EARLY SPRAYING OF SPRING CEREALS WITH MCPA (POTASSIUM) AND MCPB (SODIUM)

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Summary (and Conclusions)

Trials to compare the effect of MCPA (potassium) and MCPB (sodium) on spring cereals at the normal post-5 leaf stage, and at an early pre-5 leaf stage were carried out. Assessments were made of the weed control, incidence of malformities and of the effect on yield and grain quality of the crop.

MCPB proved inferior to MCPA for the control of annual weeds. Satisfactory control of yellow charlock (Sinapis arvensis) and fat hen (Chenopodium album) was obtained with MCPB applied at the seedling stage.

Susceptible weeds (yellow charlock, fat hen and runch (Raphanus raphanistrum) in the seedling stage were effectively controlled by lower rates of MCPA by spraying early. Moderately resistant weeds did not consistently respond better to earlier treatment.

MCPB did not produce malformities in spring cereals sprayed at the pre-tillering stage. MCPA applied at the same stage produced a high incidence of malformities in wheat and barley; it is considered inadvisable to treat these crops early with MCPA. Spring oats are considered safe to spray early with MCPA as the incidence of malformities was low and did not affect grain quality.

Early spraying gave greater yield increases than spraying at the normal time, particularly where susceptible weeds were present.

Introduction

This report presents the results of seven trials carried out in south-eastern Scotland in 1955 to compare MCPA (potassium) and MCPB (sodium) as weed-killers in spring cereals. These trials were part of a larger series which compared various formulations of MCPA salts, the main object of which was to determine whether early spraying could give better control of weeds moderately resistant to MCPA and give greater yield increases by removing weed competition earlier.

Previous work with MCPA has shown that spring oats can be sprayed safely in the early stages of growth (1 & 2).

Wheat and barley, in addition to oats, were included in the 1955 trials to investigate the susceptibility of all those crops to early spraying with MCPB in comparison with MCPA. Both chemicals were applied at low volume (12 gal/ac) at two stages of growth; early i.e. in the pre-tillering stage before five leaves had developed on the main stem, and at the normal time. MCPB was slightly handicapped by the comparison with MCPA as the acid equivalent of the MCPB sample was lower than was originally thought.

Results

Control of Weeds (Tables 1 and 2)

In all trials MCPB proved inferior to MCPA for the control of weeds, the difference between the two compounds being much greater than would be expected from the difference in the dose rate applied. The most striking difference in response appeared with those weeds which are classed as susceptible to MCPA, for example, runch, yellow charlock and fat hen. Early spraying with MCPB gave better results than spraying at the normal time in the case of yellow charlock and runch, but while the control of yellow charlock obtained with 20 oz/ac MCPB at the early stage was satisfactory, this was not the case with runch. Fat hen was also controlled with 20 oz/ac MCPB but early spraying did not prove consistently better than spraying at the normal time.

There were also large differences between MCPA and MCPB in the response of some of the moderately resistant weeds, for example, chickweed (Stellaria media) and bindweed (Polygonum convolvulus). The control of chickweed with 20 oz/ac MCPB was extremely poor. In the larger series of trials moderately resistant weeds were, in general, more severely checked in growth by spraying MCPA at the normal time than by spraying early. Chickweed falls into this category in the trials detailed here.

The control of redshank (Polygonum persicaria) with MCPB at the normal stage was only very slightly inferior to that obtained with MCPA. In one trial redshank responded better to normal spraying and in another trial better to early spraying.

In the one trial on spurrey (Spergula arvensis) there was very little difference in response between MCPB sprayed early and at the normal time. On the other hand, a better response was obtained from MCPA at the early spraying.

In two trials, fumitory (Fumaria officinalis), normally moderately susceptible to MCPA, was more severely checked by early spraying than by normal spraying by both MCPA and MCPB. It is clear, however, that for satisfactory results 20 oz MCPB should be regarded as a minimum, even for early spraying.

Malformities (Table 3)

One of the most striking features of the results was the negligible incidence of malformities in wheat, oats and barley following spraying with MCPB.

Malformities were observed following early spraying with MCPA in all trials. In oats malformities also followed spraying at the normal stage of growth. Early spraying of oats usually gave rise to a higher percentage of malformities than spraying at the normal time. The types of malformities most commonly observed in oats were supernumerary panicles arising from the uppermost node of the culm and abnormalities of the spikelets. These malformities are not considered likely to impair the quality or reduce the yield of oats.

Wheat and barley sprayed early showed a high percentage of ear malformities even at 12 oz/ac MCPA; spraying at the normal time gave negligible malformity. Opposite spikelets and whorled spikelets were the most common malformities. In wheat inflated glumes also occurred. In barley where whorled spikelets were present, the rachis was often elongated below the whorl so that the ear was bent into two.

Yield (Table 4)

These trials reflect the general trend for the yield following early spraying to be greater than that following spraying at the normal time. The difference is significant in five out of the six trials harvested. In only two of these trials, however, was the difference between the treatments as a whole and the controls significant. In both cases heavy infestations of weeds susceptible to MCPA were present.

In one trial on oats the difference in yield between early and normal spraying was the result of yield depression following spraying at the normal time. In this trial the reduction in yield of the treatments taken together over the control, is significant. Moreover, the depression in yield by the higher rate is significantly greater than that by the lower rate. The depressant effect of MCPB was less severe than that of MCPA. In this trial there was a heavy infestation of redshank.

The higher dose rate gave a significantly greater yield increase than the lower dose rate in one trial only where a moderate infestation of yellow charlock occurred in a crop of barley.

Discussion

The safety of MCPB to cereals in the early stages of growth is a phenomenon with practical possibilities which merit further investigation. MCPB may prove to be of particular value in undersown cereal crops where white clover is present and where yellow charlock and fat hen are the main weeds. In order to catch these weeds at their most susceptible stage of growth it may be necessary to spray them in the pre-tillering stage of the cereal. The lack of damage to both clovers and cereals by MCPB will make this practicable.

The inferior result obtained on moderately resistant weeds with early spraying is unexpected. In general the weather was cold and growing conditions were poor during the spraying season of 1955, particularly at the time when the earlier applications were carried out. This may account in part for the result obtained, but the inherently greater resistance of these weeds to MCPA at early stages of growth is suggested by the fact that better results also followed spraying at the normal time in a small number of trials where spraying conditions were more favourable at the time of the early spraying than at the normal time. Although it has been shown by Blackman et alia (3) that a higher percentage of plants is killed at the seedling stage than at a later stage of growth, it may be that those which survive are less affected than those which are sprayed later.

The ear malformities which follow early spraying with MCPA on wheat are not in themselves detrimental to yield or grain quality. Myers, however, has observed that when hormone type weedkillers are applied to wheat during the laying down of the last leaf initials or the beginning of the transition period, this period lasts longer than normally and the number of spikelets on the head may be reduced. This malformity is presumed to occur only in wheat because of its determinate inflorescence; it has not been seen in barley (4).

In barley there is a danger that the upper part of ears, bent into two as the result of a malformity due to spraying with MCPA, might break off before harvest and thus lead to loss of yield. There is also evidence in the literature that malformities following MCPA sprayed in the pre-tillering stage may reduce the malting quality of a sample of barley (1)

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Table 1

Percentage kill of susceptible weeds with MCPA (potassium) and MCPB (sodium)

B 55 1	Weed	MCPA (oz/ac a.e.)				MCPB (oz/ac a.e.)			
		Early		Normal		Early		Normal	
		6	12	6	12	5	10	5	10
15	Yellow charlock	91	99	52	77	36	38	14	11
15	Fat hen	57	76	26	41	23	41	27	44
-		12	24	12	24	10	20	10	20
12	Yellow charlock	97	99	100	100	58	74	53	63
7	Runch	100	99	91	97	27	15	15	24
19	Fat hen	95	97	71	86	48	74	53	58
18	Fat hen	88	93	72	83	50	59	58	69

Table 2

Control of moderately resistant weeds with MCPA (potassium) and MCPB (sodium)

(Based on a vigour grading. Total possible maximum score for each treatment = 100)

B 55 1	Weed	MCPA (oz/ac a.e.)					MCPB (oz/ac a.e.)				
		Early		Normal		Control	Early		Normal		Control
		12	24	12	24		10	20	10	20	
8	Spurrey	60	79	51	60	0	30	38	34	33	0
18	Fumitory	67	86	45	70	0	45	72	31	49	0
12	Fumitory	45	67	31	63	0	29	49	26	35	0
10	Redshank	32	45	49	55	5	13	31	46	46	5
8	Redshank	48	63	42	45	0	51	58	47	43	0
18	Black Bindweed	64	83	63	79	0	36	61	37	53	0
18	Chickweed	38	56	54	77	28	27	27	31	35	21
7	Chickweed	21	39	34	52	4	6	11	10	18	5
12	Chickweed	37	35	39	59	0	15	25	21	29	0

Note: In all tables MCPA (potassium) contained 64 oz/gal active MCPA. MCPB (sodium) contained approx. 54 oz/gal active MCPB.

Table 3

Oc-urrence of malformities in spring cereals
after spraying with MCPA (potassium) & MCPB (sodium)

Expressed as a percentage of total heads in the samples examined

B 55 1	Cereal and Variety	Days after Sowing	Growth Stage			MCPA oz/ac a.e.			MCPB oz/ac a.e.		
			Leaves	Tillers	Ht.	12	24	0	10	20	0
7	Oats Sun II	35 59	2.1 5.1	0 0 0.6	3.3 in. 10.3 in.	7.3 0.8	11.0 1.5	0.5	1.3 0.3	1.0 0.8	0.5
8	Oats Onward	45 66	3.7 5.8	0.7 0.9	6.3 in. 13.1 in.	7.5 0.8	14.0 2.3	1.0	1.5 0	2.5 0.5	0.3
10	Oats Yielder	31 51	1.6 4.7	0.0 0.5	2.6 in. 7.3 in.	3.5 1.3	5.8 2.8	0.5	1.8 3.0	1.0 3.0	0.8
18	Wheat Atle	54 72	3.4 4.7	0.4 0.8	5.6 in. 8.8 in.	46.8 0.5	84.8 1.0	0.5	0.8 0.3	1.3 1.0	0.5
19	Wheat Atle	42 65	2.9 5.6	0.2 1.4	3.8 in. 8.9 in.	37.0 0.8	55.8 0.3	0.3	0.5 0	0.5 1.3	0.8
12	Barley Carlsburg II	38 56	3.9 4.9	1.0 2.4	5.3 in. 9.2 in.	33.5 0	49.5 0	0	0.3 0	0 0	0
						6	12	0	5	10	0
15	Barley Ymer	38 60	3.2 5.6	0.3 1.9	4.8 in. 9.0 in.	19.3 0	45.0 0.5	0	0 0.3	0 0	0

Table 4

Yield of spring cereals after spraying with MCPA (potassium) & MCPB (sodium)

Expressed in cwt/ac.

B 55 1	Crop variety / Weed cover	Product	Early spraying Pints/ac 0.75	Early spraying Pints/ac 1.5	Early mean	Normal spraying Pints/ac 0.75	Normal spraying Pints/ac 1.5	Normal mean	Control	Product mean
15	Barley - Ymer	MCPA	39.2	40.1	39.7	35.7	37.5	36.6	33.9	37.3
	Heavy	MCPB	41.1	39.1	40.1	35.3	35.9	35.6	36.9	37.7
			1.5	3		1.5	3			
7	Oats - Sun II	MCPA	20.6	19.7	20.2	15.4	15.6	15.5	14.9	17.2
	Very heavy	MCPB	16.1	18.0	17.1	15.6	14.8	15.2	15.6	16.0
10	Oats-Yielder	MCPA	22.6	21.0	21.8	19.4	17.7	18.6	22.8	20.7
	Heavy	MCPB	23.2	22.3	22.8	21.1	20.2	20.7	22.7	21.9
12	Barley Carlsburg II	MCPA	24.1	26.7	25.4	21.7	25.0	23.4	23.4	24.2
	Moderate	MCPB	24.8	25.7	25.3	23.9	24.8	24.4	23.1	24.5
18	Wheat - Atle	MCPA	24.7	25.1	24.9	22.1	22.8	22.5	23.9	23.7
	Moderate	MCPB	23.8	24.4	24.1	23.7	23.4	23.6	23.1	23.7
19	Wheat - Atle	MCPA	39.5	38.1	38.8	39.7	39.6	39.7	40.5	39.5
	Light	MCPB	39.5	39.8	39.7	39.0	36.9	38.0	38.8	38.8

COMPARISON OF EARLY APPLICATIONS OF MCPB AND LOW RATES OF MCPA ON CEREALS

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Introduction

It has been demonstrated elsewhere (1) that early applications of MCPA can be a very effective method of controlling certain difficult annual weeds in cereal crops, such as Polygonum persicaria, Matricaria spp. and Veronica spp. This has been shown to be practicable in crops of spring oats (2) but not with wheat or barley, where the risk of inducing various abnormalities outweighs the advantage of more effective control of weeds.

It has been claimed that MCPB will not affect cereals at any stage of growth and is therefore a most promising herbicide for the early control of weeds in wheat and barley, as well as oats. The herbicidal activity of MCPB is generally lower than that of MCPA, and the range of weeds controlled is more restricted. Therefore, it was decided to compare a standard rate of application of MCPB with a low concentration of MCPA on spring sown cereals in 1956, in the hope that the latter would not produce an unacceptable number of deformities.

This supposition appeared to have some justification in the light of a previous report (3) which suggested that while the occurrence of deformities depended solely upon the time of application of MCPA, the rate of application also had an effect on the percentage of deformities obtained.

Experimental detail

The experiment was carried out at six centres.

Crop	Variety	Soil Type
1. Barley	Proctor	Oxfordshire clay
2. Barley	Proctor	Alluvial soil
3. Wheat	Atle	Clay with flint over chalk
4. Wheat	Atson	River gravel
5. Oats	Pendec	Deep alluvial soil
6. Oats	Sun II	Stone brash

At each centre MCPA potassium salt and MCPB sodium salt were applied at the 1-2 leaf stage and the 3-4 leaf stage of the cereal crop at the following rates and volumes:-

MCPA - 5 oz a.e.)
) In 15 gal/ac of water.
MCPB - 24 oz a.e.)

There were six replications of each treatment at all centres.

The plot size chosen was 20 ft x 36 ft.

Weather conditions

The weather during germination and early development of the cereals was extremely cold and the period between the 1-2 leaf and 3-4 leaf stages often exceeded 14 days. There was no appreciable rainfall at any centre from the time of the first application until some time after the second application. These poor growing conditions undoubtedly had some adverse effect on the degree of weed control obtained.

Observations and assessment of results

The estimation of weed control was made 7 days after the second application and a further observation of weed control was made approximately one month later. For this purpose the following scale of marking was adopted:

Marks	State of Weed Growth
1	No live weeds - evidence of killing.
2	Few live weeds but stunted. Not competing, evidence of killing.
3	Fair control, number of weeds alive suppressed, ranging to healthy plants, some evidence of killing.
4	Poor control, some suppression but most weeds making growth.
5	No control.

The crop was to be examined for abnormalities just prior to harvest. The abnormalities noted were those described by Large and Dillon Weston (4) including tubular leaf, opposite, whorled and supernumerary spikelets of barley and wheat and tubular leaf and cluster of oats.

To estimate the abnormalities, 10 x 10 ft lengths of drill were counted on each plot; this approximates to 250 ears per count where the stand was normal but on one trial centre (No. IV) straws were also counted as there was some difference in the plants. Here abnormalities were expressed as a proportion of the total ears.

Results

The results obtained from the weed counts showed that there was little significant difference between any of the treatments with possibly a slight tendency towards an improved weed control by MCPB and the later application with both herbicides. The control of Polygonum aviculare and Polygonum convolvulus was satisfactory in all cases, but Polygonum persicaria showed considerable regrowth possibly due to delayed germination.

In the majority of cases no progressive kill was noticed and the kill at the second estimation was not as good as the first (Table 1).

Abnormalities were very varied in their occurrence; practically the entire number were made up of "opposite spikelets" though occasionally "supernumerary spikelets" and "tubular leaves" occurred. However, there were far too few to form the basis of any assessment, certainly not more than two or three in any series of counts. The outstanding figure regarding distortions appears to have been with the wheat at Centre IV where more than 50% of the ears showed "opposite spikelets". At all other centres the number of distortions were much lower, no figure on barley exceeding 1 per quadrat (less than 0.5%), and oats only rising to 10 per quadrat (about 4%) at one centre.

Of the three crops wheat, barley and oats both treatments with MCPB produced slightly more abnormalities of wheat and barley than MCPA, whereas on oats the position was reversed. The mean of both early treatments showed more abnormalities were produced on wheat and oats than from the late treatments, but not significantly so, while on barley significantly more abnormalities were produced at the late application (Table 3), though the total was still very small.

Discussion

The number of tubular leaves, multiple and opposite spikelets/sub-plot were added to give the number of distortions/subplot, x. In all the trials except Centre IV, the new variable $y = \log (x + 1)$ was formed. At Centre IV the number of distortions/100 ears was taken for analysis. Analyses of variance were carried out on the variable y in the case of five trials and on the number of distortions/100 ears in the sixth case. When the analysis of variance indicated a significant difference between the treatment means the studentized range technique was employed for comparing the means.

When the estimates of weed control were analysed it was discovered that the five grade method of rating weed control was not particularly effective in this case, because it was not sufficiently sensitive to reveal any differences that might have existed between the four treatments under investigation. It was decided to use this method which has been put forward by American workers (5) as being most suitable for estimations where no clear-cut line can be expected between weeds killed and weeds not killed, but while this has failed to show any significant difference between treatments, it must be remembered that in fact very little difference could be observed at all in the field. Without doubt the dry weather which followed treatment affected weed control, and had there been ample rain no doubt there would have been more regrowth of some weeds which appeared to be adequately controlled.

It is suggested that the slightly improved weed control obtained by MCPB may be attributed to its greater residual toxicity in the soil in the cold dry spring; this would explain the better control of late germinating weeds. From Table 2 it can be seen that both the early treatments are less satisfactory than the late treatments.

Centre I
Barley

Treatment	Mean Number of Distortions/quadrat
MCPA Early	0.01
MCPB Early	0.11
MCPB Late	0.77
MCPA Late	0.83

Treatments bracketed together are not significantly different from one another. Groups are significantly different at the 1% level of probability.

There was evidence from Centre I that the barley which received MCPA or MCPB at the early stage contained fewer abnormalities per quadrat than that which received late stage applications.

There was evidence from the Centre III that the wheat to which MCPB at the late stage had been applied was freer from abnormalities than that which had received any of the other three treatments, viz. MCPA early, MCPA late, MCPB early.

Centre III
Wheat

Treatment	Mean Number of Distortions/quadrat
{ MCPB Late	0.66
{ MCPA Late	1.43
MCPA Early	1.62
MCPB Early	1.71

Treatments bracketed together are not significantly different from one another. Groups are significantly different at the 1% level of probability.

None of the other four trials yielded any significant differences between treatments.

The very high incidence of abnormalities at Centre IV is difficult to explain, and it is suggested that this may be due to a varietal susceptibility. It is interesting to note, however, that there was no significant differences between MCPA and MCPB applied at the same time. This is no doubt due to the very large area of bare soil which was presented at the time of spraying, even in the 3-4 leaf stage. The weeds were also little beyond the cotyledon stage, so that the ground covered by vegetation was extremely small. However, even at the highest rates of incidence of the abnormalities it is not anticipated that this would have been serious from the commercial point of view.

At the single centre where 50% abnormalities of wheat were observed, as the crop ripened the rachis appeared to fracture just below the opposite pairs of spikelets in a small number of cases, with the possible loss of the top of the ear. The number of ears where this did occur, however, were relatively few.

Conclusions

It would seem that early applications of 24 oz a.e. of MCPB or 5 oz a.e. of MCPA gave a comparable and satisfactory control of annual weeds during a dry spring and early summer and no significant differences were obtained between these compounds at the same time of application. It is suggested that the most satisfactory time for weed control would be at the 3-4 leaf stage under similar seasonal conditions.

Some abnormalities of cereals were produced by all treatments but in the case of oats and barley it is felt that any disadvantage accruing from the low incidence of abnormalities would be outweighed by the better control of difficult weeds obtained; the treatment only being recommended for such weed populations. In the case of wheat it appeared that a high incidence of abnormalities could occur under some conditions when the breaking of the rachis as the crop matures would lead to a considerable loss of crop.

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Table 1

Estimation of weed control (1 kill - 5 No Effect)

Centre		Polygonum aviculare		Polygonum convolvulus		Chenopodium album		Matricaria inodora		Chaerophyllum temulum		Stellaria media		Lamium spp.		Veronica spp.		Polygonum persicaria		Sinapis arvensis	
		(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)
I Barley	AE	3.7	4.0	4.2	4.3					2.5	4.5							3.4	4.3		
	AL	3.3	3.8	3.3	3.8					2.7	4.7							3.0	3.9		
	BE	3.2	4.0	3.8	4.1					3.0	4.5							3.4	4.3		
	BL	3.3	3.5	3.0	3.3					3.0	3.8							3.0	3.4		
II Barley	AE	2.2	2.3	3.2	2.4	2.8	2.8	3.2	2.4	2.5	2.8	3.0	3.8	2.7	2.7	2.7	2.7			2.0	3.0
	AL	2.5	2.3	2.5	2.5	2.3	2.5	3.5	3.2	2.2	3.0	2.8	3.7	2.7	3.0	2.3	2.8			2.2	2.0
	BE	2.8	2.3	3.2	2.3	2.7	2.3	3.2	3.2	3.2	3.3	2.8	3.7	2.7	2.3	2.8	2.3			3.2	3.2
	BL	1.8	2.0	2.0	2.5	2.3	2.2	3.0	2.8	3.0	3.3	3.0	3.6	2.3	2.6	2.7	2.5			3.0	3.5
III Wheat	AE	3.1	3.0	3.1	3.1	3.1	2.8	3.1	3.2												
	AL	2.6	2.9	2.8	2.8	2.8	3.0	2.6	3.3												
	BE	2.8	2.9	2.7	2.9	2.5	2.8	2.8	3.5												
	BL	2.8	3.0	2.8	2.7	2.3	2.6	2.7	3.2												
IV Wheat	AE	2.3	1.3	2.7				2.3	2.0				2.0								
	AL	2.7	1.3	2.7				3.0	2.2				2.0								
	BE	2.7	1.3	2.7				2.3	2.3				2.0								
	BL	2.3	1.3	2.7				3.0	2.0				2.0								
V Oats	AE		2.5		2.6	2.5	2.0														
	AL		3.0		2.3	2.0	2.1														
	BE		2.3		2.3	2.5	2.2														
	BL		3.0		2.3	3.5	2.1														
VI Oats	AE	3.7	3.6	2.8	3.4	2.9	3.1			2.8	3.0										
	AL	2.8	3.5	3.0	3.2	2.7	2.7			3.0	3.5										
	BE	3.2	3.1	2.8	2.7	3.1	3.1			3.3	3.5										
	BL	2.7	3.0	2.8	2.8	2.3	2.6			3.0	3.1										

(i) First estimation (ii) Second estimation

A = MCPA B = MCPB E = Early Application L = Late Application

Table 2

Mean of all estimates of weed control (1 kill - 5 no effect)

Centre	AE	AL	BE	BL
I Barley	3.86	3.56	3.79	3.29
II Barley	2.73	2.66	2.86	2.67
III Barley	3.31	2.85	2.86	2.67
IV Wheat	2.10	2.31	2.21	2.21
V Oats	2.62	2.38	2.36	2.82
VI Oats	3.18	3.12	3.08	2.83
Mean	2.96	2.81	2.86	2.76

A = MCPA B = MCPB E = Early Application L = Late application

Table 3

Mean of all quadrat counts of abnormalities

Crop	Barley		Wheat		Oats	
Centre	I	II	III	IV	V	VI
MCPA/Early	0.012	0.288	1.62	53.9 (134.75)	10.05	5.621
MCPA/Late	0.813	0.377	1.43	47.1 (117.75)	7.59	4.388
MCPB/Early	0.113	0.303	1.7	56.8 (142.0)	5.67	4.607
MCPB/Late	0.770	0.417	0.66	55.4 (138.5)	9.06	4.236

	Barley Mean	Wheat Mean	Cats Mean
Both Treatments Early	0.358	70.02	6.487
Both Treatments Late	0.594	64.58	6.318
Both Times MCPA	0.372	63.88	6.912
Both Times MCPB	0.400	70.71	5.893

THE EFFECT OF MCPB AND 2,4-DB ON CEREAL CROPS

PART I: Winter and Spring Wheat

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Summary

1. The results are reported of one experiment on winter wheat and five on spring wheat in which the direct effects of MCPB and 2,4-DB on the crops were investigated and compared with those of MCPA and 2,4-D.

2. When applied at 2 lb/ac to winter wheat between emergence and the seven leaf stage, MCPB produced rare tubular leaves and no head deformity, 2,4-DB caused appreciable numbers of both abnormalities. MCPB was almost non-toxic and 2,4-DB was slightly less toxic than MCPA and considerably less toxic than 2,4-D.

3. In the production of head deformity through early spraying of spring wheat, MCPB had little effect at rates up to 3 lb/ac, 2,4-DB caused up to 95% deformed heads at 1.5 lb/ac, but was slightly less toxic than MCPA. Differences in varietal susceptibility are discussed.

4. In two clean yield experiments, MCPB at 3 lb/ac and above did not significantly reduce yield. In one experiment 2,4-DB at 0.75 lb/ac and MCPA at 0.375 lb/ac caused significant reductions in yield when applied at the four leaf stage.

Introduction

An integral part of the developmental research on the phenoxybutyric acid herbicides MCPB and 2,4-DB is the investigation of their effects on the cereal crops commonly used in the United Kingdom. The potential use of these chemicals on cereals both alone and when undersown with legumes has necessitated detailed examinations of the growth, yield and grain quality that follows spraying.

The object of this series of experiments was first to compare MCPB and 2,4-DB with MCPA and 2,4-D, when applied to cereals between emergence and the six-leaf stage, in producing abnormalities of the head or panicle: secondly to ascertain the effects of MCPB and 2,4-DB on the yield of spring cereals in the absence of weed competition: and finally to measure any effects that the two chemicals might have on the quality of the grain. Owing to the late harvest and the short time available for writing this report, no information on grain quality has been included.

The ten experiments that are reported in detail were carried out in 1955 and 1956; these two seasons were characterised by abnormal weather. July and August 1955 were the driest and hottest for many years, and 1956 had a very dry spring followed by a very wet summer. Neither year was a good one for carrying out critical experiments on cereal yield.

Since the work of assessment and summary on the 1956 experiments has not been completed, this must be considered a progress report.

Details of experiments

Some of the details of the experiments are shown in Table No. 1.

H/1/55 Wytham - MCPA, MCPB, 2,4-D, 2,4-DB all at 1.5 and 3 lb/ac in 12 gal/ac were applied at four growth stages between emergence and the six leaf stage to Fylgia, Atle and Bersee Wheat; to Kenia, Proctor and Plumage Archer Barley; and to Sun II, Forward and S225 Oats. Three replicates; split plot randomised block design.

H/8/56 Wytham - MCPB, 2,4-DB and MCPA all at 2 and 4 lb/ac and MCPA at 2 lb/ac in 12 gal/ac were applied at four growth stages between emergence and the six leaf stage, to the same varieties as in H/1/55 (above.) Three replicates; split plot randomised block design.

H/42/55 Wytham - MCPB and 2,4-DB at 2 and 4 lb/ac, MCPA and 2,4-D at 2 lb/ac all in 100 gal/ac were applied to Capelle Winter Wheat at nine stages of growth from germination (pre-emergence) to the seven leaf stage. Spraying took place during autumn 1955, winter and spring 1956. Two replicates.

H/4/55 Wytham - MCPB, 2,4-DB, MCPA and 2,4-D all at 1, 4 and 8 lb/ac in 14 gal/ac were applied to spring wheat at the 2-3 leaf stage.

H/2/56 Halse - MCPB and 2,4-DB at 0.75, 1.5 and 3 lb/ac and MCPA at 0.375, 0.75 and 1.5 lb/ac were applied to clean spring wheat at the four leaf stage.

H/7/56 Wytham - MCPB and 2,4-DB at 4, 6, 9 and 13.5 lb/ac and MCPA at 2 lb/ac all in 82 gal/ac were applied to clean spring wheat at the three leaf stage. Four replicates; randomised block design.

H/5/55 Wytham - MCPA, MCPB, 2,4-D and 2,4-DB all at 1, 4 and 8 lb/ac in 14 gal/ac were applied to spring barley at the four leaf stage and lightly infested with weeds. Three replicates; randomised block design.

H/5/56 Bicester - MCPB and 2,4-DB at 1, 2 and 4 lb/ac and MCPA at 2 lb/ac were applied to clean spring barley at the 2-3 leaf stage.

H/6/56 Brackley - MCPB and 2,4-DB at 1, 2 and 4 lb/ac and MCPA at 0.5, 1 and 2 lb/ac were applied to clean spring barley at the 3 leaf stage.

H/4/56 King's Sutton - MCPB and 2,4-DB at 0.75, 1.5 and 3 lb/ac and MCPA at 0.375, 0.75 and 1.5 lb/ac were applied to spring oats at the 4-5 leaf stage.

Experiments number H/1/56, H/2/56, H/5/56, H/6/56 and H/4/56 were all of randomised block design and three replicates. They were all sprayed at 12 gal/ac.

Experiments number H/1/55 and H/8/56 were sprayed with an Oxford Precision Sprayer (1).

Experiment number H/42/55 was sprayed with a specially constructed compressed air manual sprayer.

Experiments number H/1/56, H/2/56, H/7/56, H/5/55, H/5/56, H/6/56 and H/4/56 were all sprayed with a Land Rover Sprayer (2).

Table 1
Details of experiments

Ex. No.	Location	Crops	Chemicals	Number of applications	Plot size	Assessments
H/1/55	Wytham, Berks	S.Wheat S.Barley S.Oats	MCPB, 2,4-DB MCPA, 2,4-D	4	6ft x 4 rows for each variety	Head abnormalities
H/8/56	Wytham, Berks	S.Wheat S.Barley S.Oats	MCPB, 2,4-DB MCPA	4	6ft x 4 rows for each variety	Head abnormalities
H/42/55	Wytham, Berks	S.Wheat	MCPB, 2,4-DB, MCPA, 2,4-D	9	6ft x 3ft	Growth and head abnormalities
H/4/55	Wytham, Berks	S.Wheat	MCPB, MCPA, 2,4-DB, 2,4-D	1	40yd x 4yd	Head abnormalities
H/2/56	Halse, Northants	S.Wheat	MCPB, 2,4-DB, MCPA	1	38yd x 8ft 6in	Yield
H/7/56	Wytham, Berks.	S.Wheat	MCPB, 2,4-DB, MCPA	1	40yd x 8ft 6in	Head abnormality and yield
H/5/55	Wytham, Berks	S.Barley	MCPB, 2,4-DB, MCPA, 2,4-D	1	40yd x 8ft 6in	Head abnormality and yield
H/5/56	Bicester, Oxon	S.Barley	MCPB, 2,4-DB, MCPA	1	40yd x 5yd	Head abnormalities
H/6/56	Brackley, Northants	S.Barley	MCPB, 2,4-DB, MCPA	1	40yd x 4yd	Yield
H/4/56	King's Sutton, Oxon	S.Oats	MCPB, 2,4-DB, MCPA	1	35yd x 10ft	Yield

Chemicals

MCPB and 2,4-DB were used as the sodium salts prepared from pure acid provided by May and Baker Limited. In the 1955 experiments a sodium salt of MCPA was used: in 1956 the potassium salt was substituted. In both years the triethanolamine salt of 2,4-D was applied.

In experiments H/1/55 and H/5/55 a 20% solution of Versine sodium salt at 5 ml/1 of spray solution was added to all chemicals to overcome difficulties encountered in dissolving the chemicals in the hard water of the Oxford mains. In all other experiments distilled water was used.

Assessments

The two main types of assessment that are reported were numerical counts of abnormal heads and grain yield. The normal method of assessing for abnormality has been described in detail elsewhere (3), briefly it consisted of pulling up (after head emergence) enough plants to give 100-200 heads per sample which were then individually inspected in the laboratory for abnormality or otherwise. The yield trials were arranged so that the farmer's combine harvester could make a single run down the centre of each plot; all the grain received in the bag being regarded as the yield from that plot.

Results

WINTER WHEAT

The single small plot experiment on winter wheat produced information on growth and head production, but not on yield. The first spraying took place on the 29th October, 1955, ten days before emergence, and was repeated on eight occasions during and after emergence throughout the winter until the 9th April, 1956 at which time the crop was at the seven leaf stage. Between the fifth and sixth sprayings (21st December, 1955 and 19th March, 1956) the foliage of the crop was badly scorched by frost and thereafter assessment of growth stage by counts of main stem leaves became difficult and subject to error.

During emergence it was observed that all the treatments at the first spraying had retarded emergence to some extent; the 2,4-DB plots were the least affected in this respect. However, these differences soon levelled out and the only visible effect after emergence was that the plants on the sprayed plots were a little twisted and the rows were untidy in appearance.

In the spring and summer of 1956 two qualitative effects were observed, these were tubular leaves and deformed heads. They were not all observed at the same time, nor did they result from the same times of application. Spraying up to the three leaf stage caused tubular leaves but not abnormal heads, and spraying thereafter caused deformed heads but no tubular leaves (see Figure 1).

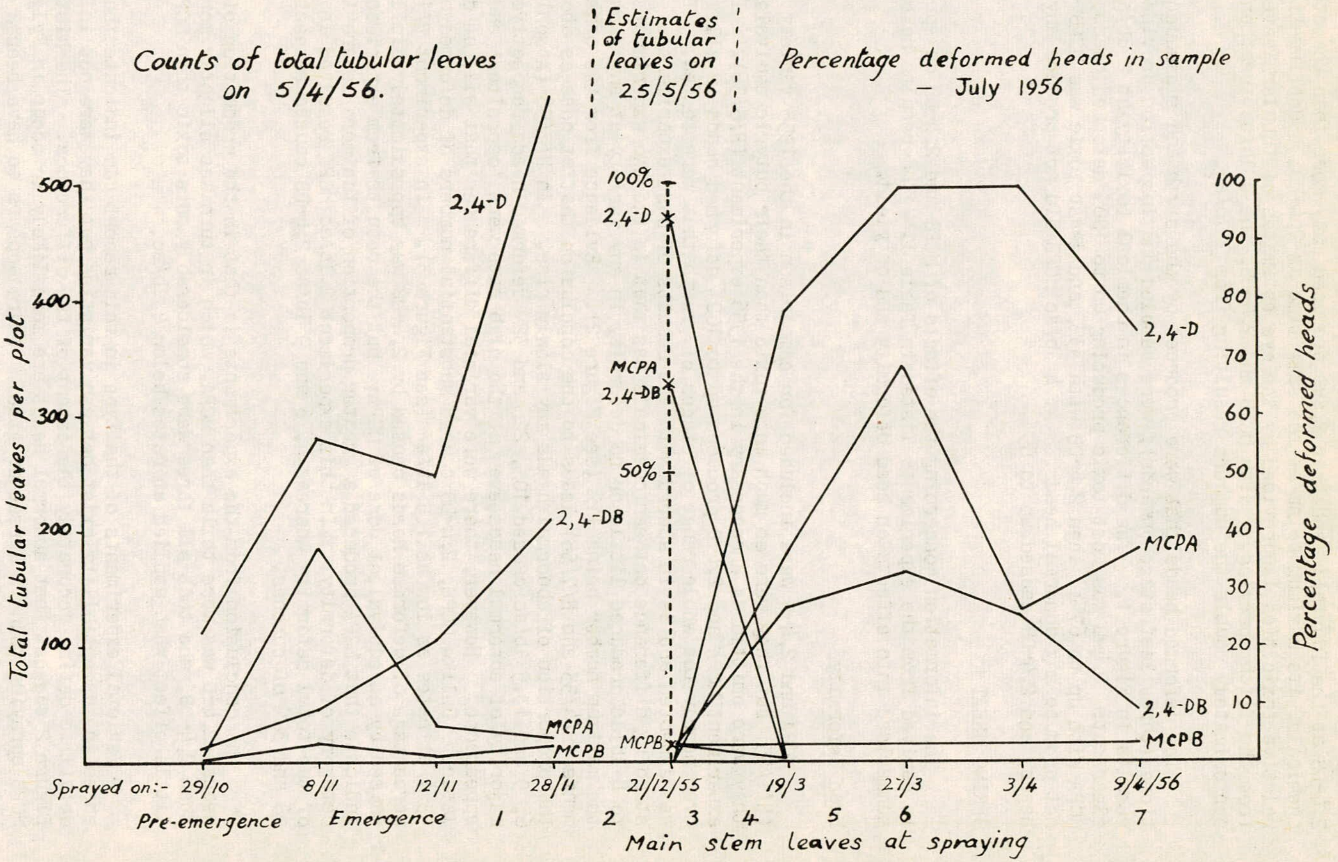
The tubular leaves did not all emerge simultaneously. Those from the first four applications were counted on 5th April, 1956 at which time the fifth application plots appeared normal: whereas six weeks later on 25th May only the fifth application plots contained tubular leaves. It will be seen from the counts on 5th April that at 2 lb/ac MCPB produced very few tubular leaves; that MCPA and 2,4-DB produced approximately equal maximum numbers but that they resulted from different times of spraying (MCPA at the second application,

(47011)

403

Figure 1. WINTER WHEAT. Experiment No. H/42/55

Graphs showing abnormal growth resulting from applications of 2 lb/ac i e of each chemical on nine different occasions. Means for each treatment.



2,4-DB at the fourth); and that 2,4-D produced many more than the other three chemicals, its maximum being at the same time as 2,4-DB. Confirmation of these relative toxicities is provided by the eye estimates of tubular leaves resulting from the fifth spraying. With MCPB and 2,4-DB, the 4 lb/ac treatments produced approximately double the numbers resulting from 2 lb/ac.

The deformed heads that were produced by the sixth and subsequent applications (three leaf stage onwards), were sampled and inspection provided the results in Figure 1. The differences in chemical toxicity at 2 lb/ac appear clear cut: 2,4-D was most toxic producing up to 100% deformed heads, next was MCPA with up to 67%; then 2,4-DB with 33%, and least toxic was MCPB which did not produce any abnormal heads. At 4 lb/ac MCPB did not produce any deformed heads, and 2,4-DB caused up to 89%.

SPRING WHEAT

The information concerning the effects of MCPB and 2,4-DB on spring wheat is derived from the experiments listed in Table 1. The results have been summarised into effects on head deformity and on yield.

Head Deformity

MCPA and 2,4-D were included for comparison in the 1955 variety experiment (H/1/55) but they were so much more toxic than their butyric equivalents that they were omitted as unnecessary in the 1956 experiment (H/8/56). In the 1955 experiment MCPA and 2,4-D produced up to 100% deformed heads in all varieties in over nearly the whole range of stages of growth that were tested. This result was expected and is in accord with the results of past experiments. The outstanding difference between chemicals was that in the two experiments MCPB at up to 4 lb/ac produced little or no deformity in any variety at any growth stage, the maximum number being 11% (see Figure 2). Evidence from two other experiments (H/4/55 and H/7/56) leads to the conclusion that at dosages above 4 lb/ac the proportion of abnormal heads may slowly rise. In H/7/56 (Atson) MCPB at 6, 9 and 13.5 lb/ac caused 10%, 22% and 32% deformed heads respectively. The majority of abnormal heads even at the high rate were 'opposites' and mild in appearance. However, there were varietal differences that will be discussed later. Unlike MCPB, 2,4-DB caused substantial numbers of deformed heads (up to 95%) at rates as low as 1.5 lb/ac (see Figure 3). In experiment H/1/55 the percentage of deformed heads caused by 2,4-DB was approximately similar to that caused by an equivalent dose of MCPA; but the results from experiment H/7/56 indicate that MCPA produced a greater proportion of the more severe 'bunched' category of deformity. In this experiment 2 lb/ac MCPA resulted in 26% bunches of the total deformity whereas 4, 6 and 9 lb/ac 2,4-DB caused respectively 8, 28 and 38% of bunches.

The conclusion from the experiments is that in the production of deformed heads, 2,4-D was more toxic than MCPA, which in turn was slightly more toxic than 2,4-DB, and that all three were considerably more toxic than MCPB which had little effect when applied at rates below 4 lb/ac.

Varietal experiments of the type in this report can indicate that differences in susceptibility exist between varieties but they were not in sufficient detail to define accurately the extent of the differences. The histograms in Figure 2 suggest that abnormal heads are more likely to occur in Fylgia after MCPB spraying than in Bersee or Atle. There appears to have been a difference between varieties in the leaf stage at which they became resistant to 2,4-DB.

Figure 2. SPRING WHEAT Experiments Nos. H/1/55 and H/8/56

Deformed heads as a mean percentage of total heads resulting from applications of MCPB

X denotes stage of growth at which application occurred

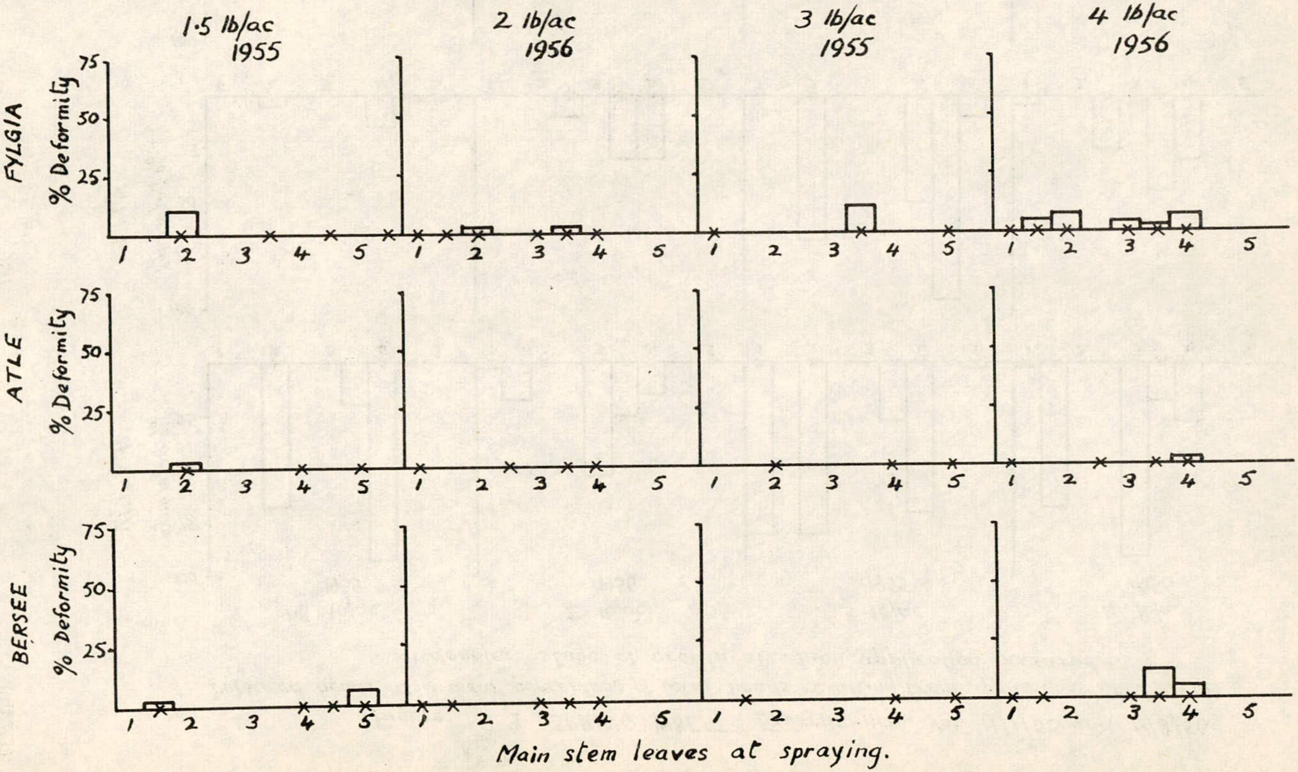


Figure 3 SPRING WHEAT Experiments Nos. H/1/55 and H/8/56

Deformed heads as a mean percentage of total heads resulting from applications of 2,4-DB

x denotes stage of growth at which application occurred

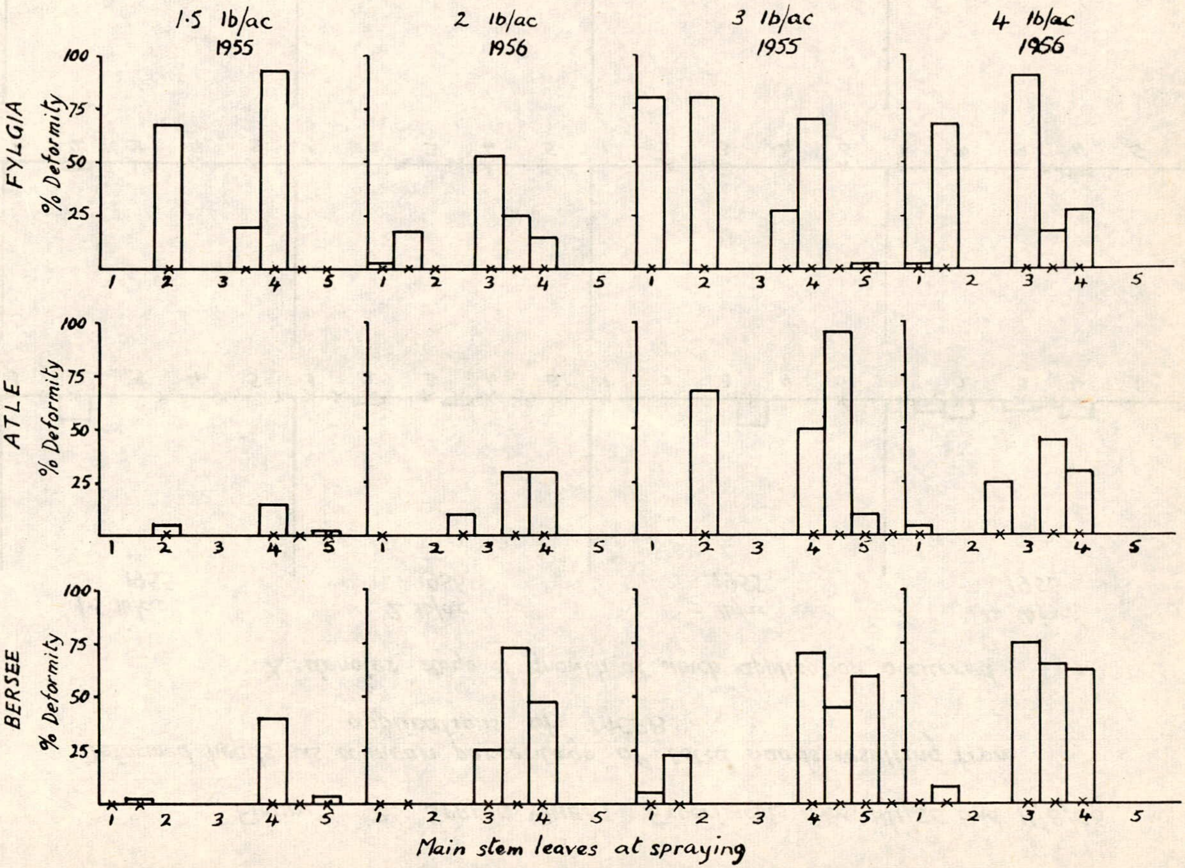


Table 2

% deformity resulting from application of 3 lb/ac 2,4-DB

Ex. No. H/1/55

	Main Stem Leaves			
	4	4.5	5	5.5
Fylgia	71	1	0	
Atle	49	95	9	0
Bersee	70	44	59	0

[a half leaf is a term used to describe one that has emerged but is not yet unrolled]

The results of applying 2 and 4 lb/ac 2,4-DB in experiment H/8/56 support the figures in Table 2.

Yield of Grain

Information concerning the effects of MCPB and 2,4-DB on grain yield has been derived from two experiments: H/2/56 at Halse allowed a comparison of the two chemicals at dosages likely to be used in practice, while H/7/56 at Wytham was designed to investigate the effects of large overdoses. Both fields were clean and healthy; at spraying the wheat at Halse was in the 4 leaf stage and at Wytham it was in the three leaf stage. The mean yields in each experiment are shown in Table 3.

Table 3

Spring Wheat

Mean yields in cwt/ac

Ex. No. H/2/56 Halse

	application lb/ac - four leaf stage			
	0.375	0.75	1.5	3
MCPB	-	35.4	35.5	34.8
2,4-DB	-	33.7	33.2	31.8
MCPA	32.8	30.0	29.1	
Control yield = 35.1				

S.E. per cent of mean = 1.6%. S.D. between two treatments = 1.5.
S.D. between a treatment and control = 1.3. P = 0.05.

Ex. No. H/7/56 application lb/ac - three leaf stage

	2	4	6	9	13.5
MCPB	-	29.3	31.9	30.1	31.3
2,4-DB	-	31.5	24.8	26.4	29.7
MCPA	29.9	-	-	-	-
	Control yield = 32.4				

S.E. per cent of mean = 6.6%. S.D. between treatments = 5.8.
S.D. between a treatment and control = 5.0. P = 0.05.

Although it is apparent from the standard errors that the experiment at Halse was more accurate than that at Wytham, nevertheless the latter was reliable.

The results of the Halse experiment may be summed up in a few words: all dosages up to 3 lb/ac of MCPB did not cause significant reduction in yield, while all dosages of 2,4-DB and MCPA (as low as 0.75 to 0.375 lb/ac respectively) caused significant reduction in yield (P = 0.05). With 2,4-DB and MCPA increased dose significantly decreased yield, whereas with MCPB it did not do so. At 0.75 and 1.5 lb/ac, the two comparable treatments of 2,4-DB and MCPA, MCPA reduced yield significantly more than did 2,4-DB.

The Wytham experiment is less easy to interpret because of the confusing factor of scorch after spraying. It had been hoped that the use of a high volume rate would prevent scorch, but this was not the case. The 13.5 lb/ac treatments of MCPB and 2,4-DB caused substantial scorch soon after spraying and to a lesser degree so did the 9 lb/ac treatments. It is probable that uptake of chemical was to some extent reduced on these plots, and it follows therefore that the results of the 4 and 6 lb/ac treatments reflect more accurately the systemic effect of the chemicals. With MCPB no treatment significantly reduced yield below control and there is no indication that increased dose decreased yield. 4 lb/ac 2,4-DB resulted in a yield not significantly below control, but 6 lb/ac significantly reduced yield below both control and that caused by 4 lb/ac. Thereafter with increased dose the yield tended to increase slightly, an effect that may have resulted from reduced uptake due to scorch. The single check application of 2 lb/ac MCPA did not cause any significant effect on yield.

Research Report No. C.11

THE EFFECT OF MCPB AND 2,4-DB ON CEREAL CROPS

Part II. Spring Barley and Spring Oats.

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Summary

1. The results are reported of five experiments on spring barley and three experiments on spring oats.

2. In two experiments, applications at the 3 and 4 leaf stages of up to 4 lb/ac of MCPB or 2,4-DB did not cause significant yield reduction in comparatively clean barley. At 2 lb/ac neither MCPB nor 2,4-DB produced deformed heads; at rates between 2 and 4 lb/ac 2,4-DB caused a small proportion of deformed heads but MCPB did not.

3. In a yield trial on clean spring oats at the four leaf stage; applications up to 3 lb/ac of MCPB or 2,4-DB did not cause significant reduction in yield. Two experiments on the production of abnormal panicles revealed varietal differences in susceptibility to MCPB and 2,4-DB. In general, MCPB was less toxic than 2,4-DB and MCPA, which showed approximately equal toxicity.

SPRING BARLEY

Information concerning the production of abnormal heads was derived from two small plot variety trials (H/1/55 and H/8/56) and from two large plot harvest trials (H/5/55 and H/5/56). Yield results were obtained from two experiments (H/5/55 and H/6/56).

Head deformity

The treatments, lay outs and locations of the experiments mentioned above may be seen in the details of experiments in Part I of this report. Space does not permit the inclusion of all the results, but the more important conclusions may be summed up as follows.

MCPB did not produce deformed heads at any rate of application at any growth stage between emergence and the seventh leaf stage.

When applied below 2 lb/ac, 2,4-DB did not produce deformed heads: between 2 and 4 lb/ac occasional 'opposites' were observed but they were mild in appearance and usually less than 10% of the total heads. At 4 lb/ac applied at the two leaf stage, 2,4-DB caused 10-20% deformed heads in all three varieties in experiment No. H/8/56.

Direct comparisons between 'butyrics' and 'acetics' were possible in two experiments. In H/1/55, 2,4-D and MCPA at 3 lb/ac caused up to 80% and 50% deformed heads respectively: at the same rate MCPB and 2,4-DB caused negligible numbers. This substantial difference in toxicity is confirmed by the Proctor at the four leaf stage in experiment No. H/5/55, in which 1 lb/ac MCPA caused greater numbers of deformed heads than 8 lb/ac 2,4-DB.

The very small numbers of deformed heads were insufficient to give any reliable indication of varietal susceptibility to MCPB and 2,4-DB.

Yield

The yield results from two experiments are shown in Table 1. Neither experiment was completely free of weeds. There were occasional plants of knotgrass (Polygonum aviculare) in H/6/56, and some thistle (Cirsium arvense) and cleavers (Galium aparine) in H/5/55; but they were not present in sufficient numbers to effect the yield of barley.

Table 1

Spring Barley

Yields at harvest in cwt/ac. Means for each treatment.

Experiment No. H/6/56 - 3 leaf stage.

	Application lb/ac				
	0.5	1	2	4	
MCPB		21.6	19.0	19.2	Control mean
2,4-DB		20.9	20.2	19.5	= 19.3
MCPA	19.6	19.4	17.4		

S.E. % of mean = 4.1% P = 0.05: SD between 2 treatments = 2.4
SD between a treatment and control = 1.9

Experiment No. H/5/55 - 4 leaf stage.

	Application lb/ac			
	1	4	8	
MCPB	35.2	35.9	35.2	Control mean
2,4-DB	34.2	32.8	32.2	
MCPA	31.5	30.5	30.9	= 33.9
2,4-D	29.8	27.0	27.0	

SE % of mean = 2.6% P = 0.05 SD between two treatments = 1.6
SD between a treatment and control = 1.3

Both the barley crops reacted to 2,4-D and MCPA in a manner that had been expected, taking into account the earliness of the applications: all applications of both chemicals in No. H/5/55 and the top rate of MCPA (2 lb/ac) in No. H/6/56 caused significant reductions in yield.

Of the four chemicals, MCPB was the least toxic; applications up to 8 lb/ac did not cause any significant reduction in yield. At the other end of the scale, 2,4-D was the most toxic, applications at 1 lb/ac (No. H/5/55) caused a yield significantly below that of control and the 1 lb treatment of the other three chemicals.

Between these two extremes of toxicity were 2,4-DB and MCPA. Of the two, 2,4-DB was less toxic; in experiment H/5/55 applications up to 4 lb/ac did not cause significant reduction in yield from control but 8 lb/ac did so. MCPA caused yields significantly below those of 2,4-DB at 2 lb/ac in H/6/56 and at 1 and 4 lb/ac in H/5/55.

SRRING OATS

Information is available from three experiments. Panicle deformities were measured in the two variety experiments (H/1/55 and H/8/56), and yield results were obtained from experiment No. H/4/56.

Panicle deformity

Both 'butyrics' and 'acetics' were included in experiment No. H/1/55 and their average relative toxicity to the three varieties, S.225, Forward and Sun II, as measured by percentage of abnormal panicles resulting from a dose of 3 lb/ac was in the proportions - MCPB-12:MCPA-31: 2,4-DB-43:2,4-D -87.

It would, however, be unwise to pay too much attention to differences between the chemicals that are based on a single dose. These experiments have shown that the dose-response curve for MCPB and 2,4-DB is very flat and that an increase in dose from 1.5 to 4 lb/ac usually resulted in negligible increase in the percentage of deformed panicles (see Figures 1 and 2). Past experience has shown that with 2,4-D and, to a lesser extent, MCPA increasing the dose appreciably increases the percentage of deformed heads. In consequence the relative toxicities of these two groups of chemicals may be expected to vary with the dose of chemicals applied.

In addition, as can be seen from Figures Nos. 1 and 2, there were very marked varietal differences in reaction to MCPB and 2,4-DB. Similar effects of 2,4-D and MCPA observed in experiment No. H/1/55 have established the greater susceptibility of the variety Forward to both 'acetics' and 'butyrics'. This varietal difference is often larger than the differences between doses or chemicals, and in consequence results based on one variety or means of several varieties must be interpreted with caution in generalisations about spring oats.

Yield

Yield information is available from one experiment, No. H/4/56. The oats, which were at the four leaf stage at spraying, were clean but partially lodged at harvest. However, the amount of grain visible in the stubble after cutting indicated that the effect was not severe enough to affect yield.

(47011)

412

Figure 1. SPRING OATS Experiments H/1/55 and H/8/56

Deformed heads as a mean percentage of total heads resulting from applications of MCP3

X denotes stage of growth at which applications occurred

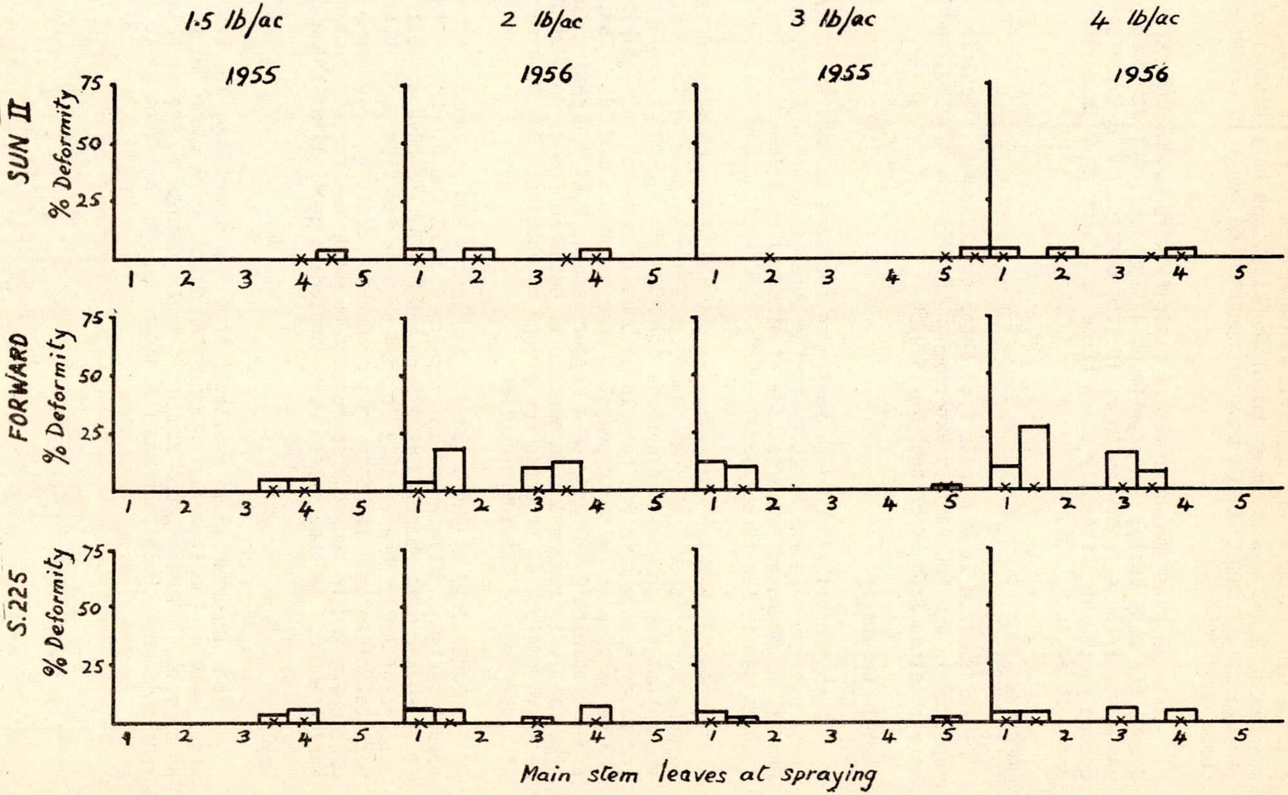

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Figure 2. SPRING OATS Experiments H/1/55 and H/8/56

Deformed heads as a mean percentage of total heads resulting from applications of 2,4-DB

x denotes stage of growth at which applications occurred

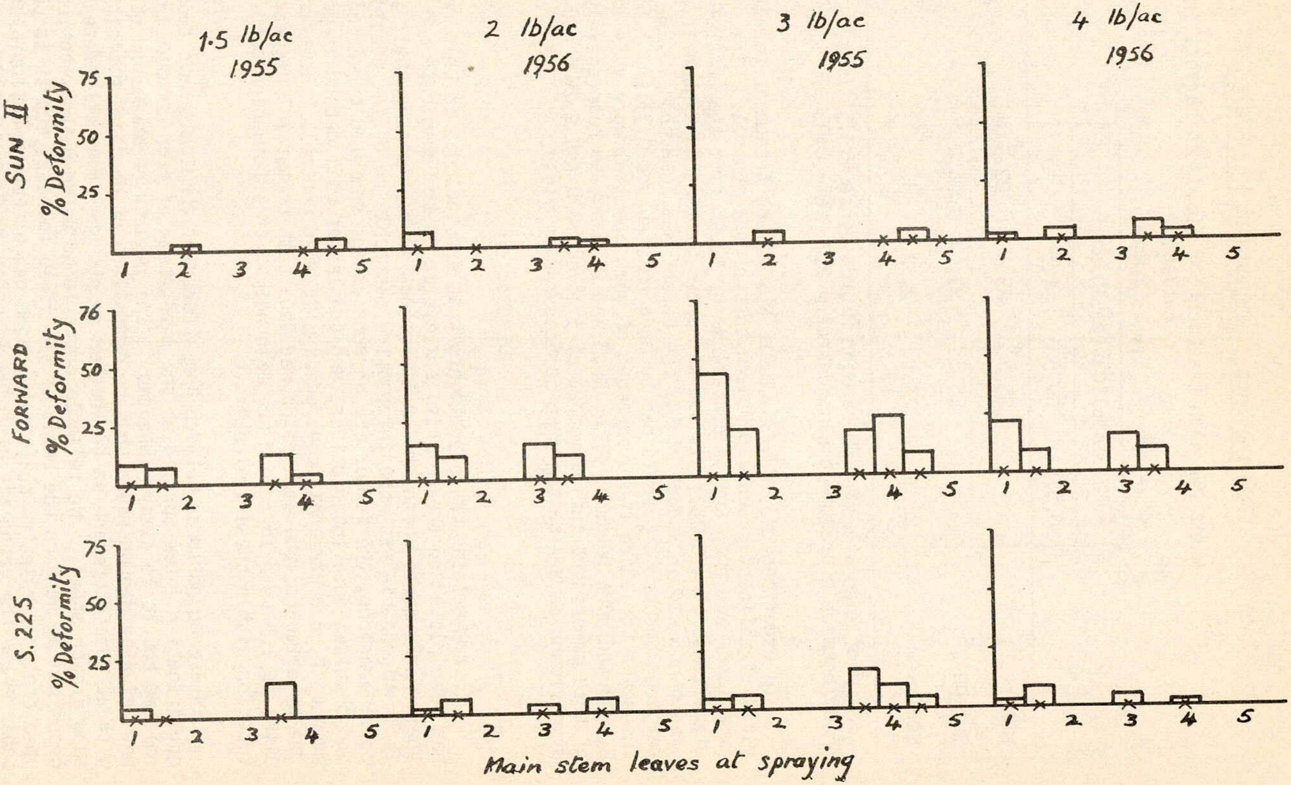

Table 2

Spring oats. Experiment No. H/4/56

Means for each treatment. Yields at harvest in cwt/ac.

	Application lb/ac				
	0.375	0.75	1.5	3	
MCPB		25.6	25.3	27.5	Control yield
2,4-DB		25.3	27.4	24.4	= 26.4
MCPA	26.4	25.1	24.2		

SE % of mean = 4.3% SD between 2 treatments = 3.3
SD between a treatment and control = 2.7 P = 0.05

In experiment No. H/4/56 (Table No. 2), no treatment resulted in a mean yield significantly above or below that of the control. The accuracy of the experiment was such that a difference of 10.2% from the control would have been significant (P = 0.05); it can therefore be concluded that if any of the treatments did influence yield, the effect was less than 10.2%. Direct comparisons between chemicals can be made only at the 0.75 and 1.5 lb/ac levels: the means for these two treatments of each chemical were very similar; MCPB, 2,4-DB and MCPA produced 25.4, 26.3 and 24.6 cwt/ac respectively. The results of this experiment indicate that at 3 lb/ac MCPB and 2,4-DB did not cause significant damage to the crop as measured by yield.

Discussion

In summarising the experiments that are included in this report, emphasis has been placed on the relative toxicities of the chemicals and the aspects of their performance which are of importance in considering their commercial use. It is impossible with the information available to define precisely these two considerations, the former are to some extent confused by varietal differences and chemical dose interactions, and the latter will depend largely upon the amount of each chemical required to give weed control. However, in planning the experiments, the assumption was made that commercial use would be at the level of 1.5 to 3 lb/ac and the main weight of information concerns crop reaction within these limits.

Where comparisons between the effects of chemicals have been made, the qualification 'when applied at the same stage of crop growth' is sometimes omitted but it is always intended. The results of these and other experiments have clearly demonstrated that no comparison of chemical toxicity can be valid without some statement as to whether or not the treatments were applied at the same growth stage. No reliable comparisons between the reactions of different crops can be made on the basis of the yield results, but it is possible to draw up a table of relative toxicities based on percentage deformities. In the table below the crops are arranged in order of susceptibility to each chemical. The comparisons are of necessity rough because they do not take into account varietal or dose-response differences.

Table of relative susceptibilities

Order of Toxicity	Crop:-			
	Winter Wheat	Spring Wheat	Spring Barley	Spring Oats
Most toxic	2,4-D	2,4-D	2,4-D	2,4-D
Intermediate (more toxic)	MCPA	MCPA	MCPA	2,4-DB /MCPA
Intermediate (less toxic)	2,4-DB	2,4-DB		
Least toxic	MCPB	MCPB	2,4-DB /MCPB	MCPB
	Chemical:-			
	2,4-D	MCPA	2,4-DB	MCPB
Most susceptible	Wheat	Wheat	Wheat	Oats
Intermediate	Oats	Barley	Oats	
Least susceptible	Barley	Oats	Barley	Wheat /Barley

The order in which the crops have been placed refers to their susceptibility before the six leaf stage of growth and does not have any bearing on the commercial use of 2,4-D and MCPA on spring wheat and barley.

Acknowledgements

The A.R.C. Unit is indebted to the N.A.A.S. officers who obtain the sites, and to the farmers who willingly lent their fields and combines for the experiments.

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THE RELATIVE TOXICITY OF MCPB, 2,4-DB AND MCPA TO CEREALS

K. Carpenter and C. Wilson, May & Baker Ltd.

Summary

The results of fifteen experiments are given in which the effect of MCPA and MCPB were compared on growth stages just prior to those normally recommended for 2,4-D and MCPA treatments. All but two of these experiments also included 2,4-DB. These show that at these growth stages:-

1. MCPB has no appreciable effect on cereal yield or ear distortion at doses up to 8 lb/ac.

2. MCPB is less toxic than MCPA in oats, wheat and barley, the difference being least in oats and greatest in barley, whether measured by yield or ear distortion.

3. 2,4-DB is intermediate in toxicity, showing a similar effect to MCPA on spring oats, somewhat less than MCPA on spring wheat and a similar effect to MCPB on spring barley.

4. It is suggested that MCPB and 2,4-DB could be particularly useful for the early treatment of Spring Barley intended for malting purposes.

Introduction

When a series of field experiments was designed in 1955 to test the toxicity of phenoxybutyric acids to cereals, it was decided to include a number of sites where the cereals were treated prior to the growth stages usually considered safe for spraying with phenoxyacetic acids. The main purpose of these experiments was to evaluate MCPB and 2,4-DB for the control of weeds in undersown cereals and all were therefore infested with weeds. The results of these experiments form the major part of this research report. When it was seen that the phenoxybutyric acids has a much lower toxicity to cereals at these early growth stages than their corresponding phenoxyacetic acids, a further series of experiments was planned for 1956 to examine this in more detail.

As our experimental crops are threshed after cutting, the late harvest has so delayed this series that only a fraction of the results are ready for inclusion in this report.

Experimental Methods and Results

1. Materials.

MCPB was used throughout in the form of a commercial preparation of a sodium salt. MCPA was used chiefly as a commercial preparation of the potassium salt. 2,4-DB was used as a solution of the sodium salt of about 98% purity.

2. Application Methods.

All materials were applied through our motorised plot sprayer at 15 gal/ac of water. The 1955 experiments (series 71) were laid down in commercial crops, the plots being 25 ft long and 4 ft 6 in. wide. The 1956 experiments (series 86) were laid down in specially sown strips in different varieties which were either 13 or 7 rows wide. The individual treatment variety plots were therefore 7 or 13 rows long and 4 ft 6 in. wide. Four replicates were used throughout.

3. Method of Assessment.

In the experiments of series 71 the cereal yields were assessed from two sub-samples per plot each of 6 ft x 4 rows of cereal. In the experiments of series 86 the whole plot, less discards, was cut.

Ear distortions were assessed at harvest by taking sub-samples of 50 ears from each yield sample.

Table 1

Effect on yield of spring oats

Expt. No.	Variety	Number of leaves at spraying	Weed no. per sq.yd.	Compound	Grain yield as % control Dose in lb/ac				
					0.75	1	1.5	2	3
71/10	Blenda	2	66	MCPB	-	112	127	98	109
				2,4-DB	-	96	118	109	107
				MCPA	128	105	121	106	-
71/11	Blenda	5	62	MCPB	-	108	107	104	106
				2,4-DB	-	93	87	88	79
				MCPA	117	101	94	88	-
71/14	Blenda	4-5	30	MCPB	-	98	97	81	96
				2,4-DB	-	104	92	105	91
				MCPA	93	85	106	91	-
71/12	S.225	4-5	95	MCPB	-	109	114	107	100
				2,4-DB	-	101	108	103	92
				MCPA	110	110	98	106	-
71/3	Black Supreme	2	76	MCPB	-	99	92	101	113
				2,4-DB	-	96	104	89	102
				MCPA	-	96	88	105	101
71/18	Sun II	4	60	MCPB	-	105	91	111	95
				2,4-DB	-	83	87	95	85
				MCPA	93	91	91	86	-

Table 2

Effect on yield of spring wheat

Expt. No.	Variety	Number of leaves at spraying	Number of weeds per sq.yd.	Compound	Grain yield as % control. Dose in lb/ac.								
					0.5	0.75	1	1.5	2	3	4	6	8
71/1	Atle	6-7	131	MCPB	-	-	-	110	104	111	112	-	-
				2,4-DB	-	-	-	93	107	96	100	-	-
				MCPA	-	-	-	112	110	107	112	-	-
71/9	Atle	4	39	MCPB	-	-	99	94	106	108	-	-	-
				2,4-DB	-	-	97	91	104	103	-	-	-
				MCPA	-	-	106	110	115	106	-	-	-
71/13	Atle	4-5	148	MCPB	-	-	112	110	79	118	-	-	-
				2,4-DB	-	-	103	107	95	98	-	-	-
				MCPA	-	-	113	95	92	101	-	-	-
71/26	Atle	5	75	MCPB	-	-	119	119	122	121	-	-	-
				2,4-DB	-	-	119	117	107	117	-	-	-
				MCPA	-	120	133	112	125	-	-	-	-
86/1	Atle	3-4	slight	MCPB	-	-	96	-	103	-	98	93	100
				MCPA	109	-	112	-	97	84	90	-	-
	Bersee	3-4	slight	MCPB	-	-	113	-	109	-	102	104	97
				MCPA	97	-	105	-	108	100	98	-	-
	Fylgia	3-4	slight	MCPB	-	-	106	-	101	-	92	99	105
				MCPA	96	-	94	-	95	92	82	-	-
	Koga II	3-4	slight	MCPB	-	-	102	-	95	-	95	103	92
				MCPA	97	-	99	-	105	95	93	-	-

Table 3

Effect on ear distortion in spring wheat

Expt. No.	Variety	Number of leaves at spraying	Compound	% of distorted ears. Dose in lb/ac								
				0.5	0.75	1	1.5	2	3	4	6	8
71/1	Atle	6-7	MCPB	-	-	-	3	9	1	2	-	-
			2,4-DB	-	-	-	9	2	0	3	-	-
			MCPA	-	-	-	2	2	6	8	-	-
71/9	Atle	4	MCPB	-	-	1	3	2	0	-	-	-
			2,4-DB	-	-	7	15	10	17	-	-	-
			MCPA	-	-	9	18	18	38	-	-	-
71/13	Atle	4-5	MCPB	-	-	0	2	5	4	-	-	-
			2,4-DB	-	-	6	7	7	14	-	-	-
			MCPA	-	7	10	15	20	-	-	-	-
71/26	Atle	5	MCPB	-	-	5	6	5	5	-	-	-
			2,4-DB	-	-	6	6	4	8	-	-	-
			MCPA	7	9	5	4	-	-	-	-	-
86/1	Atle	3-4	MCPB	-	-	0	-	0	-	4	1	8
			MCPA	1	-	6	-	9	8	22	-	-
	Bersee	No count made										
	Fylgia	3-4	MCPB	-	-	1	-	0	-	1	2	4
			MCPA	3	-	7	-	13	21	42	-	-
	Koga II	3-4	MCPB	-	-	5	-	2	-	4	8	21
			MCPA	2	-	1	-	6	9	18	-	-

Table 4

Effect on yield of spring barley, 1955

Expt. No.	Variety	Number of leaves at spraying	Number of weeds per sq.yd.	Compound	Grain yield as % control Dose in lb/ac				
					0.75	1	1.5	2	3
71/4	Earl	4-5	None	MCPB	-	95	113	84	117
				2,4-DB	-	95	104	92	106
				MCPA	-	88	90	87	91
71/19	Proctor	2	Slight	MCPB	-	117	94	104	106
				2,4-DB	-	96	95	98	96
				MCPA	98	107	87	82	-
71/20	Proctor	4	74	MCPB	-	113	123	113	122
				2,4-DB	-	109	108	113	116
				MCPA	108	113	112	103	-

Table 5

Effect on ear distortion in spring barley

Expt. No.	Variety	Number of leaves at spraying	Compound	Percentage of distorted ears Dose in lb/ac							
				0.75	1	1.5	2	3	4	6	8
71/4	Earl	4	MCPB	-	0	0	0	0	-	-	-
			2,4-DB	-	0	0	4	0	-	-	-
			MCPA	-	5	2	3	8	-	-	-
71/19	Proctor	2	MCPB	-	0	0	5	0	-	-	-
			2,4-DB	-	8	10	10	21	-	-	-
			MCPA	26	35	45	42	-	-	-	-
71/20	Proctor	4	MCPB	-	2	5	0	0	-	-	-
			2,4-DB	-	0	1	0	2	-	-	-
			MCPA	16	17	23	36	-	-	-	-
86/2	Herta	1-2	MCPB	-	0	-	0	-	1	1	1
			MCPA	-	3	-	2	9	-	27	-
		4	MCPB	-	0	-	0	-	0	0	0
			MCPA	-	1	-	0	1	-	0	-
		7	MCPB	-	0	-	0	-	0	0	1
			MCPA	-	0	-	0	1	-	0	-

Discussion and Conclusions

Growth Stages Studied

In practice it is found that, for several reasons, a very large proportion of cereal spraying could be carried out more conveniently, just prior to the 5-6 leaf stage normally recommended for 2,4-D and MCPA treatment. Obviously, where a substantial acreage is to be covered, an earlier start is desirable, especially as many of the weeds are in the most suitable stage for control at this time. Experience has shown that more consistent weed control is usually obtained, with either MCPA or MCPB, at the 3-4 leaf stage, rather than earlier, although the reasons for this are still obscure. Moreover, the cereal itself is less liable to permanent injury by tractor wheelings.

Where the cereal is undersown at or near its own drilling time, the clover will also usually reach a suitable stage for treatment with MCPB at the 3-4 leaf stage of the cereal. Most of these experiments are therefore concerned with the three, four and five leaf stages.

Spring Oats. (Table I).

Yields only were taken. None of the results for the 1956 series is yet complete, but 1955 yields clearly show that MCPB is much less toxic than either MCPA or 2,4-DB at the same dose. On balance, 2,4-DB is very slightly more toxic than MCPA.

In no case could the difference between MCPA and MCPB be considered significant at equivalent rates for general weed control. At very high rates of MCPB, i.e. 6 and 8 lb/ac, a weakening of the straw has been observed in some experiments.

Spring Wheat. (Tables 2 and 3)

There are no significant reductions in yield in any of these experiments, neither is there any consistent difference in response to weed reduction, except possibly in 71/9, where *Raphanus raphanistrum* was the chief species.

Judged on a basis of ear distortion, the relative descending order of toxicity is MCPA, 2,4-DB, MCPB. The equitoxic dose ratio between 2,4-DB and MCPA appears to be about 2:1; the MCPB/MCPA ratio cannot be measured from these data, but must be at least 8:1.

Spring Barley. (Tables 4 and 5)

On a yield basis, the descending order of toxicity is MCPA, 2,4-DB and MCPB. In barley, 2,4-DB appears to be much closer in toxicity to MCPB than to MCPA. This relationship is shown even more clearly by the ear distortion counts (Table 5). In the two crops of Proctor, MCPA produced very severe ear distortion, even at 0.75 and 1 lb/ac.

General

In general much less distortion was observed in 1956 as compared with 1955. Scoring for distortion at an early stage in some of the 1956 crops, for which final counts are not yet available, confirm this.

MCPA has been fairly well tolerated in these experiments by spring wheat at 1 lb/ac applied at the 3-4 leaf stage, but the information on earlier stages is not yet ready. Severe distortions have occurred in spring barley, at this and lower doses, and the difference between the toxicity of MCPA on the one hand, and 2,4-DB and MCPB on the other, is greater in this crop. On the whole the probability of spring barley being sprayed in the early stages is greater, at least in the eastern counties, than for the other two cereals. Moreover, ear distortions are more serious commercially in spring barley. Not only are they the cause of some loss of yield from breakage on harvesting, but they are often associated with reduction in acceptability for malting.

The low toxicity of MCPB and 2,4-DB appears to offer a particular advantage in the early treatment of appropriate weed problems in this crop, apart from permitting the time of treatment of undersown cereals to be related to the most suitable stages of weeds and clover.

A CONTRIBUTION TO THE QUESTION OF THE EFFECT OF 2,4-DB AND MCPB ON THE YIELD OF CEREALS IN DIFFERENT DEVELOPMENT STAGES

C. Baker and R. K. Pfeiffer
Chesterford Park Research Station
Fison's Pest Control Ltd.

Summary

1. The results of two yield experiments, one on barley and one on spring wheat are presented. In these experiments 2,4-DB and MCPB were compared with 2,4-D and MCPA sprayed at two dosage levels and at two development stages of the crops. Figures for the percentage of deformed ears are also presented.

2. At dosage ratios giving a similar degree of weed control, 2,4-D was the most toxic compound to both cereals, giving a significant yield depression when sprayed at early development stages. MCPA and 2,4-DB were safer (more selective) than 2,4-D and MCPB was on average safer still.

3. When sprayed after tillering none of the compounds affected the yield of barley or wheat significantly.

4. 2,4-D sprayed early produced by far the highest number of deformed ears, followed by MCPA, 2,4-DB and MCPB. Some correlation between yields and percentage deformities is indicated by the results.

Introduction

The experiments reported in this paper were designed to give additional information to that obtained by the A.R.C. Unit at Oxford in 1955 on this issue. Only two experiments were carried out, and for this reason no attempt is made to generalize or to interpret the results, but as few yield tests with these materials have yet been reported by other workers it was considered desirable to present the results of these two trials.

The yield and percentage ear deformity figures are given in the attached histograms which are self-explanatory.

Materials and methods

Materials. Commercial formulations of MCPA (sodium/potassium salt), 2,4-D (amine) and MCPB (sodium salt) were used. 2,4-DB was used as 95% pure sodium salt.

Layout. 8 replications of each treatment were sprayed on plots of 15 sq.yd each in randomized blocks.

Treatments:

	Higher Dosage (lb/ac a.e.)	Lower Dosage (lb/ac a.e.)
2,4-D	1.5	0.75
MCPA	1.5	0.75
2,4-DB	3.0	1.5
MCPB	3.0	1.5

The butyrics were used at twice the rate of the acetics because higher rates of butyrics, in this ratio for many species, are required to obtain equivalent weed control.

Stage of growth

All treatments were carried out at 2 growth stages, the first when the crop had 2.5-3 leaves, the second when it was 16-18 in. high.

Barley (Variety Earl) was sprayed 19/4 and 24/5

Wheat (Variety Koga II) was sprayed 4/5 and 6/6

Amount of weed present

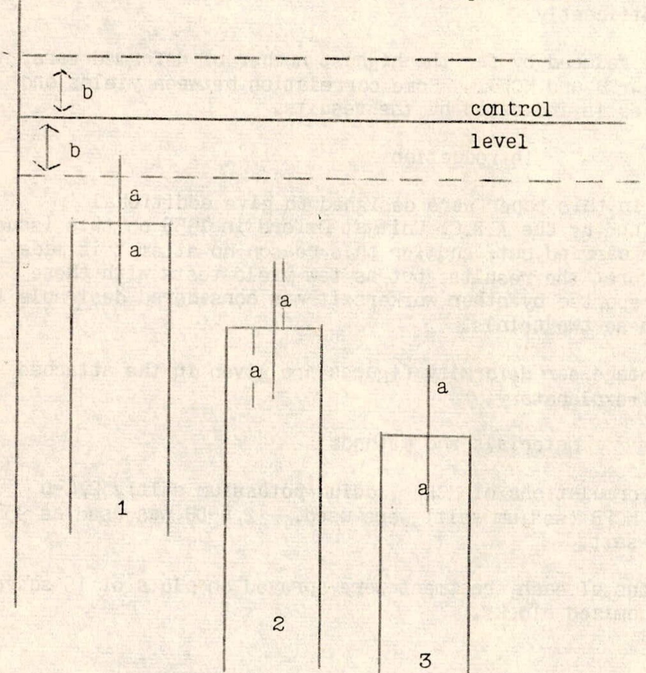
Although the crops were not clean, the weed present was not of a type to seriously affect yield, so that yield increases were not obtained by spraying.

Yield level

The mean yield of untreated controls on wheat was 20 cwt/ac and on barley 23 cwt/ac.

Explanation of method of showing significant differences

The results of statistical analysis are incorporated diagrammatically in the histograms for convenience of interpretation.



Thus in the example shown in Fig.1:

a = ½ significant difference at P = 0.05 for treatments

b = ½ significant difference at P = 0.05 for controls

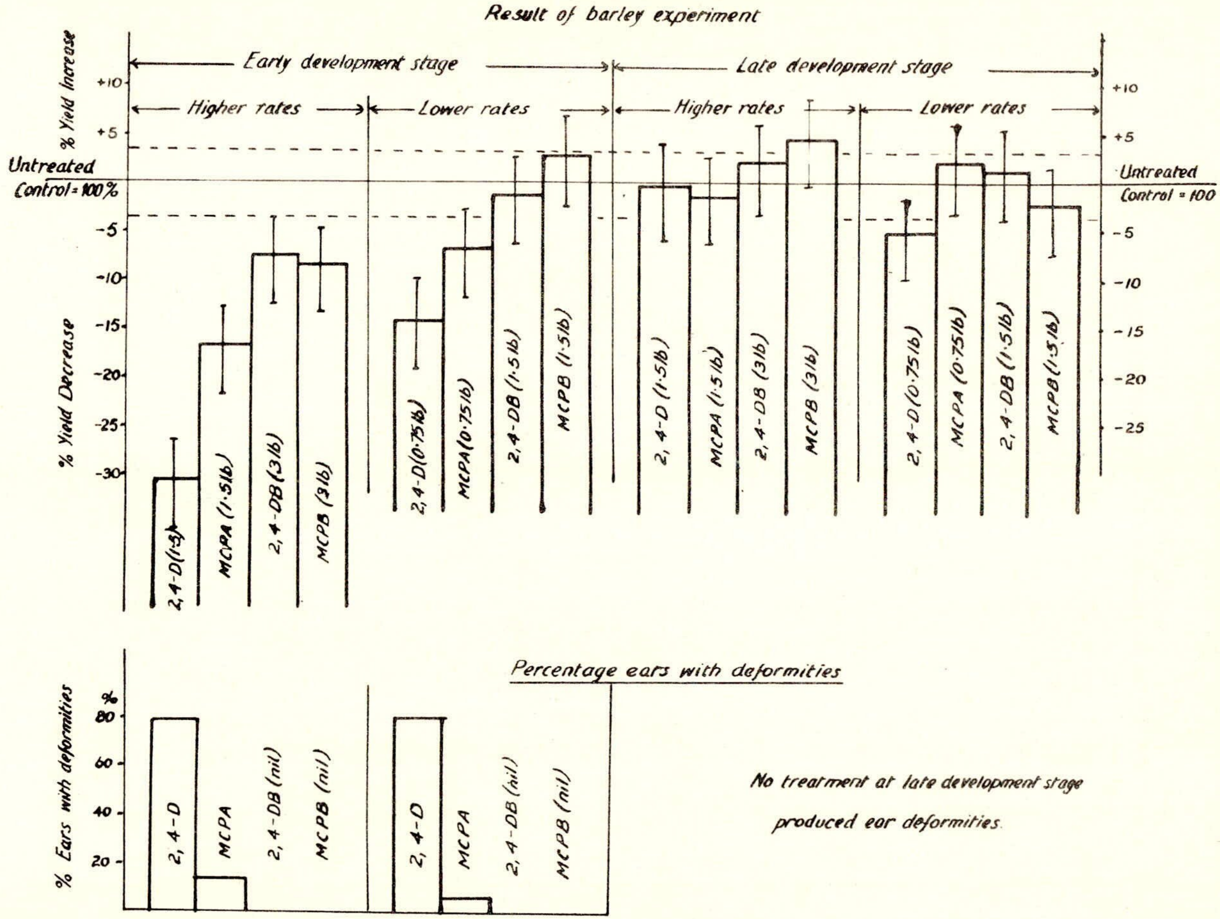
(47011)

Then Treatment I is not significantly different from Treatment 2 because Column 1 $\pm$ a overlaps Column 2 $\pm$ a.

Treatment 1 is significantly different from Treatment 3 because Column 1 $\pm$ a does not overlap Column 3 $\pm$ a.

Treatments 2 and 3 are significantly different from the Control because Columns 2 $\pm$ a and 3 $\pm$ a do not overlap the Control level $\pm$ b.

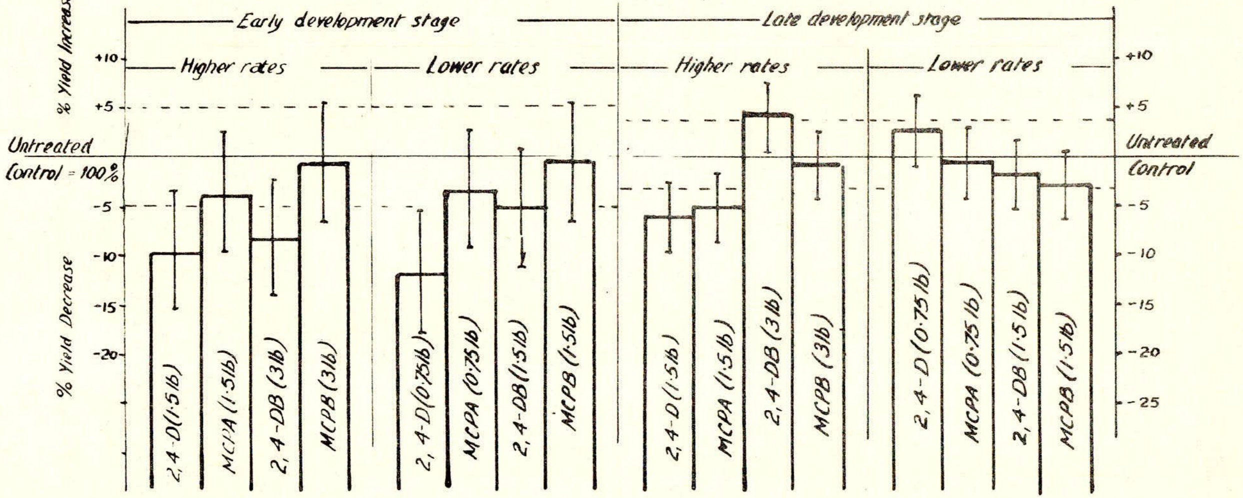
(47011)

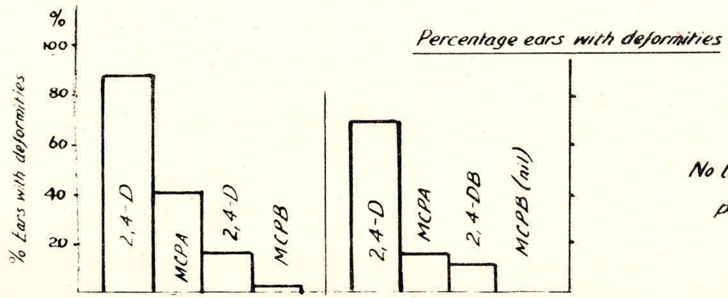


Result of Barley Experiment

426

Result of wheat experiment





No treatment at late development stage produced ear deformities

Result of Wheat Experiment

DISCUSSION ON THE PREVIOUS FIVE PAPERS

Mr. J. G. Elliott (Introduction to discussion)

I have been given the responsibility of summarising these research reports in this section that provide information on the direct effects of MCPB and 2,4-DB on cereal crops. As the reports contain a total of 44 experiments on four crops, I will have no time to comment on the information in some of the papers on the effect of weed control on cereal yield.

To build up a true and reliable picture of cereal crops reaction to a chemical, it is necessary to have information on four aspects of its life; these are:- vegetative growth, the normality or otherwise of head production, yield in the absence of weeds, and finally the effect on grain quality. The research reports do not contain any evidence on the effects of MCPB and 2,4-DB on grain quality. The main bulk of experimental data is about head abnormality and yield in spring wheat, barley and oats, while there is information on winter wheat from a single experiment dealing with growth and head abnormality.

We can dispose of winter wheat in a few words because the results show that the relative chemical toxicities are approximately the same as those for spring wheat. Let us now consider each chemical in turn on the spring cereals.

First, MCPB at any time from emergence to shooting. On spring barley, at rates up to 4 lb/ac did not cause appreciable numbers of deformed heads in any experiment; nor in three clean experiments did it produce any reduction in yield. However in one experiment reported by Pfeiffer, 3 lb/ac at the three-leaf stage caused a significant 8% reduction in yield. The 1.5 lb/ac application in the same experiment did not reduce yields. I do not think we should worry too much about this isolated yield reduction because there is evidence from another paper that 8 lb/ac did not significantly reduce yield.

On spring wheat MCPB at rates between 1.5 and 4 lb/ac either caused no deformed heads or a very small proportion that were too few and too mild in appearance to have much practical significance. There was a single exception reported by Stovell in which 1.5 lb/ac on Atson caused 55% deformed heads. This single, high incidence of deformity is contrary to the results of the other twelve experiments including one on Atson that constitute the rest of the evidence and it should I think be treated as an experimental abberation. The results on clean spring wheat are in agreement that MCPB at 3 lb/ac had no significant effect on yield, and in a single experiment applications up to 13.5 lb/ac had no significant effect on yield.

On spring oats MCPB at 1.5 lb/ac usually caused a small proportion of abnormal panicles, though these were always less than 7% of the total heads, and the numbers showed little increase when 4 lb/ac was applied. However the picture is obscured by varietal differences which indicate that Forward may be more susceptible to abnormality than Sun.II or S225. The evidence indicates that MCPB is generally less toxic to spring oats than is MCPA. In a single clean yield experiment, application of MCPB at rates up to 3 lb/ac did not have any significant effect on yield.

Turning now to 2,4-DB, again applied at various times between emergence and shooting.

On spring barley, 2,4-D at 2 lb/ac or less usually produced a negligible number of deformed heads, but there was a single exception reported by Carpenter in which 10% deformed heads were found. The evidence suggests that 4 lb/ac might cause up to 20 deformed heads per acre. No significant yield reduction followed the application of up to 3 lb/ac in clean spring barley.

On spring wheat younger than the five leaf stage, the spraying of 1.5 lb/ac 2,4-DB or more caused substantial numbers of deformed heads and significant yield reductions in some but not all of the experiments.

On spring oats, the interpretation of the effects of 2,4-DB is obscured by similar varietal differences to those produced by MCPB. However the available evidence leads to the conclusion that 2,4-DB and MCPA are approximately equal in toxicity. In a single bean experiment 2,4-DB at up to 3 lb/ac did not significantly reduce the yield of oats.

What are the general conclusions that may be drawn from the reports? They are, I think, that MCPB and 2,4-DB may be used in any cereal situation for which MCPA is at present recommended. In addition, MCPB and 2,4-DB at rates up to 2 lb/ac may safety be applied to spring barley, and MCPB at up to 3 lb/ac may safely be applied to spring wheat at any time from emergence until shooting.

The safe doses shown in the table are my conclusions from the reports and not general recommendations.

<table>
<tr><th></th><th colspan="6">MAXIMUM SAFE DOSES ON SPRING CORN
lb/ac a.e.</th></tr>
<tr><th></th><th colspan="2">WHEAT
MAIN STEM LEAVES</th><th colspan="2">BARLEY</th><th colspan="2">OATS</th></tr>
<tr><th></th><th>1-4</th><th>5-7</th><th>1-4</th><th>5-7</th><th>1-4</th><th>5-7</th></tr>
<tr><td>2,4-D</td><td></td><td>1</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td>MCPA</td><td></td><td>2</td><td></td><td>2</td><td colspan="2">1·5</td></tr>
<tr><td>2,4-DB</td><td></td><td>2</td><td>2</td><td>4</td><td colspan="2">1·5</td></tr>
<tr><td>MCPB</td><td colspan="2">3</td><td>2</td><td>4</td><td colspan="2">2</td></tr>
</table>

Mr. C. V. Dadd

In a number of cases where Koga II wheat has been sprayed with MCPA deformities appear. I doubt whether this is important but it is certainly noticeable. Perhaps it is something to do with the variety or the season. Has this been observed anywhere else?

Mr. J. G. Elliott

I have no evidence on Koga II but there is evidence for other varieties to suggest that there are definite differences not only as to the quantity of deformed heads but also as to the leaf stage at which resistance to 2,4-D and MCPA occurs.

Mr. S. J. Willis

I should like to remind Mr. Elliott of some words of wisdom that we heard yesterday, 'always to study the exceptions'. Can Mr. Stovell give us any further information?

Mr. J. G. Elliott

I thought of these experiments as I was listening to Sir John Russell yesterday and I do not suggest that we forget the exceptional results from two of the forty-four experiments that were reported. But we must keep our sense of proportion and place reliance on the great weight of experimental information and bear in mind that these exceptions may or may not occur again. Incidentally, Mr. Stovell informs me that he has checked carefully the conditions under which his experiment was carried out.

Dr. R. K. Pfeiffer

We had one experiment in which winter wheat sprayed in spring with MCPA at the normal dosage produced abnormalities. This confirms observations made by others. I suggest that it may be due to the exceptionally cold winter, and some wheat crops which were sown late might not have reached the safe development stage when sprayed early in the spring.

Mr. N. E. Goodman

In this abnormal season it has been mentioned before that quite a number of practical farmers have noticed more distortion from selective weedkillers than ever before.

I was speaking to one leading farmer in the Midlands who has been inspecting 1000 acres of cereals of all kinds for the local farmers' cereal competition. While doing so he noticed a striking amount of distortion in oats, wheat and barley, where sprayed with both MCPA and 2,4-D proprietary materials. He could only attribute the presence of this distortion to the difficult season.

Mr. J. G. Elliott

What is a normal season? Every year we hope to write that we have had a normal season but we have not done so for six years.

Mr. W. Ochiltree

I would be interested if some one could tell me whether the mechanism for laying down ear initials is directly co-ordinated with the mechanism for the formation of leaves.

Prof. G. E. Blackman

In the last number of the Journal of Experimental Botany there was a paper from New Zealand by Holdsworth who has re-examined the evidence that flower initiation does not take place before a minimum number of leaves have been formed. He reached the conclusion that this relationship was pretty rigorous.

Mr. W. van der Zweep

In Holland we have quite considerable data on the application of DNC to cereals. We usually get a 10% increase after each application, however, in 1955 due to rather warm weather conditions which occurred after ear formation, the usual applications of DNC were too late to establish yield increase. There is definitely some relationship between spraying and the development of the ear and leaflet formation. At a conference at Wageningen to discuss weed control chemicals in continental Europe, several workers have decided to co-operate in international experiments. This conference will be held again next year and thanks to the co-operation of the Swedish, Finnish, Belgian, French and Dutch workers an enquiry will be set up to discover the relative value of the various chemicals. If any British workers are interested we shall be glad to send them details.

Dr. E. Åberg

I wonder if the variations found in 1956 are due to an uneven stand. Could it be that plants in the experiments discussed were at a different stage of development when spraying took place?

Mr. J. G. Elliott

Variations in results may well be due to variations in stage of growth at spraying. The average cereal crop does not grow with such uniformity that all the plants are simultaneously at the same leaf stage. Our statements as to stage of growth are usually averages.

Mr. K. Carpenter

We have done this sort of sampling and often where the average of the crop is just before the recommended stage perhaps 30% of the plants are actually in that stage, and 60% or 70% are perhaps two leaves more or two leaves less.