Widdowson, F. V., Penny, A., Williams, R. J. B. and Cooke, G. W. 1959. Comparisons between combine-drilling and broadcasting muriate of potash for spring barley. *The Journal of Agricultural Science.* 53 (1), pp. 10-16.

COMPARISONS BETWEEN COMBINE-DRILLING AND BROADCASTING MURIATE OF POTASH FOR SPRING BARLEY

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War-time experiments reported by Crowther (1945) showed that superphosphate drilled with the seed of cereals was much more efficient than broadcast superphosphate. Many of the soils on which cereals are grown in eastern and southern England are now well supplied with phosphate and little effect can be expected from dressings of superphosphate however they are applied. The higher capital cost and more rapid depreciation of combine-drills, compared with ordinary seed drills, may be difficult to justify in these areas unless farmers can expect higher yields from drilling rather than broadcasting the nitrogen and potassium components of the compound fertilizers commonly used for spring cereals. Widdowson & Cooke (1958) showed recently that combine-drilling ammonium sulphate gave higher yields than broadcasting this fertilizer for spring barley. In a few experiments on potassium-deficient calcareous soils in Berkshire combine-drilling muriate of potash for barley was more efficient than broadcasting (Crowther, 1945); apart from this war-time work on one particular type of soil, no experiments on combine-drilling of potassium fertilizers for cereals have been reported from this country. The experiments described here were carried out to compare combine-drilling and broadcasting of muriate of potash for barley grown on a range of ordinary soils, most of which were not rich in calcium carbonate.

NATURE OF THE EXPERIMENTS

The work was carried out on commercial farms in Bedfordshire and Hertfordshire from 1955 to 1957; there were four experiments in each year. Sites were chosen by selecting soils which contained little potassium soluble in a rapid extraction with dilute hydrochloric acid. The soils are described in Appendix Table 3 and only one (taken from Stopsley in 1955) contained appreciable amounts of calcium carbonate.

The experiments measured the responses to combine-drilled and broadcast seedbed dressings of muriate of potash; each method was compared at rates supplying approximately 0·25 and 0·50 cwt. K_2O/acre. The four fertilizer treatments, together with one plot receiving no potassium, were arranged in a randomized block. There were six blocks at each centre.

Granulated mixtures of superphosphate and muriate of potash were used to apply the combine-drilled dressings of potassium, since commercial muriate of potash is unsuitable for use in a combine-drill. By applying granular superphosphate, and two compound fertilizers (containing 13% P_2O_5 and 13% K_2O, and 10% P_2O_5 and 20% K_2O, respectively), it was possible to apply the same dressing/acre of combine-drilled superphosphate to all plots in the absence of potassium and also in the presence of drilled single and double dressings of muriate of potash. Field calibrations at each centre determined the rate of the broadcast dressings of potassium which were applied by hand after drilling had been completed. Ammonium sulphate at uniform rates was broadcast by hand on all plots in the 1955 and 1956 experiments. In 1957 the combine-drill was used to drill ammonium sulphate across each experiment, this method of application was used to improve the evenness of spreading of the nitrogen and to incorporate it more deeply in the seedbed. The amount of ammonium sulphate used was chosen to suit local conditions, it varied from 2 to 3 cwt./acre.

All the experiments except that at Tingrith (in 1957) were cut by combine-harvester. The yields of straw and grain were recorded except at Studham in 1956; at this centre the barley was badly lodged and was under-sown with clover; as a result only the yields of grain could be taken. Samples of grain and straw were taken from each plot for percentage dry matter and potassium determinations. Grain yields presented here are corrected to 15% moisture content, straw yields are in terms of dry matter.

RESULTS OF THE EXPERIMENTS

Yields of grain and straw

The yields of grain obtained without potassium fertilizer and the increases obtained at each centre from broadcast and combine-drilled dressings of muriate of potash are given in Appendix Table 1. There were wide variations between the unmanured yields of the twelve experiments but there was no clear relationship between these values and the responses to the dressings tested. Average yields without potassium were highest in 1956 and lowest in 1957; the responses to potassium, however, were lower in 1957 than in either of the two previous seasons. The effects of potassium on the yields of straw at each centre are also stated in Appendix Table 1. Yields of combine-harvested straw were lower than the corresponding grain yields, but the responses to the dressings of potassium followed the same pattern.

Average yields of grain and straw without potassium and the average increases from broadcasting and from drilling muriate of potash in each year are given in Table 1. The highest responses to potassium were obtained in 1955 and the lowest in 1957. (Seedbeds prepared for the experiments in 1957 were very unsatisfactory, their effects on growth were made worse by the long dry spell following sowing and there is little doubt that yields were reduced as a result.) Over the 3 years of the experiments two-thirds of the drilled dressings increased grain yields significantly, but only half of the broadcast dressings gave significant gains. In each year combine-drilling 0·25 cwt. K_2O/acre produced higher average yields of grain than broadcasting 0·5 cwt. K_2O/acre over the seedbed. The effects of the potassium dressings on straw yields were less consistent; combine-drilling gave higher average yields than broadcasting in 1955 and 1957, but in 1956 broadcasting was slightly superior to drilling. These conflicting results may be due, in part at least, to the difficulty experienced in obtaining accurate estimates of the yields of straw. Variations in the height of the cutter-bar of the combine-harvester, and difficulties in collecting all the straw from the swathe, resulted in high coefficients of variation for straw yields. The standard errors per plot (expressed as a percentage of the mean yield) for each experiment were much greater for straw than for grain yields.

Gains from drilling as compared with broadcasting are given for each centre in Table 2. Drilling produced higher yields of grain than broadcasting at all centres in 1955 and five of the eight effects were significant. The average benefits from drilling were smaller in 1956 and 1957; most of the effects were positive but there was only one significant increase in each year. Over the three seasons there were gains from drilling at nine centres when the lower dressing was tested (four significant increases), and at all the centres when the heavier dressing was applied (three significant increases). There were no instances where broadcasting potassium gave significantly more grain than drilling. Comparisons of the effects of drilled and broadcast applications of potassium on straw yields over the 3 years are more conflicting. In 1955 drilling gave more straw than broadcasting in all of the possible comparisons and four of these increases were significant. The differences between yields of straw given by the two methods in 1956 and 1957 were smaller and more erratic; at one centre in 1956 broadcasting gave significantly more straw than combine-drilling.

Table 1. *Average yields of barley without potassium, the increases given by broadcast and combine-drilled dressings of muriate of potash, and the numbers of positive and significant positive effects*

(P = 0·05 or greater.)

	Mean yields (cwt./acre)			All years		
	1955	1956	1957	Yield (cwt./acre)	No. of positive effects	No. of significant positive effects
		For grain				
No. of experiments	4	4	4	12	—	—
Mean yields without potassium	25·8	30·8	23·8	26·8	—	—
Increase in yield from 0·25 cwt. K_2O/acre						
Broadcast	3·7	2·1	0·8	2·2	10	5
Drilled	6·6	2·4	1·2	3·4	12	8
Increase in yield from 0·5 cwt. K_2O/acre						
Broadcast	4·6	1·8	0·3	2·2	10	6
Drilled	7·3	3·6	1·6	4·2	11	8
		For straw				
No. of experiments	4	3	4	11	—	—
Mean yield without potassium	12·8	12·2	11·6	12·2	—	—
Increase in yield from 0·25 cwt. K_2O/acre						
Broadcast	2·1	1·1	1·3	1·5	9	3
Drilled	3·6	0·6	1·5	2·0	9	5
Increase in yield from 0·50 cwt. K_2O/acre						
Broadcast	2·4	1·0	0·5	1·3	7	4
Drilled	4·4	0·8	0·7	2·1	9	6

Table 2. *Gains from combine-drilling as compared with broadcasting muriate of potash in experiments on spring-sown barley*

(Significant effects are marked: * for $P = 0.05$–0.01; ** for $P > 0.01$.)

	Increases in yields of grain (cwt./acre) from drilling over broadcasting			Increases in yields of straw (cwt./acre) from drilling over broadcasting		
	At low rate	At high rate	S.E.	At low rate	At high rate	S.E.
1955 experiments						
Battlesden	2·7	2·9	1·41	1·0	2·5*	0·98
Berkhamsted	3·3*	3·9**	1·33	1·8	2·1*	0·92
Bovingdon	3·5**	2·1	1·01	1·0	1·4	1·19
Stopsley	2·3*	2·2*	0·91	2·1**	2·0**	0·71
1956 experiments						
Essendon	1·3	1·7	0·95	−1·4**	−0·2	0·49
Potterscrouch	−1·3	2·4*	0·86	−0·6	−0·3	0·84
Studham	0·4	1·7	1·27	—	—	—
Tingrith	0·7	1·3	0·69	0·5	0·1	0·72
1957 experiments						
Gaddesden	1·4*	0·3	0·59	0·3	0·4	0·44
Hertingfordbury	−0·2	1·2	0·92	0·7	0·0	0·81
Studham	0·4	0·4	0·64	−0·5	0·4	0·59
Tingrith	−0·4	3·2	1·85	0·4	0·0	1·09
Means of all years	−1·2†	1·9†	—	0·5‡	0·8‡	—

† Twelve experiments. ‡ Eleven experiments.

Uptake of potassium

The effects of the fertilizers tested on the amounts of potassium in the grain and straw at each centre are stated in Appendix Table 2. A summary of these data is given in Table 3. Apparent recoveries of applied potassium by both grain and straw were highest in 1955, and uptakes from drilled potassium were higher than from broadcast dressings in that year. In the two later years apparent recoveries were smaller and there was little difference between the uptakes from drilled and broadcast dressings. On average of all the experiments 11 % of the light-drilled dressing, and 8 % of the heavy-drilled dressing of potassium, was removed in the grain and straw.

Analyses of the soils used

Analyses of soil samples taken from the experimental sites immediately before the fertilizers were applied are given in Appendix Table 3. Hydrochloric-acid-soluble potassium was determined by a rapid method in which 12 g. of soil were shaken with 28 ml. of 0·3N-hydrochloric acid for 1 min. (This method was also used in the preliminary work of selecting soils with 'low' values for soluble potassium for the experiments.) Exchangeable soil potassium and total exchangeable bases were determined by semi-micro methods described by Metson (1956), using normal ammonium acetate solution at pH 7·0. In the 1955 experiments the two centres with the lowest values for exchangeable potassium gave the largest responses, values for hydrochloric-acid-soluble potassium were all very low and the method did not differentiate between the more responsive and less responsive sites. In the two later years acid-soluble soil potassium values tended to be higher than values obtained in 1955, but the range of values for exchangeable potassium was similar to that obtained in the earlier year. In 1956 and 1957 the general level of response was less than in 1955 and neither method of soil analysis distinguished between the centres used in each year.

DISCUSSION

On average of all the experiments in this series the response to muriate of potash was not large and the crops grown recovered only a small proportion of the fertilizer applied. As the soils used were selected on the basis of low values for acid-soluble potassium it appears that potash is not a very important fertilizer for barley in this area; quite small dressings should be sufficient to obtain full yields, provided that they are drilled with the seed.

The largest returns from potash were obtained in 1955. The soils used in that year had somewhat lower values for HCl-soluble K than those used in 1956 and 1957. In addition, 1955 was the best of the three seasons for barley; rainfall at Rothamsted in May was double the average, and an average amount of rain in June was followed by dry weather in July and August which was very suitable for ripening the grain and for harvesting. In 1956 early growth was retarded by a dry spring; summer rainfall was much above average, temperatures were

Table 3. *The uptakes of potassium by unfertilized barley and the increases in uptake from broadcast and combine-drilled dressings of muriate of potash*

	Mean uptakes of potassium (lb. of K/acre)			All years		
	1955	1956	1957	Mean uptake (lb. of K/acre)	No. of positive effects	No. of significant positive effects (P = 0·05 or greater)
		For grain				
No. of experiments	4	4	4	12	—	—
Mean uptake without potassium	10·8	13·6	9·4	11·2	—	—
Increase in uptake from low rate (23·2 lb./acre of K)						
Broadcast	1·7	1·2	0·3	1·0	10	5
Drilled	3·0	1·2	0·4	1·5	12	7
Increase in uptake from high rate (46·5 lb./acre of K)						
Broadcast	2·2	1·0	0·1	1·1	10	5
Drilled	3·4	1·6	0·6	1·9	11	8
		For straw				
No. of experiments	4	3	4	11	—	—
Mean uptake without potassium	8·9	4·8	8·8	7·7	—	—
Increase in uptake from low rate (23·2 lb./acre of K)						
Broadcast	2·0	0·4	1·1	1·2	10	3
Drilled	2·4	0·0	0·6	1·1	8	4
Increase in uptake from high rate (46·5 lb./acre of K)						
Broadcast	3·6	1·1	1·3	2·1	11	3
Drilled	4·0	0·6	0·7	1·8	11	5

below average and crops were slow to ripen. In 1957 all the experiments were sown on unsatisfactory seedbeds; dry weather persisted until mid-June and crops grew slowly and irregularly. Rainfall in late June and July was above average, but was too late to allow barley to recover from the check in spring.

On average of the results of each year's experiments, 0·25 cwt./acre of K_2O drilled with the seed gave higher yields of grain than twice as much K_2O broadcast and worked into the seedbed. As the two methods of application were each tested at two rates of dressing there were twenty-four comparisons of drilling and broadcasting in the series of twelve experiments. In twenty-one of these comparisons drilling potassium gave higher yields than broadcasting and in one-third of the comparisons the effects were significant. Of the three comparisons where broadcasting gave higher yields than drilling, none of the effects was significant and only one exceeded the appropriate standard error. The average gain in yield of barley from drilling, as compared with broadcasting, was 1·2 cwt./acre of grain at the low rate of dressing and 2·0 cwt./acre at the high rate. In most comparisons of drilling and broadcasting, gains from drilling tend to be greater at low rates and less at high rates of application. These experiments suggest that the response curves for drilling and for broadcasting potassium for barley are differently shaped. Combine-drilling gave higher average yields than could have been obtained by using several times as much broadcast potassium. It is clear that whenever potassium fertilizers are justified for barley they should be drilled with the seed to achieve full yields with least expenditure on fertilizer.

There was no close correlation between 'available' soil potassium determined by rapid extraction with 0·3N-hydrochloric acid and exchangeable potassium. Exchangeable-potassium values tended to be two to three times as great as corresponding acid-soluble potassium data. There was no close relationship between values for soluble potassium in the soils used and the responses of the crops to potassium fertilizers. Since the experiments were carried out in three contrasted growing seasons, and the sites had already been selected by choosing soils with small amounts of hydrochloric-acid-soluble potassium, no close relationship between soil analyses and crop responses is to be expected.

SUMMARY

1. Twelve experiments were carried out in Bedfordshire and Hertfordshire in 1955–57 to compare combine-drilling and broadcasting muriate of

potash for barley. Ordinary mineral soils were used and only one contained more than 25 % of calcium carbonate.

2. On average of all the experiments in each year 0·25 cwt. K_2O/acre drilled with the seed gave higher yields than 0·5 cwt. K_2O/acre broadcast and worked into the seedbed. The average extra yields of barley from combine-drilling, as compared with broadcasting, were 1·2 cwt./acre when 0·25 cwt. K_2O/acre was applied and 2·0 cwt./acre of grain when twice as much K_2O was given. In twenty-one of the total of twenty-four comparisons drilling gave higher yields than broadcasting and in one-third of these comparisons the effects were significant. Combine-drilling gave higher average yields of straw than broadcasting.

3. The average level of response was not great, the low and high rates of combine-drilled muriate of potash increasing yields by 13 and 16 %, respectively. Only a small proportion of the applied potassium was taken up by the crops; apparent recoveries by grain plus straw averaged 11 % of the light-drilled dressing and 8 % of the heavy dressing.

4. The level of response to potassium varied from year to year, but was much greater on average in the 1955 experiments than in 1956 and 1957. There was no close relationship between the degree of response and values for dilute hydrochloric-acid-soluble potassium or exchangeable potassium in the soils used.

The authors would like to thank members of the National Agricultural Advisory Service in Bedfordshire and Hertfordshire for their help in finding sites for the experiments, J. H. A. Dunwoody for the statistical analyses of the data, and other members of the Chemistry Department at Rothamsted for much assistance in carrying out the work.

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(*Received* 5 *September* 1958)

APPENDIX

Table 1. *Yields of barley grain and straw without potassium and the increases given by combine-drilled and broadcast seedbed dressings of muriate of potash*

(Significant effects are marked: * for $P = 0.05$ (to 0.01); ** for $P > 0.01$.)

Centre	Without potassium	Potassium at low rate: Broadcast	Potassium at low rate: Combine-drilled	Potassium at high rate: Broadcast	Potassium at high rate: Combine-drilled	S.E. of increases
	Yields (in cwt./acre) of grain containing 15 % moisture					
1955 experiments						
Battlesden, Beds	30·8	2·2	4·9**	1·7	4·6**	1·41
Berkhamsted, Herts	17·3	2·2	5·5**	2·8*	6·7**	1·33
Bovingdon, Herts	30·6	8·1**	11·6**	10·7**	12·8**	1·01
Stopsley, Beds	24·6	2·2*	4·5**	3·0**	5·2**	0·91
1956 experiments						
Essendon, Herts	37·4	−0·4	0·9	−1·0	0·7	0·95
Potterscrouch, Herts	25·3	4·3**	3·0**	2·8**	5·2**	0·86
Studham, Beds	34·3	3·6*	4·0**	3·9**	5·6**	1·27
Tingrith, Beds	26·1	0·8	1·5*	1·5*	2·8**	0·69
1957 experiments						
Gaddesden, Herts	26·7	−0·9	0·5	−0·7	−0·4	0·59
Hertingfordbury, Herts	23·2	0·6	0·4	0·4	1·6	0·92
Studham, Beds	28·5	1·7*	2·1**	0·6	1·0	0·64
Tingrith, Beds	16·8	2·0	1·6	1·0	4·2*	1·85
Mean of all centres	26·8	2·2	3·4	2·2	4·2	—
	Yields (in cwt./acre) of dry straw					
1955 experiments						
Battlesden	16·7	2·0	3·0**	1·7	4·2**	0·98
Berkhamsted	7·1	1·4	3·2**	1·7	3·8**	0·92
Bovingdon	12·3	5·6**	6·6**	6·5**	7·9**	1·19
Stopsley	15·2	−0·6	1·5	−0·4	1·6*	0·71
1956 experiments						
Essendon	18·5	0·3	−1·1*	−0·6	−0·8	0·49
Potterscrouch	7·3	1·6	1·0	1·8*	1·5	0·84
Tingrith	10·9	1·3	1·8*	1·7*	1·8*	0·72
1957 experiments						
Gaddesden	7·9	−0·4	−0·1	−0·6	−0·2	0·44
Hertingfordbury	12·4	0·1	0·8	0·5	0·5	0·81
Studham	7·7	1·4*	0·9	−0·3	0·1	0·59
Tingrith	18·4	4·0**	4·4**	2·5*	2·5*	1·09
Mean of all centres	12·2	1·5	2·0	1·3	2·1	—

Table 2. *The amounts of potassium in the grain and straw of unfertilized barley and the amounts taken up from broadcast and combine-drilled dressings of muriate of potash*

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

Centre	Without potassium	Increases from low rate: Broadcast	Increases from low rate: Drilled	Increases from high rate: Broadcast	Increases from high rate: Drilled	S.E. of increases
	Amounts of potassium in crop (in lb./acre of K)					
		For grain				
1955 experiments						
Battlesden	13·1	1·1	2·4**	0·7	2·1**	0·62
Berkhamsted	6·9	1·2*	2·5**	1·5*	3·1**	0·55
Bovingdon	11·9	3·5**	5·0**	4·7**	5·6**	0·44
Stopsley	11·3	1·1	2·1**	1·8**	2·6**	0·59
1956 experiments						
Essendon	18·2	−0·1	0·3	−0·3	0·2	0·48
Potterscrouch	10·4	2·2**	1·7**	1·2**	2·4**	0·35
Studham	14·5	2·1**	1·9**	2·3**	2·6**	0·56
Tingrith	11·3	0·4	0·7	0·7	1·4**	0·38
1957 experiments						
Gaddesden	10·3	−0·4	0·3	−0·1	−0·2	0·32
Hertingfordbury	9·6	0·2	0·1	0·1	0·6	0·35
Studham	11·0	0·7*	0·7*	0·1	0·3	0·27
Tingrith	6·5	0·6	0·4	0·3	1·7*	0·72
Mean of all centres	11·2	1·0	1·5	1·1	1·9	—
		For straw				
1955 experiments						
Battlesden	18·5	2·4	2·0	3·2	4·5*	2·06
Berkhamsted	5·6	2·0**	3·2**	4·0**	4·8**	0·69
Bovingdon	4·9	3·4**	2·8**	6·4**	4·3**	0·58
Stopsley	6·5	0·1	1·6*	0·7	2·2**	0·57
1956 experiments						
Essendon	6·1	0·1	−0·5	1·0	0·4	0·50
Potterscrouch	3·2	0·7	−0·1	0·9	0·7	0·47
Tingrith	5·0	0·3	0·6	1·4*	0·7	0·65
1957 experiments						
Gaddesden	4·8	−0·4	−0·4	0·5	0·3	0·62
Hertingfordbury	7·2	0·6	0·4	0·7	0·7	0·74
Studham	8·4	2·0*	1·6*	0·4	1·6*	0·75
Tingrith	14·6	2·2	0·8	3·5	0·2	1·91
Mean of all centres	7·7	1·2	1·1	2·1	1·8	—

Table 3. *Descriptions of the soils used in the field experiments*

Centre	Description of soil	pH	$CaCO_3$ (%)	0·3N-HCl-soluble potassium (mg./100 g. soil)	Exchangeable potassium (mg./100 g. of soil)	Total exchangeable bases (m-equiv./100 g. of soil)
1955						
Battlesden	Clay-loam with some sand over gault clay	6·2	—	4·0	11·0	33·1
Berkhamsted	Light gravelly-loam over clay-with-flints	6·1	—	3·3	8·2	10·7
Bovingdon	Clay-loam over clay-with-flints	7·7	0·3	2·8	7·2	23·4
Stopsley	Light loam over chalk	8·1	17·2	1·9	10·2	79·8
1956						
Essendon	Brickearth (Hatfield loam)	7·7	0·3	5·6	10·5	17·9
Potterscrouch	Light stony loam over Reading beds	7·9	0·4	4·2	7·2	15·9
Studham	Medium loam with flints over chalk	7·4	1·6	4·4	11·2	36·9
Tingrith	Sandy loam over alluvial clay	7·7	0·2	4·4	7·7	11·7
1957						
Gaddesden	Stony loam over chalk	7·3	0·2	5·4	10·2	17·0
Hertingfordbury	Light sandy loam over gravel	7·9	1·0	4·4	8·7	26·6
Studham	Medium flinty loam over chalk	6·4	—	4·2	8·7	12·8
Tingrith	Sandy loam with some clay over lower greensand	6·4	—	5·4	12·5	22·2