested in 1949–51 to determine whether there was any advantage in combining the two methods. Fertilizer placed near to the seed stimulates early growth, but the mature plant with a fully developed root system may be able to utilize fertilizer distributed through the soil more efficiently than fertilizer confined to a single band.

In all years broadcast fertilizer was applied exactly at the stated rates. Field calibrations of the drill showed only small variations from centre to centre in each year. Differences in the actual rates of applying broadcast and placed fertilizer were not sufficient to preclude direct comparisons of the two methods at the nominal rates.

Methods of laying down the experiments

The plots used were commonly six rows wide and 22 yards long. There were four blocks, each containing eight plots arranged side-by-side. The first visit was made to each centre before the seed-bed was prepared; the site was marked out and phosphate-potash fertilizer was broadcast by hand on appropriate plots. Early dressings were generally applied for autumn-sown beans before ploughing, and for spring-sown crops after ploughing. After individual farmers had prepared the seed-bed, according to their normal practice, fertilizer was broadcast on the seed-bed on appropriate plots. The special drill, which has been described previously (Cooke, 1949), was used to sow the seed on all plots and to place fertilizer beside the seed as desired. On plot boundaries the drill was stopped while adjustments were made to the fertilizer coulters and to the gear-box governing delivery rates. One row on the outside of each plot was not sown, providing a space between plots to facilitate harvesting.

Estimates of the plant populations of spring-sown crops were made about 8 weeks after sowing by counting the number of plants in two lengths of 2·2 yards chosen at random from each row of each plot. Where possible, counts of winter beans were made on several occasions in winter and spring to measure the effect of different methods of manuring on the survival of the crop.

The whole plot area was harvested. Threshed peas were cut by hand with small scythes, placed in windrows and turned until fit for threshing. In experiments on green peas all mature pods were picked and weighed. Beans were cut by binder, stooked, and threshed in the field. Samples of threshed peas and beans were taken from the produce of each plot; the percentages of moisture in the samples were determined and all yields were expressed as cwt. of dry matter per acre.

RESULTS OF THE EXPERIMENTS ON PEAS AND BEANS

Fertilizer placed 2 in. to the side of the seed caused no check to germination in any of the experiments. Fertilizer had only small effects on the numbers of plants in the experiments on beans and peas; detailed results are not presented here. The slight effects of broadcast fertilizer were irregular. For all crops, placing fertilizer gave consistently more plants than broadcasting, though the difference between the two methods was trifling.

Autumn-sown beans are generally regarded as a more certain crop than spring-sown varieties since they are less likely to be damaged by bean aphis and are less affected by summer drought. They may, however, be attacked by birds in winter or killed by fungal diseases following frost injury in severe winters. Counts were made in winter and spring to measure the effects of fertilizer dressings in overcoming loss of plants from such causes. At all centres in each year plant numbers decreased during the late winter. Compared with the general decrease on all plots the effects of fertilizer applied in different ways were very small. Placed fertilizer gave slightly more tillers per plant than broadcast fertilizer in the experiments on winter beans.

Yields of threshed peas

Mean yields of dry peas are given in Table 2 for all experiments in each year. In 1949 broadcast fertilizer, whether applied early or late, produced only small increases in yield; in 1950 broadcast fertilizer at the high rate produced larger increases in yield. In both years placing fertilizer gave higher yields than broadcasting. There were no marked differences between yields produced by early and late dressings of broadcast fertilizer. When half the dressing was broadcast and half was placed, early broadcasting gave more peas than late dressings.

Increases given by broadcast fertilizer at individual centres, comparisons of early and late broadcasting and of placing with broadcasting, averaging the two rates of dressing, are tabulated in Table 1 of the Appendix. Significant effects on yield are discussed and summarized later.

Yields of green peas

Mean yields for all experiments in each year are given in Table 2. In the single experiment in 1949 and on the average of three experiments in 1950 there were small increases in yield from broadcast fertilizer and little difference between early and late dressings. In both years placed fertilizer gave much higher yields of peas than broadcast fertilizer. When half the dressing was placed and half broadcast, yields were a little lower than when the whole dressing was placed. In 1951 there was a large

response to fertilizer broadcast early; dressings broadcast on the seed-bed did not increase yields. Placing fertilizer gave slightly lower yields than early broadcasting, both when all the fertilizer was placed, and when half was placed and half broadcast.

Comparisons of methods of broadcasting and placing fertilizer are made for each centre in Table 1 of the Appendix.

Yields of beans

Mean yields of dry beans are given in Table 3 for all experiments in each year. Early dressings of broadcast fertilizer (ploughed in at two of the three centres) gave higher yields of winter beans than late dressings on the seed-bed in 1949–50, but in 1950–1 (when early dressings were ploughed-in at all centres) the two methods of broadcasting gave

Table 2. *Variation in yields of peas with different rates and methods of applying fertilizer*

Fertilizer (cwt./acre)	Without fertilizer	All placed	All broadcast		Half placed, half broadcast	
			Early	Late	Early	Late
		Yields of dry threshed peas in cwt./acre				
Six experiments in 1949						
3·5	—	15·3	13·6	13·8	14·8	14·6
7·0	—	15·3	14·5	14·3	15·6	14·9
Mean of rates	13·7	15·3	14·0	14·0	15·2	14·7
Three experiments in 1950						
2·3	—	17·5	16·3	16·3	17·8	17·2
4·6	—	19·1	17·5	18·1	19·0	17·6
Mean of rates	16·1	18·3	16·9	17·2	18·4	17·4
		Yields of green peas in cwt./acre				
One experiment in 1949						
3·5	—	95·2	82·0	84·2	99·5	96·6
7·0	—	108·0	79·5	82·9	91·9	97·1
Mean of rates	76·6	101·6	80·7	83·6	95·7	96·9
Three experiments in 1950						
2·3	—	97·3	81·9	84·3	92·5	91·4
4·6	—	98·7	89·7	84·3	95·8	97·1
Mean of rates	83·8	98·0	85·8	84·3	94·1	94·3
Three experiments in 1951						
2·6	—	61·8	62·5	59·3	65·6	61·1
5·3	—	67·2	72·0	55·3	66·2	65·6
Mean of rates	58·5	64·5	67·3	57·3	65·9	63·4

Table 3. *Variation in yields of beans with different rates and methods of applying fertilizer*

Fertilizer (cwt./acre)	Without fertilizer	All placed	All broadcast		Half placed, half broadcast	
			Early	Late	Early	Late
		Yields of dry beans in cwt./acre				
Three experiments on winter beans in 1949–50						
3·2	—	20·5	19·5	18·6	20·9	19·7
6·4	—	20·7	20·3	19·5	21·0	20·6
Mean of rates	18·0	20·6	19·9	19·0	20·9	20·2
Six experiments on winter beans in 1950–1						
2·6	—	18·1	17·8	17·8	18·4	17·0
5·3	—	19·2	17·7	17·7	19·4	17·6
Mean of rates	16·2	18·6	17·8	17·7	18·9	17·3
Three experiments on spring beans in 1949						
3·5	—	14·3	13·7	13·4	14·4	13·2
7·0	—	15·4	14·7	12·4	15·6	14·0
Mean of rates	13·5	14·9	14·2	12·9	15·0	13·6
Four experiments on spring beans in 1950						
2·3	—	22·0	20·3	19·0	20·7	19·2
4·6	—	21·8	21·0	18·8	21·3	22·0
Mean of rates	19·0	22·0	20·6	18·9	21·0	20·6
Three experiments on spring beans in 1951						
2·6	—	16·6	16·1	17·1	16·9	16·1
5·3	—	16·4	16·6	15·6	16·2	16·2
Mean of rates	15·4	16·5	16·3	16·3	16·6	16·2

similar yields. Placing fertilizer gave higher yields than broadcasting in both years. In each year splitting the dressing, half being placed beside the seed and half broadcast early, gave slightly higher yields than placing all the fertilizer; this method was superior to placing half the fertilizer and broadcasting the remainder on the seed-bed.

Mean yields of three experiments on spring beans in 1949 were low due to the dry season; in four experiments in 1950 and three in 1951 yields were satisfactory. In 1949 and 1950 fertilizer broadcast early and worked deeply into the seed-bed increased mean yields; late dressings on the seed-bed were of no value. In 1951 early and late dressings gave similar increases in yields. In the first 2 years placed fertilizer gave markedly higher yields than early broadcasting but there was only a small advantage from placement in 1951. When half the dressing was placed and half broadcast, early broadcasting gave somewhat higher average yields than late dressings in each season.

Results of individual experiments on beans are summarized in Table 2 of the Appendix and are discussed later.

Drilling fertilizer in contact with peas and beans

Many farmers use combine-drills to sow peas. It frequently happens that germination is damaged when soluble salts are drilled through the same coulter as the seed. Some older drills, with both fertilizer and seed hoppers, sow a band of fertilizer directly beneath the seed. The special drill used in these experiments is not fitted to sow seed and fertilizer in contact through one coulter, but it may be used to place a band of fertilizer directly in front of the seed so that seed and fertilizer are in the same zone. At some of the 1950 centres additional plots were drilled with granular fertilizer (containing 14 % P_2O_5 and 14 % K_2O) in the seed zone; other plots had fertilizer placed 1 in. below the seed. The plants established on these plots were counted. The plots were not randomized or replicated but they provide some evidence on the possible dangers from drilling fertilizer too close to the seed.

Even heavy dressings placed in the seed zone were safe for winter beans at Rothamsted. Heavy rain fell after sowing and no doubt reduced the concentration of soluble salts near to the seed. For spring beans at Rothamsted 5 cwt. of fertilizer per acre placed in the seed zone reduced the plant seriously.

1·25 cwt. of fertilizer per acre placed with the seed for peas did not damage germination; 2·5 cwt. per acre was dangerous at some centres. Placing 5 cwt. of fertilizer per acre with the seed reduced plant populations at most centres, and 10 cwt. per acre was dangerous everywhere. When the fertilizer band was placed 1 in. below the seed, plant populations were reduced, but damage was not generally as serious as when the same dressings were placed with the seed.

EXPERIMENTS ON CARROTS, KALE, BEETROOT AND SPINACH

Scope of the experiments

Experiments were carried out in 1950 and 1951 to compare broadcast and placed fertilizer for these crops. For some crops there may be advantages in placing fertilizer beside the seed to give rapid early growth and supplying the later needs of the crop with broadcast dressings. In 1950 the dressings on certain plots were split, half the fertilizer being broadcast and the remainder placed beside the seed.

Each of the three methods was tested at two rates of fertilizer in experiments on carrots, kale and beetroot. The six treatment combinations, together with two 'no fertilizer' plots, were arranged in a randomized block. Usually the plots were side-by-side, but occasionally a long narrow piece of land was provided and each block consisted of two rows of four plots. There were three blocks in each experiment. In the 1950 experiment on spinach and in the 1951 experiment on kale at Rothamsted, placed and broadcast fertilizer was applied at two rates, and combinations of placed and broadcast fertilizer were not tested. These experiments consisted of three blocks, each containing four fertilized and two unfertilized plots.

For crops with a long growing season there is no theoretical or practical advantage from placing nitrogen fertilizer close to the seed; broadcast dressings are readily leached into the root zone. For carrots, kale and beetroot the experiments tested a phosphate-potash fertilizer. Sulphate of ammonia was broadcast uniformly on all plots at rates which were in general use locally. A granular compound fertilizer containing 10 % P_2O_5 and 20 % K_2O was applied at 2·5 and 5·0 cwt. per acre for carrots. For kale and beetroot granular fertilizer containing 14 % P_2O_5 and 14 % K_2O was used. The rates of application were 2·7 and 5·4 cwt. per acre. As spinach is normally harvested 8–10 weeks after sowing, broadcast nitrogen fertilizers may not be fully utilized by the scanty root system developed on heavy soils. A complete compound fertilizer (National Compound No. 2: 9 % N, 7 % P_2O_5, 7 % K_2O) was applied at 3·2 and 6·4 cwt. per acre.

Methods of laying down the experiments

At most centres the site was marked out and broadcast fertilizer was applied to appropriate plots before the seed-bed was prepared; the dressings were

worked down to 2 or 3 in. by the cultivations which followed. The plots were generally 22 yards long and 10 ft. wide, containing six rows spaced 20 in. apart. Nitrogen fertilizer was broadcast by hand for carrots, kale and beetroot during the seed-bed preparations. The special drill (Cooke, 1949) was used to sow the seed on all plots and place fertilizer beside the seed on appropriate plots. Placed fertilizer was applied in one band 2 in. to the side of the seed and 3 in. below the soil surface. Carrots were sown approximately 0·75 in. deep; beetroot, kale and spinach were sown about 1 in. deep.

After sowing, each experiment was treated in the same way as the rest of the field. At harvest the central four rows of each plot were lifted from experiments on carrots and beetroot, discarding a length at each end of each plot. In experiments on kale harvesting was spread over approximately 2 weeks, sufficient kale being cut on each occasion to feed stock on the farm for 2 days. All six rows were cut and weighed; the ends of the plots were discarded. Only three rows of spinach were sown on each plot; the crop on the whole area was cut and weighed when the best plots were judged to be ready for market.

precise experiments at East Harling and Methwold broadcast fertilizer increased yields significantly, but the effects of placed fertilizer were small and irregular. Broadcasting half the fertilizer and placing the remainder gave a significant increase in yield at East Harling. The experiments at Burwell and Chippenham were much less precise and there were no significant increases in yields from fertilizer dressings.

Experiments on kale

The results of the experiments are summarized in Table 4. At Mackerye End placed fertilizer gave a significant increase in yield both when half and when the whole dressing was placed. At Rothamsted there were no significant increases in yield in either year. There were no significant differences between yields given by broadcast and placed fertilizer.

At Mackerye End and Rothamsted in 1950 broadcast fertilizer gave better early growth than placed fertilizer on fields which had been under arable cultivation for several years. In 1951 kale was grown as the first crop after permanent pasture, and the experimental site was known to be phosphate-deficient. On plots where fertilizer was placed at the

Table 4. *Unmanured yields of carrots, kale, beetroot and spinach and increases from broadcasting and placing fertilizer, in tons per acre*

(Significant effects marked ** for $P<0·01$; * for $P=0·05$ to $0·01$.)

	Without† fertilizer	Increase in yield from fertilizer: Broadcast	Placed	Half broadcast, half placed	s.e. of increase
Experiments on carrots					
Burwell, Cambs	7·4	0·8	1·0	−0·8	0·88
Chippenham, Cambs	20·7	−1·0	1·4	0·4	1·78
East Harling, Norfolk	12·2	1·9*	−0·6	2·4**	0·78
Methwold, Norfolk	18·3	1·8*	0·6	1·6	0·80
1950 experiments on kale					
Mackerye End, Herts	17·5	2·2	4·00**	3·7*	1·33
Rothamsted, Herts	25·0	1·6	1·3	0·6	1·98
1951 experiments on kale					
Rothamsted, Herts	17·2	1·1	1·8	—	1·06
Experiment on beetroot					
Silsoe, Beds	25·8	3·5	3·6	4·1*	1·73
Experiment on spinach					
Sharnbrook, Beds	4·12	0·67	1·74**	—	0·44

† For carrots, kale and beetroot a dressing of nitrogen fertilizer was applied to all plots of the experiments.

RESULTS OF EXPERIMENTS ON CARROTS, KALE, BEETROOT AND SPINACH

The results at individual centres are summarized in Table 4 after averaging rates of fertilizer application.

Experiments on carrots

Yields (Table 4) were satisfactory, except at Burwell, where the crop was damaged by flooding and became very weedy later in the season. In two

side of the seed the kale grew more vigorously in 1951 than on plots where fertilizer was broadcast. At harvest time there were no visible differences between crops given by placed and broadcast fertilizer in any of the experiments.

Experiment on beetroot

One experiment in 1950 gave a heavy crop of beetroot; all methods of applying fertilizer gave similar increases in yield (Table 4).

Experiment on spinach

There was one experiment on spinach in 1950; increases in yield from broadcast and placed fertilizer (averaging rates of dressing) are given in Table 4. Placed fertilizer gave significantly more spinach than broadcast fertilizer.

Weather in 1949, 1950 *and* 1951

1949 was a dry year. Seed-beds were generally good when sowing started in March. Rainfall in March and April was below average. There was a dry period during the first 3 weeks of May, followed by good rainfall in late May and early June. From early in June until the end of July, when the pea experiments were harvested, there was little more than 1 in. of rain at Rothamsted.

In 1950 there was heavy rain in February, but March was dry; the experiments were generally drilled on good seed-beds and germination was rapid. Total rainfall in April and May was near to average. Temperatures in June were high and rainfall was below average. July rainfall at Rothamsted was more than twice the average; August and September were both wet months.

The 1951 season was most abnormal. Winter beans were drilled in good conditions in a dry spell in October 1950. In November 1950 and the first five months of 1951 rainfall was much above average. Continuous wet weather persisted until early April, and on the heavy soils where these experiments were planned it was impossible to begin drilling until mid-April. Spring-sown crops were drilled in bad conditions at most centres. Cold and wet weather persisted until the end of May and crops germinated slowly. June and July were both very dry months, but rainfall in August and September was considerably greater than average.

DISCUSSION

In earlier experiments (Cooke, 1949) bands of fertilizer were most effective when placed as close to the seed as was consistent with avoiding damage to germination. It was recommended that generally fertilizer should be placed 2 in. to the side of the seed. This position was adopted in the work reported here, and there was no injury to germination in any of the experiments. Dressings of fertilizer had little effect on the numbers of autumn-sown beans which survived the winter, but placing fertilizer gave slightly more tillers on each plant than broadcasting. In some seasons placing fertilizer may improve a thin plant.

In a few observation plots on beans and peas in 1950 fertilizer was placed close to the seed and in a band 1 in. below the seed. Most sites were on heavy soils, and moderate rain followed sowing. Plant establishment was satisfactory when small quantities of phosphate-potash fertilizer were applied by these methods but heavier dressings reduced plant establishment seriously. More serious damage is likely when seed and fertilizer are sown together by combine-drill; damage will be most severe on light soils and when long dry periods follow sowing. Combine-drilling of soluble fertilizer with seed of sensitive crops such as peas should not be recommended; even if quite small dressings are used, dry soil conditions at sowing or dry and hot weather afterwards may cause injury to germination.

The results of all experiments on beans and peas are summarized in Table 5, including experiments on threshed peas described previously (Cooke, 1949). Broadcast fertilizer gave small increases in yield of all crops in dry years (1947 and 1949) and larger increases in wet years (1948, 1950 and 1951).

Extra yields from dressings broadcast early and cultivated deeply into the seed-bed are related to rainfall and soil conditions during the season. In the very wet winter and spring of 1950–1 late dressings broadcast on the seed-bed and early dressings ploughed-in gave the same average yields of winter beans. Heavy rain may have washed fertilizer deeply into the seed-bed and kept the undisturbed surface soil moist well into the summer (there was little opportunity for inter-row cultivations in the spring of 1951). Under other conditions fertilizer ploughed-in may give dramatic increases in yields. In two experiments on green peas in 1951, early dressings were broadcast before ploughing in spring. On these freshly ploughed fields roots penetrated easily and utilized nutrients incorporated 6–7 in. deep. Fertilizer bands placed 3 in. below the surface were in dry soil for several critical weeks in June and July. In both experiments fertilizer on the seed-bed produced lower yields than unfertilized plots; ploughed-in fertilizer gave higher yields than fertilizer placed at the side of the seed. Early dressings ploughed-in for peas at Silsoe in 1949 and for beans at Rothamsted in 1951 gave yields similar to those given by placed fertilizer in both experiments. There would be advantages in incorporating fertilizer in loose and dry seed-beds more deeply than is customary.

On the average of all experiments on each crop, placed fertilizer gave higher yields than broadcast fertilizer. The increases given by broadcast fertilizer and the additional increases from placing as compared with broadcasting, averaging all experiments on each crop, were:

	Increase in yield from broadcast fertilizer	Additional increase over broadcasting from placing
	Yields in cwt./acre	
Threshed peas (17 experiments)	0·7	1·8
Green peas (7 experiments)	2·9	9·3
Winter beans (9 experiments)	1·5	1·0
Spring beans (10 experiments)	0·6	1·3

Table 5. *Comparisons of methods of broadcasting and placing fertilizer for beans and peas in experiments in* 1947–51

	No. of expts.	Yield without fertilizer (cwt./acre)	Increases from broadcast fertilizer: Yield (cwt./acre)	Increases from broadcast fertilizer: No. of significant differences	Early minus late broadcasting: Yield (cwt./acre)	Early minus late broadcasting: No. of significant differences	Additional increase over broadcasting from placing: Yield (cwt./acre)	Additional increase over broadcasting from placing: No. of significant differences
Experiments on threshed peas*								
1947	3	13·2	0·3	0	—	—	2·8	2
1948	5	12·6	1·3	2	0·8	0	2·2	2
1949	6	13·7	0·3	0	0·0	0	1·2	2
1950	3	16·1	1·0	1	−0·3	0	1·2	1
Experiments on green peas								
1949	1	76·6	5·5	0	−2·9	0	19·5	1
1950	3	83·8	1·2	0	1·5	0	13·0	1
1951	3	58·5	3·8	2	9·9	2	2·2	0
Experiments on winter beans								
1950	3	18·0	1·5	1	0·9	1	1·1	1
1951	6	16·2	1·5	2	0·0	1	0·9	2
Experiments on spring beans								
1949	3	13·5	0·1	0	1·3	1	1·3	1
1950	4	19·0	0·8	0	1·8	1	2·2	3
1951	3	15·4	1·0	0	0·0	1	0·1	0

* Yields of threshed peas in 1947 and 1948 are stated as threshed produce (containing approximately 15 per cent moisture). Yields of dry matter are stated in other experiments on threshed peas and in all experiments on beans.

For spring-sown crops the extra yields from placed as compared with broadcast fertilizer were greater than the increases from broadcasting alone. For autumn-sown beans placed fertilizer gave higher yields than broadcasting, but the advantages of the method were smaller than for spring crops.

The experiments also tested broadcasting half of the fertilizer dressing and placing half beside the seed. There were no consistent advantages from this method of application over placing of the whole dressing for peas and for spring beans. The highest average yield of winter beans in both years was obtained when half the fertilizer was ploughed-in and half was placed. In each year the average extra yield given by splitting the dressing in this way as compared with drilling the whole dressing at the side of the seed was 0·3 cwt. of beans per acre. Such a gain is probably not sufficient to cover the cost of the extra operation of broadcasting part of the fertilizer.

In most experiments on beans and peas the single rate of placed fertilizer gave yields at least as great as those given by the double rate of broadcast fertilizer, and was adequate for maximum yields. When fertilizer is placed in the correct position for these crops quite small quantities are sufficient, and the use of suitable methods allows considerable economies in the amounts of fertilizer needed.

Table 5 also sets out the number of significant ($P = 0{\cdot}05$ or less) effects on yield for the comparisons between methods of application discussed above. In roughly one-third of all experiments on each crop there were significant increases in yield from placing as compared with broadcasting fertilizer. Placed fertilizer never gave a significantly lower yield than broadcast fertilizer. In about one-quarter of the experiments on beans and green peas fertilizer broadcast early and either ploughed or cultivated deeply into the soil gave significantly higher yields than late dressings worked into the seed-bed. Early broadcasting never gave significantly lower yields than late broadcasting. Where special placement drills are not available farmers are advised to broadcast fertilizer for beans and peas before cultivating to prepare the seed-bed, and, when possible, the dressing should be ploughed-in. In some seasons early and late broadcast dressings may give similar yields, but in other seasons early application may have advantages. There is little risk of dressings incorporated deeply being less efficient than seed-bed dressings.

In experiments on soils where carrots are commonly grown in eastern England, placing phosphate-potash fertilizer at the side and below the level of the seed gave lower yields than broadcasting. Farmers should be advised to broadcast fertilizer for carrots during the cultivations given to prepare the seed-bed. There were no significant differences between yields of kale given by broadcast and placed fertilizer. The bulk of the fertilizer needed should be broadcast before sowing, and on phosphate-deficient soils a small dressing of superphosphate placed close to the seed may provide rapid early growth and help to overcome attacks by insects and competition by weeds.

From earlier experiments (Cooke, 1949) it was

concluded that placement is of particular value for crops having a short growing season or limited root range and for crops made sensitive to nutrient deficiency by poverty of the soil or immobilization of nutrients by drought. The work described here confirms these conclusions. Peas and spring-sown beans have a short season and peas have a poor root system; both crops gave increased yields when fertilizer was placed at the side of the seed. Winter beans with a longer growing season show smaller benefits from placed fertilizer than spring beans. Peas picked green for market have given proportionately larger increases in yield from placed fertilizer than more slowly growing varieties harvested when fully ripe. Kale has a long growing season and develops an extensive root system; in these experiments it utilized broadcast and placed fertilizer equally well during the period when the bulk of growth is made (July to October). Beetroot of the type grown in 1950 is a long-season crop and behaved in the same way as sugar beet and mangolds in earlier experiments. In contrast spinach had the shortest growing season of the crops tested and placing was much superior to broadcasting.

The results of these experiments are in accordance with the more extensive work on fertilizer placement carried out in the United States. For all crops grown under similar conditions the American recommendations as given by the National Joint Committee on Fertilizer Application (1948) agree with those made here. The results of American work may be applied to British farming provided that the conditions under which crops are grown are sufficiently closely defined. Contradictory fertilizer recommendations in the two countries may result from different soil conditions, seasons, cultural methods or from economic circumstances. Thus, American workers recommend that fertilizers for sugar beet be placed in bands at the side of the seed. This method was developed to overcome the older and dangerous practice of placing fertilizer in contact with the seed; comparisons with broadcasting were not made. American workers have rarely compared placing and broadcasting such heavy dressings of fertilizers as are commonly used in England.

Special drills designed to place fertilizer beside the seed should prove profitable to farmers growing an appreciable acreage of beans or peas. There is need for a commercial placement drill designed for crops grown on wide rows since no satisfactory machines are marketed at present in Britain. In the absence of suitable placement drills a few English growers of large acreages of peas have modified combine-drills, intended for cereals, so that bands of fertilizer are placed beside rows of seed sown 14–21 in. apart. Skilful adaptations of existing successful drills may prove more satisfactory to farmers and manufacturers than attempts to produce a special placement drill. Both beans and peas must be sown deeply to secure good germination and reduce the risk from birds. On heavy soils in eastern England 'Suffolk' drills are popular since they are able to sow large-seeded crops deeply on difficult seed-beds. Such drills should prove suitable for adaptation as placement drills. Alternatively, where independent seed units are mounted on a tool bar, fertilizer units could be incorporated.

SUMMARY

In experiments on peas, beans, carrots, kale, beetroot and spinach appropriate dressings of fertilizers placed in one band 3 in. below the soil surface and 2 in. to the side of the seed did not damage germination. Peas and beans are likely to be injured when even small dressings of soluble fertilizers are drilled in contact with or below the seed.

In sixteen experiments on peas and nineteen experiments on beans in 1949–51 broadcast fertilizer gave small increases in yield of beans and peas in dry years and larger increases in wet years. In about one-quarter of all the experiments fertilizer broadcast early and either ploughed or cultivated deeply into the soils gave significantly higher yields than late dressings worked into the seed-beds. In roughly one-third of all the experiments on each crop there were significant increases in yield from placing as compared with broadcasting fertilizer. The average extra yields produced by placing fertilizer were 1·8 cwt. per acre of threshed peas, 9·3 cwt. per acre of green peas, 1·0 cwt. per acre of winter beans and 1·3 cwt. per acre of spring beans. For spring-sown crops extra yields from placement were greater than the increases from broadcasting fertilizer. There was little advantage from splitting the fertilizer dressing, broadcasting half and placing the remainder beside the seed.

In most experiments on peas and beans, yields given by a single dressing of placed fertilizer were equal to, or greater than, the yields given by double dressings of broadcast fertilizer. When placed in the correct position quite small quantities of fertilizer are sufficient for maximum yields of such crops. The use of suitable drills should be profitable to farmers growing appreciable acreages of peas, beans and rapidly maturing horticultural crops. Where special placement drills are not available, fertilizers for peas and beans should be broadcast before cultivating to prepare the seed-bed and, when possible, the dressings should be ploughed-in. There was no advantage from placing fertilizer at the side of the seed for carrots, kale or beet. Placed fertilizer gave a higher yield of spinach than broadcast fertilizer.

Placing fertilizer at the side and below the level of

the seed is likely to give better yields than broadcast fertilizer for crops having short growing seasons or poorly developed roots and when broadcast nutrients are immobilized in the surface soil by drought.

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 members of the staffs of the National Institute of Agricultural Engineering, the National Agricultural Advisory Service and the Chemistry and Statistical Departments of Rothamsted Experimental Station for much assistance in carrying out the work.

REFERENCES

COOKE, G. W. (1949). *J. Agric. Sci.* **39**, 359.
COOKE, G. W. (1951). *J. Agric. Sci.* **41**, 174.
NATIONAL JOINT COMMITTEE ON FERTILIZER APPLICATION (1948). *Pamphl. Nat. Fertil. Ass. Wash.* no. 149.

APPENDIX

Table 1. *Comparisons of methods of broadcasting and placing fertilizer in experiments on peas*

(Significant effect marked ** for $P<0.01$; * for $P=0.05$ to 0·01.)

	Without fertilizer	Increase from broadcast fertilizer	Increase from early over late broadcasting		Increase from placing over broadcasting		s.e. per plot
			All broadcast	Half broadcast	Half placed	All placed	
No. of plots	8	8–8	4–4	4–4	8–8	8–8	
			Yields of dry threshed peas in cwt./acre				
1949 experiments							
Kimbolton, Hunts†	13·7	1·9	1·7	2·8	1·6	1·5	1·34
Long Sutton, Lincs	19·9	0·3	−0·7	−0·7	−0·3	−0·7	0·86
Rabley Heath, Herts	10·7	0·2	0·0	1·0	1·8**	2·2**	0·72
Rothamsted, Herts	14·3	−1·0	−1·5	−0·5	2·1*	2·7**	1·60
Sharnbrook, Beds	14·8	0·1	−0·4	−1·3	0·2	1·2	1·27
Silsoe, Beds	9·0	0·4	0·9	1·6*	0·0	0·4	0·97
Mean	13·7	0·3	0·0	0·5	0·9	1·2	—
1950 experiments							
Bolnhurst, Beds	15·1	0·2	0·0	1·6	0·8	0·7	1·90
Rabley Heath, Herts	14·3	1·9**	−0·7	1·0	1·2*	2·4**	1·13
Sharnbrook, Beds	18·9	0·8	−0·1	0·3	0·5	0·5	1·41
Mean	16·1	1·0	−0·3	1·0	0·8	1·2	—
			Yields of green peas in cwt./acre				
1949 experiment							
Sharnbrook, Beds	76·6	5·5	−2·9	−1·2	14·2**	19·5**	8·84
1950 experiments							
Bolnhurst, Beds	94·3	4·9	−2·7	4·4	0·5	−0·6	11·91
Fyfield, Essex	71·4	−1·9	2·2	1·5	15·1**	10·4	9·98
Sharnbrook, Beds	85·8	0·7	5·0	−6·3	11·8	29·1**	12·62
Mean	83·8	1·2	1·5	−0·1	9·1	13·0	—
1951 experiments							
Elstow, Beds	50·4	6·8**	16·0**	5·0	−2·3	−1·8	4·71
Little Laver, Essex	47·0	4·9*	1·1	−8·3*	−1·5	4·3	5·52
Potter Street, Essex	78·2	−0·3	12·7*	10·7	10·7*	4·1	8·43
Mean	58·5	3·8	9·9	2·5	2·3	2·2	—

† At Kimbolton only two blocks were harvested and there were half the usual number of plots for each comparison.

Table 2. *Comparisons of methods of broadcasting and placing fertilizer in experiments on beans*

(Significant effects marked ** for $P<0.01$; * for $P=0.05$ to 0·01.)

	Without fertilizer	Increase from broadcast fertilizer	Increase from early over late broadcasting		Increase from placing over broadcasting		S.E. per plot
			All broadcast	Half broadcast	Half placed	All placed	
No. of plots	8	8–8	4–4	4–4	8–8	8–8	
			Yields of dry beans in cwt./acre				
1949–50 experiments on winter beans							
Brent Pelham, Herts	18·3	0·2	−1·1	1·3	0·7	0·5	1·94
Rothamsted, Herts	15·3	4·2**	2·5**	0·1	1·7**	1·8**	1·16
Silsoe, Beds	20·5	0·0	1·3	0·8	0·7	0·9	2·67
Mean	18·0	1·5	0·9	0·7	1·0	1·1	—
1950–1 experiments on winter beans							
Brent Pelham, Herts	19·4	1·0	1·1	2·1	0·6	−0·1	1·73
Carlton, Beds	16·1	−0·5	0·9	1·5	−0·2	−0·1	1·15
Cranfield, Beds	17·7	1·6	−1·3	1·3	0·5	2·4*	1·75
Rothamsted, Herts	12·3	2·2**	1·4*	0·1	2·2**	3·0**	0·90
Silsoe, Beds	14·5	2·2*	−1·2	0·8	−0·2	1·0	1·94
Stapleford, Herts	17·5	2·3	−0·6	3·6*	−0·4	−0·6	2·39
Mean	16·2	1·5	0·0	1·6	0·4	0·9	—
1949 experiments on spring beans							
Brent Pelham, Herts	13·1	−0·4	0·2	2·7	1·1	0·9	2·00
Rothamsted, Herts	7·8	−0·6	−0·8	−0·3	0·2	0·8	1·01
Willingham, Cambs	19·6	1·2	4·5**	1·9	0·8	2·2*	1·53
Mean	13·5	0·1	1·3	1·4	0·7	1·3	—
1950 experiments on spring beans							
Much Hadham, Herts	23·3	1·2	2·1*	1·3	−0·2	1·0	1·24
Pertenhall, Beds	19·6	−0·1	0·6	−0·5	0·5	1·9**	1·20
Rothamsted, Herts	14·5	1·7	2·4	−1·0	3·0**	2·7**	1·83
Willingham, Cambs	18·6	0·2	2·0	1·8	0·9	3·2**	2·03
Mean	19·0	0·8	1·8	0·4	1·0	2·2	—
1951 experiments on spring beans							
Much Hadham, Herts	20·7	−0·3	1·5	0·9	1·0	1·0	1·47
Pertenhall, Beds	13·2	2·2	−3·6	−0·9	−0·5	−1·4	2·86
Rothamsted, Herts	12·2	1·1	2·2*	1·4	−0·5	0·7	1·32
Mean	15·4	1·0	0·0	0·5	0·1	0·1	—

(*Received* 29 *December* 1952)