SELECTIVE WEED CONTROL IN CEREALS WITH CMPP AND SODIUM MONOCHLOROACETATE

by

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In a series of trials ,α(4-chloro-2-methylphenoxy)propionic acid (CMPP) 2·5 lb./acre was very effective against *Galium aparine* (cleavers), but 2 lb./acre was unsatisfactory for control of over-wintered infestations in winter cereals. *Stellaria media* (chickweed) was eradicated with 2 lb./acre of CMPP.

Sodium monochloroacetate was generally disappointing against these weeds. The standard dosage rate of 20 lb./acre reduced *Galium aparine* by 59% and *Stellaria media* by 63% on an over-all average. *Polygonum persicaria* (redshank) and *Polygonum convolvulus* (black bindweed) are very susceptible to sodium monochloroacetate.

Both CMPP and sodium monochloroacetate caused a negligible incidence of malformity to wheat, oats and barley sprayed early, and neither material caused significant reductions in yields of these crops.

CMPP was more effective than MCPA/sodium monochloroacetate mixtures when applied to mixed stands of *Galium aparine* and *Chenopodium album* (fat hen). Cereal yields were not significantly reduced by spray applications of 1·5 lb. MCPA+20 lb. sodium monochloroacetate/acre.

Introduction

The results of a programme of trials carried out in 1955 and 1956 to test sodium monochloroacetate spray applications as a means of selective weed control (mainly against *Galium aparine*) in cereals, were published in a paper presented to the 3rd British Weed Control Conference, 1956.[1] At the same conference Lush and Leafe reported a number of trials in which α-(4-chloro-2-methylphenoxy)propionic acid (CMPP) had been found satisfactory for selective weed control in cereals.[2] Main emphasis was again placed upon *Galium aparine* and it was claimed that *Stellaria media* was particularly susceptible to this material. Furthermore, it was claimed that MCPA-susceptible weeds responded similarly to CMPP when applied at equal rates of active acid.

This paper records the results of a series of trials carried out in 1957 to compare the two products, mainly for the control of *Galium aparine* and *Stellaria media.*

In 1955/56 sodium monochloroacetate was found to be ineffective against *Chenopodium album* and since this weed frequently occurs together with *Galium aparine* the effect of mixtures of MCPA and sodium monochloroacetate for control of both weeds was also studied. Particular emphasis was placed upon the effect of such mixtures upon yield of cereals.

Experimental

Fourteen large plot trials designed to obtain cereal yields and herbicidal data were laid down in the Northamptonshire area as follows:

(i) In two trials each on spring wheat (var. Atson), spring barley (var. Herta) and spring oats (var. Blenda), infested with *Galium aparine* or *Stellaria media*, CMPP (diethanolamine salt) at 2·5 lb./acre and sodium monochloroacetate at 20 lb./acre were applied in 20 gal. of water/acre to crops at two stages of growth, about two weeks apart.

(ii) In one trial each on winter wheat (var. Cappelle), winter oats (var. S.147), spring barley (var. Herta) and spring oats (var. Sun II), infested with *Galium aparine* and *Stellaria media*, CMPP (K salt) at 1, 2 and 3 lb./acre were applied, each in 20 gal. of water/acre, and sodium monochloroacetate at 20, 25 and 30 lb./acre in 20, 25 and 30 gal. of water/acre, respectively.

(iii) In one trial each on spring wheat (var. Koga II) and spring barley (var. Proctor) and two on spring oats (var. Sun II), the crops being infested with *Galium aparine* and *Chenopodium album,* there were applied, each in 20 gal. of water/acre: MCPA (K salt) at 0·75 and 1·5 lb./acre; sodium monochloroacetate at 15 and 20 lb./acre; MCPA (K salt) at 0·75 and 1·5 lb./acre in mixture with both 15 and 20 lb./acre of sodium monochloroacetate; and CMPP (diethanolamine salt) at 1·25 and 2·5 lb./acre.

In addition, five small plot trials were laid down in West Sussex to compare CMPP (diethanolamine salt) at 1·7, 2·5 and 3·4 lb./acre, sodium monochloroacetate at 20 lb./acre and MCPA at 1·5 lb./acre for control of *Polygonum convolvulus, P. persicaria, Senecio vulgaris* (groundsel), *Galeopsis tetrahit* (hemp nettle), *Achillea millefolium* (yarrow), *Stellaria media* and *Chenopodium album.*

N.B.—Application rates of CMPP referred to are a mixture of the *d*- and *l*- isomers.

Layout

All trials consisted of four randomised blocks. Plots in the large-scale trials were 80 × 5 yd. and chemicals were applied by means of a Land Rover-mounted sprayer. In the small plot trials, chemicals were applied to plots 6 × 2 yd. by means of an Oxford Precision Sprayer. Spraying was carried out at 40 lb./sq. in. pressure.

Assessment methods

Weed control was assessed about 4–6 weeks after spraying. Ten counts of one-square yard quadrats and ten gradings of the vigour of the remaining plants were made at random in each plot. The control of *Stellaria media* was estimated by gradings.

Head malformities.—In all large-scale trials 100 heads were taken at random from each plot and examined for evidence of malformity.

Cereal yield.—Visual gradings of the appearance of crops were made within a few weeks of spraying. Yield data were obtained by weighing the grain yield of a single cut of the co-operating farmer's pusher-type combine harvester, through the middle of each 15-ft. plot. The plot area harvested was usually 1/21 acre.

A 2-lb. sample of grain was taken from each plot in selected trials to determine the content of weed seed and rubbish present. Samples were also taken from each plot harvested to determine the moisture content of the grain in a Marconi moisture meter.

Results

Weed control

(a) *Galium aparine.*—The average control of *Galium aparine* obtained from applications of 2·5–3 lb./acre of CMPP over 15 applications was 88%. The corresponding average from 20 lb. of sodium monochloroacetate/acre over 16 applications was 59%. Throughout the trials the growth stages of the weed when sprayed ranged from seedlings to adult plants. There was no evidence to support the suggestion that *Galium aparine* is less susceptible to CMPP when sprayed at the seedling stage than when the weed is more established.[2]

CMPP at 2 lb./acre was insufficient for control of a heavy infestation of over-wintered *Galium aparine* sprayed in cold weather. The level of control obtained was 40–50%. Paradoxically, CMPP at 1·3 lb./acre was satisfactory for control of *Galium aparine* in spring cereals and reduced the weed by an average of over 80%. Sodium monochloroacetate applied at 30 lb./acre gave an average control of 63% over 3 trials.

(b) *Stellaria media.*—CMPP was found to be particularly effective against *Stellaria media* and was significantly more effective than sodium monochloroacetate in each of six comparisons. CMPP at 2 lb./acre almost totally eradicated the weed in each case; sodium monochloroacetate at 20 lb./acre gave 63% control. CMPP at 1 lb./acre gave 99% control of seedling *Stellaria media* in a single trial.

(c) *Polygonum persicaria.*—The level of control was around 60% with CMPP at 2·5–3 lb./acre, but about 80% with sodium monochloroacetate at 20 lb./acre.

(d) *Polygonum convolvulus.*—Sodium monochloroacetate at 20 lb./acre gave 90% control in each of two trials. From the evidence of a single comparison trial, CMPP at 2–3 lb./acre caused only 60–70% reduction.

(e) *Chenopodium album* and *Papaver* sp. (poppy).—These were found to be very susceptible to CMPP at 2–3 lb./acre, but sodium monochloroacetate was useless against them.

(f) *Galeopsis tetrahit* was well controlled by both materials.

(g) *Achillea millefolium* was only slightly affected by CMPP but sodium monochloroacetate gave 72% control.

Head malformities

Negligible incidence of head malformity followed applications of up to 2·5 lb./acre of CMPP and 20 lb./acre of sodium monochloroacetate on *spring wheat* at growth stages of 4–7 leaves and *spring barley* at 3–7 leaves. No malformity was found in *winter oats* sprayed when well tillered in the spring. Whilst CMPP caused a higher incidence of malformity of *spring oats* than of wheat and barley the over-all average was less than 1% and only fractionally more than that occurring from natural causes in untreated controls. The types of malformity most commonly encountered were supernumerary panicles emerging from the uppermost node of the culm and abnormality of the spikelets. Neither of these abnormalities is considered likely to affect grain quality or yield. There was virtually no malformity following spraying with sodium monochloroacetate.

Cereal yield

Twelve of the fourteen trials laid down were harvested. One trial on winter wheat and another on spring oats were ruined by the weather. Harvesting conditions were usually good.

The presence of green matter and weed seed in the grain output from the combine harvester can bias the yield data against an efficient herbicide in comparison with untreated controls in trials of the type carried out. Samples taken in these trials have shown that grain from CMPP plots and, to a lesser degree, plots treated with sodium monochloroacetate, is almost invariably drier than that from control plots. Furthermore, in some trials the treated plots contained far less extraneous matter than the untreated control plots. The effect of adjustment of the gross yield data to allow for these factors has, in some instances, converted a gross yield reduction to a net yield gain. Only net yields are reported in this paper.

Yields of wheat, oats and barley were not consistently increased by the control of infestations of *Galium aparine* and *Stellaria media* (Tables I, II and III).

Spring wheat

Two trials on Atson wheat were each sprayed at two growth stages, 4–5 leaves and 6–7 leaves respectively, and one trial on Koga II wheat was sprayed at 6 leaves. A significant yield increase (P=5%) of 17% was obtained in one trial from spraying wheat at 4–5 leaf stage of growth (Table I, Serial 9). No other significant effect upon yield was caused by CMPP at 2·5 lb./acre or sodium monochloroacetate at 20 lb./acre.

Spring barley

Two trials on Herta barley were sprayed at 3 and 6 leaves and 4 and 7 leaves growth stages respectively. Neither CMPP at 2·5 lb./acre nor sodium monochloroacetate at 20 lb./acre significantly affected the yield of barley. In a third trial on Herta barley sprayed at 6 leaves, application of 1, 2 and 3 lb./acre of CMPP and 20 lb./acre of sodium monochloroacetate each gave a significant (P=5%) yield increase of about 30% (Table II, Serial 12). The control plots in this trial suffered very considerably from the competitive effect of *Chenopodium album* and *Polygonum persicaria* in addition to *Galium aparine*. Neither CMPP at 2·5 lb./acre nor sodium monochloroacetate at 20 lb./acre significantly affected the yield of Proctor barley in the fourth trial.

Winter oats

The yield of S.147 oats was not significantly affected by up to 3 lb./acre of CMPP or by 20 lb./acre of sodium monochloroacetate in a single trial (Table II, Serial 3).

Spring oats

CMPP at 2·5 lb./acre and sodium monochloroacetate at 20 lb./acre were applied to crops of Blenda oats showing 4, 5 and 6 leaves. Plots with 20 lb. of sodium monochloroacetate gave a significant yield increase (P=5%) of 6% in one instance (5 leaves) (Table I, Serial 7), but otherwise neither material significantly affected the yield of oats.

Two crops of Sun II oats were sprayed with sodium monochloroacetate at 20 lb./acre without significant effect upon yield. CMPP was applied in only one of these trials and 1·25 lb. and 2·5 lb./acre gave significant yield increases (P=5%) of 12% and 15% respectively (Table III, Serial 13).

Table I
Growth-stage trials

Serial No.	Date sprayed	Weed	Growth stage R	Growth stage B	Growth stage H	% Weed control CMPP†	% Weed control Na monochloro-acetate‡	C. of V., %	Crop	Growth stage L	Growth stage T	Growth stage H	Net yield (as % of untreated plots) CMPP	Net yield Na monochloro-acetate	C. of V., %
5	20.5.57	*Galium aparine*	2	—	2	68	49	16	Herta barley	3	2	10	102·6	100·0	12
	3.6.57	,, ,,		3–4	3–4	57*	4		,, ,,	6	3–4	17	92·3	97·4	
10	31.5.57	*Galium aparine*		2	2	94*	52	14	Herta barley	4	2	11	102·9	99·2	7
	13.6.57	,, ,,		3	3	100*	82		,, ,,	7	3	15	98·5	97·5	
	31.5.57	*Polygonum persicaria*		Seedling		63	88*	41							
	13.6.57	,, ,,		Advanced seedling		66	75								
8	28.5.57	*Galium aparine*		2–3	3	94	70	37	Atson wheat	4	1–2	10	91·9	99·0	8
	11.6.57	,, ,,		4–5	7	95	69		,, ,,	7	2	22	108·5	·01·5	
9	29.5.57	*Galium aparine*		2	1½	96	75	32	Atson wheat	4–5	3–4	11	116·7*	103·9	8
	11.6.57	,, ,,		3–4	4	96*	64		,, ,,	6–7	4–5	14	107·3	90·8	
11	5.6.57	*Galium aparine*		2–3	4	92	87	59	Blenda oats	6	2–3	15	101·3	103·5	7
	5.6.57	*Stellaria media*		4-in. clumps		99*	63	54							
7	23.5.57	*Stellaria media*	2–4 L		1–2	100*	72	19	Blenda oats	4	2	13	96·0	102·4	3
		,, ,,	5–6 L		2 (diam.)	97*	51		,, ,,	5	2	18	98·2	105·9*	

* Significantly > CMPP or sodium monochloroacetate (P=5%)　　† 2·5 lb./acre　　‡ 20 lb./acre

Table II
Dosage rate comparisons
(dosages in lb./acre)

Serial No.	Date sprayed	Weed	Growth stage L	Growth stage B	Growth stage H	% Weed control CMPP dosage 1	2	3	Sodium monochloroacetate dosage 20	25	30	C. of V., %	Crop	Growth stage L	Growth stage T	Growth stage H	Net yield (as % of untreated plots) CMPP dosage 1	2	3	Sodium monochloroacetate 20	25	30	C. of V., %
3	1.5.57	*Galium aparine*	—	7	6	6	50	83	68	72	81	56	S.147 oats	8	3	10	94·9	103·4	98·3	95·7	88·5	90·1	9
4	16.4.57	*Galium aparine*	—	4	5	24	41	85	64	81	91	37	Cappelle wheat	7	2	8			Not	harvested			
6	21.5.57	*Stellaria media*	2–5		3	99	99	100	79	82	86	32	Sun II oats	4–5	2	12			Not	harvested			
			CMPP > sodium monochloroacetate (P=5%)																				
		Papaver sp.	5–6		2–3	84	96	100	29	16	42	27											
			CMPP > sodium monochloroacetate (P=5%)																				
12	6.6.57	*Galium aparine*		4	3–4	33	76	81	5	13	17	22	Herta barley	6	4	14	126·5*	128·3*	136·7*	130·7*	109·0	113·9	13
			CMPP > sodium monochloroacetate (P=5%)																				
		Polygonum persicaria	5–6		4–5	38	69	11	77	85	91	104											
			Sodium monochloroacetate > CMPP (P=5%)																				

Table III
MCPA/sodium monochloroacetate mixtures and CMPP
(dosages in lb./acre)

Serial No.	Date sprayed	Weed	Growth stage L	Growth stage B	Growth stage H	% Weed control 1·5 lb. MCPA	20 lb. SMCA	1·5 lb. MCPA 20 lb. SMCA	CMPP 1·25 lb.	CMPP 2·5 lb.	C. of V., %	Crop	Growth stage L	Growth stage T	Growth stage H	Net yield (as % of untreated plots) 1·5 lb. MCPA	20 lb. SMCA	1·5 lb. MCPA 20 lb. SMCA	CMPP 1·25 lb.	CMPP 2·5 lb.	C. of V., %
14	10.6.57	*Galium aparine*	—	3–4	3	0	68	71	96	98	72	Koga II wheat	6	2–3	15	99·0	99·7	98·6	102·2	109·3	6
		Chenopodium album	6–7	—	2½	98	0	99	98	98	24										
15	12.6.57	*Galium aparine*	—	2	1	29	83	90	91	97	28	Proctor barley	5	2–3	12	105·7	96·1	93·9	101·6	102·5	7
		Chenopodium album	4	—	1	100	10	100	100	100	56										
13	8.6.57	*Galium aparine*	—	3–4	3	20	52	46	66	87	40	Sun II oats	5–6	3	15	106·9	92·3	103·6	112·4*	115·0*	8
		Chenopodium album	8–9	—	2½	98	21	91	97	99	38										
16	5.6.57	*Galium aparine*	—	2–3	5	–6	48	52	—	—	27	Sun II oats	6	3	17	104·2	93·4	87·7	—	—	13
		Chenopodium album	7	—	4	99	8	89	—	—	15										
		Polygonum persicaria	4–5	—	3	23	88	80	—	—	38										
		Polygonum convolvulus	3–4	—	3	65	92	90	—	—	17										

R=rosettes　L=leaves　B=branches　T=tillers　H=height of plant, in.　C. of V.=coefficient of variation.　　* Significantly > or < untreated control (P=5%)

MCPA/sodium monochloroacetate (Table III)

The effect of applying mixtures of MCPA and sodium monochloroacetate to mixed stands of *Galium aparine* and *Chenopodium album* corresponded roughly to that obtained from separate applications of the components of the mixture. A good control of *Chenopodium album* and a fair control of *Galium aparine* was obtained with a mixture of 1·5 lb. of MCPA/20 lb. of sodium monochloroacetate per acre. The use of such mixtures could, therefore, be regarded as satisfactory having regard to the limitations of the performance of sodium monochloroacetate in the trials now reported. Spring wheat, oats and barley were tolerant of the highest mixture concentration used, viz. 1·5 lb. of MCPA and 20 lb. of sodium monochloroacetate per acre. There is no evidence to suggest that the addition of sodium monochloroacetate to MCPA causes greater incidence of malformity to cereals.

CMPP at 2·5 lb./acre gave a high degree of control (over 90%) of both *Galium aparine* and *Chenopodium album* in each of the three trials in which it was used against the two weeds.

Discussion

On the evidence of these trials, it can be concluded that CMPP is a more efficient selective weedkiller than sodium monochloroacetate for use in cereals infested with *Galium aparine, Stellaria media, Chenopodium album* and *Papaver* sp. *Sodium monochloroacetate is the better* material for control of *Polygonum persicaria,* and probably *Polygonum convolvulus.* Mixed infestations of *Galium aparine* and *Chenopodium album* can be effectively dealt with by CMPP without resorting to mixtures of MCPA/sodium monochloroacetate.

Greenhouse tests carried out concurrently with the above trials showed no significant difference between the biological activity of various CMPP formulations used in the trials. The responses from the various formulations used are, therefore, regarded as comparable with one another. CMPP at 2·5 lb./acre proved very satisfactory for control of *Galium aparine,* but 2 lb./acre was clearly insufficient for satisfactory control of a heavy over-wintered infestation.

The over-all average control of *Galium aparine* achieved with sodium monochloroacetate at 20 lb./acre was 59%, compared with 80% in the trials carried out in 1956. The failure of the material to obtain the same degree of consistency of control as in 1956 cannot be correlated with any factors such as growth stages or temperature. Rates up to 30 lb. of sodium monochloroacetate per acre were not consistently effective against *Galium aparine.*

Neither CMPP nor sodium monochloroacetate caused an appreciable incidence of malformity to wheat and oats sprayed when four leaves were on the main stem and barley from three leaves. It is of interest that in a single trial MCPA at 1·5 lb./acre produced 10·5% malformity of heads of Proctor barley compared with 0·75% from plots sprayed with CMPP at 2·5 lb./acre. The barley was showing 3–4 leaves when sprayed and the malformity usually consisted of a slight elongation of the rachis and pairing of the spikelets.

Wheat, oats and barley were not affected adversely by spray applications of up to 2·5–3 lb./acre of CMPP or 20 lb./acre of sodium monochloroacetate. Yields were not consistently increased by the control of *Galium aparine* and/or *Stellaria media,* but the removal of these weeds is desirable to reduce the risk of lodging and facilitate harvesting. Furthermore, crops sprayed with these materials and particularly CMPP, usually produced drier grain than unsprayed crops.

[1] Breese, T. C., & Wheeler, A. F. J., *Proc. Brit. Weed Control Conf., 1956,* p. 759

[2] Lush, G. B., & Leafe, E. L., *Proc. Brit. Weed Control Conf., 1956,* p. 625

found to be equally susceptible. In some cases practically 100% eradication of white campion was achieved, whilst in adjacent plots sprayed with MCPA and 2,4-D formulations, little reduction in numbers had been effected although the plants had been checked and prevented from flowering. Figures taken from the results of a trial near Peterborough are typical of others as far apart as Chichester and Winchester, and are given in Table I. This group of weeds is a useful addition to the list of those controlled by CMPP.

Scentless mayweed (Matricaria maritima, *sub-sp.* inodora).—A considerable number of cases have occurred in 1957 and 1958 where mayweeds, particularly the scentless mayweed, have been satisfactorily controlled by CMPP at the rate of 2·4 lb. acid equiv./acre. Control is the more effective if treatment is carried out during early stages in the development of the plant, when very effective eradication can be achieved. In all cases no more than a slight check was effected by MCPA and 2,4-D formulations included in the trial.

Redshank (Polygonum persicaria).—The response of this weed to CMPP is interesting but far from clear cut. As indicated in Table II, in a number of trials CMPP at 2·4 acid equiv./acre has given better results than MCPA at 1·2 lb./acre, when sprayed at reasonably early growth stages (up to 6 leaves) under favourable conditions. On other occasions, however, under apparently similar conditions the reverse has been the case, the control with CMPP being markedly inferior to that achieved by MCPA. It might well be that where conditions favour rapid growth CMPP gives the more effective control of this weed, the effect diminishing until the reverse is true under unfavourable growing conditions.

Pale persicaria (*P. lapathifolium*) seems generally to be less susceptible than *Polygonum persicaria.*

Fat hen (Chenopodium album) and *orache* (Atriplex patula).—A marked difference in response to CMPP has been observed in these two weeds, both of which are often referred to by farmers as fat hen. Both are adequately controlled by CMPP at 2·4 lb./acre, fat hen the more responsive, being adequately controlled by 2 lb./acre. Frequent satisfactory controls of fat hen have been achieved by 1·6 lb./acre, at which rate control of orache is quite unsatisfactory. This tendency is indicated in Table III.

Table I

White campion
(no. of plants surviving)

Herbicide	Dosage, lb./acre	Block A	Block B	Block C	Total	Mean	% of control
CMPP	2·4	0	17	9	26	8·6	9·6
CMPP	2·0	11	12	9	32	10·6	11·8
MCPA	1·2	21	22	33	76	25·3	28·2
Control		95	100	74	269	89·6	100·0

Significant difference: P=0·05—20·8%; P=·01—31·5%

Experimental details

Spraying was carried out under favourable conditions. Temperature 60°F. White campion in a fairly advanced stage, some in flower. Visually a very marked difference showed between CMPP- and MCPA-treated plots in all replicates, although when analysed the difference between the compounds failed to be significant.

Table II

Polygonum persicaria
(fresh weight of plants surviving)

Herbicide	Dosage, lb./acre	Block A	Block B	Block C	Total	Mean	% of control
CMPP	2·4	60·2	84·0	71·0	215·7	71·9	17·9
CMPP	3·2	90·7	93·0	133·0	317·3	105·8	26·3
MCPA	1·2	281·0	129·8	219·0	629·8	209·9	52·1
Control		324·0	260·0	624·0	1208·4	402·8	100·0

Significant difference P=·05—76·6%

Experimental details

Polygonum persicaria from 1½ to 5 in. tall with up to 5 leaves. Temperature 60°F, moist conditions. Figures represent fresh weight of living plants per unit area.

In this experiment the crop was badly laid when assessed quantitatively and, because of high standard error in a badly laid field, no significant difference between CMPP and MCPA exists. CMPP at 2·4 lb., however, is significantly different from control while MCPA is not.

Table III

Fat hen and orache

(fresh weight of plants surviving)

Herbicide	Dosage, lb./acre	Weed	Block A	Block B	Block C	Totals	% of control
CMPP	2·4	Fat hen	2·3	2·5	0	4·8	0·5
		Orache	27·2	3·2	15·0	45·4	11·5
CMPP	2·0	Fat hen	2·0	1·2	0·5	3·7	0·4
		Orache	22·5	3·5	12·5	38·5	10·0
CMPP	1·6	Fat hen	0·1	9·5	1·5	11·1	1·2
		Orache	60·9	26·0	27·0	113·9	29·5
Control		Fat hen	476·2	352·5	101·3	930·0	100·0
		Orache	180·2	89·8	117·2	387·2	100·0

Experimental details

Both weeds were approximately 6 in. tall when sprayed. Temperature 65°F. Moist, good growing conditions prevailing. Figures represent fresh weight of living plants per unit area.

The results of this experiment, whilst not statistically significant, indicate the usual difference between the susceptibilities of fat hen and orache to CMPP.

Knotgrass (Polygonum aviculare), *perennial sowthistle* (Sonchus arvensis) and *black bindweed* (Polygonum convolvulus).—These three weeds stand out as being sometimes exceptionally well controlled by CMPP but which on average receive only a useful check. In trials it has frequently been observed that black bindweed is much more effectively controlled by CMPP at 2·4 lb./acre than by MCPA at conventional rates. The same applies to perennial sowthistle and, to a lesser degree, to knotgrass, which latter can on very rare occasions be extremely well controlled. The reasons for this variable response on the part of knotgrass and black bindweed are probably related to stage of growth, neither of these weeds being particularly easy to classify into growth stages. In the case of sowthistle, which is more amenable in this respect, the variable control seems to be affected considerably by crop competition and climatic conditions. In wet periods re-growth of perennial sowthistle is much more likely than with most weeds.

Conclusions

The excellent control of cleavers with CMPP at 2·4 lb./acre has been confirmed. Early spraying of this weed gives satisfactory control provided climatic conditions are favourable.

Chickweed has been found to be extremely susceptible to CMPP at rates from 1·6 lb./acre. The climatic requirements for control of this weed are almost negligible, good control being possible under very unfavourable conditions. Under these circumstances 2 lb./acre should be used.

The common 2,4-D- and MCPA-susceptible cereal weeds can be effectively controlled when spraying for cleavers at 2·4 lb./acre and a number of these can also be controlled at the 2-lb. rate, when chickweed is the main consideration.

In addition, the campions and scentless mayweed which are not significantly affected by 2,4-D and MCPA can be adequately controlled by CMPP at the 2·4-lb. rate.

Extensive work has shown that both amine and potassium formulations of CMPP can confidently be expected to give the same degree of weed control.

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Appendix

List of weeds showing relative susceptibilities to CMPP when growing in cereal crops

Annual weeds are more effectively controlled in the seedling stage whilst perennial weeds are more responsive nearer to the flowering stage.

GROUP I. Controlled by 2·0 lb. of CMPP /acre when spraying to control chickweed (*Stellaria media*)

Charlock	*Sinapis arvensis*
Corn buttercup	*Ranunculus arvensis*
Dock, broad leaved	*Rumex obtusifolius*
Dock, curled	*Rumex crispus*
Fat hen	*Chenopodium album*
Mustard white	*Sinapis alba*
Plantain, greater	*Plantago major*
Plantain, ribwort	*Plantago lanceolata*
Runch	*Raphanus raphanistrum*
Shepherd's purse	*Capsella bursa-pastoris*
Thistle, creeping	*Cirsium arvense*

GROUP II. Controlled by 2·4 lb. of CMPP /acre when spraying to control cleavers (*Galium aparine*)

Buttercup, creeping	*Ranunculus repens*
Campion, bladder	*Silene cucubalus*
Campion, white	*Melandrium album*
Corn poppy	*Papaver rhoeas**
Crowfoot	*Ranunculus acris*
Fumitory	*Fumaria officinalis*
Mayweed, scentless	*Matricaria maritima* s.sp. *inodora**
Nettle, annual	*Urtica urens*
Nettle, perennial	*Urtica dioica*
Orache	*Atriplex patula*
Vetch	*Vicia sativa*

* When sprayed in early stages.

GROUP III. When spraying to control cleavers at 2·4 lb./acre these weeds suffer a useful check

Bindweed, black	*Polygonum convolvulus*
Groundsel	*Senecio vulgaris*
Hempnettle	*Galeopsis tetrahit*
Knotgrass	*Polygonum aviculare*
Redshank	*Polygonum persicaria*
Scabious, field	*Knautia arvensis*
Sowthistle, annual	*Sonchus oleraceus*
Sowthistle, perennial	*Sonchus arvensis*
Spurrey, corn	*Spergula arvensis*

GROUP IV. These weeds are not significantly affected by CMPP when used at 2·4 lb./acre to control cleavers

Bindweed, field	*Convolvulus arvensis*
Chamomile, wild	*Matricaria chamomilla*
Coltsfoot	*Tussilago farfara*
Deadnettle, red	*Lamium purpureum*
Forget-me-not	*Myosotis arvensis*
Heartsease	*Viola tricolor*
Marigold, corn	*Chrysanthemum segetum*
Mint, corn	*Mentha arvensis*
Pansy, field	*Viola arvensis*
Persicaria, pale	*Polygonum lapathifolium*
Pignut	*Conopodium majus*
Scarlet pimpernel	*Anagallis arvensis*
Speedwell, field	*Veronica agrestis*
Speedwell, germander	*Veronica chamaedrys*
Toadflax, small	*Chaenorrhinum minus*

PART II. CROP SAFETY

The position of CMPP with regard to cereal tolerance is introduced. Special emphasis is given to the question of early spraying, and varietal susceptibility during the early phases of growth. The relationship of morphological stage to susceptibility is reiterated.

Results of variety and yield trials show that, of the barley and oat varieties tested, none has outstanding susceptibility to CMPP. Extension of recommendations to include spraying at these early stages is now considered safe. In the case of wheat, susceptibility of the varieties Atle and Atson when sprayed at an early leaf stage (i.e. during the early differentiation of spikelet initials or 'double ridges') makes an over-all recommendation inadvisable, but, in view of its extensive use, a special recommendation is considered for the non-susceptible variety Koga II.

Introduction

At the 3rd British Weed Control Conference in 1956, the discovery of the value of CMPP as a herbicide was first announced.[1] It was shown that in the major cereals, although the period of susceptibility to CMPP was largely similar to that to MCPA, the degree of damage following spraying during the susceptible period was very much less. The advantages, from the weed control standpoint, of early spraying, or, more important, maximum latitude in spraying, have been discussed in the preceding paper.

It was known that spraying with MCPA during the susceptible period gives rise to damage, the extent of which is appreciably dependent on cereal variety and furthermore on environmental conditions.[2, 3] It was against this background that, in 1956, it was decided to defer recommendations for early spraying with CMPP until varietal response and the effect of environment had been investigated more fully. This work has proceeded during the last two years.

Experimental

The experimental work was designed to evaluate the susceptibility of a wide range of cereal varieties, some established and some of recent introduction, when sprayed with CMPP, particularly during the early phases of growth when they are characteristically susceptible to MCPA and 2,4-D. Wheat is susceptible prior to and during double ridge, glume and early pale initiation, but after this stage, except at a very late stage, damage does not occur. In barley the situation is analogous and the safe stage is reached once pale initiation is well established. The development of the fifth leaf on the main stem is the accepted practical indication that the safe stage of development has been reached in spring wheat and barley. In oats the situation is more complex and factors other than stage of development tend to be overriding.

Two types of trial, complementary in purpose, were employed:

(1) small triplicated trials which were assessed by visual observation of head abnormality. This type of trial was employed to determine varietal susceptibility to CMPP and were variously situated in Nottinghamshire, Lincolnshire, Ayrshire and Angus; and

(2) yield trials in which a larger plot size and a larger number of replicates were used. This type was employed to determine the effect of CMPP on the yield of selected wheat, barley and oat varieties and furthermore to correlate yield depression and head abnormality. Sites were chosen which showed even fertility and germination, and which showed promise of remaining weed free, thus allowing a direct comparison of treatment and untreated control without the interference of a weed control factor.

Varieties

In variety trials, the numbers of varieties tested were seven wheat, nine barley and twelve oats, and in yield trials four wheat, three barley and three oats, some being included in both trials.

Rates of application

It has been found that 6 pints/acre of a water-soluble salt containing 32% w/v of CMPP free acid equivalent are necessary for adequate weed control. This rate is equivalent to 2·4 lb./acre of the acid. This standard rate and the excessive rate of 9 pints, equivalent to 3·6 lb./acre of the acid, have been used throughout the cereal work. Where MCPA was used in comparison, the rates were 3 and 6 pints of a solution of similar concentration equivalent to 1·2 and 2·4 lb. of acid/acre respectively.

Generally, spraying was carried out at low or medium volume.

Stages of application.—Spraying was carried out at a series of well-defined morphological stages which showed more or less close correspondence with leaf stages. These are dealt with under assessment.

Assessment

The variety trials were assessed by counting the percentage and type of morphological abnormality occurring in 50 or 100 heads, selected at random from each plot. The type of abnormality reflects the stage of development at the time of spraying (see Table I).

The susceptibility of oats to MCPA is complex. Susceptibility to CMPP follows a different pattern and will be discussed below.

The yield trials were assessed by determining the yield per plot and comparing treatment with untreated control. At some sites the control yield clearly has been depressed by weed competition. Lay-out and interpretation followed conventional statistical principles. Examination of the plots prior to harvesting was avoided in order to minimise yield differences other than those arising from treatment, but in some cases the percentage of abnormal heads was counted or an assessment made.

Table I

	Wheat	Barley
Stage 1	1–3 leaves	1–3 leaves
Apex	Vegetative or transitional.	Vegetative, transitional or bearing one or two double ridges.
Abnormality	Tubular leaves or abnormalities of the lower spikelets.	Tubular leaves and abnormalities of the lower spikelets.
Stage 2	3–4 leaves	3–4 leaves
Apex	Double ridge initiation, none or very little suppression of lower part.	Double ridge initiation and suppression of lower part. Six-row formation sometimes evident.
Abnormality	Abnormally arranged and aberrent spikelets.	Abnormally arranged and aberrent spikelets.
Stage 3	4–5 leaves	4–5 leaves
Apex	Suppression of lower part of the double ridge. Early glume initiation.	Late six-row formation and early pale initiation.
Abnormality	As at 3–4 leaves. Also fusion and enlargement of glumes and pales.	Abnormalities of upper spikelets and enlargement of pales.
Stage 4	5–6 leaves	5–6 leaves
Apex	Glumes and pales differentiating. Anther initials appearing.	Anthers differentiating and lobing.
Abnormality	Usually none.	Usually none.
Stage 5	6–8 leaves	6–8 leaves
Apex	Anthers stalked, ovary closed or nearly so and often bearing style.	Anthers stalked, ovary closing and sometimes closed and bearing bifid style.
Abnormality	Usually none.	Usually none.
Oats	*Stage 1*	*Stage 2*
	1–3 leaves	3–4 leaves
Apex	Vegetative or transitional.	Branch initiation.
Abnormality	Tubular leaves.	Bunching of the panicle.
	Stages 3 and 4	*Stage 5*
	4–6 leaves	6–8 leaves
Apex	Spikelet differentiation.	Glumes enclose most spikelets, panicle becoming lax.
Abnormality	Mainly spikelet sterility.	Mainly spikelet sterility.

Results and discussion

The results are presented as combined data from both years' work. For brevity the full results for the abnormality trials are given only where there was a significant degree of abnormality and only the figures for CMPP are given. Yields throughout are given as a percentage of the yield from unsprayed and unweeded control plots except in wheat trial No. 5, where yields are expressed as a percentage of a hand-weeded control.

Barley

Variety trials (Grimsby, Lincs., and Thurgarton, Notts., 1957 and 1958)

The varieties tested were Domen, Haisa II, Ingrid, Pirol, Maythorpe, Proctor, Provost and Rika at the five stages mentioned above and also at jointing in the last four named. CMPP rates of 2·4 and 3·6 lb. acid equiv./acre were used and abnormalities noticed were negligible. The variety Carlsberg was tested in 1956 and showed negligible abnormality at normal and excessive rates of application.

Yield trials (yields are expressed as % of control yield)

	Trial 1 *Edwinstowe, Notts., 1957*			*Trial 2* *Whatton, Notts., 1957*			*Trial 3* *Woodborough, Notts., 1957*		
	Variety Proctor			Variety Domen			Variety Proctor		
	Control yield 21·8 cwt./acre			Control yield 31·7 cwt./acre			Control yield 19·7 cwt./acre		
CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 5–6 leaves	Stage 1 2–3 leaves	Stage 2 3–4 leaves	Stage 3 5–6 leaves
2·4	116·3**	112·6*	103·8	103·7	102·6	105·2	111·9	111·2	93·7
3·6	114·4**	117·1**	102·2	103·2	102·0	101·4	99·8	109·4	100·5
Significant differences from control	P = ·05—12·2 P = ·01—14·0			P = ·05—6·4			P = ·05—13·6		
S.E. of mean	4·5			2·3			4·9		

Trial 4
Edwinstowe, Notts., 1958
Variety Proctor
Control yield 28·8 cwt./acre

CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 5–6 leaves
2·4	103·1	104·0	104·9	105·5
3·6	100·2	107·6*	110·2**	105·6
Significant differences from control	P=·05—7·4 P=·01—9·7			
S.E. of mean	2·67			

Trial 5
Whatton, Notts., 1958
Variety Rika
Control yield 27·4 cwt./acre

CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 5–6 leaves
2·4	110·9**	100·6	106·8	107·9*
3·6	111·2**	108·2*	108·4*	107·9*
Significant differences from control	P=·05—7·0 P=·01—9·2			
S.E. of mean	2·56			

As may be seen from the results, treatment with CMPP at 2·4 lb. and 3·6 lb. acid equiv./ acre has, in all the barley varieties tested, given rise to a negligible number of abnormal heads even when spraying was carried out at highly susceptible stages of development. The effect of these treatments on the yield of certain varieties shows a satisfactory picture. In Trials 1, 4 and 5 significant and highly significant yield increases have been recorded. These increases, it is assumed, are due to the removal of weed competition. The increase in yield was not consistently greater through the earlier removal of weeds by the earlier treatments as compared with the 5–6 leaf treatment. No great significance should, however, be attached to this since the trials were, by intent, comparatively weed-free and the weed competition factor would not be fully operative.

Oats

Variety trials (Alloway, Ayrshire, and Craigeassie, Angus, 1957 and 1958)

The varieties tested were Ayr Bounty, Ayr Everest, Ayr Line, Marne, Pendek, R.30, Sun II and Victory at the leaf stages 1–2, 3–4, 4–5, and Blenda, Ayr Commando, Forward, Max, Milford and Yielder at these stages and at the 5–6-leaf stage. CMPP rates of 2·4 and 3·6 acid. equiv./acre were used and a negligible amount of abnormality was seen. A very late spray was applied at the 'boot' stage and this gave rise to spikelet sterility in all varieties. The degree of damage was worse in the varieties Yielder, Ayr Commando, Ayr Line, but was appreciable in all varieties.

Yield trials

Trial 1. Edwinstowe, Notts., 1957
Variety Sun II
Control yield 28·1 cwt./acre

CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 5–6 leaves
2·4	95·9	—	96·7
3·6	96·3	92·7	93·1
Significant differences from control	P=·05—8·6		
S.E. of mean	3·1		

Trial 2. Hope, Derbyshire, 1957
Oats Variety S.84
Control yield 19·7 cwt./acre

CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 5–6 leaves
2·4	116·8	89·8	99·2
3·6	122·6*	101·0	92·6
Significant differences from control	P=·05—21·1		
S.E. of mean	7·7		

Trial 3. Edwinstowe, Notts., 1958
Variety Sun II
Control yield 26·6 cwt./acre

CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 Boot
2·4	98·8	96·3	96·5	95·7
3·6	96·0	102·3	99·9	93·6*
Significant differences from control	P=·05—5·4			
S.E. of mean	1·95			

Trial 4. Woodborough, Notts., 1958
Variety Blenda
Control yield 27·5 cwt./acre

CMPP, lb. acid equiv./acre	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 Boot
2·4	99·5	99·2	96·5	81·1**
3·6	93·9	96·5	95·0	79·8**
Significant differences from control	P=·05— 8·5 P=·01—11·8			
S.E. of mean	3·1			

These results show that of the oat varieties tested, none showed outstanding susceptibility when sprayed during the early phases of growth. All varieties, and especially Yielder, Ayr Commando and Ayr Line, which are known to be susceptible to MCPA, exhibited spikelet sterility when sprayed with CMPP at the 'boot' stage. This is reflected in a depression of the yield of Sun II at Edwinstowe and Blenda at Woodborough in 1958 when sprayed at the 'boot' stage. The former was depressed by the high rate and the latter by both rates.

Weed control and mechanical damage considerations will normally ensure that spraying is completed long before the 'boot' stage. The occurrence of damage at this stage makes it imperative that spraying of oats with CMPP should be completed by the jointing stage.

At early growth stages CMPP caused very few tubular leaves and no bunching of the panicle or sterility whereas in some varieties, notably Yielder, Ayr Commando and Ayr Line, MCPA caused appreciable damage, however formulated.

Wheat

Variety trials

Abnormality counts and assessments (CMPP rates as lb. acid equiv./acre).—At Grimsby, 1957, 2·4 and 3·6 lb. CMPP acid equiv./acre applied at leaf stages 2–3, 4–5, 5–6 and 6–7 gave negligible abnormality with varieties Atle, Atson, Carpo, Koga II, Langensteiner, Peko and Svenno. At Woodborough, Notts., in 1957 there was considerable abnormality at the 2–3-leaf stage on the Atle variety. Other trials gave the results shown in Table II.

Table II

Variety	CMPP rates	Leaf stage tested	Abnormality %
	Linby, Notts., 1957		
Atson	2·4	2–3	Slight
,,	3·6		Considerable
Atson	2·4	3–4	Moderate
,,	3·6		Considerable
	Linby, Notts., 1958		
Koga II	2·4	1–2, 3–4	Negligible
,,	3·6	4–5, 5–6	
	Woodborough, Notts., 1958		
Atle	2·4	3–4	44
,,	3·6		70
Atle	2·4	1–2	Negligible
,,	3·6	4–5	
		5–6	
	Sibthorpe, Notts., 1958		
Atson	2·4	3–4	39
,,	3·6		55
Atson	2·4	1–2	Negligible
,,	3·6	4–5	
		5–6	

Variety	CMPP rates	Leaf stage tested	Abnormality %
	Thurgarton, Notts., 1958		
Atle	2·4	1–2	—
,,	3·6		2
Atle	2·4	3–4	17
,,	3·6		44
Atle	2·4	4–5	2·5
,,	3·6		6
Atle	2·4	5–6	Negligible
,,	3·6	6–7	
Atson	2·4	1–2	2
,,	3·6		4
Atson	2·4	3–4	13
,,	3·6		18
Atson	2·4	4–5	Negligible
,,	3·6	5–6	
		6–8	
Koga II	2·4	1–2	Negligible
,,	3·6	3–4	
		4–5	
		5–6	
		6–8	

Yield trials

The results are shown in Table III, where the yield is expressed as a percentage of control yield.

The outstanding feature of the trials with wheat is the susceptibility of the varieties Atle and Atson when sprayed during the early stages of double ridge initiation. At Grimsby in 1957 there was apparent anomaly in that only a negligible number of abnormalities occurred in these two varieties after spraying during double ridge initiation, that is at the 3–4-leaf stage. At Woodborough and at Linby in 1957 a high proportion of abnormalities ensued after spraying at this stage and, in 1958, at Woodborough, Sibthorpe and Thurgarton this pattern was repeated. It may be that the stage when CMPP causes abnormalities in wheat is extremely critical, i.e. after double ridge initiation but before appreciable suppression of the lower part. At Grimsby, where abnormalities did not occur, there was appreciable suppression of the lower part of the double ridge at the 3–4-leaf stage, whereas in the other instances there was no suppression or very little. This point will be further investigated. The yield results confirm the sensitivity of these two varieties during double ridge initiation.

The variety Koga II has consistently shown resistance to damage at all stages of growth, both in variety and yield trials. The results obtained with other varieties of spring wheat require more consideration before any conclusion can be drawn.

In the case of winter wheat, spraying in the spring is unlikely to be carried out until

Table III

CMPP, lb. acid equiv./acre	*Trial 1* *Linby, Notts., 1957* Variety Atson Control yield 24·2 cwt./acre			*Trial 2* *Woodborough, Notts, 1957* Variety Atle Control yield 22·5 cwt./acre			*Trial 3* *Kettering, Northants, 1957* Variety Cappelle Control yield 40 cwt./acre
	Stage 1 2–3 leaves	Stage 2 3–4 leaves	Stage 3 5–6 leaves	Stage 1 2–3 leaves	Stage 2 4–5 leaves	Stage 3 5–6 leaves	Fully tillered
2·4	90·9*	95·9	99·1	96·4	101·3	100·2	102·2
3·6	86·4**	86·4**	101·7	84·4**	98·2	101·1	
Significant differences from control		P=·05— 8·2			P=·05— 9·2		P=·05—4·7
		P=·01 —10·8			P=·01—12·1		
S.E. of mean		3·0			3·3		1·6

CMPP, lb. acid equiv./acre	*Trial 4* *Sibthorpe, Notts., 1958* Variety Atson Control yield 17·7 cwt./acre				*Trial 5* *Linby, Notts., 1958* Variety Koga II Control† yield 20·6 cwt./acre			
	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 6–8 leaves	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 5–6 leaves
2·4	95·3	88·2	103·0	93·9	102·8	100·0	97·8	103·0
3·6	94·6	91·8	92·0	86·3*	100·6	102·0	97·2	99·4
Significant differences from control		P=·05—13·0				P=·05—11·1††		
						P=·01—14·6††		
S.E. of mean		4·7				4·0		

† Control, not weeded, in this experiment yielded 77% of hand-weeded control.
†† Significant difference from hand-weeded control.

CMPP, lb. acid equiv./acre	*Trial 6* *Woodborough, Notts., 1958* Variety Atle Control yield 21·0 cwt./acre			
	Stage 1 1–2 leaves	Stage 2 3–4 leaves	Stage 3 4–5 leaves	Stage 4 6–8 leaves
2·4	107·0	102·1	111·9**	108·0
3·6	100·5	100·5	106·8	107·0
Significant differences from control		P=·05— 8·4		
		P=·01—11·2		
S.E. of mean		3·0		

weather conditions are suitable. Generally by then the crop will be well tillered and a safe stage of development reached. It should be borne in mind that leaf number does not bear the same relationship to apex development as in spring crops nor is it the constant relationship found in spring wheat and barley. The variety Cappelle, sprayed with CMPP at 2·4 lb. acid equivalent when well tillered, gave rise to no abnormalities and suffered no yield reduction.

Conclusions

The past two years' work has added considerably to our knowledge of the effect of CMPP on cereals.

It has been shown that on a wide range of barley and oat varieties, where weed growth makes it desirable and weather conditions permit, spraying may safely be carried out at the early stages of cereal growth. Spring oats and barley may be sprayed from the one to two leaf stage onwards but should not be sprayed once the 'jointing' stage has been reached.

The position in wheat is more complex. Whereas the varieties Atle and Atson are damaged when sprayed during double ridge initiation, that is, when the leaf stage is between two and four, Koga II is safe at all stages. Koga II may be sprayed from the one-to-two leaf stage up to the 'jointing' stage. Atle and Atson and, at present, other spring wheat varieties may be sprayed between the five-leaf stage and 'jointing'. Spraying before the five-leaf stage may give rise to abnormal heads and reduction of yield.

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SOME ASPECTS OF THE USE OF 2,3,6-TBA/MCPA MIXTURES FOR SELECTIVE WEED CONTROL IN CEREALS

by

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Results are presented for 42 yield experiments carried out during the last three years with a mixture of MCPA and 2,3,6-trichlorobenzoic acid.* This new combination of growth-regulating substances (TBA/MCPA) was in most cases compared with other selective cereal weedkillers.

All cereal crops with the exception of spring wheat were unaffected if sprayed between tillering and the beginning of the jointing stage. The safe period on spring wheat appears to be shorter and more work is required to clarify this point.

Some aspects of weed control with TBA/MCPA are briefly discussed and factors affecting the performance of TBA/MCPA are listed. Four reasons in favour of early spraying of TBA/MCPA are presented and discussed. These reasons are (*a*) maximum crop safety at earlier development stages, (*b*) most reliable weed control at early spraying, (*c*) no effect of cold weather on the action of TBA/MCPA, (*d*) early weed control is likely to give maximum yield increase.

Introduction

In an attempt to find an answer to the increasing problem of MCPA- and 2,4-D-resistant weeds in cereals, a specific activity of 2,3,6-TBA and some closely related compounds on many 'hormone-resistant' species was discovered at Chesterford Park. Further work led to the development of a new weedkiller based on a mixture of polychlorobenzoic acids (predominantly 2,3,6-TBA) with MCPA. This new herbicide combination will be referred to as TBA/MCPA in this paper.

A considerable amount of experimental work has since been carried out on this mixture in European and some tropical countries, as well as in Australia, Canada and Japan. Experimental results of the work carried out in the United Kingdom have so far not been published except in a brief summarised form by Pfeiffer,[1] while the response of 100 East African weed species to TBA/MCPA has recently been published by Gregory.[2]

The objective of this paper is to present the results of three years' field work on TBA/MCPA with emphasis on yield results. Some interesting observations and factors affecting the performance of this compound are included in this paper in a summarised form only, because of lack of space, but it is hoped that the detailed experimental evidence will soon be published elsewhere.

* It is at present not practicable to use pure 2,3,6-TBA on a commercial scale. Other chlorobenzoic acids are active, some only slightly and none as active as 2,3,6-TBA. Exact allowance for these can only be made on the basis of extensive biological tests. Most of the work described was carried out with a standard product as sold under the proprietary name Fisons 18-15.

In 2,3,6-TBA for the first time a growth-regulating compound is introduced for weed control in cereals, which in many respects differs fundamentally from phenoxy-type compounds like MCPA, 2,4-D and CMPP. For this reason a repetition could not be avoided of the type of fundamental field studies which had to be carried out over several years after MCPA and 2,4-D were introduced to agriculture and which led to a greater understanding of many practical and basic aspects of their use.

While the optimum spraying times, climatic conditions, and symptoms on plants of MCPA, 2,4-D, CMPP, etc., broadly speaking follow the same pattern, 2,3,6-TBA shows in many respects an entirely different reaction.

I. Crop Safety

Following the discovery of specific susceptibility of some important weeds to low rates of 2,3,6-TBA, problems of crop response and safety were investigated in 1956. The emphasis in the following two years was on the crop response to the TBA/MCPA combination. Practically nothing was known and published in 1956 about the effect of post-emergence sprays with 2,3,6-TBA on cereal yields, safety at low dosages, the capacity to produce ear deformities and safe crop development stages.

Results 1956

In the first year of field investigations ten yield experiments were laid out on wheat and barley with the logarithmic sprayer, to obtain an approximate idea of the dosage yield response. Owing to the small quantities of 2,3,6-TBA available only two replications could be sprayed on each site. At harvest time each logarithmic plot was sub-divided into seven sub-plots and these were harvested individually.

By taking the average of the yields obtained from the corresponding sub-plots of all ten experiments the dosage–yield response curve shown in Fig. 1 was obtained.

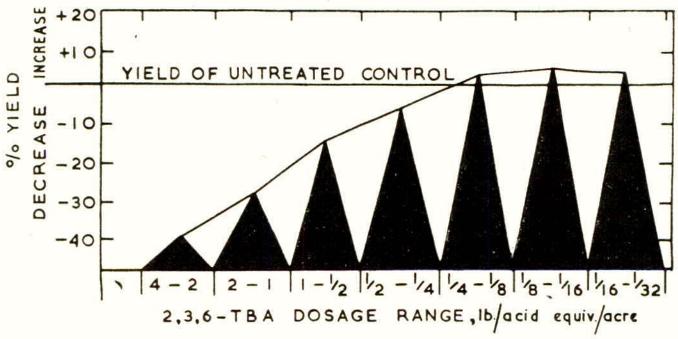

FIG. 1.—*Dosage/yield response to 2,3,6-TBA*
(average of 10 relatively weed-free logarithmic experiments, 1956)

This curve, together with other visual observations on crop safety and weed control, showed the optimum dosage to be near 4 oz. of active 2,3,6-TBA isomer per acre. No evidence obtained in the following two years gave reason to believe that this dosage was not near the optimum selectivity. In 1956 two further replicated yield experiments were carried out in addition to the ten logarithmic experiments. As at that stage insufficient was known about the safe dosage, 1 and 2 lb./acre TBA acid equivalent were chosen, this being four and eight times the safe and optimum dosage of TBA. Both experiments were on weed-free crops and showed significant yield depressions (Table I). Logarithmic experiments indicated a higher resistance of barley and oats to higher rates of TBA than spring wheat.

Results 1957

Based on the preliminary 1956 results, 22 large-yield experiments were carried out in 1957. Approximately 180 observation trials (half of them using the logarithmic sprayer) in the United Kingdom and simpler trials by other research workers in Switzerland, Holland, Denmark and Sweden as well as larger scale trials by our Contract Dept. gave additional evidence.

Table I

Relative yields of two replicated winter wheat experiments in 1956 on weed-free crops with high rates of 2,3,6-TBA

Compound	Dosage, lb. acid equiv./acre	Expt. 1	Expt. 2
2,3,6-TBA	1	72·1	77·7
2,3,6-TBA	2	57·2	68·3
MCPA	1	107·2	87·7
MCPA	2	99·2	88·9
2,4-D	1	95·6	95·3
2,4-D	2	94·2	90·3
Controls	—	100·0	100·0
Significant difference at P=·05	—	22·5	19·7

Yield experiments included a standard dosage of MCPA, CMPP, DNC, 2,4-D and a mixture of dinoseb with MCPA as well as the TBA/MCPA combination. Each treatment was eight times replicated on each experiment. The results are presented in Tables IIa–d. Most experiments were chosen on practically weed-free sites in order to allow a critical assessment of crop safety.

Table II

Yield results in 1957
(yields as % of untreated controls)

(a) *Winter wheat*. Varieties: Cappelle in Expts. 1–3, 6, 7; Hybrid 46 in Expt. 4; Minister in Expt. 5

No.	Spraying date	Treatments, lb./acre: MCPA 0·78	CMPP 2	TBA/MCPA 0·25 2,3,6-TBA	MCPB 2	DNC 6	Dinoseb +MCPA 0·9+0·3	Smallest significant difference at P=·05	Untreated control, yield, cwt./acre
1	8.1.57	120·2	124·5	119·2	122·1	118·4	124·3	10·8	26·5
2	25.3.57	114·1	146·5	153·5	—	161·0	146·8	—*	12·9
3	11.1.57	98·3	101·8	100·8	101·2	—	—	8·8	27·3
4	29.3.57	104·1	103·4	102·5	—	104·4	102·9	4·4	42·4
5	29.3.57	101·6	106·4	103·2	—	102·4	104·4	8·0	34·4
6	1.4.57	102·0	99·1	95·6	—	104·0	99·7	5·6	39·1
7	1.4.57	99·4	97·1	87·3	—	98·2	94·0	13·4	29·8

* Due to great variation, analysis of variance not applicable

(b) *Spring barley*. Proctor variety

No.	Spraying date	Treatments, lb./acre: MCPA 0·78	2,4-D 1	CMPP 2	TBA/MCPA 0·25 2,3,6-TBA	DNC 6	Smallest significant difference at P=·05	Untreated control, yield, cwt./acre
1†	31.5.57	99·8	96·9	93·4	93·1	102·8	18·5	14·9
2†	22.5.57	101·1	98·2	94·9	96·1	105·1	6·4	27·5
3†	28.5.57	99·1	99·3	100·4	90·7	92·8	13·5	26·6
4†	30.5.57	99·6	106·2	97·4	94·1	102·2	7·6	19·1
5†	14.6.57	92·8	92·8	101·0	90·0	94·8	15·3	17·1
6	15.5.57	97·7	97·5	101·3	99·2	—	8·1	34·8
7†	29.5.57	95·5	94·9	99·4	97·9	—	8·1	34·8

† All these experiments were sprayed late (end of May and early June)

(c) *Spring wheat*. Varieties: Progress in Expt. 1; Peko in Expt. 2; Koga II in Expt. 3; Atson in Expt. 4

No.	Spraying date	MCPA 0·78	2,4-D 1	CMPP 2	TBA/MCPA 0·25 2,3,6-TBA	DNC 6	Smallest significant difference at P=·05	Untreated control, yield, cwt./acre
1	21.5.57	95·1	91·1	92·8	101·4	102·2	7·4	33·2
2††	22.5.57	104·0	95·9	103·0	93·2	102·4	8·7	18·2
3††	30.5.57	95·6	96·7	90·3	88·3	101·0	7·9	23·4
4††	29.5.57	99·7	100·3	95·1	85·2	108·8	12·5	14·1

†† These three experiments were sprayed end of May at the advanced jointing stage

(d) *Spring oats*. Varieties: Blenda in Expts. 1, 2 and 4; Deva in Expt. 3

No.	Spraying date	MCPA 0·78	2,4-D 1	CMPP 2	TBA/MCPA 0·25 2,3,6-TBA	DNC 6	Smallest significant difference at P=·05	Untreated control, yield, cwt./acre
1	31.5.57	100·8	69·9	82·2	95·7	94·9	19·9	10·3
2	21.5.57	99·3	95·5	99·0	98·4	95·3	9·5	34·5
3	28.5.57	108·3	100·4	93·7	100·8	103·8	9·4	16·5
4	21.5.57	95·6	90·9	102·5	99·8	99·7	9·0	23·8

The climatic conditions in 1957 were characterised by a rather exceptional drought in May and June. As sufficient was not known at that time about safe crop development stages, the spraying was done at a wide range of such stages. The results clearly indicated the dangers of too late spraying on spring wheat.

The question of correct timing with particular reference to ear deformities was investigated in 1957 in a spring barley experiment in which spraying was carried out at 14 different dates ranging from the three-leaf stage to ear emergence. Yields were taken from six replications for each spraying date. The results shown in Table III indicate crop sensitivity to late sprayings of TBA/MCPA.

Table III

Relative yield results from a spring barley experiment in 1957
(dosage, lb./acre)

No.	Spraying date	Stage of plants when sprayed	Yields (% of control) 2,4-D 1	MCPA 1	TBA/MCPA 0·25 2,3,6-TBA
1	3.5.57	3 leaves, 50% plants with 1 small tiller	89	97	93
2	7.5.57	3–4 leaves, 0–2 tillers	102	99	105
3	10.5.57	3–4 leaves, 1–2 tillers	93	94	102
4	13.5.57	5 leaves, 2 tillers	87	96	105
5	17.5.37	6–8 leaves, 3 tillers	89	106	95
6	21.5.57	7–10 leaves, 3–4 tillers	106	106	94
7	23.5.57	10–14 leaves, 3–6 tillers	103	103	96
8	27.5.57	14″	100	91	100
9	30.5.57	15″, ear 1–2″ up main tiller	95	93	94
10	5.6.57	18″, ear 4–6″ up main tiller	101	95	93
11	7.6.57	20″, ear 6″ up main tiller	109	106	101
12	11.6.57	22″, ear 8″ up main tiller	104	96	87
13	17.6.57	ear 10″ up main tiller	91	94	81
14	2.7.57	Ears fully emerged	98	93	89

It was therefore decided to restrict the practical recommendations to spraying before the jointing stage of the crops. Only one yield experiment on spring wheat was sprayed before the jointing stage; this did not show a yield reduction due to TBA/MCPA.

The number of deformed ears after spraying with MCPA, 2,4-D and TBA/MCPA was counted in two spring barley and one spring wheat experiment in 1957. The results are shown in Table IV. In each of these experiments spraying was carried out within the early sensitive growing period of the crops. Each figure in Table IV is based on a representative sample of approximately 500 ears. It can be concluded from the results that TBA/MCPA compares favourably with a normal dosage of MCPA in its capacity to produce ear deformities and is much less toxic in this respect than a normal dosage of 2,4-D.

Table IV

Relative degree of ear deformity produced by early spraying with MCPA, 2,4-D and TBA/MCPA
(dosages, lb./acre)

		Relative deformity					
		High rates			Low rates		
Crop	No. of sprayings averaged*	MCPA 1½	2,4-D 1½	TBA/MCPA 0·25 2,3,6-TBA	MCPA ¾	2,4-D ¾	TBA/MCPA ⅛ 2,3,6-TBA
Spring barley	5	100	306	102	36	157	47
Spring barley	5	100	230	107	67	125	70
Spring wheat	6	100	178	70	64	187	46
Average		100	238	93	56	123	54

* Different plots were sprayed every 3 or 4 days, and the results are the average of all sprayings carried out within the susceptible stage.

The 1000-grain weight of samples from 25 experiments sprayed in 1957 with TBA/MCPA and untreated controls were taken showing the following results (Table V). No significant differences could be detected.

Results 1958

Since the results in 1957 indicated that correct timing is a very important factor for optimum selective effects with TBA/MCPA, particular emphasis was paid to an investigation of this aspect in 1958. It was evident from previous experience that correct timing was of far less importance on oats and barley than on winter wheat and especially on spring wheat.

Three winter wheat and three spring wheat experiments were therefore laid out in which TBA/MCPA, MCPA, 2,4-D, CMPP and DNC were sprayed at five and four different development stages respectively, ranging from the two-leaf stage to full ear emergence. The treatments

Table V

1000-grain weights from trials in 1957

Crop	No. of expt. on which figures are based	1000-grain weight, g. Untreated	TBA/MCPA 4 oz. 2,3,6-TBA/acre	
Winter wheat	7	50·8	51·5	Difference not significant at P = ·05
Spring wheat	5	40·6	39·7	
Winter barley	1	35·8	39·0	
Spring barley	5	38·4	38·4	
Winter oats	2	32·0	32·8	
Spring oats	5	32·7	31·6	

at each time were replicated eight times in each experiment. All experimental sites with one exception (spring wheat) were either practically weed-free or infested with a moderate population of annual grass weeds or *Viola tricolor*, a weed resistant to all growth-regulating substances including TBA/MCPA. Significant results were obtained particularly by averaging the results from the three winter wheat experiments and the three spring wheat experiments.

(a) *Winter wheat*

Three winter wheat experiments were conducted as follows:

	Expt. 1	*Expt. 2*	*Expt. 3*
Variety	Hybrid 46	Cappelle	Cappelle
Site	Peat fen soil (Haddenham)	Light chalky loam (Royston)	Chalky loam (Fulbourn)
Mean control yield, cwt./acre	34·9	24·2	22·1
Significant difference at P = ·05 (split plot design):			
For treatments at one time	8·16	6·94	8·87
For one treatment at different times	8·17	7·75	13·40

The average results are shown in Table VI, from which the following points can clearly be seen:

(1) Spraying before tillering was remarkably safe with TBA/MCPA, CMPP, MCPA and DNC. 2,4-D sprayed at the same time caused a marked and significant depression in yield associated with numerous onion leaves and ear deformities.

(2) DNC showed a significant yield increase in one experiment at the early sprayings, which confirms Riepma's[3] original findings.

(3) TBA/MCPA, while safe up to the beginning of jointing, significantly reduced the yield if sprayed later. TBA/MCPA thus shows the opposite behaviour to 2,4-D.

(4) MCPA and CMPP appear to be relatively safe at all development stages.

Table VI

Average yield result of the three winter wheat experiments, 1958

Treatments	Spraying date and crop development stage: December 1–3 leaves	End March Tillering	Early May Early jointing	End May Pre-ear emergence	Early June Ears emerging
MCPA–1 lb./acre	97·3	104·0	104·3	102·7	99·7
2,4-D–1 lb./acre	81·7	94·9	99·7	98·5	97·9
TBA/MCPA–4 oz. 2,3,6-TBA	100·9	102·2	99·4	89·3	73·1
CMPP–2 lb./acre	101·4	99·9	98·7	97·0	100·5
DNC–6 lb./acre	107·7	104·1	103·1	101·3	97·1
Controls	100·0	100·0	100·0	100·0	100·0

Significant difference for P = ·05–8·68

(b) *Spring wheat*

The results of the three spring wheat experiments using Koga II variety confirm the 1957 yield results indicating that spring wheat is the most sensitive of all cereal crops with regard to correct timing. It appears that the period at which TBA/MCPA can be sprayed with complete safety is rather short. More detailed work will be undertaken on this subject in 1959.

In one of the experiments which was heavily infested with hempnettle and wheat yield was low, there were large increases (Table VII) which by far outweigh the depression which was likely to have occurred if this crop had been weed-free. This experiment is of particular interest since it reflects similar relative effects of all compounds as was shown in Table VI on winter wheat. The only substantial difference is that in this weedy experiment all yields are far above the untreated controls giving yield increases of 100–300%.

(c) *Spring barley*

Only one large experiment was carried out on this crop. Contrary to the results obtained on wheat, 2,4-D, MCPA and TBA/MCPA slightly reduced the yield if sprayed before tillering, while CMPP proved safe in this respect. The results are shown in Table VIII.

Table VII

Spring wheat experiment III/58
Koga II: peat fen soil (Burwell)
(very weedy site; hempnettle)
Mean control yield = 3·2 cwt./acre

Treatment	Spraying date and crop development stage			
	16.4.58	9.5.58	21.5.58	10.6.58
	2 leaves	Tillering	Jointing	Pre-ear emergence
MCPA–1 lb./acre	171·0	368·2	363·1	407·2
2,4D–1 lb./acre	82·0	182·9	115·0	292·5
TBA/MCPA– 4 oz. 2,3,6-TBA	248·6	372·4	309·1	149·1
CMPP–2 lb./acre	135·7	368·2	338·3	306·1
DNC–6 lb./acre	292·8	411·7	473·6	324·8
Controls	100·0	100·0	100·0	100·0

Significant differences for
P = ·05 (split plot design)
For treatments at one time = 59·96.
For one treatment at different times = 66·47.

Table VIII

Spring barley experiment I/58
Proctor: heavy clay (Chesterford)
Mean control yield = 23·7 cwt./acre

Treatment	Spraying date and crop development stage			
	8.5.58	19.5.58	13.6.58	30.6.58
	3 leaves	Tillering	Pre-ear emergence	At ear emergence
MCPA–1 lb./acre	85·1	89·2	92·9	96·4
2,4D–1 lb./acre	80·5	93·9	92·0	94·8
TBA/MCPA– 4 oz. 2,3,6-TBA	90·5	98·1	88·5	93·6
CMPP–2 lb./acre	97·6	96·4	88·6	91·1
DNC–6 lb./acre	99·2	97·2	86·4	87·8
Controls	100·0	100·0	100·0	100·0

For treatments at one time = 8·31.
For one treatment at different times = 8·83.

II. Factors affecting weed control

About 200 field trials over three years supported by laboratory investigations during the winter have enabled us to throw some light on the weed response and factors influencing the performance of TBA/MCPA. Large-scale field experience in 1958 and trials carried out over two years in a number of European and other countries contribute to the significance of the general conclusions presented in a summarised form below.

(1) Experience to date confirms that the following of the more important 'hormone-resistant' weeds are susceptible to TBA/MCPA: cleavers (*Galium aparine*), mayweed (*Matricularia* and *Anthemis* species), redshank (*Polygonum persicaria*), chickweed (*Stellaria media*). Coltsfoot (*Tussilago farfara*), originally thought to be controlled, proved rather resistant in field practice. Bugloss (*Echium vulgare*), on the other hand, proved highly susceptible, contrary to expectations. Different mayweed species appear to react somewhat differently but further work is required to clarify this point.

(2) In order to get reliable and complete control, weeds susceptible to TBA must be fully exposed to the spray. The recommended dosage of 4 oz. of TBA/acre is rather critical and cannot be regarded as a substantial overdose, such as for instance the normal MCPA dosage recommended for charlock control. The flag of the crop covering the weeds can prevent sufficient penetration of the spray to the weeds. Many of the 'hormone-resistant' weeds, such as mayweeds, chickweed and cleavers, are often well hidden under the crop in contrast to weeds such as charlock (*Sinapis arvensis*) and hempnettle (*Galeopsis tetrahit*) which grow up with it.

(3) All results up to date clearly indicate the importance of early spraying with TBA/MCPA. Outstanding results have been obtained wherever early spraying was done even in the most difficult season of 1958. This point cannot be over-emphasised.

(4) In the extremely wet season of 1958, mayweeds, cleavers and chickweed in some cases

outgrew the severe initial effect of TBA/MCPA. This phenomenon had never been experienced in 1956 and 1957 when death ultimately followed the initial severe check. Experimental evidence has shown a positive correlation between the growing vigour of weeds and the dosage of TBA required to give lasting control. This is contrary to experience with phenoxy-type herbicides which require active growth for maximum effectiveness.

(5) Our original discovery that the action of TBA is not affected by cold weather conditions has been confirmed by experiments in Scandinavia and Japan as well as by this year's large field experience in the U.K. Information from the same sources independently indicates that TBA/MCPA is less affected by rain following soon after spraying, than other growth-regulating herbicides.

General discussion to Parts I and II

All experimental results indicate that maximum selectivity and reliability can be obtained from *early* applications of TBA/MCPA. The reasons in favour of early spraying are:

(1) Spraying of cereal crops is safest in their earlier development stages (between tillering and the beginning of the jointing stage).

(2) Weeds are best controlled if sprayed when small and fully exposed to the spray.

(3) The action of TBA/MCPA is unaffected by cold weather.

(4) Maximum yield increase is likely to occur from eliminating weed competition not later than the tillering stage.

Some aspects of these points need further consideration. The problem of safety to spring wheat is not yet clarified by experimental evidence and the safe period when this crop can be sprayed with TBA/MCPA may be too short to allow reliable recommendations to be made. The safe period for winter wheat extends to at least 6 weeks from mid-March to early May. Later spraying leads to marked yield reductions. These reductions may be due to the fact that as the total foliage area of a wheat plant increases, the dosage received and absorbed by the plant increases accordingly. Thus damage symptoms occur which are of the same nature as those following application of 4–8 times the recommended dosage at earlier development stages.

The symptoms of overdosing or too late application are sterility of flowers and increased susceptibility to certain fungi such as Cladosporium. It must be emphasised that no such effects have been observed when spraying is carried out at the recommended dosage during the safe growing period.

Very early spraying for obvious reasons cannot give a control of late-emerging weeds such as thistles. There is no other answer to this problem, which is a very general one, than a second and later application of MCPA.

Work on TBA/MCPA can by no means be regarded as completed, and will even be intensified in the next few years. It is not unlikely that the unexpected and specific properties of TBA can be used to produce new combinations of herbicides with an even wider range of weed control and greater selectivity than TBA/MCPA.

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THE RELATIVE SUSCEPTIBILITY OF CEREAL VARIETIES TO GROWTH REGULATOR HERBICIDES. SOME PRELIMINARY INVESTIGATIONS WITH MCPA AND 2,4-D (ALSO CMPP AND 2,3,6-TBA)

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Experiments were carried out during the period 1955–8 mainly to investigate the effects of MCPA and 2,4-D on different varieties of spring wheats, oats and barleys. CMPP and 2,3,6-TBA were also tested on a limited scale in 1957 and 1958. Heavy doses of MCPA and 2,4-D when applied at an early growth stage caused more ear deformities in some varieties than in others. The evidence suggests that this is not simply due to different stages of development having been reached at the time of spraying. There are also indications of varietal differences in reaction to 2,3,6-TBA and to a lesser extent CMPP.

Introduction

With the great increase in use during recent years of the growth regulator herbicides there have been various reports by farmers and others of varietal differences in susceptibility to spray damage. A most striking example occurred at Sutton Bonington in 1955 in a spring oat variety trial sprayed with a commercial 2,4-D (ester) preparation at 4 oz./acre just before shooting. Of the six varieties included in the trial only two, namely, Blanche de Wattines and Flamande-Desprez, were severely damaged. In these, the flag leaves were rolled, the panicle branches tended to be erect and there were many blind florets. The crop did not mature normally, forming late tillers which were still green at harvest. The yield of both was reduced to less than 50% of the yield of Sun II, which was the 'control' variety, although it has been shown by many trials that under normal conditions the yield of these two varieties is only slightly less than Sun II. The estimated loss in yield through using 2,4-D on these particularly susceptible oat varieties is estimated to be about 17–18 cwt./acre in this instance.

The aim of the work summarised here was to investigate this subject and the problem of testing cereal varieties for susceptibility to spray damage during the period that they are undergoing normal variety trials at the N.I.A.B. In these experiments which were carried out at Cambridge and planned in consultation with the staff of the A.R.C. Unit of Experimental Agronomy at Oxford, the criterion of spray damage was plant deformity and not the possible effect on yield.

Material and methods

It was decided in 1955 to restrict the work in the first place to an investigation into the effect of a single, rather heavy dose of MCPA and 2,4-D to be applied at a fairly early growth stage to those spring varieties of wheats, oats and barleys which were included on the Recommended Lists of the N.I.A.B. at that time. The rates chosen were 3 lb./acre acid equiv. of MCPA amine and 2 lb./acre of 2,4-D amine to be applied when all varieties were at about the 2- or 3-leaf stage. This experiment was repeated in 1956 with certain extra varieties.

In Expts. 1 and 2 the corn was drilled in a randomised block lay-out with 4 replications. Each plot, which was 5 rows wide and about 9 yards long, was sub-divided into three sub-plots for the two treatments and control. The sprays were applied in a 2-yard swath across the plots by means of an Oxford Precision Sprayer (30 lb./sq. in., 10·6 gal./acre). Records on the behaviour of the varieties were made throughout the growing season and, at maturity, the plants from 1-yard lengths of the centre of the inner three rows of each sub-plot were assessed for deformities and the percentage of normal and deformed ears calculated. The wheats and barleys were assessed in the field, the oats were pulled up and assessed in the laboratory.

In 1957 and 1958 further work was carried out using the logarithmic spraying principle with the same chemicals applied to three varieties of each crop which appeared to differ in susceptibility in the 1955 and 1956 experiments. In 1958 CMPP and 2,3,6-TBA were also used. The results of this work will be reported elsewhere.

Results

Expt. 1 was drilled on 21st March, 1955, and Expt. 2 on 22nd March, 1956. In both years the barleys were sprayed on 23rd April. In 1955 by this date the varieties were, on the average, almost at the 3-leaf stage, and in 1956 they were just past the 2-leaf stage. The wheats and oats were sprayed a few days later in each year, when the wheats were almost at the 3-leaf stage and oats at the 2–3-leaf stage.

The mean percentage of normal ears remaining in the sprayed sub-plots of each variety is given in Table I.

Spring wheats

Bersee gave the highest proportion of normal ears in 1955 and in 1956 from both MCPA and 2,4-D plots. In each case it was significantly better than most, if not all, the other spring wheats tested. Fylgia suffered most damage in 1955 from both chemicals. It was not as bad in 1956, although Fylgia II did suffer badly that year. Atle was severely damaged by 2,4-D in 1956. Peko and Svenno, which were introduced in 1956 for the first time, were less damaged than any of the other varieties, except Bersee.

Spring oats

Maldwyn, and to a less extent Milford, Primus II and Clinton, appeared to be more than usually susceptible to MCPA damage in 1955, also in 1956 although damage in that season was slight even in these varieties. Flamande-Desprez, which was introduced in 1956, suffered far greater damage from MCPA than any other oat. In the case of the 2,4-D results one interesting

Table I

% of normal ears following spraying with MCPA amine at 3 lb./acre and 2,4-D amine at 2 lb.-acre at the 2–3-leaf stage

(dosage as acid equiv.)

	MCPA			2,4-D		
	1955	1956	Means	1955	1956	Means
a) *Wheat*						
Atle	66	50	58	25	12	19
Atson	54	42	48	20	30	25
Bersee	72	82	77	38	46	42
Fylgia	24	52	38	8	25	17
Fylgia II	—	38	—	—	14	—
Peko	—	57	—	—	39	—
Svenno	—	62	—	—	28	—
Significant difference (P=·05)	15	12		17	13	
(b) *Oats*						
Blenda	94	100	97	58	72	65
Clinton	85	93	89	53	39	46
Eagle	94	100	97	62	55	59
Maldwyn	64	92	78	32	54	43
Milford	68	98	83	65	64	65
Opus	92	98	95	61	62	62
Orion III	92	98	95	82	80	81
Primus II	82	97	90	47	37	42
Sun II	92	100	96	64	52	58
Flamande-Desprez	—	81	—	—	39	—
Significant difference (P=·05)	16	5		19	16	
(c) *Barley*						
Camton	59	65	62	48	45	47
Carlsberg	26	36	31	16	16	16
Earl	38	63	51	51	66	59
Freja	56	51	54	52	50	51
Herta	48	58	53	52	50	51
Maythorpe	21	37	29	28	31	30
Plumage-Archer	48	63	56	40	48	44
Proctor	41	60	51	29	18	24
Provost	36	47	42	34	38	36
Rika	53	62	58	50	56	53
Spratt-Archer	57	75	66	58	55	57
Kenia	—	56	—	—	28	—
Significant difference (P=·05)	15	Not significant		10	20	

point is that the two earliest ripening varieties, namely Orion III and Primus II, were, respectively, the least and among the most, damaged both in 1955 and 1956. Differences between the other varieties were not very great. As with MCPA, Clinton and Flamande-Desprez suffered rather more than other varieties.

Spring barleys

Carlsberg and Maythorpe were the two barley varieties most susceptible to damage from MCPA and Carlsberg from 2,4-D. The results of these experiments give some confirmation to the commonly held belief that the older English barleys, Spratt-Archer, Plumage-Archer and Earl, are less liable to be damaged than the more recently introduced Scandinavian varieties and crosses.

The technique used in Expts. 1 and 2 necessitated spraying all varieties of each crop at the same time. A detailed assessment of the exact growth stage of each variety at the time of spraying was not made, but it was clear that there were no great differences in the leaf number of each variety. Nevertheless, it seemed possible that the apparent varietal difference in susceptibility shown in Expts. 1 and 2 could be accounted for by differences in stage of development at the time of spraying.

Growth stage

Accordingly in 1957 Expt. 3 was carried out. Three varieties of wheat and oats and four varieties of barley, which appeared, from the previous work, to differ in susceptibility, were each sown in single, long, adjacent rows on 2nd April, 1957. Successive short lengths of all were sprayed on nine occasions at intervals of 3 or 4 days commencing on 23rd April, when the plants were at the 1- to 2-leaf stage. The last treatment was given on 21st May when the oats were between the 4- and 5-leaf stage, the wheats at about the 5-leaf stage, and the barleys between the 5- and 6-leaf stage. 2,4-D amine was used at the rate of 2 lb./acre acid equiv. The average leaf number of each variety at each time of spraying was calculated from counts made on 20 plants. The plants were scored on 5th June for severity of leaf deformity, namely narrow and erect, or tubular leaves. The spring wheats were also harvested at maturity and the percentage of normal and deformed ears of each variety with each treatment assessed. Unfortunately the oats and barleys became lodged and too badly damaged to give useful counts of deformities.

Table II shows, for each time of spraying, the stage of growth reached by each variety (as judged by the leaf number), the assessment of damage on 5th June, and in the case of the wheats the percentage of deformed ears produced. In each of the crops there were generally slight differences in leaf number between the varieties at each time of spraying. The primordia were not dissected out but it is reasonable to conclude that there were also certain differences in primordial development which could account for some differences in spray damage. However, in the case of the wheat and oats varieties in this experiment it seems very unlikely that differences in rate of development of the plant could, alone, account for such large differences in susceptibility as were apparent. When scored on 5th June, Fylgia II at every stage of spraying from the 2-leaf to the 4-leaf stage was more severely damaged than Svenno at any stage during this period. Similarly Flamande-Desprez and, to a lesser extent, Maldwyn were much more severely damaged after every spray treatment than was Sun II after any treatment between the 1-leaf and $2\frac{1}{2}$-leaf stage. This covered a period of two weeks during which time the three varieties must have passed through similar stages of development, even if they did not occur at exactly the same time. It appears that some factor other than stage of development at the time of spraying must be involved.

New varieties

In order to obtain some early indication of whether any of the new varieties which are undergoing trials at the N.I.A.B. might be particularly susceptible to spray damage, simple observations on the effect of the herbicides on the new varieties have been undertaken during the last two years. In 1957 a single heavy dose of MCPA, 2,4-D and CMPP was applied to the ends of the plots of the preliminary variety trials at Cambridge of spring wheat, oats and barley (Expt. 4). An Oxford Precision Sprayer was used (30 lb./sq. in., 10·6 gal./acre) and details of the rates of application and materials used are given in Table III. This experiment

Table II

Varietal differences in the extent of deformities caused by spraying with 2,4-D amine at 2 lb./acre acid equiv. at various growth stages
(Date of sowing, 2nd April, 1957)

		April			May					
	Date of spraying:	23	26	30	3	7	10	14	17	21
Wheat										
Average no. of leaves visible at each spraying	Atle	1·7	2·0	2·4	2·9	3·2	3·6	4·1	4·5	4·6
	Fylgia II	1·8	2·0	2·7	2·9	3·0	3·8	4·1	4·8	5·0
	Svenno	1·9	2·0	2·8	3·0	3·4	3·9	4·4	4·8	5·3
Visual assessment of damage on 5th June*	Atle	2	2	2	2	3	2	1	1	0–1
	Fylgia II	3	2	2	3	2	2	1	1	0–1
	Svenno	2	1	0–1	1	0–1	0–1	0–1	0–1	0
% of normal ears at maturity	Atle	39	29	6	7	25	28	47	83	89
	Fylgia II	65	36	25	14	5	30	70	80	93
	Svenno	55	38	17	34	38	81	91	97	100
Oats										
Average no. of leaves visible at each spraying	Sun II	1·1	1·9	2·1	2·8	3·1	3·5	4·1	4·8	4·9
	Maldwyn	1·0	1·3	1·8	2·2	2·7	3·0	3·5	3·9	4·6
	Flamande-Desprez	1·4	1·8	2·0	2·4	2·9	3·1	3·7	3·9	4·3
Visual assessment of damage on 5th June*	Sun II	1	2	1	1	1	0	0	0	0
	Maldwyn	3	3	3	3	2–3	1	0	0	0
	Flamande-Desprez	4	4	3	3	2	1	0	0	0
Barley										
Average no. of leaves visible at each spraying	Earl	2·0	2·0	2·9	3·1	4·0	4·4	4·9	5·1	5·6
	Spratt-Archer	2·0	2·1	2·7	3·1	3·6	4·2	4·3	4·8	5·5
	Proctor	2·0	2·0	3·0	3·1	3·9	4·0	4·6	5·0	5·7
	Carlsberg II	2·0	2·1	2·6	3·2	4·0	4·5	5·0	5·2	5·7
Visual assessment of damage on 5th June*	Earl	1	1	1	0	0	0	0	0	0
	Spratt-Archer	1	1	2	0	0	0	0	0	0
	Proctor	1–2	1	1	0	0	0	0	0	0
	Carlsberg II	1–2	0–1	0	0	0	0	0	0	0

* Scale 0 (= no damage) to 4 (= 100% abnormal leaves).

was repeated in 1958 with the addition of 2,3,6-TBA (Expt. 5). Each variety was scored on a simple scale for the amount of obvious damage, this included both ear deformities and general stunting of the plant.

The number of varieties tested in this way in 1957 and 1958 respectively were: spring wheat 16, 20; spring oats 25, 24; spring barley 12, 30; the total number of different varieties tested being 26, 34 and 36 respectively.

The results of the assessments are summarised in Table III. Only the varieties which appeared to be unusually liable to, or resistant to, damage from the chemicals concerned are listed. The treatments were applied to two replicates of each variety in 1957 and three in 1958. Critical examinations were not possible on such a large number of plots. Wide differences in maturity and differences in ear or panicle type between varieties make simple observations of this type liable to error. Nevertheless it is felt that varieties which are highly resistant or susceptible to damage can be picked out.

The difference between varieties of spring wheat in their reaction to the heavy and late application of 2,3,6-TBA in 1958 was particularly obvious. Not only was there a substantially greater reduction in plant height in certain varieties, but there was also a lack of development in the spikelets in the upper part of the ear. Measurements were made of certain varieties. The straw length of Strube 6339/48 was reduced by 2·8 in. but of Jufy I by only 0·6 in.

Discussion

These experiments have confirmed that varieties of spring wheats, oats and barleys do differ in their reaction to the growth regulator herbicides. In some instances the differences appear to be quite large, which emphasises the importance of testing any new herbicide on a wide range of varieties before it is placed on the market. The factors which cause one variety

Table III

Varieties which simple observations suggested might be unusually liable to, and resistant to, spray damage
(Expt. 4 and 5)

Chemical	MCPA		2,4-D		CMPP		2,3,6-TBA
Year	1957	1958	1957	1958	1957	1958	1958
Rate of application, oz./acre	48 (amine)	32 (K salt)	32 (amine)	28 (amine)	48 (amine)	64 (amine)	8 (Na salt)
Wheat							
Average growth stage at time of spraying	(3–)4 leaf	4–5 leaf	(3–)4 leaf	4–5 leaf	(3–)4 leaf	4–5 leaf	Shooting
Appeared most severely damaged	Werna	Carpo W.5323	Alfy II Erli Teutonen	Heurtebise Koga II Svenno Sv. 01281	Alfy II Ritchie Sv. 01200	No damage recorded	Atle Carpo Strube 6339/48 Svenno W.5050 W.5323 Jufy I Norrona W.5583
Appeared least severely damaged	Alter Carpo Koga II	ELS Norrona Phoebus Werna Sv. 01281 W.5050	Alter Carpo Svenno	Werna Sv. 01280	Alter Carpo Koga II		
Oats							
Average growth stage at time of spraying	(3–)4 leaf		(3–)4 leaf		(3–)4 leaf		Shooting
Appeared most severely damaged	Angus Blanche de Wattines Flamande-Desprez	Lodging too severe to record plots	Angus Nestor 16004	Lodging too severe to record plots	Angus Blanche de Wattines Flamande-Desprez Max Milford 26/7	Lodging too severe to record plots	Condor Silber II Vollbringer 3449
Appeared least severely damaged	All others (no damage)		Starlette de Moyencourt Sun II 26/7		All others (no damage)		Vigor 16004 54015
Barley							
Average growth stage at time of spraying	3 leaf	(4–)5 leaf	3 leaf	(4–)5 leaf	3 leaf	(4–)5 leaf	Nearly in ear
Appeared most severely damaged	Glasnevin No. 3 Ymer	Maythorpe W.5573	Glasnevin No. 3 Mentor Ymer	Beka Frisia Vada Union W.5573	Mentor Ymer	No damage recorded	Luidenberg 51/1 Sv. 50/102 HB.281/6/5/9
Appeared least severely damaged	Frisia	All others (no damage)	Frisia Ponote	All others (negligible)	Frisia Piroline Wisa		Frisia Volla

to be more resistant to damage than another have not been fully investigated except to show that some feature other than growth stage appears to be involved. The possible effects of different formulations have not been explored, nor has sufficient work been carried out on the practical significance to the farmer of such differences as appear to exist between varieties.

In these experiments heavy doses were used and in many cases the chemicals were not applied at the commercially recommended growth stage. It is assumed that the varietal differences in response which were demonstrated would have been far smaller, or even absent, if the manufacturers' recommendations had been followed.

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CONTROL OF *GALIUM APARINE* WITH MCPP IN FRANCE

by

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Introduction

We have conducted some experiments with α-(chloro-2-methylphenoxy)propionic acid (MCPP), which is known to have a selective phytotoxicity on *Galium*,[1] which plant is now very common in France.

Control of *Galium aparine* L. (cleavers) constitutes an important problem in connexion with cereals, not only because of its bad effect on the growth of cultivated plants, but also because it makes harvesting very difficult using mechanical means. For many years, the most widely employed chemical control method has been the use of synthetic herbicides such as 2-methyl-4-chlorophenoxyacetic acid (MCPA) and 2,4-dichlorophenoxyacetic acid (2,4-D). The number of weeds susceptible to those chemicals has considerably decreased, but places free of weeds become infested with 'resistant' weeds, among which *Galium aparine* is one of the most important. Furthermore, the propagation of seeds has been aggravated by the use of machinery in agricultural works.

In 1958 the first seeds germinated about 25th February and seedlings were found continually until harvest. The oldest plants started flowering in the region of Paris on 10th May and the first seeds were ripe at the beginning of July. In some places more than 100 plants per sq. m. were found, representing a vegetal bulk of about 400 g. in weight.

G. aparine is often coupled with chickweed (*Stellaria media* Will.), annual dog's mercury (*Mercurialis annua* L.), peachwort (*Polygonum fusicaria*), knotweed (*Polygonum aviculare*), ivy-leaved speedwell (*Veronica hederifolia* L.) and germander speedwell or bird's eye (*Veronica chamaedrys* L.).

G. aparine grows throughout France but chiefly in the northern part, in the Massif Central (particularly on the western borders), Brittany and in some places in the Ile de France and Alsace.

Experiments in 1958

Procedure

The tests were carried out in the Ile de France at Vélannes (Seine-et-Oise). Plots were 10 × 10 m. and weeds were counted at the commencement of the trial. Each experiment was repeated four times. MCPP was used as the potassium salt (MCPP-K) containing 32% of acid equivalent. It was used at the rate of 1·92 and 2·56 kg. of active material in 1000 l./ha. A portable spraying apparatus was used. The plots were sprayed on 23rd April, i.e. after tillering of the cereal and when *Galium* were 12 cm. tall.

DNOC ammonium salt (DNOC-NH_4) was used as a reference material. The product was applied on 4th March, 1958, at the rate of 2–4 kg./ha., when *Galium* plantlets were 2 cm. tall and in the 1- and 2-leaf stage. Some plots were left untreated as controls.

The weather conditions for the DNOC treatment were:

On 4th March there were clouds in the morning and bright periods in the afternoon; ground temperatures, max. 16°, min. 3°.

Between 5th and 15th March the average temperatures were: max. 10·2°, min. —3·1°. There were clouds, snow and a few sunny periods.

Results

Results were obtained for treated and untreated plots by collecting all weeds in four different areas each of 1 sq. m. and the plants were counted and weighed. The results are shown in Table I. From this table it is seen that in plots treated with MCPP at the rate of 2·56 kg./ha. an average of 13 *Galium* per sq. m. was found. Weeds having an average weight of about 1·1 g. were severely injured when the counts and test weights were made. Malformations shown by *Galium* treated with MCPP-K consisted particularly of closer internodes at the head of the plants; abnormal development of roots on the stem; leaves and the whole vegetative system turning red; the plants were no longer vertical and had rather the appearance of creeping plants. Furthermore, quite a number of weeds were killed after some time in areas where no collection was made.

On the other hand, in plots treated with DNOC-NH_4, seedlings found in a greater number and having an average weight of 0·9 g. had germinated a long time after the herbicide was applied. They did not grow normally because of the increased growth of the cereal.

At the time of harvest, counts of *Galium* seeds per 1000 wheat seeds gave significant differences at the 5% level of significance between plots treated respectively with 1·25, 1·92 and 2·56 kg. of MCPP-K/ha. Only MCPP-K at 2·56 kg. gave a complete kill.

Table I

Results of herbicide treatments with MCPP and DNOC-NH_4

Product	Dosage, kg./ha.	Average total weight of weeds per sq. m., g.	Average weight of *Galium* per sq. m., g.	No. of *Galium* per sq. m.	Weight, g., of one *Galium*	Observations
MCPP-K	1·92	105	34	21	1·6	Severely injured weeds
MCPP-K	2·56	53	16	13	1·1	Severely injured weeds
DNOC-NH_4	2·4	68	27	29	0·9	Uninjured seedlings appeared after treatment
Control	nil	436	287	48	5·9	Weeds as tall as the cereal
Significant difference P=·05		116	93	13	—	

Conclusion

It is possible in France to obtain complete control of *G. aparine* either by treating with DNOC-NH_4 or with MCPP-K. With the former, a rate of 2·4 kg./ha. is sufficient, provided that the treatment is made when *Galium* is in the 2-leaf stage (maximum). With MCPP it is possible to treat later, and this year, in our experiments, the best time was between 15th April and 10th May, i.e. during more than 3 weeks.

Many tests have shown that the right dosage is 2·56 kg./ha. using 200, 400 or 1000 l. of water per hectare.

Reference

[1] Lush, G. B., & Leafe, E. L., *3rd Brit. Weed Control Conf., 1956*, p. 625

Discussion on the four preceding papers

Mr. E. B. Scragg (North of Scotland College of Agriculture).—I would like to mention two trials carried out this season in which crops of barley (Scandinavian varieties) were deliberately sprayed with MCPA at their most sensitive stage. In one crop 40% and in the other 70% of abnormal ears resulted. These were replicated trials and yields were determined. Complete analysis of the results has not yet been made, but yields were definitely not reduced by comparison with the controls. For some years we have considered the possibility of very early spraying with the associated advantages of weed control. As our barley is mainly for feeding or distilling purposes, where quality is not so critical as in malting, we are not unduly disturbed by the presence of morphological abnormality in the grain. The results I have described were most encouraging. However, in the course of the season, I encountered a farmer's crop where the degree of damage approached 100% and there appeared to be a very considerable positive risk of loss in yield due to fracture of the ears. One would hesitate to advise a farmer to spray early in the knowledge that such damage might result.

We have been spraying with dinoseb for the past five years in the North-East of Scotland. We are particularly concerned with the control of corn marigold, and find that dinoseb ammonium salt, at 3 pints in 30 gal./acre gives an excellent control of this weed and all other species, with the exception of corn spurrey (*Spergula avensis*). The treatment can be made with the farmer's own low-volume sprayer. We find that oats show some scorch from which they rapidly recover. Barley is more sensitive, and we do not normally recommend its treatment. The treatment is very much cheaper than with CMPP and the other chemicals recommended for the weeds resistant to MCPA, which in any event are not the most effective against corn marigold.

Mr. E. P. Whitaker.—Mr. Lush confined his remarks to the susceptibility of CMPP to scentless mayweed; is stinking mayweed resistant, and if so can he suggest a reason?

Mr. Lush.—My experience is with the scentless variety only.

Dr. G. E. Barnsley (Shell Research Co.).—Can Dr. Pfeiffer give any information on crop residue and persistence of 2,3,6-trichlorobenzoic acid.

Dr. Pfeiffer.—A considerable amount of work has been carried out at Chesterford Park Research Station on this subject. We found that 4 oz./acre of TBA disappeared within four months on heavy soil under last year's weather conditions. We attributed most of this disappearance to leaching of the chemical but were able in the meantime to obtain conclusive evidence of biological breakdown of TBA in soils.

Mr. W. H. Booth (May & Baker Ltd.).—Is there any danger of a cumulative build-up of TBA in soil over successive years of spray treatment which may adversely affect the succeeding root crops?

Dr. Pfeiffer.—Not enough time has yet elapsed to investigate this subject fully. Observations, however, indicate that such a build-up is unlikely if low dosages of TBA are used.

Mr. V. Cory (N.A.A.S.).—In connexion with the use of CMPP and sodium monochloroacetate, Mr. Wheeler outlined the killing range of each. CMPP is effective in a greater range of species, including *Galium, Stellaria, Chenopodium album* and *Papaver*. Since sodium monochloroacetate was useful for *Polygonum persicaria* and *convolvulus*, is there not a case for using a mixture of the two materials and is experimental work on this possibility being considered?

Mr. Wheeler.—A mixture of CMPP and sodium monochloroacetate has interesting possibilities and would probably control the full range of weeds indicated by Mr. Cory. We have examined mixtures of MCPA and sodium monochloroacetate, and the effect appears to be additive with no evidence of synergism. I would expect a similar effect with mixtures of CMPP and sodium monochloroacetate, and in this event the full dose of each material would be required to obtain satisfactory weed control. This would be a very costly spray.